DOE/RL-2010-98
Draft A

# Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2 and 100-IU-6 Operable Units

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

U.S. DEPARTMENT OF ENERGY | Richland Operations Office
**P.O. Box 550**
**Richland, Washington 99352**

**Approved for Public Release;
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***APPROVED***
***By G. E. Bratton at 2:40 pm, Dec 17, 2012***

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# Executive Summary

This document presents the results of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[1] Remedial Investigation (RI)/Feasibility Study (FS) undertaken for a portion of the Hanford National Priorities List (NPL) Site referred to as 100-F/IU. The 100-F/IU has four source operable units (OUs) (100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6) and a groundwater OU (100-FR-3). As a result of the RI evaluation, a determination has been made that contaminants in the vadose zone (the soil between ground surface and the top of the groundwater) and groundwater pose a threat to the environment and that CERCLA remedial action is warranted. Based on the 100-F/IU RI/FS, the U.S. Department of Energy, Richland Operations Office (DOE-RL), in collaboration with the Environmental Protection Agency (EPA), will issue a Proposed Plan that identifies a Preferred Alternative, as well as other alternatives, considered for cleanup of the 100-F/IU contaminated soil and groundwater in order to receive comment from the Tribal Nations and the public. The U.S. Environmental Protection Agency (EPA), working in cooperation with DOE-RL, will consider input submitted during the comment period as well as any new information that becomes available, and issue a Record of Decision (ROD) that identifies the final remedial alternatives selected for the 100-F/IU OUs and will document responses made to Tribal Nations and public comments.

The 100-F/IU includes 400 sites or locations where waste was potentially disposed during past operations. To verify this, DOE reviewed the relevant operational histories and conducted field investigations as necessary to determine the status of each site. These reviews and investigations revealed that 114 of the 400 locations do not pose a risk requiring remedial action. A decision under the ROD is required for the 286 waste sites evaluated in the 100-F/IU RI/FS. Of the 286 waste sites, 153 have been identified as requiring no further action. Sixteen waste sites have been identified for institutional controls (ICs) to ensure protectiveness. The remaining 117 sites are evaluated for remedial action. Eighty-one waste sites are anticipated to be addressed under the interim action ROD. Thirty-six waste sites are expected to be remediated after the 100-F/IU OUs ROD is issued, and are included in the cost estimate.

[1] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq., Pub. L. 107-377, December 31, 2002. Available at: http://epw.senate.gov/cercla.pdf.

DOE-RL is currently remediating 100-F/IU waste sites under the existing interim action RODs, which require removal, treatment (if necessary), and disposal of contaminated soil and debris at the onsite Environmental Restoration Disposal Facility (ERDF). These waste sites will continue to be remediated under the interim action RODs. All 286 waste sites and the groundwater will require a decision under the 100-F/IU OUs ROD.

This RI/FS, which supports the Proposed Plan, has the following objectives:

- Provide information concerning the physical environmental setting for 100-F/IU.
- Draw conclusions concerning the nature and extent of contamination and the potential for migration of contamination.
- Evaluate the potential for adverse effects on human health and the environment (HHE) if no action is taken.
- Develop and evaluate an appropriate range of remedial action alternatives to address unacceptable risk to HHE.

The RI/FS was prepared based on information gathered from operating information and process knowledge, historical studies and investigations, data collected during implementation of Interim Action RODs, and recent field investigations. Waste site cleanup actions and assessments have been performed since the early 1990s. RI work, done specifically to provide information to supplement what was already known regarding nature and extent of contamination, included installing three groundwater monitoring wells, three vadose zone boreholes, and sampling aquifer tubes and pore water to refine the conceptual site model. In addition, a select network of wells was sampled to determine spatial and temporal variations in groundwater contamination.

## 100-F/IU Background

The 100-F/IU area is divided into the 100-F Reactor area, and the IU-2 and IU-6 areas within the 100 Area (commonly referred to as the River Corridor). The 100-F area is located in the northeastern portion of the Hanford Site, adjacent to the Columbia River, and is the site of the 105-F Reactor. The 100-F area encompasses approximately 2.8 $km^2$ (1.1 $mi^2$). Construction of the 105-F Reactor began in December 1943. The reactor's primary mission was plutonium production, which began in February 1945 and continued until deactivation in 1965. Reactor operations were supported by multiple facilities that included infrastructure for water treatment, air filtration, nuclear fuel handling, cooling

water effluent disposal, laboratories, and administration. The secondary mission of the 100-F area was the Experimental Animal Farm (EAF), a biological laboratory used to examine the effects of radiation and radioactive contamination on plants, animals, and fish. The EAF operated until 1976.

The water-cooled nuclear reactor, associated structures, and processes that generated solid and liquid wastes were the primary sources of contamination at 100-F. Solid waste was placed in unlined burial grounds. Liquid contaminants were released to the environment by discharging effluent directly to the soil column via retention basins, trenches, cribs, ditches, and through outfall piping to the Columbia River.

The 100-IU-2 and 100-IU-6 (100-IU-2/IU-6) OUs consist of an area between and outside the reactor and production areas within the 100 Area. Pre-Hanford agriculture-based town of White Bluffs and the Hanford town site were located within these OUs. Waste sites associated with pre-Hanford activities include landfills and surface debris. During the development of the Hanford Site, the area was used for housing and staging equipment and materials for the Hanford Site. Waste sites generally originated from industrial chemical use, and include landfills, dumpsites, surface debris, and unplanned releases.

## Physical/Environmental Setting

The conceptual site model includes consideration of the physical and chemical characteristics of vadose materials, geologic features of the area, local groundwater characteristics, and the interaction of these elements with the Columbia River. The physical characteristics of the study area influence the movement of contaminants within the environment.

The topography of the reactor area at 100-F is relatively flat, with elevations generally between 120 and 128 m (394 and 420 ft) above mean sea level (amsl) inland from the Columbia River. The area has been disturbed and graded extensively since reactor construction through present-day waste site remediation activities. The elevation at the river shore is approximately 115 m (377 ft) amsl. A low bench of land southeast of 100-F with elevations below 114 m (374 ft) amsl is submerged when river stage is above average. The topography within 100-IU-2/IU-6 varies widely. Portions of this region are relatively flat, but it also includes Gable Butte and Gable Mountain, which rise approximately 60 m (200 ft) and 180 m (590 ft), respectively, above surrounding land.

The physical characteristics most affecting contaminant transport at 100-F are the hydrogeology and the rate of infiltration. The vadose zone consists primarily of unconsolidated gravel and sand of the Hanford formation. The unconfined aquifer beneath 100-F comprises Hanford formation gravels that range in thickness from less than 1 m (3 ft) in southwestern 100-F to 8 m (26 ft) in eastern 100-F nearest the Columbia River. The Ringold Upper Mud (RUM)—a zone of low permeability composed of intermixed sand, clay, and silt zones—forms the base of the unconfined aquifer. The direction of groundwater flow is east-northeast in the northern part of 100-F and east-southeast in the southern part, with flow velocities ranging from 0.19 to 0.62 m/day (0.58 to 1.9 ft/day). Normal seasonal variability observed in the water table in 100-F is more than 3 m (10 ft) in wells near the river and decreases farther inland.

The hydrostratigraphy of the 100-IU-2/IU-6 OUs is variable because of the large area covered. Groundwater flows west to east beneath the southern portion of 100-IU-2/IU-6, discharging to the Columbia River at the eastern edge of the Hanford Site. Some groundwater flows northward through the gap between Gable Mountain and Gable Butte, and then toward the river. Recharge to the aquifer is low because of the Hanford Site's hot, arid climate. Recharge during reactor operations was greater than natural recharge, and came from liquid waste releases to the ground, spills, and localized leaks from facilities associated with the water supply.

Recharge rates are dependent on vegetation. Currently in the 100-F area, there is little to no vegetation, whereas 100-IU-2/IU-6 is composed of large areas of mature vegetation. Recharge rates may be as low as 1.5 mm/yr (0.059 in./yr) where mature vegetation is present, and as high as 52 mm/yr (2.0 in./yr) on disturbed soil. There is little recharge in areas with natural vegetation, as annual net evapotranspiration is near zero.

## Nature and Extent of Contamination

This document describes the current distribution of contaminants in the environment, predicts migration rate of contaminants through the physical setting (fate and transport), and evaluates the potential for contaminant migration in groundwater and subsequent discharge to the Columbia River.

Large volumes of water containing low concentrations of hexavalent chromium (Cr(VI)) and radionuclides were discharged to the soil via trenches, cribs, and leaks from pipelines and the 116-F-14 retention basin. Liquid effluent was also discharged through outfalls to the

Columbia River. During the operational period, large groundwater mounds formed beneath disposal areas. These mounds accelerated the radial spreading of mobile contaminants, such as Cr(VI) and nitrate in the aquifer, enabling them to move inland.

Some contaminants were released in relatively low volumes, but at higher concentrations. Contaminants released in this manner often remained in vadose zone soil, rather than being transported deeper into the vadose zone by high volumes of water. By comparison with other Hanford Site reactors, 100-F used dry sodium dichromate for a longer period, resulting in fewer releases of high-concentration sodium dichromate solution. Current Cr(VI) concentrations in groundwater do not indicate the presence of a high-concentration, persistent source.

Low-mobility contaminants, including many metals and radionuclides, sorbed to fine textured sediments in the vadose zone. These contaminants were found at the greatest concentrations within and near the areas of discharge. When little or no liquid effluent was discharged to a waste site, soil contamination remained in the shallow sediment. Most of this shallow contamination has been removed during remediation activities. Strontium-90 is a moderately mobile contaminant in the subsurface and was observed in several 100-F waste sites, including the 118-F-1 and 118-F-6 burial grounds, and 116-F-9 and 116-F-2 trenches. This contaminant migrated a limited distance vertically and horizontally in groundwater during the operational period; the residual contaminant is mostly sorbed to fine textured sediment in the vadose zone and aquifer.

After reactor operations and liquid effluent disposal ceased, there was a significant decrease in water infiltrating the vadose zone. The artificially elevated groundwater mounds largely dissipated within 3 to 5 years. Natural rainfall and snowmelt infiltration carried some additional contamination to groundwater; net infiltration of 8 to 10 cm/yr (3 to 4 in./yr) likely continued at nonvegetated waste sites.

Waste Site cleanup in 100-F/IU began in the mid-1990s under an Interim Action ROD and is nearly complete. Interim action waste site cleanup consists primarily of removing and disposing of contaminated material, then backfilling and revegetating to protect HHE.

The RI soil sample results indicated that several radiological contaminants (i.e., carbon-14, cobalt-60, cesium-137, europium-152, and europium-154, nickel-63, plutonium-239/240, strontium-90, tritium, and uranium isotopes) were detected above background in the deep vadose zone. Total chromium above background concentrations was observed in all new

wells and borehole samples while Cr(VI) was only detected in two separate well soil samples collected near the water table.

Contaminants of concern (COCs) in 100-F groundwater are Cr(VI), strontium-90, nitrate, and trichloroethene. Data from wells installed for the RI helped define the extent of these contaminants horizontally and vertically. Plumes that originated near or east of the largest liquid disposal facilities generally flow eastward to the river, whereas plumes that originated west of the largest liquid disposal facilities are moving south-southeast. Cr(VI) exceeds the 10 µg/L state water quality standard beneath a portion of eastern 100-F; however, of the 19 monitoring wells used for spatial and temporal monitoring, only two wells exceeded the 48 µg/L DWS in 2009 through 2011. Of the 32 aquifer tubes sampled, only one aquifer tube groundwater sample exceeded the state water quality standard for Cr(VI) in 2009, and none in 2010 or 2011. Strontium-90 exceeds the 8 pCi/L DWS in a small plume beneath eastern 100-F. The plume is near the Columbia River, but concentrations of strontium-90 in aquifer tubes were less than the DWS, with concentrations declining with depth in the aquifer. The nitrate plume is generally located west of the main liquid disposal area(s) and extends south from 100-F for a distance of approximately 2 km (1.2 mi) at a concentration that exceeds the 45 mg/L DWS. Trichloroethene concentrations in three wells exceed the 5 µg/L DWS in southwestern 100-F. The low density of wells to the south creates uncertainty in the interpretation, and the plume probably extends farther south than can be interpreted based on available data. Wells in other locations around 100-F have occasionally reported trichloroethene at concentrations greater than the DWS. Trichloroethene concentrations within the plume have been declining, and a concentrated residual source is not suspected. Groundwater contamination is limited to the unconfined aquifer.

Contaminated groundwater has been identified in the unconfined aquifer beneath the 100-IU-2 and 100-IU-6 OUs. The contamination does not appear to originate from sources in the 100-IU-2/IU-6 OUs, with the possible exception of trichloroethene, and is addressed by the CERCLA decisions for the groundwater OUs where the contamination originated.

## Exposure Assessment

Exposure scenarios were developed to allow assessment of potential human health risk and ecological effects. The principal contaminants identified in the soil associated with one or more waste sites include radionuclides, metals, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons. The risk assessment identified Cr(VI), strontium-90,

nitrate, and trichloroethene as the principal groundwater contaminants in 100-F. These soil and groundwater contaminants are evaluated for potential remedial technologies in the FS.

The evaluations of risk for specific waste sites rely on a comprehensive review of field data, radiological surveys, process history, analogous site information, personal interviews, engineering drawings and as-builts, and any other information identified during the development of the RI/FS. For waste sites proposed for remediation, the data review indicated a need for action. This comprehensive review of the characteristics of each site is sufficiently defined for the purpose of alternative development and comparison in the FS.

In addition, of the 286 waste sites evaluated in the RI/FS, 144 waste sites in 100-F/IU had closeout verification data available following the implementation of interim action removal and disposal. These sites were remediated to meet interim action cleanup levels (remedial action goals [RAGs]). New soil screening levels (SSLs) and preliminary remediation goals (PRGs) are established in this RI for each environmental media of interest (soil and groundwater), each type of contaminant (hazardous substances and radionuclides), and human and ecological receptors. The SSLs and PRGs are based on EPA guidance and a scenario that includes assumptions of vadose zone contamination and an infiltration/recharge rate based on irrigated agriculture for SSLs and conservation land use for PRGs. All 144 sites were remediated to levels that are protective of groundwater and surface water, based on preliminary remediation goals (PRGs). Sixteen waste sites at 100-F have residual radionuclide contamination that exceeds human health direct-contact SSLs at depths great than 4.6 (15 ft) below ground surface, where there is an incomplete pathway.

## Alternatives Development

The feasibility study portion of the RI/FS consists of three phases: screening of remedial technologies, development of remedial alternatives, and detailed analysis of selected alternatives. Remedial technologies were assembled into alternatives that address contamination on a media- or source-specific basis.

Remedial action objectives (RAOs) are identified for groundwater, surface water, and soil. RAOs are general descriptions of what a cleanup under CERCLA is expected to accomplish. They are narrative statements that define the extent to which waste sites require cleanup to protect HHE. To meet RAOs, PRGs are established for each contaminant, exposure pathway, and environmental media of interest. The interim action

RAGs, and SSLs and PRGs developed in this RI/FS, are used to identify cleanup levels for each COC. Contaminant concentrations at all 100-F/IU waste sites will be evaluated against cleanup levels defined in the ROD.

A range of response actions using different process options to meet RAOs is identified in the RI/FS. Process options retained for waste sites include no action, standard and deep excavation, disposal, treatment, and ICs. Process options retained for groundwater include no action, ICs, monitored natural attenuation (MNA), containment, pump-and-treat, in situ treatment, injection/extraction, ion exchange, and air stripping. Process options and technologies for the range of response actions are evaluated for relative effectiveness, implementability, and cost.

The remedial technologies, retained from the screening process, were combined to provide a range of separate alternatives for waste site and groundwater remediation. With the exception of No Action, which is required for evaluation under the "National Oil and Hazardous Substances Pollution Contingency Plan" (NCP)[2], the remedial alternatives were developed to achieve the RAOs by considering the CERCLA program goals and expectations. Waste site alternatives evaluated include Alternative S-1 (No Action) and Alternative S-2 (removal, treatment, and disposal [RTD]). Alternatives evaluated for groundwater include Alternative GW-1 (No Action), Alternative GW-2 (ICs and MNA), Alternative GW-3 (Pump-and-Treat optimized with other technologies), and Alternative GW-4 (Enhanced Pump-and-Treat).

## Alternative Evaluation

Eighty-one sites are anticipated to be remediated under the interim action ROD. An additional 36 waste sites for which remedial actions are not expected to be started until after the ROD is issued were evaluated individually and comparatively against seven of the nine CERCLA criteria. Two criteria, overall protection of human health and the environment and compliance with applicable or relevant and appropriate requirements (ARARs), are "threshold criteria." The next five are "balancing criteria" and include long-term effectiveness; reduction of toxicity, mobility, and volume (TMV) through treatment; short-term effectiveness; implementability; and cost. The two remaining "modifying criteria," state acceptance and community acceptance, will be evaluated in the responsiveness summary of the 100-F/IU OUs ROD after the Proposed Plan goes

[2] 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," *Code of Federal Regulations*. Available at: http://www.gpo.gov/fdsys/pkg/CFR-2010-title40-vol27/xml/CFR-2010-title40-vol27-part300.xml.

through the Tribal Nation and public review and comment process. The purpose of the detailed and comparative analysis is to develop the information necessary to recommend a preferred alternative in a Proposed Plan. The analysis of the alternatives showed:

- Alternative S-1 did not satisfy the threshold criteria for protection of HHE and compliance with ARARs. Alternative GW-1 did not satisfy the threshold criteria for protection of HHE or compliance with ARARs. Therefore, these alternatives were not evaluated against the balancing criteria.

- Alternative S-2 is protective of HHE, will achieve cleanup levels within a reasonable time frame, and meet this threshold criterion. Alternatives GW-2, GW-3, and GW-4 are protective of HHE, will achieve cleanup within a reasonable time frame, and meet this threshold criterion.

- Alternative S-2 performs very well for the long-term effectiveness and permanence, and implementability criteria; moderately well for short-term effectiveness; and less well for the reduction of TMV through treatment. Alternatives GW-2, GW-3, and GW-4 perform very well in long-term effectiveness and permanence and moderately well for short-term effectiveness. Alternative GW-4 performs very well in the reduction of TMV through treatment, while Alternative GW-3 performs moderately well, and Alternative GW-2 performs less well. Alternative GW-2 performs very well in implementability, Alternative GW-4 performs moderately well, and Alternative GW-3 performs less well against this criterion.

All the groundwater alternatives require ICs and a similar time frame to achieve RAOs. Alternative GW-2, MNA, is readily implementable and is a fraction of the cost of the other alternatives. The in situ treatment for Alternative GW-3 would require specialized biological reagents and, although it is a proven technology, it would require design testing for this site. Although Alternative GW-4 achieves RAOs for some COCs sooner than the other alternatives, it is more intensive to implement, and has the highest cost. The analysis provides enough information to be able to recommend a preferred alternative in the Proposed Plan.

There will be a period of time between when the ROD is approved and when the required Remedial Design/Remedial Action Work Plan (RD/RAWP) is prepared and issued. During this period, DOE-RL plans to continue interim remedial activities such as waste site remediation. In order for these actions to be consistent with the final action remedy

selection, the current interim action RDR/RAWPs will be modified using the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology, EPA, and DOE, 1989)[3] change notice process to include the final cleanup levels specified in the ROD. All 286 waste sites will be included in the ROD for final remedy decision to be documented, even if no further remedial activities are needed.

[3] Ecology, EPA, and DOE, 1989, *Hanford Federal Facility Agreement and Consent Order*, 2 vols., as amended, Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy, Olympia, Washington. Available at: http://www.hanford.gov/?page=81.

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# Terms

| | |
|---|---|
| AEA | *Atomic Energy Act of 1954* |
| AEC | Atomic Energy Commission |
| amsl | above mean sea level |
| ARAR | applicable or relevant and appropriate requirement |
| ARCL | allowable residual contamination level |
| ASTM | American Society for Testing and Materials |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| AUF | area use factor |
| AVS/SEM | Acid volatile sulfides/simultaneously extracted metals |
| AWQC | ambient water quality criteria |
| BAF | bioaccumulation factors |
| BCG | Biota Concentration Guides |
| BDL | below detectable limits |
| BG | background |
| Bgs | below ground surface |
| BRA | baseline risk assessment |
| CalEPA | California EPA |
| CAS | Chemical Abstract Service |
| CCC | criteria continuous concentration |
| CERCLA | *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* |
| CHPRC | CH2M HILL Plateau Remediation Company |
| CLARC | Cleanup Levels and Risk Calculations |
| CLUP | Comprehensive Land-Use Plan |
| Cmax | maximum predicted concentration |
| CMC | criteria maximum concentrations |
| COC | contaminant of concern |
| COEC | chemical of ecological concern |
| COPC | contaminant of potential concern |

| | |
|---|---|
| COPEC | contaminant of potential ecological concern |
| COPC | contaminant of potential concern |
| Cr(VI) | hexavalent chromium |
| CRC | Columbia River Component |
| CREHST | Columbia River Exhibition of History, Science, and Technology |
| CSL | clean up screening level |
| CSM | conceptual site model |
| CSS | Colorado Silica Sand |
| CTUIR | Confederated Tribes of the Umatilla Indian Reservation |
| CUL | cleanup level |
| CV | coefficient of variation |
| CVP | cleanup verification package |
| CWA | *Clean Water Act of 1972* |
| D4 | deactivation, decommission, decontamination, and demolition |
| D&D | decontamination and decommissioning |
| DAD | dermal absorbed dose |
| DDT | dichlorodiphenyltrichloroethene |
| DOC | dissolved organic carbon |
| DOE | U.S. Department of Energy |
| DOE-RL | U.S. Department of Energy, Richland Operations Office |
| DQA | data quality assessment |
| DQO | data quality objectives |
| DWS | drinking water standard |
| EAF | Experimental Animal Farm |
| Ecology | Washington State Department of Ecology |
| EHQ | ecological hazard quotient |
| EIS | environmental impact statement |
| ELCR | excess lifetime cancer risk |
| ENRE | Environmental Remediation database |
| EPA | U.S. Environmental Protection Agency |

| | |
|---|---|
| EPC | exposure point concentrations |
| EQL | estimated quantitation limit |
| ERA | ecological risk assessment |
| ERAGS | *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final* (EPA 540-R-97-006) |
| ERDF | Environmental Restoration Disposal Facility |
| ET barrier | Evapotranspiration barrier |
| ETF | Effluent Treatment Facility |
| FEP | features, events, and processes |
| FS | feasibility study |
| FSB | fuel storage basin |
| GCW | groundwater circulation wells |
| GEA | gamma energy analysis |
| GHG | greenhouse gas |
| GPS | global positioning system |
| GRA | general response actions |
| GW | Groundwater |
| H&S | health and safety |
| HAER | Historic American Engineering Record |
| HCP EIS | *Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement* |
| HEAST | *Health Effects Assessment Summary Tables* |
| HEIS | Hanford Environmental Information System |
| Hf | Hanford formation |
| HH | Human Health for the Consumption of Water + Organism |
| HHE | human health and the environment |
| HHO | Human Health Water + Organism |
| HHRA | human health risk assessment |
| HI | hazard index |
| HMS | Hanford Meteorological Station |
| HQ | hazard quotient |

| | |
|---|---|
| HRNM | Hanford Reach National Monument |
| HSB | Hanford Site background |
| HSP | health and safety plan |
| IAROD | interim action record of decision |
| IC | institutional control |
| ICP | inductively coupled plasma |
| ICP-MS | inductively coupled plasma-mass spectrometry |
| ICR | incremental cancer risk |
| IDL | instrument detection limit |
| IDMS | Integrated Document Management System |
| IEUBK | Integrated Exposure Uptake Biokinetic |
| IRA | interim remedial action |
| IRIS | Integrated Risk Information System |
| IRM | interim remedial measure |
| ISGR | in situ gaseous reduction |
| ISRM | In Situ Redox Manipulation |
| ISS | interim safe storage |
| IX | ion exchange |
| $K_d$ | distribution coefficient |
| LFI | limited field investigation |
| LiDAR | Light Detection and Ranging |
| LIGO | Laser Interferometer Gravitational-Wave Observatory |
| LOAEC | lowest-observed-adverse-effects concentration |
| LOAEL | lowest observed adverse effects levels |
| LOEC | lowest observed effect concentrations |
| MATC | maximum acceptable toxicant concentration |
| MCL | maximum contaminant levels |
| MCLG | maximum contaminant level goals |
| MDA | minimum detectable activity |
| MDL | method detection limit |

| | |
|---|---|
| MESC | maintain existing soil cover |
| MNA | monitored natural attenuation |
| MRDL | Maximum Residual Disinfectant Levels |
| MTCA | "Model Toxics Control Act—Cleanup" (WAC 173-340) |
| N/A | not applicable |
| NCEA | National Center for Environmental Assessment |
| NCP | "National Oil and Hazardous Substances Pollution Contingency Plan" (40 CFR 300) |
| ND | not detected |
| NEPA | *National Environmental Policy Act of 1969* |
| NESHAP | National Emission Standards for Hazardous Air Pollutants |
| NHPA | *National Historic Preservation Act of 1966* |
| NJDEP | New Jersey Department of Environmental Protection |
| NOAEC | no-observed-adverse-effects concentration |
| NOAEL | no observed adverse effect levels |
| NPDES | National Pollutant Discharge Elimination System |
| NPDWR | National Primary Drinking Water Regulations |
| NPL | "National Priorities List" (40 CFR 300, Appendix B) |
| NPV | net present value |
| NR | nonrepresentative results |
| NRHP | National Register of Historic Places |
| NS | not sampled |
| NSF | National Science Foundation |
| NTU | nephelometric turbidity units |
| O&M | operations and maintenance |
| OEHHA | Office of Environmental Health Hazard Assessment |
| OHWM | ordinary high water mark |
| ORNL | Oak Ridge National Laboratory |
| OSE | orphan site evaluation |
| OU | Operable Unit |
| PA | Preliminary Assessment |

| | |
|---|---|
| PAH | polyaromatic hydrocarbon |
| PCB | polychlorinated biphenyls |
| PEF | particulate emission factors |
| PNNL | Pacific Northwest National Laboratory |
| PPE | personal protective equipment |
| PPRTV | Provisional Peer Reviewed Toxicity Values |
| PQL | practical quantitation limit |
| PRG | preliminary remediation goal |
| PUREX | Plutonium Uranium Extraction Facility |
| PVC | polyvinyl chloride |
| QA | quality assurance |
| QAPjP | Quality Assurance Project Plan |
| QC | quality control |
| QRA | qualitative risk assessment |
| RA | risk assessment |
| RAA | remedial action alternative |
| RACER ™ | Remedial Action Cost Engineering and Requirements |
| RAG | remedial action goal |
| RAIS | Risk Assessment Information System |
| RAO | remedial action objective |
| RBSL | risk-based screening level |
| RCBRA | River Corridor Baseline Risk Assessment |
| RCRA | *Resource Conservation and Recovery Act of 1976* |
| RD/RA | remedial design/remedial action |
| RDR/RAWP | remedial design report/removal action work plan |
| RESRAD | RESidual RADioactivity |
| RfD | reference dose |
| RI | remedial investigation |
| RL | reporting limit |
| RME | reasonable maximum exposure |

| | |
|---|---|
| ROD | record of decision |
| RSVP | remaining site verification package |
| RTD | removal, treatment, and disposal |
| RUM | Ringold Upper Mud |
| SAP | sampling and analysis plan |
| SARA | *Superfund Amendments and Reauthorization Act of 1986* |
| SDWA | *Safe Drinking Water Act of 1974* |
| SESP | Surface Environmental Surveillance Project |
| SMDP | scientific management decision point |
| SI | Site Investigation |
| SOF | sum of fractions |
| SSL | soil screening level |
| STOMP | Subsurface Transport Over Multiple Phases |
| STSC | Superfund Health Risk Technical Support Center |
| SVOC | semi-volatile organic compound |
| SW | surface water |
| $T_{1/2}$ | half lives |
| TBC | to-be-considered |
| TCE | trichloroethene |
| TEQ | toxicity equivalent quotient |
| TIC | total inorganic carbon |
| TMV | toxicity, mobility, and volume |
| TOC | total organic carbon |
| TPA | Tri-Party Agreement |
| TPH | total petroleum hydrocarbons |
| Tri-Parties | U.S. Department of Energy, U.S. Environmental Protection Agency, and Washington State Department of Ecology |
| Tri-Party Agreement | *Hanford Federal Facility Agreement and Consent Order* |
| TRU | transuranic |
| TRV | toxicity reference values |
| TSCA | *Toxic Substances Control Act of 1976* |

| | |
|---|---|
| TSD | treatment, storage, and disposal |
| UCL | upper confidence limit |
| UNSCEAR | United Nations Scientific Committee on the Effects of Atomic Radiation |
| UPR | unplanned releases |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| VOC | volatile organic compound |
| WAC | *Washington Administrative Code* |
| WCH | Washington Closure Hanford |
| WIDL | Well Information and Document Lookup |
| WIDS | Waste Information Data System |
| WOE | weight of evidence |
| WRIA | Waters by Water Resource Inventory Area |
| WSRF | waste site reclassification form |
| XRF | X-ray fluorescence |

1
2

# 1 Introduction

In 1989, the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology) (known as the Tri-Parties) signed the *Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a), hereinafter called the Tri-Party Agreement (TPA), to provide a framework for the cleanup of the Hanford Site (Figure 1-1). The scope of the agreement addressed the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) remediation of inactive hazardous waste sites, active waste management operations, *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action for solid waste management units, and closure of RCRA treatment, storage, and/or disposal units across the Hanford Site.

For the purpose of CERCLA cleanup, four sections of the Hanford Site were placed on the 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan," (hereinafter called NCP) Appendix B, "National Priorities List" (hereinafter called NPL), as separate areas: 100 Area (Reactor Operations), 200 Area (Irradiated Fuel Reprocessing and Waste Management), 300 Area (Nuclear Fuel Production and Research and Development), and 1100 Area (Equipment and Maintenance). Due to the large number of waste sites, unplanned releases (UPRs), and extensive groundwater contamination, the 100 Area was further divided into source and groundwater operable units (OUs) for management of the investigation and remediation.

This document presents the results of a CERCLA Remedial Investigation/Feasibility Study (RI/FS) of the 100-F/IU-2/IU-6 OUs. The information contained in this RI/FS supports a proposed plan that will be available to Tribal Nations and the public for review and comment. The RI/FS and responses to Tribal and public comments (the Responsiveness Summary) provide the basis for a Record of Decision (ROD). The RI/FS process supports remedy selection and provides the basis for a ROD to remediate source OUs 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 as well as the 100-FR-3 Groundwater OU, hereinafter collectively referred to as 100-F/IU.

Much of Chapter 1 is devoted to summarizing the assessment and remediation work, treatability tests, and other relevant studies. This historical information provides a comprehensive picture of current 100-F/IU OUs site conditions and establishes a foundation for the remainder of the RI/FS document.

The list of waste sites for 100-F/IU OUs has been refined over time. During operations, waste disposal locations were constructed and operated as needed. Eventually, these locations were assigned an identification number. As technology evolved, computer databases were developed to store and track waste site information. The Waste Information Data System (WIDS) is the database of waste site information for the Hanford Site. WIDS assigns standardized identification numbers (site codes) and tracks the status of each waste site. As a result of the potential listing on the NPL (40 CFR 300, Appendix B), a preliminary assessment/site investigation (PA/SI) was conducted. This PA/SI identified potential waste sites by geographic area across the Hanford Site and assigned each waste site a hazard ranking. This combined hazard ranking score resulted in four areas (100, 200, 300, and 1100) to be added to the NPL (40 CFR 300, Appendix B). Waste sites identified within the geographic areas included 100-F, and areas shown on Figure 1-1. These waste sites were included in WIDS and formed the basis for the preliminary list of waste sites in the 100-F/IU OUs. Since the PA/SI, additional efforts have been conducted to ensure that all waste sites posing a threat to human health and the environment (HHE) are identified through the Nonoperational Area Evaluation process, including the Orphan Site Evaluation and Discovery Site processes.

In 1991, the Tri-Parties determined there was a need to prioritize the CERCLA investigations and identify early actions to address waste sites and groundwater contamination. *Hanford Past-Practice Strategy* (DOE/RL-91-40), hereinafter called Past-Practice Strategy, provided the basis for prioritizing

investigations and cleanup actions across the Hanford Site. This strategy emphasized the need to address waste sites and groundwater contamination that may pose a near-term impact to public health and the environment. In addition, the strategy proposed a bias for action to clean up waste sites and existing contamination where the need for a remedy was evident.

For 100-F/IU OUs, the Past-Practice Strategy (DOE/RL-91-40) translated into limited field investigations (LFIs) being completed. LFIs (*Limited Field Investigation Report for the 100-FR-1 Operable Unit* [DOE/RL-93-82], hereinafter called 100-FR-1 LFI, and *Limited Field Investigation Report for the 100-FR-3 Operable Unit* [DOE/RL-93-83], hereinafter called 100-FR-3 LFI) were initiated for the 100-FR-1 and 100-FR-3. These LFIs were an initial step in characterizing the nature and extent of contamination in the vadose zone, structures, and debris that received radioactive liquid effluent discharges. Radionuclides, metals, and organics were analyzed in the LFI samples. No LFIs were conducted for 100-IU-2 and 100-IU-6 OUs.

As a result of the LFIs, substantial work to remove contaminated soil and facilities has been completed under the following interim action RODs:

- *Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-95/126)
- *Amendment to the Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington* (EPA/AMD/R10-97/044), hereinafter called 1997 Interim Action ROD Amendment
- *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)* (EPA/ROD/R10-99/039), hereinafter called the 100 Area Remaining Sites ROD
- *Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington* (EPA/ROD/R10-00/121)

Current River Corridor cleanup work is progressing based on Interim Action RODs. An objective of waste site cleanup is to remove sources of contamination and contaminated environmental media that are close to the Columbia River and place them in the Environmental Restoration Disposal Facility (ERDF) for final disposal on the Central Plateau. Reducing the concentrations of contaminants entering the Columbia River and restoring the groundwater to beneficial use remain the key objectives of groundwater remediation within 100-F/IU OUs. Interim Remedial Action Objectives (RAOs) for the cleanup of waste sites within the 100-F/IU OUs focus on protecting human health and ecological receptors from contaminants in the soil, controlling the sources of groundwater contamination to minimize the impacts to groundwater resources, and protecting the Columbia River from adverse impacts due to Hanford site contamination.

DOE is the lead federal agency at Hanford, per CERCLA, *Superfund Implementation* (Executive Order 12580), and the TPA (Ecology et al., 1989a). DOE develops implementation strategies and conducts response actions in this lead federal agency role. With implementation of the Past-Practice Strategy (DOE/RL-91-40) and progress with the interim remedial actions, DOE prepared the *Hanford Site Cleanup Completion Framework* (DOE/RL-2009-10), hereinafter called Cleanup Completion Framework, to describe the cleanup strategy (Table 1-1). One of the principal components of the framework is the River Corridor, which consists of approximately 570 $km^2$ (220 $mi^2$) of the Hanford Site along the Columbia

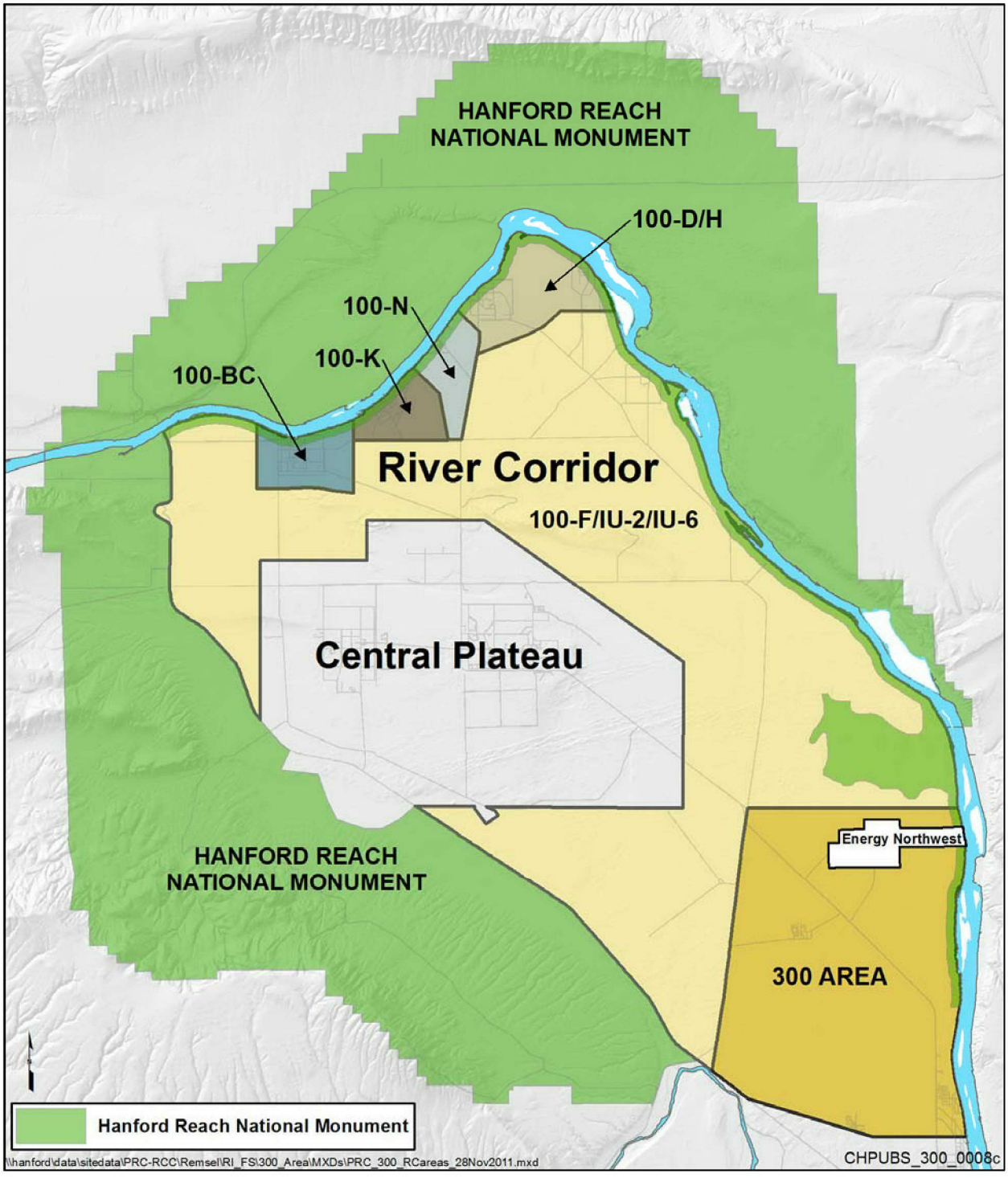


Figure 1-1. River Corridor Area Boundaries

Table 1-1. Overarching Goals for Hanford Site Cleanup

| Goal | Description |
|---|---|
| 1 | Protect the Columbia River. |
| 2 | Restore groundwater to its beneficial use to protect human health, the environment, and the Columbia River. |
| 3 | Clean up River Corridor waste sites and facilities to:<br>• Protect groundwater and the Columbia River<br>• Shrink the active cleanup footprint to the Central Plateau<br>• Support anticipated future land uses |
| 4 | Clean up Central Plateau waste sites, tank farms, and facilities to:<br>• Protect groundwater<br>• Minimize the footprint of areas requiring long-term waste management activities<br>• Support anticipated future land uses |
| 5 | Safely manage and transfer legacy materials scheduled for offsite disposition, including special nuclear material (including plutonium), spent nuclear fuel, transuranic waste, and immobilized high-level waste. |
| 6 | Consolidate waste treatment, storage, and disposal operations on the Central Plateau. |
| 7 | Develop and implement institutional controls and long-term stewardship activities that protect human health, the environment, and Hanford Site's unique cultural, historical, and ecological resources after cleanup activities are completed. |

River. It includes a contiguous area that extends from the 100 and the 300 Areas to the Central Plateau boundaries (Figure 1-1).

For sites in the River Corridor, final remedial actions are expected to restore groundwater to drinking water standards and protect aquatic life in the Columbia River by achieving ambient water quality criteria (AWQC) and state water quality standards at the groundwater/surface water interface. Unless technically impracticable, these objectives will be achieved within a reasonable period. If RAOs are not achievable in a reasonable period or are determined to be technically impracticable, programs will be implemented to prevent further migration of the plumes, prevent exposure to contaminated groundwater, and evaluate further risk reduction opportunities as new technologies become available. Cleanup actions will support reasonably anticipated future land uses consistent with the Hanford Reach National Monument and "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)" (64 FR 61615).

The River Corridor was divided into six geographic decision areas, including 100-F/IU, to achieve final source and groundwater remedy decisions (Figure 1-1). These decisions will provide comprehensive coverage for all areas within the River Corridor and will incorporate interim action cleanup activities. Cleanup levels will be established that will protect HHE. These levels will also comply with applicable or relevant and appropriate requirements (ARARs) and consider the cleanup levels previously used in implementation of Interim Action RODs for River Corridor OUs.

The RI/FS process builds on previous work including the River Corridor Baseline Risk Assessment (RCBRA) (*River Corridor Baseline Risk Assessment* [DOE/RL-2007-21]) and the Columbia River Component (CRC) (*Columbia River Component Risk Assessment* [DOE/RL-2010-117]), discussed in

Chapters 6 and 7, to provide a comprehensive understanding of current site conditions, as they have been affected by the extensive remediation effort to date, and to present and evaluate a set of alternatives for addressing the remaining environmental risks at 100-F/IU.

For the purpose of this RI/FS, the vadose zone is defined as follows:

- **Shallow vadose zone**—from ground surface to a depth of 4.6 m (15 ft). This depth interval is evaluated for protection of human health and ecological receptors as well as protection of groundwater and surface water.
- **Deep vadose zone**—from below a depth of 4.6 m (15 ft). This depth interval is evaluated for protection of groundwater and surface water. Residual contaminant concentrations in this zone are evaluated for human health protection to provide risk management information.

The RI/FS for 100-F/IU was conducted in accordance with *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* (DOE/RL-2008-46), hereinafter called the Integrated Work Plan, which contains the planning elements that are common to all of the Hanford Site 100 Area source and groundwater OUs, and *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* (DOE/RL-2008-46-ADD4), hereinafter called the 100-F/IU Work Plan, which is specific to 100-F/IU, as well as the *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-43), hereinafter called the 100-F/IU SAP.

This introductory chapter is followed by the RI portion of the report (Chapters 2 through 7), the FS portion of the report (Chapters 8 through 10), and a list of the references used in preparing this report (Chapter 11):

- Chapter 2 Study Area Investigation
- Chapter 3 Physical Characteristics of the Study Area
- Chapter 4 Nature and Extent of Contamination
- Chapter 5 Contaminant Fate and Transport
- Chapter 6 Human Health Risk Assessment
- Chapter 7 Ecological Risk Assessment
- Chapter 8 Identification and Screening of Technologies
- Chapter 9 Development and Screening of Alternatives
- Chapter 10 Detailed Analysis of Alternatives
- Chapter 11 References

This RI/FS includes extensive data used to perform calculations and assessments. Due to the volume of information (such as laboratory analytical data and risk calculations), summaries of data are provided in this document and appendices, and electronic links are provided to direct the reader to more detailed information contained in particular studies, databases, or reports found in the Administrative Record. Appendices are as follows:

- Appendix A Site Map
- Appendix B Annotated Bibliography
- Appendix C Supporting Information for Wells and Boreholes

- Appendix D Analytical Data
- Appendix E Waste Site Table
- Appendix F Fate and Transport Modeling Documentation
- Appendix G Summary of Risk Characterization Results with Inclusion of Background Concentrations
- Appendix H Ecological Risk Assessment Calculation Briefs
- Appendix I Technology Screening—Not Retained Technologies
- Appendix J Nonoperational Area
- Appendix K Cost Estimate
- Appendix L Riparian/Nearshore Evaluation
- Appendix M Monitored Natural Attenuation Evaluation

## 1.1 Purpose and Scope of Report

The RI/FS process is outlined in EPA and DOE RI/FS guidance (*Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA, Interim Final* [EPA/540/G-89/004], hereinafter called CERCLA RI/FS Guidance, and *Remedial Investigation/Feasibility Study (RI/FS) Process, Elements and Techniques* [DOE/EH-94007658]). The RI/FS process is the methodology that the *Superfund Amendments and Reauthorization Act of 1986* program has established for characterizing the nature and extent of contamination at uncontrolled hazardous waste sites, the risks posed by that contamination and an evaluation of potential remedial options.

This RI/FS was prepared in accordance with the previously referenced guidance as well as *CERCLA Compliance with Other Laws Manual: Interim Final* (EPA/540/G-89/006), and *CERCLA Compliance with Other Laws Manual: Part I* (EPA/540/G-89/009). These guidance documents provide information on the regulations and standards that govern the RI/FS process, as well as an overview of requirements for each chapter of the RI/FS.

This RI/FS Report has the following objectives:

- Provide information concerning the physical environmental setting and site characterization.
- Draw conclusions concerning the nature and extent of contamination present at the site, the potential for migration of contamination, and the potential for adverse human health and environmental effects if no action is taken at the site and exposure occurs. This goal is achieved by evaluating the historical and operational information about the site, identifying contaminants of potential concern (COPCs), evaluating potential migration pathways, and understanding potential impacts to receptors, by estimating exposure (dose) affects in consideration of contaminant toxicity.
- Develop and evaluate an appropriate range of remedial action alternatives for the site that address unacceptable risk to human health or the environment.

DOE has completed the RI/FS for 100-F/IU OUs and is issuing this report as a component its responsibilities under the NCP (40 CFR 300), acting in its role as lead agency for the cleanup. EPA is the lead regulatory agency for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 OUs and has the responsibility for overseeing all remedial action alternatives (RAAs) to ensure they meet applicable requirements. DOE is responsible for performing all 100 Area remedial actions. This report also fulfills DOE's responsibility under the *National Environmental Policy Act of 1969* (NEPA) to assess NEPA values when evaluating CERCLA remedial actions. The U.S. Department of Energy, Richland Operations Office (DOE-RL), in collaboration with EPA, will issue a Proposed Plan detailing the proposed final remedies for comment by the Tribal Nations and the public. EPA and DOE-RL will issue a ROD for the 100-F/IU OUs, which will include responses to the comments received pertaining to the 100-F/IU recommended remedies. After the ROD is issued, a remedial design report/remedial action work plan (RDR/RAWP) will be developed, approved, and then implemented.

The conceptual site model (CSM) is used in this RI/FS to present what is known about 100-F/IU The American Society for Testing and Materials *Standard Guide for Developing Conceptual Site Models for Contaminated Sites* (ASTM E1689-95) defines the CSM as "a written or pictorial representation of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system." For the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4), the CSM was used to integrate relevant site information, determine whether information or data were missing (data gaps), and identify additional information to be collected. In Chapters 2 through 7 of this report, the model is refined by the additional information and then used to identify and evaluate potential risks to HHE.

Figure 1-2 presents the basic elements associated with a CSM:

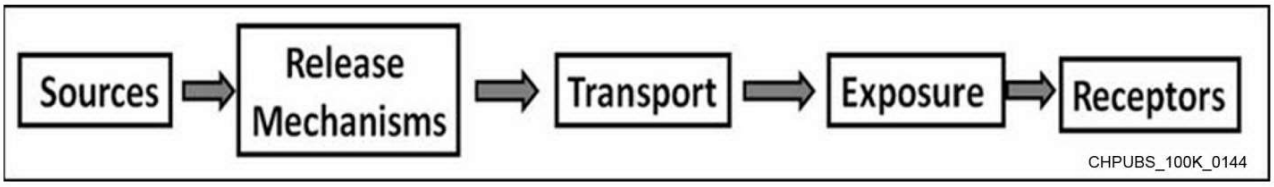


Figure 1-2. Conceptual Site Model

- **Source**—the location where a contaminant enters the physical setting. The primary sources of contaminants—releases related to reactor operations—are described in Chapter 1. Secondary sources are created when contaminants are mixed in the vadose zone and then the groundwater. Reactor operations at 100-F/IU have ceased, interim actions have largely removed the primary sources, and with the exception of the reactor structure containing the core that has been placed in Interim Safe Storage (ISS), contaminated buildings have been removed; therefore, this document focuses on secondary contaminant sources in the vadose zone and groundwater along with potential risks to HHE. These secondary sources are described in Chapter 5.

- **Release Mechanisms**—the actions necessary to release contaminants to the environment through resuspension of contaminated particulate matter, surface runoff, leaching to the vadose zone, plant intrusion, animal burrowing, erosion, or groundwater migration. Release mechanisms and relevant physical features are introduced in Chapter 3 and discussed in Chapter 5 in the context of fate and transport modeling.

- **Transport**—movement of a radiological, chemical, or physical agent in the environment where human or ecological exposure could occur. Contaminants introduced into the environment can be

transported between environmental media such as air, vadose zone, groundwater, and surface water as a result of interconnecting release mechanisms. Transport is discussed in Chapter 5.

- **Exposure**—the process by which a contaminant or physical agent in the environment comes into direct contact with the body, tissues, or exchange boundaries of humans, plants, or animals (for example, ingestion, inhalation, dermal absorption, or root uptake). Contaminants in the environment move from sources to potential receptors via pathways. An exposure pathway is complete when a receptor encounters contaminated environmental media. Potential exposure scenarios are discussed in Chapters 6 and 7.

- **Receptors**—humans and other organisms (for example, plants, animals, and other species) that may come into contact with the contaminants. Chapters 6 and 7 evaluate exposure to receptors.

The identification of data needs in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) led to development of a SAP that established characterization activities specific to 100-F/IU (*Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*, hereinafter called 100-F/IU SAP [DOE/RL-2009-43]). The approved 100-F/IU SAP (DOE/RL-2009-43) includes a field sampling plan describing the sampling strategy and techniques that were used to obtain the RI/FS data presented in this report. The 100-F/II SAP (DOE/RL-2009-43) also provides a Quality Assurance Project Plan (QAPjP) to ensure that data collected meet the appropriate quality assurance (QA) and quality control (QC) requirements.

## 1.2 Site Background

The Hanford Site encompasses approximately 1,517 $km^2$ (586 $mi^2$) in Benton, Franklin, and Grant Counties in south-central Washington State within the semi-arid Pasco Basin of the Columbia Plateau. The Site stretches approximately 50 km (30 mi) north to south and about 40 km (24 mi) east to west, immediately north-northwest of the confluence of the Yakima and Columbia Rivers, the Cities of Kennewick, Pasco, and Richland (the Tri-Cities), and the City of West Richland. The Columbia River flows 80 km (50 mi) through the northern part of the Hanford Site and, turning south, forms part of the Site's eastern boundary, while the Yakima River runs near the southern boundary of the Hanford Site, joining the Columbia River at the City of Richland. The central portion of the Hanford Site is punctuated by two small east-west trending ridges, Gable Butte and Gable Mountain. Lands adjoining the Site to the west, north, and east are principally range and agricultural. State Routes 240 and 24 skirt the southwestern and northern portions of the Site, respectively.

The Hanford Site area is culturally rich, experiencing a history of multiple occupations by both Native and non-Native Americans. For thousands of years, Native American peoples have inhabited the lands within and around the Hanford Site (*Tribal Distribution in Washington* [Spier, 1936]; and *Handbook of North American Indians: Volume 12, Plateau* [Walker and Sturtevant, 1998]). Non-Native American presence in the mid-Columbia area began in 1805 with the arrival of the Lewis and Clark Expedition along the Columbia and Snake Rivers. In the late 19$^{th}$ and early 20$^{th}$ centuries, non-Native people began intensive settlement on the Hanford Site, establishing an early settler and farming landscape. Farmstead communities existed from 1880 to 1943, located primarily in the upland environment adjacent to the Columbia River. The area became one of the premier orchard regions in the state of Washington following formation of the Hanford Irrigation and Development Company in 1905.

The River Corridor includes approximately 8,300 acres of historical farmsteads of which approximately 5,000 acres were orchard lands. Within the farmstead areas and specifically on the orchard lands, lead arsenate was applied as a pesticide. The farming life at Hanford came to an abrupt halt in 1943 when the U.S. government took possession of the land to produce weapons-grade plutonium as a part of the

Manhattan Project. Lead arsenate use in Washington State effectively terminated in 1948, when dichlorodiphenyltrichloroethane (DDT) became widely available to the public (*Re-establishing Apples Orchards in the Chelan-Manson Area* [Benson et al., 1969]).

The persistence of residuals from lead arsenate that was applied as a pesticide before Hanford operations began is a concern that merits an assessment of potential impacts to HHE. To address this concern, the Tri-Parties have established the 100-OL-1 orchard lands OU (TPA [Ecology et al., 1989a] change notice C-12-01). An RI of the 100-OL-1 OU will be conducted to determine if actions are needed to mitigate potential environmental or human health impacts. If results from the RI indicate a need for action, an FS will be conducted to identify and evaluate a range of remedial alternatives.

Until 1943, White Bluffs was an agriculture-based community of approximately 500 people. Many of the sites within the 100-IU-2 OU are remnants of the town and the surrounding farms. While most government activities in 100-IU-2 ceased early in the 1950s, it was not until the 1970s that the majority of remaining facilities were removed (*White Bluffs, 100-IU-2 Operable Unit Baseline Technical Report* [BHI-00448]). At the Hanford Townsite, government operations had ceased by 1945, and waste sites remaining within 100-IU-6 included surface debris, oil spills, trash dumps, building foundations, and ash piles from both pre-Hanford and Hanford-era Site activities (*100-IU-6 Operable Unit Technical Baseline Report* [BHI-00146]).

### 1.2.1 Site Description

The Hanford Site is divided into numerically designated areas. These areas served as the location for reactor, chemical separation, and related activities for the production and purification of special nuclear materials and other nuclear activities. The reactors and their ancillary/support facilities were located along the south shore of the Columbia River in the 100 Area, due to the need for large quantities of water to dissipate the heat generated during reactor operations. The 200 Area, located about 11 km (7 mi) from the Columbia River, contained all the facilities used to separate, isolate, store, and ship the plutonium. The 300 Area, located adjacent to and north of the City of Richland, contained the reactor fuel manufacturing plants and the research and development laboratories, while the 400 Area, located 8 km (5 mi) northwest of the 300 Area, contained the Fast Flux Test Facility designed for testing liquid metal reactor systems. The 600 Area, meanwhile, consisted of facilities that served more than one specific area, or in some cases, the entire project.

The 100-F/IU area can be divided into two primary areas of use: the 100-F Reactor area, and the IU-2 and IU-6 areas. The 100-F area encompasses the F Reactor operating region and includes the 100-FR-1 and 100-FR-2 source OUs, and the 100-FR-3 groundwater OU. The IU-2 and IU-6 source OUs cover a large area outside of Hanford's primary reactor operating areas. Figure 1-1 shows the location of the 100-F/IU Area in relation to the rest of the Hanford Site and the surrounding communities.

*Laser Interferometer Gravitational-Wave Observatory.* The Laser Interferometer Gravitational-Wave Observatory (LIGO) is situated on a section of property residing within the area bounded by 100-IU-2/6 (see Figure 1-3). The LIGO operates under a permit granted by DOE to the National Science Foundation (NSF) under Contract No. R006-93PR10998.000. The permit was signed in August 1993 and expires 25 years from the date thereof, unless either extended or terminated by mutual agreement between the NSF and DOE.

As a precursor to construction of the LIGO facility, *Environmental Assessment for Construction and Operation of a Laser Interferometer Gravitational-Wave Observatory on the Hanford Site, Richland, Washington* (NSF-EA-93-02) was completed, and it addressed the environment anticipated to be affected by construction and operation of the facility. As part of this assessment, a radiological survey of the LIGO

site was conducted that revealed no surface radiation levels above background. Additionally, DOE provided for cultural, radiological, and cursory biological surveys of the area in support of a NEPA Categorical Exclusion (*Categorical Exclusion for Laser Interferometer Gravitational-Wave Observatory Site Characterization, Hanford Site, Richland Washington* [DOE, 1992]), which determined that no threatened or endangered species were known to occur on the LIGO site and only one late historical site was discovered located approximately 200 m (660 ft) from the construction zone.

Based upon the evaluations performed in support of the environmental assessment and the permit granted to NSF by DOE, the land occupied by LIGO is excluded from further consideration under 100-IU-2/6 as no contaminated sites were found that would preclude the use of the land for its intended purpose for the LIGO.

### 1.2.2 Hanford Site and Operational History

This section provides an overview of the history of the Hanford Site as well as the operational and process histories of 100-F/IU OUs. It describes the 100-F Reactor and support facilities, cooling water systems, and radioactive and nonradioactive waste streams, as well as the types of waste disposal facilities used during Hanford Site operations. It also describes the types of locations where contaminants were released and indicates the types of contaminants that are likely to be found in various locations at 100-F/IU OUs.

#### *1.2.2.1 Hanford Site History*

The Hanford Site was selected for plutonium production to support development of military nuclear weapons in 1942 as part of the Manhattan Project because of the availability of water from the Columbia River, access to power from the Bonneville and Grand Coulee Dams, its remote location, and its relatively small population. Land acquisition for the Hanford Site took place in February 1943 and represented one of the largest land procurements (approximately 160,000 ha [400,000 ac]) carried out during World War II. Site construction that began the following month was largely completed with the first three reactors (B, D, and F) online by early 1945.

Between 1947 and 1955, the Atomic Energy Commission (AEC) added five new reactors (C, H, DR, KE, and KW) at the Hanford Site and boosted the output of the three Manhattan Project reactors (B, D, and F). The five new reactors were built with the intent of replacing some of the older Manhattan Project reactors, whose graphite blocks were showing signs of deformation, and increasing the plutonium output. Incremental improvements in the basic components of the World War II Manhattan Project reactors and a construction program that incorporated these improvements into the new reactors accounted for doubling the plutonium output at the Hanford Site in 1952 and 1953.

The period from 1956 through 1964 saw the most intense defense production at the Hanford Site, including the construction of a new dual-purpose reactor (N Reactor) capable of generating electricity and producing plutonium. Construction of the N Reactor, which featured a new closed-loop, primary cooling system, was completed in 1963, with plutonium production beginning in 1964. The N-Reactor's 800-megawatt steam plant began producing electricity in 1966 and was the world's largest nuclear power plant for many years.

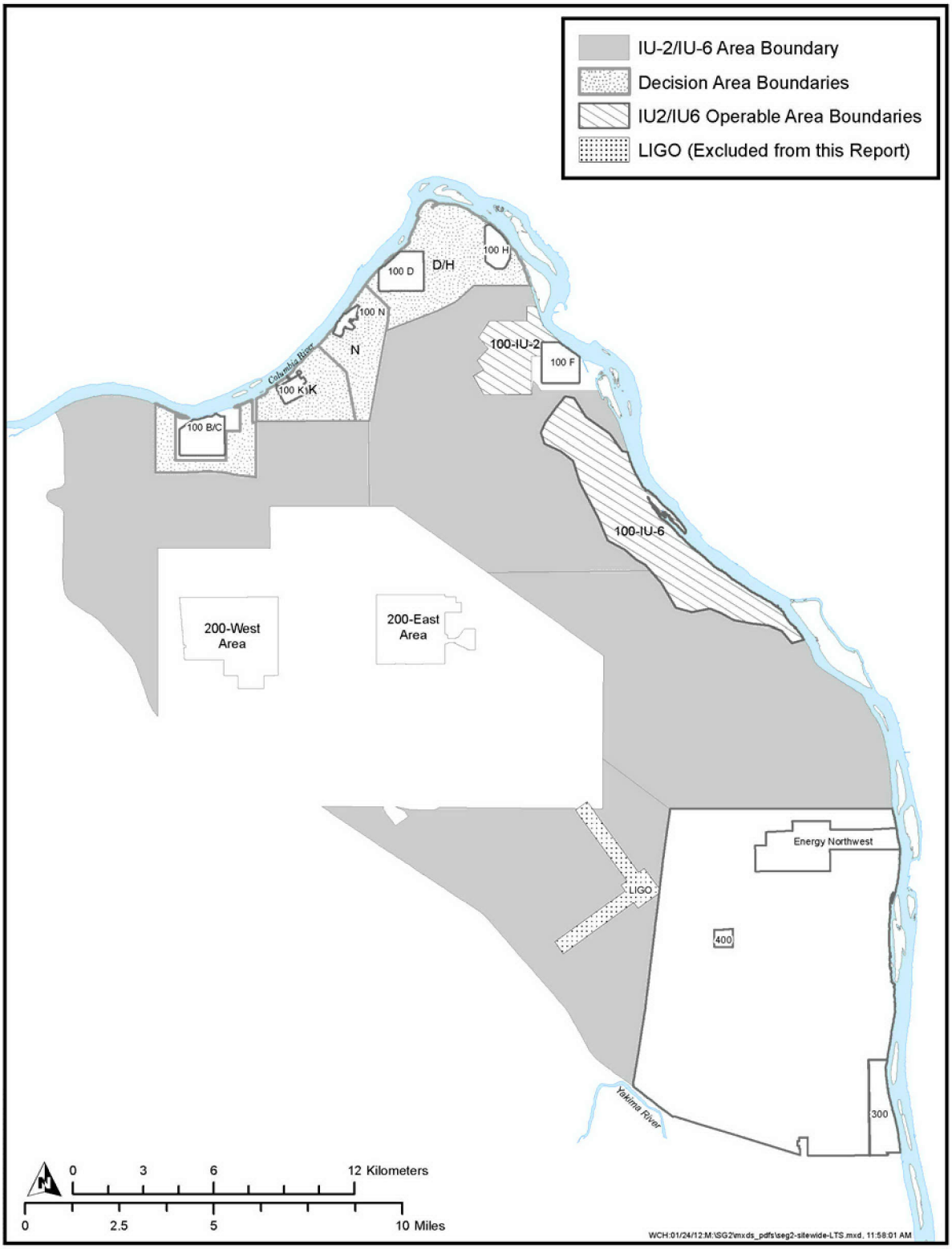


Figure 1-3. Laser Interferometer Gravitational-Wave Observatory Location

By the 1960s, however, the nation's plutonium stockpile was much larger than deemed necessary; and plutonium production at the Hanford Site gradually decreased. In 1964, the AEC shut down the 105-H, 105-DR, and 105-F Reactors, followed by 105-D Reactor in 1967 and 105-B Reactor in 1968. The 105-C, 105-KE, and 105-KW reactors were shut down in 1971. The 105-N Reactor was shut down in 1986 and transitioned to cold standby in 1989, signaling the close of the Hanford Site's production mission and the start of its cleanup mission. During the Manhattan Project and Cold War, more than 67,000 kg (147,000 lb) of plutonium were produced at the Hanford Site, 13,000 kg (29,000 lb) of which were fuel-grade plutonium. The Hanford Site produced the entire nation's nuclear arsenal plutonium between 1945 and 1963, and accounted for more than 65 percent of all plutonium in the history of U.S. plutonium production.

The environmental impacts associated with the ultimate disposition of the reactors were evaluated in *Addendum (Final Environmental Impact Statement): Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE/EIS-0119F). The Environmental Impact Statement (EIS) ROD ("Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington" (58 FR 48509), hereinafter called the NEPA Reactor ROD, documented the selection of ISS for the reactors. ISS is the provision of an upgraded, weather-resistant shell to isolate the reactor core until remedial activities are conducted. Following a period of up to 75 years for radioactive decay of short and intermediate half-life radionuclides, the reactors are planned to be disposed in burial grounds. Figure 1-4 shows the 105-F Reactor in its ISS configuration.

The 100-F area (100-FR-1 and 100-FR-2 OUs), located downstream from the 100-H area and upstream from the 300 Area, contains the F Reactor and associated infrastructure. The 100-IU-2 and 100-IU-6 OUs were not part of reactor operations; they include the Hanford and White Bluffs Townsites, and consist of large expanses of open land between and outside the various production areas. Groundwater contamination in the areas underlying the 100-IU-2 and 100-IU-6 OUs is from past disposal practices in the 100 and 200 Areas. For cleanup purposes, groundwater OUs are linked to the source of the contaminant plume, not to the plume's physical location. There is no groundwater contaminant source from within the 100-IU-2 and 100-IU-6 OUs. Groundwater contamination underlying the 100-IU-2 and 100-IU-6 OUs will be addressed by River Corridor and Central Plateau groundwater OUs.

Producing plutonium for national defense was the primary mission of the Hanford Site reactors. Materials that passed through the reactors were considered radiologically contaminated. These materials represent the majority of the wastes that were produced. Active physical barriers and strong administrative measures were in place to minimize radiological hazards throughout the Hanford Site production areas to protect plant personnel. These measures affected the placement of disposal locations and waste management procedures for various waste streams.

#### *1.2.2.2 105-F Operations*

The 100-F Reactor was supported by multiple facilities associated with services for water treatment, air filtration, nuclear fuel handling, effluent disposal, and laboratories, with various other administrative buildings (*100-F Reactor Site Technical Baseline Report Including Operable Units 100-FR-1 and 100-FR-2* [WHC-SD-EN-TI-169], hereinafter called the 100-F Reactor Site Baseline Report). The 100-F area also included the Experimental Animal Farm (EAF), where biological research studies were performed to examine the effects of radiation and radioactive contamination on plants, animals, and fish. Operations within 100-IU-2 and 100-IU-6 were primarily related to other uses, such as historical agricultural uses and other uses associated with human occupation, as discussed in Section 1.2.2.7.

Figure 1-4. 105-F Reactor Safe Storage Enclosure (August 2008)

Construction of the F Reactor (105-F Building) began in December 1943. This reactor was the third of three original Hanford Site reactors built during World War II as part of the Manhattan Project. These original reactors were considered "single-pass" reactors, because the cooling water made a single pass through the reactor before discharge back to the Columbia River. The facility was completed in February 1945 and activated later that month after comprehensive equipment testing. Operations were initially conducted at 265 megawatts and over time gradually increased to a final level of 2,090 megawatts in 1961. The F Reactor continued operating at maximum authorized power levels from 1961 until it was deactivated in 1965, after 20 years of operation. Figure 1-5 shows 100-F during the production years.

Reactor operations and processes were the primary sources of contamination in the 100-F area. Experimentation associated with the 100-F EAF secondary mission, coupled with waste disposal associated with the reactor, comprised secondary sources of contamination associated with the 100-F/IU Area (1.2.2 and 1.2.3). Further information is provided in Section 5.2 as it pertains to fate and transport.

Liquid wastes from reactor operations and associated facilities were released to the soil column and the Columbia River. Solid wastes were disposed in burial grounds associated with the facilities. Wastes released to or buried within the environment created secondary sources of contamination, such as liquid waste sites (ponds, trenches, cribs, and French drains), burial grounds, and numerous small miscellaneous waste sites scattered throughout the river corridor.

Figure 1-5. Aerial View of the 100-F Area during Production (1962)

*Trenches*. Shallow, narrow, unlined surface liquid waste sites of variable length received limited quantities of sludge and/or liquid wastes (cooling water, contaminated water and sludge, sodium dichromate, fuel cladding failure effluent, and decontamination solutions [i.e., citric acid, nitric acid, and solvents]). Trenches typically were 15 to 40 m (50 to 130 ft) long, 3 to 5 m (10 to 17 ft) wide, and 2 to 6 m (6 to 20 ft) deep.

*Cribs*. Subsurface liquid waste disposal sites percolated wastewater into the ground without exposure to the atmosphere. The cribs typically were 3 × 3 × 3 m (10 × 10 × 10 ft) boxes, shored with wooden railroad ties, and filled with gravel. Early waste management practices used cribs to receive low-level radioactive waste for disposal and to provide a physical barrier against surface exposure. Cribs received contaminated water and sludge, contaminated process tube effluent, fuel storage effluent, spent laboratory solutions, and potassium borate solutions.

*French Drains*. Subsurface liquid waste disposal sites were designed to percolate wastewater into the ground without exposure to the atmosphere. These sites were usually constructed with a 1 m (3 ft) diameter, open or gravel-filled pipe placed vertically to less than 5 m (16 ft) below ground surface (bgs). French drains typically received low volumes of low-level radioactive waste for disposal.

*Solid Waste Burial Grounds*. These areas were used for near-surface disposal of solid waste containing radioactive and nonradioactive hazardous substances, construction debris (such as steel, concrete, and wood) from reactor modifications, contaminated construction equipment, contaminated vadose zone material, irradiated reactor parts, and low-level radioactive combustible material (*Estimates of Solid Waste Buried in 100 Area Burial Grounds* [WHC-EP-0087]; *Historical Events—Reactors and Fuels Fabrication* [RL-REA-2247]).

*Unplanned Release Sites*. At these sites, wastes unintentionally released to the environment created sources of contamination. Waste sites in this group typically related to liquid waste spills.

*Retention Basins*. Large, open, compartmentalized, reinforced concrete structures were designed to hold cooling water temporarily from reactor operations, then discharge it to the Columbia River after cooling and decay of short-lived radioactive contaminants. Although retention basins are sometimes considered liquid waste sites because they leaked substantially to the surrounding vadose zone, they were not designed to percolate liquids into the vadose zone.

*Pipelines*. Closed transfer lines between facilities or structures were used to transfer chemicals or waste effluents and included lines that may have leaked.

#### 1.2.2.3 Reactor Mechanics and Layout

This section describes the mechanics and layout of the reactor and associated facilities. All reactor areas used the same nomenclature for numbering the reactors and associated facilities.

***Reactor.*** The 105-F Reactor was a graphite-moderated, water-cooled unit used to produce weapons-grade plutonium. Each reactor structure includes a concrete foundation, steel base plate, cast iron bottom shield, cubical stack of graphite blocks, cast iron thermal shield walls/top, steel/Masonite® biological shield walls/top, and aluminum process tubes to hold the uranium fuel and carry the cooling water. The reactor facility (designated as 105-F) includes a reactor block, control rod and safety rod facilities, reactor control room, fuel storage basin and associated fuel handling equipment, fans and ducts for the ventilation and recirculating gas systems, and supporting offices, shops, and laboratories. Vertical safety rods hung above the reactor and could decrease or increase the reactivity, respectively.

#### 1.2.2.4 Cooling Water

This section describes how cooling water was obtained and prepared for use in the reactor. It also describes the fate of the cooling water as it passed through the reactor and was subsequently discharged to the river or to the vadose zone.

A continuous supply of high-quality cooling water was essential to reactor operations to prevent reactor core damage from heat generated by the fission reactions. In general, cooling water obtained from the Columbia River was circulated in a single pass through the reactor. The water was circulated through fuel process tubes, cooling tubes imbedded in the thermal shield, and reactor horizontal control rods. The cooling water exiting the reactor contained radioactive materials from the reactor and chemical contaminants added to treat the raw water before use. After exiting the reactor, the cooling water passed through a retention basin system and was subsequently discharged to the river.

*Water Treatment and System Infrastructure.* To produce reactor coolant for the F Reactor, water was pumped directly from the Columbia River at the 181-F Pump House to either the 183-F Facilities to remove impurities by conventional physical and chemical treatment or the 182-F Holding Reservoir. Water from the reservoir was typically used to supply the 184-F Powerhouse and the export water system. Water was treated at the 183-F Facility with chemical additives consisting of the following:

- Aluminum sulfate (alum) with excess hydrated calcium oxide (to enhance the removal of suspended sediment by flocculation)
- Sulfuric acid (to control pH)
- Chlorine (to control algae growth)

The alum was produced in the upper floor of the 183-F Treatment Building by mixing bauxite with sulfuric acid. The bauxite was stored in bunkers on the third floor. The concentrated sulfuric acid was stored in steel tanks outside of 183-F (*Hazards Summary Report: Volume 3 – Description of the 100-B, 100-C, 100-DR, 100-F and 100-H Production Reactor Plants* [HW-74094]). The additives were introduced as the water passed down a flume into a mixing chamber. From there, the water was transferred to a basin equipped with paddle wheel flocculators. The specifications for the different additives and filtration are discussed in *Process Specifications Reactor Cooling Water Treatment* (HW-28505).

After passing through the flocculators, the water passed to one of twelve open-air settling basins, also located with the 183-F Facility, where the heavier particulates were allowed to settle out. After the particulates settled out of the water, an organic polyelectrolyte was added to the water, and the water was filtered through gravel, sand, and crushed anthracite coal filters. These filters were backwashed periodically and the resulting wastewater discharged to the process sewer and the 1904-F Outfall (116-F-8) (*Process Specifications Reactor Cooling Water Treatment* [HW-28505]).

Following filtration, the water was pumped to 34 million L (9 million gal) clearwells. Water was pumped into both the elevated emergency storage tanks (1.1 million L [300,000 gal] each) located adjacent to the reactor and to the four large-capacity storage tanks located in the 190-F Building annex). The four 190-F storage tanks were each approximately 6.65 million L (1.75 million gal) in size. Approximately 2 mg/L sodium dichromate was added at the inlet of these tanks in order to inhibit corrosion of the aluminum process tubes (*Process Specifications Reactor Cooling Water Treatment* [HW-28505]; 100-FR-3 RI/FS Work Plan [DOE/RL-91-53]). More than 4.19 million kg (4,620 tons) of sodium dichromate were used at 100-F between 1945 and 1965.

The treated water was pumped from the large-capacity tanks to a high-pressure pumping station located in the 190-F Building Annex. From this high-pressure pumping station, the water was delivered to a valve pit in the F Reactor building, and then pumped to the reactor. There were several flow paths through the reactor block itself. The primary cooling water pathway was through the process tubes in which the cylindrical fuel elements were located. Cooling water also flowed through cooling pipes located in the thermal shield and the horizontal control rods and experimental test holes that penetrated the reactor core. The cooling water streams from all flow pathways were recombined before exiting the reactor. Another significant waste stream that was combined with the cooling water effluent was the diatomaceous earth slurry used periodically to scour the corrosion film from the inner surfaces of the piping, the process tubes, and fuel elements in order to reduce friction losses in the system (*Hazards Summary Report: Volume 3–Description of the 100-B, 100-C, 100-DR, 100-F, and 100-H Production Reactor Plants* [HW-74094]). This slurry was a major source of solids in the cooling water.

While the water was in the reactor, it absorbed thermal energy from the nuclear process and became contaminated with radioactive isotopes (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]; 100-FR-3 RI/FS Work Plan [DOE/RL-91-53]). Several sources of contamination were as follows:

- The high neutron flux in the reactor core activated elements in the cooling water, creating species such as calcium-41, chromium-51, and zinc-65. Most of the species were relatively short lived and have since decayed to negligible levels (calcium-41 is an exception). Calcium-41 is a long-lived isotope (1.03E5 years). However, there are mitigating factors to it posing a risk to HHE. First, the neutron cross section for calcium-40 (the source) is extremely low (less than 1 barn); therefore, the production rate would be extremely low. Cooling water retention times in the reactor were short, so actual generation would be minimal. Second, the energy emitted is essentially nonexistent, as there are no associated particle emissions, only low-energy x-rays that have not been detectable by classical

analytical methods. Third, calcium-41 is naturally present in the top 1 m (3.3 ft) of soil as a result of cosmological activation, which goes virtually undetected.

- Contaminants picked up and carried during passage of cooling water through the reactors include activation products from targets or reactor components (e.g., tritium, cobalt-60, and nickle-63), and products released through breached fuel cladding (e.g., cesium-137, strontium-90, uranium, plutonium isotopes, and carbon-14).

- Fuel element fission products such as strontium-90 and cesium-137 and transuranics such as plutonium-239 and plutonium-240 were introduced into the cooling water in the event of fuel cladding failures. Other products from this process (sodium-24, neptunium-239, arsenic-76, zinc-65, and phosphorus-32) were short lived radionuclides and have since decayed to negligible levels (*History of the Plutonium Production Facilities at the Hanford Site Historic District, 1943-1990* [DOE/RL-97-1047]).

*Cooling Water Effluent.* Water discharged from the reactor was near boiling. Reactor cooling water was generated, passed through the reactor, and discharged at an average rate of 180,560 L/min (47,700 gal/min) until 1956 when the flow was increased to 268,760 L/min (71,000 gal/min) (*Historical Events-Reactors and Fuels Fabrication* [RL-REA-2247]).

The retention time for effluent within the fuel storage basin varied from 1.5 to 4 hours for flow rates occurring during the last three years of operation. Holding times also fluctuated based on the flow rates through the reactor (*Effective Retention Time of the Hanford 107 Reactor Effluent Retention Basins* [HW-28830]). The total radioactivity in the reactor cooling water four hours after exiting the reactor was reported to have been in the range of 0.2 μCi/L to 2.0 μCi/L during normal operations.

Upon exiting the reactor, the coolant was conveyed to the 107-F Retention Basin (116-F-14) by gravity flow via the effluent water line. The 107-F Retention Basin (116-F-14) was located approximately 400 m (1,300 ft) northeast of the 105-F Building. The basin was a rectangular concrete reservoir designed for pool depths of approximately 4.6 m (15 ft). The water was held in the 107-F Retention Basin long enough to allow for the decay of the short half-life radioactive elements. Water was then passed through another large-diameter pipe to the 1904-F Outfall structure (116-F-8). Under normal conditions, the water flowed out of the outfall through two 1 m (42 in.) diameter pipes, the river discharge lines, which ran under the surface of the river to a point near the middle of the river where the effluent was discharged. During periods of high water, or in the case of a line obstruction, the effluent would overflow the outfall structure and discharge to the river through a spillway.

The 107-F Liquid Waste Disposal Trench (116-F-2) was located 46 m (150 ft) southeast of the southeast corner of the 107-F Retention Basin (116-F-14). This trench was an open ditch approximately 158 m (521 ft) long × 6.1 m (20 ft) wide × 3.35 m (11 ft) deep with a V-shaped cross section and lined with fairly coarse gravel. The trench was used to receive the reactor effluent during outages caused by fuel cladding ruptures. Originally, the trench was supplied by directing the water as it exited the 107-F Retention Basin (116-F-14) from its normal path down to the 1904-F Outfall (116-F-8) structure into a special 0.3 m (12 in.) diameter pipeline that ran to the head (north end) of the trench. However, changes were eventually made in the total effluent system, which permitted bypassing the retention basin by diverting the reactor effluent to the trench directly from the 1 m (42 in.) effluent line before it entered the basin via a feeder trench between the effluent line and the main waste disposal trench. This ditch was approximately 91 m (300 ft) long and entered the main trench about 30.5 m (100 ft) below its north end.

Radioactive coolant was discharged to the 107-F Liquid Waste Disposal Trench (116-F-2) between 1950 and 1965. Contaminants estimated from *Hazard Ranking System Evaluation of CERCLA Inactive Waste*

*Sites at Hanford (Volume 1 – Evaluation Methods and Results, Volume 2 – Engineered-Facility Sites [HISS Data Base], Volume 3 – Unplanned-Release Sites [HISS Data Base])* (PNL-6456) for 116-F-2 included tritium, cobalt-60, strontium-90, cesium-137, plutonium-239, and europium-152; with a hazardous chemical inventory estimate that included 60,000 kg (65 tons) of sodium dichromate.

Radioactive coolant discharge also occurred at a soil column disposal site near the F Reactor. The 105-F Pluto Crib (116-F-4) received waste briefly from 1950 to 1952. After 1952, the highly contaminated cooling water was no longer segregated from the bulk of the cooling water. The 107-F Liquid Waste Disposal Trench (116-F-2) and 105-F Pluto Crib (116-F-4) were significant because they consisted of direct soil column discharge of liquid wastes with presumably high contaminant concentrations (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]).

Major reactor maintenance and upgrade outages generated large volumes of cooling water effluent to be disposed. When the Ball 3X system was installed in 1953, the reactor effluent was discharged to the river via the Lewis Canal (116-F-1). The 105-F Cooling Water Trench (116-F-6), located just south of the reactor building, was another major disposal area for cooling water effluent during reactor and retention basin maintenance outages between 1952 and 1965.

*Sodium Dichromate-Corrosion Prevention.* Sodium dichromate was added continuously to the reactor cooling water after the coagulation and filtration treatment, and accounted for nearly all of the sodium dichromate used. Figure 1-6 presents the facilities and waste sites where sodium dichromate was handled/disposed at 100-F, based on process history information.

Bulk sodium dichromate salt was used as the stock material for cooling-water treatment from approximately 1944 to 1959 at the F Reactor when the transition to concentrated sodium dichromate solution was implemented (*Monthly Record Report, Irradiation Processing Department, August, 1959* [HW-61789]). Sodium dichromate was added to the water in the 190-F Building. The crystalline sodium dichromate salt was batch dissolved in water to make a working solution of 10 to 15 percent sodium dichromate. This solution was then used to treat cooling water for the reactors.

High-concentration (greater than 70 weight percent) sodium dichromate solutions were used as the stock material after 1959 until closure of the reactor. These materials were received by rail and truck tankers. The concentrated solution was subsequently diluted with water to make a 10 to 15 percent working solution. The moderate concentration solution was then metered into the cooling-water stream in the 190-F Building, downstream of the flocculation/sedimentation basin.

Initially, a Cr(VI) concentration of 700 to 800 µg/L [2 mg/L of sodium dichromate] was used in coolant water. Additionally, the volume of flow through the reactor was increased over time (*Historical Events-Single Pass Reactors and Fuels Fabrication* [DUN-6888]). From these data, an approximate total coolant volume of 2.3 trillion L (608 billion gal) passed through the reactor, containing about 1,600,000 kg (3,527,396 lb) of Cr(VI), assuming the lower end of the concentration range of 700 µg/L.

#### 1.2.2.5 Radioactivity Sources

Radioactivity was introduced into the cooling water at several stages of the production process. The reactors contributed the most activity to the cooling water through the fuel elements and the resultant cooling water, which was discharged to various storage facilities.

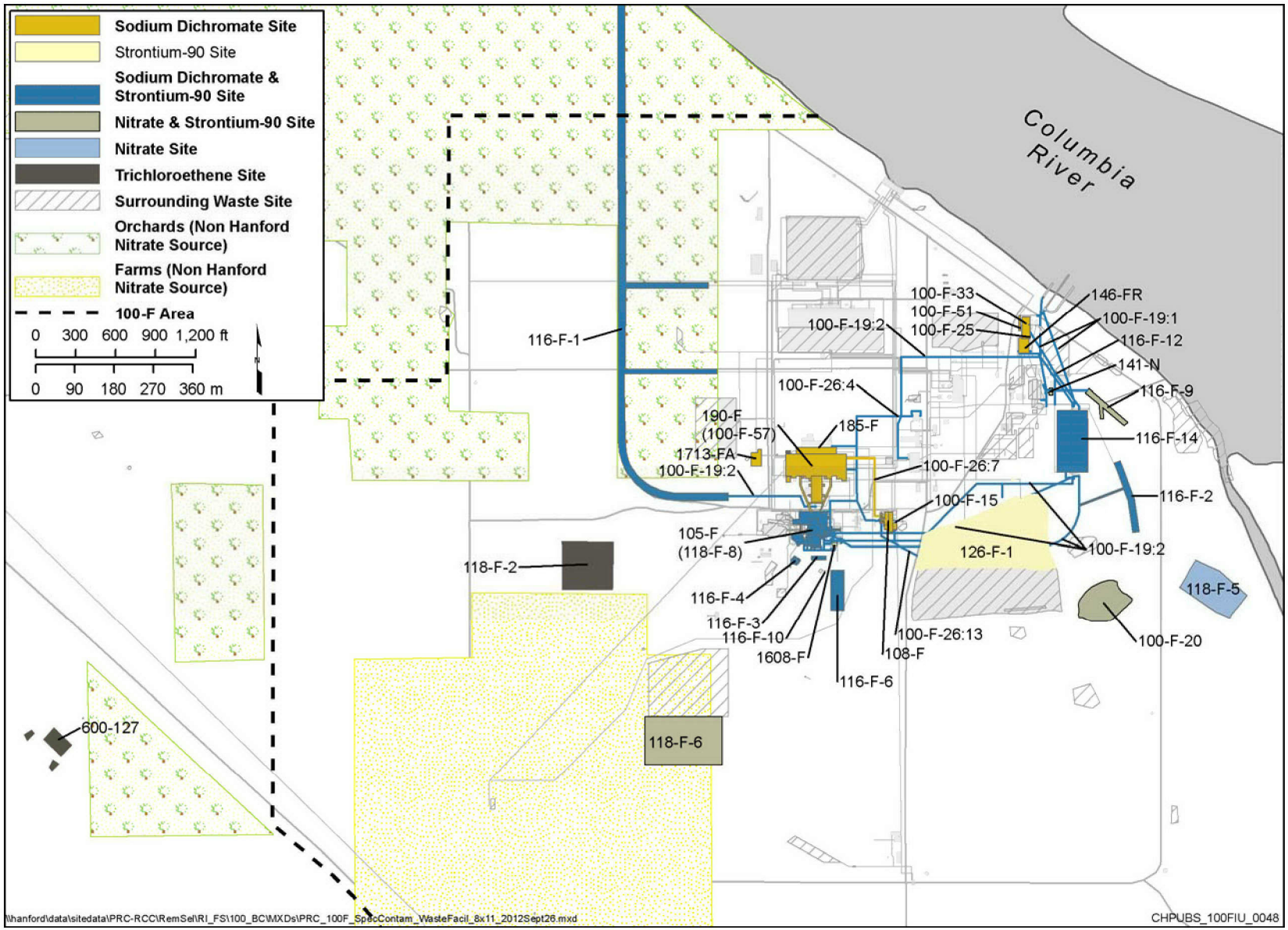


Figure 1-6. Facilities and Waste Sites Where Contaminants Were Handled at 100-F

*Fuel Elements and Failures.* During reactor operations, fuel cladding failures sometimes occurred while the fuel elements were in the process tubes. The first such cladding failure in a reactor occurred at the F Reactor in 1948. Over the operational lifetime of the reactor, several hundred such cladding failures occurred (*Historical Events—Reactors and Fuels Fabrication* [RL-REA-2247]). Fuel element and infrastructure failures (e.g., pipe leaks) were a source of secondary contamination to the environment.

When fuel cladding failed, the cooling water in the affected process tube became highly contaminated, and elevated radiation levels were observed in the cooling water exiting the reactor core. A decision was made to divert the contaminated water through a trench to the soil column rather than to the river via the retention basin. In 1947, the 107-F Liquid Waste Disposal Trench (116-F-2) was excavated in the area just south of the retention basin. The retention basin was, by construction, divided into two compartments. When a fuel cladding failure occurred, the highly contaminated water was segregated into one of the two compartments and drained to the overflow trench (116-F-2). This practice continued on a regular basis until 1954, when increased flows and structural stresses on the basin due to the temperature differences between the full and empty sides necessitated that both sides of the basin be used in parallel. It appears that at that time, a ditch (the emergency bypass ditch) was excavated from the basin inlet to the center of the overflow trench and was used to direct contaminated cooling water to the trench.

The 105-F Pluto Crib (116-F-4) was briefly used for handling contaminated cooling water from fuel cladding failures. The 105-F Pluto Crib (116-F-4) received only the highly contaminated water that was flushed directly from the process tube affected by the fuel cladding failure before it could mix with water from unaffected tubes. The crib was used from 1950 to 1952, after which the highly contaminated cooling water was no longer segregated from the bulk of the cooling water (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]).

Over the operating lifetime of the reactor facility, the retention basins and effluent piping developed leaks, releasing cooling water to the area in and around the basins, lines, and river shore at a rate as high as several thousand liters per minute (*Radiological Characterization of the Retired 100 Areas* [UNI-946]). Specific information on leak rates from the 107-F Retention Basin (116-F-14) is not available; however, contamination detected around the basin indicates that leakage did occur. A particularly significant release occurred at the basin in May 1955 when baffles in the basin broke loose and plugged the basin outlet. The cooling water overflow contaminated the immediate vicinity of the basin and drained to the Columbia River via a narrow trench near the northeast corner of the basin (the basin leak trench) (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]).

*Fuel Storage Basin.* The 105-F Fuel Storage Basin (118-F-8:3) and transfer area served as a collection, storage, and transfer facility for irradiated fuel elements after they were discharged from the reactor. The storage basin was a large concrete tank measuring approximately 24.7 m (81 ft) × 22.6 m (74 ft) × 6.32 m (20.7 ft) that was normally filled with filtered water to a depth of 5.5 m (18 ft). The heavy concrete walls, which shield the back face of the reactor, form one end of the basin. An underwater chute through this wall provides access from the basin into the rear face, and it is through this chute that the fuel elements fell as they were discharged from the reactor. In this area, the pick-up chutes or segregation area, the fuel elements were sorted from the fuel spacers and placed into metal buckets that were supported by an overhead monorail by means of a long steel yoke. The full buckets were brought out into the storage basin proper by means of the monorail. The storage basin monorail system was set up to provide 20 parallel rows of bucket storage on 1.22 m (4 ft) center and each 18.3 m (60 ft) long. Rows of concrete columns between the rows supported the wood decking that formed the storage area floor. The monorail system included the switches and cross tracks necessary to position the fuel storage basket at any desired location within the basin. The buckets of irradiated elements were lowered to the basin floor where the short-lived

radionuclides were allowed to decay for approximately 30 days before the fuel was shipped to the 200 Area for processing.

The transfer area is located alongside of, and is open to, both the storage area basin and building. The transfer area building is approximately 7.92 m (26 ft) wide × 22.6 m (74 ft) long × 11.6 m (38 ft) high. Two transfer pits, measuring 1.93 m (6.3 ft) wide × 2.74 m (9 ft) long × 8.23 m (27 ft) deep, are located in the end of the transfer area that is open to the storage area. The transfer pits are connected to the storage area basin by a canal over which the monorail system runs. Railroad tracks entered the building through a large door on the end opposite the transfer pits. The building was equipped with a 27,200 kg (30 ton) capacity bridge crane that was used to lift the heavy steel and lead fuel element shipping cask out of the railroad well car and lower it into the transfer pit. The bucket of irradiated fuel was lowered into the cask by means of a hydraulic hoist located over the pit. When loaded, the cask was raised by the crane and replaced in the well car. The building was equipped with steel-supported operating platforms for the crane operator. A third pit, also connected to the storage area system, was located in one corner of the transfer area and was equipped to permit the underwater examination of individual fuel elements and process tubing sections (*Production Reactor Decommissioning Study 100-F Site and Facilities Description* [UNI-1001]).

Occasionally, a fuel element in the storage basin would rupture or an element would be found to be ruptured when discharged from the reactor core. This caused the storage basin shielding water to become highly contaminated. From the information available on the F Reactor, it is not clear how often this occurred or where the contaminated water was disposed. When the storage basin was decommissioned in 1970, the water level was drained to within 0.6 to 1.2 m (2 to 4 ft) from the basin bottom, and the water was drained to the 116-F-2 Trench. The basin was subsequently backfilled with soil, burying the sludge and miscellaneous equipment (fuel buckets and spacers, aluminum tubing, and wood floor planking) that were in the basin at the time (*Radiological Characterization of the Retired 100 Areas* [UNI-946]).

#### 1.2.2.6 Radioactive Waste Streams

Wastes resulting from supporting production operations were disposed in each area according to phase, quantity, radioactivity, and composition. The primary waste produced was a radioactive liquid, the cooling water discussed previously. Other categories of wastes include liquids, solids, high/low mass or volume, high-level, low-level, strictly chemical, and septic wastes. Liquid and solid disposal locations were constructed, and waste management practices were developed to manage these materials consistently. The facilities and waste sites where strontium-90 was known to be present at 100-F, based on process history information, are presented in Figure 1-6.

*Radioactive Sludge and Solid Wastes.* Several thousand tons of radioactive sludge were generated during reactor operations and accumulated in the 116-F-14 Retention Basin and in the reactor fuel storage basin. Smaller volumes of sludge also collected in water traps located in the 115-F Gas Recirculating Facility (132-F-3) and the 117-F Ventilation Exhaust Filter Building (132-F-5), also referred to as the 117-F Filter Building. The sludge consisted of diatomaceous earth used periodically to scour the reactor process tubes, wind-blown sand, and fine particulate matter that originated from dissolved and suspended solids in river water, pipe slag, rust, failed fuel elements, graphite powder, and other undefined solids. The sludge was contaminated with radionuclides and various chemical contaminants. The total volume of sludge generated during reactor operation is unknown.

The bulk of the sludge accumulated in the 116-F-14 Retention Basin and the 118-F-8:3 reactor fuel storage basin. At least once during reactor operations, an unknown quantity of sludge was removed from the 116-F-14 Retention Basin to an unspecified burial site (100-FR-3 RI/FS Work Plan [DOE/RL-91-53]). Approximately 1,800 metric tons (1,980 tons) of sludge were estimated to remain in the retention basin

(*Radiological Characterization of the Retired 100 Areas* [UNI-946]). The retention basin has subsequently been remediated and the remaining sludge has been removed and disposed in accordance with the 1997 Interim Action ROD Amendment as documented in *Cleanup Verification Package for the 116-F-14 Retention Basin* (CVP-2001-00009).

Sludge from the 118-F-8:3 reactor fuel storage basin was removed once in 1951 and placed in the 116-F-3 Storage Basin Trench. In 1970, the fuel storage basin was pumped until 0.6 m (2 ft) of water remained, where sediment/sludge and miscellaneous items were found. Fine streambed sand was then placed into the remained of the basin with the remaining sludge buried in place in 1970. Between 2002 and 2003, the site was excavated, and the remaining sludge and basin waste was disposed in the ERDF (*Cleanup Verification Package for the 116-F-3 Fuel Storage Basin Trench* [CVP-2002-00008]).

Radioactive solid wastes generally consisted of reactor components, contaminated equipment, tools, and miscellaneous contaminated items (paper, rags, structural concrete, etc.). The main source of these wastes was reactor operations, and the most highly contaminated solid wastes were the reactor components. These included aluminum spacers, lead-cadmium reactor neutron poison pieces, boron splines, graphite, process tubes, and lead. Lesser quantities of gun barrels, thimbles, control rods, nozzles, pigtails, and cadmium sheets were also present (*Estimates of Solid Waste Buried in 100 Area Burial Grounds* [WHC-EP-0087]). Neutron activation of elements in the reactor components caused them to become highly radioactive. In addition, both the reactor components and other solid objects received surface contamination from contact with radioactive solutions and environments. The predominant radionuclides associated with the reactor components are cobalt-60 and nickle-63. The following two reactor modification projects were responsible for much of the solid waste from the F Reactor:

- The Ball 3X Project, in which the liquid boron system for emergency reactor shutdown was modified to a system using solid boron steel and carbon steel balls.
- The tube replacement project, in which nearly 4,000 aluminum process tubes from the F Reactor were replaced between 1956 and 1965 (*Historical Events—Reactors and Fuels Fabrication* [RL-REA-2247]).

It is likely that other facilities associated with the F Reactor and waste management activities generated radioactive solid wastes; examples include air filters in the 115-F Gas Recirculation Building and the 117-F Exhaust Air Filter Building, equipment used in connection with the cooling water effluent system, and contaminated dirt removed from near the effluent lines.

The primary disposal areas for the 100-F Area were the 118-F-1 and 118-F-2 Burial Grounds located in the 100-FR-2 OU. Irradiated reactor components removed during the Ball 3X system installation were buried in the 118-F-3 Burial Ground. Other reactor hardware was placed in the 118-F-7 Storage Box, a buried concrete vault with a wooden lid.

In addition, the radioactive solid waste buried within the boundaries of 100-F included decommissioning wastes such as building foundations, contaminated concrete-lined tunnels, pieces of concrete and other materials from demolished buildings, and pipelines. Contamination in these cases resulted mainly from surface contact with contaminated air, dust, and liquid solutions. Radiation levels are low in cases where decontamination and decommissioning (D&D) have occurred (*Remedial Investigation/Feasibility Study Work Plan for the 100-FR-1 Operable Unit, Hanford Site, Richland, Washington* [DOE/RL-90-33]).

*Decontamination Solutions.* During reactor operations and reactor shutdowns, large quantities of decontamination solutions were used routinely to remove radionuclides from reactor equipment and

facility surfaces. Decontamination activities took place at the F Reactor dummy decontamination facility wash pad, which was adjacent to the fuel storage basin.

Known decontamination solutions used at 100-F included chromic acid, citric acid, oxalic acid, nitric acid, sulfamic and sulfuric acids (neutralized with sodium carbonate before disposal), and sodium fluoride. Other chemicals, including organic solvents (e.g., trichloroethene [TCE]), were also used for some decontamination processes. These solutions were generally disposed in cribs, trenches, and/or French drains near the building where they were used. Decontamination solutions from the 189-F Building were released to the 116-F-1 Trench. Occasionally, solutions were combined with the cooling water and discharged to the river via the 107-F Retention Basin. The solutions contained both radionuclide and chemical contaminants. Some compounds used in the decontamination solutions, such as oxalate and organic complexants, may potentially have solubilized and transported radionuclides and metals. The quantities of decontamination solutions, as well as other disposal locations, are not known (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]; 100-FR-3 RI/FS Work Plan [DOE/RL-91-53]).The facilities and waste sites where trichloroethene was known to be present at 100-F (based on process history information) are presented in Figure 1-6.

Decontamination solutions using higher concentrations of sodium dichromate were also used at 100-F, but management and disposition of these spent solutions was not always clear from process documentation. Several other paths for disposal of these solutions were available, including disposal to the soil column and to the process sewer/outfall piping discharging to the river. Decontamination fluids, used to clean radioactively contaminated equipment and containing Cr(VI) in the form of chromic acid, were discharged near the reactor at the 116-F-10 Dummy Decontamination French Drain. This site received liquid waste containing 2,000 kg (2.2 tons) each of sodium dichromate, sodium oxalate, and sodium sulfamate and may have received other chemicals as well (100-FR-3 RI/FS Work Plan [DOE/RL-91-53]).

#### *1.2.2.7 Non-Radioactive Waste Streams*

Other waste streams associated with reactor operations included sanitary wastes, other liquids containing hazardous (but not radioactive) waste, and various solid wastes, described as follows.

*Sanitary Liquid Wastes.* Sanitary wastes were produced in the various buildings equipped with sanitary facilities in the 100-F area. These wastes were routed by server lines to five septic tanks and leach fields located within the OU. Nonsanitary wastes such as detergents, cleaning compounds, and solvents likely entered these sewer systems. Laboratory wastes containing low levels of both radioactive and hazardous chemical contaminants may have been disposed via the sanitary sewers. These wastes likely contributed to100-F nitrate contamination in the vadose zone and groundwater. In addition, fertilizer use on pre-Hanford Site agricultural lands likely contributed to local nitrate contamination. Additional nitrate contributions were the result of animal waste from the EAF. Figure 1-6 shows the facilities and pre-Hanford Site agricultural lands where nitrate was known to be present at 100-F, based on process history.

*Non-Radioactive Liquid Wastes.* Nonsanitary, nonradioactive liquid chemicals that were used at 100-F potentially contributed to contamination there. These include hazardous wastes and hazardous substances. Contamination from liquids, including gasoline, diesel fuel, solvents, and other chemical compounds, would be expected near aboveground or belowground storage tanks and their piping systems and in areas where these materials were used or stored. Releases could have resulted from leakage, spillage, or disposal. The following activities may have resulted in the generation of nonradioactive liquid wastes (100-FR-3 RI/FS Work Plan [DOE/RL-91-53]):

- Water treatment chemicals (alum, sulfuric acid, chlorine, and sodium dichromate) were used and stored near the 183-F and 190-F Buildings, as discussed previously.

- Wet-type electrical transformers and hydraulic machinery containing oil contaminated with polychlorinated biphenyls (PCBs) were used at several locations within 100-F. Fluids contaminated with PCBs may have been released or disposed during operation, equipment repair, or D&D activities.
- Boiler water treatment chemicals for the 184-F Powerhouse included sodium sulfate, tri-sodium phosphate, and chromates. These chemicals were used to treat the boiler water and ended up in the boiler sludge. Disposal methods for this sludge are unknown.
- Three zeolite water softeners were located in the 184-F Powerhouse where filtered water was treated before use in the heat exchangers. Sodium chloride solutions were used to regenerate the zeolite beds in the water softener tanks. The salt was delivered in railcar lots to brine pits located adjacent to railroad tracks just north of the powerhouse. The disposal of the waste from this process is not known, and there are no records of leaks or spills.
- Emergency electrical power for instrumentation in the F Reactor Building consisted of two backup systems: a 10-kVA gasoline engine generator for the station in general and a set of batteries for the Ball 3X system. Fuel for the generators was stored outside the reactor building in tanks placed on tall concrete saddles for gravity feed to the system.
- Oils, paints, and solvents were stored or used at the 1715-F and 1717-F Buildings.
- Automotive repair and service was performed at the 1716-F Building.
- Three 94,625 L (25,000 gal) oil tanks were located on the west side of the 1717-F Maintenance Shop Building (*184-B Powerhouse, 184-D Powerhouse, 1717-F Maintenance Shop Facility Decommissioning Report* [SD-DD-TI-033]).
- Additional wastewater was generated during various cleaning processes. Disposal locations for these solutions are unknown at this time.

*Nonradioactive Solid Wastes.* Nonradioactive solid waste generated in 100-F primarily included miscellaneous materials such as paper, trash, pieces of metal, and plastic parts used in the facilities. Waste Site 128-F-1 is listed in *Hazard Ranking System Evaluation of CERCLA Inactive Waste Sites at Hanford: Volume 2 – Engineered-Facility Sites (HISS Data Base)* (PNL-6456) as a burning pit in which combustible wastes were disposed. The 128-F-2 Burn Pit served a similar purpose and also received uncontaminated hardware.

Other solid waste consisted of relatively uncontaminated concrete, metal parts, and other materials generated during D&D activities. Asbestos, chemical waste, and contaminated solids were removed from the area to an unknown location during the D&D work. Building materials that were not considered to be contaminated were buried in place. Some of these materials may have had very low-level radiological contamination.

#### 1.2.2.8 Research Related Operations

Each reactor area typically had a specific secondary mission that was dictated by the Hanford Site's general production stance. These secondary missions contributed specific waste management challenges for each reactor area that introduced variations from the initial common design and requirements, and increased the complexity of waste management operations. The secondary mission of the facilities at and around the F Reactor was the EAF, a biological laboratory used to examine the effects of radiation and radioactive contamination on plants, animals, and fish (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]).

The EAF was located adjacent to the reactor site and operated from 1945 to 1976 (Figure 1-7). Acute and lifetime exposure studies using a variety of isotopes (iodine-131, cesium-137, strontium-90, radium-226, and plutonium-239) were performed on animals including swine, sheep, dogs, cats, rodents, cows, chickens, and miniature goats at the EAF. Approximately 1,000 animals at a time were kept at the farm, with experiments on larger animals focused on the 20-year lifetime exposure effects. The main facilities used to house the animals were 141-F and 141-C. Animal pens in both buildings had concrete floors and were connected to a special sewer system for contaminated animal wastes. Two smaller buildings, 141-P and 141-S, were also used for housing animals. These buildings had dirt floors. Feed was stored in Building 141-B, and the laboratory facilities were located in Building 141-H. The animal monitoring laboratory, which contained a whole body counter, was located in Building 145-F. Figure 1-8 shows the locations of the various buildings associated with the EAF.

The other major animal research effort was studying the effects of ionizing radiation on beagle dogs. Approximately 300 to 400 dogs were housed in the 144-R dog kennel runs located on the south side of the 141-F Barn. The main isotope used in the dog studies was plutonium-238. The laboratory facilities for these experiments were located at the 132-F-2 Inhalation Laboratory (100-FR-3 RI/FS Work Plan [DOE/RL-91-53]). These experiments produced contaminated solid and liquid wastes, including animal remains, dung, and urine that were disposed onsite.

The earliest animal experiments at the 100-F Area involved fish research at the 146-F Fish Laboratory in 1945. These studies involved exposing fish (mainly salmon and trout) to varying concentrations of reactor cooling water effluent to assess possible effects of effluent discharge on aquatic life in the Columbia River. In addition to the hatchery troughs located in the 146-F Laboratory, six rearing ponds were located next to the laboratory (*Aquatic Bioenvironmental Studies: The Hanford Experience 1944-1984* [Becker, 1990]). Effluent water was supplied to the laboratory facilities via the 147-F Pump House. Water was continuously circulated through the troughs at a rate of approximately 0.15 to 0.38 L/sec (2 to 5 gal/min) (*Some Effects of Pile Area Effluent Water on Young Chinook Salmon and Steelhead Trout* [HW-7-4759]) and was discharged to the PNL outfall structure via the 147-F Pump House. Fish research expanded around 1951 with the construction of the 146-FR Fish Laboratory (Figure 1-9). Building 146-FR also had hatchery troughs and laboratories. With its construction, the146-F Fish Laboratory was phased out and the building used for storage. Biological experiments with fish and other aquatic organisms continued at the 100-F Area until 1976 (Figure 1-10).

Other experiments involving radioecology were conducted in greenhouses in 1705-F to determine the effects of ionizing radiation and radioactive contaminants on plants, both genetically and in the food chain. In addition, gardens located in the southwest corner of the 100-F Area were used for growing cereal grains, alfalfa, and other crops in soil containing controlled amounts of strontium-90 and cesium-137, referred to as the "strontium gardens." A 4 ha (10 ac) pasture near the "strontium gardens" was used to hold pregnant animals and animals too young for experimental activities (100-FR-3 RI/FS Work Plan [DOE/RL-91-53]). At the end of their operational life, these facilities were deactivated, decontaminated, decommissioned, and often demolished in place.

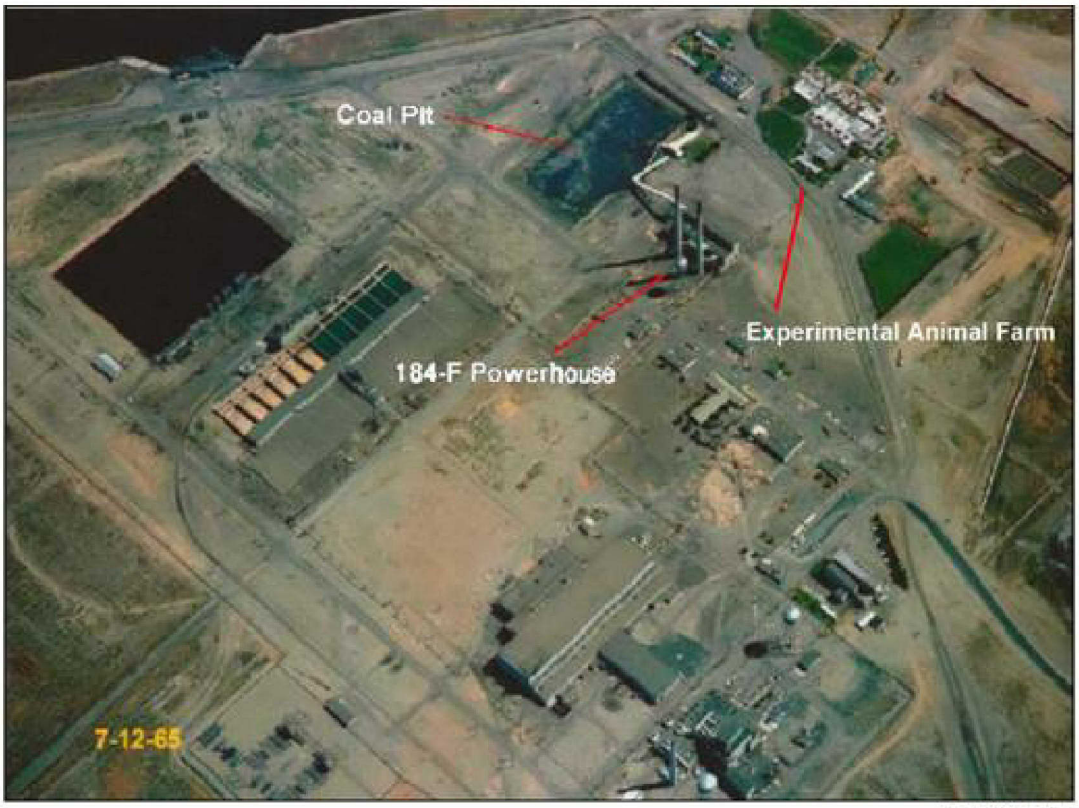


Figure 1-7. Aerial View of 100-F Area and Experimental Animal Farm (in top right corner)

Figure 1-8. Experimental Animal Farm Holding Areas and Fish Ponds (1965)

Figure 1-9. Construction of 146-FR

Note: Radiological posting

Figure 1-10. Fish Tanks in One of the Biological Laboratories

Solids disposal ranged from burial of solid animal wastes similar to other contaminated materials (e.g., packaging in plastic, boxes, or drums) in burial grounds to incineration and burial of animal remains. Disposal methods for these wastes varied widely, depending on their activity and amount. Liquid wastes were discharged with other laboratory wastes to liquid waste disposal sites.

Contaminated manure and sawdust were removed from animal pens on a regular basis and placed in plastic-lined cardboard radiation boxes, which were buried in the 118-F-6 Burial Ground. Each box was 45.7 × 45.7 × 61 cm (18 × 18 × 24 in.) and weighed 22.7 to 34 kg (50 to 75 lb).

The contaminated manure and sawdust that could not be shoveled out of the animal pens were washed into a sewer that drained to the 141-N Sump. When the sump became full, the wastewater was pumped through a screen to the river via the PNL Outfall. The solids trapped by the screen were dried and sent to the 118-F-5 Sawdust Pit. Manure and sawdust from uncontaminated areas were also sent to the same pit. In 1963, the 116-F-9 animal leach trench was constructed near the northeast corner of the 116-F-14 Retention Basin, and the liquid portion of the contaminated pen wash wastewater from the 141-N Sump was diverted there (100-FR-3 RI/FS Work Plan [DOE/RL-91-53]).

Contaminated animal carcasses and tissue were incinerated. The carcasses were placed in one of two railcar tanks (referred to by workers as "submarines") that were located near the 118-F-6 Burial Ground. The carcasses were dropped through a manhole into the tank, and lime was added to facilitate decomposition. When the tank was sufficiently full, 1,500 to 1,900 L (400 to 500 gal) of fuel oil was added to the tank and ignited. Reportedly, the carcasses burned relatively completely, with only small amounts of ash remaining. The ash was not cleaned out and when one tank eventually began to fill with ash, the second tank was constructed. Both tanks were buried in the 118-F-6 Burial Ground (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]).

The majority of the plutonium-239-contaminated carcasses and animal wastes from the dog experiments were incinerated as part of the experimental analysis. The carcasses and tissue were incinerated in a muffle furnace in 144-F, and analysis was performed on the ash to determine the total radionuclide burden in the animals. The contaminated waste from the laboratory was placed in radiation boxes and buried in the 118-F-6 Burial Ground. Other contaminated solid waste generated by the biology laboratories was also disposed in this manner.

An unplanned release associated with the EAF occurred in March 1971. The main sewer line between the EAF and the 141-C Hog Barn became plugged and overflowed onto the surface adjacent to the building. This contaminated soil occupied approximately 148.6 $m^2$ (1,600 $ft^2$). The spill consisted of wash water used to clean out animal pens and contained strontium-90 and plutonium-239 (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]).

The 108-F Building (Figure 1-11) was originally a chemical make-up facility and reactor laboratory (1945 through 1948) supporting the F Reactor. It was the main chemical pump house that provided water treatment corrosion control, with a layout similar to those at the B and D Reactors. That task at the F Reactor was moved and the building remodeled to serve as the main biology laboratory facility at about the same time as the water treatment mission was moved or consolidated at the other original production reactors (1948 through 1949).

After the 1949 remodeling, a large-scale biology study of the effects of radiation on various organisms commenced at Building 108-F. Experiments ranged from using animals to determine health effects on nuclear workers to tests for the military (*On the Home Front: The Cold War Legacy of the Hanford Nuclear Site* [Gerber, 2007]). This mission continued until 1973, when biological experiments and testing performed at the 108-F Building were transferred to the 300 Area.

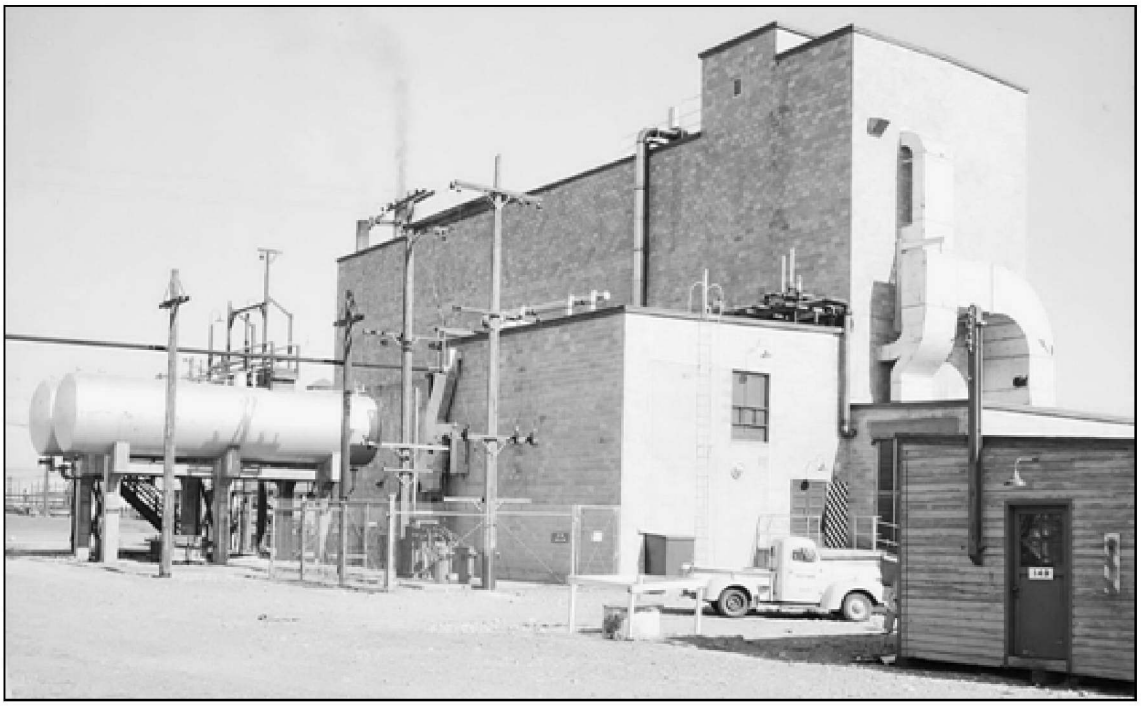

Figure 1-11. 108-F Laboratory Facility (1954)

This facility, and others that were repurposed once the reactor was shut down, had dedicated disposal sites for contaminated animal or plant experiment wastes in addition to those in place suitable for dual use. In 1977, a housekeeping program to remove highly contaminated material was conducted at the 108-F Building, with additional decontamination conducted in 1983 (*108-F Biological Laboratory D&D Project Closeout Report* [BHI-01399]). Facility demolition was completed in 1999.

After reactor operations at 100-F ceased in 1965, animal research operations took over the office buildings and maintenance shops previously associated with the F Reactor until 1976 (*An Aerial Radiological Survey of the U.S. Energy Research and Development Administration's Hanford Reservation (Survey Period: 1973-1974)* [EGG-1183-1661]). The 1707-F Building was converted for use as a dog inhalation laboratory. The 1707-FA Building was converted for use as a rodent inhalation laboratory. The 1713-F Building was used as a pathology laboratory, and the 1719-F Building was converted for use as an animal care facility. Small animals were housed in the 1701-FA Building (100-FR-3 RI/FS Work Plan [DOE/RL-91-53]).

#### *1.2.2.9 Other Uses (100-IU-2/IU-6 Area)*

Waste sites and facilities in the 100-IU-2 and 100-IU-6 OUs were mainly associated with housing, staging equipment, and material for the project; most of the area was previously occupied by homesteads and farms. The area includes roads, railroads, a fire station, fuel stations, storage facilities, an old concrete batch plant site, storage vaults in the east end of Gable Mountain, and pre-Hanford Site farm sites and landfills (e.g., pre-1943 municipal and farm waste sites). The area abuts part of the Arid Lands Ecology Reserve including Rattlesnake Mountain. Typical waste site classifications include landfills and dump sites. Contamination in this area generally originated from light industrial chemical use and agriculture, rather than nuclear material production and chemical processing.

The former Town of White Bluffs, the site of an agriculture-based community of approximately 500 people that existed before the Manhattan Project era, is located in the 100-IU-2 OU. Many of the

sites within the 100-IU-2 OU are remnants of that town and the surrounding farms. When the government took possession of the Hanford Site, many of the houses were demolished and new temporary buildings such as blacksmith shops, receiving and storage warehouses, and offices were erected (*White Bluffs, 100-IU-2 Operable Unit Baseline Technical Report* [BHI-00448]). The White Bluffs area was the location of the central shops to support the Manhattan Project.

The Hanford Townsite is located in the 100-IU-6 OU. Figure 1-12 shows the Hanford Townsite in 1943 after the camp construction. During the life of the construction camp, 1,175 buildings, 9 service facilities, and 7 trailer camps were constructed. Following termination of operations at the construction camp, a small force of patrol, fire, and boat repair personnel remained. In general, the sites within the 100-IU-6 OU included surface debris, oil spills, trash dumps, building foundations, surface depressions, and ash piles, either from the pre-Manhattan Project towns or activities of that era (*100-IU-6 Operable Unit Technical Baseline Report* [BHI-00146]). All portable hutments and trailers were dismantled and shipped offsite.

Figure 1-12. Hanford Townsite in 1943

All of the pre-Manhattan Project buildings on the Hanford Townsite have been removed, with the exception of two structures—Hanford High School and the Hanford Electrical Substation/Switching Station. These structures require no further action; therefore, they are not listed as facilities in the official Hanford WIDS database, which is the information source regarding known and suspected waste sites.

A total of 14 facilities were related to Manhattan Project or post-Manhattan Project activities. Most of these facilities were used to support laboratory activities, Hanford Site patrol activities, or communications. All have been demolished or removed.

### 1.2.3 Previous and Ongoing Investigations and Remediation

This subsection summarizes the significant investigations and remediation activities for facilities, waste sites, and groundwater at 100-F/IU. Since the beginning of reactor operations, investigations were conducted to determine impacts to the environment, including the Columbia River. With the issuance of the TPA (Ecology et al., 1989a), investigation activities transitioned to CERCLA cleanup activities, which have been ongoing to protect HHE within the River Corridor including 100-F/IU OUs.

The relevant data and conclusions from investigations and remediation activities (see Appendix B) provide supporting information that is analyzed and evaluated in this final RI/FS. The following are examples of the various data sets used to develop this RI/FS:

- Vadose zone contaminants
- Groundwater contaminants
- Geologic contact information, fate and transport parameters (e.g., distribution coefficient [$K_d$] dispersivity, hydraulic conductivity, and soil bulk density)
- Well and borehole information (e.g., drill depth, screen length, and screen depth)
- Groundwater elevations and river stage
- Geographic information system shape files (e.g., aerial photography, Columbia River, and locations of wells and boreholes, salmon redds, facilities, roads, and waste sites)

#### *1.2.3.1 Previous Facility Demolition Activities*

Since its original construction, 100-F has included a total of 158 facilities used or constructed in 100-F/IU, with the majority of these within 100-F. These facilities include the 105-F Reactor Building, office and storage buildings, retention basins, a reactor stack, maintenance shops, process plants, electrical substations, storage tanks, pump stations, and outfall structures. Some of these structures cover source waste sites. Until the structures over a source site have been removed, no vadose zone remediation can be completed. Therefore, the facilities[1] (including contaminated pipelines associated with them) are and have been undergoing removal to clear the way for the remedial work that focuses on contamination in the vadose zone.

Of the 158 facilities, 146 have been demolished or removed. Facilities that were used during the operation of the reactors—the retention basin, reactor stack, office and storage buildings, maintenance shops, process plants, electric substation, storage tanks, and pump stations—comprise most of the demolished or removed facilities. The only facilities remaining within the 100-F Area include the 105-F Reactor building (currently inactive) and an emergency siren (currently active). Guard stations and emergency sirens comprise most of the nine active facilities within the 100-IU-2/IU-6. A radio transmitter is the only inactive facility still present in the area. Table 1-2 provides summary information on the status of facilities.

[1] "Facility" is defined here as a freestanding building, plant, laboratory, or other enclosure or associated building that fulfills or fulfilled a specific purpose and is owned by or otherwise under the responsibility of DOE. This usage differs substantially from that contained in CERCLA or RCRA.

Table 1-2. Summary of Facilities in the 100-F/IU Area

| OU | Total Number of Facilities | Demolished | Removed | Active | Inactive |
|---|---|---|---|---|---|
| 100-FR-1 | 100 | 89 | 9 | 1 | 1 |
| 100-FR-2 | 14 | 14 | 0 | 0 | 0 |
| **Total Facilities for F Area** | **114** | **103** | **9** | **1** | **1** |
| 100-IU-2 | 9 | 5 | 0 | 4 | 0 |
| 100-IU-6 | 35 | 26 | 3 | 5 | 1 |
| **Total Facilities for IU Area** | **44** | **31** | **3** | **9** | **1** |
| **Total Facilities for F/IU Area** | **158** | **134** | **12** | **10** | **2** |

**Reclassification Status**

Demolished = Facility has been removed to grade (slab or foundation remains)

Inactive = Facility is no longer in use and awaiting D&D

Removed = Facility foundation has been removed and any substructure is 0.3 to 0.9 m (1 to 3 ft) below grade

Four of these facilities—the 115-F Gas Recirculation Facility, 116-F Reactor Exhaust Stack, 117-F Filter Building, and the 1608-F Lift Station—were decommissioned and demolished using *Allowable Residual-Contamination Levels for Decommissioning Facilities in the 100 Areas of the Hanford Site* (PNL-4722) methodology. In general, these facilities were decontaminated, demolished in-place and/or into adjacent trenches, and covered with clean fill material with a thickness ranging between 1 and 5 m (3 and 16 ft).

Under interim actions, the remaining footprint and debris of the facilities were identified as the 132-F-3 (117-F Filter Building), 132-F-4:1 and 132-F-4:2 (116-F Reactor Exhaust Stack), 132-F-5 (117-F Filter Building), and 132-F-6 (1608-F Lift Station) waste sites. The previous decommissioning data were reviewed and evaluated using residual radioactivity (RESRAD) dose modeling, including an allowance for the clean cover material, and were reclassified as No Action. These five sites are evaluated in the risk assessment presented in Chapter 6 to determine whether they pose an unacceptable risk to HHE.

*100-F Reactor.* In the 1993 NEPA Reactor ROD (58 FR 48509), DOE decided on safe storage of the eight reactors followed by deferred one-piece removal. The NEPA Reactor ROD (58 FR 48509) also states that the department intends to integrate and prioritize this decision with the related CERCLA remediation activities scheduled under the TPA (Ecology et al., 1989a).

DOE issued *Amended Record of Decision for the Decommissioning of Eight Surplus Reactors at the Hanford Site, Richland WA* (75 FR 43158) on July 23, 2010. DOE broadened the decommissioning approach for these eight surplus reactors, including the 105-F Reactor, retaining the deferred one-piece removal option, and, added an option for immediate dismantlement based on *Supplement Analysis: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE/EIS-0119F-SA-01).

DOE uses the CERCLA process to decommission and dismantle reactors based on the joint EPA/DOE policy on decommissioning signed in 1995 and incorporated into the TPA (Ecology et al., 1989a). Since the NEPA Reactor ROD (58 FR 48509) in 1993, documentation has been prepared and implemented

under CERCLA, resulting in placement of six of the eight surplus reactors (C, D, DR, F, H, and N) into ISS designed to prevent deterioration and release of contamination from the reactors. ISS for the 105-F Reactor was completed in 2005 to ensure the safety of the reactor for up to 75 years as part of the remediation activities in 100-F.

DOE evaluated the coordination of decommissioning actions with the completion of interim field remediation for 100-F/IU. Based on October 2012 field remediation information, all waste sites in the immediate vicinity of the reactors are interim closed-out under the Interim Action ROD. Until reactor removal is complete, DOE will continue to conduct routine reactor maintenance, surveillance, and radiological monitoring to ensure continued HHE protection during the ISS period. All other waste sites in the immediate vicinity of the reactor have been remediated under the Interim Action ROD.

#### 1.2.3.2 Vadose Zone Remedial Actions and Waste Site Investigations

Information regarding the behavior of contaminants in the soil column has been an important consideration in Hanford Site operations since the 1940s. Some reports (e.g., *Underground Waste Disposal at Hanford Works: An Interim Report Covering the 200 West Area* [HW-9671]; *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington* [HW-17088]) examined the issues related to waste disposal at injection wells, shallow burial cribs, and surface ponds. Groundwater monitoring via wells began in the late 1940s to evaluate the rate of migration through the vadose zone and in the aquifer. Although most attention was focused on radionuclides, primarily within the 200 Area, groundwater monitoring around the 107-F Waste Disposal Trench and the 108-B Crib was reported for some chemicals. Waste site designs sometimes included wells where geophysical logging could assess radionuclide movement through the aquifer. Continued waste site use depended on the vertical migration of contaminants, and sites were shut down when contamination reached certain predetermined concentrations in groundwater at these wells. As such, hydrologic and geochemical processes in the vadose zone were of interest, but were not well understood.

*Vadose Zone Investigations.* The vadose zone at the Hanford Site has been extensively studied since the 1980s. *Unsaturated Water Flow at the Hanford Site: A Review of Literature and Annotated Bibliography* (PNL-5428) provided an overview of the status of vadose zone studies in 1985. By 1992, a significant amount of data had been collected from lysimeters at a wide range of sites at Hanford ("Variations in Recharge at the Hanford Site" [Gee et al., 1992]). Recharge (sometimes called deep percolation) measurements using lysimetry and other techniques at the Hanford Site has been extensive over the past two decades (*Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates* [PNNL-17841]). Recharge rates applicable to different soil and surface cover conditions at the Hanford Site are listed in *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection* (DOE/RL-2011-50).

During the construction, operations, and remediation years, the topsoil was scraped off a large portion of 100-F. Based on results from "Variations in Recharge at the Hanford Site" (Gee et al., 1992), this condition affected a significant change in vadose zone dynamics with a substantial increase in vadose zone water flux since construction. Under native vegetation, the recharge rate would typically be expected to be 4.0 mm/yr (0.16 in.) or less (*Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection* [DOE/RL-2011-50]), while bare (unvegetated) ground would be subject to substantially greater recharge. For example, Ephrata sandy loam soil with native shrub steppe vegetation would be expected to yield a recharge of 1.5 mm/yr (0.06 in.), but the same soil in disturbed state and without vegetative cover can be expected to yield a recharge rate of 17 mm/yr (0.67 in.) (*Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection* [DOE/RL-2011-50]). Localized recharge rates could be even higher where buildings, tanks, and other structures divert precipitation laterally to specified locations. In addition, large volumes of water have been

added to historical waste site locations for purposes of the dust control during remediation activities. Once remediation is complete and native vegetation cover is reestablished, the recharge flux will return to the low recharge conditions that existed before the Manhattan Project activities at Hanford.

Table 1-3 presents a list of significant previous investigations completed as of 2011 as well as details and significant results.

Vadose zone remedial activity has been focused on the removal of contamination sources (waste sites). Potential source areas, as they are identified, are classified as waste sites and then evaluated. Each waste site is entered into the WIDS database using the classification definitions provided in *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" (RL-TPA-90-0001).

Table 1-3. Summary of Previous Vadose Zone and Waste Site Investigations

| Document Title | Document Number/Date | Summary of Observations and Conclusions |
|---|---|---|
| *Limited Field Investigation Report for the 100-FR-1 Operable Unit* | DOE/RL-93-82/ Sept. 1995 | Soil sampling and analysis was conducted at 9 representative waste sites to determine the need for IRMs (116-F-1, 116-F-2, 116-F-3, 116-F-4, 116-F-6, 116-F-9, 116-F-14, 108-F, and 132-F-1). potassium-40, cobalt-60, strontium-90, cesium-137, europium-152, 154, radium-226, thorium-228, and plutonium-238 were the principal radionuclides of concern. The highest concentrations of radionuclides were detected in the 116-F-4 Crib and 116-F-14 Retention Basin. Contaminant concentrations confirmed historical information documented in early reports (*Radiological Characterization of the Retired 100 Areas* [UNI-946]). The qualitative risk assessment identified human health risk from external exposure to radionuclides (cobalt-60, cesium-137, europium-152, europium-154, plutonium-238, potassium-40, radium-226, strontium-90, and thorium-228). Based on the evaluation of representative waste sites, 14 waste sites were recommended for IRMs. |
| *Radiological Characterization of the Retired 100 Areas* | UNI-946/May 1978 | In the mid-1970s, radiological characterization of waste sites was conducted to establish radionuclide inventories and contaminant distribution. The focus of the sampling was the 100-F liquid waste receiving sites to a maximum depth of 9 m (30 ft). Maximum contaminant concentrations were generally detected less than 7.6 m (25 ft) bgs. Samples at 15 waste sites were analyzed for carbon-14, cobalt-60, cesium-134, cesium-137, europium-152, europium-154, europium-155, nickle-63, plutonium-238, and plutonium-239/240. Radiological inventory estimates are presented in the report. The estimates reflect pre-remedial action inventories. Data from this report were considered in the preparation of the LFI Reports for the 100-FR-1 OUs. The data are not considered in this RI because they pre-date standardized EPA procedures. |

Table 1-3. Summary of Previous Vadose Zone and Waste Site Investigations

| Document Title | Document Number/Date | Summary of Observations and Conclusions |
|---|---|---|
| *Cleanup Verification Package for the 100-F-19:1 and 100-F-19:3 Reactor Cooling Water Effluent Pipelines, 100-F-34 Biology Facility French Drain, and 116-F-12 French Drain,* Appendix D*, 100-F Area Soil Cr(VI) and Carbon-14 Leachability Study Summary Report* | CVP-2001-00002/ May 2002 | This CVP is included because it contains a soil leachability study assessing the leaching potential of Cr(VI) and carbon-14 in soil at 100-F. Soil with elevated levels of Cr(VI) and carbon-14 collected from the 116-F-14 Retention Basin was selected for the leachability study. Results showed that Cr(VI) remaining in the soil column is not readily mobilized, based on the low concentrations of Cr(VI) and total chromium detected in the leachate. The results from the 100-F aggressive single batch leach tests are consistent with the aggressive leach tests conducted for 100-D soil (*Cleanup Verification Package for the 116-D-7 Retention Basin* [CVP-99-00007]) and 100-H soil (*Cleanup Verification Package for the 116-H-7 Retention Basin* [CVP-2000-00027]).<br><br>During leachability testing, soil with concentrations of carbon-14 up to 48.7 pCi/g did not leach detectable concentrations of carbon-14. The aggressive leachability testing of 100-F soil demonstrates that carbon-14 in the soil is not mobilized or leached by water with the typical composition of 100 Area groundwater, and it has been concluded that additional carbon-14 testing using column leach tests is not necessary. |
| *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* | PNNL-17674/July 2008 | The major objectives of this study were to determine the leaching characteristics of Cr(VI) from sediments collected at 100 Area spill sites, elucidate possible Cr(VI) mineral and/or chemical associations that may be responsible for Cr(VI) retention in 100 Area soil, and provide information to construct a conceptual model of Cr(VI) geochemistry in the 100 Area vadose zone. Results from column experiments indicated that most of the Cr(VI) traveled quickly through the column sediments and was present in the effluent. Calculated retardation coefficients were close to one (1.0).<br><br>Calcium polysulfide solutions readily reduced Cr(VI) to Cr(III) in column experiments. However, a significant amount of the Cr(VI) was mobilized before the polysulfide solution front. The experiments suggested that it would be difficult to design a remedial measure using infiltration of liquid phase reductants without increasing Cr(VI) transport toward the water table. |

Table 1-3. Summary of Previous Vadose Zone and Waste Site Investigations

| Document Title | Document Number/Date | Summary of Observations and Conclusions |
|---|---|---|
| | | The microscopic characterization results were consistent with the column studies. Cr(VI) was a ubiquitous coating on sediment grain surfaces.<br><br>This study also indicated that small, higher-concentration Cr(VI) sites were generally associated with secondary clay mineral inclusions with occasional barium chromate minerals, and that Cr(VI) was reduced to chromium(III) in association with iron oxides (that are most likely magnetite primary minerals). Within the restricted access domains of the sediment matrix, ferrous iron could also diffuse from in situ, high-surface-area minerals to cause the reductive immobilization of Cr(VI). This process may be favored at microscale geochemical zones where ferrous iron could be supplied. |
| *100-F Area Orphan Sites Evaluation Report* | OSR-2005-0001/Feb. 2012 | The orphan site evaluation process is a systematic approach to review land parcels and identify potential waste sites not listed in CERCLA decision documents. A total of 14 new discovery sites were identified in the 100-F orphan site evaluation process. These sites were evaluated according to *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" [RL-TPA-90-0001]) for possible inclusion in the Hanford Site cleanup work scope. |
| *100-IU-2 and 100-IU-6 Areas Orphan Sites Evaluation Report* | OSR-2008-0001/ Feb. 2009 | The orphan site evaluation process is a systematic approach to review land parcels and identify potential waste sites not listed in CERCLA decision documents. Forty-three new discovery sites were identified in the 100-IU-2 and 100-IU-6 orphan site evaluation process with 20 assigned to 100-IU-2 and 23 assigned to 100-IU-6. These sites were evaluated according to TPA-MA-14 for possible inclusion in the Hanford Site cleanup work scope. |
| *100-F/IU-2/IU-6 Area – Segment 1 Orphan Sites Evaluation Report* | OSR-2009-0002/ Apr. 2010 | The orphan site evaluation process is a systematic approach to review land parcels and identify potential waste sites not listed in CERCLA decision documents. Six new discovery sites were identified as a result of the 100-IU-2 and 100-IU-6 Segment 1 orphan site evaluation process, with all six assigned to 100-IU-2. These sites were evaluated according to TPA-MA-14 for possible inclusion in the Hanford Site cleanup work scope. |

Table 1-3. Summary of Previous Vadose Zone and Waste Site Investigations

| Document Title | Document Number/Date | Summary of Observations and Conclusions |
|---|---|---|
| *100-F/IU-2/IU-6 Area – Segment 2 Orphan Sites Evaluation Report* | OSR-2010-0001/ Aug. 2010 | The orphan site evaluation process is a systematic approach to review land parcels and identify potential waste sites not listed in CERCLA decision documents. No new discovery sites were identified in the 100-IU-2 and 100-IU-6 Segment 2 orphan site evaluation process. |
| *100-F/IU-2/IU-6 Area – Segment 3 Orphan Sites Evaluation Report* | OSR-2010-0004/ Jan. 2011 | The orphan site evaluation process is a systematic approach to review land parcels and identify potential waste sites not listed in CERCLA decision documents. No new discovery sites were identified in the 100-IU-2 and 100-IU-6 Segment 3 orphan site evaluation process. |
| *100-F/IU-2/IU-6 Area – Segment 4 Orphan Sites Evaluation Report* | OSR-2011-0001/ Nov. 2011 | The orphan site evaluation process is a systematic approach to review land parcels and identify potential waste sites not listed in CERCLA decision documents. Nineteen orphan sites were identified as a result of the 100-IU-2 and 100-IU-6 Segment 4 orphan site evaluation process with 12 sites assigned to IU-6, six assigned to 100-HR-2, and one site assigned to 100-FR-2. These sites were evaluated according to TPA-MA-14 for possible inclusion in the Hanford Site cleanup work scope. |
| *100-F/IU-2/IU-6 Area – Segment 5 Orphan Sites Evaluation Report* | OSR-2011-0002/ Dec. 2011 | The orphan site evaluation process is a systematic approach to review land parcels and identify potential waste sites not listed in CERCLA decision documents. One new discovery site was identified as a result of the 100-IU-2 and 100-IU-6 Segment 5 orphan site evaluation process with that site assigned to 300-FF-2. |
| *Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River* | PNL-8789/Sept. 1993 | The levels of radionuclides and trace metals along the Hanford Reach were measured and reported. The work was conducted as part of the Surface Environmental Surveillance Project, PNL. The survey consisted of measuring exposure rates and soil samples at locations within the Hanford Reach, where elevated rates are known or expected to be present based on *An Aerial Radiological Survey of the Hanford Site and Surrounding Area*, *Richland, Washington* (EGG-10617-1062) (the base report was not available for review).<br><br>Background rates measured at Vernita ranged from 4 to 11 µR/hr, and from 8 to 28 µR/hr at the White Bluffs Slough area. Sampling indicated that areas with elevated (compared to background) soil concentrations of major radioactive constituents include 100-D island, the shoreline of the Hanford Townsite, and the White Bluffs Slough area. No results regarding the distribution of radionuclides along the remaining areas of the Hanford Reach were discussed. |

Table 1-3. Summary of Previous Vadose Zone and Waste Site Investigations

| Document Title | Document Number/Date | Summary of Observations and Conclusions |
|---|---|---|
| | | The only sample location with significantly elevated concentrations of a trace metal (chromium) was near the 100-F floodplain.<br>The report concluded that several areas along the Hanford Reach still show impacts from Hanford operations. No short-lived radionuclides were detected, and no significant variation among trace metal concentrations was found. |
| *Measurement of Environmental Radiation Exposure Rates from Vernita, Hanford Reach, and Richland Area Shores* | PNL-8789, Addendum 1/Feb. 1995 | This report presents additional radiation survey results and a statistical analysis of the previous investigation.<br>The 1994 radiation exposure measurements from the Vernita area (14 sites) ranged from 8 to 11 μR/hr, Hanford Reach area (19 sites) measurements ranged from 8 to 15 μR/hr, and Richland area measurements (16 sites) ranged from 7 to 10 μR/hr.<br>The report summarizes the statistical differences between the areas measured. Significant differences were only identified when the Hanford Reach results were compared to the Richland area results. |

*Waste Site Remediation*. Full-scale remediation of the waste sites in 100-F/IU began in 1997 under the authority provided by the 1997 Interim Action ROD Amendment (EPA/AMD/R10-97/044) and continues to the present. The majority of the remediation consisted of removal, treatment, and disposal (RTD). In a few cases, such as for "no action" waste sites, remediation was not warranted based on assessment of quantitative waste site data, which indicate that contaminant concentrations are below RAGs.

Three interim remedial action RODs (Interim Action RODs) have been prepared to address source contamination in the 100-F/IU: *Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units* (EPA/ROD/R10-95/126) as amended by the 1997 Interim Action ROD Amendment (EPA/AMD/R10-97/044); the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039); and *Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington* (EPA/ROD/R10-00/121). While action to clean up soil contamination is mandated mainly by the Interim Action RODs, actions to mitigate impact from facilities have been initiated in accordance with the CERCLA action memorandum signed by the Tri-Parties (*Action Memorandum: USDOE Hanford 100 Area National Priorities List (NPL), 105-F and 105-DR Reactor Buildings and Ancillary Facilities, Hanford Site, Benton County, Washington* [Wagoner et al., 1998]).

Characterization of waste sites includes sample collection and analysis for the purposes of assessing the nature and extent of contamination and verifying achievement of remedial action objectives (RAOs) and interim RAGs. Achievement of RAOs is based on attaining RAGs for direct exposure, protection of groundwater, and protection of surface waters. Interim action RAOs and RAGs, as described in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17), hereinafter called the 100 Area RDR/RAWP, were achieved at all interim closed and no action waste sites. The use and evolution of onsite facilities and their roles in waste management operations are described more

completely in other technical documents (100-F Reactor Site Baseline Report [WHC-SD-EN-TI-169]; 100-FR-3 LFI [DOE/RL-93-83]). Specific site information obtained from contemporary characterization and remediation activities is available from WIDS.

Radioactive liquid effluent waste sites were targeted first by interim remediation as primary contributors to contamination at 100-F. Field data from previous investigations indicated that contaminant concentrations at high volume, liquid waste disposal sites (for example, lead and cesium-137) were highest at the bottom of the former disposal facility and generally decreased rapidly with depth in underlying soil. Waste sites that received small amounts of liquid were generally found to contain soil contamination extending limited distances into the vadose zone beneath the waste sites. Most of these high priority liquid waste sites in 100-F were remediated by 2002, followed by the remediation of burial grounds and other remaining site types.

Remedial actions are designed to achieve RAOs and goals specified in Interim Action RODs for direct exposure applicable to soil 0 to 4.6 m (0 to 15 ft) bgs and protection of groundwater and the Columbia River. In practice, this has involved excavating wastes and soil that exceed cleanup criteria, followed by disposal in the ERDF located in the Central Plateau. Residual contamination remaining after excavation is sampled and modeled to assess potential impacts to groundwater and the Columbia River. Where RAOs and the interim RAGs are achieved, the waste site is classified as "interim closed."

As of June 30, 2012, 132 100-F/IU waste sites have been remediated in accordance with the RAOs specified in the Interim Action ROD and backfilled with approved fill soil. Over 1.353 billion kg (1.492 million tons) of contaminated soil and debris have been removed from waste sites located in 100-F/IU and disposed at the ERDF. The remediated waste sites within 100-F consist mainly of basins, trenches, ditches, cribs, ponds, burial grounds, and unplanned releases. Figure 1-13 partially illustrates the extent of RTD activities accomplished in 100-F. Most waste sites within 100-IU-2 and 100-IU-6 are generally related to pre-Hanford Site or nonproduction-related features and are not radioactive in nature. The process of removing contaminated material from waste sites has the net effect of changing the nature and extent of waste site contamination. Therefore, information from previous investigations presented in *Radiological Characterization of the Retired 100 Areas* (UNI-946) and LFI reports for the 100-F/IU OUs no longer reflect post-interim remediation conditions, at least to the depth of remedial action.

*Waste Site Cleanup Documentation.* A cleanup verification document is prepared, following completion of the interim remedial actions or confirmatory investigations at a waste site in accordance with the applicable Interim Action ROD. These documents are referred to as either cleanup verification packages (CVPs) or remaining sites verification packages (RSVPs), depending on the applicable Interim Action ROD. This document contains verification sampling results and other supporting information to demonstrate that the attainment of interim RAGs and interim RAOs has been achieved. The CVP or RSVP usually includes a description of the site, contaminants and waste forms requiring action, interim remedial action conducted, disposal information, sampling plan and subsequent data and risk calculations, and comparison of closeout data to RAGs and risk requirements.

The exposure factors and assumptions used in the rural residential scenario are defined in the 100 Area RDR/RAWP [DOE/RL-96-17]). Soil interim RAGs for protection of groundwater are intended to achieve state or federal drinking water standards. In addition, RAGs were developed to protect aquatic organisms in the Columbia River. However, RAGs were not developed for the protection of terrestrial ecological receptors due to the absence of regulatory guidance at that time. CVPs currently consider "Model Toxics Control Act—Cleanup" (WAC 173-340), hereinafter called MTCA, standards for terrestrial receptors.

To support interim closure of waste sites, soil samples are typically collected and analyzed from the exposed surface at the bottom and sidewalls of an excavation. The sample methodology for verification

samples is described in the applicable SAP for each waste site. The analytical data are evaluated and, as appropriate, used to determine statistical values for comparison to RAGs and, if appropriate, in site specific modeling calculations. The primary statistical calculation to evaluate compliance with cleanup standards is the 95 percent upper confidence limit (UCL) on the arithmetic mean of the data. Maximum analyte concentrations are also used as appropriate to demonstrate that interim action cleanup goals have been achieved. The CVP and RSVP data are summarized in Appendix E and generally include the maximum concentrations and/or concentrations representing the 95 percent UCL for analytes for both the shallow (0 to 4.6 m [15 ft] bgs) and deep zones (greater than 4.6 m [15 ft] bgs), as appropriate.

#### *1.2.3.3 Waste Site Summary*

Table 1-4 summarizes the classification/reclassification status of 100-F/IU waste sites as of June 30, 2012. Table 1-5 lists the Accepted waste sites. Appendix A provides maps with the waste sites and facilities shown. Appendix E provides a description and history for each waste site.

Table 1-4. Summary of Waste Sites in the 100-F/IU OUs

| OU | Total Number of Waste Sites[a] | Closed Out[b] | Interim Closed Out[c] | No Action[d] | Not Accepted[e] | Rejected[f] | Accepted[g] |
|---|---|---|---|---|---|---|---|
| 100-FR-1 | 127 | 0 | 74 | 29 | 7 | 12 | 5 |
| 100-FR-2 | 22 | 0 | 14 | 4 | 1 | 3 | 0 |
| **Total for F Area** | **149** | **0** | **88** | **33** | **8** | **15** | **5[h]** |
| 100-IU-2 | 128 | 0 | 27 | 6 | 33 | 19 | 43 |
| 100-IU-6 | 123 | 1 | 17 | 11 | 7 | 15 | 72 |
| **Total for IU Area** | **251** | **1** | **44** | **17** | **40** | **34** | **115** |
| **Total for F/IU Area** | **400** | **1** | **132** | **50** | **48** | **49** | **120** |

Source: Waste Information Data System (WIDS), June 30, 2012

a. Summary metrics are based on accounting for subsites as individual sites. Additional information provided in Appendix E.

b. Closed Out—A reclassification status indicating, due to actions taken, a waste management unit meets applicable cleanup standards or closure requirements.

c. Interim Closed Out—A reclassification status indicating, due to actions taken, a waste management unit meets cleanup standards specified in an Interim Action ROD or Action Memorandum, but for which a Final ROD has not been issued. Further final actions may be necessary.

d. No Action—A reclassification status indicating a waste site does not require any further remedial action under RCRA Corrective Action, CERCLA, or other cleanup standards based on an assessment of quantitative data collected for the waste site. Existing "no action" reclassifications have been made under Interim Action RODs, and further final actions may be necessary.

e. Not Accepted—A classification status indicating an assessment has been made that a WIDS site is not a waste management unit and is not within the scope of *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b).

f. Rejected—A reclassification status indicating a waste site does not require remediation under CERCLA, or other cleanup standards based on qualitative information such as a review of historical records, photographs, drawings, walkdowns, ground penetrating radar scans, and shallow test pits. Such investigations do not include quantitative measurements.

g. Accepted—A classification status indicating an assessment has been made that a WIDS site is a waste management unit as defined in *Hanford Federal Facility Agreement and Consent Order Action Plan* (Ecology et al., 1989b). Sites accounted for as "accepted" are those for which no further action reclassification has yet been approved.

h. As of June 30, 2012, the five sites included the western half of the 190-F Process Water Pump House Debris (100-F-57:2), a green stained area along the railroad tracks immediately west of 190-F (100-F-65), the Riparian Area Contamination originating from 128-F-2 (100-F-59), the 100-F River Effluent Pipelines (100-F-39), and the 105-F Reactor Core and ISS Project (118-F-8:2).

*100-F-59*. The 100-F-59 waste site, riparian area contamination originating from 128-F-2, includes the section of the former 128-F-2 burn pit that is below the ordinary high water mark (OHWM) and a portion of the adjoining slough. Figure 1-14 is a historical photo showing the former burn pit during high water flow with the downstream slough inundated. Figure 1-15 shows the remediated 128-F-2 site and the general location of 100-F-59, with the shoreline area that is below the OHWM inundated.

Initial remediation of the 128-F-2 waste site was performed from August to October 2005. Additional remediation occurred in February 2007 to remove shoreline contamination extending below the OHWM. Final sampling results indicated the riparian area below the OHWM did not meet upland soil remedial action goals for multiple metals. Additional characterization sampling was performed of riparian areas upriver, downriver, and surrounding the contaminated area. Elevated metals results were primarily located in the area downstream and adjacent to the contaminated area. Therefore, this area was combined with the adjoining portion of the slough area to create the 100-F-59 waste site.

Figure 1-13. 100-F Area Waste Site Excavation Activities

Table 1-5. 100-F/IU Accepted Waste Sites

| Operable Unit | Waste Site |
|---|---|
| 100-FR-1 | 100-F-39, 100-F-57:2, 100-F-59, 100-F-65, 118-F-8:2 |
| 100-IU-2 | 600-279, 600-293, 600-294, 600-298:1, 600-298:2, 600-298:3, 600-298:4, 600-298:5, 600-298:6, 600-298:7, 600-298:8, 600-299:1, 600-299:2, 600-299:3, 600-299:4, 600-299:5, 600-299:6, 600-300:1, 600-300:2, 600-300:3, 600-300:4, 600-300:5, 600-300:6, 600-300:7, 600-300:8, 600-300:9, 600-300:10, 600-300:11, 600-300:12, 600-301, 600-303, 600-305:1, 600-305:2, 600-305:3, 600-305:4, 600-305:5, 600-306, 600-307, 600-308, 600-309, 600-310, 600-311, 600-312 |
| 100-IU-6 | 600-20, 600-313, 600-314:1, 600-314:2, 600-314:3, 600-314:4, 600-314:5, 600-316:1, 600-316:2, 600-316:3, 600-316:4, 600-316:5, 600-316:6, 600-317, 600-318:1, 600-318:2, 600-318:3, 600-318:4, 600-318:5, 600-319:1, 600-319:2, 600-319:3, 600-320:1, 600-320:2, 600-320:3, 600-320:4, 600-320:5, 600-320:6, 600-320:7, 600-320:8, 600-320:9, 600-321:1, 600-321:2, 600-321:3, 600-321:4, 600-324, 600-325:1, 600-325:2, 600-326:1, 600-326:2, 600-328, 600-329, 600-331, 600-332, 600-334:2, 600-349, 600-358, 600-368, 600-369:1, 600-369:2, 600-369:3, 600-369:4, 600-369:5, 600-369:6, 600-369:7, 600-369:8, 600-370, 600-371, 600-372:1, 600-372:2, 600-373, 600-374, 600-375:1, 600-375:2, 600-375:3, 600-375:4, 600-375:5, 600-376:1, 600-376:2, 600-377, 600-378, 600-379 |

#### *1.2.3.4 Waste Sites Consideration in the RI/FS.*

All waste sites were considered in this RI/FS to determine whether the sites are protective of HHE. While unique factors were considered individually, waste sites were considered in the following manner based on their classification/reclassification status:

- Sites with a "closed out" status were reviewed to confirm that the determination was made under appropriate regulatory authority. There is only one site in 100-F/IU with a "closed out" status. This site is discussed further in Section 1.2.3.5.

- Sites with a "rejected" or "not accepted" status were reviewed to determine whether new information, if available, is consistent with existing documented basis for rejection or nonacceptance. When the existing classification/reclassification was appropriate, the site was not considered further within the RI/FS process. Two rejected or not accepted sites at 100-F were found to have information that was inconsistent with the existing determinations. The existing determinations are documented for each site in accordance with *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" (RL-TPA-90-0001).

- Sites with a "no action" or "interim closed out" reclassification based on confirmatory and/or verification data are considered within the overall RI and are quantitatively evaluated against PRGs, as described in Chapters 5 through 7. Sites with a "no action" or "interim closed" reclassification, with a basis other than direct data (for example, historical decommissioning data) were considered on a site-by-site basis. Institutional controls may be implemented for a specific site if deemed warranted based on evaluation of the data.

Figure 1-14. Historical Aerial Photograph Showing 128-F-2 Burn Pit and Slough

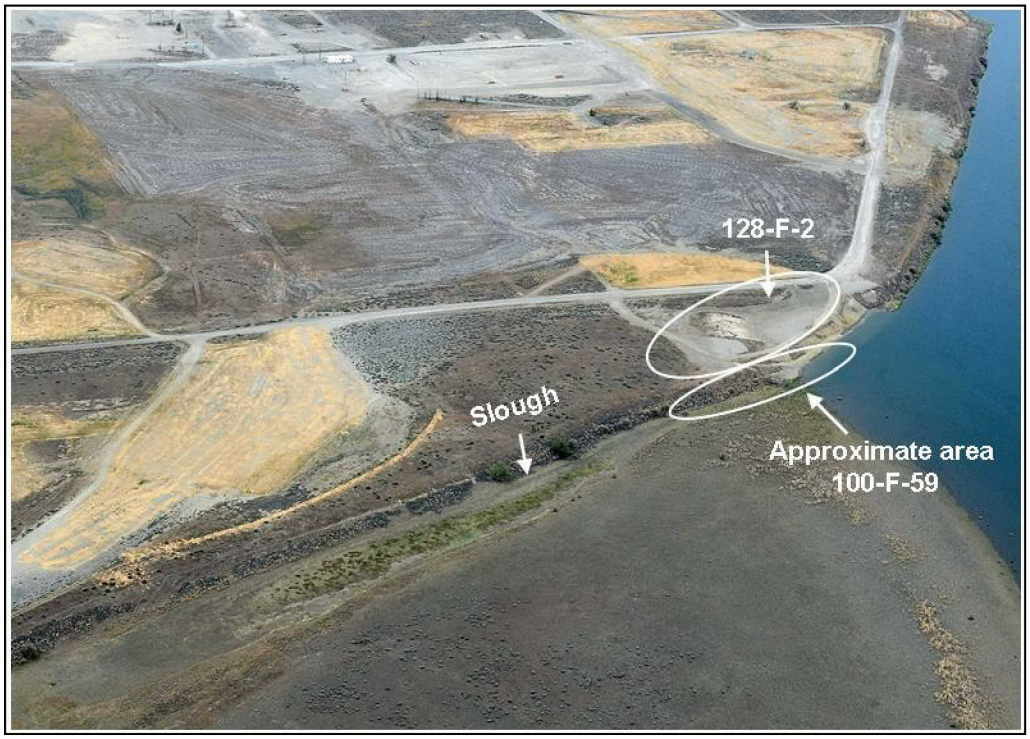


Figure 1-15. Aerial Photograph Identified General Locations of the 100-F-59 and 128-F-2 Waste Sites

- Sites with an "accepted" classification fit into two broad subcategories:
  - Sites where an interim remedial action requirement has been identified, but for which an interim remedial action has not been completed (via an approved waste site reclassification). These sites were considered within the RI from the standpoint that a remedial action determination has already been made. Further consideration is based on the expectation for how complete interim remedial actions will be at the time of issuance of a final action ROD.
  - Candidate sites under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) are sites for which an interim remedial action determination has not yet been made. The 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) established a process whereby new and existing sites that did not have sufficient information to warrant a remedial action determination or exclusion from consideration as a formal waste site could be evaluated in order to make this determination. These sites are referred to as "candidate sites" or "confirmatory sites" under the interim action framework. Until such time as the ROD is promulgated, the candidate process to add these waste sites will be retained under the Interim Action ROD, and these sites will continue to be dispositioned according to that process, including site-specific evaluation for protection of HHE.

*Waste Sites Requiring No Further Consideration at 100-F/IU OUs.* Waste sites with a "rejected" or "not accepted" classification/reclassification status were reconsidered to determine if there was an existing adequate basis for this determination. Those sites for which the existing basis was sufficient will not be addressed further in this RI/FS process and are identified in Table 1-6. In addition to these sites, some sites with other classification/reclassification statuses and site-specific factors will not be addressed further in this RI/FS process. These sites are also listed in Table 1-6, with additional explanation provided below. However, all 100-F/IU waste sites identified in Appendix C of the TPA Action Plan (Ecology et al., 1989b) will be included in the final action ROD for final remedy decision to be documented, even if no further remedial activities are needed.

*Closed Out.* The UPR-600-11 site addresses a discovery of radiologically contaminated material within the JA Jones 1 waste site. The JA Jones 1 site was previously used for disposal of miscellaneous debris, construction waste, and paint products. During routine surveys, it was discovered that material with low-level beta-gamma contamination had been disposed in the non-radioactive landfill. Approximately 77 $m^3$ (100 $yd^3$) of contaminated material was removed and disposed, and the UPR-600-11 site was reclassified as "closed out." A "closed out" reclassification is not appropriate, but the entire JA Jones 1 waste site was subsequently remediated and reclassified as "interim closed out." No further action is warranted for the UPR-600-11 site; the JA Jones 1 site is considered further within the RI/FS process.

*Not Accepted Sites.* The sites listed in Table 1-6 were not accepted as waste sites at the discovery phase of *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" (RL-TPA-90-0001). No new or conflicting information was identified to suggest that these sites should be reconsidered as waste management units.

*Rejected Sites.* The sites listed in Table 1-6 have been reclassified as rejected in accordance with *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" (RL-TPA-90-0001). No new or conflicting information was identified to suggest that the reclassification of the sites should be reconsidered.

Table 1-6. 100-F/IU Waste Sites Not Considered Further in the RI/FS

| Classification/ Reclassification Status | Waste Sites |
|---|---|
| Closed Out | UPR-600-11 |
| Not Accepted | 100-F-1, 100-F-6, 100-F-17, 100-F-21, 100-F-30, 100-F-32, 116-F-13, 132-F-2, 600-122, 600-123, 600-126, 600-130, 600-136, 600-138, 600-153, 600-157, 600-158, 600-159, 600-160, 600-161, 600-162, 600-163, 600-164, 600-165, 600-166, 600-167, 600-168, 600-169, 600-170, 600-171:1 thru 600-171:10, 600-192, 600-195 600-196, 600-198, 600-234, 600-250, 600-251, 600-283, 600-304 |
| Rejected | 100-F-5, 100-F-8, 100-F-28,100-F-40, 100-F-41, 100-F-41:1 thru 100-F-41:4, 100-F-44:3, 100-F-44:6, 100-F-44:7, 100-F-44:10, 118-F-9, 600-24, 600-26, 600-27, 600-31, 600-50, 600-121, 600-135, 600-172, 600-173, 600-174, 600-175, 600-177, 600-179, 600-180, 600-183, 600-184, 600-185, 600-189, 600-193, 600-194, 600-199, 600-200, 600-203, 600-206, 600-207, 600-209, 600-213, 600-240, 600-263, 600-330, 600-333, 600-335, UPR-600-18, UPR-600-19 |
| No action | 100-F-44:1, 100-F-44:4, 600-52, 600-98, 600-99, 600-110, 600-201, 600-208, 600-235, 600-239 |
| Interim Closed Out | 100-F-56:2, 100-F-58, 600-129, 600-149:1, 600-191, 600-342 |
| Accepted | 118-F-8:2 |

*600-121, 600-199, and 600-207.* The 600-121 and 600-207 sites consist of the former primary coal ash disposal pits for the 100-F and 100-IU-2/IU-6 areas, respectively. In addition, site 600-199 consists of a concrete foundation pad that is completely covered with coal ash. The original purpose for the pad is unknown. These sites were previously reclassified as rejected on the basis that coal ash is not a regulated waste and that previous studies demonstrated that Hanford Site coal ash was nonradioactive and not dangerous. DOE performed an additional evaluation of coal ash under *Sampling and Analysis Plan for Characterization of Hanford Site Coal Ash Components* (DOE/RL-2010-113). The site rejection is appropriate for these sites.

*No Action Sites.* As discussed in the following text, the determination of no action for these sites remains appropriate for the final action purposes.

*100-F-44:1.* The 100-F-44:1 subsite consists of a 20 cm (8 in.) carbon steel pipe segment associated with the 182-FA Pump Test Stand and the 100-F-26:1 sewer. The subsite was previously reclassified as “no action” on the basis that the pipeline carried only raw water and that no action had been determined to be necessary for the associated portion of the 100-F-26:1 subsite based on sampling. This determination remains appropriate for final action purposes.

*100-F-44:4.* The 100-F-44:4 subsite consisted of a steel pipe discovered during trenching to locate the 118-F-4 Silica Gel Pit. No pipeline is indicated on historical drawings, and the visual evidence indicates this pipe is a piece of electrical conduit debris and not a process pipeline or sewer pipeline. Accordingly, the site was previously reclassified as “no action;” this determination remains appropriate for final action purposes.

*600-52.* The 600-52 site is a surface depression that was fed excess water during the late 1940s and early 1950s from a trench from the White Bluffs Icehouse. It is also suspected to have received accidental overflow from the adjacent 600-106 Pickling Acid Crib waste site, which has been closed out in the

100-IU-5 OU and is not addressed further by this RI/FS. During sampling for closeout of 600-106, three locations in 600-52 were also sampled for a wide variety of analytes, including radionuclides, organics, pH, and metals. No significant contamination was detected, and no action was required to remove similar or higher contaminant levels at the pickling acid crib. A field walkdown conducted at 600-52 in April 2003 revealed no debris or anomalies. The site was previously reclassified as "no action" based on the information from the site history, previous sample results, disposition of the 600-106 waste site, and the field walkdown; this determination remains appropriate for final action purposes.

*600-98.* The 600-98 site consisted of two unlined, pre-Hanford Site landfills. A small amount of scattered surface debris (cans, glass, and wood) was visible at dump area 1. Dump area 2 was an area of gravel ridges and surface scars. Both areas were used for the disposal of normal industrial and domestic wastes. Following operational use, the sites were backfilled. The results of an evaluation have demonstrated that the site was a pre-Hanford Site dumping area and borrow pit and showed that there are no hazardous/dangerous materials present at the site and no residual contamination in the soil. Accordingly, this site was previously reclassified as "no action;" this determination remains appropriate for final action purposes.

*600-99.* The 600-99 site contained minor construction equipment used by the J. A. Jones Construction Company, including wood scraps, concrete, and some metallic waste. However, the excavation records indicate that the site contents were removed to the 200 Area Burial Grounds in 1971. In 2003, a ground penetrating radar survey showed three anomalies of scattered and concentrated debris near the site. Test pits at these locations showed that two areas were unbroken caliche at a depth of 1.2 m (4 ft), and the third area was part of a concrete foundation at a depth of 7.6 cm (3 in.). No debris was found, and no sampling was required. The historical record and the 2003 investigations demonstrate that the site contains no hazardous substances above cleanup criteria. Accordingly, this site was previously reclassified as "no action;" this determination remains appropriate for final action purposes.

*600-110.* The 600-110 site was the former Hanford Townsite Landfill, reportedly used for disposal of domestic and industrial wastes. Exploratory excavation within the landfill revealed no suspect hazardous debris or stained soils. Therefore, the site was previously reclassified as "no action;" this determination remains appropriate for final action purposes.

*600-201.* The 600-201 site is the location of the White Bluffs Paint and Solid Waste Disposal Site. Solid waste debris observed at the site included glass, metal shavings, metal parts, and army green canvas material. In 2003, only minor debris remained on the surface. In May 2003, a test pit was excavated to investigate a geophysical anomaly. The test pit revealed only a flattened steel bucket and some decaying wood. The only suspect hazardous waste item noted was a piece of hardened paint, which was removed. Based on the absence of any further suspect hazardous waste, the site was previously reclassified as "no action;" this determination remains appropriate for final action purposes.

*600-208.* The 600-208 site is the former Hanford Construction Camp Boiler House Ponds. Eighteen semipermanent boiler houses were erected, each with an associated pond. Boiler water discharge was generated to remove scale (e.g., calcium carbonate and magnesium carbonate) buildup in the steam generation water and discharged to the ground. Historical knowledge indicates that no hazardous chemicals were used in the process, and the boiler water discharge would not be hazardous or present a risk to human health or the environment. The previous "no action" decision for the 600-208 site is supported, based on reviews of the processes associated with steam boilers, site history, field observations, and geophysical surveys; and this determination remains appropriate for final action purposes.

*600-235.* The 600-235 site consists of approximately 204 km (126 mi) of buried lead-sheathed telephone cables left in place across the Hanford Site. Following an evaluation of the soil surrounding the cable, including the collection and analysis of samples for established contaminants of potential concern, it was

determined that concentrations of metals detected in the soil assigned with the cables are at or below the Hanford Site background levels. The site was subsequently reclassified as "no action," which remains an appropriate determination for final action purposes.

*600-239.* The 600-239 site contains several large wooden beams, wooden pallets, large-diameter steel pipe, steel plates, large mesh steel screens, and rubber tires. All wastes observed were lying in neat piles on the ground surface within a pit; none appeared to be partially buried. This gravel pit was related to the adjacent Hot Mix Plant (600-20 waste site). However, some of the stored materials in the pit may have come from other projects. The site was previously reclassified as "no action" based on the absence of any hazardous materials at the site; this determination remains appropriate for final action purposes.

*Interim Closed Out Sites.* As discussed in the following paragraphs, the interim closed out reclassification of these sites is appropriate, and no further consideration is warranted.

*100-F-56:2.* The 100-F-56:2 site contained various sizes and forms of solid surface debris left during the construction, operation, D&D, and risk assessment (RA) activities at the 100-F Area. The surface debris was confined to the observed location with little or no potential for release to the environment. The debris was removed, and there are no significant environmental contaminants of concern for this site because the debris is expected to leave no residue during removal.

*100-F-58.* The solid waste at the 100-F-58 site consisted of scattered debris, mainly in the form of transite. The surface debris was confined to the observed location with little or no potential for release to the environment. Remedial action activities included surface pick-up only, generating less than 1 bank cubic meter (1.3 bank cubic yards) of potential asbestos-containing material that was directly loaded for disposal at the ERDF.

*600-129.* The 600-129 site was in a large depression littered with domestic and industrial debris. It was presumed this dump area was used by residents of White Bluffs and later by the Manhattan Engineering District to a lesser degree. Suspect hazardous solid debris was removed, and the site was reclassified as "interim closed out" based on the removal. No further action is warranted for final action purposes.

*600-149:1.* The 600-149:1 site was the former Range Complex that consisted of the Range House Building, Well Pump House, and four firing ranges. The berm behind the pistol/rifle firing range was remediated as subsite 600-149:2. The 600-149:1 subsite was addressed as a survey and subsequent clearance for unexploded ordnance. The clearance was performed in three phases with any anomalies investigated further and identified ordnance items removed. The site has been reclassified as "interim closed;" this determination remains appropriate for final action purposes.

*600-191.* The 600-191 site was an area littered with miscellaneous trash and debris. This was believed to be a domestic waste disposal site for White Bluffs residents, also subsequently used by the Manhattan Engineering District. Suspect hazardous solid debris was removed, and the site was reclassified as "interim closed out" based on the removal. No further action is warranted for final action purposes.

*600-342.* This site is an area that contained discarded radiological protective clothing. The clothing was disposed, and a systematic radiological survey was subsequently performed. No radiological contamination was present; accordingly, no further action is warranted for this site.

*Accepted Sites. 118-F-8:2.* The 118-F-8:2 subsite is the safe storage enclosure for the 105-F Reactor core, which was completed in 2003. The ISS represented a series of actions taken to protect the reactor from environmental degradation and to prevent the spread of contamination by providing an upgraded, weather-resistant shell to isolate the reactor core until final remedial activities are conducted. This action also minimizes the facility footprint by removing all peripheral reactor buildings and equipment and disposing of the debris. The primary objective of the 105-F Reactor ISS Project was to provide storage for up to 75 years with minimal maintenance required. The future disposition of the reactor core is described further in Section 1.2.2.2.

*Rejected and Not Accepted Waste Sites with Potentially Inadequate Existing Basis*

Waste sites with a "rejected" or "not accepted" classification/reclassification status were reconsidered to ensure that there was sufficient existing basis for this determination. Through this process, two sites were identified for which the existing basis warrants reconsideration:

*600-20.* The site was a former hot mix plant for road asphalt. Valve pits, discarded asphalt waste, pails, and drums are still present at the site. The 600-20 site was previously reclassified as "rejected" based on the absence of evidence of hazardous or radiological waste in the area. This basis is not adequate, given the nature of the site, and reclassification to "accepted" is being proposed under interim actions. For the purposes of the FS, this site will be considered as a site expected to be remediated prior to issuance of a final action ROD.

One additional site was identified for which the existing basis warrants reconsideration, but which will not be directly considered further:

*UPR-600-19.* This site was the location of a pre-Hanford operations release of lime sulfur pesticide from a deteriorated barrel. The residual contents and underlying soil were removed in 1997; and the site was reclassified as "rejected" based on the absence of hazardous, dangerous, or radioactive waste. However, samples collected from residual soil showed significantly elevated lead and arsenic; and this site is located in a former orchard area. A separate waste site (600-331) has already been created to address the elevated arsenic and lead results observed. The 600-331 site is addressed further in the RI/FS, and orchard areas are being programmatically considered as a separate OU. Therefore, the UPR-600-19 site will not be considered further.

### *1.2.3.5 Nonoperational Areas*

The Nonoperational Area evaluation is provided in Appendix J. The nonoperational evaluation considered the five transport mechanisms, physical features, and climate conditions that could influence transport, and used surface and near-surface information from a number of available sources:

- Orphan sites evaluations
- Air emissions reports
- Environmental monitoring programs
- Statistical modeling

The majority of waste sites associated with 100-F/IU OUs are located within immediate proximity to the decommissioned F-Reactor. The land shows little or no indication of past or present releases of hazardous constituent(s) between the reactor area and the Central Plateau. 100-IU-2 and 100-IU-6 comprise a large part of what are known as the nonoperational areas. In 2011, an evaluation of the area was completed to assess the potential for contaminants to migrate into the nonoperational areas. Five mechanisms were identified as credible means to transport contamination:

- Human disposal of materials
- Biological vectors

- Point source dispersal (e.g., stack emissions)
- Wind dispersal
- Overland flows

The nonoperational evaluation considered these transport mechanisms, physical features, and climate conditions that could influence transport, and used surface and near-surface information from a number of available sources. The evaluation additionally used statistical modeling to support the data analyses and development of technical recommendations (e.g., additional sampling) for the River Corridor nonoperational areas.

The nonoperational evaluation incorporates information from the orphan site evaluation (OSE) (Table 1-7), and uses established approaches and datasets in an approach similar to that adopted by the Central Plateau with River Corridor-specific issues such as potential overland flow and impacts on riparian and nearshore areas. In addition to the conceptual site models developed for the Central Plateau, the River Corridor CSM also addresses the potential for overland flow and potential impacts to riparian and nearshore areas. Statistical analyses were used to represent the conceptual model and incorporate the available data to support a quantitative basis for the probability that a (undiscovered) waste site might exist in nonoperational areas.

Table 1-7. 100-F/IU Orphan Site Evaluations

| 100-F/IU Area | Orphan Site Field Investigation Completed | OSE Report ID* | OSE Report Issued (Rev. 0) |
|---|---|---|---|
| 100-F | Sep-05 | OSR-2005-0001 | Feb-12 |
| 100-IU-2 | Oct-07 | OSR-2008-0001 | Feb-09 |
| 100-IU-6 | Oct-07 | OSR-2008-0001 | Feb-09 |
| Segment 1 | Jul-09 | OSR-2009-0002 | Apr-10 |
| Segment 2 | Jan-10 | OSR-2010-0001 | Aug-10 |
| Segment 3 | Aug-10 | OSR-2010-0004 | Jan-11 |
| Segment 4 | Jan-11 | OSR-2011-0001 | Nov-11 |
| Segment 5 | Apr-11 | OSR-2011-0002 | Dec-11 |

*Complete reference citations are provided in Chapter 11.

*Orphan Sites Evaluation.* Two key elements of an orphan sites evaluation are a historical review and a field investigation. Review of historical information was conducted to identify potential orphan sites and to target areas for further evaluation concurrent with the associated field investigation. Historical research focused on identifying specific items or features typically associated with a waste site. The most common features associated with a waste site in reactor areas include drains, cribs, drywells/French drains, burial grounds, pipelines, above- and belowground storage tanks, septic systems, drain fields, burn pits, trenches, ditches, pits, spills, sumps, vaults, ash pits, disposal areas, pumps, and buildings and facilities that contain chemicals and radiological contaminants. Information obtained and used in the historical review included the following resource types:

- Maps
- Construction and operations drawings
- Technical and operations documents

- Construction and operations photographs
- Aerial photographs
- Geophysical survey results
- Cleanup verification packages
- Sampling logbooks
- Personnel interviews

Field investigation activities were used to provide another level of assurance by conducting systematic walking surveys of operational areas to document potential orphan sites and to follow up on potential orphan sites identified from historical review. Three primary tools provided the media to record the information observed in the field—hand-held global positioning system (GPS) units, digital cameras, and field logbooks. Geophysical survey instrumentation was used to supplement these tools in selected areas of suspect subsurface features identified during the historical review or field investigation.

To ensure a systematic approach for area coverage, standardized 30 × 30 m (98 × 98 ft) conceptual grids were established over the investigation areas. The grid and existing known features in the areas were loaded onto the GPS units, which were used in the field to monitor progress and record information. Walking surveys were typically performed in pairs with approximately 15 m (49 ft) spacing between individuals. Features encountered during this investigation were recorded using the GPS unit, digital camera, and a field logbook.

The field investigation for regions of the River Corridor between the operational areas used a graded approach. High-resolution, four-band (red, green, blue, and near-infrared) orthophotography imagery and Light Detection and Ranging (LiDAR) topography data were collected for approximately 57,468 ha (142,000 ac) of the River Corridor in April 2008. The data were collected in the early spring when foliage and undergrowth obscuring the ground surface was at a minimum. The orthophotography and LiDAR data were used to conduct "virtual walkdowns" of the areas. Based on results of these "virtual walkdowns," areas were selected to conduct walking surveys consistent with the approach for operational areas (e.g., 30 × 30 m (98 × 98 ft) reference grid system). Vehicle surveys along accessible roads and utility easements are also part of the field investigation for the nonoperational areas. In addition, standard walking surveys were conducted throughout the River Corridor along the Columbia River based on the level of interest in the shoreline area and its inclusion as part of the Hanford Reach National Monument ("Establishment of the Hanford Reach National Monument" [65 FR 37253]). Results of the evaluations were reviewed with participation from DOE and the regulatory agencies and were summarized in OSE reports.

The OSE field investigation for 100-F was completed in 2005 (*100-F Area Orphan Sites Evaluation Report* [OSR-2005-0001]). The total area covered for 100-F was approximately 322 ha (795 ac), and 14 new discovery sites were identified. These waste sites, which include pipelines, French drains, septic systems, contaminated soil, and debris, will be evaluated and dispositioned.

An initial OSE field investigation inside the 100-IU-2 and 100-IU-6 OUs was completed in 2007. The area covering the 100-IU-2 and 100-IU-6 OUs includes the White Bluffs community and the Hanford Townsite, which collectively cover a total area of approximately 3,561 ha (8,800 ac). Forty-three new discovery sites were identified during this evaluation process (*100-IU-2 and 100-IU-6 Area Orphan Sites Evaluation Report* [OSR-2008-0001]). A comprehensive orphan site evaluation for the 100-IU-2 and 100-IU-6 OUs was completed in 2011 for five segments of 100-IU-2/IU-6, including an extensive and detailed review of aerial photographs for the remaining areas of the 100-IU-2/IU-6 Area. During this review, disturbed areas, as indicated in the photographs, were noted and further investigated. This process

identified 24 additional new discovery sites to be addressed under 100-IU-2 and 100-IU-6 OUs with one new site identified under 100-FR-2. Potential sites are evaluated under *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" (RL-TPA-90-0001) process and assigned to an OU and ROD as appropriate for a remedial decision and action.

DOE has implemented a number of processes to identify new waste sites. The process of identifying new waste sites increases confidence that waste disposal and releases requiring characterization and cleanup within a given land parcel on the Hanford Site are addressed. In 1996, 170 waste sites were identified in the WIDS database for 100-F/IU. As of June 25, 2012, 400 waste sites have been identified under 100-F/IU, including numerous subsites that comprise the primary waste sites.

Biological vectors, point source contamination, wind dispersal, and overland flows were also considered in the nonoperational evaluation as means by which contamination could be transported. Hanford Site stack air emissions were considered for potential River Corridor impacts by point source contamination and wind dispersal. The first source was the 200 Areas facilities that separated plutonium and uranium from irradiated reactor fuel that were active between 1944 and 1972. The second source was exhaust ventilation from the nine production nuclear reactors in the 100 Area. The reactor ventilation was a relatively minor source of emissions compared to the 200 Area facilities. With the shutdown of active operations, potential point sources of contamination and continuing air emissions have been halted. However, scenarios for biological vectors (e.g., rodents and insects), wind dispersal (e.g., tumbleweeds), and overland flow remain potential routes for contamination as cleanup proceeds. Details of these scenarios and supporting environmental monitoring data are provided in Appendix J. Environmental monitoring is further discussed in Chapter 2.

*Air Emissions Reports.* Two groups of sources of Hanford Site stack air emissions had the potential to affect the River Corridor by air deposition. The first source group, where most of the Hanford Site stack air emissions occurred between 1944 and 1972, were the facilities in the 200 Area that separated plutonium and uranium from irradiated reactor fuel. The second source group, the nine production nuclear reactors in the 100 Area, had stacks to exhaust ventilation air from the working areas of the reactor facilities. These were minor sources of emissions compared to the 200 Area facilities that separated plutonium and uranium from irradiated reactor fuel (*RCBRA Stack Air Emissions Deposition Scoping Document* [DOE/RL-2005-49]). Aerial radiation surveys of the Hanford Site and widespread sampling over many years support this conclusion (*An Aerial Radiological Survey of the Hanford Site and Surrounding Area, Richland, Washington* [EGG-10617-1062]).

*Environmental Monitoring Programs.* Data from ongoing monitoring programs were also used as described in Appendix J. A number of these programs are described in Chapter 2, starting in Sections 2.1.4 (Contaminant Source Investigations) and continuing through Section 2.1.12 (River Corridor Supplemental Investigations).

*Statistical Modeling.* Statistical modeling was used to support the data analyses and development of technical recommendations such as additional sampling for the nonoperational areas in the River Corridor. The statistical evaluations provide estimates of the likelihood of finding previously undiscovered waste sites in the nonoperational property areas and the potential for exposure to selected radionuclides (e.g., cesium-137) exceeding selected threshold concentrations in surface soil. Statistical analysis of the geographical distribution of waste sites based on anthropogenic features and topography describes the likely locations of waste sites near 100-F/IU. The results from this analysis reinforce the findings from the OSE, which has systematically identified the remaining waste sites within 100-F/IU. Statistical analysis of the distribution of radionuclide concentrations observable from aerial surveys has

confirmed that the probability of detecting elevated radionuclide concentrations in nonoperational area soils is very small. Appendix J provides additional detailed discussion.

#### 1.2.3.6 Previous Groundwater Investigations

Groundwater monitoring projects are established under *General Environmental Protection Program* (DOE O 5400.1 Chg 1), to meet the requirements of *Radiation Protection of the Public and the Environment* (DOE O 5400.5 Chg 2), which deals with radiation protection of the public and the environment, and federal and state regulations. The TPA (Ecology et al., 1989a) is a legally binding document that is used to coordinate groundwater protection and remedial action efforts.

Table 1-8 lists previous groundwater investigations. The following text provides additional information.

The earliest groundwater monitoring wells were installed in 1943. Additional wells were installed in the 1990s to the present:

- Seventeen wells were installed in 100-F between 1943 and 1960. Most of these were drilled to the top of the Ringold upper mud (RUM) or slightly deeper and all are screened in the unconfined aquifer. Twelve of the wells have been decommissioned.
- Most of the monitoring wells in 100-IU-2/IU-6 (well names with 699 prefix) were installed in the 1940s through 1960s.
- One well (199-F7-2) was installed in 1988 to monitor the 116-F-1 Trench
- Thirteen wells were installed in 100-F in 1992 for the LFI (100-FR-3 LFI [DOE/RL-93-83]). Additional vadose borings were also drilled but not completed as monitoring wells.
- One well (199-F8-7) was installed in 2008 to monitor the 116-F-6 Burial Ground, where strontium-90 was detected in a grab sample of groundwater collected during excavation of the burial ground
- Three wells (199-F5-52, -53, -54) were installed in 2010 for the RI/FS (100-F/IU SAP [DOE/RL-2009-43])
- Three boreholes were installed in 2010 for the RI/FS (100-F/IU SAP [DOE/RL-2009-43]), with two of the three subsequently completed as wells (199-F5-55, -56)

Data from the early decades are limited. Some of the wells have historical data for water levels, gross beta, nitrate, tritium, and other radionuclides. Comprehensive sampling began in the early 1990s.

The current groundwater monitoring program for 100-F is based on results of the data quality objectives process (*Data Quality Objectives Summary Report – Designing a Groundwater Monitoring and Assessment Network for the 100-BC-5 and 100-FR-3 Operable Units* [PNNL-14287]). The monitoring program is described in *100-FR-3 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-49), hereinafter called 100-FR-3 SAP, as modified by *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: 100-FR-3 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-49, Rev. 1 and TPA-CN-228 (July 14, 2008)* (TPA-CN-241). Groundwater contaminants include Cr(VI), nitrate, strontium-90, and trichloroethene (Section 4.3).

Table 1-8. Summary of Previous Groundwater Investigations

| Document Title | Document Number/Date | Summary of Observations and Conclusions |
|---|---|---|
| *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2; Hanford Site Groundwater Monitoring Report for 2010* | (e.g., DOE/RL-2010-11/Aug. 2010; DOE/RL-2011-01/Aug. 2011) | This series of annual reports presents the results of groundwater monitoring. 100-F groundwater plumes include nitrate, strontium-90, Cr(VI), and trichloroethene. Groundwater in 100-IU-2/IU-6 is contaminated with tritium, iodine-129, and nitrate. These contaminants originated from multiple sources and are mobile in groundwater. |
| *Limited Field Investigation Report for the 100-FR-3 Operable Unit* | DOE/RL-93-83/April 1994 | The LFI was conducted to optimize the use of interim remedial measures. The primary methods of investigation were the installation of monitoring wells, groundwater sampling, and soil sampling. The analytical data were screened to include contaminants of potential concern. This screening method eliminated from further consideration any constituents that were below risk-based concentration values and ARARs, or those constituents that could not be distinguished from background. These results were based on three rounds of sampling gathered over a 6 month period. |
| *Qualitative Risk Assessment for the 100-FR-3 Groundwater Operable Unit* | WHC-SD-EN-RA-012/ Apr. 1994 | In 1992 and 1993, a qualitative risk assessment was completed that screened COPCs identified during the LFI for human health and ecological risks.<br>The qualitative risk assessment determined a medium to low risk for contaminants in groundwater under the frequent-use scenario, and low to very low risk under the occasional-use scenario. As a result, no IRM for groundwater was undertaken. However, it was recommended that the OU remain on the IRM pathway, and remedial actions at the 100-FR-3 Groundwater OU would be coordinated with the remediation of the overlying source units (100-FR-1 and 100-FR-2 OUs). |
| *100-FR-3 Groundwater/ Soil Gas Supplemental Limited Field Investigation Report* | DOE/RL-95-99/Apr. 1996 | The objectives of this supplemental LFI were to assess the lateral extent of trichloroethene contamination in groundwater, assess soil gas concentrations to identify the source of trichloroethene, and refine the site conceptual model. The trichloroethene plume contributing to groundwater contamination was characterized and delineated. |

ARAR = applicable or relevant and appropriate requirement
COPC = contaminants of potential concern
IRM = interim remedial measure
LFI = limited field investigation
OU = operable unit

Wells in the IU-2 and IU-6 OUs are monitored according to requirements determined for the 200-BP-5 and 200-PO-1 OUs (*Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* [DOE/RL-2001-49]; *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* [DOE/RL-2003-04]).

Groundwater samples typically are collected every 1 to 3 years, depending on location. New wells may be sampled quarterly for the first year. Groundwater data are used to create maps and plots that illustrate groundwater flow, water table elevations, hydrogeochemistry, and contaminant concentration trends and distribution. The results are published annually in the annual Hanford Site groundwater monitoring report (e.g., *Hanford Site Groundwater Monitoring and Performance Report for 2009, Volumes 1 & 2* [DOE/RL-2010-11]). Chapter 4 summarizes recent results of groundwater monitoring.

*100-FR-3 Operable Unit Groundwater Limited Field Investigation.* In 1992 and 1993, as part of the RI/FS process, an LFI was conducted as an initial step to characterize the nature and extent of hazardous and radioactive materials in groundwater and to evaluate the applicability of interim remedial measures (IRMs) for reducing HHE risks posed by the 100-FR-3 groundwater OU (100-FR-3 LFI [DOE/RL-93-83]). Thirteen groundwater monitoring wells were installed as part of this effort. Results of the LFI fed into a qualitative risk assessment (QRA) as discussed as follows.

Deep well 199-F5-43B was drilled 46 m (150 ft) into the Ringold Formation and screened in the upper confined/semiconfined aquifer (*Geology of the 100-FR-3 Operable Unit, Hanford Site South-Central Washington*, hereinafter called the 100-FR-3 Geology Report [WHC-SD-EN-TI-221]); the well did not reach basalt (100-FR-3 LFI [DOE/RL-93-83]). Twelve wells (199-F1-2, 199-F5-42, 199-F53-43A, 199-F5-44, 199-F5-45, 199-F5-46, 199-F5-47, 199-F5-48, 199-F6-1, 199-F7-3, 199-F8-3, and 199-F8-4) were screened across the water table in the Hanford formation.

*100-FR-3 Groundwater Operable Unit Qualitative Risk Assessment.* In 1992 and 1993, a QRA was completed for the 100-FR-3 Groundwater OU (*Qualitative Risk Assessment for the 100-FR-3 Groundwater Operable Unit* [WHC-SD-EN-RA-012]) that screened COPCs identified during the LFI for human health and ecological risks. The resulting, refined list of COPCs included arsenic, chromium, manganese, nitrate/nitrite, strontium-90, and tritium (100-FR-3 LFI [DOE/RL-93-83]). The ecological risk assessment identified chromium, copper, and lead as COPCs. Although trichloroethene was not identified by the QRA as a risk driver, it was carried forward because it exceeded "National Primary Drinking Water Regulations" (40 CFR 141).

Using a predefined set of human and environmental exposure scenarios, the QRA assessed the risk to human health and ecological receptors posed by the groundwater and the discharge of groundwater contaminants to the Columbia River. Four noncarcinogenic COPCs have hazard quotients (HQs) for human health above 1.0 as part of the frequent-use scenario: aluminum, arsenic, manganese, and nitrate/nitrite. The HQ is the ratio of a contaminant exposure estimate to a concentration considered to represent a safe environmental concentration or dose. Under the occasional-use scenario, the HQ is less than 1.0 for all COPCs.

Nine carcinogenic COPCs were identified and evaluated as part of the frequent-use scenario. The risk associated with each COPC and the total risk from all COPCs were calculated. Under the frequent-use scenario, the total risk estimated by incremental cancer risk (ICR) calculations is medium (ICR between $10^{-4}$ and $10^{-2}$). The inorganic constituent arsenic and radionuclides strontium-90 and tritium also have medium-risk estimations. Organic constituents chloroform and trichloroethene and radionuclides carbon-14, uranium-233/234, and uranium-238 had low risk estimates (ICR between $10^{-6}$ and $10^{-4}$); and uranium-235 had a very low risk estimate (ICR less than or equal to $10^{-6}$).

Near-river groundwater samples were also evaluated for aquatic toxicity to fish from nonradioactive contaminants. The ecological hazard quotient (EHQ) for nonradionuclides (hazardous chemicals) indicates that the chronic EHQs, based on near-river well concentrations, exceeded 1.0 for Cr(VI), lead, and copper. The acute EHQ exceeded 1.0 for Cr(VI). No radionuclide dose exceeded the levels established in DOE O 5400.5 Chg 2. For all radionuclides evaluated, none exceeded an EHQ of 1.0.

The QRA further determined a medium to low risk for identified contaminants in groundwater under the frequent-use scenario and low to very low risk for identified contaminants under the occasional-use scenario detected. As a result, no IRM for groundwater has been undertaken. However, the OU was recommended to remain on the IRM pathway, and remedial actions at the 100-FR-3 Groundwater OU will be coordinated with the remediation of the overlying source units (100-FR-1 and 100-FR-2 OUs).

Continued groundwater quality monitoring was proposed with a provision to recalculate risk if contaminant concentrations increased. Post-source remediation activities would include groundwater re-evaluation to identify potential risk reduction resulting from the remedial activities. The QRA results suggest re-evaluation activities should be conducted in tandem with the ongoing RI/FS and deactivation, decommission, decontamination, and demolition (D4) activities (*Qualitative Risk Assessment for the 100-FR-3 Groundwater Operable Unit* [WHC-SD-EN-RA-012]).

*Groundwater/Soil Gas Supplemental Limited Field Investigation Report (1996).* In groundwater samples taken in 1994, trichloroethene was detected at levels in excess of the EPA DWS of 5 μg/L. A supplemental LFI was conducted to determine the extent and potential source(s) of trichloroethene groundwater contamination (*100-FR-3 Groundwater/Soil Gas Supplemental Limited Field Investigation Report* [DOE/RL-95-99]). The shallow trichloroethene groundwater plume exceeding EPA and Ecology drinking water standards was identified and delineated, and the highest observed groundwater concentration (at the time) was 52 μg/L.

Forty-nine sampling locations were established in an area west of 100-F, covering about 5.2 $km^2$ (2 $mi^2$). From those identified locations, 40 soil gas samples and 41 groundwater samples were collected using a hydraulic probe driver. In addition, groundwater samples were collected from 10 existing groundwater monitoring wells in the area. Relatively low concentrations of TCE were detected in soil gas collected from the vadose zone throughout the study area. The highest concentration of TCE in soil gas was 77 parts per billion by volume (ppbv). The locations of elevated trichloroethene soil gas detections in the study area did not appear to coincide with potential or observed sources of TCE contamination, and soil gas concentrations did not show a positive correlation with groundwater TCE concentrations. However, the lateral extent of TCE detected in the vadose zone soil gas correlated directly with the lateral extent of the TCE plume in the underlying groundwater. Additionally, the zones of elevated soil gas TCE concentrations were found to be upgradient of and adjacent to zones of elevated TCE in groundwater.

A human health and ecological qualitative risk assessment (QRA) for TCE based on data gathered during this study, along with previously obtained data, categorized risk to human, riparian, or aquatic organisms as low (i.e., for human health, ICR is between $10^{-6}$ and $10^{-4}$; and for ecological, EHQ is less than 1.0).

*Groundwater Remedial Actions.* To date, there have not been any remedial actions conducted for the groundwater contamination at 100-F/IU OUs.

### *1.2.3.7 Risk Assessments*

Risk assessments have been conducted for the 100 Area to provide the foundation for establishing the need for remedial action to protect HHE. Three key risk assessments, i.e., the qualitative risk assessments (QRAs) performed in the early 1990s, RCBRA (DOE/RL-2007-21), and CRC (DOE/RL-2010-117), are

summarized below. The results of RCBRA and the CRC are described in more detail (and used) in Chapters 4, 6, and 7 of this RI/FS.

*Qualitative Risk Assessments.* QRAs were conducted to define the basis for remedial actions under Interim Action RODs (Past-Practice Strategy [DOE/RL-91-40]). Human health risks were assessed based on frequent use and occasional use scenarios. COPCs were identified from the historical site data and data collected during the LFIs, taking into consideration Hanford Site background activity of radionuclides and inorganic concentrations in vadose zone, and risk based screening using residential exposure parameters (*Hanford Site Risk Assessment Methodology* [DOE/RL-91-45]). Human health risks presented in the QRAs were based on the maximum concentrations detected in waste site vadose zone material and in groundwater. Human health risks were quantified for a limited set of exposure pathways (soil ingestion, fugitive dust or volatile inhalation, and external exposure). Ecological risks were estimated using a streamlined approach, focusing on a single receptor, the Great Basin pocket mouse, using the assumption that the waste site was the home range.

*River Corridor Baseline Risk Assessment.* The RCBRA has been conducted to characterize current and potential future risks to HHE that may be posed by releases of contaminants in the River Corridor. The RCBRA (DOE/RL-2007-21, Volumes II and I) supports the current remediation decisions and consists of a human health risk assessment (HHRA) and an ecological risk assessment (ERA), respectively.

The HHRA (DOE/RL-2007-21, Volume II) provides an assessment of residual risks for remediated waste sites using the unrestricted land use exposure scenario that was the basis for the cleanup values for the Interim Action ROD cleanups. In addition, the RCBRA (DOE/RL-2007-21, Volume II) provides an assessment of residual risks for remediated waste sites and broad areas using a broad range of hypothetical receptors, including adults and children living in the River Corridor, Tribal members, recreational users, and adults working on the site. A screening level groundwater risk assessment is also completed to evaluate potential risks associated with potential exposure to contaminated groundwater.

One of the objectives of the RCBRA is to determine if the interim actions were protective of ecological receptors. This determination was achieved through the evaluations conducted in the ERA (DOE/RL-2007-21, Volume I). The scope of this ERA addresses upland areas, including remediated CERCLA waste sites, the White Bluffs and Hanford Townsites, and the 300 Area. In addition, the ERA evaluates the riparian and nearshore aquatic zones as well as groundwater and areas of groundwater emergence on the south and west shoreline of the Columbia River. The ERA approach is based on an overall conceptual site model that presents a framework for evaluating the data from waste sites (including the location of contamination sources) and describes transport and exposure pathways through various environmental media that may be important in evaluating potential exposure to ecological receptors. Where possible, multiple lines of evidence were employed to comprehensively evaluate the potential for adverse effects on plants, invertebrates, and wildlife.

*Columbia River Component Risk Assessment.* The CRC (DOE/RL-2010-117) provides a comprehensive HHRA (Volume II) and a screening-level ERA (Volume I). The intent of the CRC HHRA (DOE/RL-2010-117, Volume II) was to complete the assessment of the "bank-to-bank" Hanford Reach and downstream areas (i.e., Lake Wallula) of the Columbia River, characterizing risk in areas not previously addressed under the RCBRA (DOE/RL-2007-21, Volume I). Human exposure scenarios include an avid angler, casual user, hypothetical future resident, and a Native American (Yakama Nation) subsistence fisher. The CRC HHRA (DOE/RL-2010-117, Volume II) identifies fish consumption as the largest potential contribution to overall human health risks. The CRC (DOE/RL-2010-117, Volume I) also uses analytical chemistry collected from surface water, sediment, pore water, island soils, and fish to evaluate the potential for risk to ecological receptors including aquatic life living within the Columbia

River and wildlife frequenting or inhabiting the islands within the river. Based on a screening-level ecological risk assessment, the CRC identifies some contaminants as COPECs; mostly metals. The CRC further considered whether COPECs are attributable to Hanford Site-related sources. Conclusions from the CRC HHRA (DOE/RL-2010-117, Volume II) are discussed in Section 6.4.2, and the CRC ERA (DOE/RL-2010-117, Volume I) is reviewed in Section 7.5.2.

*Riparian and Near Shore Areas.* The River Corridor has been divided into three environmental zones for purposes of investigation (RCBRA [DOE/RL-2007-21]; Integrated Work Plan [DOE/RL-2008-46]). The three zones—upland, riparian, and nearshore aquatic—are described in Section 3.9.

Riparian and nearshore environments are of specific interest in the 100 and 300 Areas. The riparian zone contains plant communities requiring more water than the shrub-steppe vegetation of the upland zone, and because of the shallow water table, is generally green throughout the year (*Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment* [PNNL-SA-41467], hereinafter called RCBRA Literature Review). While the wildlife and food webs of the upland and riparian zones overlap, some wildlife species occur specifically within the riparian zone (*DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* [BHI-01757]). The nearshore zone is more frequently under water and is capable of sustaining aquatic biota.

There are few waste sites located within the riparian zone[2]. However, releases and contaminant transport from waste sites could have resulted in hazardous or radioactive constituents being released to riparian and nearshore media. In addition, riparian and nearshore areas can be contaminated from upstream, non-Hanford sources. Groundwater from the Hanford Site discharges into the Columbia River through seeps, springs, and other upwelling locations. Discharge of groundwater could also have resulted in hazardous or radioactive constituents being released to riparian or nearshore zones.

Investigations that were historically conducted in the riparian and nearshore areas of 100-F/IU are summarized in the RCBRA Literature Review (PNNL-SA-41467). In addition to these historical investigations, other sampling and analytical data have been collected from riparian and nearshore areas as part of the Surface Environmental Surveillance Program (SESP). The data from the SESP are summarized in the Annual Environmental Reports for the Hanford Site. Finally, investigations of riparian and nearshore areas were conducted as part of the RCBRA (DOE/RL-2007-21) and *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan* (DOE/RL-2005-42), hereinafter called RCBRA SAP.

*Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River* (PNL-5289) identified riverbank springs and groundwater seeps along the length of the Hanford Site shoreline and presented analytical results for tritium detected in groundwater, riverbank springs, and adjacent surface water for samples collected in 1983 including samples near White Bluffs (IU-2), 100-F, and the Hanford Townsite (IU-6). The highest concentrations of tritium near the White Bluffs (and 100-H Area), 100-F Area, and Hanford Townsite, respectively were 64,900 pCi/L, 1,900 pCi/L, and 230,000 pCi/L in groundwater, 4,000 pCi/L 270 pCi/L, and 110,000 pCi/L in springs, and 153 pCi/L, 143 pCi/L, and 12,300 pCi/L in surface water.

Sampling of riverbank springs and adjacent surface water performed in 1991, in the vicinity of 100-F/IU, detected chromium (2 to 36 µg/L in the springs; 2 to 10 µg/L in surface water), tritium (300 to 4,500

[2] 100-F-59 is a waste site located in the riparian area that is addressed in detail in Appendix L as part of the evaluation of the riparian and nearshore environment associated with the 100-F/IU Source OUs and the 100-FR-3 GW OU.

pCi/L in the springs, 200 to 300 pCi/L in surface water), strontium-90 (0.3 to 800 pCi/L in the springs; <0.4 to 50 pCi/L in the surface water). Samples of riverbank spring sediment from the 100-F had concentrations of metals and strontium-90, (*Riverbank Seepage of Groundwater Along the 100 Areas Shoreline, Hanford Site* [WHC-EP-0609], Figure 4-6).

Also in 1991, eight sediment samples were collected from five locations near 100-F (*100 Area Columbia River Sediment Sampling* [WHC-SN-EN-TI-198]). Maximum concentrations of inorganic constituents detected in these samples included chromium (45.7 mg/kg), copper (69.6 mg/kg), lead (55.7 mg/kg), and zinc (315 mg/kg). Cesium-137 (0.83 pCi/g), europium-152 (0.92 pCi/g), europium-154 (0.16 pCi/g), uranium-233/234 (1.6 pCi/g), and uranium-238 (2.0 pCi/g) were also detected.

The SESP does not routinely monitor surface water near 100-F/IU. The nearest routinely monitored locations are transects located at 100-N and Hanford Townsite. Riverbank spring locations near 100-F have been monitored by the SESP. The trends in metals concentrations in spring samples are reported to have been consistent over the past several years. With the exception of chromium, concentrations of metals in spring samples in 100-F were below Washington State chronic ambient surface water quality criteria in "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A). Concentrations of radionuclides detected in springs in 2010 were reported to be similar to those in previous years, although tritium concentrations were greater than the Washington State chronic ambient surface water quality criteria in "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A). Tritium, strontium-90, and total uranium were the only radionuclides reported above minimum detectable concentrations. Concentrations of radionuclides and metals in 100-F sediments were similar to levels detected in previous years (*Hanford Site Environmental Report for Calendar Year 2010* [PNNL-20548], hereinafter called 2010 Sitewide Environmental Report).

Investigations of riparian and nearshore areas were conducted in support of the RCBRA (DOE/RL-2007-21, Volume I). Riparian and nearshore areas were selected where affected media (seeps, springs, or runoff) may have created exposure pathways to biota (RCBRA SAP [DOE/RL-2005-42]). Riparian sampling locations also were identified based on radiation field survey results (RCBRA SAP [DOE/RL-2005-42], Appendix C; *DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* [BHI-01757], Appendix H). Radiation survey results and detection of chromium and strontium in groundwater, aquifer tube, and biota (bivalve) samples provided the basis for selection of riparian and nearshore study sites in the 100-F decision area (RCBRA SAP [DOE/RL-2005-42], Table C-1). Six nearshore (aquatic) study sites were located near 100-F/IU (study sites 2j, 2l, 2m, 3b, 4a, and 4d) (RCBRA [DOE/RL-2007-21], Figure 6-3). These were located downstream from the 100-N operation areas (strontium-90 groundwater plume), 100-D/H operational areas (Cr[VI] groundwater plume) and upstream from the 300 Area (uranium groundwater plume), within the discharge zone of a Cr(VI) groundwater plume (RCBRA SAP [DOE/RL-2005-42], Figure C-1) in the 100-IU-6 Area. Five riparian study sites were also associated with 100-F/IU (study sites 2j, Rip7, 2l, 3b, and 4a) (RCBRA [DOE/RL-2007-21], Figure 5-3).

Sample collection rationale and techniques varied by area and medium. Investigation areas characterized by data collected under the RCBRA SAP (DOE/RL-2005-42) included the upland, riparian, and nearshore river zones. Sites selected for sampling were identified based on existing data demonstrating a range of contaminant concentrations. Reference sites were identified using evidence/knowledge of areas not affected by contaminant release and selected based on physical/ecological similarity to onsite investigation areas.

Media collected in the upland and riparian zones included soil, vegetation, invertebrates, small mammals, and kingbirds (kingbirds in riparian zone only). Nearshore media included sediment, interstitial pore

water, surface water, benthic macroinvertebrates, clams, and sculpin. Toxicity testing was performed on soil, sediment, and water to provide Hanford Site-specific information on the ecological effects of contaminant mixtures and contaminant bioavailability. The results of these tests are used to make informed inferences on the toxicity of contaminants to Hanford Site biota. A more detailed discussion of the results from the RCBRA in riparian and nearshore areas is presented in Appendix L of this RI/FS.

*100-F River Effluent Pipeline Investigations.* During operations, water used in fuel production to cool the reactors was discharged to the Columbia River via effluent pipelines. The release of this cooling water ended when the associated reactors and facilities were shut down. Today, the two inactive 100-F effluent pipelines remain in their original locations in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the pipelines.

In 1984, *River Discharge Lines Characterization Report* (UNI-3262) discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the 105-C, 105-DR, and 105-F Reactors. Additionally, the pipelines were visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides. The major radionuclides detected included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. The dose rates measured for direct contact with the interior of the pipe surfaces were less than 1 mrem/hr, and readings on the exterior were below the instrument's detection capability.

In 1994, a comprehensive geophysical survey (*Columbia River Effluent Pipeline Survey* [WHC-SD-EN-TI-278]) located and mapped the reactor effluent pipelines. The study relied mainly on remote sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and ground penetrating radar. The results indicated that the pipelines have neither broken loose nor moved from their original locations. However, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D areas were sampled and physically characterized using a robotic transporter (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (*River Discharge Lines Characterization Report* [UNI-3262]) and were expected to represent "worst case" conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the 105-B and 105-D/DR Reactors.

### 1.2.4 CERCLA Five-Year Review

Effectiveness of the interim actions is evaluated through the CERCLA five-year review process. This evaluation determines whether the selected remedies remain protective of HHE. Since the issuance of the first Interim Action ROD, there have been three five-year reviews for the 100 Area NPL (40 CFR 300, Appendix B) Site. The first two five-year reviews indicated that RTD was an effective cleanup remedy for vadose contamination. *The Second CERCLA Five-Year Review Report for the Hanford Site* (DOE/RL-2006-20) listed that no issues or actions specific to the 100-F/IU were identified. *Hanford Site Third CERCLA Five-Year Review Report* (DOE/RL-2011-56) again listed issues or actions specifically for 100-F/IU OUs.

### 1.2.5 Summary

Chapter 1 summarized historical information, prior assessments and remediation work, treatability tests, and other relevant studies. This information provides a picture of current 100-F/IU OUs site conditions and establishes a foundation for the remainder of the RI/FS document.

# 2 Study Area Investigation

The Study Area Investigation combined results of previous studies, monitoring, and remediation with vadose zone and groundwater data collected under the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). Previous data included soil analytical data from waste site remediation and field investigations, groundwater monitoring data, and geological data from wells and boreholes. The 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) identified additional information that was needed to provide an understanding of the nature and extent of contamination in the OUs and support a remedial alternative evaluation and decision. This chapter describes the data needs, the data collected to fill them, and the corresponding scope of work (including field activities, tests, analyses, and data sources) that was designed and carried out in the RI/FS. The 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) and the 100-F/IU SAP (DOE/RL-2009-43) detail the scope of work. Chapters 3, 4, and 5 present results of the RI/FS activities. These chapters include data from previous studies and historical information to identify the nature and extent of contamination.

*Highlights*

- Field studies were performed in 2010 and early 2011 to address data needs identified in the100-F/IU Work Plan.
- Three vadose zone boreholes were drilled in 100-F, and soil samples were analyzed for contaminants.
- Three groundwater monitoring wells were installed in 100-F. Geologic and groundwater data from the new wells helped refine the conceptual model.
- Existing monitoring wells in 100-F and in 100-IU-2/IU-6 were sampled three times to evaluate spatial and temporal variability of groundwater contamination
- The new RI data combined with previous information are sufficient to support remedial action decisions.

Section 2.1 describes RI/FS field activities, as well as other investigations and ongoing activities that contributed to this RI/FS. These additional investigations include those with the potential to affect the development of the remedial action alternatives, including the RCBRA (DOE/RL-2007-21), *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling* (hereinafter called the Field Summary Report [WCH-380]), and ongoing groundwater and aquifer tube monitoring.

Section 2.2 summarizes the field activity documentation. Subsequent sections of this report describe the results of this work and integrate it with the existing information (Chapter 1) to update the CSM and to identify and evaluate options for achieving RAOs.

## 2.1 Remedial Investigation Activities

This section describes the investigation activities performed to fill the 100-F/IU data needs—analytical (laboratory sample results), quantitative (sample geographical coordinates), and process-related (fate and transport calculations).

Table 2-1 presents the relationship of the field activities and the data needs and Additional Tasks identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). Table 2-2 lists the supplemental investigations identified in the Integrated Work Plan (DOE/RL-2008-46), and other investigations that may potentially affect decisions regarding 100-F/IU waste site and groundwater contamination. Tables 2-3 and 2-4 summarize the field sampling program, and Figures 2-1 and 2-2 show the field sampling locations. The 100-F/IU SAP (DOE/RL-2009-43) provides additional details, such as specific sample intervals and sampling and analytical methodology, and technical memorandums summarizing each field activity. Section 2.2 includes additional documentation of field activities. The following sections also present details of investigation activities conducted under other scopes of work that may

affect FS decisions including *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* (hereinafter called the Columbia River RI Work Plan [DOE/RL-2008-11]) and the RCBRA (DOE/RL-2007-21).

*Work Plan Deviations.* 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) deviations are as follows:

- **Physical properties analyses:** Split-spoon samples often yielded insufficient sample volume for both chemical and physical analyses, because of the unconsolidated nature of the Hanford formation sediments. Approximately 25 percent of the physical property intervals required under the 100-F/IU SAP (DOE/RL-2009-43) were not analyzed (Appendix C). However, sufficient data were available to fill the data need.

- **Vadose zone boreholes:** Boreholes C7970 (116-F-14) and C7972 (118-F-85) were completed as temporary wells 199-F5-55 and 199-F5-56, respectively, in order to obtain a water sample. The temporary wells were screened at the top of the aquifer, and groundwater samples were collected after well completion. This deviation resulted in better-quality samples than would have been collected from the unfinished boreholes.

- **Aquifer tube sampling:** Existing aquifer tubes were scheduled for sampling in fall 2010. The sampling was delayed until 2011, and 18 of 32 tubes were sampled in February or early March. Before the remaining tubes were sampled, the river rose and submerged them so they could not be sampled until fall. The aquifer tubes were successfully sampled in November and December 2011 and again in fall 2012, and there is no adverse impact from the delay.

- **Spatial/temporal groundwater sampling:** Three rounds of samples were to be collected within 30-day windows. Because of field conditions and a safety-related work stoppage, the 30-day windows were not met for one of the three rounds at 100-F and for all three of the 100-IU-2/IU-6 rounds (42 to 107 days). The impact of this deviation is believed to be negligible, as discussed in Section 2.1.10.4.

### 2.1.1 Data Used in RI/FS

Historical data as well as data collected from the RI were evaluated in this report. Data are provided in Appendix D. The following is a list of the available data that were compiled for the RI/FS:

- Waste site remediation soil analytical data (CVP and RSVP through June 2012). These data were used in the evaluation of groundwater protection (Chapter 5), human health risk assessment (Chapter 6), and ecological risk assessment (Chapter 7).

- Field investigation soil analytical data (LFI data). These data were used in the evaluation of nature and extent (Chapter 4).

- Data collected as part of the ongoing interim waste site remediation (in process sampling), which are used to develop and refine the CSM, are qualitatively discussed in Chapter 4.

- Soil analytical data. Depth-specific soil samples collected during RI boring and well installation are used to evaluate contaminate distribution in the vadose zone and refine the CSM (Chapter 4).

Soil physical properties (grain size, moisture content, and porosity). These data were used in the groundwater model development (Chapter 5 and Appendix F).

Table 2-1. Data Gaps and Work Conducted Under 100-F/IU Remedial Investigation

| Data Gap | Data Need | Scope of Work Identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) | Work Conducted/Section with Discussion | Data Gap Filled? |
|---|---|---|---|---|
| 1. Data are needed to refine the conceptual site model of contaminant distribution beneath unremediated waste sites. | Assess the nature and vertical extent of contamination beneath unremediated waste sites. | Complete contaminated soil removal and sampling at 14 waste sites in the 100-F Area and 70 waste sites in the 100-IU-2/IU-6 OUs. The unremediated waste sites are listed in Appendix E, and the 100-F/IU SAP (DOE/RL-2009-43).<br>A site-specific evaluation will be performed onsite at 100-F-59 to determine whether existing data are consistent with the current RCBRA. | Section 2.1.9.1, Ongoing Waste Site Remediation | Yes |
| 2. Data are needed to refine the conceptual site model of contaminant distribution beneath selected remediated wastes sites. | Assess the nature and vertical extent of contamination beneath selected remediated waste sites. | Drill one borehole each at the following waste sites: the 116-F-14 Retention Basin and the 118-F-1 Burial Ground. Collect and analyze soil samples for target analytes. Details are presented in the 100-F/IU SAP (DOE/RL-2009-43). | Boreholes C7970 and C7971 were drilled and sampled<br>Section 2.1.9.2, Boreholes<br>Section 4.2, Vadose Zone Contamination | Yes |
| 3. Data are needed to refine the conceptual site model of contaminant distribution beneath and around reactor structures. | Assess the nature and vertical extent of contamination in the vadose zone around the 105-F Reactor structure. | Drill one borehole in the boundary of the 118-F-8 Reactor fuel storage basin. Collect and analyze soil samples for target analytes. Details are presented in the 100-F/IU SAP (DOE/RL-2009-43). | Borehole C7972 was drilled at the fuel storage basin<br>Section 2.1.9.2, Boreholes<br>Section 4.2, Vadose Zone Contamination | Yes |
| 4. The nature and extent of contamination exceeding cleanup standards in the unconfined aquifer has not been defined in all areas, nor for all COPCs. | Identify groundwater contaminants and define the extent of contamination horizontally and vertically. | Install three new groundwater monitoring wells (Figure 2-1). Well 1 will be installed to define the extent of Cr(VI) further. Well 2 will be installed to define the extent of strontium-90 further. Well 3 will be drilled into the RUM unit and will define the vertical distribution of contaminants through the unconfined aquifer and within the RUM unit. Groundwater samples will be collected at various depths and analyzed for COPCs, as specified in the SAP.<br>Sample new and existing monitoring wells for all groundwater COPCs. Details are found in the 100-F/IU SAP (DOE/RL-2009-43). Sampling will also be conducted to address Data Gap 8. | Three new groundwater monitoring wells were installed as per the scope of work:<br>Well 1 is 199-F5-52<br>Well 2 is 199-F5-54<br>Well 3 is 199-F5-53<br>Section 2.1.10, Groundwater Investigations<br>Section 4.3, Groundwater Contamination | Yes |

Table 2-1. Data Gaps and Work Conducted Under 100-F/IU Remedial Investigation

| Data Gap | Data Need | Scope of Work Identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) | Work Conducted/Section with Discussion | Data Gap Filled? |
|---|---|---|---|---|
| 5. Contaminant concentrations entering the Columbia River are not well known. | Data from the aquifer tube network are needed to monitor contaminant concentrations over time and with depth near the river. | Continue routine sampling of existing aquifer tubes per the *Sampling and Analysis Plan for Aquifer Sampling Tubes* (DOE/RL-2000-59). Collect pore water samples per the RI SAP (DOE/RL-2009-43 as revised by *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study, DOE/RL-2009-43, Rev. 0* (TPA-CN-391). | Section 2.1.7, Surface Water and Sediment Investigations<br>Section 2.1.10.3, Aquifer/River Interactions<br>Section 4.3, Groundwater Contamination | Yes |
| 6. Contaminant fate and transport beneath the unconfined aquifer have not been evaluated sufficiently over 100-F/IU. | Evaluate the integrity of the aquitard unit and contaminant fate and transport within the aquitard. | Collect split-spoon soil samples from 1.5 m (5 ft) into the RUM unit during drilling for new Wells 1 and 2, and 15 m (50 ft) into the RUM unit during drilling for new Well 3. Screen Well 3 within the first water-bearing zone within the RUM unit and analyze groundwater samples for COPCs. | Section 2.1.9.2, Boreholes<br>Section 2.1.10, Groundwater Investigations<br>Section 3.4, Geology<br>Section 3.6, Hydrogeology | Yes |
| 7. Data are needed for a better understanding of hydrogeological conditions, aquifer and surface water interactions, and contaminant mobility through the vadose zone. | Geological characterization, physical, and hydraulic property data are needed to support modeling and analysis. | Drill and sample soil and groundwater from the three new wells (Figure 2-1). Drill Wells 1 and 2 to a depth of 5 m (15 ft) into the RUM unit, and drill Well 3 to a depth of 15 m (50 ft) into the RUM unit. Screen Well 3 in the first water-bearing zone encountered in the RUM unit. Analyze soil samples collected from the vadose zone, unconfined aquifer, and RUM unit and analyze groundwater samples from the unconfined aquifer and the RUM unit (if sufficient water is available for sampling) per the 100-F/IU SAP (DOE/RL-2009-43).<br>Install and monitor pressure transducers in selected wells to determine horizontal hydraulic gradient and vertical gradient. | Three new groundwater monitoring wells were installed as per the scope of work:<br>Well 1 is 199-F5-52<br>Well 2 is 199-F5-54<br>Well 3 is 199-F5-53<br>Pressure transducers were installed and monitored.<br>Section 2.1.9.2 Boreholes<br>Section 2.1.10, Groundwater Investigations<br>Section 3.4, Geology<br>Section 3.6, Hydrogeology | Yes |

Table 2-1. Data Gaps and Work Conducted Under 100-F/IU Remedial Investigation

| Data Gap | Data Need | Scope of Work Identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) | Work Conducted/Section with Discussion | Data Gap Filled? |
|---|---|---|---|---|
| 8. Data are needed to reduce the uncertainty in the nature and spatial and temporal distribution of groundwater contamination. | Reduce uncertainty in assessing risks posed by groundwater contamination. | Collect and analyze groundwater samples from 55 groundwater monitoring wells in 100-F/IU to characterize the nature and extent, and temporal variability, of groundwater contamination. Three rounds of groundwater sampling will be conducted during high, low, and transitional river stage. Wells are shown on Figures 2-1 and 2-2. Details are presented in the 100-F/IU SAP (DOE/RL-2009-43). | Section 2.1.10, Groundwater Investigations<br>Section 4.3, Groundwater Contamination<br>Section 6.3, Groundwater Risk Assessment | Yes |

| Task | | Additional Tasks Identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) |
|---|---|---|
| 1 | Opportunistic groundwater sampling | Groundwater samples were collected during drilling activities for each borehole. Two of the boreholes were completed as temporary wells to obtain representative samples and allow future sampling.<br>Section 2.1.10, Groundwater Investigations<br>Section 4.3, Groundwater Contamination |
| 2 | Develop potential remedial technologies | Chapter 8, Identification and Screening of Technologies |
| 3 | Update bathymetry data for the river adjacent to 100-F/IU to support calculations of contaminant transport to the river and ecological receptors | Section 2.1.8.2, Bathymetric Evaluation<br>Section 3.4, Geology |

Table 2-2. Supplemental Investigations and Other Primary Investigations

| Summary | Section |
|---|---|
| Evaluating and developing approaches to obtain data that will demonstrate compliance with ambient water quality standards in the river for final RODs. In April 2008, a technical review panel was convened to evaluate groundwater interactions with the Columbia River (*Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area* [SGW-39305]). The panel suggested that the current mixing/dilution conceptual model should be re-evaluated. In addition, data may be needed to show representativeness of contaminant concentrations for compliance. Therefore, evaluation will include determination of whether 1:1 dilution assumption for groundwater entering the river is valid, and may include evaluation of whether data from aquifer tube samples are representative. Data collected as part of the RI for Site releases to the Columbia River may be useful in this evaluation. | Section 2.1.7, Surface Water and Sediment Investigations |
| Collecting data and developing River Corridor background values in soil for antimony, boron, molybdenum, and selenium. Site-specific background values for these constituents may be needed to determine final soil RAG values where calculated risk-based concentrations and/or ecological protection concentrations are less than background. Interim remedial actions have used Washington State background values for antimony and selenium; interim soil RAGs for boron and molybdenum are above expected site-specific background values. | Section 2.1.12, Supplemental Investigations |
| Re-evaluating soil cleanup level for Cr(VI) to support the final ROD. The lowest soil RAG for Cr(VI) under the interim action RODs is 2.0 mg/kg. However, the calculated "Model Toxics Control Act—Cleanup," "Deriving Soil Concentrations for Groundwater Protection" (WAC-173-340-747(3)(a)) soil RAG value may be below the current limits of analytical quantitation in environmental samples, depending on the soil-partitioning value and groundwater-to-river dilution attenuation factor used, and final soil cleanup values may default to the limits of quantitation. Because there is uncertainty in analytical detection and quantitation of Cr(VI) near the limits of detection, it may be necessary to consider the realistic capabilities of analytical performance in determination of a final soil cleanup value. | Section 2.1.12, Supplemental Investigations |
| Determining a site-specific soil-partitioning value for antimony. This value is necessary for calculation of the "Deriving Soil Concentrations for Groundwater Protection" (WAC-173-340-747(3)(a)) soil RAG values for antimony. Antimony is not a significant contaminant in the River Corridor, and determination will include review of scientific literature, which suggests antimony soil-partitioning values in the range of 1.4 to 45 ml/g. | Section 2.1.12, Supplemental Investigations |

Table 2-2. Supplemental Investigations and Other Primary Investigations

| Summary | Section |
|---|---|
| Re-evaluating soil cleanup levels for arsenic to support the final ROD. The soil RAG for arsenic under the interim action RODs is 20 mg/kg, based on the Tri-Party Agreement (Ecology et al., 1989a) to use the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(2)) Method A value (100 Area RDR/RAWP [DOE/RL-96-17]). The "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(2) [2007]) Method A value is also 20 mg/kg. The "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(3)) Method B and "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747(3)(a)) soil values for arsenic are below the Site arsenic background of 6.5 mg/kg. Selection of a final soil cleanup level for arsenic in the River Corridor will be accomplished through development of final RODs. | Section 2.1.12, Supplemental Investigations |
| **Other Primary Investigations that Potentially Affect Feasibility Study Decisions for Waste Sites and Groundwater Contamination** | |
| Columbia River Pore Water Remedial Investigation | Section 2.1.7, Surface Water and Sediment Investigation<br>Section 3.6.4, Zone of Surface Water/ Groundwater Interaction<br>Section 4.4, Columbia River Water and Sediments |
| River Corridor Baseline Risk Assessment | Section 4.4, Columbia River Water and Sediments |
| Annual Groundwater Monitoring | Section 2.1.10, Groundwater Investigation<br>Section 4.3, Groundwater Contamination |
| Ongoing Aquifer Tube Sampling | Section 2.1.10, Groundwater Investigation<br>Section 4.3, Groundwater Contamination |

RUM = Ringold Upper Mud

Table 2-3. Summary of Soil Samples Collected for 100-F/IU

| Well ID | Well Name | Soil Chemistry | | Physical Properties | | Deviations from SAP* |
|---|---|---|---|---|---|---|
| | | No. Planned | No. Received | No. Planned | No. Received | |
| **Monitoring Wells** | | | | | | |
| C7790 | 199-F5-52 | 8 | 8 | 8 | 8 | One required interval had insufficient sample volume for physical properties |
| C7791 | 199-F5-53 | 10 | 10 | 10 | 7 | Three intervals had insufficient sample volumes for physical properties |
| C7792 | 199-F5-54 | 8 | 12 | 8 | 7 | Three intervals had insufficient sample volumes for physical properties |
| **Vadose Boreholes** | | | | | | |
| C7970 | 199-F5-55 | 9 | 9 | 1 | 0 | Insufficient sample volume for physical properties |
| C7971 | N/A | 5 | 5 | 2 | 1 | Physical property sample for Hanford formation missed; RUM shallower than estimated |
| C7972 | 199-F5-56 | 8 | 8 | 1 | 0 | Insufficient sample volume for physical properties |

* Appendix C contains additional detail for each sampling interval.

N/A = not applicable

1

Table 2-4. Summary of Water Samples Collected for 100-F/IU

| Well ID | Well Name | SAP Requirements | Depths Sampled, m (ft) | No. Intervals Sampled | Deviations from SAP |
|---|---|---|---|---|---|
| **Monitoring Wells** | | | | | |
| C7790 | 199-F5-52 | Every 1.5 m (5 ft) from water table to top of RUM | 15.0 to 19.5 (49.1 to 64) | 4 | None |
| C7791 | 199-F5-53 | Every 1.5 m (5 ft) from water table to top of RUM and one sample from water-bearing zone of RUM | 13.4 to 30.8 (44 to 100.9) | 3 | None |
| C7792 | 199-F5-54 | Every 1.5 m (5 ft) from water table to top of RUM | 14.6 to 20.6 (48 to 67.5) | 5 | None |

Table 2-4. Summary of Water Samples Collected for 100-F/IU

| Well ID | Well Name | SAP Requirements | Depths Sampled, m (ft) | No. Intervals Sampled | Deviations from SAP |
|---|---|---|---|---|---|
| | Various | Sample 55 wells three times: low, high, and transitional river stage (spatial/temporal well network; Tables 3-2 and 3-3 of the 100-F/IU SAP [DOE/RL-2009-43]) | Upper unconfined aquifer | 1 each | See Section 2.1.10.4 |
| **Vadose Boreholes** | | | | | |
| C7970 | 199-F5-55* | One sample from top of aquifer | 13.0 to 15.2* (42.6 to 50) | 1 | Completed as a well |
| C7971 | N/A | One sample from top of aquifer | 28.1 (8.6) | 1 | None |
| C7972 | 199-F5-56* | One sample from top of aquifer | 13.4 to 15.2* (43.9 to 50) | 1 | Completed as a well |

* These boreholes were completed as wells to allow for more representative groundwater samples. The depths sampled represent the screened interval below the water table.

- Hydraulic conductivity. These data were used in the groundwater model development (Chapter 5 and Appendix F).
- Geophysical logging. The geophysical logs from the RI borings are presented in Chapter 3. These data help with the understanding of the CSM and transport of contaminants through the vadose zone.
- Groundwater analytical data. Various subsets of data were used for different purposes:
  - Data from the period January 2007 to December 2011 were used for statistical summaries in Chapter 4.
  - Spatial and temporal groundwater monitoring data, used for risk assessment (Chapters 6 and 7), were a subset of the first bullet and were limited to specific wells and sampling events specified under the 100-F/IU SAP.
  - 2010 and 2011 data were used to produce plume maps in Chapter 4.
  - The maximum concentration at each 100-F well in 2009 through 2011 was used to produce for the initial plumes for groundwater modeling (Chapter 5 and Appendix F).
  - Groundwater characterization data, collected from unfinished boreholes during drilling RI wells, were used to construct vertical profiles and cross sections (Chapter 4).
- Pore water analytical data collected in 2009 through 2011. These data were used to describe groundwater and surface water interactions.
- Well and borehole drilling and construction information. These data were used in the development of the geologic cross sections (Chapter 3) and the groundwater model (Chapter 5 and Appendix F).

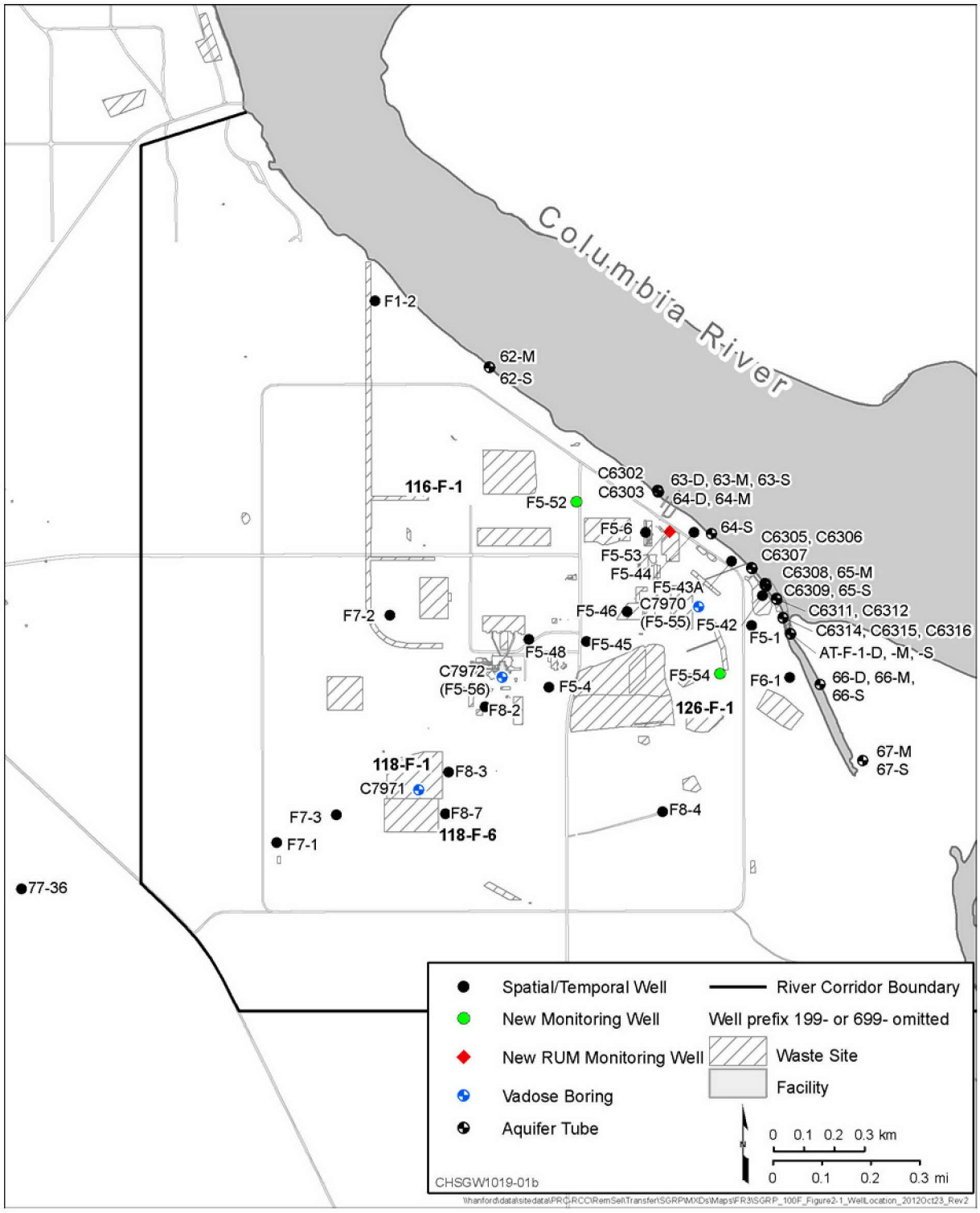


Figure 2-1. 100-F Field Characterization Sampling Locations

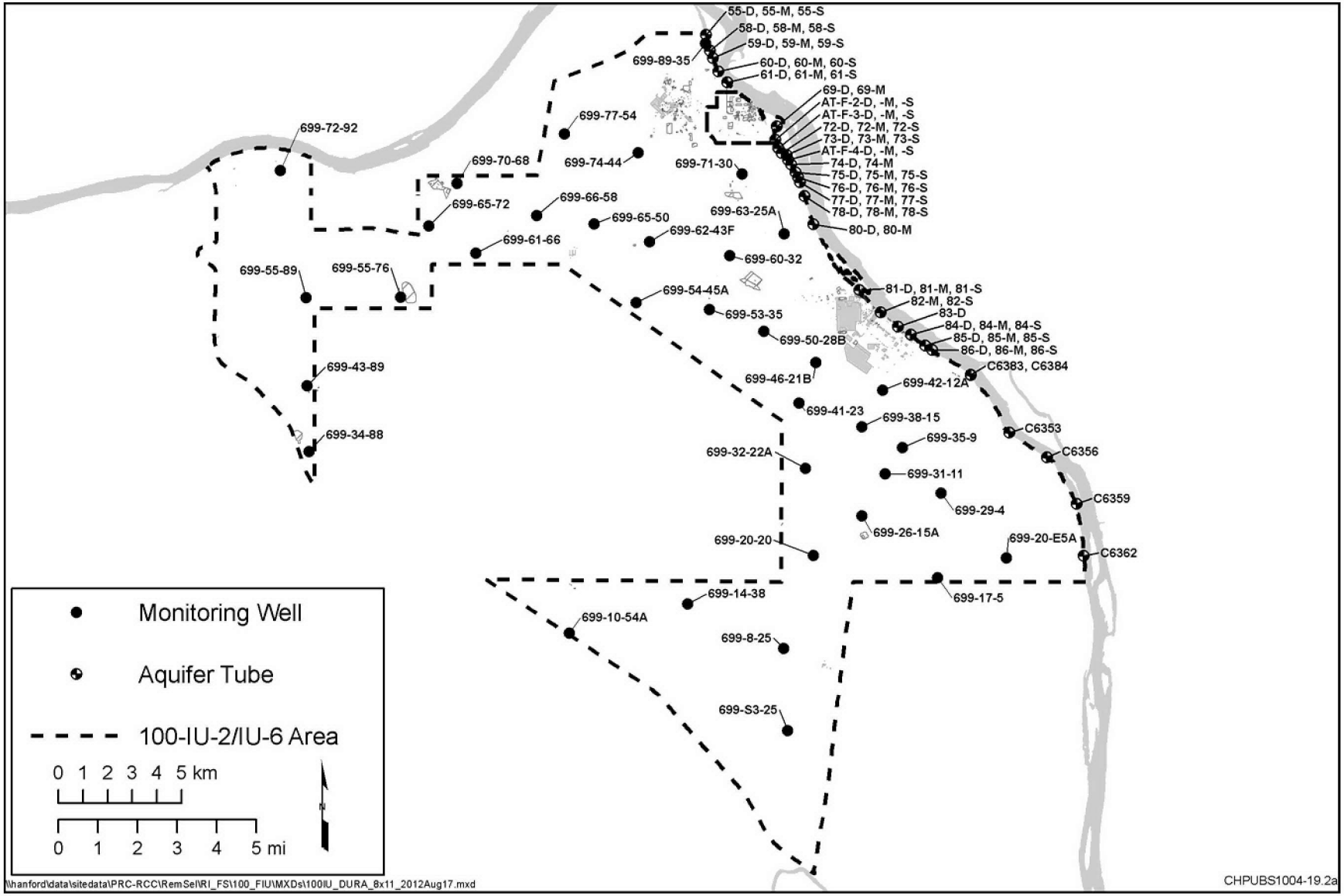


Figure 2-2. 100-IU-2/IU-6 Field Characterization Sampling Locations

- Fate and transport parameters (e.g., geochemical parameters, hydrogeologic parameters, soil physical properties). These data were used in the development of the groundwater model and fate and transport evaluations (Chapter 5 and Appendix F).
- Distribution coefficient ($K_d$) data for metals. These data were used in the evaluation of fate and transport of metals (Chapter 5).
- Geologic information. These data were used in the development of the geologic cross sections (Chapter 3) and the groundwater model (Chapter 5 and Appendix F).
- Groundwater levels and river stage. These data were used in the development of groundwater flow maps (Chapter 3) and the groundwater model (Chapter 5 and Appendix F).

Analytical data that were used in the RI/FS were collected and analyzed in a fixed laboratory using approved methods with specific quality assurance/quality control (QA/QC) requirements. Detection limits, precisions, accuracy, and completeness were assessed to determine whether the chemical and radiochemical data obtained were the right type, quality, and quantity to support regulatory decision-making. Data validation qualifiers for the RI/FS are included in Appendix D.

The results of th validation, verification, and quality assessments of the historical data used in the RI/FS are documented or summarized in the associated data quality assessment (DQA) reports, CVPs, RSVPs, LFIs, etc., which are incorporated by reference. The data quality assessment of the new data collected during the RI is summarized in DOE/RL-2012-66, *Data QualityAssessment for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study.*

### 2.1.2 Historical Information Review

Historical information on 100-F/IU was researched and reviewed during 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) preparation. The information considered is summarized in Section 1.2.3, and in the Annotated Bibliography (Appendix B) of this document.

### 2.1.3 Surface Features

Surface feature mapping, such as high-resolution topography, was conducted using Light Detection and Ranging (LIDAR) technology in 2008. LIDAR is an optical remote-sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The prevalent method to determine distance to an object or surface is to use laser pulses. The LIDAR-based topography was used to identify areas with surface anomalies. These areas were further investigated to determine the potential for discovery sites in those locations. The current accuracy of the LIDAR mapping is estimated at 0.11 m (4.3 in.). LIDAR data were used to create topographic maps of 100-F and 100-IU-2/IU-6. Chapter 3 presents topographic maps based on the LIDAR data

### 2.1.4 Contaminant Source Investigations

The OSE field investigation was completed for the 100-F operational areas in 2005, and the report was finalized in February 2012. For 100-IU-2 and 100-IU-6, the OSE field investigation was completed in April 2011; and the final report was issued in December 2011. The discovery site process in 100-F/IU will continue during ongoing remedial action activities (e.g., RTD excavations of known waste sites). Section 1.2.3.2, Vadose Zone Remedial Actions and Waste Site Investigations, describes the discovery process.

### 2.1.5 Meteorological Investigations

The Hanford Meteorological Station (HMS) (http://www.hanford.gov/hms) provides a range of Site weather forecast products, real-time meteorological data, and an extensive historical database of meteorological and climatological data. Meteorological measurements have been made at HMS since late 1944. Information specific to precipitation and wind speed has the potential to affect remedial actions, as discussed in Section 3.2. No additional meteorological data were collected as part of this RI/FS.

### 2.1.6 Air Investigations

Hanford Site contractors monitor radionuclide airborne emissions from site facilities through several programs. The Near-Facility Environmental Monitoring Program measures concentrations of radionuclides in the ambient air on the Hanford Site in or near facilities and operations. The Hanford Site Environmental Surveillance Program measures the ambient air at Sitewide locations away from facilities, offsite around the perimeter of the site, and in nearby and distant communities. In addition, emissions from stacks, vents, or other types of point sources are monitored individually by analyzing samples extracted from the outflow at each point of release. The data collected by each program are used to assess the effectiveness of emission treatment and control systems and pollution management practices, and determine compliance with state and federal regulatory requirements. These regulations include a radiological standard that requires that all Hanford Site emissions combined shall be controlled such that no member of the public in any area of unrestricted access receives greater than 10 mrem/yr total effective dose equivalent. Washington State and the EPA each require that all Hanford Site emissions and the resulting total effective dose equivalent to the public be reported, detailing the contributions from each point source of emissions and from all fugitive or diffuse sources of emissions of radionuclides. These reports are required to include emissions from both routine and non-routine operations.

Nonradioactive air pollutants are emitted from a wide variety of sources at the Hanford Site. These emissions are monitored at the source when activities are known to actually or potentially generate pollutants of concern. The following paragraphs describes Hanford Site air monitoring activities (*Hanford Site Environmental Report for Calendar Year 2009* [PNNL-19455], hereinafter called 2009 Sitewide Environmental Report). Section 4.6 summarizes results of air monitoring.

#### *2.1.6.1 Air Monitoring Near Facilities and Operations*

In 2009, ambient air was monitored for radionuclides at locations on the Hanford Site near facilities and operations. Samplers were located primarily at or within about 500 m (1,640 ft) of sites or facilities having the potential for, or a history of, radioactive contaminant releases. This near-facility environmental monitoring is conducted near facilities or projects that provide the potential to disperse radioactivity. Monitoring locations are associated largely with major nuclear facilities and waste storage, disposal, or cleanup activities.

#### *2.1.6.2 Air Monitoring at Hanford Sitewide and Offsite Locations*

During 2009, as part of the Hanford Site Environmental Surveillance Program, samples were collected at 42 continuously operating Sitewide and offsite locations: 23 onsite (Sitewide), 11 at site perimeter locations, 7 in nearby communities, and 1 in a distant community. Samples are collected from known or expected air transport pathways, which are generally downwind of potential or actual airborne releases and downgradient of liquid discharges. Airborne particle samples were collected at each station biweekly and monitored for gross alpha and gross beta concentrations. Biweekly samples were combined into quarterly composite samples and analyzed for gamma-emitting radionuclides. Samples of atmospheric water vapor were collected every 4 weeks at 20 locations and analyzed for tritium. Ambient air sampling is the primary method used in monitoring fugitive emissions, with other media samples possibly useful as secondary indicators.

Hanford Site contractors also monitor for other impacts from airborne emissions or other releases from site facilities. This is done through sampling of various environmental media besides the air, also as part of the Surface Environmental Surveillance Program. Routine monitoring includes sampling, surface contamination, external radiation doses, soil, vegetation, and animals.

No additional air monitoring, with the exception of in-process monitoring at the immediate worksite during select borehole and well activities, was conducted as part of this RI/FS. The state of Washington Department of Health also conducts independent sampling and analysis of various media, including ambient air, soil, and biota, both on and off the Hanford Site. This independent sampling and analysis routinely confirms little or no environmental impacts outside of the Site's most closely controlled work areas.

### 2.1.7 Surface Water and Sediment Investigations

Additional data related to groundwater discharge to surface water (Data Gap 5) were identified as necessary to support remedy decisions. An investigation of pore water, surface water, and sediment was conducted to identify the nature and extent of contaminants entering the Columbia River, specifically by groundwater upwelling in the Columbia River. An additional study was performed for this RI as specified in the 100-F/IU SAP (DOE/RL-2009-43) as revised by *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study, DOE/RL-2009-43, Rev. 0* (TPA-CN-391). The following sections provide details on these investigations. Results are described in Sections 3.6.4 and 4.4.

#### *2.1.7.1 Groundwater Upwelling and Discharge into the Columbia River (Pore Water, Surface Water, and Sediment Sampling)*

The groundwater beneath the Hanford Site discharges to the Columbia River via seeps and upwelling to the riverbed. This flow path for groundwater provides a means for transporting Hanford Site-associated contaminants, which have leached into groundwater from past waste disposal practices, to the Columbia River.

The near-shore groundwater conditions are directly affected by river stage. Limited historical data are available to understand groundwater flow paths, contaminant migration, and mixing in the near-shore area adequately. A wide range of mixing ratios has been observed between upwelling water at the bottom of the river and groundwater at near-shore locations (*Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area* [SGW-39305]). This mixing ratio represents a continuum from pure groundwater to pure river water, depending on where the measurement is taken and when.

Scenarios for plume discharge to the river vary widely because of seasonality and dynamic conditions in the zone of interaction. The greatest contaminant flux and highest concentrations at exposure locations are postulated to occur during periods of low river stage. During this period, the hydraulic gradient toward the river is steepest, and mixing between river water and groundwater is minimal.

To address the uncertainty related to the nature and extent of contamination entering the Columbia River, including the contaminant transport mechanisms, data were collected near both 100-F and Hanford Townsite (a portion of 100-IU-2/IU-6) in 2009 and 2010. Pore water sampling in the Columbia River was conducted during three phases, as outlined in the Columbia River RI Work Plan (DOE/RL-2008-11).

The first phase of the Columbia River RI pore water sampling, termed Phase II(a), focused on identification of riverbed areas where groundwater was entering the Columbia River. The second phase, termed Phase II(b), returned to a subset of the Phase II(a) sample locations to collect samples of pore

water for indicator contaminant analysis. For 100-F, the indicator contaminant was Cr(VI), and at the Hanford Townsite the indicator contaminant was tritium. The third phase identified a subset of the previous sample locations for sampling and analysis of pore water, surface water (defined as water 0.3 m [1 ft] above the riverbed) and co-located sediment for a wide range of potential contaminants. Chapter 3 presents the results of Phase II(a) and Chapter 4 the results of Phases II(b) and III.

*Pore Water.* The objective of Phase II(a) sampling was to identify and delineate plumes of groundwater upwelling in the Columbia River adjacent to Hanford Site operations areas. Pore water data were collected using a multi-sensor water-sampling probe capable of being inserted approximately 30 cm (12 in.) into the riverbed, and measuring conductivity and temperature in situ. Five cross-river transects in each of the 100-F and Hanford Townsite areas, each of which had five separate sample locations, were the focus of data collection. Additionally, up to 10 locations surrounding each transect were sampled. All pore water sample data collected in Phase II(a) were analyzed for specific conductance and temperature only.

Pore water sampling for Phase II(b) was conducted at a subset of the Phase II(a) locations that clearly showed groundwater upwelling based on conductivity and temperature variances between the river and pore water, and were deemed most likely to show contamination. These sample locations were approved by the Tri-Parties and are shown on Figures 2-3 through 2-5.

Pore water samples for Phase III (Figures 2-6 through 2-8) were collected from established upwelling locations, with the focus on sites where the indicator contaminant was detected in the Phase II(b) pore water samples. For Phase III sampling, the Tri-Parties selected only two sample locations near 100-F and five sample locations across the broader Hanford Townsite area for collection of pore water, surface water, and sediment. Phase III characterization samples were analyzed for a range of radiological and nonradiological analytes as shown in Tables 2-5 and 2-6. While samples were successfully collected at each specified location in both areas, not all media and/or analyses could be collected and/or conducted for each sample location due to site-specific sampling or sample volume constraints.

Information on the number and time period in which pore water samples were attained during each sampling phase are presented in Table 2-7.

*Surface Water.* During Phase III, the influence of contaminants on the water immediately above groundwater upwelling locations was determined by taking surface water samples. River water was collected concurrently during pore water sample collection at approximately 0.3 m (12 in.) above the riverbed. Surface water sample analysis included the analytes in Tables 2-5 and Table 2-6.

*Sediment.* As described above, Phase III samples, collected from the locations shown on Figures 2-6 through 2-8, were analyzed for a range of radiological and nonradiological analytes (Tables 2-5 and 2-6). Sediment samples were obtained as close to the pore water sample locations as reasonably possible, with a preference given to locations with sediment deposits. Information on the number and time period in which sediment samples were obtained is presented in Table 2-7.

#### 2.1.7.2 RI Pore Water Sampling

Supplemental pore water sampling was conducted at 100-F in February 2011 (*Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study, DOE/RL-2009-43, Rev. 0* [TPA-CN-391]). Pore water samples were collected with the Trident probe from 20 locations along two nearshore transects within the Columbia River. Unlike previous sampling efforts, sampling was not restricted to locations with characteristics of groundwater upwelling. Samples were analyzed for total chromium and Cr(VI) only. Chapter 4 summarizes the results of the study.

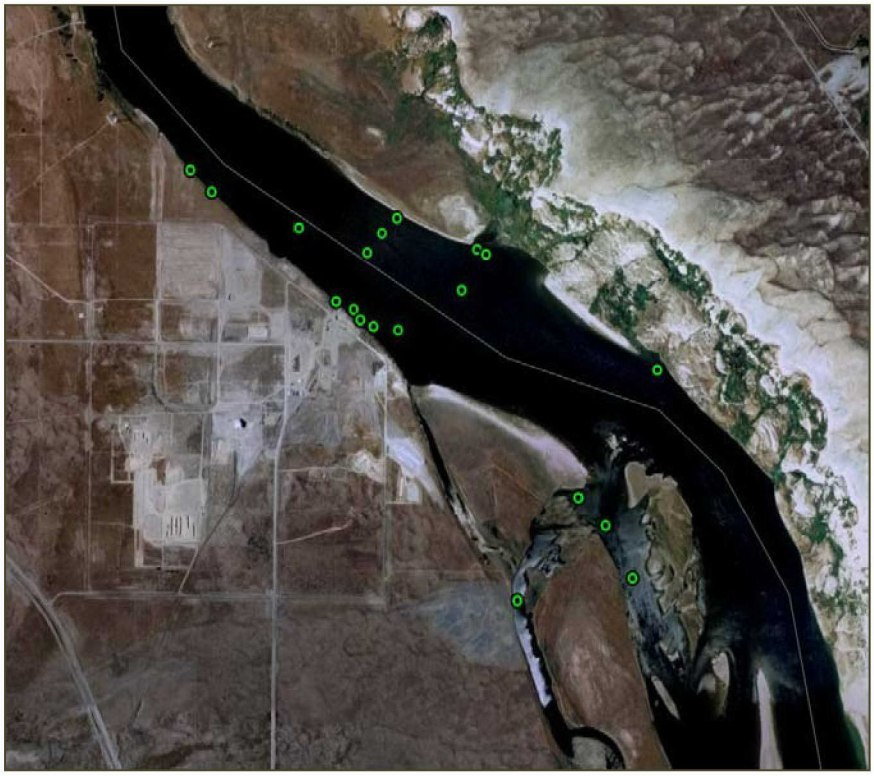

Figure 2-3. Remedial Investigation for Hanford Site Releases to the Columbia River – Phase II(a) Characterization Sample Locations for 100-F

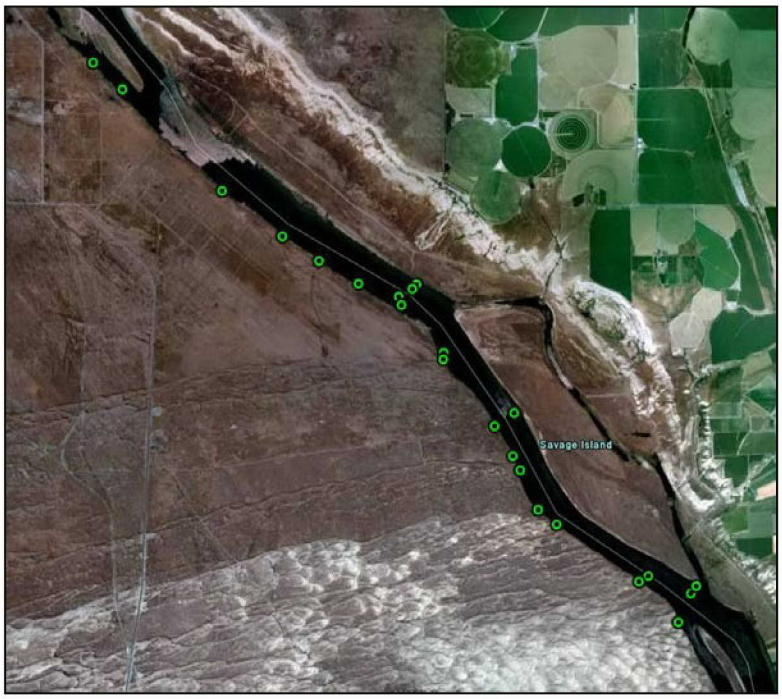


Figure 2-4. Remedial Investigation for Hanford Site Releases to the Columbia River – Phase II(a) Characterization Sample Locations for the Hanford Townsite (Northern Portion)

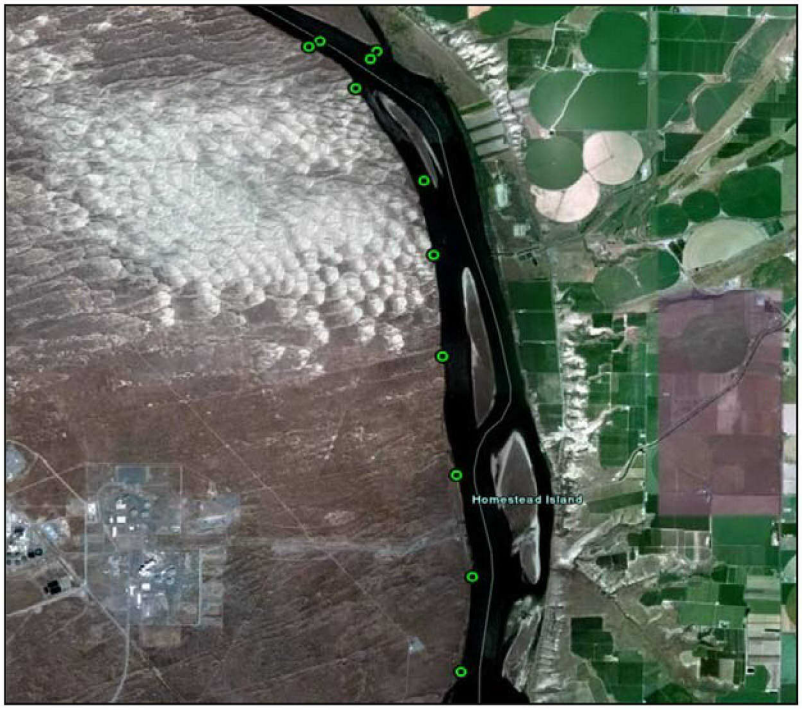


Figure 2-5. Remedial Investigation for Hanford Site Releases to the Columbia River – Phase II(a) Characterization Sample Locations for the Hanford Townsite (Southern Portion)

Figure 2-6. Remedial Investigation for Site Releases to the Columbia River – Phase III Characterization Sample Locations for 100-F

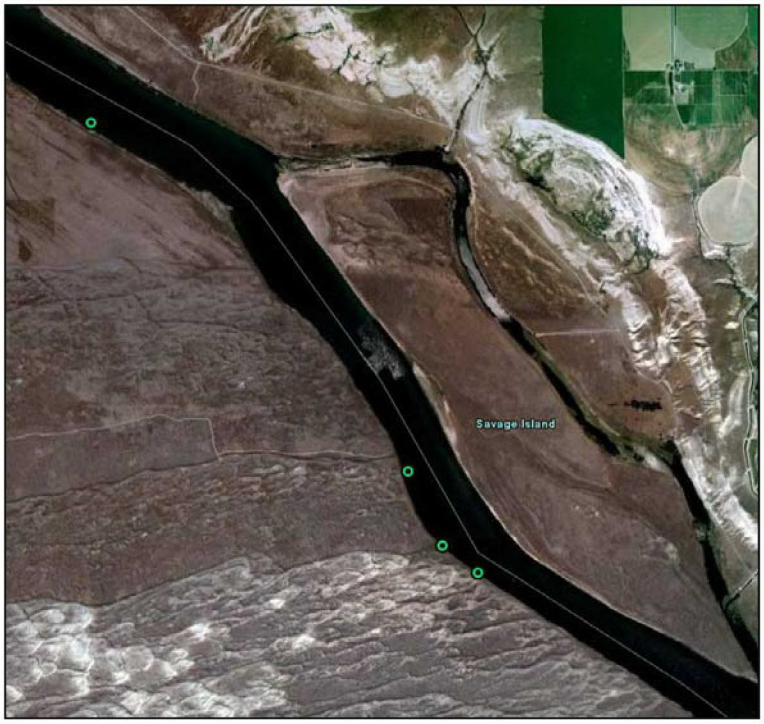


Figure 2-7. Remedial Investigation for Site Releases to the Columbia River – Phase III Characterization Sample Locations for Hanford Townsite (Northern End)

Figure 2-8. Remedial Investigation for Site Releases to the Columbia River – Phase III Characterization Sample Locations for Hanford Townsite (Southern End)

Table 2-5. Analytes for Columbia River Remedial Investigation (Phase III) Sampling at 100-F

| Media | Analytes | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Metals (filtered)[a] | Metals (unfiltered)[a] | Metals (solid)[a] | Cr(VI) | Nitrate and Anions | AVS/SEM | Hardness/DOC/Alkalinity | TOC/TIC | TOC/Grain Size | Isotopic Thorium | Isotopic Plutonium | Tritium | Strontium-89/90 | Isotopic Uranium | Radionuclides, GEA[b] | Field Parameters[c] |
| Pore Water | X | X | | X | X | | | X | | | | X | X | | | X |
| Surface Water | X | X | | X | X | | X | | | X | X | | X | X | X | X |
| Sediment | | | X | X | | X | | | X | X | X | | X | X | X | |

Source: WCH-286, *Sampling and Analysis Instructions for the Remedial Investigation of Hanford Site Releases to the Columbia River.*

a. Metals including uranium (Method 6010TR) and mercury (Methods 7470/7471).

b. Radionuclides include americium-241, antimony-125, beryllium-7, cesium-134, cobalt-60, europium-152, europium-154, europium-155, potassium-40, radium-226, radium-228, and ruthenium-106.

c. Field parameters for pore and surface water include temperature, specific conductance, dissolved oxygen, and pH.

AVS/SEM = acid volatile sulfides/simultaneously extracted metals
DOC = dissolved organic carbon
GEA = gamma energy analysis
X = Undetermined

#### 2.1.7.3 Surface Water Sampling

In addition to that sampling described in the preceding sections, supplemental samples of surface water, sediment, and island soil samples were taken during the Columbia River RI at locations described in *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, River Sediments, and Island Soils* (WCH-352), and *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-398), hereinafter called the Hanford Site Releases Data Summary, for identifying the nature and extent of potential releases of contaminants associated with operations at the Hanford Site. Figures 5-12a and 5-12b in the Hanford Site Releases Data Summary (WCH-398) show these sample locations near 100-F, whereas Figures 5-13a through 5-13d show the sample locations along the Hanford Townsite area. Table 2-8 provides a summary of the number of additional samples collected.

*Routine Monitoring of Surface Water.* DOE conducts routine monitoring of surface water and sediment on the Hanford Site (2009 Sitewide Environmental Report [PNNL-19455]). Samples are collected upstream from the Hanford Site at Priest Rapids Dam, downstream from the Site at the City of Richland, and at several locations on the Site. A cross-river transect is sampled at the Hanford Townsite. River water is not sampled at 100-F. Constituents of interest in Columbia River water samples collected at Priest Rapids Dam and the City of Richland include gamma-emitting radionuclides, tritium, strontium-90, technetium-99, uranium isotopes, and plutonium isotopes.

Table 2-6. Analytes for Columbia River Remedial Investigation (Phase III) Sampling at Hanford Townsite

| Media | Analytes | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Metals (filtered)[a] | Metals (unfiltered)[a] | Metals (solid)[a] | Cr(VI) | Nitrate and Anions | AVS/SEM | Hardness/DOC/Alkalinity | TOC/TIC | TOC/Grain Size | Isotopic Thorium | Isotopic Plutonium | Tritium | Strontium-89/90 | Isotopic Uranium | Radionuclides, GEA[b] | Technetium-99[c] | Field Parameters[d] |
| Pore Water | X | X | | X | X | | | X | | | | X | X | | | X | X |
| Surface Water | X | X | | | X | | X | | | X | X | X | X | X | X | X | X |
| Sediment | | | X | | | X | | | X | X | X | X | X | X | X | X | |

Source: WCH-286, *Sampling and Analysis Instructions for the Remedial Investigation of Hanford Site Releases to the Columbia River*.

a. Metals including uranium (Method 6010TR) and mercury (Methods 7470/7471).

b. Radionuclides include americium-241, antimony-125, beryllium-7, cesium-134, cesium-137, cobalt-60, europium-152, europium-154, europium-155, potassium-40, radium-226, radium-228, and ruthenium-106.

c. Technicium-99 samples were collected only at the three locations west of Savage Island.

d. Field parameters for pore and surface water include temperature, specific conductance, dissolved oxygen, and pH.

X = Undetermined

### 2.1.8 Geologic Investigations

Geologic investigations to support the RI included installing three new monitoring wells (and evaluating geologic data from RI vadose boreholes and older monitoring wells), evaluating bathymetric data, and conducting geophysical logging.

#### *2.1.8.1 Geologic Characterization*

Geologic characterization data, plus physical and hydraulic property data, were needed to support modeling and analysis and to form a better understanding of the hydrogeologic conditions, aquifer interactions, and contaminant mobility through the vadose zone (Data Gap 7). Geologic data also were needed to evaluate the integrity of the aquitard unit and contaminant fate and transport within the aquitard (Data Gap 6).

Geologic samples were collected at approximately 1.5 m (5 ft) depth intervals, with field screening conducted during drilling. In general, the major stratigraphic units encountered during this project included backfill and/or Holocene eolian deposits, cataclysmic flood deposits of the Hanford formation, and fluvially derived Ringold Formation deposits.

Table 2-7. Summary of 100-F/IU Pore Water Sampling

| Sampling Objective | Constituents Analyzed | Sample Collection Period | Number of Locations Sampled | Reference |
|---|---|---|---|---|
| **100-F** | | | | |
| Mapping upwelling | Specific conductance, temperature, other field parameters | January-March 2009 | 64 | Phase II(a) (Columbia River RI Work Plan [DOE/RL-2008-11]) |
| Indicator contaminant screening | Cr(VI) and field parameters | November 2009 | 19 | Phase II(b) (Columbia River RI Work Plan [DOE/RL-2008-11]) |
| Contaminant characterization | Cr(VI), strontium-90, tritium, and others (Table 2-5) | February 2010 | 2 | Phase III (Columbia River RI Work Plan [DOE/RL-2008-11]) |
| Supplemental information | Cr(VI) and total chromium | February 2011 | 20 | *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/ Feasibility Study, DOE/RL-2009-43, Rev. 0* (TPA-CN-391) |
| **100-IU-2/IU-6** | | | | |
| Mapping upwelling | Specific conductance, temperature, other field parameters | January-March 2009 | 80 | Phase II(a) (Columbia River RI Work Plan, [DOE/RL-2008-11]) |
| Indicator contaminant screening | Tritium and field parameters | November-December 2009 | 29 | Phase II(b) (Columbia River RI Work Plan [DOE/RL-2008-11]) |
| Contaminant characterization | Tritium, iodine-129, nitrate and others (Table 2-6) | February 2010 | 5 | Phase III (Columbia River RI Work Plan [DOE/RL-2008-11]) |

Table 2-8. Summary of Additional Samples Collected in the Vicinity of the 100-F and Hanford Townsite Areas during the Columbia River Remedial Investigation

| Media Collected | Number of Samples | |
|---|---|---|
| | 100-F | Hanford Townsite |
| Island Soil | 0 | 20[a] |
| Surface Water | 5 | 2 |
| Sediment[b] | 20 | 92 |

a. Includes Homestead and Johnson islands.
b. Includes shoreline, shallow, and core samples.

Section 4.4 discusses results of surface water and sediment sampling.

Table 2-9 summarizes generalized geology and screen depths for RI wells and boreholes. Geologic data from the RI wells were combined with data from older wells to create updated interpretations of 100-F geology. For the portion of 100-IU-2/IU-6 north of Gable Mountain and Gable Butte, geologic data

from existing wells were compiled and reinterpreted (*100 Area Stratigraphic Database Development* [ECF-100NPL-11-0070]). Geologists used the data to construct geologic cross sections and maps of 100-F and the northern portion of 100-IU-2/IU-6. Geology of the southern portions of 100-IU-2/IU-6 is coincident with other groundwater OUs, primarily 200-PO-1. Geologic interpretations for that portion of the Site were taken from *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2009-85), hereinafter called the 200-PO-1 RI Report. Section 3.4 presents detailed results of the RI/FS geologic investigations.

#### 2.1.8.2 Bathymetric Evaluation

Contaminant flow paths from 100-F/IU to the Columbia River are related to the geology of the Site and the locations of the various geologic units both on shore and within the Columbia River. Geologic data from wells and boreholes indicate the bottom of the river channel intersects the top of the RUM unit at 100-F. In the portion of shoreline within 100-IU-2/IU-6, south of 100-F, the RUM unit is deeper and not intersected by the river channel.

The CSM for the aquifer/river interaction assumes that the groundwater flow is primarily above the top of the aquitard. In order to evaluate flow paths of contaminants to receptors (particularly from beneath the unconfined aquifer), updated and accurate bathymetric data for the river were used.

High-resolution topographic/bathymetric data for the upper portion of the Hanford Reach were collected in 2003. Additional 2008 data were collected from the Columbia River, adjacent to 100-F/IU. These data were evaluated during 2010. To complete the interpretations, key hydrogeologic unit surfaces (e.g., structure maps of the RUM) are projected (using the available well control) beneath the footprint of the river. The river bathymetry (river bottom surface elevations) is then overlain onto the individual hydrogeologic unit structure maps to define areas where projected unit surfaces cross over (are elevated above) the river bottom bathymetry. The line formed by the intersection of the two surfaces is defined as the truncation boundary, i.e., the area where the river has eroded into and removed that unit. The river bathymetry becomes the unit surface within those areas of overlap. If the two surfaces do not cross, the particular unit is either too deep to intersect the river bottom or not present. Chapter 3 presents the results of the bathymetry mapping.

#### 2.1.8.3 Geophysical Logging

Geophysical logging was conducted at each of the soil borings and groundwater monitoring wells installed as part of the scope of this RI. The data address Data Gap 7 and provide further information on the geology of the area. Each borehole was geophysically logged with a high-resolution, spectral gamma-ray logging system. Logging was conducted using spectral gamma and neutron-moisture logging systems to identify natural and anthropogenic gamma-emitting radionuclides present near the boreholes. Soil moisture was determined using a neutron logging tool. The starting point for logging, either the ground surface or top of the casing, was recorded for each well or borehole. Borehole logging was performed through the temporary casing to produce a geophysical log of the entire length of the borehole.

Geophysical logs are available in borehole summary reports (*Borehole Summary Report for the Installation of Three Groundwater Wells in the 100-FR-3 Area to Support RI/FS* [SGW-49445]; *Borehole Summary Report for the Installation of 2 Temporary Monitoring Wells and 1 Characterization Borehole Within the 100-FR-3 Area in Support of the Integrated 100 Area Remedial Investigation/Feasibility Study, FY2010-2011* [SGW-50130]).

Table 2-9. Summary of Construction Information for RI Wells and Boreholes at 100-F

| Well Name | Well ID | Dates Drilled | Surface Elev. (m) | Drilled Depth (m) | Elev. Top Screen (m) | Elev. Bottom Screen (m) | Elev. Top RUM (m) | Water Level Elev. (m) | Water Level Date | Objective of Well (DOE/RL-2008-46-ADD4) | Hydrogeologic Unit Monitored |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Monitoring Wells** | | | | | | | | | | | |
| 199-F5-52 | C7790 | July–Aug 2010 | 127.62 | 22.5 | 115.4 | 109.3 | 107.5 | 113.83 | 8/5/2010 | Define Cr(VI) plume | Top of unconfined |
| 199-F5-53 | C7791 | Sep–Dec 2010 | 125.11 | 35.3 | 96.1 | 93.1 | 108.5 | 112.68 | 11/4/2010 | Monitor RUM | RUM |
| 199-F5-54 | C7792 | Aug–Sep 2010 | 126.62 | 23.6 | 115.0 | 108.9 | 105.3 | 113.37 | 8/24/2010 | Define strontium-90 plume | Top of unconfined |
| **Vadose Boreholes** | | | | | | | | | | | |
| 199-F5-55* | C7970 | Feb 10-14, 2011 | 126.81 | 15.2 | 114.4 | 111.4 | >TD | 113.8 | 2/16/2011 | 116-F-14 | Top of unconfined |
| N/A | C7971 | Feb 9-11, 2011 | 122.14 | 10.2 | N/A | N/A | 8.8 | 114.2 | 2/11/2011 | 118-F-1 | N/A |
| 199-F5-56* | C7972 | Feb 15-17, 2011 | 127.22 | 15.5 | 114.6 | 111.6 | >TD | 113.82 | 2/17/2011 | 118-F-8:3 | Top of unconfined |

Notes: Additional detail is available in borehole summary reports: Borehole Summary Report for the Installation of Three Wells in the 100-FR-3 Operable Unit to Support RI/FS in Fiscal Year 2010 (SGW-49445) and Borehole Summary Report for the Installation of 2 Temporary Monitoring Wells and 1 Characterization Borehole within the 100-FR-3 Area in Support of the Integrated 100 Area Remedial Investigation/Feasibility Study, FY2010-2011 (SGW-50130).

*Completed as temporary monitoring wells

>TD = greater than total depth; borehole did not reach RUM

### 2.1.9 Vadose Zone Investigations

Historical soil borings and interim action ROD waste site remediation activities provided important information on the nature and extent of contaminants and the overall condition of the soil and vadose zone within 100-F/IU. These data were supplemented with RI data collected to address uncertainties identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) related to the nature and extent of contamination beneath select interim closed out waste sites, potential contamination around and beneath the reactor structures, and to provide better information on subsurface conditions (Data Gaps 2, 3, 5, and 7). For purposes of this discussion, waste sites referred to here are the sites that are identified in the WIDS database, as described in Chapter 1.

All waste sites were re-evaluated in the RI/FS as follows:

- Rejected, not accepted, or closed out sites were reviewed to confirm that their status was appropriate. Sites whose status was confirmed were documented in Chapter 1 as requiring no additional RI/FS evaluation. Rejected, not accepted, or closed out sites whose status was not confirmed were further evaluated in this RI/FS.
- Interim closed out and no action sites were evaluated in the RI (Chapters 4, 5, 6, and 7) to determine whether they should be evaluated through the FS process.
- Waste sites requiring remediation that were not completed by June 30, 2012, were evaluated in the FS (Chapters 8, 9, and 10).

#### *2.1.9.1 Ongoing Waste Site Remediation*

A total of 119 of 120 accepted waste sites are scheduled for remedial action under the interim action ROD. The one accepted waste site that will not be addressed under the interim action ROD is 118-F-8:2, which consists of the reactor that has been placed in interim safe storage. For the remaining 119 sites, remediation under the interim action ROD consists of RTD, where contaminated soil and debris are removed, treated (as required), and disposed at the ERDF or other EPA-approved landfill (as appropriate). Waste excavation is guided by field observations, field instrument screening measurements, and quick-turnaround laboratory analyses performed concurrently with the excavation. Following the completion of RTD activities, data are collected to verify waste site cleanup, and regulator concurrence is obtained on achieving interim RAGs relative to direct exposure, protection of groundwater, and protection of the Columbia River. Data collected during ongoing site cleanup address Data Gap 1 and help refine overall 100-F/IU knowledge.

Ongoing waste site cleanup provides opportunities to further refine the nature and extent of contamination to ensure that all sites completely address site contaminants. This process partly addresses Data Gap 4. Data collected as part of the ongoing interim waste site remediation (in process sampling) are used as a component of the CSM, and assist in determining the nature and extent of contamination. The data are discussed in Chapter 4.

*100-F-59 Special Case.* The 100-F-59 Burn Pit is a nonradiological accepted waste site located within the riparian zone adjacent to the Columbia River. Potential ecological risk in this area is evaluated as part of the Riparian and Nearshore Evaluation in Appendix L using sediment management standards recently released by Ecology for public review (*Development of Benthic SQVs for Freshwater Sediment in Washington, Oregon, and Idaho* [Ecology Publication 11-09-054]) and other risk-based sediment thresholds.

### 2.1.9.2 Boreholes

Uncertainties were identified in the CSM related to the extent of residual contaminants at previously remediated waste sites (Data Gap 2). To determine those waste sites that may require further characterization to address CSM uncertainties regarding the nature and extent of contamination and fate and transport, all of the area waste sites were placed into three general categories based on current site status. The selection process of the waste sites for further characterization was outlined in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4).

To address the uncertainty associated with Data Gap 2, two boreholes were drilled to obtain the data needed to refine the CSM. One borehole was drilled at the 116-F-14 Retention Basin and one at the 118-F-1 Burial Ground. Soil samples were collected during drilling and analyzed to assess the nature and vertical extent of contamination immediately below the depth of remedial action at these sites.

Additional CSM uncertainties were identified, related to the presence and extent of contamination beneath and around the 105-F Reactor, which has been placed into ISS. Historical information indicates that the fuel storage basin contained contaminated materials (reactor cooling water, spent fuel, and sludge) and that it leaked during operations. To address this uncertainty (Data Gap 3), a borehole was drilled near the 105-F Reactor fuel storage basin. Borehole samples were collected and analyzed to assess the vertical extent of contamination in the vadose zone beneath the reactor fuel storage basin, the most likely source of potential vadose zone contamination beneath and around the 105-F Reactor.

In addition, geologic characterization and physical/hydraulic property data were collected to support modeling and analysis (Data Gap 7). Information collected to address this uncertainty included: grain-size analysis, porosity, moisture content, saturated hydraulic conductivity, bulk density, and distribution coefficients. Reactor borehole soil data were also collected and analyzed for leachable Cr(VI) and select metals per the 100-F/IU SAP (DOE/RL-2009-43).

Soil samples were collected and analyzed from soil borings as described in the 100-F/IU SAP (DOE/RL-2009-43). The locations of the boreholes and waste sites of interest are shown on Figure 2-1 and described in Table 2-10, along with a justification for inclusion in the RI. Table 2-9 lists the dates of drilling, total depth, and water table elevation of each borehole, and Tables 2-3 and 2-4 summarize the status of soil and water sampling. Additional details on soil sample depths, observations, and field screening are presented in Appendix C and in *Borehole Summary Report for the Installation of 2 Temporary Monitoring Wells and 1 Characterization Borehole Within the 100-FR-3 Area in Support of the Integrated 100 Area Remedial Investigation/Feasibility Study, FY2010-2011* (SGW-50130).

Table 2-9 includes information about the drilling of 100-F vadose boreholes. During drilling, split-spoon samples were collected at the depth intervals specified in the 100-F/IU SAP (DOE/RL-2009-43). These intervals were typically 1.5 m (5 ft) from the top of native soil (i.e., the bottom of prior excavation and backfill, estimated at between 0 to 8.5 m [0 to 28 ft] bgs), and at changes in lithology, to the water table. The split-spoon samples were collected in 0.76 m (2.5 ft) long (including shoe), 10.2 cm (4 in.) diameter split-spoon samplers lined with four, 15.2 cm (6 in.) long LEXAN® or stainless-steel liners. The sampler was driven the full 0.76 m (2.5 ft) or until refusal (as determined by the onsite field geologist), whichever occurred first. Overdriving the sample was avoided. One split-spoon sample was collected from the saturated zone in each borehole approximately 1.5 m (5 ft) into the unconfined aquifer.

Table 2-10. Borehole Locations and Justification for Investigation

| Waste Site | Site Status | Characterization Description | Justification for Inclusion |
|---|---|---|---|
| 116-F-14 Retention Basin | Interim Closed | Borehole B1 (C7970; completed as Well 199-F5-55) | This site was a high-volume liquid site at which significant leakage was reported, and effluent reached groundwater during operations. LFI soil concentrations (cadmium, copper, total chromium, zinc, and mercury) exceeded Site background concentrations. This site has high residual Cr(VI) concentrations relative to other remediated sites, and the CVP verification soil contamination increased with depth. This site is also located near the strontium-90 plume. |
| 118-F-1 Burial Ground | Interim Closed | Borehole B2 (C7971) | This was a primary burial ground and suspected of being the source of a Cr(VI) and tritium plume detected in the 1990s. |
| 118-F-8:3 Reactor fuel storage basin | Interim Closed | Borehole B3 (C7972; completed as Well 199-F5-56) | The 105-F Reactor structure was put into ISS. Facilities associated with the structure were removed to the extent practicable and associated waste sites were remediated using RTD. Limited characterization has been conducted of the soil beneath the reactor structure because of the process of placing the reactor into ISS. Remediation of the 118-F-8 Reactor fuel storage basin included the removal of the subsurface structure and disposal of contaminated materials, including soil underlying the former fuel storage basin floor and side slopes. Contaminant data were collected during remediation to 6.4 m (21.5 ft) bgs.<br>Contaminants passed through the reactor or were produced in the reactor as part of operations, and therefore contaminants may be present beneath the reactor at concentrations that pose risk to human health or ecological receptors. Insufficient data are available to assess the potential contamination beneath the reactor. In addition, there were documented leaks at the fuel storage basin. |

One filtered groundwater sample was collected from the saturated zone in each borehole. Groundwater samples were collected using a submersible pump. Before sampling, the borehole was purged of at least three borehole volumes of water and until field parameters stabilized. Two of the boreholes were completed as wells because there was some doubt about whether the groundwater samples from the boreholes were representative.[1] Borehole C7970 was completed as Well 199-F5-55 and borehole C7972 was completed as Well 199-F5-56. The wells have 10 cm (4 in.) diameter polyvinyl chloride (PVC) casing and screens, 10-20 mesh Colorado Silica Sand (CSS) filter packs, and bentonite annular seals.

Borehole C7971 was decommissioned immediately upon completion of sampling activities, after reaching total depth. The borehole was backfilled to 1.2 m (4 ft) above static water level (to account for variability of the water table) with 10-20 mesh CSS. The remaining borehole was filled with granular bentonite to within 0.9 m (3 ft) of ground surface. A cement seal was then placed from 0.9 m (3 ft) bgs to ground surface and marked with the name and date of the decommissioned boring.

[1] Drilling activities can create locally reducing conditions, affecting the concentrations of some metals like Cr(VI).

*116-F-14 Retention Basin.* Borehole C7970 was drilled from February 9 through 11, 2011, to a total depth of 15.2 m (50 ft). The water table was at a depth of approximately 12.9 m (42.3 ft). The borehole did not reach the RUM. A water sample was collected from the borehole on February 14, 2011. The preliminary Cr(VI) result was undetected, which was unexpected, given the location of the borehole. It was decided to complete the borehole as a temporary well in order to obtain a more defensibly representative sample. The well (199-F5-55) was completed and developed by February 18, 2011, and sampled on March 31, 2011. Results are evaluated to determine whether the well will be decommissioned or retained for an additional monitoring point.

*118-F-1 Burial Ground.* Borehole C7971 was drilled from February 10 through 14, 2011, to a total depth of 10.2 m (33.5 ft). The water table was at a depth of approximately 8.0 m (26.2 ft). The RUM was encountered at 8.8 m (29 ft). A water sample was collected from the borehole on February 15, 2011, and it was then decommissioned.

*118-F-8:3 Reactor Fuel Storage Basin.* Borehole C7972 was drilled from February 15 through 17, 2011, to a total depth of 15.5 m (50.9 ft). The well did not reach the RUM. The water table was at a depth of approximately 13.3 m (43.5 ft). A water sample was collected from the borehole on February 18, 2011. The sample had high turbidity and low oxygen content, suggesting it might not be representative. It was decided to complete the borehole as a temporary well in order to obtain a more defensibly representative sample. The well (199-F5-56) was completed and developed by February 23, 2011, and sampled on March 31, 2011. Results are evaluated to determine whether the well will be decommissioned or retained for an additional monitoring point.

### 2.1.10 Groundwater Investigations

Groundwater was investigated to address uncertainties associated with the nature and extent of contamination, aquifer properties, and aquifer/river interactions. The following sections describe the investigations conducted. Sections 3.6 and 4.3 present results of groundwater investigations.

#### *2.1.10.1 Define the Extent of Groundwater Contamination Horizontally and Vertically*

Knowledge of the nature and extent of groundwater contamination across 100-F was limited because of the depth, location, and number of existing monitoring wells. In addition, not all groundwater COPCs are routinely monitored. Data from previous investigations were often limited in the number of contaminants analyzed and the frequency of sampling, leading to uncertainty of the vertical and horizontal extent of the groundwater plumes. In addition, the contaminant distribution in the re-wetted zone and through the unconfined aquifer was not well defined.

To address this uncertainty (Data Gap 4), groundwater monitoring wells were installed at strategic locations within 100-F (Figure 2-1). During field activities, groundwater and soil were sampled and analyzed to better define the vertical extent of contaminants as described in the 100-F/IU SAP (DOE/RL-2009-43). Table 2-9 provides information about the RI wells.

Two of the wells (199-F5-52 and 199-F5-54) were completed in the unconfined aquifer in 100-F to address uncertainty in the groundwater quality vertically through the aquifer (Figure 2-1). Well 199-F5-52 is located to define the extent of Cr(VI) contamination further, since the extent of Cr(VI) to the west of Well 199-F5-6 was not known. Well 199-F5-54 is positioned to define the extent of strontium-90 contamination further, since the extent of strontium-90 to the south of the 116-F-14 Retention Basin was not known.

Before this investigation, only Well 199-F5-43B in 100-F extended into the RUM. An uncertainty was identified during the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) development regarding the

continuity and integrity of the aquitard (the RUM), and potential contaminant transport within the RUM in 100-F (Data Gap 6). To address this uncertainty, a monitoring well was drilled and completed within the RUM (199-F5-53). The well is located within the footprint of the Cr(VI) plume in the unconfined aquifer, and the likelihood of contamination to be present in the unconfined aquifer was considered highest. Well 199-F5-53 was screened within the first water-bearing unit identified within the RUM.

While drilling each borehole (for later completion as a groundwater monitoring well), groundwater samples were collected every 1.5 m (5 ft) within the unconfined aquifer to determine the vertical distribution of contaminants within the aquifer and to address Data Gap 4. At Well 199-F5-53, groundwater samples also were collected from the confined aquifer within the RUM. In addition, in all wells, split-spoon soil samples were collected from the vadose zone, within the unconfined aquifer, and before and after entering the RUM unit. Tables 2-3 and 2-4 summarize samples collected during drilling.

Figure 2-9 illustrates general well construction. All wells were constructed with Schedule 10, Type 304, 316, 304L, or 316L stainless-steel, V-slot continuous wire wrap screen atop a 0.6 m (2 ft) long sump with end cap. The sump, end cap, and riser casing are of the same schedule and grade stainless steel as the screen. Centralizers were used above and below the screen and every 12 m (40 ft) to ground surface to ensure straightness during well construction. The casing and screen diameter of Wells 199-F5-52 and 199-F5-54 is 15 cm (6 in.). Well 199-F5-53, screened in the RUM, is 10 cm (4 in.) in diameter.

For Wells 199-F5-52 and 199-F5-54, the portion of the borehole that extended below the bottom of the designed well bottom was filled in with natural formation slough below 10-20 mesh CSS fill material to a depth that allowed for a 1.5 m (5 ft) bentonite pellet seal below the well sump. The filter pack was placed from the lower bentonite pellet seal (installed 1.5 m [5 ft] below the bottom of the screened interval) to 1.5 m (5 ft) above the top of the screened interval. The filter pack consisted of 10-20 mesh CSS, with a 0.9 m (3 ft) layer of bentonite pellets placed immediately above the filter pack. Bentonite crumbles were placed above the bentonite pellets to approximately 3 m (10 ft) bgs. A cement grout seal was placed above the bentonite crumbles to ground surface.

Well 199-F5-53, screened in the RUM, has a filter pack of 20-40 mesh CSS. The annular seal above the filter pack is neat grout, some formation slough, bentonite crumbles, and cement grout.

Each well was protected with a Type 304 (or higher grade, e.g., 304L, 316, or 316L) stainless-steel casing. This casing is at least 5 cm (2 in.) larger in diameter than the permanent casing, extends approximately 1 m (3 ft) above ground surface (surrounding the groundwater monitoring well), and has a 38 cm (15 in.) diameter lockable cap. Wells are identified with a brass survey marker located on the well pad.

Table 2-9 provides a summary of the well construction. Details are provided in a borehole summary report (*Borehole Summary Report for the Installation of Three Groundwater Wells in the 100-FR-3 Area to Support RI/FS* [SGW-49445]).

Following construction, wells were developed by pumping at a flow rate from 0.15 to 7.58 L/sec (2 to 100 gal/min). Development was continued until the well produced water with low turbidity ($\leq$ 5 nephelometric turbidity units [NTU]) and stable field parameters (at least three consecutive temperature, pH, and specific conductance measurements within 10 percent of each other).

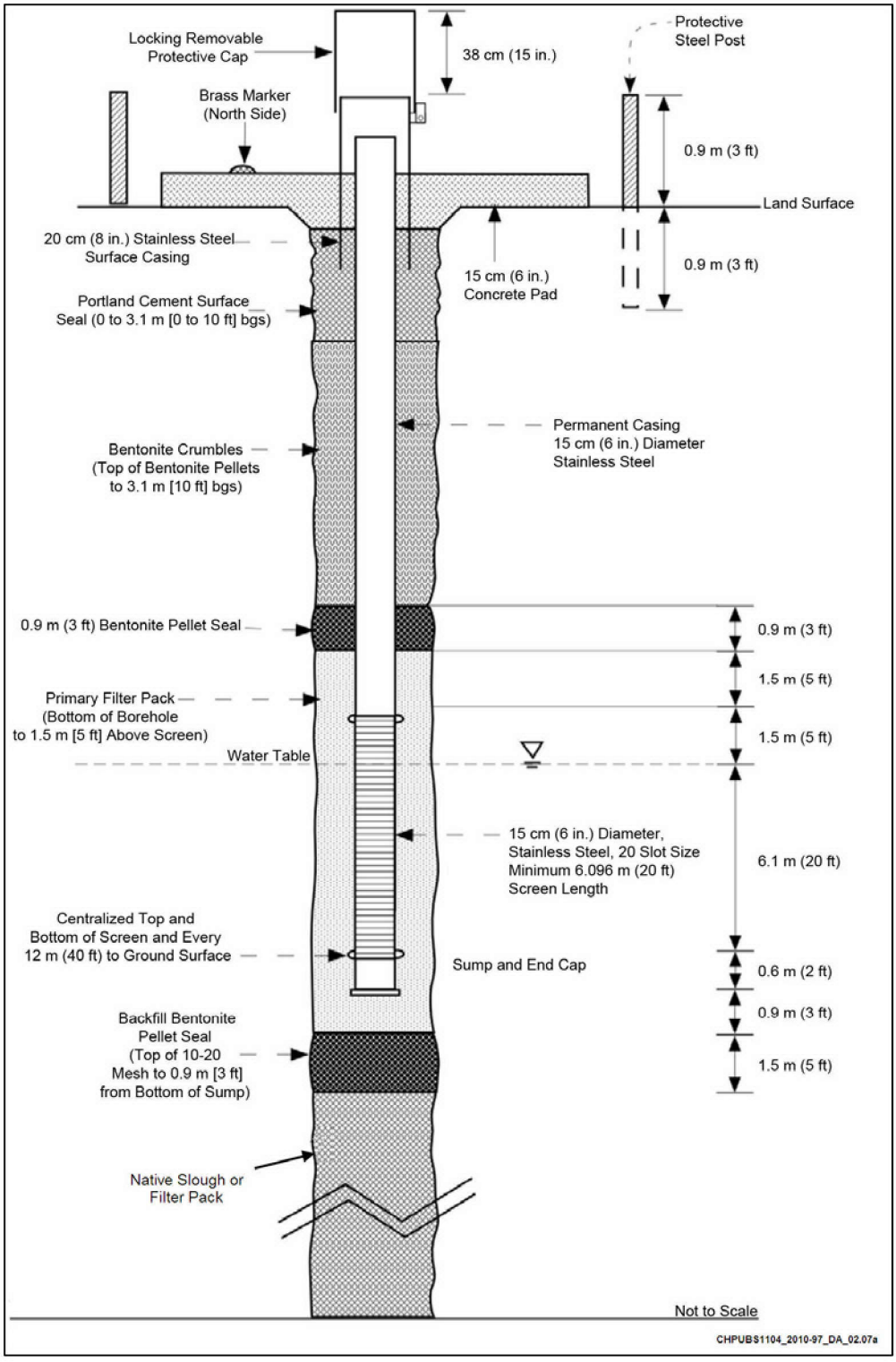


Figure 2-9. General Well Design

Before RI/FS investigations, the nature and extent of all COPCs had not been determined in 100-F and 100-IU-2/IU-6 (Data Gap 4). Consequently, wells were sampled for all groundwater COPCs (100-F/IU SAP [DOE/RL-2009-43]). The 55 existing wells sampled to provide information on spatial and temporal variability (Data Gap 8; Section 2.1.10.4) included most of the available wells. The three wells installed in 100-F under the RI provided additional data points. Groundwater samples are being collected from the wells installed for the RI under the scope of the 100-F/IU SAP (DOE/RL-2009-43) quarterly for the first year, with a reduction in frequency for subsequent years if warranted. Sampling and analysis after the first year will be conducted as part of routine sampling under the 100-FR-3 SAP (DOE/RL-2003-49).

#### *2.1.10.2 Characterize Hydraulic Properties of the Aquifer and Aquitard*

Knowledge of hydraulic properties is needed to help evaluate contaminant fate and transport. Data Gap 6 identified a need to evaluate the integrity of the aquitard unit (RUM), and fate and transport beneath the aquitard. Data Gap 7 called for physical and hydraulic property data from the vadose zone, unconfined aquifer, and the aquitard, to support modeling and analysis. Physical testing of sediment samples and aquifer tests provided data to fill this need. Installation and monitoring of pressure transducers provided additional data on hydraulic gradients. Section 3.6.2 presents results of testing for hydraulic properties.

To address the uncertainty related to soil and hydrogeologic properties (Data Gap 7), soil samples were collected and analyzed for various physical characteristics including the following:

- Grain-size analysis (sieve)
- Porosity
- Sediment moisture content (unsaturated soil only)
- Saturated hydraulic conductivity
- Bulk density
- pH (saturated soil only)
- Distribution coefficient for various contaminants (as per the 100-F/IU SAP [DOE/RL-2009-43])

Soil samples for each well were generally collected at 4.6, 3, 1.5, and 0.6 m (15, 10, 5, and 2 ft) above the water table, at the water table, 1.5 m (5 ft) below the water table, at the bottom of the unconfined aquifer, and at the total depth of drilling (1.5 m [5 ft] within the RUM). Additional samples were collected at deeper Well 199-F5-53. Generally, soil samples were collected as described for soil borings, in Section 2.1.9.2. The physical property samples were collected in conjunction with other split-spoon sample intervals, where possible.

Slug tests and a pumping test were conducted in 100-F wells to determine the hydraulic conductivity in the unconfined aquifer and the RUM. Table 2-11 summarizes the tests conducted and the hydrogeologic units tested. Section 3.6 presents results of aquifer testing.

To address the uncertainty associated with variations in vertical and horizontal hydraulic gradients and their effect on contaminant mobility (Data Gap 7), pressure transducers were installed in selected 100-F wells (Table 2-12). The new transducer systems were integrated with many other stations on the Hanford Site as part of an automated water-level monitoring network. The pressure transducer stations measure and record hydraulic pressure hourly and transmit the data to a central location where they are converted to water-level elevations. Section 3.6.3 discusses results of transducer monitoring as related to groundwater flow.

Table 2-11. 100-F Aquifer Tests

| Well | Reason for inclusion | Type of Test |
|---|---|---|
| 199-F5-42 | Located near the shoreline | Slug injection and withdrawal |
| 199-F5-43A | Located near the shoreline and close to the extent of the Cr(VI) plume | Slug injection and withdrawal |
| 199-F5-43B | Located along the direction of groundwater flow during low river stage and screened in the RUM | Slug injection and withdrawal |
| 199-F5-44 | Located near the shoreline and close to the extent of the Cr(VI) plume | Slug injection and withdrawal |
| 199-F5-46 | Located along the direction of groundwater flow during low river stage | Slug injection and withdrawal |
| 199-F5-47 | Located along the direction of groundwater flow during low river stage | Slug injection and withdrawal |
| 199-F5-52 | Located near the shoreline and close to the extent of the Cr(VI) plume | Slug injection and withdrawal |
| 199-F5-53 | Located near the shoreline and close to the extent of the Cr(VI) plume; screened in the RUM | Slug injection and withdrawal; pumping test |
| 199-F5-54 | Located near the shoreline and close to the extent of the Cr(VI) plume | Slug injection and withdrawal |
| 199-F7-3 | Located along the direction of groundwater flow during low river stage | Slug injection and withdrawal |

#### *2.1.10.3 Aquifer/River Interactions*

To address the uncertainty related to the level of contamination entering the Columbia River, data were collected from among the rocky bed of the Columbia River (pore water) and from aquifer tubes adjacent to the river.

Site discharges to the Columbia River occur via seeps and areas of upwelling through the riverbed. This groundwater flow provides a pathway for contaminant transport to the Columbia River. Rapid, periodic, or cyclic elevation fluctuations of the river occur in controlled response to flood conditions, hydroelectric production, and salmon spawning programs at a series of dams and reservoirs upriver of the Site. These rapid elevation changes in the river cause periodic influences on flow conditions within the aquifer. Daily fluctuations of more than 2 m (6 ft) are common. Even greater changes (more than 4.5 m [13 ft]) are observed seasonally, with a period of high river stage in the spring or early summer and low river stage in the fall.

The near-shore groundwater conditions are directly affected by river stage. A wide range of mixing ratios has been observed between upwelling water at the bottom of the river and groundwater at near-shore locations (*Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area* [SGW-39305]). This mixing ratio represents a continuum from pure groundwater to pure river water, depending on where in the groundwater pathway the measurement is taken.

Table 2-12. Automated Water-Level Stations in 100-F

| Purpose | Well | Screened | Operating |
|---|---|---|---|
| Water table in eastern 100-F Area for 3-point calculations; vertical gradient between RUM and unconfined aquifer | 199-F5-43A | Water Table | 9/29/2010 to 9/30/2011[a] |
| | 199-F5-43B | RUM | 9/29/2010 to 9/30/2011[a] |
| Water table in southeastern 100-F Area for 3-point calculations | 199-F8-4 | Water Table | 9/28/2010 to 9/30/2011[a] |
| Water table in southwestern 100-F Area for 3-point calculations | 199-F7-1 | Water Table | 9/29/2010 to 9/30/2011[a] |
| Water table in west-central 100-F Area for 3-point calculations | 199-F7-2 | Water Table | 9/28/2010 to 9/30/2011[a] |
| Monitor river stage | River gauge | -- | 7/20/2010[b] to 9/30/2011[a] |

a. Transducer and data logger remained operating after this date but calibration not being maintained.

b. Data for years before 2010 also available for river gauge.

Scenarios for contaminant plume discharge to the river vary widely because of dynamic seasonal conditions in the zone of interaction. The greatest contaminant flux and highest concentrations at exposure locations occur during periods of low river stage conditions. During this period, the hydraulic gradient toward the river is steepest and mixing between river water and groundwater is at its lowest stage.

*Aquifer Tube Monitoring.* An uncertainty on the nature and extent of contamination entering the Columbia River was identified during the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) process (Data Gap 5).

Initial characterization of Site contamination near the river relied on data from a limited number of near-river wells, contaminant plume migration predictions, and riverbank seep sampling to anticipate shoreline conditions. To resolve the uncertainty, aquifer tubes were installed along the river corridor, including 100-F/IU, to assist with characterizing near-shore contaminants. As a result, groundwater data have been collected from the selected 100-F/IU aquifer tubes annually for more than 10 years. As part of this RI/FS, the tubes were sampled in accordance with *Sampling and Analysis Plan for Aquifer Sampling Tubes* (DOE/RL-2000-59), hereinafter called the SAP for Aquifer Sampling Tubes.

Aquifer tubes are small-diameter polyethylene tubes with a screen at the lower end (Figure 2-10). The tubes were implanted into the aquifer by driving a temporary steel casing into the ground and inserting a tube into the casing. The end of each tube was fitted with a screened section, which acts as the sampling port. The temporary steel casing was driven either by a hydraulic ram attached to a vehicle or by a hand-carried pneumatic hammer. The steel casings were then backpulled, leaving the tube (and the stainless-steel drive point) in place. During sampling, water was withdrawn from the tube using a peristaltic pump. The tubing exposed at the ground surface was protected from wildlife and the elements with a PVC conduit.

No new aquifer tubes were installed for the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). A subset of aquifer tubes at 100-F and 100-IU-2/IU-6 (Hanford Townsite) generally is sampled annually under the SAP for Aquifer Sampling Tubes (DOE/RL-2000-59). The 100-F tubes were sampled in November and

December 2011 and again in fall 2012. The Hanford Townsite tubes were sampled in February 2012 and again in fall 2012.

#### 2.1.10.4 Spatial and Temporal Groundwater Sampling

Uncertainties associated with the groundwater risk assessment in the HHRA portion of the RCBRA (DOE/RL-2007-21, Volume II) are related to the ability of the existing data to represent current baseline conditions (Data Gap 8). Analytical data used for the HHRA are obtained from several groundwater-monitoring programs, including the *Atomic Energy Act of 1954* (AEA) surveillance program, the RCRA compliance program, and the CERCLA program. Sampling and analysis data from these programs comprehensively define the suite of contaminants associated with existing and potential groundwater contamination sources. However, differences in sampling frequencies, analytes analyzed at each monitoring well (radiological and chemical), and method detection limits create uncertainties associated with the spatial, chemical, and temporal representative qualities of the data used for the risk assessment.

Monitoring well locations were identified to represent conditions at (DOE/RL-2008-46-ADD4) without regard to the location of surface facilities, waste sites, or known groundwater plumes. To provide the number of sampling points for a monitoring well network, the average groundwater yields are used to determine the number of residences supported on one supply well. Thus, the grid size specific to each area is determined. Use of a random grid generator provides approximate locations for sampling points based on the final number of sampling points and the total area. Groundwater samples were collected so that they chemically, radiologically, spatially, and temporally represent the groundwater in the area. A total of 19 monitoring wells in 100-F and 36 wells in 100-IU-2/IU-6 were sampled and analyzed for this purpose. In addition, groundwater elevation data were collected for evaluation of groundwater and plume flow direction.

These wells were then sampled to obtain temporal representation of groundwater conditions. This sampling was conducted at high, low, and transitional river stages. Three rounds of groundwater samples were collected for analysis of all COPCs to support the RI for each contaminant. A sampling round, or event, was conducted for each seasonal high, low, and transition river stage, totaling three samples per well. The goal was to complete each round of monitoring within 30 consecutive calendar days to minimize statistical variability in water levels. This was not accomplished in all cases (Table 2-13). In most cases during rounds 1 and 2, delays were caused by well maintenance needs. During round three, all groundwater sampling on the Hanford Site was temporarily stopped because of a worker safety concern. The delay was most pronounced in the 100-IU-2/IU-6 round three sampling, with 107 days elapsed between the first and last wells to be sampled. The period is not significant for these OUs because most of the wells are not located near the Columbia River and are not subject to seasonal variability in water levels. The third sampling round for 100-F occurred over 65 days. However, the river stage was seasonally low throughout this period.

Groundwater samples were collected for COPCs to provide data that are representative of potential releases to the groundwater. The data were evaluated and results are discussed in Chapters 6 and 7.

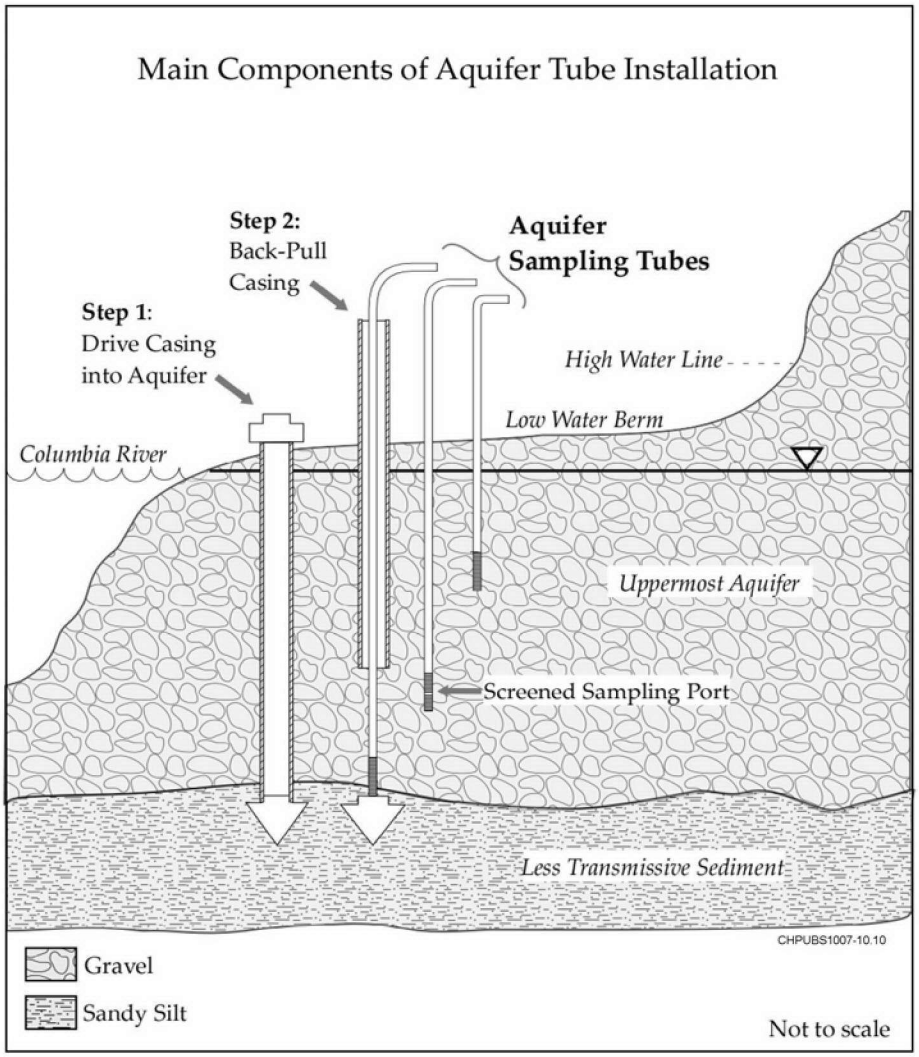


Figure 2-10. Aquifer Tube Installation

Table 2-13. Dates of Spatial/Temporal Groundwater Sampling

| | Start | End | Duration (days) |
|---|---|---|---|
| 100-F Round 1 | 5/5/2010 | 5/17/2010 | 13 |
| 100-F Round 2 | 7/8/2010 | 7/26/2010 | 19 |
| 100-F Round 3 | 9/26/2010 | 11/29/2010 | 65 |
| IU-2/IU-6 Round 1 | 4/9/2010 | 5/20/2010 | 42 |
| IU-2/IU-6 Round 2 | 6/10/2010 | 9/1/2010 | 84 |
| IU-2/IU-6 Round 3 | 9/2/2010 | 12/17/2010 | 107 |

### 2.1.11 Ecological Investigations

DOE monitors and surveys Hanford Site plant and animal resources to establish potential radiological exposures resulting from Site activities; assess the condition of endangered, threatened, or sensitive species; and evaluate breeding locations, habitat use, and distribution of key wildlife species. The following subsections describe Site ecological monitoring activities (*Summary of the Hanford Site Environmental Report for Calendar Year 2008* [PNNL-18427-SUM]). The 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) did not identify a need for additional ecological investigations. Section 3.9 summarizes the ecology of the Hanford Site, and Section 4.5 summarizes results of DOE's biota monitoring.

#### *2.1.11.1 Vegetation Monitoring*

Vegetation samples were collected on or adjacent to former waste disposal sites, and from locations downwind and near or within the boundaries of operating facilities and remedial action sites to monitor for radioactive contaminants.

#### *2.1.11.2 Fish and Wildlife Monitoring*

Fish and wildlife on the Site are monitored for Site-produced contaminants. Sucker, common carp, smallmouth bass, and deer were collected at locations on and around the Site. Tissue samples were analyzed for strontium-90 and gamma emitters, including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples. In addition, liver tissues from fish and deer were monitored for 17 trace metals.

#### *2.1.11.3 Plant Communities and Population Surveys*

Plant populations monitored on the Site include species listed by Washington State as endangered, threatened, or sensitive, and species with insufficient data to evaluate their status. Monitoring data are used to develop baseline information and monitor for changes resulting from Site operations. Surveys for rare species were conducted as part of annual compliance review activities. More than 100 plants listed by the State as endangered, threatened, sensitive, or on the view or watch list are found on the Site (Section 3.9.3). No plants on the federal list of threatened and endangered plants are known to occur on the Hanford Site (RCBRA Literature Review [PNNL-SA-41467]).

#### *2.1.11.4 Wildlife Populations Surveys*

Four fish and wildlife species on the Site are surveyed annually: fall Chinook salmon, steelhead, bald eagles, and mule deer. The number of fall Chinook salmon spawning nests (redds) in the Hanford Reach is estimated by aerial surveys. Two aerial surveys were conducted to identify possible steelhead spawning areas.

#### *2.1.11.5 Habitat and Species Characterizations*

Ecological monitoring on the Site includes characterizing breeding locations, habitat use, and distribution of key wildlife species. Characterization studies focused on the Woodhouse's toad and the burrowing owl, a Washington State candidate species and federal species of concern in this region. Toads were monitored using radio telemetry and found predominantly within 200 m (656 ft) of the Columbia River or the high-water channel of the 100-F Slough. Burrowing owl distributions and nesting habitats were evaluated.

#### *2.1.11.6 Contaminated Biota*

Radiological surveys are conducted around active and inactive waste sites at the Hanford Site to detect surface radiological contamination, including biointrusion, from plants and animals (including insects). The results from these surveys are used to determine trends, assess environmental impacts, and identify

corrective actions, as appropriate. None of the 100 Area sites falls within the priority ranking for contamination incidents at the Hanford Site (most incidents are reported in the 200 Area). A total of 18 contamination episodes, mostly animal-related, were reported across the entire 100 Area in 2010 (*Quarterly Environmental Radiological Survey Summary, Fourth Quarter Calendar Year 2010* [HNF-SP-0665]).

### 2.1.12 River Corridor Supplemental Investigations

To support information needs for the entire River Corridor, the following supplemental activities from the Integrated Work Plan (DOE/RL-2008-46) were carried out separately from the RI field investigation activities described in the 100-F/IU SAP (DOE/RL-2009-43):

- **Evaluated groundwater and surface water interactions for the River Corridor.** Flow paths in the groundwater/river zone of interaction vary with daily and seasonal fluctuations in river stage. River water infiltrates the banks during high river stages, moves inland, and then reverses flow as the river stage subsides and moves back through the hyporheic zone and discharges to the riverbed. Monitoring and modeling studies suggest that this back-and-forth motion of groundwater and river is cyclical in response to the diurnal river stage cycle, which typically includes two high stages and two low stages in response to power peaking demands. Review of modeling suggests that there is a significant back-and-forth motion in the groundwater such that an individual molecule experiences a significant lengthening of the flow path as it moves back and forth through the aquifer. It will experience numerous reversals in flow direction before it eventually reaches the water column in the river.

- **Analyzed samples to determine River Corridor background concentration values for antimony, boron, cadmium, lithium, mercury, molybdenum, selenium, silver, and thallium in soil.** Site-specific background values for these constituents were needed to determine soil RAG values because calculated risk-based concentrations and/or ecological protection concentrations were less than Washington State or expected site-specific background values. Provisional data have been calculated and are presented in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038). Background values are discussed further in Section 4.1.

- **Re-evaluated soil cleanup level for Cr(VI) to support the ROD.** The lowest soil RAG for Cr(VI) under the interim action RODs is 2.0 mg/kg. Based on the evaluation of soil cleanup levels and analytical methods, the accepted modeling approach was used to establish preliminary remediation goals (PRGs) for this RI/FS. The development of PRGs for groundwater and surface water protection are presented in Chapter 5.

- **Determined a site-specific contaminant $K_d$ for antimony.** Over the past several years, different $K_d$ values have been identified at the Hanford Site for antimony. A site-specific value is needed to calculate soil RAG values (Model Toxics Control Act [MTCA], "Deriving Soil Concentrations for Groundwater Protection" [WAC 173-340-747(3)(a)]). The summary of a scientific literature review conducted for this task is presented below:

  - The 1.4 mL/g Kd value is based on testing of Rainier Mesa tuff and does not appear to be comparable to Hanford Site soil types.

  - The 0 to 40 mL/g Kd range appears to be based largely on experience and general knowledge rather than on specific test results. Laboratory Measurements of Radionuclide Distribution Between Selected Ground Water and Geologic Media (PNL-SA-6957), a document considered in establishing this range, presents a Kd of approximately 65 mL/g antimony desorption from soil.

This appears to be one of the few references available that presents actual Kd desorption data; the value supports the conclusion that desorption values are "much greater" than sorption values.

- The 45 mL/g Kd value is a calculated value based on a theoretical correlation between Kd and the soil-to-plant concentration factor; it does not represent a value from experimental determination. This value is used by EPA and identified in the "Cleanup Levels and Risk Calculations" (CLARC) database (Ecology, 2003).

- The 3.76 mL/g Kd value comes from actual static batch equilibrium testing on sand/clay soil at a pH of 7.6, and appears to be a reasonable approximation of Hanford Site soil types. This value is based on sorption, not desorption.

Based on this review, a $K_d$ value of 3.76 mL/g was used in the groundwater modeling presented in Chapter 5. This is considered a conservative value since it assumes a higher level of mobility than suggested by the technical review of the literature. The $K_d$ value used, while conservative, results in the maximum concentration of the analyte reaching the groundwater at a peak year much greater than 1,000 years, and an elimination of antimony as a COPC. A higher $K_d$ value would have no effect on that result.

- **Re-evaluated soil cleanup levels for arsenic to support the ROD.** The soil RAG for arsenic under the interim action RODs is 20 mg/kg, based on the Tri-Party Agreement (Ecology et al., 1989a) stipulation to use the MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740(2)]) 1996 Method A value (100 Area RDR/RAWP [DOE/RL-96-17]). The MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740(2)]) 2007 Method A value is also 20 mg/kg. However, this 20 mg/kg value for arsenic exceeds the $1 \times 10^{-6}$ individual cancer risk based on the MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740(3)]) 2007 Method B value (0.67 mg/kg) and the MTCA ("Deriving Soil Concentrations for Groundwater Protection" [WAC 173-340-747(3)(a)]), groundwater protection value (0.00737 mg/kg). Both of these values are below the Hanford Site arsenic background concentration of 6.5 mg/kg.

Arsenic is a statewide concern because of historical smelter operations and pesticide use in agricultural areas (e.g., orchards). The state of Washington has established programs to evaluate arsenic contamination continue to consider the Method A soil cleanup level of 20 mg/kg as a trigger for action. The Method A level (20 mg/kg) is proposed for continued use, which is consistent with other cleanup actions throughout the state.

## 2.2 Field Activity Documentation

As discussed in previous sections, field investigations have been conducted in 100-F/IU to address the data needs identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). The results of these field investigations are summarized in a variety of documents and tables, as listed in Table 2-14. Appendix D includes soil, groundwater, and water-level data collected for 100-F/IU.

Table 2-14. Field Activity Documentation

| Field Activity | Documentation |
|---|---|
| Monitoring well installation | *Borehole Summary Report for the Installation of Three Groundwater Wells in the 100-FR-3 Area to Support RI/FS* (SGW-49445)<br>Well database (2012 Environmental Dashboard Application) |
| Drilling of vadose boreholes | *Borehole Summary Report for the Installation of 2 Temporary Monitoring Wells and 1 Characterization Borehole within the 100-FR-3 Area in Support of the Integrated 100 Area Remedial Investigation/Feasibility Study, FY2010-2011* (SGW-50130)<br>Well database (2012 Environmental Dashboard Application) |
| Characterization sampling during drilling (soil and groundwater) | Sampling paperwork in project files<br>Data in HEIS (2012 Environmental Dashboard Application) and Appendix D |
| Aquifer tube sampling | Sampling paperwork in project files<br>Data in HEIS (2012 Environmental Dashboard Application) |
| Aquifer testing | *Analysis of Slug Test Data at the 100-FR-3 Operable Unit* (ECF-100FR3-11-0146 in Appendix C)<br>*Aquifer Test Analyses for Wells 199-B2-15 and 199-F5-53* (ECF-HANFORD-11-0149 in Appendix C) |
| Pore water Sampling | *Columbia River Pore Water Sampling in 100-F Area, February 2011* (SGW-49575) |
| Collection of automated hydraulic head data | WIDL (automated water-level network) |
| Groundwater sampling of spatial and temporal monitoring network | Groundwater sample records in IDMS; groundwater data in HEIS (2012 Environmental Dashboard Application) and Appendix D |

HEIS = Hanford Environmental and Information System
IDMS = Integrated Document Management System

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# 3 Physical Characteristics of the Study Area

This chapter describes the physical setting of 100-F/IU. Understanding the setting through which contaminants move will assist in establishing the framework for contaminant fate and transport. The following site features are discussed in this chapter: surface features, meteorology, surface water, geology, hydrogeology, artificial water systems, ecology, and cultural resources. This chapter also includes a discussion of current land use, future land use, and demography to support risk characterization efforts. The physical setting is an important component of the CSM as it establishes the framework for understanding the nature and extent of contamination, which is described in Chapter 4. Key aspects of the physical setting that influence the movement of contaminants within the environment are examined in Chapter 5.

*Highlights for 100-F*

- The vadose zone comprises unconsolidated gravel and sand of the Hanford formation. The vadose zone is up to 15 m (49 ft) thick.
- The uppermost aquifer is unconfined and comprises the gravel and sand of the Hanford formation. Its saturated thickness ranges from just 1 m (3 ft) in southwestern 100-F to 8 m (25 ft) in eastern 100-F. A low-permeability geologic unit, informally termed the RUM unit, forms the bottom of the unconfined aquifer. This unit is continuous beneath 100-F.
- Groundwater flows toward the east northeast in the northern part of 100-F near the river and toward the east in the southwestern part. Southeast of 100-F, the direction of groundwater flow is approximately parallel to the river.
- Current land use at 100-F consists of waste management, environmental monitoring, and waste site remediation/restoration.

*Highlights for 100-IU-2/IU-6*

- Vadose zone thickness ranges from near zero adjacent to the Columbia River to greater than 107 m (350 ft) in the central Hanford Site.
- Hydrostratigraphy of 100-IU-2/IU-6 is variable because of the large area covered by these OUs. The uppermost aquifer is unconfined, and comprises Ringold unit E, the Hanford formation, or the Cold Creek unit. The base of the unconfined aquifer is one of several low-permeability units in the Ringold Formation.
- Groundwater flows west to east beneath the southern portion of 100-IU-2/IU-6, discharging to the Columbia River at the eastern edge of the Hanford Site. Some groundwater flows northward through the gap between Gable Mountain and Gable Butte, and then toward the river.
- Current land use at 100-IU-2/IU-6 consists of environmental monitoring and waste site remediation/restoration.

## 3.1 Surface Features

The 100-F/IU Areas cover 38,000 ha (93,000 acres) of the Hanford Site. Figures 3-1 and 3-2 show major features and well locations in 100-F and 100-IU-2/IU-6. The topography of the reactor area at 100-F is relatively flat, with elevations generally between 120 and 128 m (394 and 420 ft) above mean sea level (amsl) inland from the Columbia River (Figure 3-3). The area has been disturbed and graded extensively since reactor construction began in 1943 through present-day waste site remediation activities. The elevation at the river shore is approximately 115 m (377 ft) amsl. A low bench of land southeast of 100-F with elevations below 114 m (374 ft) amsl is submerged when river stage is above average.

The topography within 100-IU-2/IU-6 varies widely. Portions of this region are relatively flat, but it also includes Gable Butte and Gable Mountain, which rise approximately 60 m (200 ft) and 180 m (590 ft) above surrounding land, respectively (Figure 3-4).

## 3.2 Meteorology

The Hanford Site is characterized by a semi-arid climate, and is located in the driest and warmest portion of the Columbia Basin. The Cascade Range, to the west, creates a rain shadow effect on the Hanford Site climate, while the Rocky Mountains and mountain ranges in southern British Columbia protect it from the more severe polar air masses from the north (*Hanford Site Climatological Summary 2004 with Historical Data* [PNNL-15160], hereinafter called 2004 Hanford Climatological Summary).

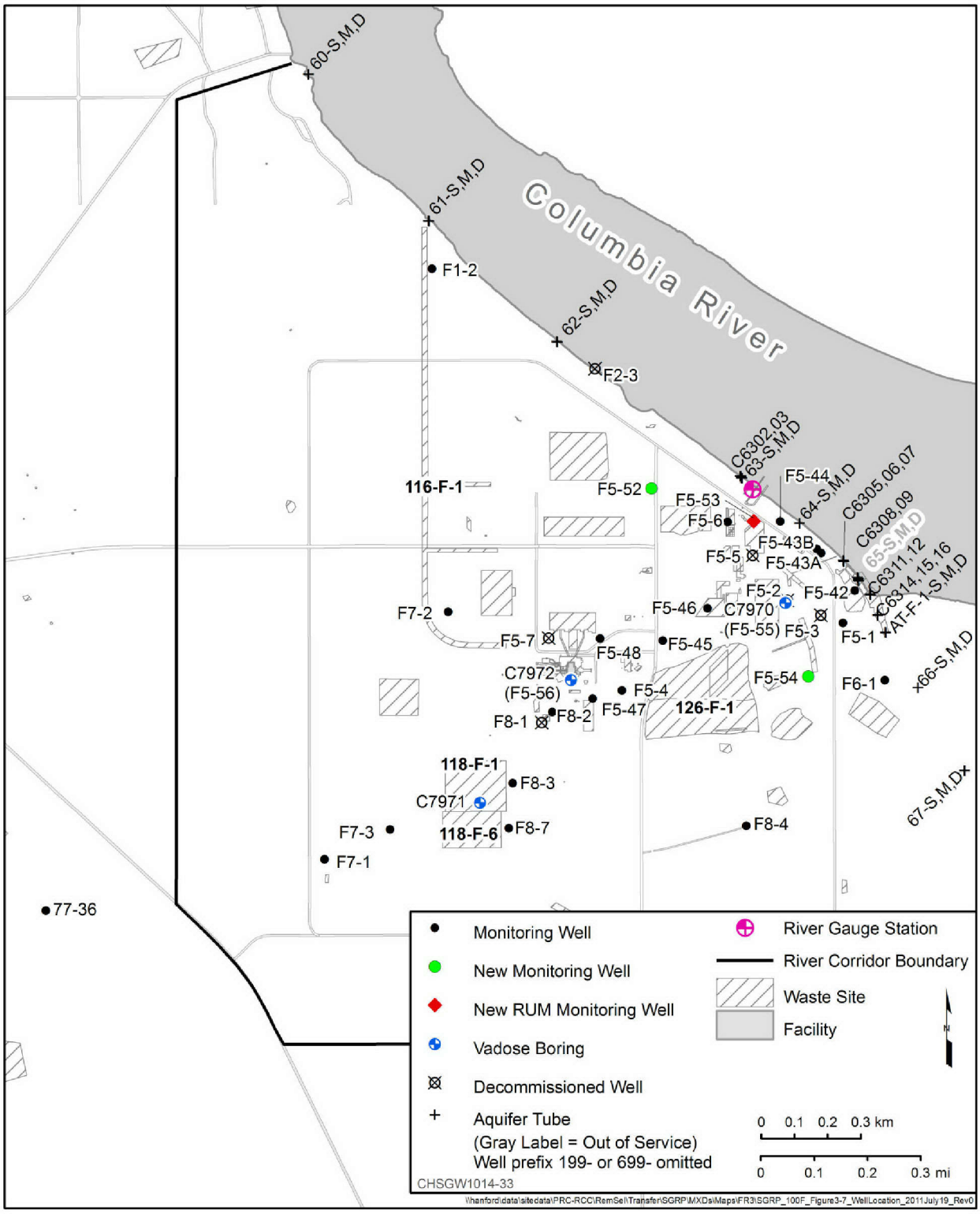
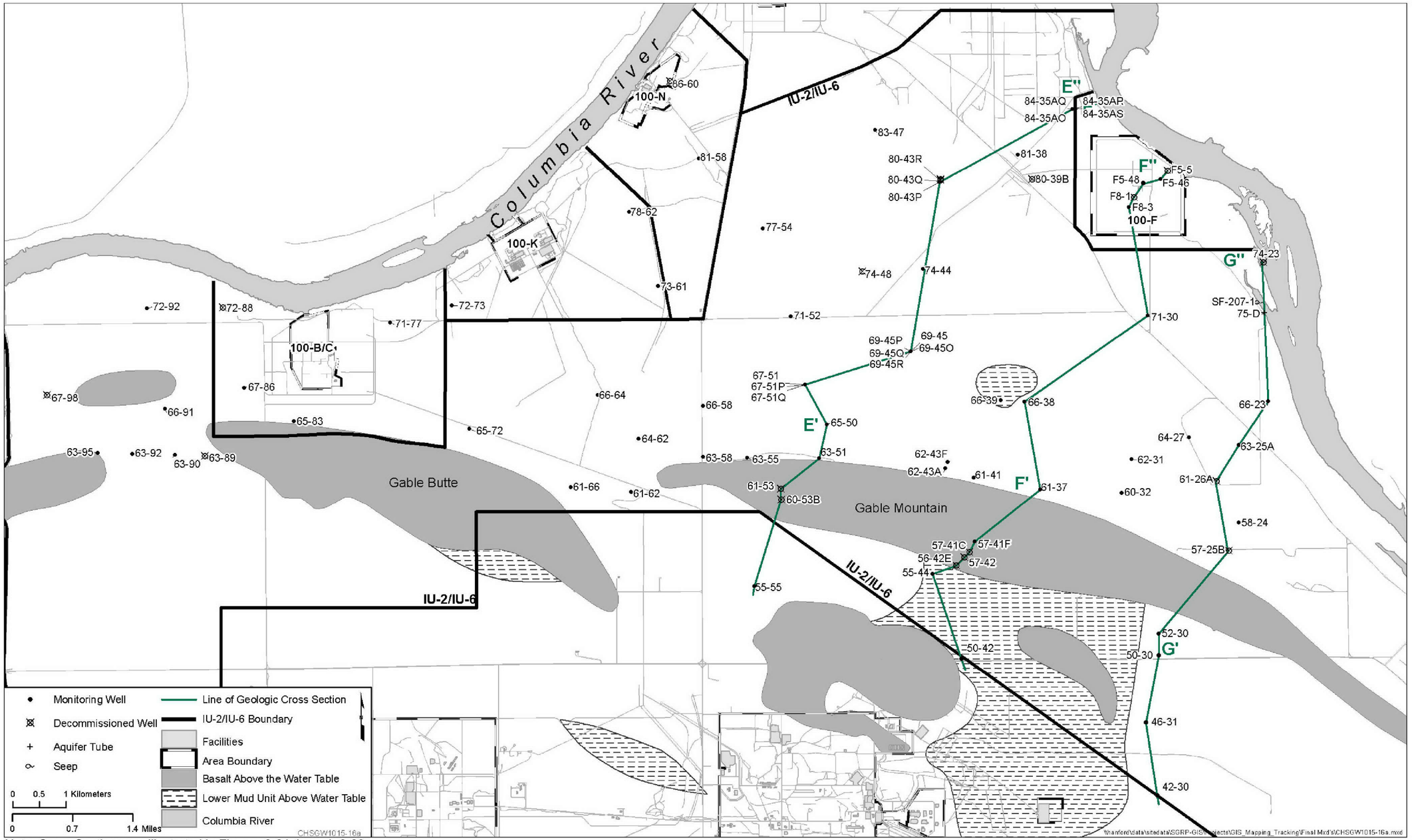



Figure 3-1. Major Features and Well Locations in 100-F




Note: Cross Sections are illustrated in Figures 3-21 through 3-23.

Figure 3-2. Major Features, Well Locations, and Geologic Cross Sections in Northern Portion of 100-IU-2/IU-6

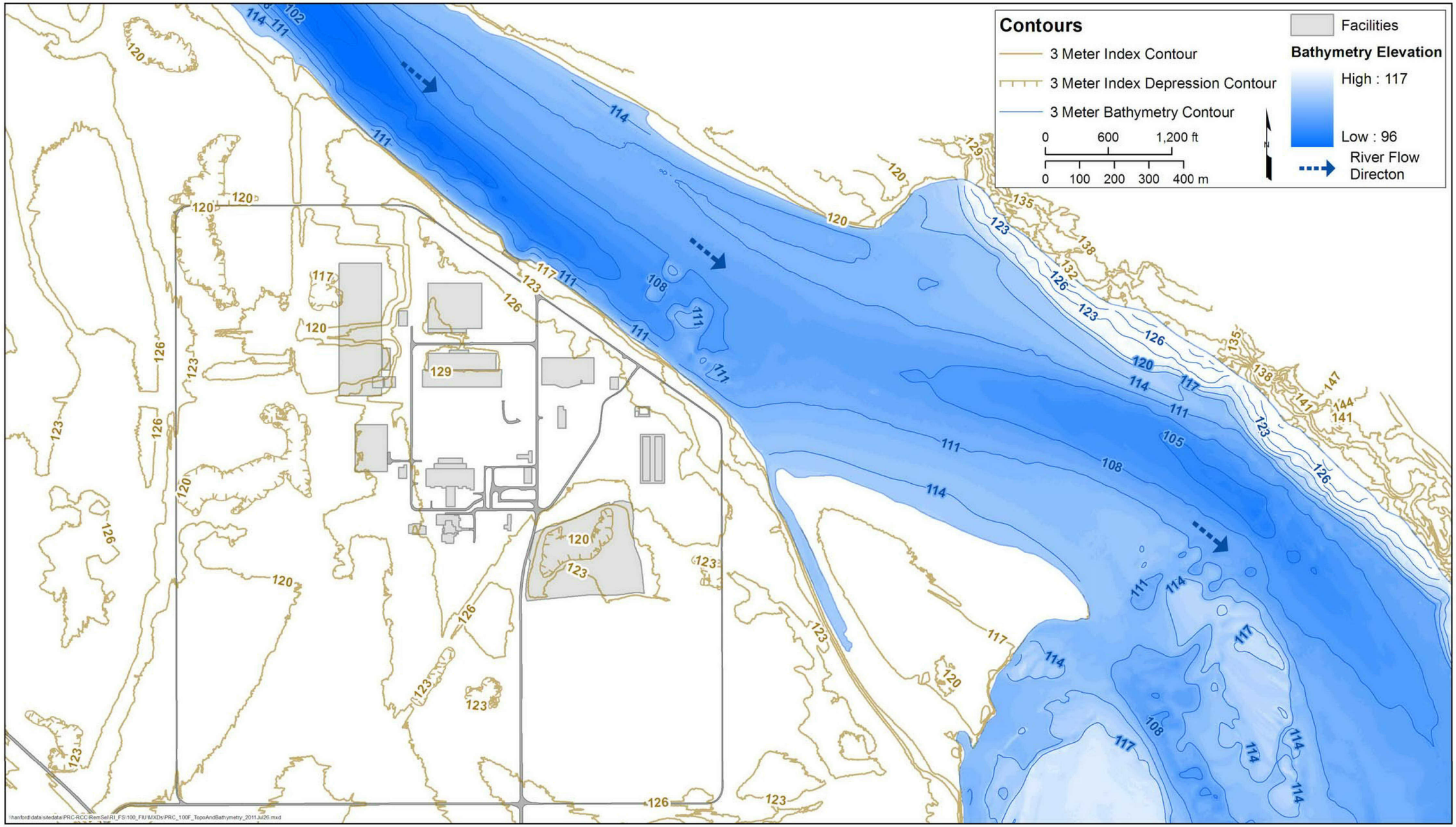



Figure 3-3. Topography of 100-F

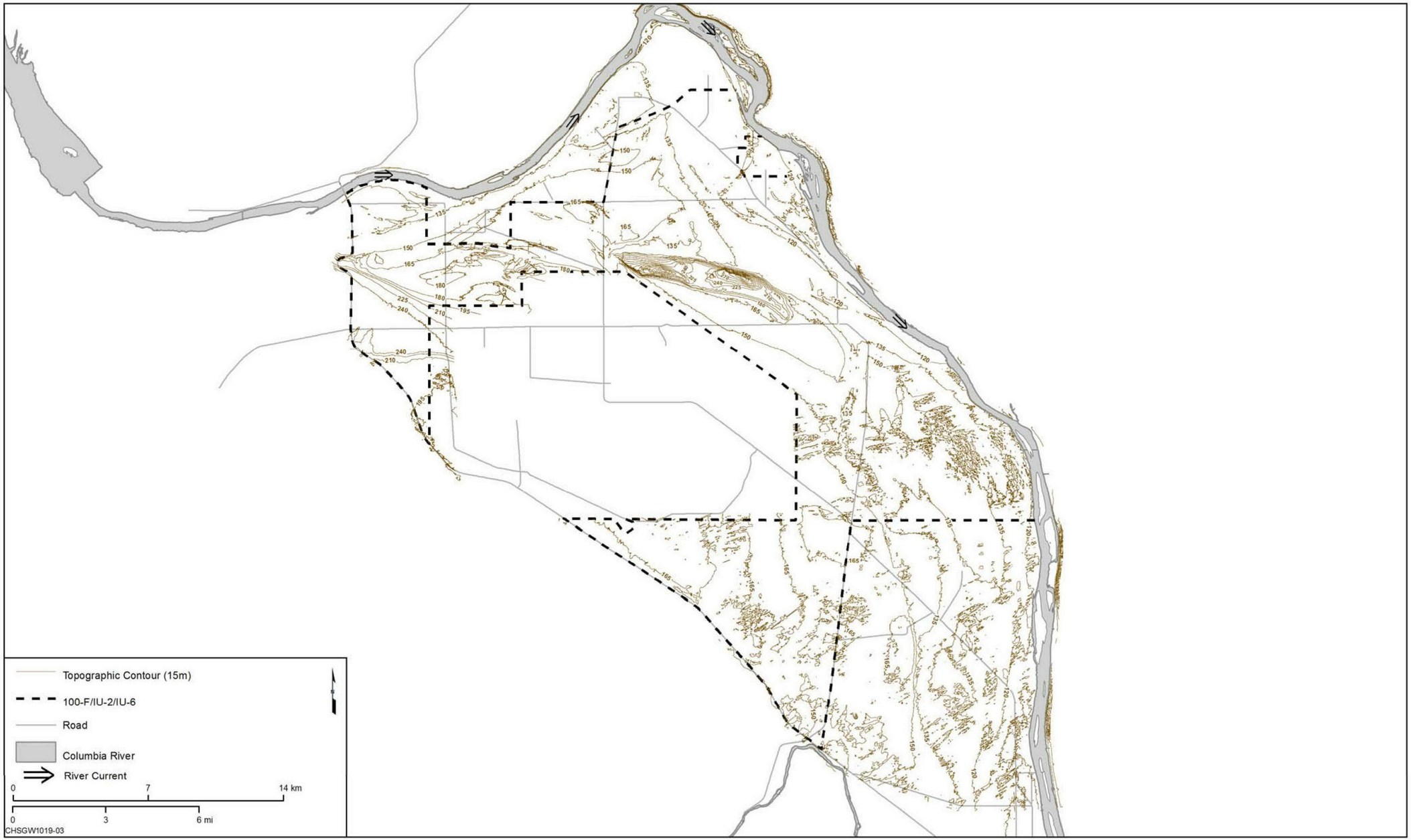



Figure 3-4. Topography of 100-IU-2/IU-6

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The HMS and 30 monitoring locations throughout the Hanford Site and local area provide climate data. From 1945 through 2009, the recorded maximum temperature was 45°C (113°F) during July 2002 and August 1961, and the recorded minimum temperature was -30.6°C (-23°F) during February 1950 (*Hanford Site National Environmental Policy Act (NEPA) Characterization* hereinafter called NEPA Characterization Report [PNNL-6415]). Tables 3-1 and 3-2 list monthly minimum and maximum temperatures. The annual average relative humidity is 54 percent (NEPA Characterization Report [PNNL-6415]).

Table 3-1. Monthly Minimum Temperatures from 1945 through 2009

| 1945-2009 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average (°F) | 6 | 12 | 21 | 29 | 35 | 44 | 49 | 49 | 39 | 27 | 18 | 9 |
| Average (°C) | -14 | -11 | -6 | -2 | 2 | 7 | 9 | 9 | 4 | -3 | -8 | -13 |
| Lowest (°F) | -22 | -23 | 6 | 21 | 28 | 37 | 39 | 41 | 30 | 7 | -13 | -14 |
| Lowest (°C) | -30 | -31 | -14 | -6 | -2 | 3 | 4 | 5 | -1 | -14 | -25 | -26 |
| Highest (°F) | 24 | 29 | 32 | 37 | 48 | 52 | 58 | 56 | 48 | 34 | 28 | 23 |
| Highest (°C) | -4 | -2 | 0 | 3 | 9 | 11 | 14 | 13 | 9 | 1 | -2 | -5 |

Note: Data are from http://www.hanford.gov/page.cfm/hms/products/minmonth.

Table 3-2. Monthly Maximum Temperatures from 1945 through 2009

| 1945-2009 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average (°F) | 57 | 62 | 70 | 81 | 93 | 99 | 105 | 104 | 95 | 80 | 65 | 57 |
| Average (°C) | 14 | 17 | 21 | 27 | 34 | 37 | 41 | 40 | 35 | 27 | 18 | 14 |
| Lowest (°F) | 36 | 46 | 63 | 71 | 81 | 86 | 96 | 96 | 86 | 72 | 54 | 39 |
| Lowest (°C) | 2 | 8 | 17 | 22 | 27 | 30 | 36 | 36 | 30 | 22 | 12 | 4 |
| Highest (°F) | 72 | 72 | 83 | 94 | 104 | 111 | 113 | 113 | 106 | 89 | 76 | 69 |
| Highest (°C) | 22 | 22 | 28 | 34 | 40 | 44 | 45 | 45 | 41 | 32 | 24 | 21 |

Note: Data are from http://www.hanford.gov/page.cfm/hms/products/maxmonth.

Annual precipitation historically recorded at the Hanford Site has varied from 7.6 to 31.3 cm/year (3.0 to 12.3 in./year) since 1947, with an average of 17.2 cm/year (6.8 in./year). Most precipitation occurs during late autumn and winter, with more than half of the annual amount occurring from November through February (Table 3-3). Snowfall accounts for approximately 38 percent of precipitation from December through February (NEPA Characterization Report [PNNL-6415]). Winter monthly average snowfall ranges from 5.6 cm (2.2 in.) in February to 13.2 cm (5.2 in.) in January.

Along the Columbia River, local winds are influenced by near river topography (NEPA Characterization Report [PNNL-6415]). Figure 3-5 contains composite wind roses and joint frequency distributions for the Hanford meteorological monitoring network for the period 1982 through 2004.[1] Table 3-4 lists wind speeds and directions from 1945 through 2004. The prevailing wind direction at the Hanford Site is from the

[1] Wind speed averages have not been published for years 2005 to present. However, speeds are not expected to have varied considerably during that time range.

west-northwest or northwest, and the peak gusts are from the south-southwest, southwest, or west-southwest. The highest monthly average wind speeds occur in June, the lowest in December. The variability in monthly average wind speeds is much greater in the winter months than during the remainder of the year.

Table 3-3. Average, Minimum, and Maximum Monthly and Annual Precipitation from 1947 through 2009

| 1947-2009 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average (in.) | 0.95 | 0.65 | 0.50 | 0.51 | 0.52 | 0.55 | 0.25 | 0.29 | 0.32 | 0.55 | 0.89 | 1.04 | 6.76 |
| Average (cm) | 2.40 | 1.66 | 1.26 | 1.30 | 1.32 | 1.40 | 0.63 | 0.73 | 0.81 | 1.40 | 2.26 | 2.64 | 17.18 |
| Minimum (in.) | 0.08 | 0.01 | 0.02 | 0.01 | 0.02 | 0.01 | 0.00 | 0.00 | 0.00 | 0.01 | 0.02 | 0.07 | 2.99 |
| Minimum (cm) | 0.20 | 0.03 | 0.05 | 0.03 | 0.05 | 0.03 | 0.00 | 0.00 | 0.00 | 0.03 | 0.05 | 0.18 | 7.59 |
| Maximum (in.) | 2.47 | 2.10 | 1.86 | 2.23 | 2.03 | 2.92 | 1.76 | 1.36 | 1.34 | 2.72 | 2.67 | 3.69 | 12.31 |
| Maximum (cm) | 6.27 | 5.33 | 4.72 | 5.66 | 5.16 | 7.42 | 4.47 | 3.45 | 3.40 | 6.91 | 6.78 | 9.37 | 31.27 |

Note: Data are from http://www.hanford.gov/page.cfm/hms/products/totprcp.

The wind speed class with the highest frequency of occurrence is 6.4 to 11 km/hr (4 to 7 mph), with winds in that category occurring 37 percent of the time. The speed class with the second highest frequency is 13 to 19 km/hr (8 to 12 mph), at 25 percent. Winds averaging greater than 40 km/hr (25 mph) occur only 1 percent of the time on an annual basis, with the highest frequency occurring in March (1.6 percent) (2004 Hanford Climatological Summary [PNNL-15160]). High-speed surface winds in the summer from the southwest can generate regional dust storms that sometimes lead to onsite work terminations. Figure 3-6 shows the Hanford Construction Camp during one such dust storm, taken around 1944.

## 3.3 Surface Water Hydrology

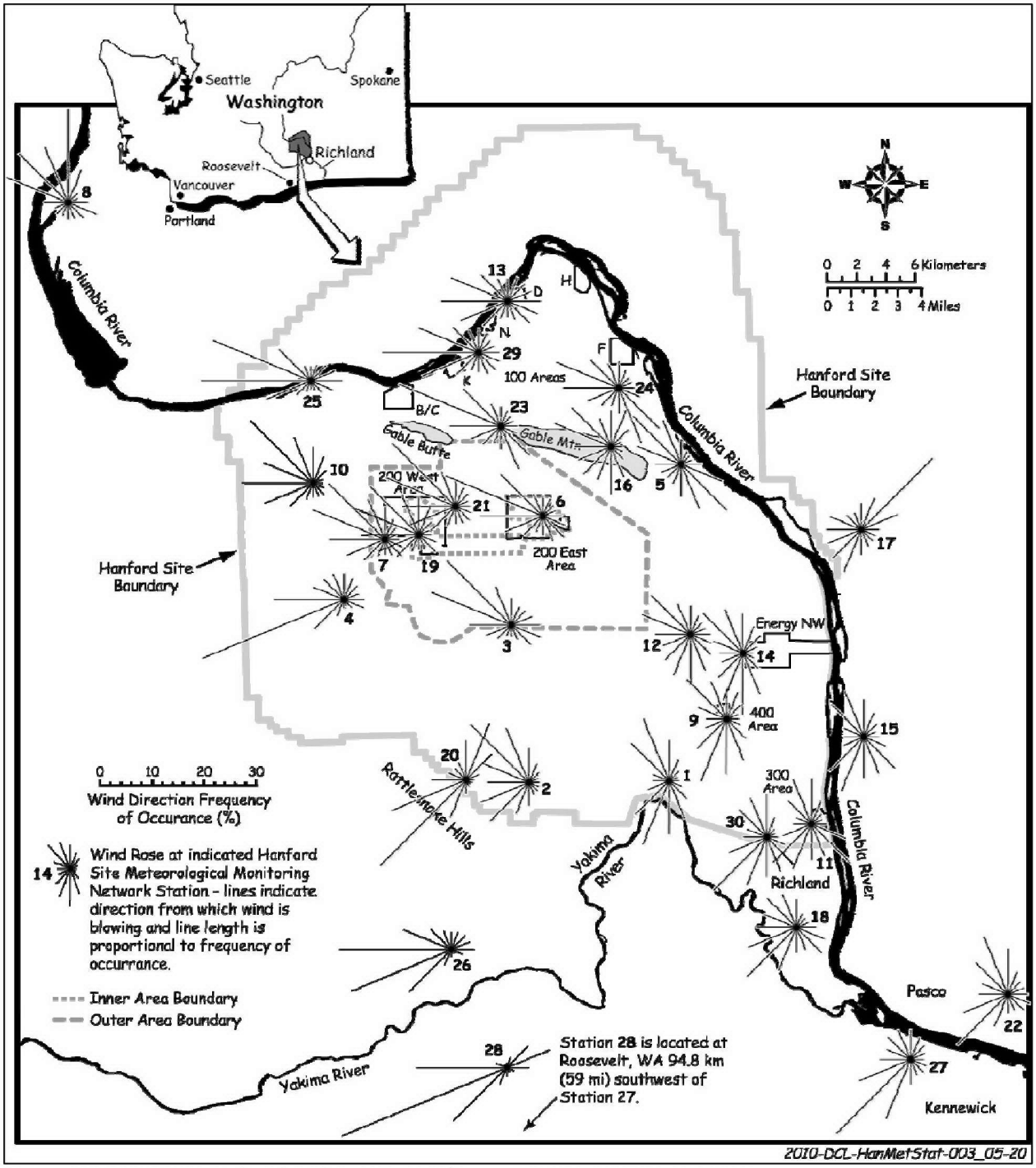
This section describes the Columbia River and surface water use at 100-F/IU.

### 3.3.1 Columbia River

The Columbia River is the only natural surface water feature in 100-F or 100-IU-2/IU-6. The Columbia River has played a major role in the depositional and erosional processes that helped produce the sedimentary and geologic features across the Hanford Site.

The portion of the Columbia River flowing through the Hanford Site is the only remaining, free-flowing portion of the river above Bonneville Dam in the United States. This stretch of the river is referred to as the "Hanford Reach," and it extends from Priest Rapids Dam to the headwaters of Lake Wallula. In May 2000, the Hanford Reach was incorporated into the 70,820 ha (175,000 ac) Hanford Reach National Monument.

Figure 3-3 illustrates the bathymetry of the river bottom at 100-F, where the deepest part of the river has elevations below 102 m (335 ft) amsl. At average river stage, this corresponds to a depth of approximately 11.5 m (38 ft). Southeast of 100-F, a broad bench of land and nearby islands are partially submerged at times of high river stage.




Source: PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*.

Figure 3-5. Hanford Meteorological Monitoring Network Wind Roses at 9.1 m (30 ft), 1982 through 2004

Table 3-4. Monthly and Annual Prevailing Wind Directions, Average Speeds, and Peak Gusts at Hanford Meteorological Station, 15.2 m (50 ft) Level, 1945 through 2004

| Month | Prevailing Direction | Average Speed (mph)[a] | Highest Average | | Lowest Average | | Peak Gusts | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | mph | Year | mph | Year | mph | Direction | Year |
| January | NW | 6.3 | 10.3 | 1972 | 2.9 | 1985 | 80 | SW | 1972 |
| February | NW | 7.0 | 11.1 | 1999 | 4.6 | 1963 | 65 | SSW | 1999[b] |
| March | WNW | 8.2 | 10.7 | 1977[b] | 5.9 | 1958 | 70 | SW | 1956 |
| April | WNW | 8.8 | 11.1 | 1972[b] | 7.4 | 1989[b] | 73 | SSW | 1972 |
| May | WNW | 8.8 | 10.7 | 1983 | 5.8 | 1957 | 71 | SSW | 1948 |
| June | NW | 9.1 | 10.7 | 1983[b] | 7.7 | 1950[b] | 72 | SW | 1957 |
| July | NW | 8.6 | 10.7 | 1983 | 6.8 | 1955 | 69 | WSW | 1979 |
| August | WNW | 8.0 | 9.5 | 1996 | 6.0 | 1956 | 66 | SW | 1961 |
| September | WNW | 7.4 | 9.2 | 1961 | 5.4 | 1957 | 65 | SSW | 1953 |
| October | NW | 6.6 | 9.1 | 1946 | 4.4 | 1952 | 72 | SW | 1997 |
| November | NW | 6.4 | 10.0 | 1990 | 2.9 | 1956 | 67 | WSW | 1993 |
| December | NW | 6.0 | 8.3 | 1968 | 3.3 | 1985 | 71 | SW | 1955 |
| Annual | NW | 7.6 | 8.8 | 1999 | 6.2 | 1989 | 80 | SW | 1972 |

Note: Wind speed averages have not been published for years 2005 to present.
Source: PNNL-15160, *Hanford Site Climatological Summary 2004 with Historical Data*.
a. 1 mph = 1.61 km/hr
b. Also in earlier years

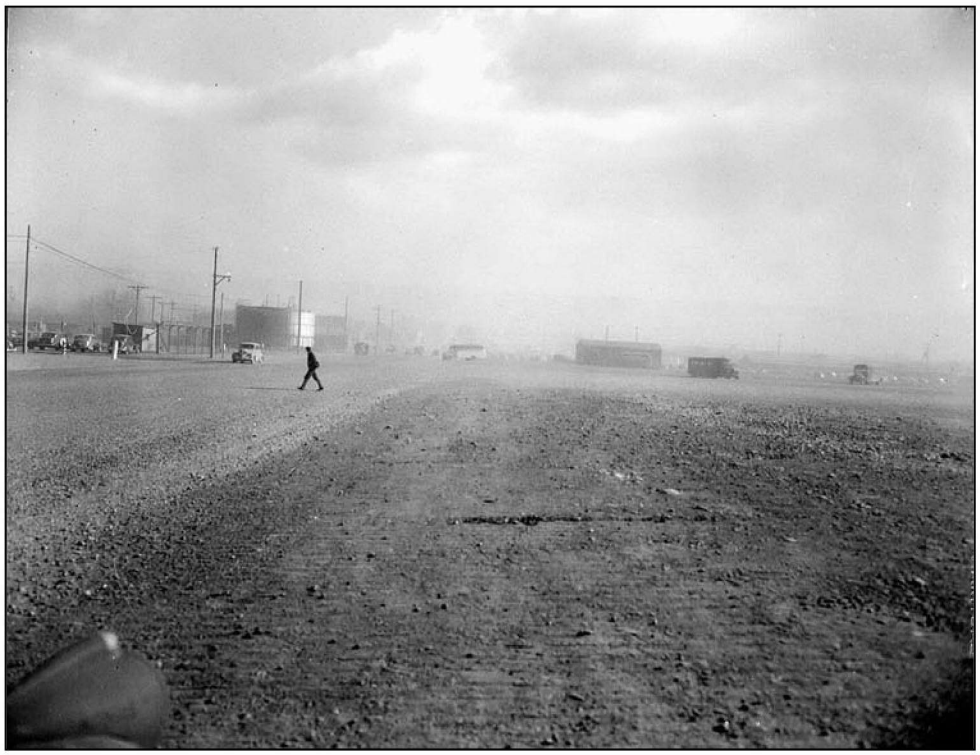


Figure 3-6. Dust Storm at Hanford Site Construction Camp, Circa 1944

The flow of the Columbia River at 100-F is to the southeast and controlled mainly by Priest Rapids Dam approximately 50 km (31 mi) upstream. River flows are managed mainly for generating power, controlling floods, and promoting salmon egg and embryo survival. The flow rate at Priest Rapids Dam from 1992 through 2009 averaged approximately 3,220 $m^3$/sec (114,000 $ft^3$/sec). The highest average flow occurred in 1997 and the lowest flow in 2001 (Figure 3-7, top panel). The bottom panel of Figure 3-7 illustrates the flow in these maximum and minimum years, and in 2009. Flow volumes typically peak in May and June during spring runoff from regional and high elevation snowmelt, and flows are lowest from September through October.

Since 1992, a river gauge has operated at 100-F (location is shown on Figure 3-1). The gauge frequently has been out of service because (1) in the past, maintaining a gauge at 100-F was considered a lower priority than gauges in other areas of the Hanford Site, and (2) in recent years, waste site remediation activities and facility demolition have occasionally interfered with access and maintenance. When operating, the gauge records river stage hourly. River stage at 100-F can be estimated from data collected in 100-H, where the gauge operates continuously. The river stage at 100-F averages 1.82 m (6.0 ft) lower than 100-H. These estimates were combined with 100-F measured river stage on Figure 3-8. High river stage is typically 115 to 116 m (377 to 381 ft) amsl and generally occurs in May through July. Low river stage, approximately 112 to 113 m (367 to 371 ft) amsl, typically occurs in September or October. Diurnal fluctuations of 1 m (3 ft) are typical, and can range up to 3 m (10 ft). Seasonal fluctuations average approximately 3 m (10 ft).

Another river gauge records water levels at the downstream end of the Hanford Reach at the 300 Area. The river stage in the 300 Area is approximately 8 m (26 ft) lower than at 100-F.

The water quality of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, has been designated as Class A, Excellent, by Washington State (2009 Sitewide Environmental Report [PNNL-19455]). Class A waters are suitable for essentially all uses, including drinking water, recreation, and wildlife habitat. The suspended sediment load in the Columbia River is typically very low. The bed load consists mainly of fine and medium sand. The river also has a low nutrient content, and an absence of microbial contaminants (*Site Characterization Plan: Reference Repository Location,* Hanford *Site, Washington* [DOE/RW-0164]). Typical flow rates in the study area suggest that little deposition is occurring along the Hanford Reach, except along the shoreline portion of islands (Columbia River RI Work Plan [DOE/RL-2008-11]).

### 3.3.2 Surface Water Use

Users withdraw water in the Hanford Reach for offsite irrigation, for use at the Energy Northwest nuclear power plant, and for Hanford Site water use. In addition, the Columbia River provides extensive recreation opportunities, including fishing, hunting, boating, sailing, waterskiing, diving, and swimming. The Columbia River also supplies water for public and domestic use, irrigation, barge transportation, industry, and wildlife habitat (*100-B/C Pilot Project Risk Assessment Report* [DOE/RL-2005-40]).

No surface water is withdrawn from the Columbia River at 100-F or 100-IU-2/IU-6 for use on the Hanford Site.

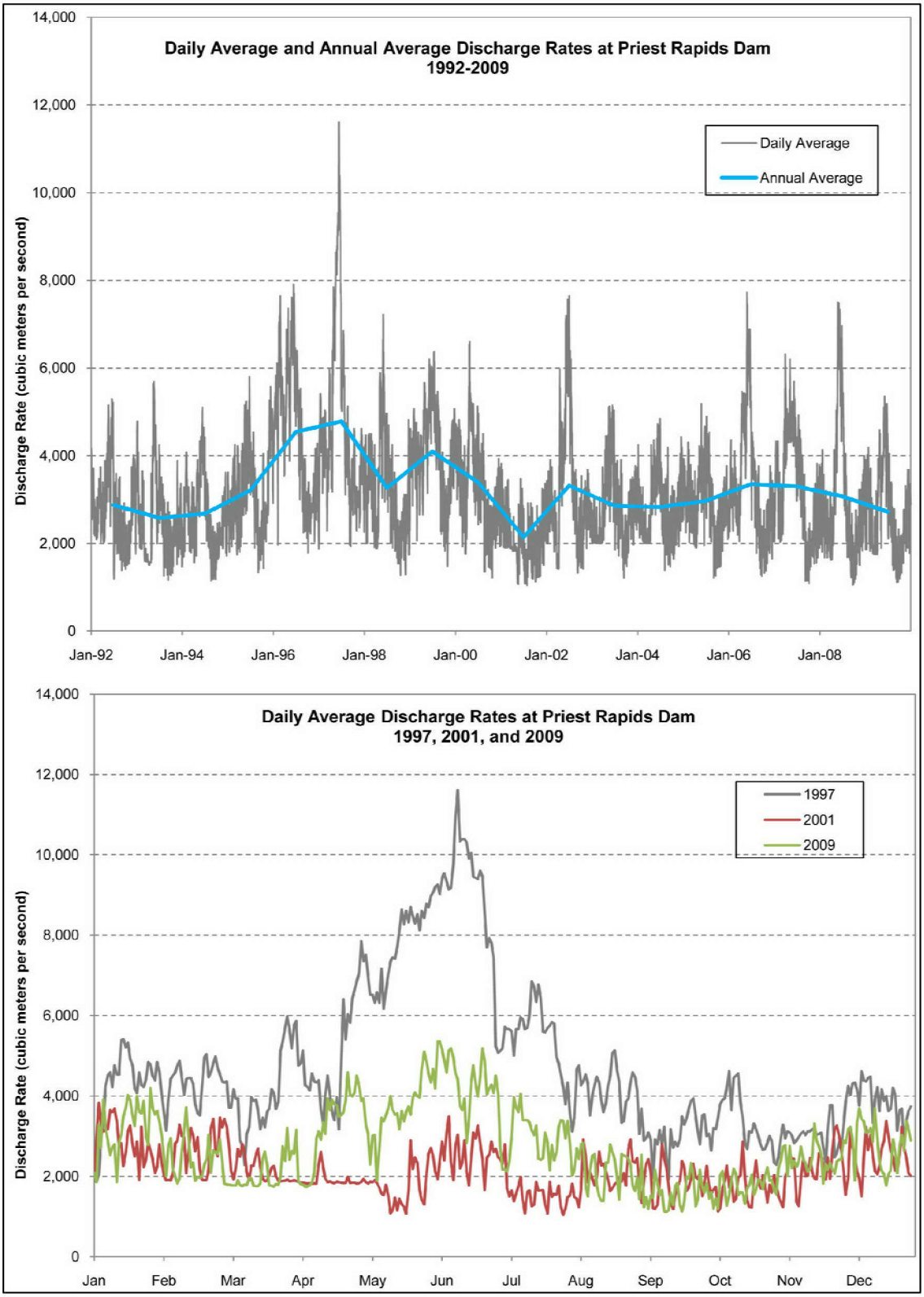



Figure 3-7. Columbia River Flow Volume at Priest Rapids Dam

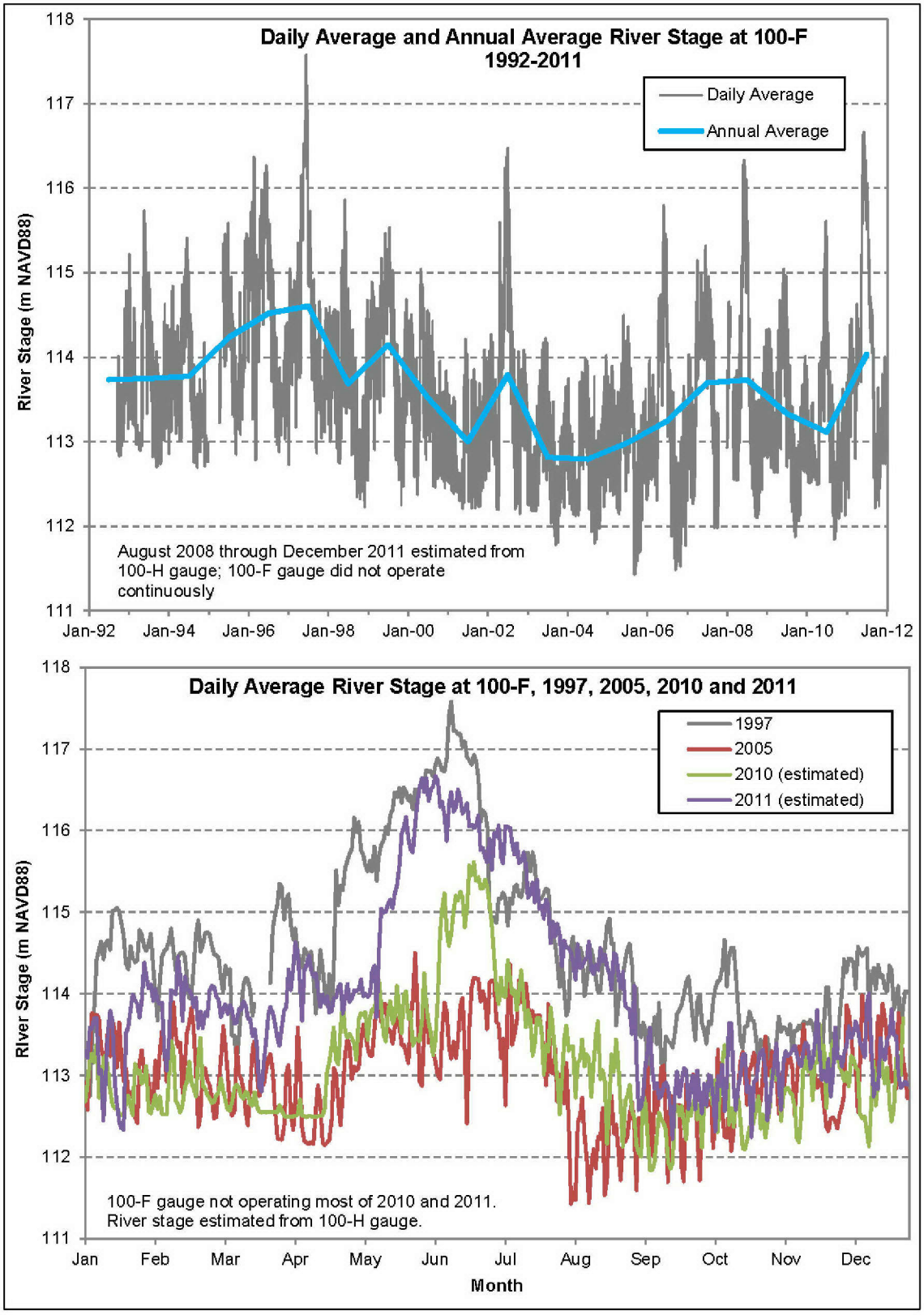



Figure 3-8. 100-F River Stage

## 3.4 Geology

This section describes the geology of 100-F/IU. Figures 3-1 and 3-2 show the locations of wells discussed in this chapter. Table 3-5 summarizes geologic and well construction data for wells in and near 100-F, and for wells representative of 100-IU-2/IU-6 north of Gable Mountain. Geologic information for the region of 100-IU-2/IU-6 south of Gable Mountain is summarized from the 200-PO-1 RI Report (DOE/RL-2009-85). Geologic and geophysical logs for wells and vadose boreholes installed for the RI are included in borehole summary reports (*Borehole Summary Report for the Installation of Three Groundwater Wells in the 100-FR-3 Area to Support RI/FS* [SGW-49445]; *Borehole Summary Report for the Installation of 2 Temporary Monitoring Wells and 1 Characterization Borehole within the 100-FR-3 Area in Support of the Integrated 100 Area Remedial Investigation/Feasibility Study, FY2010-2011* [SGW-50130]).

A partial listing of previous reports used to supplement the RI data includes (but is not limited to) the following documents:

- *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin* (DOE/RL-2002-39)
- *Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas* (WHC-SD-EN-TI-011)
- *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* (BHI-00184)
- U.S. Geological Survey (USGS) Professional Paper 717, *Geology and Ground-Water Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington* (Newcomb et al., 1972)
- *Sedimentology and Stratigraphy of the Miocene-Pliocene Ringold Formation, Hanford Site, South-Central Washington* (WHC-SA-0740-FP)
- *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports* (WHC-SD-ER-TI-003), hereinafter called Geology and Hydrology of the Hanford Site
- *Site Characterization Plan: Reference Repository Location, Hanford Site, Washington* (DOE/RW-0164)

### 3.4.1 Stratigraphy

Figures 3-9 and 3-10 show the generalized stratigraphy of 100-F/IU. The region is underlain by Miocene (approximately 17 to 8.5 million years before present) basalt of the Columbia River Basalt Group and late Miocene to Pleistocene (approximately 10.5 million to 12,000 years before present) suprabasalt sediments. The Columbia River Basalt Group is greater than 3,000 m (9,800 ft) thick.

Sediments overlying the basalt are more than 184 m (600 ft) thick. Most of this sedimentary sequence can be divided into two main units: the Ringold Formation of late Miocene to middle Pliocene age (approximately 10.5 million to 3 million years before present) and the Hanford formation of Pleistocene to Recent age (approximately 1 million to 12,000 years before present). Holocene surficial deposits of silt, sand, and gravel form the veneer at the surface.

Table 3-5. Geologic and Well Construction Data for 100-F Wells and Selected Wells in 100-IU-2/IU-6 in Northern Hanford Site

| Well Name | Year Installed | Well Type | Casing and Screen Type | Well Status | Top of Casing Elev. (m) | Surface Elev. (m) | Drilled Depth (ft) | Elev. Top Screen or Perf. (m) | Elev. Bottom Screen or Perf. (m) | Water Level (m) | Water Level Date | Depth to Ringold E (ft) | Elev. Top Ringold E (m) | Depth to RUM (ft) | Elev. Top of RUM (m) | Thickness Upper Aquifer (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 199-F1-2 | 1992 | Well | SS, Screen | In use | 122.33 | 121.47 | 37.5 | 115.4 | 110.9 | 113.26 | 3/4/2009 | Absent | Absent | 35.0 | 110.8 | 2.5 | Screened across aquifer thickness. |
| 199-F2-3 | 1943 | Well | Unknown | Decommissioned | 122.75 | 121.84 | 48.0 | 109.3 | 107.6 | | | X | X | 46.7 | 107.6 | | |
| 199-F5-1 | 1948 | Well | CS, Perf | In use | 124.57 | 124.27 | 67.0 | 113.6 | 105.1 | 113.15 | 3/4/2009 | X | X | 62.0 | 105.4 | 7.8 | Screened across aquifer thickness. |
| 199-F5-2 | 1953 | Well | CS, Perf | Decommissioned | 126.90 | 126.47 | 100.0 | 118.9 | 96.0 | | | 75.0 | 103.6 | 76.0 | 103.3 | | Possible remnant Ringold E? |
| 199-F5-3 | 1953 | Well | CS, Perf | Decommissioned | 125.56 | 125.13 | 90.0 | 118.4 | 105.9 | | | Absent | Absent | 65.0 | 105.3 | | |
| 199-F5-4 | 1953 | Well | CS, Perf | In use | 126.64 | 126.47 | 115.0 | 115.8 | 102.1 | 113.86 | 3/4/2009 | X | X | 50.0 | 111.2 | 2.6 | Screened across aquifer thickness. |
| 199-F5-5 | 1953 | Well | CS, Perf | Decommissioned | 126.80 | 125.88 | 100.0 | 121.3 | 101.5 | | | X | X | 72.0 | 103.9 | | |
| 199-F5-6 | 1956 | Well | CS, Perf | In use | 127.04 | 126.62 | 192.0 | 116.0 | 104.3 | 113.28 | 3/4/2009 | X | X | 69.0 | 105.6 | 7.7 | Screened across aquifer thickness. |
| 199-F5-7 | 1958 | Well | CS, Perf | Decommissioned | 126.81 | 126.39 | 30.0 | 126.8 | Unknown | | | X | X | >30.0 | <117.2 | | |
| 199-F5-42 | 1992 | Well | SS, Screen | In use | 120.22 | 119.36 | 35.2 | 114.7 | 108.6 | 113.43 | 5/5/2010 | X | X | >35.2 | <108.6 | | Did not reach RUM. |
| 199-F5-43A | 1992 | Well | SS, Screen | In use | 121.54 | 120.61 | 49.7 | 114.5 | 108.4 | 112.93 | 3/4/2009 | X | X | 47.5 | 106.1 | 6.8 | |
| 199-F5-43B | 1992 | Well | SS, Screen | In use | 121.39 | 120.43 | 190.0 | 76.3 | 73.2 | 112.61 | 10/6/2009 | X | X | 43.0 | 107.3 | 5.3 | Screened in RUM. |
| 199-F5-44 | 1992 | Well | SS, Screen | In use | 123.76 | 122.85 | 49.1 | 114.4 | 108.3 | 112.45 | 10/6/2009 | X | X | >49.1 | <107.9 | | Did not reach RUM. |
| 199-F5-45 | 1992 | Well | SS, Screen | In use | 127.31 | 126.37 | 52.6 | 115.2 | 110.6 | 113.30 | 5/5/2010 | X | X | 51.5 | 110.7 | 2.6 | Screened across aquifer thickness. |
| 199-F5-46 | 1992 | Well | SS, Screen | In use | 128.12 | 127.19 | 57.0 | 114.8 | 110.2 | 113.47 | 3/4/2009 | X | X | 56.5 | 110.0 | 3.5 | Screened across aquifer thickness. |
| 199-F5-47 | 1992 | Well | SS, Screen | In use | 128.75 | 127.84 | 63.5 | 115.8 | 109.7 | 113.94 | 10/6/2009 | X | X | 62.5 | 108.8 | 5.1 | |
| 199-F5-48 | 1992 | Well | SS, Screen | In use | 128.24 | 127.29 | 55.0 | 115.7 | 111.0 | 114.53 | 5/5/2010 | 18.0 | 121.8 | 52.0 | 111.4 | 3.1 | Screened across aquifer thickness. Possible remnant Ringold E? |
| 199-F5-49 | 1993 | Borehole | N/A | Decommissioned | N/A | 126.42 | 35.7 | N/A | N/A | N/A | N/A | 18.0 | 120.9 | >35.7 | <115.5 | | Possible remnant Ringold E? |
| 199-F5-52 | 2010 | Well | SS, Screen | In use | 128.50 | 127.62 | 73.8 | 115.4 | 109.3 | 113.83 | 8/5/2010 | Absent | Absent | 66.0 | 107.5 | 6.3 | |
| 199-F5-53 | 2010 | Well | SS, Screen | In use | 125.93 | 125.11 | 116.0 | 96.1 | 93.1 | 112.68 | 11/4/2010 | Absent | Absent | 54.5 | 108.5 | 4.2 | Screened in RUM. |
| 199-F5-54 | 2010 | Well | SS, Screen | In use | 127.40 | 126.62 | 77.4 | 115.0 | 108.9 | 113.37 | 8/24/2010 | Absent | Absent | 69.8 | 105.3 | 8.0 | |
| 199-F5-55 | 2011 | Well | PVC | Temporary | 126.82 | 126.81 | 50.5 | 114.4 | 111.4 | 113.84 | 2/16/2011 | X | X | >50.5 | <111.4 | >2.4 | |
| 199-F5-56 | 2011 | Well | PVC | Temporary | 127.21 | 127.22 | 50.9 | 114.6 | 111.6 | 113.82 | 2/17/2011 | X | X | >50.9 | <111.7 | >2.1 | |
| 199-F6-1 | 1992 | Well | SS, Screen | In use | 124.52 | 123.60 | 53.0 | 114.7 | 108.6 | 113.12 | 3/4/2009 | X | X | 50.0 | 108.4 | 4.8 | Screened across aquifer thickness. |
| 199-F7-1 | 1956 | Well | CS, Perf | In use | 120.05 | 118.59 | 150.0 | 115.5 | 101.8 | 114.86 | 3/4/2009 | X | X | 30.0 | 109.4 | 5.4 | |
| 199-F7-2 | 1988 | Well | SS, Screen | In use | 121.28 | 120.63 | 31.0 | 116.1 | 111.3 | 114.25 | 3/4/2009 | X | X | >31.0 | <111.2 | >3.1 | Did not reach RUM. |
| 199-F7-3 | 1992 | Well | SS, Screen | In use | 121.37 | 120.49 | 33.0 | 115.3 | 110.7 | 114.69 | 3/4/2009 | 17.0 | 115.3 | 29.0 | 111.7 | 3.0 | Screened across aquifer thickness. Possible remnant Ringold E? |
| 199-F8-1 | 1960 | Well | CS, Perf | Decommissioned | 124.73 | 124.06 | 57.0 | 120.1 | 107.9 | | | 25.0 | 116.4 | 45.0 | 110.3 | | Possible remnant Ringold E? |

Table 3-5. Geologic and Well Construction Data for 100-F Wells and Selected Wells in 100-IU-2/IU-6 in Northern Hanford Site

| Well Name | Year Installed | Well Type | Casing and Screen Type | Well Status | Top of Casing Elev. (m) | Surface Elev. (m) | Drilled Depth (ft) | Elev. Top Screen or Perf. (m) | Elev. Bottom Screen or Perf. (m) | Water Level (m) | Water Level Date | Depth to Ringold E (ft) | Elev. Top Ringold E (m) | Depth to RUM (ft) | Elev. Top of RUM (m) | Thickness Upper Aquifer (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 199-F8-2 | 1960 | Well | CS, Perf | In use | 126.22 | 125.46 | 55.0 | 122.4 | 109.3 | 114.07 | 3/4/2009 | X | X | 54.0 | 109.0 | 5.1 | Screened across aquifer thickness. |
| 199-F8-3 | 1992 | Well | SS, Screen | In use | 122.86 | 121.95 | 34.0 | 115.5 | 112.5 | 114.34 | 3/4/2009 | X | X | 30.0 | 112.8 | 1.5 | Screened across aquifer thickness. |
| 199-F8-4 | 1992 | Well | SS, Screen | In use | 126.28 | 125.37 | 47.5 | 114.3 | 111.3 | 113.05 | 3/4/2009 | X | X | 46.5 | 111.2 | 1.9 | Screened across aquifer thickness. |
| 199-F8-7 | 2008 | Well | SS, Screen | In use | 123.97 | 123.17 | 35.0 | 116.5 | 113.4 | 114.44 | 3/4/2009 | X | X | 32.0 | 113.4 | 1.0 | |
| 699-57-16 | 1943 | Well | Unknown | Decommissioned | 118.20 | 117.29 | 42.0 | Unknown | Unknown | | | X | X | 38.0 | 105.7 | | |
| 699-57-25B | 1975 | Well | CS | Decommissioned | 127.553 | 126.79 | 81.0 | Unknown | Unknown | | | X | X | 79.0 | 102.7 | | |
| 699-58-24 | 1971 | Well | CS, Screen | In use | 128.66 | 127.75 | 63.0 | 112.8 | 109.8 | 110.89 | 3/4/2009 | X | X | >63.0 | <108.5 | >2.4 | |
| 699-59-32 | 1971 | Well | CS, screen | In use | 130.34 | 129.64 | 75.0 | 109.8 | 100.7 | 110.96 | 3/4/2009 | X | X | >75.0 | <106.8 | >4.2 | |
| 699-60-32 | 1971 | Well | CS, Screen | In use | 130.65 | 129.68 | 85.0 | 106.8 | 103.8 | 110.923 | 3/4/2009 | X | X | 65 | 109.9 | 1.1 | |
| 699-60-57 | 1972 | Well | CS, Screen | In use | 144.13 | 143.44 | 155 | 128.3 | 100.3 | 121.87 | 3/19/2009 | X | X | 96 | 114.2 | 7.7 | |
| 699-60-60 | 1948 | Well | CS, Perf | In use | 157.075 | 156.36 | 128 | 125.9 | 117.6 | 121.78 | 3/2/2009 | 60.0 | 138.1 | 98 | 126.5 | -4.7 | No unconfined aquifer. Water table in RUM. Basalt at 128 ft (39.0 m). |
| 699-61-26A | 1943 | Borehole? | Unknown | Decommissioned | 126.03 | 125.12 | 363.0 | Unknown | Unknown | | | 44.0 | 111.7 | 44.0 | 111.7 | | |
| 699-61-37 | 1971 | Well | CS, Screen | In use | 136.06 | 135.06 | 76.0 | 114.9 | 111.9 | 116.79 | 3/12/2009 | X | X | >76.0 | <111.9 | >4.9 | |
| 699-61-41 | 1971 | Well | CS, Perf | in use | 131.79 | 130.82 | 52.0 | 121.7 | 118.6 | 121.071 | 3/12/2009 | X | X | 40 | 118.6 | 2.4 | |
| 699-61-62 | 1972 | Well | CS, Perf | in use | 152.66 | 151.76 | 188.0 | 125.5 | 121.3 | 121.854 | 3/13/2009 | X | X | Absent | N/A | | Basalt at 177.8 ft (54.2 m). |
| 699-61-66 | 1955 | Well | CS, Perf | In use | 160.19 | 159.28 | 225.0 | 127.3 | 110.5 | 121.806 | 3/13/2009 | X | X | Absent | N/A | | Basalt at 216 ft (65.8 m). |
| 699-62-31 | 1971 | Well | CS, Screen | In use | 133.34 | 132.42 | 84.0 | 109.9 | 106.8 | 111.02 | 3/4/2009 | X | X | >84.0 | <106.8 | >4.2 | |
| 699-62-43A | 1944 | Well | CS, Perf | In use | 132.81 | 132.20 | 78.0 | 116.0 | 113.0 | 121.09 | 3/12/2009 | X | X | 66.0 | 112.1 | 9.0 | |
| 699-62-43F | 1959 | Well | CS, Perf | In use | 130.09 | 129.31 | 81.0 | 122.5 | 107.8 | 119.35 | 10/20/2009 | X | X | 70.0 | 108.0 | 11.4 | |
| 699-63-25A | 1945 | Well | CS, Perf | In use | 121.47 | 121.23 | 110.0 | 112.9 | 92.2 | 110.89 | 3/4/2009 | X | X | 62.0 | 102.3 | 8.6 | |
| 699-63-51 | 1971 | Well | CS, Perf | In use | 130.41 | 129.49 | 36.0 | 124.9 | 121.0 | | | X | X | 25.0 | 121.9 | | Ringold E not present? |
| 699-63-55 | 1972 | Well | CS, Perf | In use | 131.01 | 130.19 | 125.0 | 124.0 | 119.2 | 121.67 | 3/12/2009 | 65.0 | 110.4 | 82.0 | 105.2 | 16.5 | Basalt at 112 ft (34.1 m). |
| 699-63-58 | 1972 | Well | CS, Screen | In use | 150.92 | 150.37 | 130.0 | 126.5 | 120.4 | 121.71 | 3/12/2009 | 110.0 | 116.8 | Absent | Absent | | Basalt at 120 ft (36.6 m). |
| 699-63-89 | 1973 | Well | CS, Open | Decommissioned | 157.24 | 156.24 | 220 | 103.0 | 90.8 | | | 100 | 125.8 | Absent | Absent | | 178 ft (54.3 m) to basalt. |
| 699-63-90 | 1948 | Well | CS, Perf | In use | 156.86 | 156.28 | 253 | 127.3 | 111.5 | 122.40 | 3/2/2009 | 105 | 124.3 | Absent | Absent | | 240 ft (73.2 m) to basalt; RUM not present? Driller's log unclear. |
| 699-63-92 | 1973 | Well | CS, Open | In use | 152.63 | 151.81 | 186 | 106.1 | 95.1 | 122.18 | 3/2/2009 | X | X | Absent | Absent | | 150 ft (45.7 m) to basalt. |
| 699-63-95 | 19890 | Well | CS, Open | In use | 148.78 | 148.33 | 707 | -11.4 | -67.2 | 122.26 | 3/2/2009 | X | X | Absent | Absent | | 78 ft (22.9 m) to basalt. |
| 699-64-27 | 1974 | Well | CS, Perf | In use | 127.28 | 127.04 | 84.0 | 112.0 | 104.7 | 110.92 | 3/4/2009 | X | X | 74.0 | 104.5 | 6.4 | |

Table 3-5. Geologic and Well Construction Data for 100-F Wells and Selected Wells in 100-IU-2/IU-6 in Northern Hanford Site

| Well Name | Year Installed | Well Type | Casing and Screen Type | Well Status | Top of Casing Elev. (m) | Surface Elev. (m) | Drilled Depth (ft) | Elev. Top Screen or Perf. (m) | Elev. Bottom Screen or Perf. (m) | Water Level (m) | Water Level Date | Depth to Ringold E (ft) | Elev. Top Ringold E (m) | Depth to RUM (ft) | Elev. Top of RUM (m) | Thickness Upper Aquifer (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 699-65-50 | 1955 | Well | CS, Perf | In use | 143.37 | 142.57 | 585 | 125.8 | 104.5 | 121.52 | 3/12/2009 | X | X | 115 | 107.5 | 14.0 | 585 ft (178,3 m) to basalt. |
| 699-65-72 | Unknown | Well | CS, perf | In use | 152.63 | 152.33 | 216 | 110.6 | 104.5 | 121.62 | 3/13/2009 | X | X | | | | |
| 699-65-83 | 1967 | Well | CS, perf | In use | 149.05 | 148.12 | 121 | 129.8 | 112.5 | 121.69 | 3/2/2009 | 85 | 122.2 | >121 | <129.8 | >8.1 | |
| 699-66-23 | 1961 | Well | CS, Perf | In use | 119.59 | 119.03 | 100 | 112.9 | 94.6 | 110.97 | 3/4/2009 | X | X | 55 | 102.3 | 8.7 | Piezo P decommissioned. |
| 699-66-38 | 1962 | Well | CS, Perf | In use | 133.98 | 133.30 | 150 | 124.5 | 110.4 | 123.71 | 3/12/2009 | X | X | 27 | 125.1 | -1.4 | Piezos O, P, and Q decommissioned. Water table in RUM. |
| 699-66-39 | 1971 | Well | CS, Perf | In use | 139.33 | 138.43 | 90 | 126.8 | 118.6 | 125.38 | 3/12/2009 | X | X | 42 | 125.6 | -0.3 | No unconfined aquifer. |
| 699-66-58 | 1972 | Well | CS, Screen | In use | 154.40 | 153.44 | 112.5 | 125.2 | 119.1 | 121.687 | 3/12/2009 | X | X | X | X | | |
| 699-66-64 | 1972 | Well | CS, Screen | In use | 155.19 | 154.31 | 118 | 125.0 | 119.0 | 121.676 | 3/13/2009 | X | X | X | X | | |
| 699-66-91 | 1973 | Well | CS, Open | In use | 143.57 | 142.62 | 190 | 112.8 | 84.7 | 122.25 | 3/2/2009 | 78 | 118.8 | Absent | Absent | | Basalt at 98 ft (29.9 m). |
| 699-67-51 | 1961 | Piezo Host | CS, Perf | In use | 160.88 | 160.21 | 250 | 129.7 | 84.0 | 121.53 | 3/12/2009 | 145 | 116.0 | 210 | 96.2 | 25.3 | |
| 699-67-51P | 1961 | Piezo | CS, Screen | In use | 160.89 | 160.21 | 250 | 90.1 | 88.6 | 121.32 | 3/12/2009 | X | X | X | X | | |
| 699-67-51Q | 1961 | Piezo | CS, Screen | In use | 160.89 | 160.21 | 250 | 104.1 | 101.1 | 121.54 | 3/12/2009 | X | X | X | X | | |
| 699-67-77 | Unknown | Unknown | Unknown | Decommissioned | Un-known | Un-known | Un-known | Unknown | Unknown | | | X | X | X | X | | No log available. |
| 699-67-86 | 1962 | Piezo Host | CS, Perf | In use | 145.02 | 144.47 | 467 | 126.2 | 114.0 | 121.64 | 3/2/2009 | 73 | 122.2 | 247 | 69.2 | 52.5 | May be deeper mud, not "RUM." Piezos P, Q, R, and S decommissioned. 457 ft (139.3 m) to Lower mud. |
| 699-67-98 | 1960 | Well | CS, Perf | Decommissioned | 139.84 | 139.15 | 185 | 123.9 | 105.6 | | | X | X | 129 | 99.8 | | Basalt at 185 ft (56.4 m). |
| 699-68-105 | 1952 | Well | CS, Perf | In use | 139.45 | 138.93 | 94 | 125.2 | 112.1 | 121.37 | 3/2/2009 | X | X | X | X | | |
| 699-69-45 | 1961 | Piezo Host | CS, Perf | In use | 149.43 | 148.66 | 300 | 124.3 | 57.2 | 121.43 | 3/12/2009 | X | X | 135 | 107.5 | 13.9 | |
| 699-69-45O | 1962 | Piezo | PVC | In use | 149.48 | 148.66 | 300 | 119.1 | 113.0 | 121.43 | 3/12/2009 | X | X | X | X | | |
| 699-69-45P | 1962 | Piezo | PVC | In use | 149.49 | 148.66 | 300 | 70.9 | 64.2 | 120.28 | 3/12/2009 | X | X | X | X | | |
| 699-69-45Q | 1962 | Piezo | PVC | In use | 149.49 | 148.66 | 300 | 142.3 | 57.2 | 119.52 | 3/12/2009 | X | X | X | X | | |
| 699-69-45R | 1962 | Piezo | PVC | In use | 149.49 | 148.66 | 300 | 102.3 | 94.4 | | | X | X | X | X | | |
| 699-71-30 | 1957 | Well | CS, Perf | In use | 123.13 | 122.68 | 150.0 | 115.1 | 98.3 | 113.88 | 3/4/2009 | X | X | 37.0 | 111.4 | 2.5 | |
| 699-71-52 | 1954 | Well | CS, Perf | In use | 160.43 | 159.94 | 210 | 123.4 | 115.1 | 121.29 | 3/12/2009 | X | X | 175 | 106.6 | 14.7 | |
| 699-71-77 | 1962 | Well | CS, Perf | In use | 144.96 | 144.23 | 300 | 125.9 | 106.1 | 121.04 | 3/2/2009 | 80 | 119.8 | 180 | 89.4 | 31.7 | |
| 699-72-73 | 1961 | Well | CS, Perf | In use | 148.13 | 147.55 | 200 | 129.3 | 106.4 | 121.08 | 3/2/2009 | 90 | 120.1 | 167 | 96.6 | 24.4 | |
| 699-72-88 | 1980 | Well | CS, Perf | Decommissioned | 133.10 | 132.38 | 54 | 122.3 | 117.8 | | | X | X | X | X | | |

Table 3-5. Geologic and Well Construction Data for 100-F Wells and Selected Wells in 100-IU-2/IU-6 in Northern Hanford Site

| Well Name | Year Installed | Well Type | Casing and Screen Type | Well Status | Top of Casing Elev. (m) | Surface Elev. (m) | Drilled Depth (ft) | Elev. Top Screen or Perf. (m) | Elev. Bottom Screen or Perf. (m) | Water Level (m) | Water Level Date | Depth to Ringold E (ft) | Elev. Top Ringold E (m) | Depth to RUM (ft) | Elev. Top of RUM (m) | Thickness Upper Aquifer (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 699-72-92 | 1961 | Piezo Host | CS, Perf | In use | 138.05 | 137.20 | 200 | 123.8 | 109.8 | 121.36 | 3/2/2009 | 47.2 | 122.8 | X | X | | Piezos O, P, and Q decommissioned. Ringold E pick uncertain. |
| 699-73-61 | 1962 | Well | CS, Perf | In use | 163.01 | 162.50 | 150 | 129.9 | 118.0 | 121.554 | 3/2/2009 | X | X | X | X | | |
| 699-74-23 | 1943 | Well | | Decommissioned | 115.82 | 114.91 | 50.0 | Unknown | Unknown | | | X | X | 25.0 | 107.3 | | |
| 699-74-44 | 1957 | Well | CS, Perf | In use | 136.70 | 136.28 | 150.0 | 131.1 | 115.9 | 121.32 | 3/12/2009 | X | X | 75.0 | 113.4 | 7.9 | |
| 699-74-48 | 1962 | Piezo Host | CS, Perf | Decommissioned | 149.42 | 148.88 | 150.0 | 124.5 | 104.1 | 115.40 | 3/12/2009 | X | X | 124.0 | 111.1 | 4.3 | Piezos O and P decommissioned. |
| 699-75-23A | 1943 | Well | Unknown | Decommissioned | 116.61 | 115.69 | 35.0 | Unknown | Unknown | | | X | X | 35.0 | 105.0 | | RUM at fine sand. |
| 699-75-23B | 1943 | Well | Unknown | Decommissioned | 116.89 | 115.98 | 36.0 | Unknown | Unknown | | | X | X | 36.0 | 105.0 | | RUM at fine sand. |
| 699-77-36 | 1957 | Well | CS, Perf | In use | 126.67 | 126.09 | 150.0 | 116.3 | 101.1 | 120.62 | 3/12/2009 | X | X | 50.0 | 110.9 | 9.8 | |
| 699-77-54 | 1957 | Well | CS, Perf | In use | 147.35 | 146.92 | 150.0 | 125.6 | 111.3 | 120.57 | 3/1/2010 | 95.0 | 118.0 | 152.0 | 100.6 | 20.0 | Cemented gravel assumed to be RE. |
| 699-78-62 | 1957 | Well | CS, Perf | In use | 144.20 | 143.62 | 150.0 | 122.3 | 110.7 | 123.766 | 3/12/2009 | 63.0 | 124.4 | 130.0 | 104.0 | 19.8 | Cemented gravel assumed to be RE. |
| 699-80-39B | 1944 | Well | CS, Perf | Decommissioned | 124.37 | 123.45 | 53 | Unknown | Unknown | | | X | X | 43 | 110.3 | | |
| 699-80-43P | 1965 | Single Piezo | CS, Screen | In use | 127.14 | 126.68 | 450.0 | -5.9 | -9.0 | 126.17 | 3/1/2010 | X | X | 45.0 | 113.0 | 13.2 | Basalt at 440 ft (134.1 m) depth; screened across basalt/Ringold contact. |
| 699-80-43Q | 1965 | Single Piezo | CS, Screen | Decommissioned | 126.87 | 126.41 | 232.0 | 59.2 | 56.2 | | | X | X | 45.0 | 112.7 | | |
| 699-80-43R | 1965 | Single Piezo | CS, Screen | Decommissioned | 126.91 | 126.46 | 140.0 | 86.8 | 83.8 | | | X | X | 45.0 | 112.7 | | |
| 699-80-43S | 1965 | Single Piezo | CS, Screen | In use | 126.82 | 126.36 | 50.0 | 117.2 | 111.1 | 118.42 | 3/12/2009 | X | X | X | X | | |
| 699-81-38 | Unknown | Well | Aluminum | In use | 124.89 | 124.76 | 35.4 | Unknown | Unknown | 116.17 | 3/12/2009 | X | X | X | X | | |
| 699-81-58 | 1962 | Well | CS, Perf | In use | 134.99 | 134.20 | 150.0 | 123.5 | 108.6 | 119.88 | 3/3/2009 | X | X | 95.0 | 105.2 | 14.6 | Piezos O and P removed. |
| 699-83-47 | 1957 | Well | CS, Perf | In use | 133.70 | 133.17 | 150.0 | 122.5 | 107.3 | 118.76 | 3/12/2009 | 35.0 | 122.5 | 95.0 | 104.2 | 14.5 | |
| 699-84-35A | 1962 | Piezo Host | CS, Perf | In use | 122.96 | 122.34 | 370.0 | 119.3 | 14.1 | | | X | X | X | X | | Basalt at 360 ft (109.7 m). |
| 699-84-35AO | 1962 | Piezo | ABS | In use | 123.03 | 122.40 | 370.0 | 119.3 | 107.7 | 115.04 | 3/12/2009 | X | X | X | X | | Monitors unconfined aquifer. |
| 699-84-35AP | 1962 | Piezo | ABS | In use | 123.03 | 122.40 | 370.0 | 20.0 | 12.4 | 121.66 | 3/12/2009 | X | X | X | X | | Screened in Ringold lower mud? |
| 699-84-35AQ | 1962 | Piezo | ABS | In use | 123.03 | 122.41 | 370.0 | 45.3 | 37.7 | 114.89 | 3/12/2009 | X | X | X | X | | Screened in Ringold unit B? |
| 699-84-35AR | 1962 | Piezo | ABS | In use | 123.03 | 122.41 | 370.0 | 86.5 | 78.8 | 114.66 | 3/12/2009 | X | X | X | X | | Screened in paleosol/overbank deposits? |
| 699-84-35AS | 1962 | Piezo | ABS | In use | 123.03 | 122.40 | 370.0 | 121.4 | 113.7 | 114.64 | 3/12/2009 | X | X | X | X | | Screened in paleosol/overbank deposits? |
| 699-86-60 | 1961 | Borehole | CS, Perf | Decommissioned | 139.32 | 138.41 | 531.0 | 123.2 | -14.0 | | | 55 | 121.6 | 96.0 | 109.1 | | Basalt at 520 ft (158.5). |

Table 3-5. Geologic and Well Construction Data for 100-F Wells and Selected Wells in 100-IU-2/IU-6 in Northern Hanford Site

| Well Name | Year Installed | Well Type | Casing and Screen Type | Well Status | Top of Casing Elev. (m) | Surface Elev. (m) | Drilled Depth (ft) | Elev. Top Screen or Perf. (m) | Elev. Bottom Screen or Perf. (m) | Water Level (m) | Water Level Date | Depth to Ringold E (ft) | Elev. Top Ringold E (m) | Depth to RUM (ft) | Elev. Top of RUM (m) | Thickness Upper Aquifer (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 699-89-35 | 1961 | Well | CS, Perf | In use | 122.35 | 121.77 | 75.0 | 115.7 | 102.3 | 114.02 | 3/5/2009 | X | X | 55.0 | 105.0 | 9.0 | |
| C7971 | 2011 | Borehole | N/A | Decommissioned | N/A | 122.14 | 33.5 | None | None | 114.15 | 2/11/2011 | X | X | 29 | 113.3 | 0.8 | |

Notes:

199-F1-1, 199-F2-1, 199-F2-2, 199-F2-4, 199-F2-5, and 199-F4-2 additional F wells installed 1943 -- no data in HEIS, limited documentation. Decommissioned.

199-F5-8 through -F5-41:Limited documentation. Possibly vadose boreholes. Decommissioned.

199-F5-49, -50, -51, 199-F8-5, and -6 vadose boreholes installed and decommissioned 1993

ABS = acrylonitrile-butadiene-styrene (terpolymer)

CS = carbon steel

SS = stainless steel

Perf = perforated casing

X = undetermined

1

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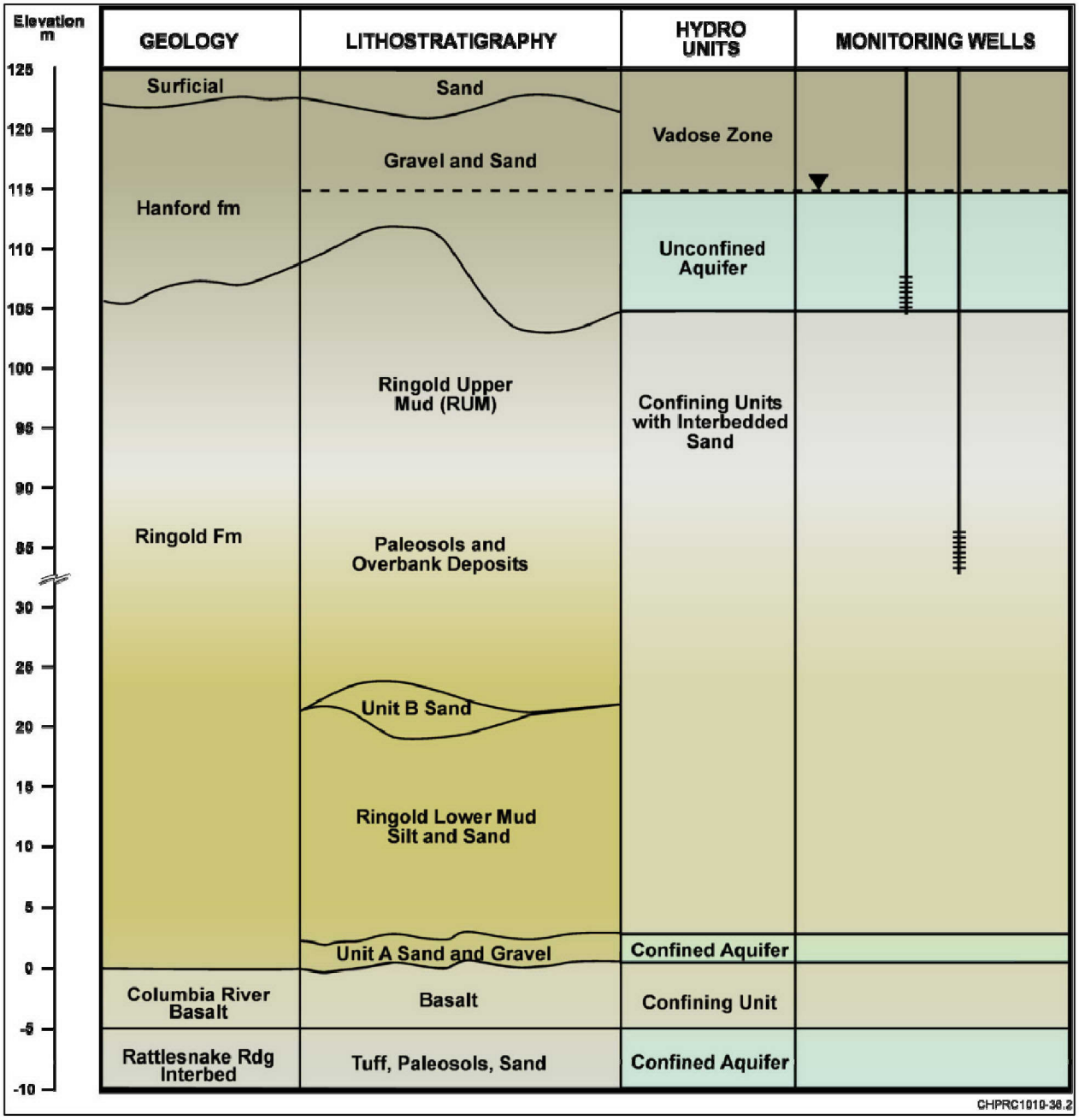


Figure 3-9. Stratigraphy and Hydrogeologic Units of 100-F

The following paragraphs provide generalized descriptions of the major geologic units, from shallowest to deepest. General geologic descriptions are taken from *Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports* (WHC-SD-ER-TI-003). Sections 3.4.2 through 3.4.5 provide descriptions of geology specific to 100-F, 100-IU-2/IU-6 north of Gable Mountain, and 100-IU-2/IU-6 south of Gable Mountain.

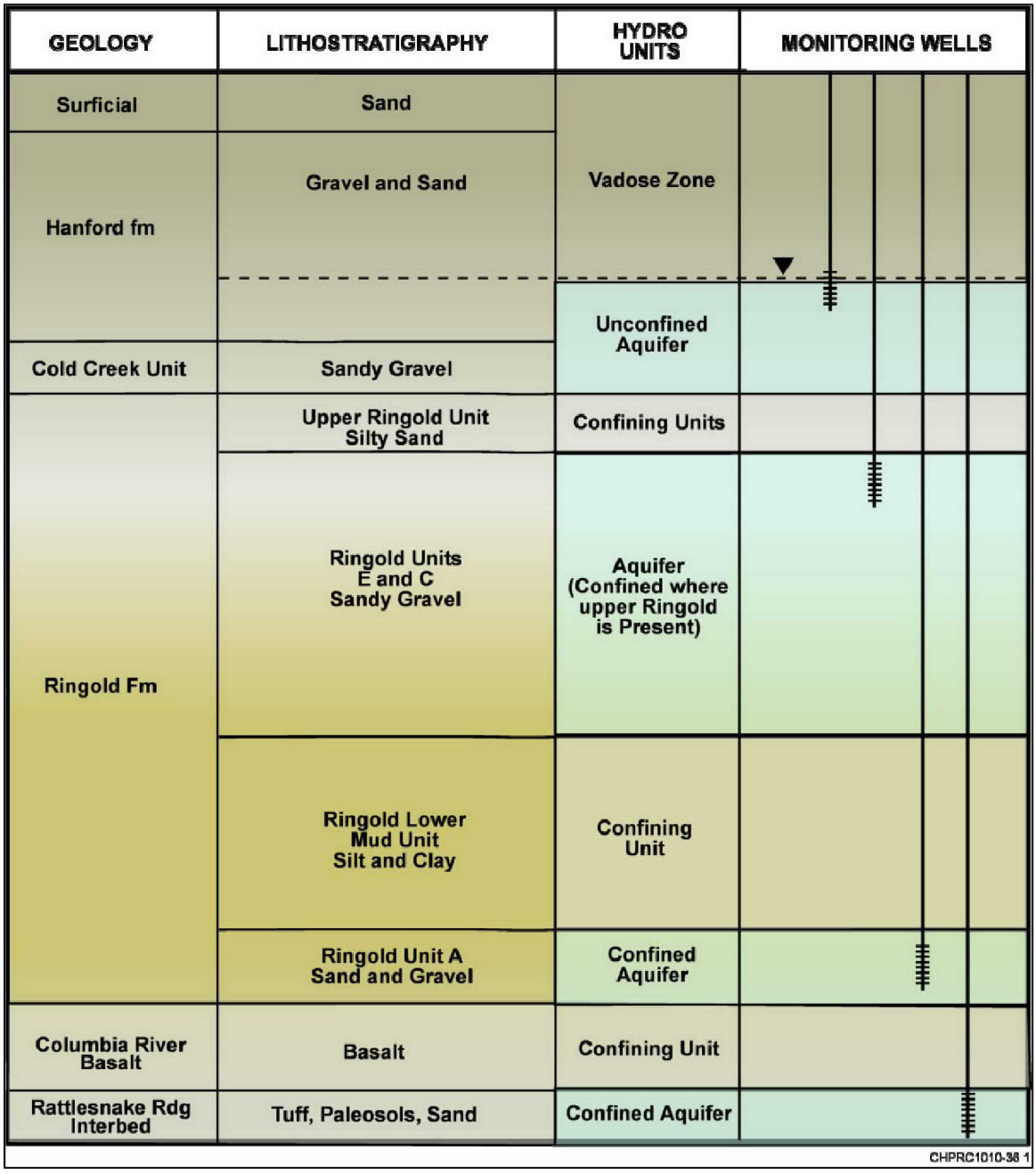


Figure 3-10. Stratigraphy and Hydrogeologic Units of 100-IU-2/IU-6

**Surface Deposits:** Recent, localized surficial deposits consist of silt, sand, and gravel that form a relatively thin (less than 5 m [16 ft]) veneer across the area. These sediments were deposited by a mix of eolian and alluvial processes during the past 10,000 years and consist of very fine- to medium-grained angular to sub-angular sand with small amounts of silt and gravel. In some portions of the area, the surficial sediments consist of reworked backfill material comprising Hanford formation materials.

**Hanford formation:** This unit is characterized by cobble- to boulder-size clasts in open framework gravels that include discrete sand lenses, with minor to no silt and clay material. The grains typically are sub-round to round gravel and sub-angular to round in the sand grain fraction. The gravel-dominated

facies is typically well stratified and contains little to no cementation (*Geologic Setting of the 100-HR-3 Operable Unit, Hanford Site, South-Central Washington* [WHC-SD-EN-TI-132]).

The Hanford formation is divided into three facies: (1) gravel-dominated, (2) sand-dominated, and (3) silt-dominated (*Standardized Stratigraphic Nomenclature for the Post-Ringold-Formation Sediments Within the Central Pasco Basin* [DOE/RL-2002-39]). The Hanford formation comprises the dominant material throughout the 100 Area vadose zone, where numerous contaminant sources either have been remediated or await remediation.

**Post-Ringold, Pre-Hanford Deposits:** Thin alluvial deposits between the Ringold Formation and Hanford formation are found in some portions of 100-IU-2/IU-6. These deposits are informally referred to as the Plio-Pleistocene unit, Cold Creek unit (formerly known as pre-Missoula gravels), and early "Palouse" soil.

**Ringold Formation:** This sedimentary unit is composed of units of loose to semi-hardened clay, silt, sand, and gravel. The Ringold Formation units include:

- Ringold units E, C, B, and A: Sand and gravel units of variable thickness, separated stratigraphically by finer-grained sediments (paleosol/lacustrine/overbank deposits). Not all of these units are continuous and often cannot be correlated from area to area.
- RUM: The shallowest, fine-grained layer beneath the northern Hanford Site has been informally termed the RUM unit. It is present beneath Ringold unit E and the Hanford formation. This unit is not always distinct from other fine-grained sediments of the Ringold Formation. The term "RUM" has not been applied to the area south of Gable Mountain.
- Upper Ringold: Fine-grained sediments that overlie Ringold unit E in some locations south of Gable Mountain.
- Ringold lower mud: Deepest layer of fine-grained sediments in the Ringold Formation.

**Columbia River Basalt Group:** This thick sequence forms the bedrock beneath the sediments of the Hanford Site. The Columbia River Basalt Group is greater than 3,000 m (9,800 ft) thick. The uppermost basalt unit beneath the Hanford Site is the Saddle Mountains Basalt, except where it is eroded away near the 300 Area (Geology and Hydrology of the Hanford Site [WHC-SD-ER-TI-003]). Sedimentary interbeds of the Ellensburg Formation (for example, Rattlesnake Ridge and Levey interbeds) are layered between basalt flows.

Major geologic structures on the Hanford Site (Geology and Hydrology of the Hanford Site [WHC-SD-ER-TI-003]) include:

- Gable Mountain anticline is a segmented anticlinal ridge extending in an east-west direction between the 100 and 200 Areas. The structure includes Umtanum Ridge, Gable Butte, and Gable Mountain.
- Cold Creek syncline lies south of the Gable Mountain anticline, and is an asymmetric and relatively flat-bottom structure.
- Wahluke syncline is an asymmetric, flat-bottomed structure trending east-west through the 100 Area. The steepest limb is adjacent to the Gable Mountain anticline.

### 3.4.2 Geology of 100-F

The primary geologic units beneath 100-F are the Hanford formation, the RUM unit, deeper units of the Ringold Formation, and Columbia River Basalt (Figure 3-9). The shallow stratigraphy of 100-F was fairly

well defined before RI activities. Data from recent RI wells and boreholes contributed a small amount of new geologic information. This was combined with re-evaluated data from older wells to create new geologic cross sections and maps. *100 Area Stratigraphic Database Development* (ECF-100NPL-11-0070) describes the process used to create geologic maps and cross sections presented in this section.

The Hanford formation beneath 100-F varies in thickness from approximately 9 m (30 ft) in the southwest (Well 199-F7-1) to approximately 21 m (69 ft) in the northeast (Well 199-F5-6) (*Geology of the 100-FR-3 Operable Unit, Hanford Site South-Central Washington* [WHC-SD-EN-TI-221]). Gravel-rich strata appear to be most common. Sand-dominated intervals also are present, but appear to be local in extent. Silt-dominated strata have not been identified at 100-F.

The RUM underlies the Hanford formation beneath 100-F; Ringold unit E generally is not present. Borehole logs from some wells, mainly those in central 100-F, suggest the possible presence of remnants of Ringold unit E (Table 3-5), but it is difficult to distinguish between Hanford and Ringold gravels. Because the possible contacts are uncertain, cross sections presented in this chapter do not depict the presence of Ringold unit E and assume the gravels are Hanford formation.

The deepest well in 100-F, 199-F5-43B, was drilled 46 m (150 ft) into silty clay and clayey silt. These fine-grained sediments may be a combination of the RUM and deeper fines. No wells in 100-F penetrate the full thickness of these fine-grained sediments. Deeper water-bearing units and aquitards in the Ringold Formation beneath 100-F are inferred from driller's logs from nearby wells. These may consist of gravel units B and C and paleosol-lacustrine deposits including the Ringold lower mud (*Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas* [WHC-SD-EN-TI-011]).

Most wells in 100-F were drilled to the top of the RUM at elevations ranging from 105 to 112 m (344 to 367 ft) amsl. Figure 3-11 illustrates the elevation of the top of the RUM beneath 100-F. The RUM was scoured by river channel migration and glacial flood erosion that ultimately laid down the Hanford formation, resulting in an undulating surface that slopes generally toward the present-day Columbia River in this region. The current river channel cuts into RUM in the northern portion of the shoreline (Figure 3-12).

No wells located in 100-F reach basalt. Nearby wells that reach basalt include Well 699-84-35A, with basalt at a depth of 110 m (360 ft), or elevation of 13 m (40 ft) amsl; and Well 699-80-43, with basalt at a depth of 134 m (440 ft), or elevation of ~7 m (24 ft) m below mean sea level.

Figures 3-12 and 3-13 are geologic cross sections through 100-F. The sections show a consistent stratigraphy of Hanford formation (sandy gravel) over a thick unit of Ringold Formation mud (silt).

### 3.4.3 Geologic Data from RI Wells and Boreholes in 100-F

Table 3-5 includes geologic and well construction data of the wells and boreholes installed for the RI. Additional information, including geologic and geophysical logs, are included in borehole summary reports (SGW-49445 and SGW-50130). Figure 3-1 shows the locations of wells and boreholes discussed in this chapter.

Figures 3-14 through 3-19 summarize information about monitoring wells and vadose zone boreholes drilled for the RI, including geology, sampled intervals, well completion, geophysics, and soil contaminants. The subsections below discuss geologic information for each well and borehole. Section 3.5.2 discusses physical properties of the vadose zone, and Section 3.6.2 describes hydrogeologic properties of the aquifer and aquitard. Results of spectral gamma logging and chemical analyses of sediment and groundwater samples are described in Sections 4.2 and 4.3.

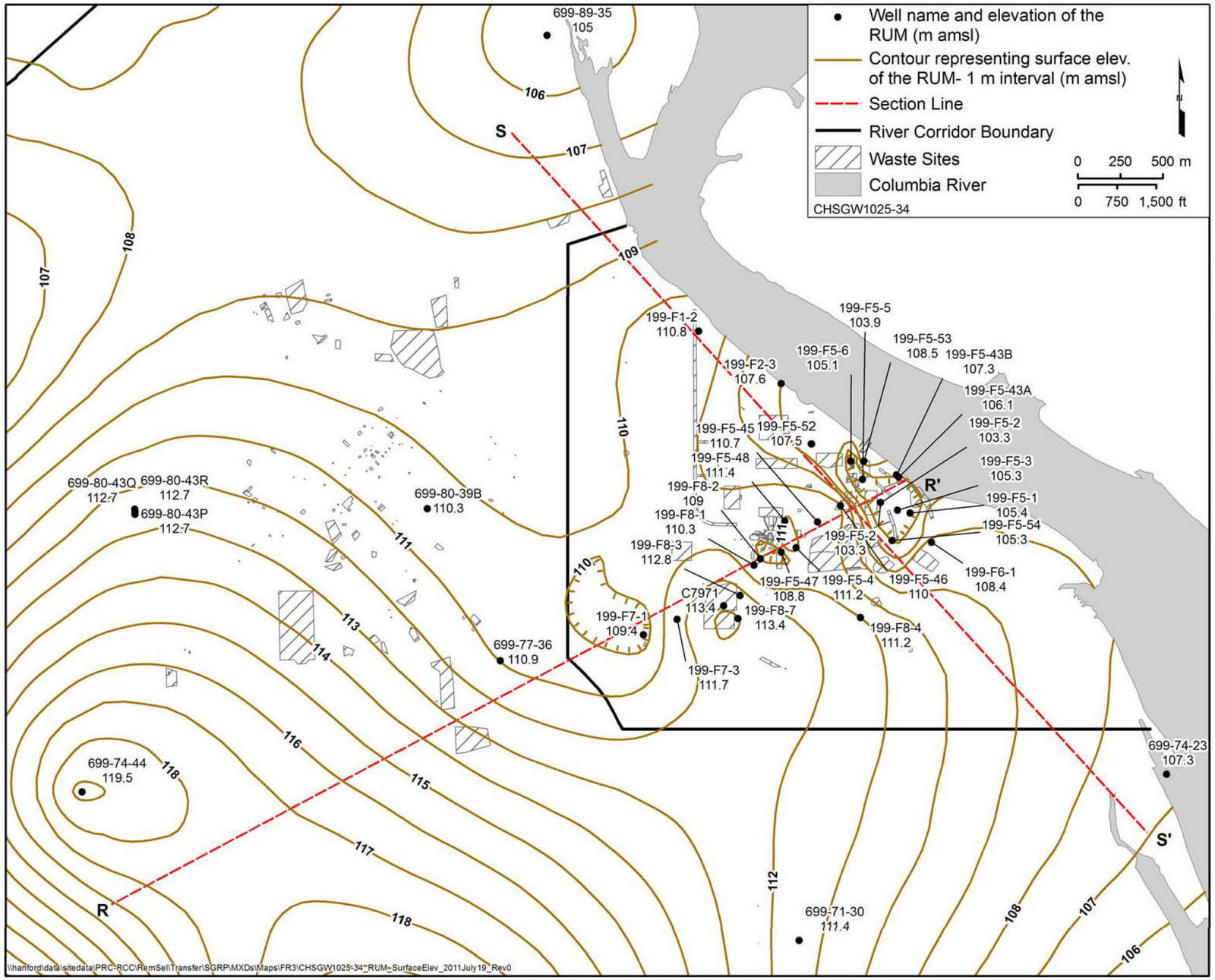


Figure 3-11. Elevation of Top of Ringold Upper Mud, 100-F

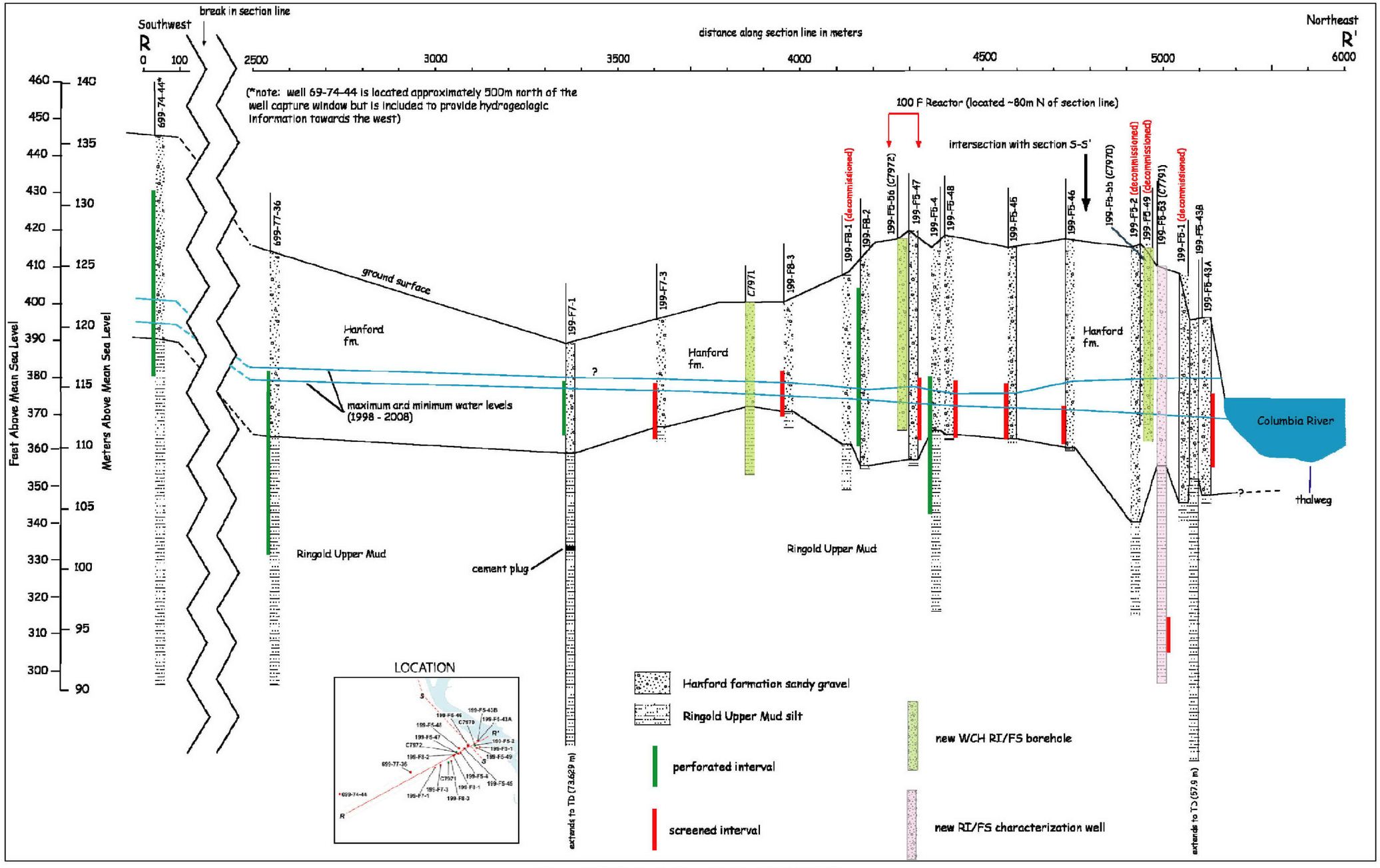


Figure 3-12. Geologic Cross Section R-R' at 100-F

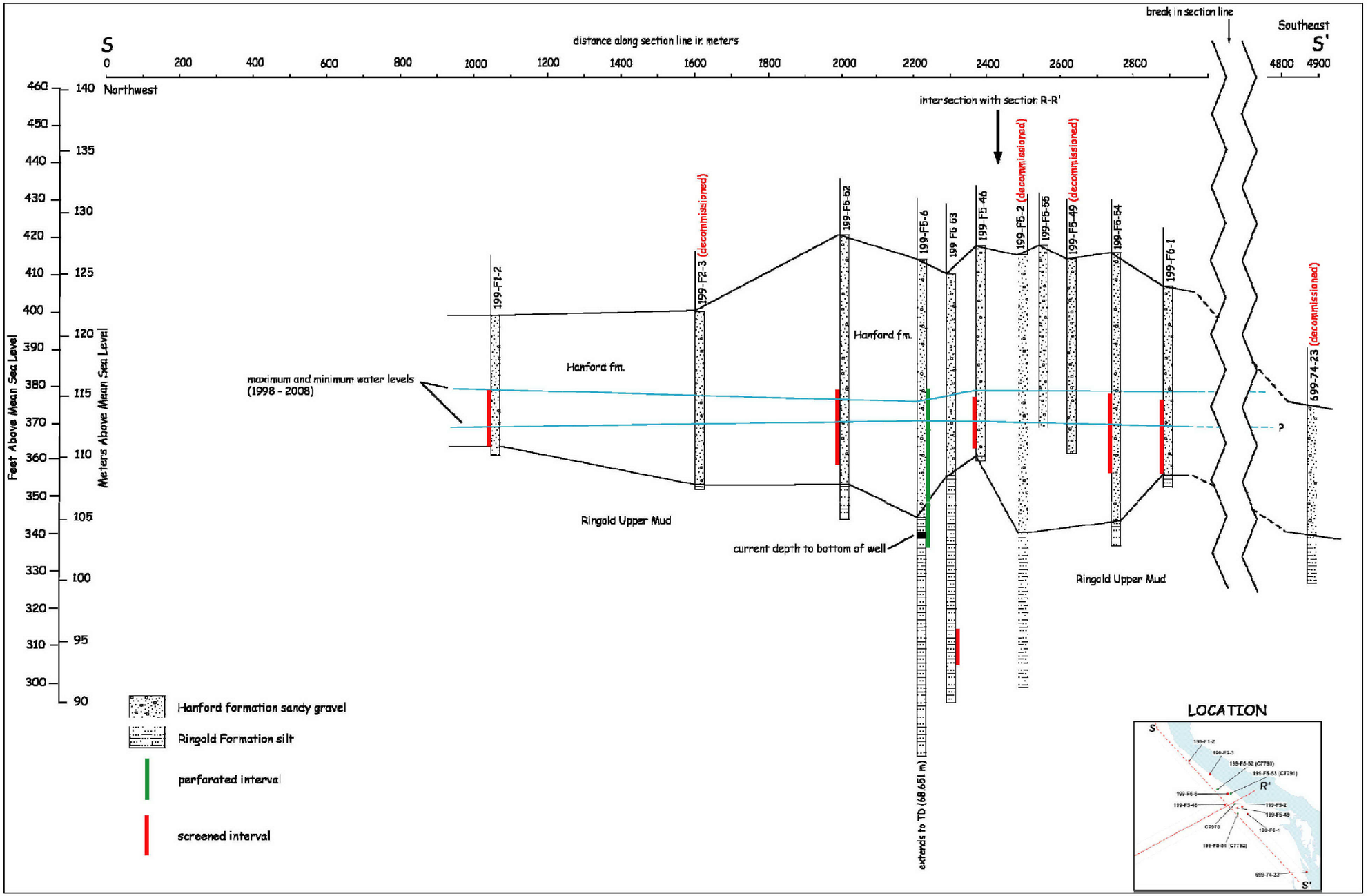


Figure 3-13. Geologic Cross Section S-S' at 100-F

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Geologic information gained from the recent RI wells and boreholes did not significantly change geologic interpretations. The contact between the Hanford formation and the RUM was fairly well established before the RI wells were drilled.

#### 3.4.3.1 Well 199-F5-52

Figure 3-14 summarizes information for Well 199-F5-52, located in northern 100-F. The borehole was drilled using cable tool and a drive barrel. The well is screened in the uppermost portion of the unconfined aquifer, which is approximately 6 m (20 ft) thick at this location.

Stratigraphic units encountered during drilling included backfill, Hanford formation, and the RUM unit. Gravel backfill from the drill pad was present to a depth of 0.3 m (1 ft) bgs. The Hanford formation was encountered from 0.3 to 20 m (1 to 66 ft) bgs and generally comprised gravel, sandy gravel, silty gravel, silty sandy gravel, and gravelly sand. Clasts were subangular to rounded, granule- to cobble-sized gravels and basaltic clasts tended to be more angular and more common than those of other mineralogical compositions (i.e., quartzofeldspathic and metamorphic). Gradual changes with depth in the mineralogy of the Hanford formation were visible. The basalt content of the Hanford formation varied from approximately 70 percent near the ground surface to approximately 45 percent near the Hanford/RUM contact. Carbonates in the formation near the ground surface were evidenced by cemented sediments and a strong reaction to hydrochloric acid, which began to weaken at 6.7 m (22 ft) bgs and was no longer visible at 11 m (36 ft) bgs. The RUM unit was encountered at 20 m (66 ft) bgs and continued to the total depth of 22.5 m (73.8 ft). The Hanford/RUM contact was marked by a very sharp transition from a grayish-brown gravel to a carbonate-rich, pale yellow caliche, and light olive brown silt.

#### 3.4.3.2 Well 199-F5-53

Figure 3-15 summarizes information for Well 199-F5-53, located in northeastern 100-F. The borehole was drilled using cable tool with a drive barrel. The well is screened in a water-bearing zone of the RUM.

Stratigraphic units encountered during drilling included backfill, Hanford formation, and the RUM unit. Gravel backfill from the drill pad was present to a depth of 0.3 m (1 ft) bgs. The Hanford formation was encountered from 0.3 to 16.6 m (1 to 54.5 ft) bgs and generally consisted of sandy gravel and gravel with a mineralogical composition similar to that of Well 199-F5-52. Fine-grained layers of silty sand from 2.7 to 3.9 m (9 to 13 ft) bgs and sand from 14.6 to 16.6 m (48 to 54.5 ft) bgs were observed. A weak to moderate reaction to hydrochloric acid was in evidence from 2.7 to 6.7 m (9 to 22 ft) bgs. A sharp Hanford/RUM contact was encountered at 16.6 m (54.5 ft) bgs. The RUM consisted of clayey silt from the Hanford/RUM contact to 19.5 m (64 ft) bgs and clayey silty sand and silt to the borehole's total depth of 35.4 m (116.0 ft). The sand component of the RUM had a mineralogical makeup that was mainly quartzofeldspathic with some carbonate. Caliche was observed as discrete layers or as cement nodules within the sand between 18.3 and 20.7 m (60 and 68 ft) bgs. A water-bearing unit within the RUM was observed from 30.8 to 32.9 m (101 to 108 ft) bgs.

#### 3.4.3.3 Well 199-F5-54

Figure 3-16 summarizes information for Well 199-F5-54, located in eastern 100-F. The borehole was drilled using cable tool and a drive barrel. The well is screened in the uppermost portion of the unconfined aquifer, which is approximately 7.9 m (26 ft) thick at this location.

Stratigraphic units encountered during drilling included backfill, Hanford formation, and the RUM unit. Gravel backfill of the drill pad was present to a depth of 0.3 m (1 ft) bgs. The Hanford formation was encountered from 0.3 to 21.3 m (1 to 69.8 ft) bgs and generally consisted of silty sandy gravel, sandy gravel, gravelly sand, and sand. The gravel contained a range of clasts from angular, basaltic granules and pebbles to rounded, quartzofeldspathic and metamorphic cobbles. Gradual changes with depth in

the mineralogy and grain size distribution of the Hanford formation were visible. The basalt content of the Hanford formation varied from approximately 60 percent near the ground surface to approximately 25 percent near the Hanford/RUM contact. The average grain size of the Hanford formation also decreased with depth from a more gravelly texture near the ground surface to nearly pure sand near the Hanford/RUM contact. Carbonates in the formation near the ground surface were evidenced by a weak to moderate reaction to hydrochloric acid, which began to weaken at 5.8 m (19 ft) bgs, decreasing to no reaction below 8.5 m (28 ft) bgs. The RUM unit was encountered at 21.3 m (69.8 ft) bgs and continued to the total depth of 23.6 m (77.4 ft). The Hanford/RUM contact was marked by a very sharp transition from a dark grayish-brown sand to a multicolored, clayey silt with moderate reaction to hydrochloric acid.

#### *3.4.3.4 Borehole C7970 (Well 199-F5-55)*

Figure 3-17 summarizes information for borehole C7970, located at waste site 116-F-14. The borehole was drilled using cable tool with a drive barrel.

Stratigraphic units encountered during drilling included backfill and the Hanford formation. From ground surface to 3.0 m (10 ft) bgs, the material was represented by 60 percent sand and 40 percent gravel and is classified as sandy gravel. The sand ranged from very fine to very coarse, sub-round to sub-angular. Approximately 90 percent of the gravels ranged from very fine to coarse pebbles, while 10 percent were large cobbles. The bulk of the material was mafic and the remaining material was felsic. The dominant color was brown, and there was no reaction with hydrochloric acid. At 3.0 m (10 ft) bgs, the color changed to dark grayish-brown. Grain sizes comprised 10 percent large cobbles, 30 percent very fine to coarse pebbles, 55 percent sand, and 5 percent silt. The sand at this depth has a weak reaction to hydrochloric acid.

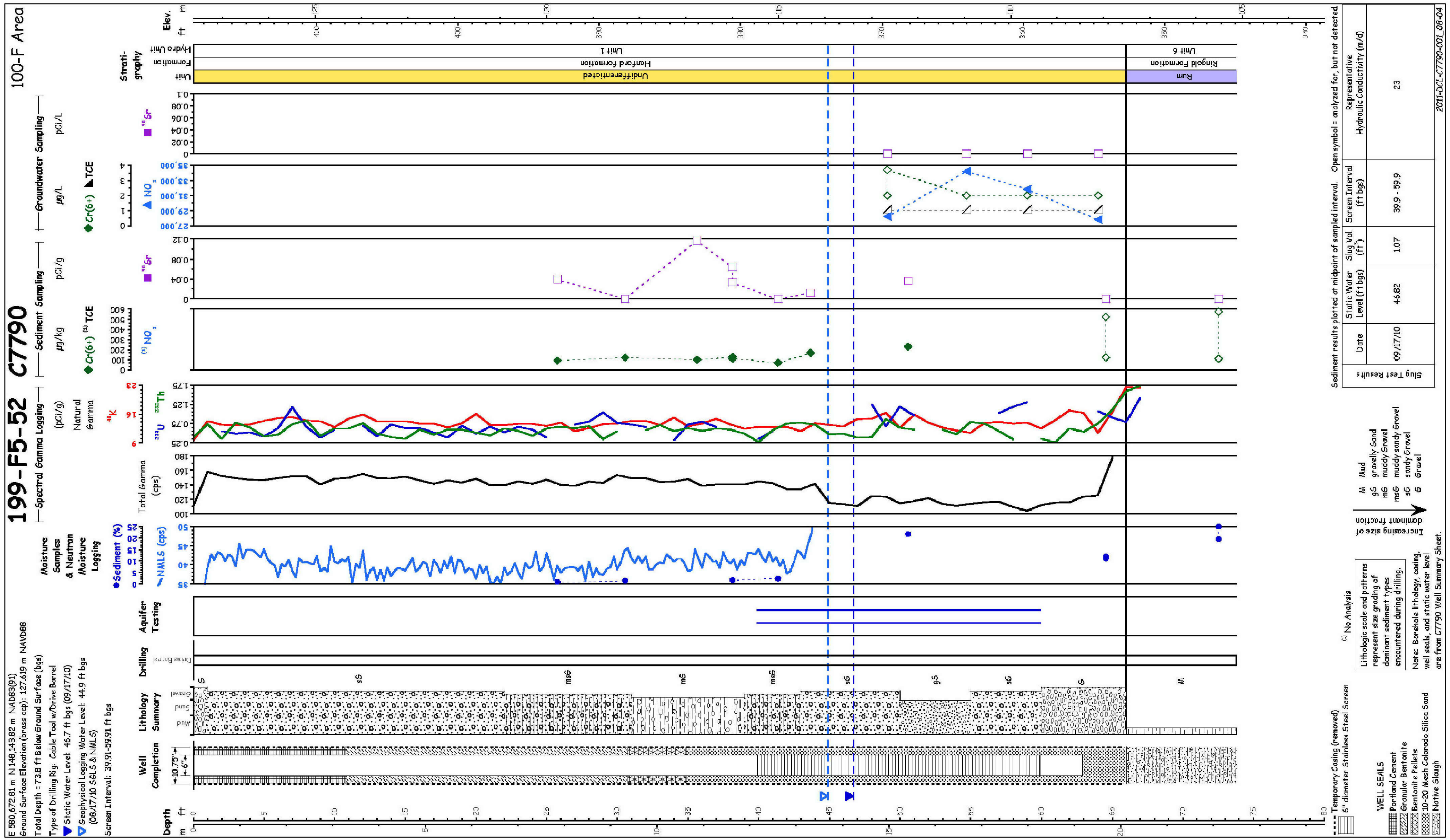
From 6.0 to 14.8 m (20 to 48.4 ft) bgs, silty sandy gravel dominated. Gravel consistency ranged from very fine to very coarse pebbles. The sand content ranged from 35 to 45 percent. The silt percentage held consistent near 10 percent. The dominant color of the material varied from a red-brown grading to a dark grey. At 6.0 m (20 ft) bgs, 90 percent of the material was felsic and the remaining 10 percent was mafic. The felsic content decreased with depth to 20 percent felsic and 80 percent mafic at 12.2 m (40 ft) bgs. The material did not react with hydrochloric acid in this range, except weakly at 6.0 m (20 ft) bgs. The static water table was encountered at 12.9 m (42.3 ft) bgs.

The total depth of this borehole was 15.2 m (50.0 ft). It was completed as a temporary well, 199-F5-55, screened at the top of the unconfined aquifer.

#### *3.4.3.5 Borehole C7971*

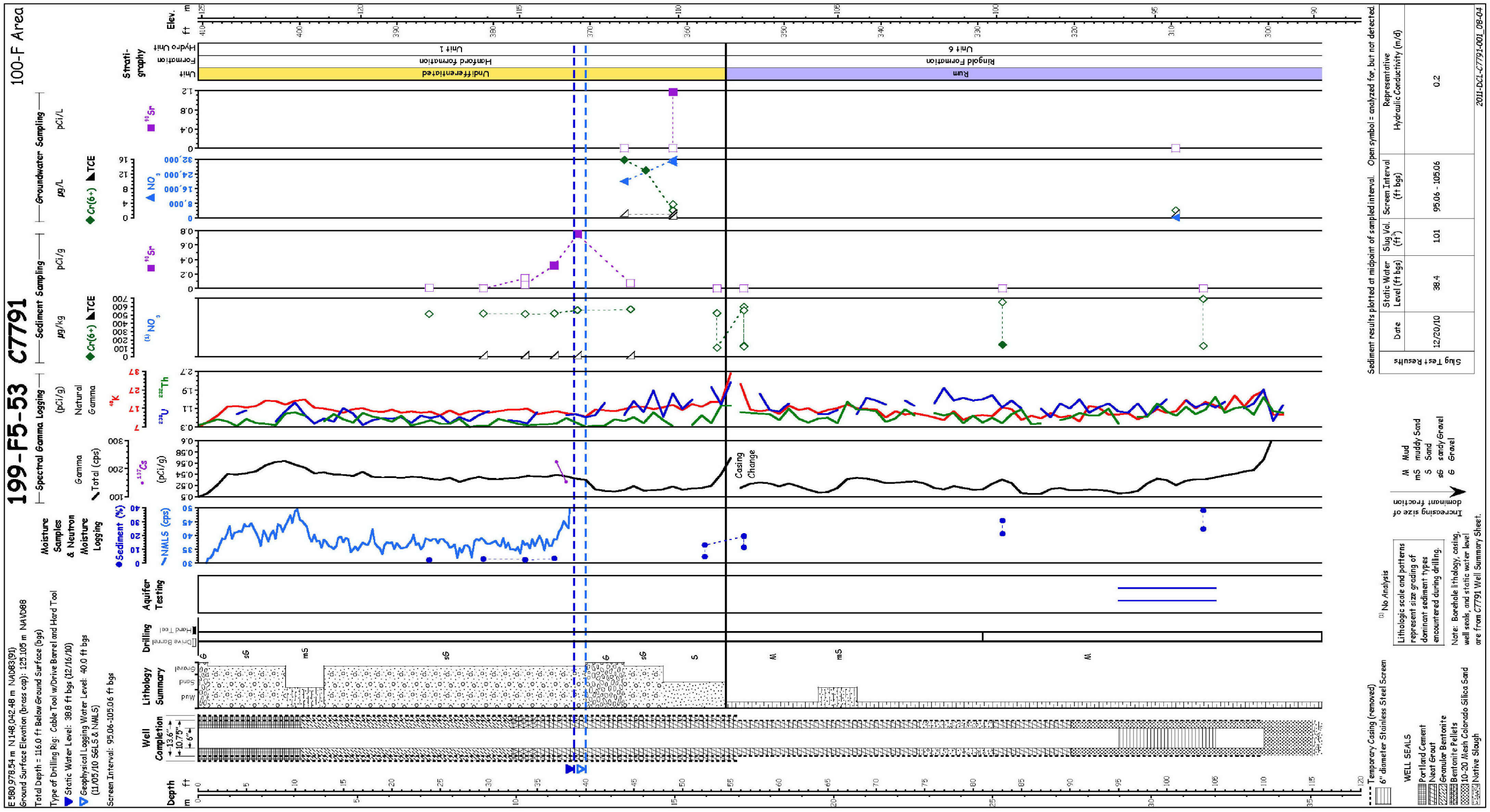
Figure 3-18 summarizes information for borehole C7971, located at the waste site 116-F-1 burial ground. The borehole was drilled using cable tool with a drive barrel and was decommissioned after sampling. Geologic units encountered throughout the drilling of this borehole were eolian sands, the Hanford formation, and the RUM unit.

Eolian sandy gravel was present from ground surface to 4.0 m (13 ft) bgs The sandy gravel was represented by 60 percent medium-grained, sub-rounded sand and 40 percent gravel (medium pebbles to large cobbles). The mineralogy of sandy gravel was 15 percent mafic and 85 percent felsic. The dominant color of the sandy gravel was dark gray, and there was a weak reaction to hydrochloric acid.



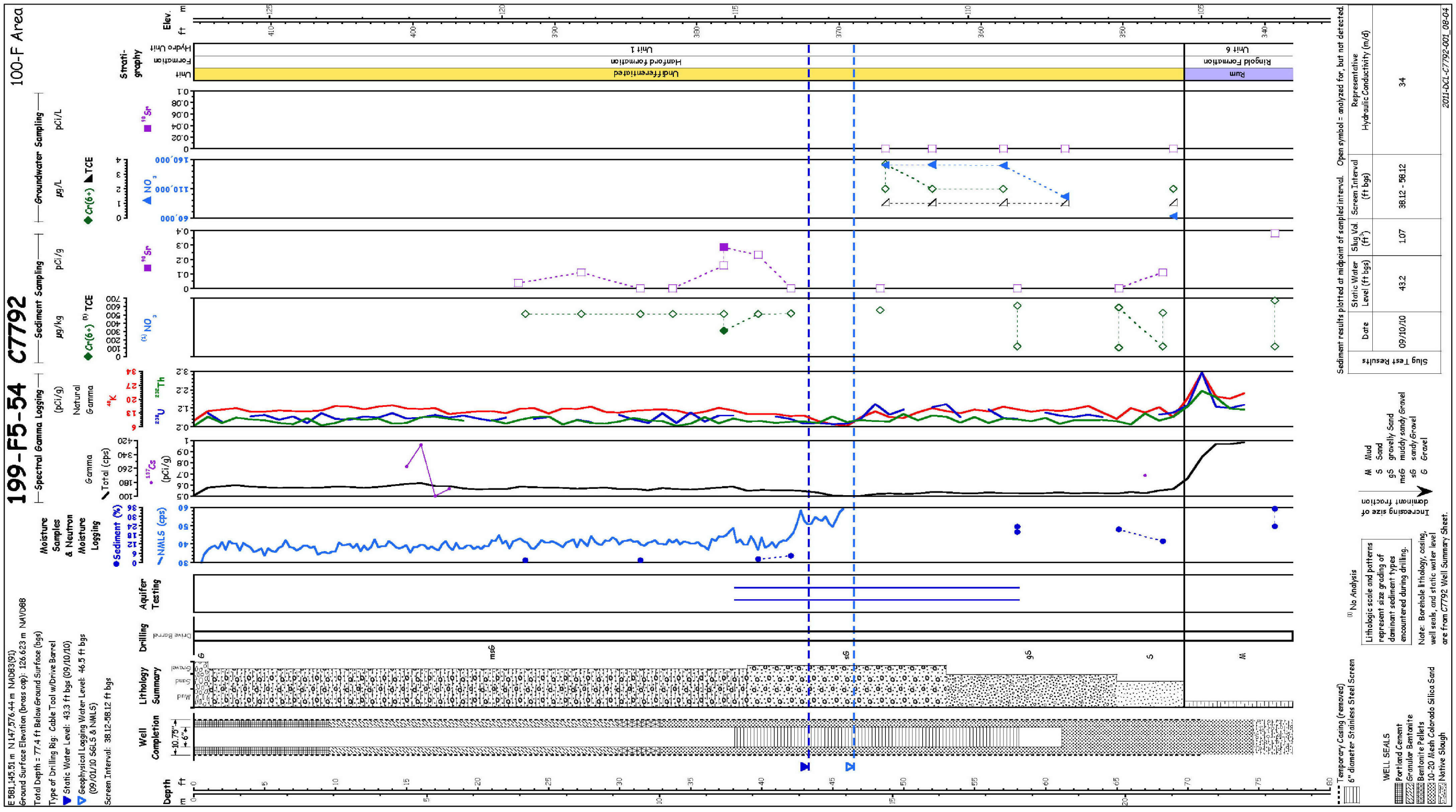

Sources: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

Figure 3-14. Summary of Characterization Data for Well 199-F5-52



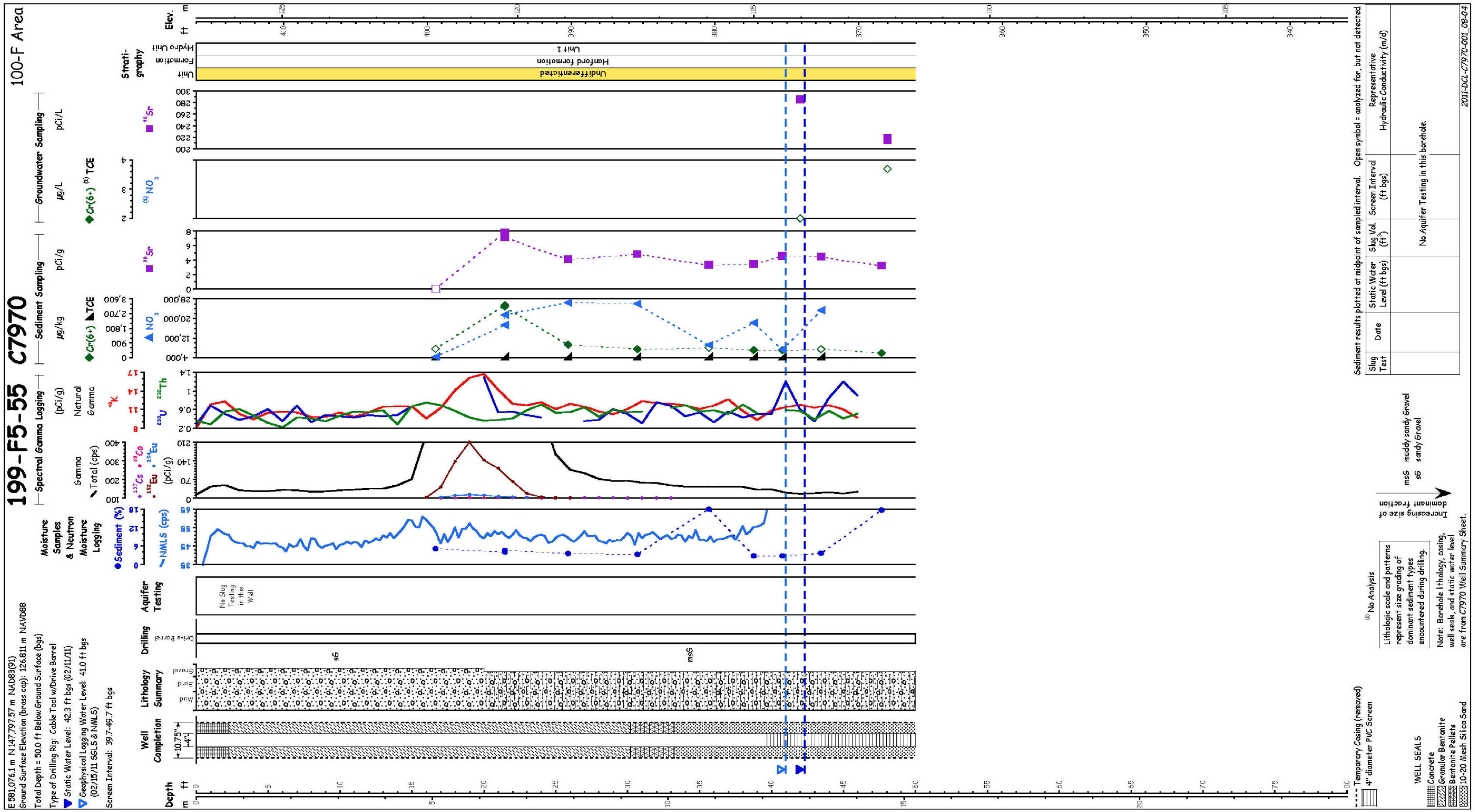

Sources: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

Figure 3-15. Summary of Characterization Data for Well 199-F5-53



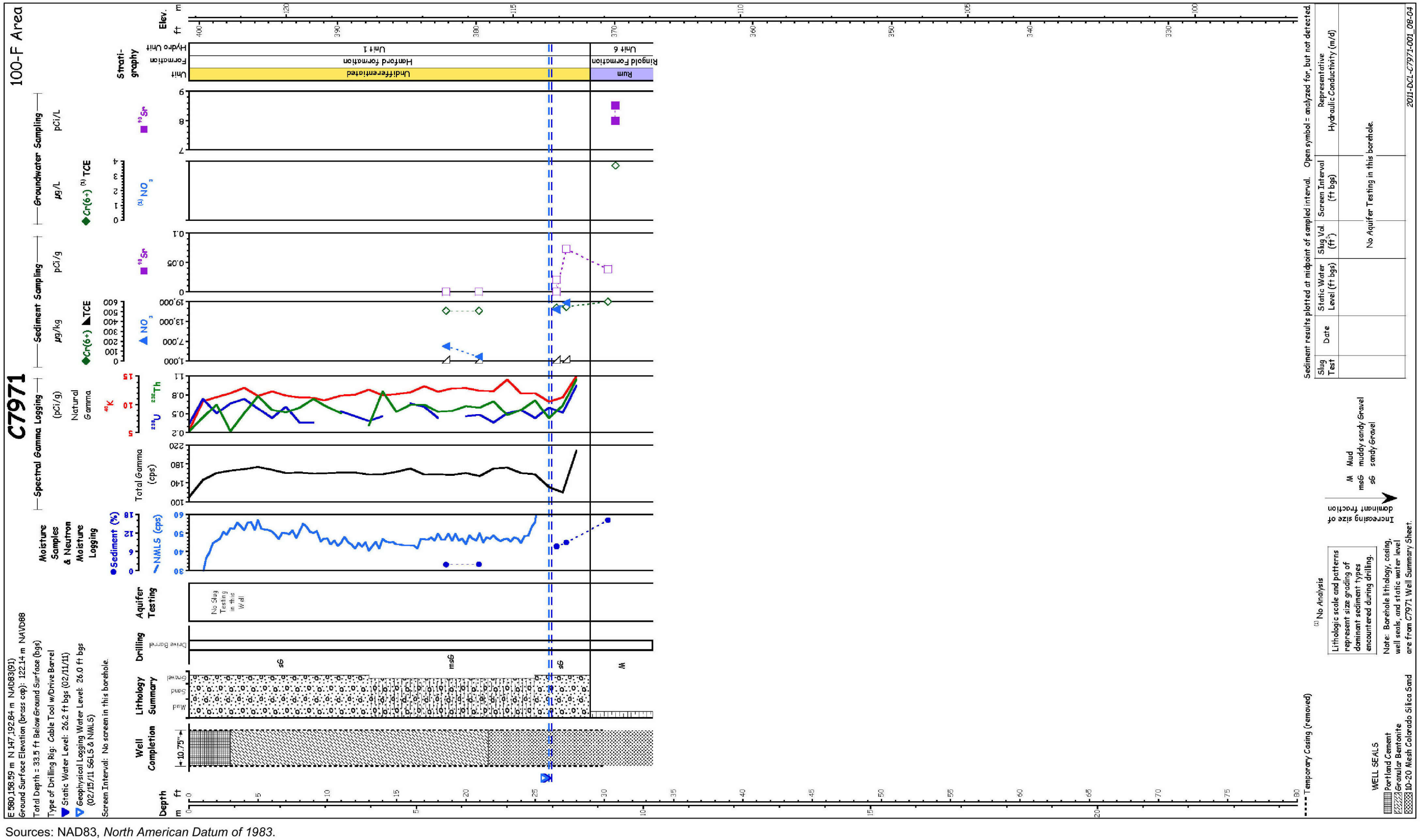

Sources: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

Figure 3-16. Summary of Characterization Data for Well 199-F5-54



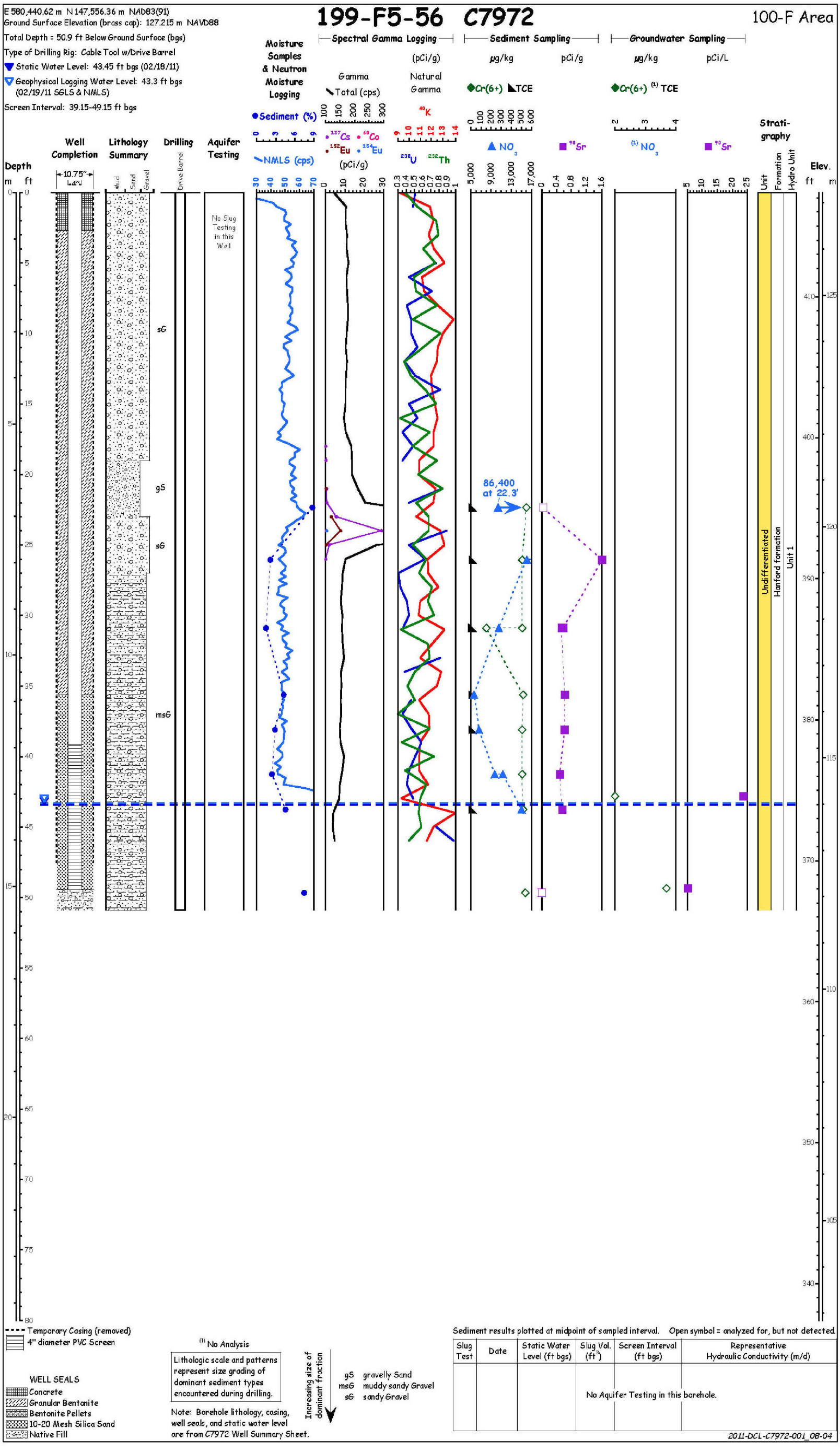

Sources: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

Figure 3-17. Summary of Characterization Data for Borehole C7970 (Well 199-F5-55)




Sources: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

Figure 3-18. Summary of Characterization Data for Borehole C7971




Source: NAD83, *North American Datum of 1983*.
NAVD88, *North American Vertical Datum of 1988*.

Figure 3-19. Summary of Characterization Data for Borehole C7972 (Well 199-F5-56)

The Hanford formation was present from 4.0 to 8.8 m (13 to 29 ft) bgs. Gravelly sandy silt was present to a depth of 6.7 m (22 ft) bgs. Grain sizes were 20 percent sand, 20 percent gravel, and 60 percent silt. The sand ranged from fine to medium grained. The gravel ranged from fine to medium pebbles. The mineralogy of the gravelly sandy silt was 85 percent mafic and 15 percent felsic. The dominant color was gray and there was a moderate reaction to hydrochloric acid. From 6.7 to 7.6 m (22 to 25 ft) bgs, slightly silty sandy gravel was present. The sand ranged from medium to coarse-grained and sub-rounded to rounded. The gravel ranged from fine to coarse pebbles and was sub-angular to sub-rounded. The mineralogy of the gravel was 80 percent mafic and 20 percent felsic. The dominant color was dark gray, and there was no reaction to hydrochloric acid. From 7.6 to 8.8 m (25 to 29 ft) bgs sandy gravel was present. The sand was consistently course grained and sub-rounded. The gravel was fine to very coarse pebbles and sub-rounded. The dominant color was very dark gray. From 8.8 m (29 ft) to the total depth of 10.2 m (33.5 ft), clay was present, interpreted to be the RUM unit. The clay showed high levels of plasticity, and the dominant color was gray.

#### *3.4.3.6 Borehole C7972 (Well 199-F5-56)*

Figure 3-19 summarizes information for borehole C7972, located at waste site 116-F-8. The borehole was drilled using cable tool with a drive barrel.

The only unit encountered throughout the drilling of this borehole was the Hanford formation. From ground surface to 5.8 m (19 ft) bgs, sandy gravel was present. The sand ranged from very fine to very coarse grained and sub-rounded to sub-angular. The gravels ranged from very fine to very coarse pebbles that were dominantly sub-rounded. The material was 70 percent mafic and 30 percent felsic. The dominant color was brown, and there was no reaction with hydrochloric acid.

From 5.8 to 7.0 m (19 to 23 ft) bgs gravelly sand was present. The sand ranged from very fine to coarse grained. The gravel ranged from very fine to coarse pebbles and was sub-rounded. The dominant color was brown, and there was no reaction to hydrochloric acid.

From 7.0 to 8.2 m (23 to 27 ft) bgs sandy gravel was present. The sand ranged from very fine to very coarse grained and sub-rounded to sub-angular. The gravel ranged from very fine to very coarse pebbles and was dominantly sub-rounded. The mineralogy of the sandy gravel was 50 percent mafic and 50 percent felsic. The dominant color was grayish-brown, and there was a moderate reaction to hydrochloric acid.

From 8.2 to 9.8 m (27 to 32 ft) bgs, silty sandy gravel was present. The sand ranged from very fine to coarse-grained sand. The gravel ranged from very fine to very coarse pebbles and was sub-rounded to sub-angular. The mineralogy of the silty sandy gravel was 50 percent mafic and 50 percent felsic. The dominant color of the silty sandy gravel was light brownish-gray.

From 9.8 m (32 ft) bgs to total depth of 15.5 m (50.9 ft), sandy gravel dominated. The gravel ranged from very fine to coarse pebbles), and the sand ranged from very fine to coarse grained. Approximately 5 to 50 percent silt was present. The dominant color was brown. The mafic to felsic ratio gradated with depth, starting at 75 percent mafic, 25 percent felsic and ending with 60 percent mafic, 40 percent felsic. Hydrochloric acid did not react with the material except for strong reaction at 11.3 m (37 ft) bgs.

The static water table was encountered at 13.2 m (43.45 ft) bgs. The borehole was completed as a temporary well, 199-F5-56, screened at the top of the unconfined aquifer.

### 3.4.4 Geology of 100-IU-2/IU-6 North of Gable Mountain

*Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas* (WHC-SD-EN-TI-011) describes geology of this portion of 100-IU-2/IU-6. Figure 3-10 shows the general stratigraphy of 100-IU-2/IU-6. As part of the RI, existing data from older wells in the

northern Hanford Site were evaluated to create new geologic maps and cross sections of the region of 100-IU-2/IU-6 north of Gable Mountain and Gable Butte.

North of Gable Mountain and Gable Butte, the gravel-dominated facies dominates the Hanford formation. Thickness ranges from 11 m (36 ft) in Well 699-83-47 to 44 m (144 ft) in Well 699-67-51. None of the post-Ringold, pre-Hanford deposits is present north of Gable Mountain and Gable Butte.

The shallowest Ringold sediments in the northern Hanford Site are Ringold unit E, typically consisting of fluvial gravels with lesser amounts of sand, silt, and clay, with areas of local cementation. At the westernmost portion of the Hanford Site, Ringold unit E is more than 40 m (130 ft) thick (*Geology of the 100-B/C Area, Hanford Site, South-Central Washington* [WHC-SD-EN-TI-133]). Ringold unit E thins eastward until it pinches out west of 100-F. The elevation of the top of the RUM in the northern Hanford Site ranges from less than 80 m (262 ft) beneath 100-BC to 125 m (410 ft) north of Gable Butte and Gable Mountain (Figure 3-20).

The RUM unit is a silt and clay-rich unit that is substantially less permeable than the overlying units and is considered an aquitard. Existing driller's logs do not permit distinguishing this unit from deeper fine-grained Ringold sediments.

Deeper Ringold units are inferred from driller's logs, including fluvial sequence B (ranging from sand-dominated to gravel-dominated) and intervening paleosol/overbank deposits (muds). Beneath these sequences, the Ringold lower mud unit is up to 42 m (140 ft) thick. It comprises overbank and lacustrine deposits and appears to be continuous beneath 100-IU-2/IU-6. The lowermost Ringold unit, gravel-dominated fluvial sequence A, is up to 45 m (150 ft) thick. Depth to basalt ranges from approximately 200 m (660 ft) near 100-BC to 110 m (360 ft) near 100-F.

Figure 3-21 shows a geologic cross section that runs through the eastern portion of Gable Mountain to former Well 699-74-23, located southeast of 100-F at the Columbia River. Most of the well logs do not provide sufficient detail to distinguish between Hanford and Ringold E sediments, nor between the RUM and other Ringold silt/clay units. The top of the RUM north of Gable Mountain is at approximately the same elevation as the Ringold lower mud south of the structure. This may reflect a difference in terminology applied to these units, which are not formally defined. Alternatively, structural displacement of the units may have occurred.

Figure 3-22 is a geologic cross section that runs through Gable Mountain, through Well 699-66-38, where the RUM elevation is high, and to the Columbia River at 100-F. The elevation of the RUM north of Gable Mountain is lower than the elevation of the Ringold lower mud unit south of the structure.

Figure 3-23 is a similar cross section farther to the west, intersecting the river northwest of 100-F. No Ringold Formation sediment is present south of Gable Mountain at this location. North of Gable Mountain, Hanford/Ringold gravels are underlain by fine-grained Ringold sediments (RUM and deeper units). Two of the wells in this section reached basalt at elevations of 36 and 7 m (118 and 23 ft) below sea level.

### 3.4.5 Geology of 100-IU-2/IU-6 South of Gable Mountain

Major geologic units south of the Gable Mountain anticline include the Hanford formation, the Cold Creek unit, the Ringold Formation, the Columbia River Basalt Group, and sedimentary interbeds (Figure 3-10). Much of 100-IU-2/IU-6 coincides with the "far-field" portion of the 200-PO-1 OU, (i.e., the large region southeast and east of the 200 East Area). The information in this section is summarized from the 200-PO-1 RI Report (DOE/RL-2009-85).

The Hanford formation sediments are generally the most permeable of the suprabasalt sediments. In the far-field region of the 200-PO-1 OU, the Hanford formation is deposited on top of the Cold Creek unit (where present) and/or the Ringold unit E or upper Ringold.

Pre-Hanford/Post-Ringold sediments in this region comprise the Cold Creek unit, a clast-supported, sandy pebble/cobble gravel. This coarse-grained, highly permeable sediment exists only in the central, northern, and northeastern portions of the far-field region of the 200-PO-1 OU. The unit ranges in thickness from 0 to 46 m (0 to 150 ft). It is not identified near the southern boundary of the OU or near the 300 Area.

The upper Ringold unit is present throughout the central and northeast portion of the 200-PO-1 OU. Data indicate that this fine-grained unit is less permeable than either the Cold Creek unit or Ringold unit E. It attains a thickness up to 18 m (60 ft) toward the east.

Within the 200-PO-1 far-field area, Ringold unit E thickens toward the southeast and ranges to more than 70 m (230 ft) thick.

The Ringold lower mud unit forms a semi-regional confining unit, separating the Ringold unit A from the overlying Ringold sediments (unit E). The lower mud ranges from 6 m (20 ft) near the 300 Area to more than 33 m (110 ft) near the Solid Waste Landfill; it is 15 m (50 ft) thick in the northeast portion of the 200-PO-1 OU, near the Columbia River.

Ringold unit A underlies the lower mud and overlies basalt. The unit thickens to greater than 35 m (115 ft) in the center of the 200-PO-1 OU. This unit pinches out (is not present) beneath the 300-FF-5 OU to the southeast, adjacent to the Columbia River. Characterization data suggest that Ringold unit A thickens into the Cold Creek syncline, thinning to the south out of the basin and to the east near the Columbia River.

Depth to basalt ranges from zero on Gable Mountain and other places basalt crops out, to more than 230 m (750 ft) in the Cold Creek syncline. The shallowest sedimentary interbed is either the Levey or the Rattlesnake Ridge interbed, depending on location.

Figure 3-24 shows a geologic cross section running south to north and ending at the eastern edge of Gable Mountain (Figure 3-21 extended this section north of Gable Mountain). Figure 3-25 shows a geologic cross section running west to east, south of the 200 Area. The Hanford formation is the primary unit present at the surface. This unit is underlain by the Cold Creek unit, the upper Ringold, and Ringold unit C (undifferentiated). Fine-grained sediment classified as Ringold lower mud, and coarser-grained Ringold unit A overlie the basalt.

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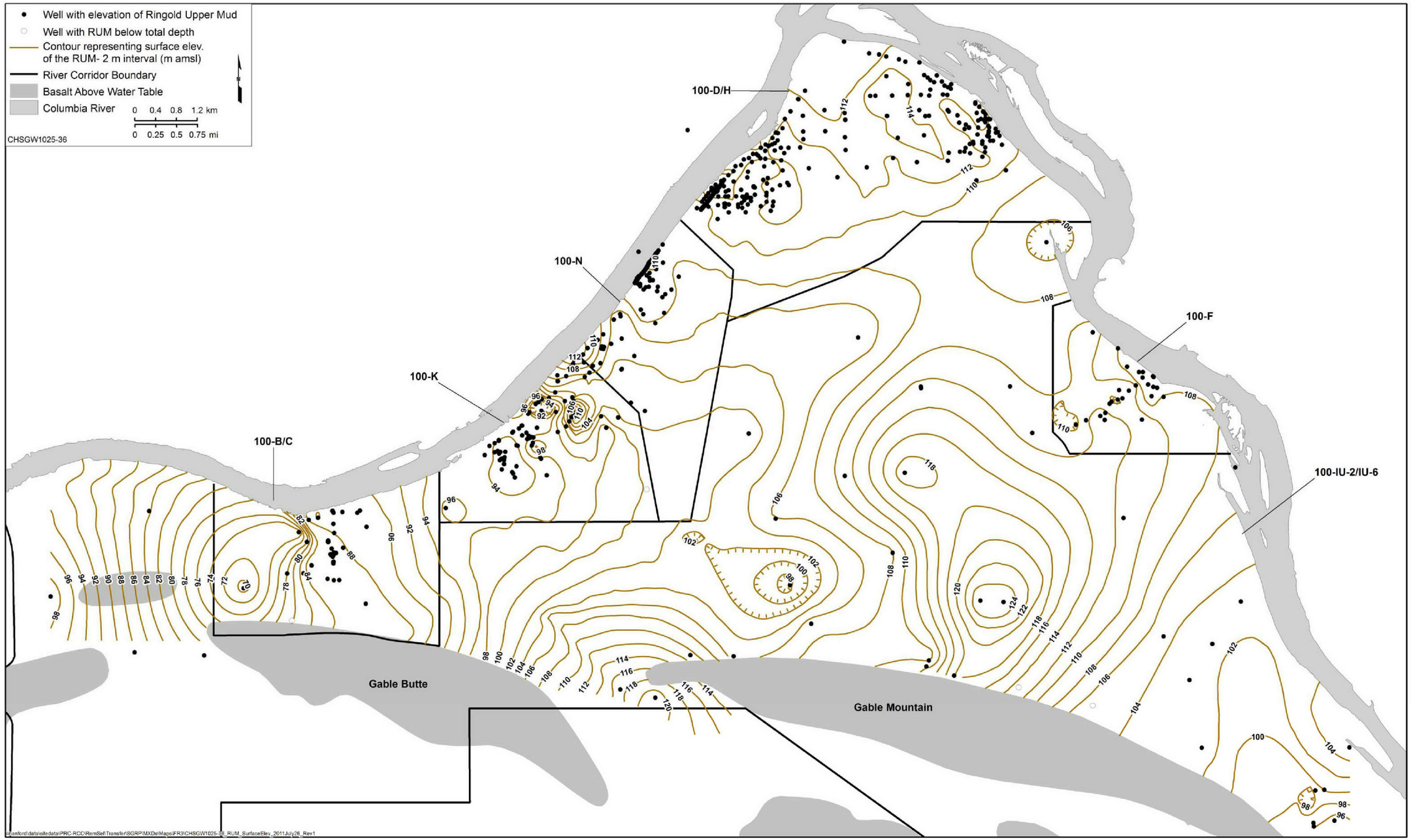



Figure 3-20. Elevation of Top of Ringold Upper Mud, Northern Hanford Site

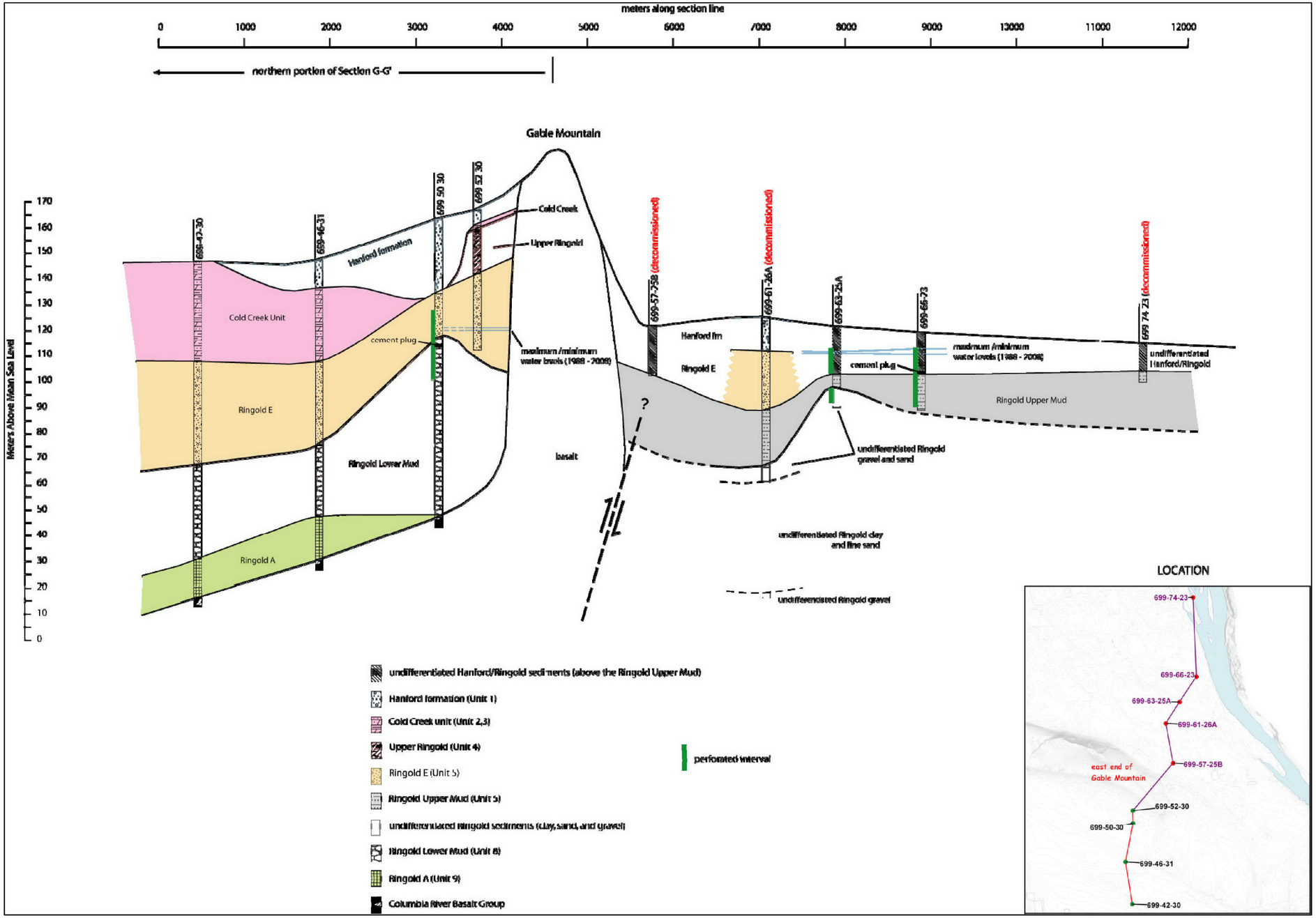



Figure 3-21. Geologic Cross Section G'-G'', 100-IU-2/IU-6 North of Gable Mountain

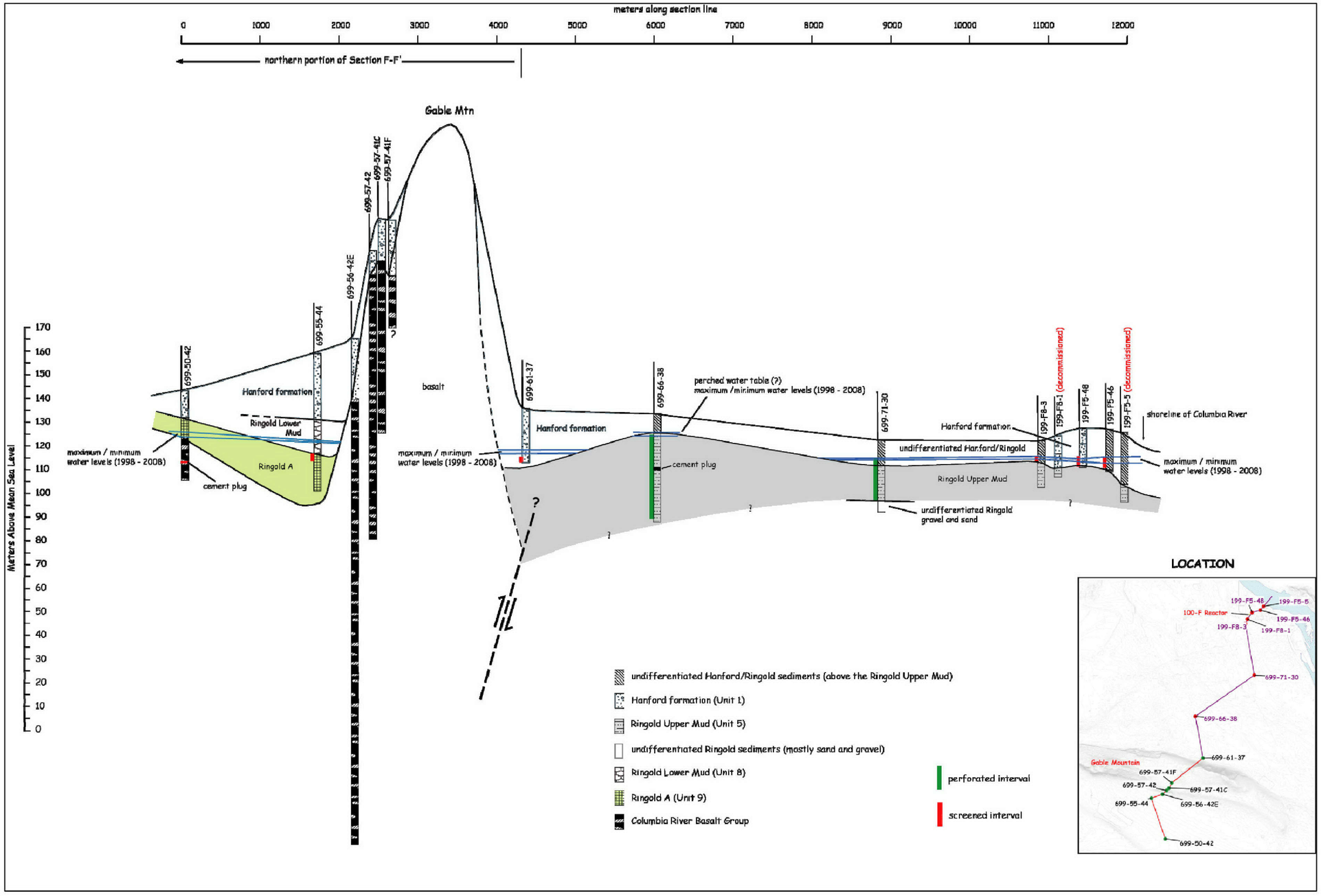



Figure 3-22. Geologic Cross Section F'-F'', 100-IU-2/IU-6 North of Gable Mountain

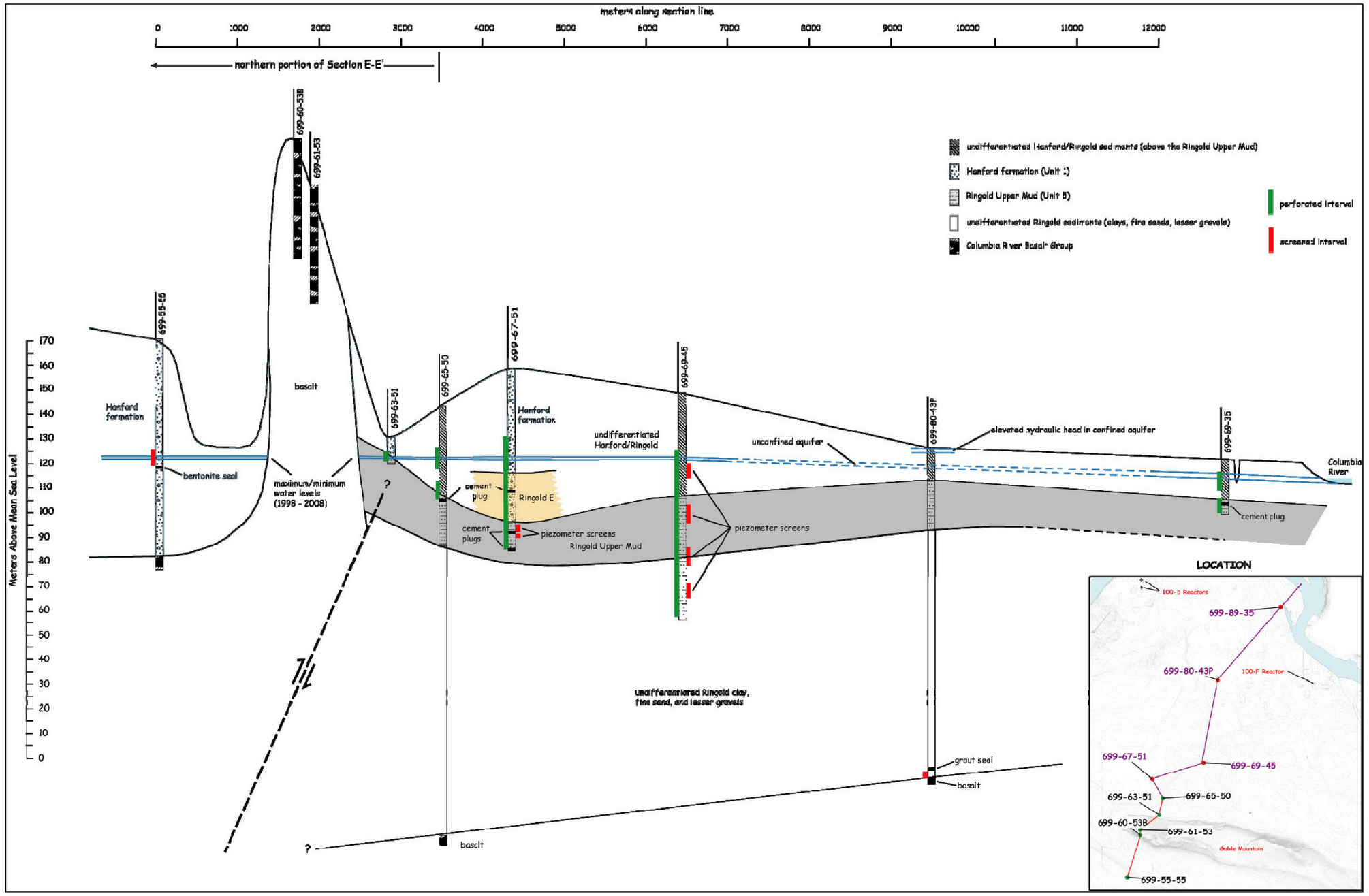
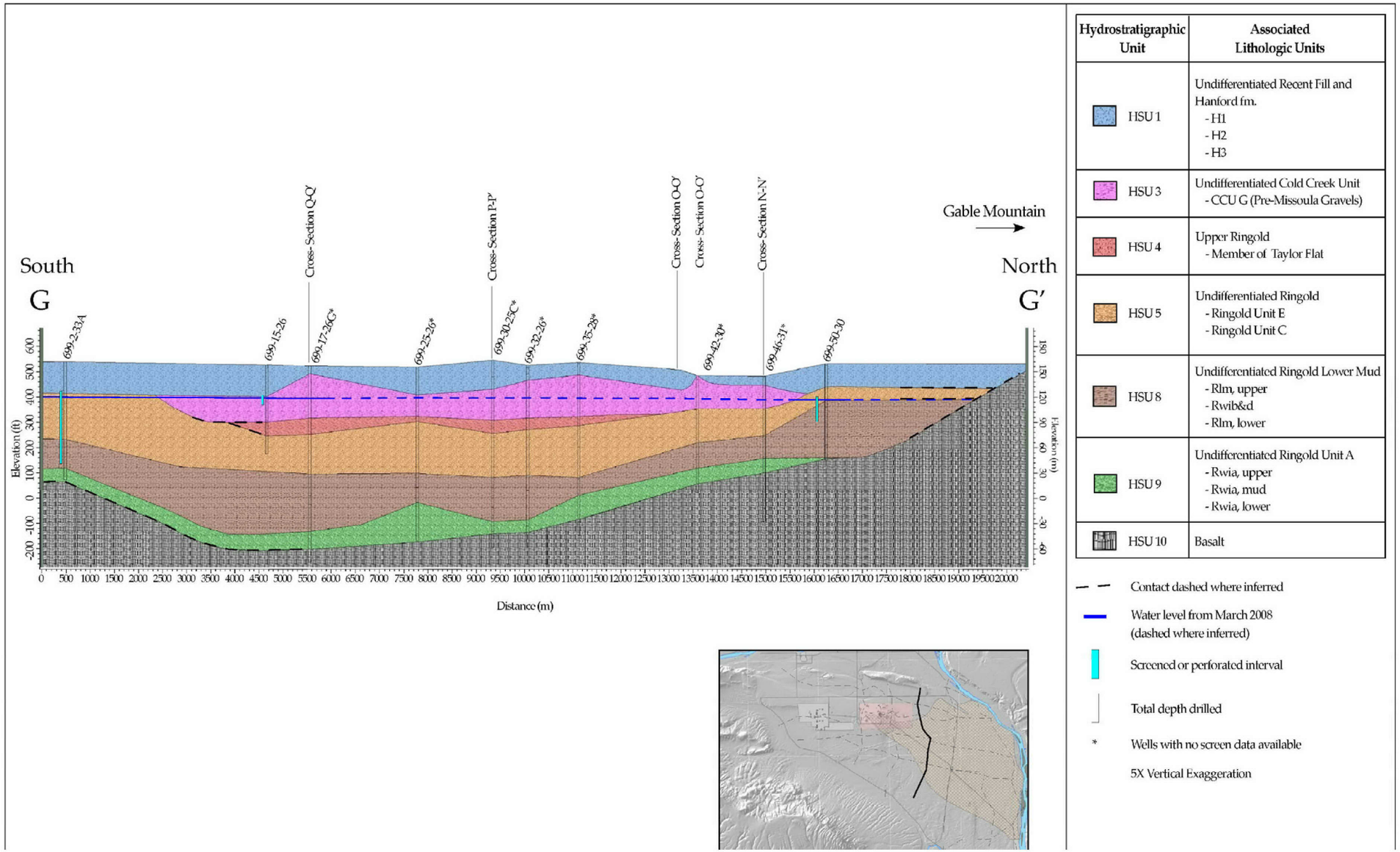
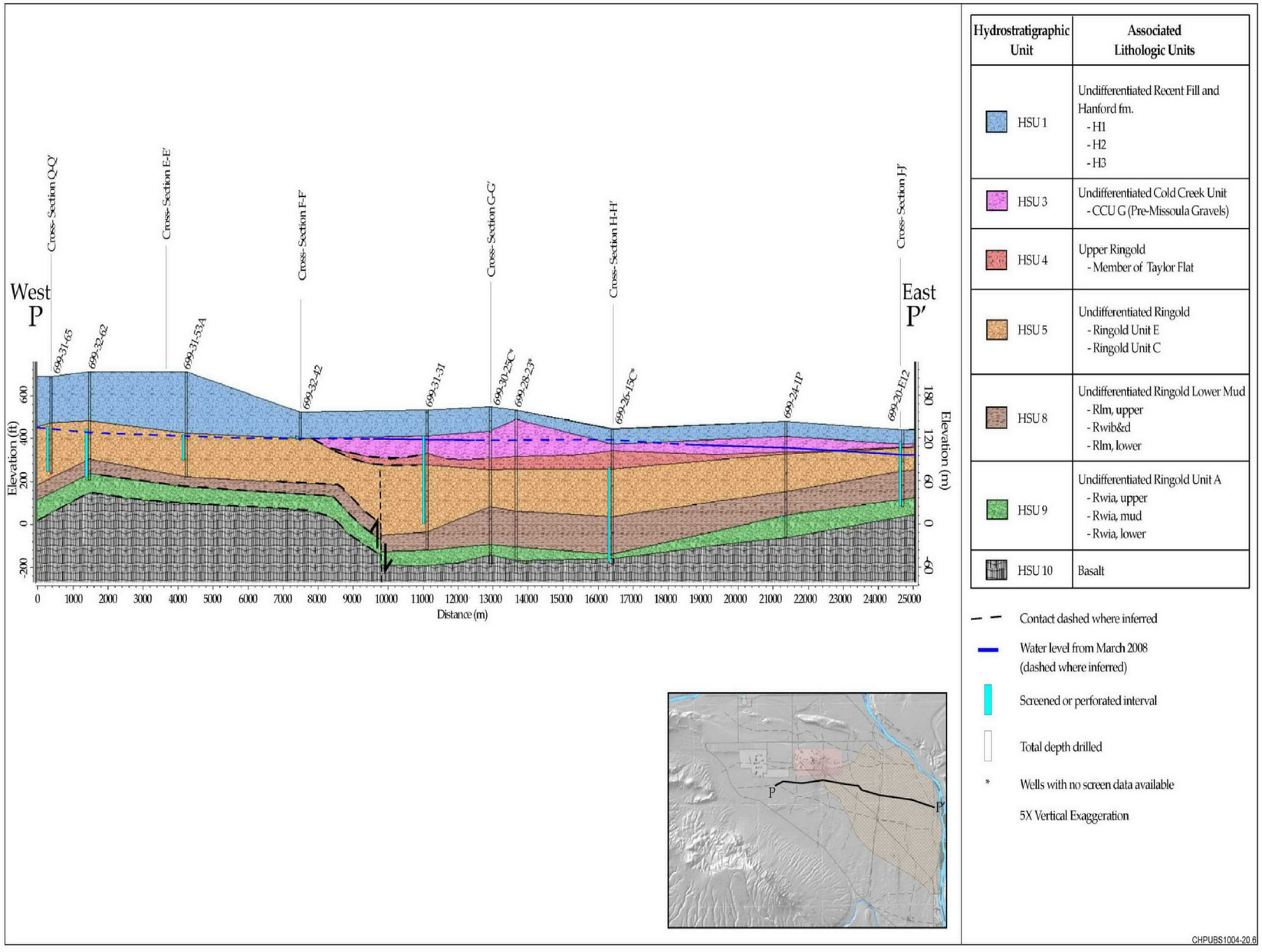



Figure 3-23. Geologic Cross Section E'-E'', 100-IU-2/IU-6 North of Gable Mountain




Source: DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*.

Figure 3-24. Geologic Cross Section G-G', 100-IU-2/IU-6 South of Gable Mountain




Source: DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*.

Figure 3-25. Geologic Cross Section P-P', 100-IU-2/IU-6 South of Gable Mountain

## 3.5 Vadose Zone

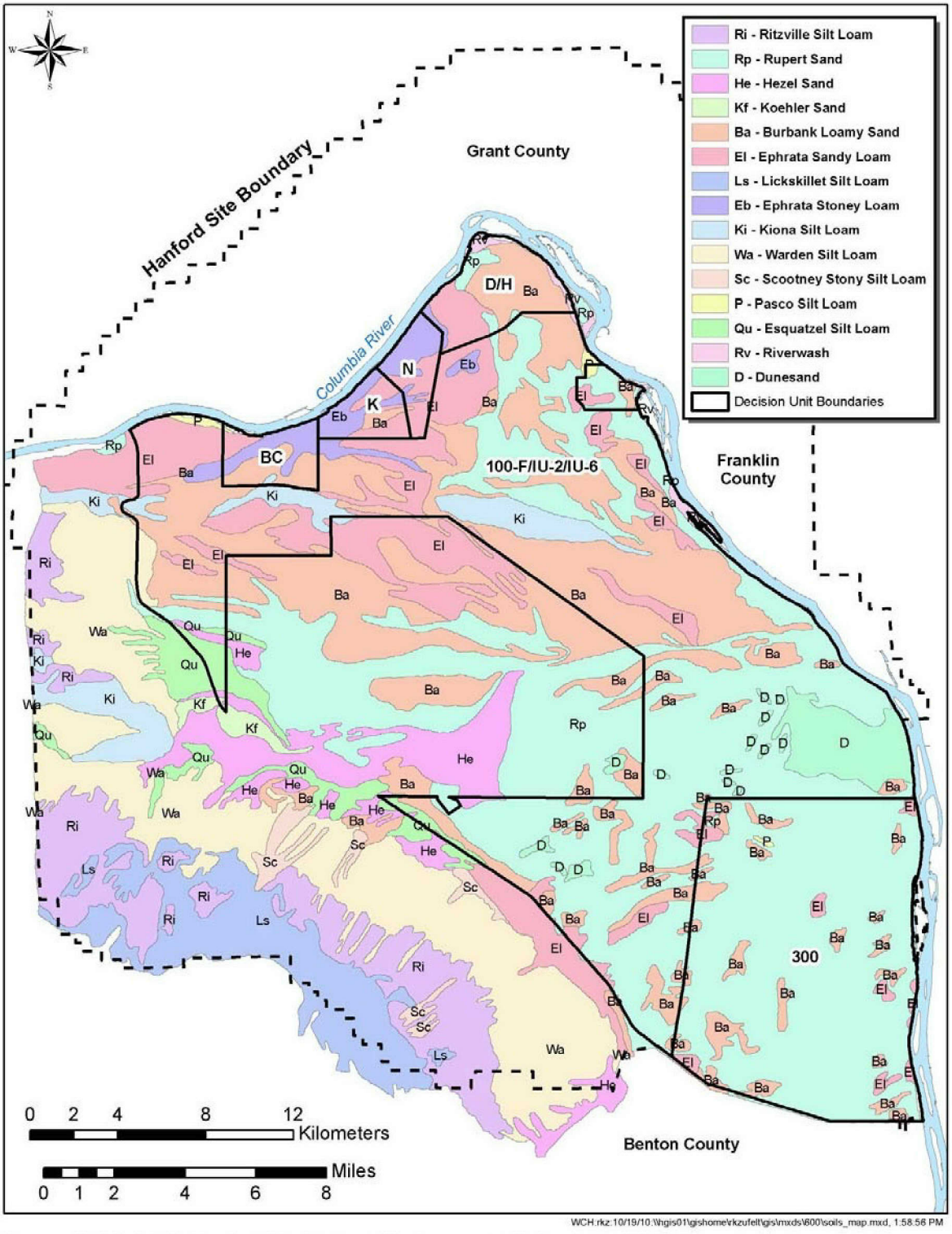
This section describes shallow soil and deeper vadose (unsaturated) zone sediments in 100-F/IU.

### 3.5.1 Soil Types

*Soil Survey Hanford Project in Benton County Washington* (BNWL-243) describes 15 soil types on the Hanford Site. Eleven soil types occur within 100-F or 100-IU-2/IU-6 (Figure 3-26):

- Rupert Sand represents one of the most extensive soil types on the Hanford Site. The surface is a brown to grayish-brown coarse sand, which grades to a dark grayish-brown sand at about 91 cm (36 in.) bgs. Rupert Sand developed under grass, sagebrush, and hopsage in coarse sandy alluvial deposits that were mantled by wind-blown sand.
- Hezel Sand is similar to Rupert Sand; however, a laminated grayish-brown, strongly calcareous silt loam subsoil is usually encountered within 102 cm (40 in.) of the surface. The surface soil, which is very dark brown, was formed in wind-blown sands that mantled lake-laid sediments.
- Burbank loamy sand is a dark-colored, coarse-textured soil underlain by gravel. Its surface soil is usually about 40 cm (16 in.) thick, but may be as much as 75 cm (30 in.) thick. The gravel content of its subsoil ranges from 20 to 80 percent.
- Ephrata Sandy Loam is found on level topography on the Hanford Site. Its surface is darkly colored, and its subsoil is dark grayish-brown medium-textured soil underlain by gravelly material that may continue for many feet.
- Ephrata Stony Loam is similar to Ephrata sandy loam. It differs in that many large, hummocky ridges are made up of debris released from melting glaciers. Areas of Ephrata Stony Loam located between hummocks contain many boulders several feet in diameter.
- Kiona Silt Loam occupies steep slopes and ridges, including Gable Mountain and Gable Butte. Its surface soil is very dark grayish-brown, is about 10 cm (4 in.) thick, and has dark-brown subsoil containing basalt fragments 30 cm (12 in.) and larger in diameter. Many basalt fragments are found in its surface layer, and basalt rock outcrops are often present.
- Warden Silt Loam is a dark grayish-brown soil. The surface layer is usually 23 cm (9 in.) thick. The silt loam subsoil becomes strongly calcareous and lighter colored (grayish-brown) at about 51 cm (20 in.) bgs. Granitic boulders are found in many areas. Usually this soil is greater than 152 cm (60 in.) deep.
- Pasco Silt Loam is poorly drained, very dark grayish-brown soil formed in recent alluvial material. Its subsoil is variable, consisting of stratified layers. A small area of Pasco Silt Loam is found in a low area adjacent to the Columbia River.
- Esquatzel Silt Loam is a deep dark brown soil formed in recent alluvium derived from loess and lake sediments. Color and texture of the subsoil is variable because of the stratified nature of the alluvial deposits.
- Riverwash sediments are wet, periodically flooded areas of sand, gravel, and boulder deposits that make up overflowed islands in the Columbia River and areas adjacent to the river.

- Dune sand represents a miscellaneous land type, which consists of hills or ridges of sand-sized particles drifted and piled up by wind. These dunes are either actively shifting or are so recently stabilized that no soil horizons have developed.




Source: PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization.*

**Figure 3-26. Soil Types of the Hanford Site**

### 3.5.2 Vadose Zone

Beneath 100-F, the vadose zone comprises primarily Hanford formation gravels and is 0 to 15 m (0 to 49 ft) thick. In 100-IU-2/IU-6, vadose zone thickness ranges from near zero adjacent to the Columbia River to greater than 107 m (350 ft) in the central Hanford Site.

Where mature native vegetation is present, most of the ambient precipitation is returned to the atmosphere by plants through evapotranspiration, resulting in dry conditions in the vadose zone sediments with high negative pressure heads and little water transported to the aquifer. The portion of precipitation that reaches the water table is termed natural recharge. When human activity disturbs the natural evapotranspiration cycle, there is a potential for an increased portion of precipitation recharging the aquifer. The portion of dust-suppression water that reaches the aquifer is identified as artificial recharge, and this provides the additional driving force that increases the transport of contaminated leachate within the vadose zone.

The topsoil that has developed at the top of the vadose zone since the last Pleistocene flood provides the foundation for the plants that grow within the shrub-steppe ecosystem. Well-developed soil profiles promote water retention and plant growth within the upper few meters of the vadose zone. The topsoil and vegetation work together to maximize consumptive use of the annual precipitation by the ecosystem. Soil properties such as hydraulic conductivity are important for an understanding of contaminant fate and transport. As such, this section presents a number of soil properties that are used in the fate and transport analysis presented in Chapter 5.

Physical property samples were collected from the 100-F RI boreholes and wells, and analyzed for particle size, percent moisture, saturated hydraulic conductivity, and bulk density in the vadose zone (Tables 3-6 and 3-7). Data collected from the vadose zone as part of this RI confirm that soil moisture is low and porosity is high. Vertical hydraulic conductivity data were highly variable.

Density was reported both as bulk density and as dry density. Porosity is a calculated value determined by the following equation and reported as a percent:

$$Porosity = 1 - \frac{Bulk\ Density}{Particle\ Density}$$

For purposes of calculating porosity, normal particle density is assumed to be 2.65 g/cm$^3$ (165.4 lb/ft$^3$).

Results of physical testing of the vadose zone samples are summarized below:

- Grain size: As expected, the soils associated with the wells were primarily sandy gravels with silt/clay ranging from 2.5 to 22.7 percent. The single interval collected from Borehole C7971 comprised 94.3 percent silt and clay, with the remaining 5.7 percent being sand. This sample was collected from the RUM unit.

- Moisture percent: The Hanford Site's semi-arid climate keeps the vadose zone soil moisture relatively low. Leaks from the water export system and the application of dust suppression water are potential sources of artificial recharge. Historically, effluent discharge to the soil column increased soil moisture beneath waste sites, and it is possible that some drainage will continue in areas where large volumes of liquid waste were formerly discharged. However, RI data did not find evidence to support this. Moisture for the vadose zone soils ranged from 1.1 percent to 4.5 percent, increasing for those samples collected within or just above the top of the aquifer.

- Bulk density: The bulk density ranged from 1,984 to 2,744 kg/m$^3$ (123.9 to 171.3 lb/ft$^3$) with dry density being slightly less for all samples.

- Porosity: The calculated result for Well 199-F5-52 interval I-004 was negative because of an anomalous bulk density measurement. Excluding this result, porosity ranged from 4.9 percent to 25 percent, with an average of 16 percent.

- Saturated hydraulic conductivity was determined in accordance with *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter* (ASTM D5084-03) for soil with low hydraulic conductivity (silt or a mud) or *Standard Test Method for Permeability of Granular Soils (Constant Head)* (ASTM D2434-68 [2006]) for soil with high hydraulic conductivity (sand or sandy gravel). Table 3-7 summarizes results of saturated vertical hydraulic conductivity tests of split-spoon samples from wells and boreholes. These include samples from the vadose zone, aquifer, and aquitard. Hydraulic conductivity of the vadose zone samples ranged from 0.0012 to 17 m/d (0.0040 to 57 ft/d) and averaged 2.8 m/d (9.2 ft/d). The large variability is probably partly a result of sample conditions, since it is difficult to get an intact sample of an unconsolidated sand or gravel. Section 3.6 discusses vertical hydraulic conductivity of the aquifer and aquitard.

Vertical hydraulic conductivity is a key parameter governing contaminant fate and transport in the vadose zone and is correlated to moisture content. In the late 1990s, moisture retention and unsaturated conductivity data were obtained in the laboratory for 15 soil samples from the 100 Area, including two from 100-F (Table 3-8; *Far-Field Hydrology Data Package for Immobilized Low-Activity Tank Waste Performance Assessment* [HNF-4769]). These data provided estimated values for vertical saturated hydraulic conductivity. Vertical unsaturated hydraulic conductivity can, in turn, be estimated mathematically from vertical saturated hydraulic conductivity as a function of matric potential or pressure head. Estimated unsaturated hydraulic conductivities (based on saturated conductivity and "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils" [van Genuchten, 1980]) can often differ by up to several orders of magnitude with measured conductivities. Therefore, a simultaneous fit of both laboratory-measured moisture retention and unsaturated conductivity data was used, and all five unknown parameters (residual moisture content, saturated moisture content, saturated hydraulic conductivity, and the two van Genuchten fitting parameters) were fitted to the data. The function can be written as follows:

$$\theta = \theta_r + (\theta_s - \theta_r)[(1 + (\alpha h)^n]^{-m}$$

where:

$\theta_s$ = saturated water content ($cm^3/cm^3$)

$\theta_r$ = residual water content ($cm^3/cm^3$)

$H$ = matric potential (cm)

$\alpha, n, m$ = empirical fitting parameters ($\alpha$ units are 1/cm; $n$ and $m$ are dimensionless)

Vertical saturated hydraulic conductivities for the two 100-F samples (Table 3-8) were approximately 0.0001 cm/s (0.3 ft/day).

In the vadose zone, the pressure head is negative under unsaturated conditions. This reflects the fact that water in the unsaturated zone is held in the soil pores under negative pressure by surface tension forces. If the volume of water in the vadose zone equals the volume that can be retained by surface tension forces (field capacity), no water is available to migrate. As additional water from precipitation or artificial sources infiltrates into the vadose zone, it will migrate vertically under the force of gravity. This occurs because an increase in water content reduces the surface tension forces holding the water within the pore spaces in the vadose zone, thus increasing the moisture flux.

**Table 3-6. Grain Size, Bulk Density, and Calculated Porosity of 100-F Vadose Zone Sediment Samples from RI Wells and Boreholes**

| Well or Borehole | Interval | Depth (ft) | Formation | Grain Size (% Passing Sieve) | | | | | | | | | | | | Classification (%) | | | Calc. Porosity (%) | Moisture (%) | Density | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 3 in. | 1.5 in. | 0.75 in. | 0.375 in. | #4 | #10 | #20 | #40 | #60 | #100 | #140 | #200 | Gravel | Sand | Silt/ Clay | | | Bulk ($lb/ft^3$) | Bulk ($kg/m^3$) | Dry ($lb/ft^3$) | Dry ($kg/m^3$) |
| 199-F5-52 | I-001 | 24.5 – 27.0 | Hanford | 100 | 74.6 | 65.7 | 61.8 | 59.0 | 53.3 | 46.2 | 41.0 | 33.5 | 27.6 | 24.9 | 22.6 | 41.0 | 36.4 | 22.6 | 0.250 | 1.10 | 124.0 | 1984.0 | 122.6 | 1961.6 |
| | I-002 | 29.8 – 31.1 | Hanford | 100 | 71.4 | 62.3 | 57.8 | 54.3 | 49.1 | 44.1 | 38.8 | 29.2 | 22.8 | 20.1 | 17.8 | 45.7 | 36.5 | 17.8 | 0.163 | 1.52 | 138.5 | 2216.0 | 136.8 | 2188.8 |
| | I-004 | 37.3 – 39.0 | Hanford | 100 | 68.1 | 63.1 | 54.9 | 51.3 | 46.8 | 41.5 | 36.9 | 31.7 | 27.2 | 24.9 | 22.7 | 48.7 | 28.6 | 22.7 | -0.037* | 1.87 | 171.5 | 2744.0 | 169.1 | 2705.6 |
| | I-005 | 40.1 – 42.6 | Hanford | 100 | 57.6 | 44.5 | 31.8 | 26.5 | 23.7 | 22.4 | 18.2 | 8.9 | 4.2 | 3.1 | 2.5 | 73.5 | 24.0 | 2.5 | 0.200 | 2.55 | 132.4 | 2118.4 | 130.0 | 2080.0 |
| | I-006 | 42.4 – 44.9 | Hanford | 100 | 100 | 74.9 | 59.6 | 44.2 | 33.2 | 25.9 | 20.2 | 13.6 | 9.8 | 8.4 | 7.2 | 55.8 | 37.0 | 7.2 | 0.206 | NC | 131.4 | 2102.4 | 129.0 | 2064.0 |
| | I-011 | 49.3 – 51.8 | Hanford <WT | 100 | 72.9 | 63.0 | 56.6 | 52.2 | 48.4 | 45.0 | 31.5 | 11.9 | 5.1 | 3.6 | 2.8 | 47.8 | 49.4 | 2.8 | 0.125 | *21.8* | 144.8 | 2316.8 | 131.8 | 2108.8 |
| 199-F5-53 | I-001 | 22.6 – 25.1 | Hanford | 100 | 80.2 | 70.1 | 62.9 | 55.0 | 47.7 | 42.1 | 37.5 | 31.6 | 26.3 | 23.7 | 21.4 | 45.0 | 33.6 | 21.4 | 0.147 | 2.43 | 141.1 | 2257.6 | 138.9 | 2222.4 |
| | I-002 | 28.2 – 30.7 | Hanford | 100 | 76.1 | 50.4 | 35.5 | 27.6 | 23.2 | 20.9 | 15.8 | 7.8 | 4.3 | 3.5 | 3.0 | 72.4 | 24.6 | 3.0 | 0.133 | 3.16 | 143.4 | 2294.4 | 140.1 | 2241.6 |
| | I-004 | 35.5 – 38.0 | Hanford | 100 | 85.0 | 63.5 | 47.5 | 37.6 | 30.7 | 25.9 | 20.0 | 13.0 | 9.6 | 8.3 | 7.2 | 62.4 | 30.3 | 7.2 | 0.241 | 3.52 | 125.6 | 2009.6 | 123.1 | 1969.6 |
| | I-005 | 38.2 – 40.1 | Hanford <WT | 100 | 90.4 | 57.4 | 40.2 | 33.6 | 30.1 | 28.8 | 23.9 | 12.5 | 6.0 | 4.2 | 3.2 | 66.4 | 30.4 | 3.2 | 0.082 | *6.40* | 151.8 | 2428.8 | 142.6 | 2281.6 |
| 199-F5-54 | I-001 | 21.6 – 24.1 | Hanford | 100 | 75.9 | 58.8 | 40.6 | 35.2 | 30.5 | 27.0 | 23.5 | 19.1 | 14.5 | 12.3 | 10.4 | 64.8 | 24.8 | 10.4 | 0.191 | 1.67 | 133.8 | 2140.8 | 131.6 | 2105.6 |
| | I-003 | 30.7 – 32.2 | Hanford | 100 | 89.4 | 68.9 | 62.2 | 57.4 | 52.8 | 48.7 | 43.3 | 32.1 | 23.3 | 20.1 | 17.4 | 42.6 | 40.0 | 17.4 | 0.049 | 1.44 | 157.4 | 2518.4 | 154.1 | 2465.6 |
| | I-006 | 38.5 – 41.0 | Hanford | 100 | 67.7 | 51.3 | 41.2 | 32.6 | 27.4 | 25.1 | 20.0 | 10.0 | 5.9 | 4.8 | 4.0 | 67.4 | 28.6 | 4.0 | 0.171 | 2.27 | 137.2 | 2195.2 | 134.6 | 2153.6 |
| | I-007 | 40.8 – 43.3 | Hanford | 100 | 100 | 94.3 | 82.2 | 70.1 | 58.3 | 48.1 | 40.8 | 32.6 | 26.2 | 23.4 | 20.7 | 29.9 | 49.4 | 20.7 | 0.165 | 4.46 | 138.2 | 2211.2 | 135.1 | 2161.6 |
| | I-008 | 47.1 – 49.6 | Hanford <WT | 100 | 77.3 | 64.5 | 56.1 | 46.0 | 37.4 | 31.5 | 21.6 | 8.9 | 4.6 | 3.6 | 2.9 | 54.0 | 43.0 | 2.9 | 0.102 | *NC* | 148.5 | 2376.0 | 138.3 | 2212.8 |
| C7971 | I-011 | 29.0 – 31.5 | RUM <WT | 100 | 100 | 100 | 100 | 100 | 99.1 | 96.7 | 95.9 | 95.4 | 95.0 | 94.7 | 94.3 | 0.0 | 5.7 | 94.3 | 0.221 | *16.2* | 128.8 | 2060.8 | 107.3 | 1716.8 |

* Negative calculated porosity due to anomalously high bulk density.

NC = Sample not collected—insufficient recovery while sampling.

<WT = Sample interval below water table. Moisture content in italics.

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**Table 3-7. Vertical Hydraulic Conductivity of 100-F Sediment Samples from RI Wells and Boreholes**

| Well or Borehole | Interval Bottom | | Geology | Hydrogeologic Unit | Vertical Hydraulic Conductivity | |
|---|---|---|---|---|---|---|
| | m | ft | | | m/d | ft/d |
| 199-F5-52 | 8.2 | 27 | Hf: silty sandy gravel | Vadose | 0.0012 | 0.0040 |
| | 9.5 | 31.1 | Hf: silty sandy gravel | Vadose | 0.018 | 0.060 |
| | 11.9 | 39 | Hf: silty gravel | Vadose | 0.0019 | 0.0062 |
| | 13.0 | 42.6 | Hf: silty sandy gravel | Vadose | 4.4 | 14 |
| | 13.7 | 44.9 | Hf: sandy gravel | Vadose | 5.1 | 17 |
| | 15.8 | 51.8 | Hf: gravelly sand | Unconfined aquifer | 25 | 84 |
| | 20.1 | 65.8 | Hf: gravel | Unconfined aquifer | 0.18 | 0.60 |
| | 22.5 | 73.8 | RUM: mud | Aquitard | 0.0017 | 0.0057 |
| 199-F5-53 | 7.7 | 25.1 | Hf: sandy gravel | Vadose | 0.031 | 0.10 |
| | 9.4 | 30.7 | Hf: sandy gravel | Vadose | 17 | 57 |
| | 11.6 | 38.0 | Hf: sandy gravel | Vadose | 0.41 | 1.4 |
| | 12.2 | 40.1 | Hf: sandy gravel | Unconfined aquifer | 15 | 48 |
| | 15.9 | 52.3 | Hf: sand | Unconfined aquifer | 0.00045 | 0.0015 |
| | 25.7 | 84.3 | RUM: mud | Aquitard | 0.017 | 0.057 |
| | 32.0 | 105.0 | RUM: mud | Aquitard | 0.0086 | 0.028 |
| 199-F5-54 | 7.4 | 24.1 | Hf: silty sandy gravel | Vadose | 0.032 | 0.10 |
| | 9.8 | 32.2 | Hf: silty sandy gravel | Vadose | 0.060 | 0.20 |
| | 12.5 | 41.0 | Hf: sandy gravel | Vadose | 6.2 | 20.3 |
| | 13.2 | 43.3 | Hf: sandy gravel | Vadose | 0.0019 | 0.0062 |
| | 15.1 | 49.6 | Hf: sandy gravel | Unconfined aquifer | 2.8 | 9.2 |
| | 18.0 | 59.0 | Hf: gravelly sand | Unconfined aquifer | 1.4 | 4.5 |
| | 23.6 | 77.4 | RUM: mud | Aquitard | 0.0054 | 0.018 |
| C7971 | 9.6 | 31.5 | RUM: clay | Aquitard | 0.000037 | 0.00012 |

**Table 3-7. Vertical Hydraulic Conductivity of 100-F Sediment Samples from RI Wells and Boreholes**

| Well or Borehole | Interval Bottom | | Geology | Hydrogeologic Unit | Vertical Hydraulic Conductivity | |
|---|---|---|---|---|---|---|
| | m | ft | | | m/d | ft/d |
| **Summary** | | | | | | |
| **Geologic Unit** | **No. Samples** | **Minimum m/d (ft/d)** | | **Average m/d (ft/d)** | **Maximum m/d (ft/d)** | |
| Hanford sand and gravel | 16 | 0.0012 (0.0040) | | 4.6 (15) | 25 (84) | |
| Hanford sand | 1 | -- | | -- | 0.00045 (0.0015) | |
| RUM | 5 | 0.000037 (0.00012) | | 0.0066 (0.022) | 0.017 (0.057) | |

Hf = Hanford formation
RUM = Ringold upper mud unit

1

**Table 3-8. van Genuchten Parameters and Fitted Vertical Saturated Hydraulic Conductivity Data for Two Sandy Gravel Soil Samples from 100-F**

| Sample | Well or Site Number | Depth (m) | Formation | % Gravel | θs | θr | α (1/cm) | n | Fitted Ks (cm/s) | Bulk Density (g/cm$^3$) |
|---|---|---|---|---|---|---|---|---|---|---|
| 3-0577 | 199-F5-43B | 7.16 | Hanford | 66 | 0.107 | 0.00 | 0.0166 | 1.359 | 0.000249 | 2.32 |
| 3-0686 | 116-F-14 | 6.49 | Hanford | 55 | 0.184 | 0.00 | 0.0123 | 1.600 | 0.00059 | 2.17 |

Sources: Modified from HNF-4769, *Far-Field Hydrology Data Package for the Immobilized Low-Activity Tank Waste Performance Assessment.*
van Genuchten, M. Th., 1980, "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils."

θs = saturated moisture content (dimensionless)
θr = residual moisture content (dimensionless)
α = a fitting parameter
n = a fitting parameter (dimensionless)
Ks = saturated hydraulic conductivity

## 3.6 Hydrogeology

Liquid waste containing radionuclides and hazardous chemicals has been discharged to the surface in 100-F and in some locations within or adjacent to 100-IU-2/IU-6. Some of these contaminants have reached groundwater. An understanding of groundwater movement in 100-F/IU is necessary to monitor groundwater conditions and the fate and transport of contaminants properly.

### 3.6.1 Hydrostratigraphy

From shallowest to deepest, hydrologic units include the following:

- Vadose (unsaturated) zone
- Unconfined aquifer
- Uppermost aquitard
- Series of confined or semiconfined aquifers in the Ringold Formation (units A, B, and C), separated by fine-grained Ringold sediments
- Basalt aquitard and basalt confined aquifers (shallowest is the Rattlesnake Ridge interbed)

Section 3.5.2 described the vadose zone. The following subsections describe the aquifers and aquitards.

#### *3.6.1.1 100-F Hydrostratigraphy*

Figure 3-9 illustrates the major hydrologic units beneath 100-F.

The unconfined aquifer beneath 100-F comprises Hanford formation gravels. Figure 3-27 illustrates the thickness of the uppermost aquifer beneath 100-F, ranging from less than 1 m (3 ft) in southwestern 100-F to 8 m (26 ft) in eastern 100-F. The figure shows the distance between the water table (March 2009) and the shallowest low-permeability unit in the RUM.

Below the unconfined aquifer, the Ringold Formation consists of a series of aquitards and water-bearing zones. The low-permeability RUM unit is the base of the unconfined aquifer. The top of the RUM unit is at an elevation of 104 to 113 m (341 to 371 ft) amsl beneath 100-F (Figure 3-11).

Well 199-F5-43B is screened in a clayey silt or silty clay 39 m (129 ft) below the water table. RI Well 199-F5-53 is screened in silt 19 m (62 ft) below the water table. These sediments are considered part of the RUM unit or underlying, fine-grained sediments, but produce sufficient water for sampling.

No wells are screened below the RUM unit in 100-F. A series of piezometers monitors deeper units in Well 699-84-35A, located northwest of 100-F. Documentation of the geology and well completion is limited, but the piezometers appear to monitor the Ringold units below the RUM unit (Table 3-5), with the deepest piezometer monitoring the Ringold lower mud.

#### *3.6.1.2 100-IU-2/IU-6 Hydrostratigraphy*

The hydrostratigraphy of the 100-IU-2/IU-6 OUs is variable because of the large area covered by these OUs. Figure 3-10 illustrates the major hydrostratigraphic units.

Beneath the western 100 Area, the unconfined aquifer is in Ringold unit E and the lower portion of the Hanford formation. The base of the aquifer in most locations is the RUM unit. In the far western portion of 100-IU-2/IU-6 (west of 100-BC), the aquifer is greater than 50 m (160 ft) thick, and the RUM unit may not be present. In this area, another fine-grained Ringold unit forms the base of the unconfined aquifer. The unconfined aquifer generally thins toward the east, and is mainly in the Hanford formation. Directly north of Gable Mountain, the water table is within the RUM unit locally, and there is no unconfined aquifer in the Hanford formation or Ringold unit E (Figure 3-22).

South of Gable Mountain and Gable Butte, the water table may be in Ringold unit E (western part of Figure 3-25), the Cold Creek unit (central and eastern portions of Figure 3-25), or the Hanford formation (northern portion of Figure 3-24). Any of these units forms an aquifer when saturated. The bottom of the uppermost, unconfined aquifer south of Gable Mountain is either a fine-grained unit of the upper Ringold

Formation, or the Ringold lower mud, depending on location (Figures 3-24 and 3-25). Figure 3-28 shows that the thickness of the unconfined aquifer system (above the basalt) in this portion of the Hanford Site ranges from 0 to greater than 200 m (650 ft). It is thickest in the region southeast of the 200 Area.

### 3.6.2 Hydrogeologic Properties

Laboratory and field tests for the RI provided additional data on hydrogeologic properties of the aquifer and aquitard at 100-F. Selected soil samples from new monitoring wells were tested for vertical hydraulic conductivity, bulk density, and moisture content. Properties of the vadose zone and just below the water table were discussed in Section 3.4. Table 3-9 lists the data from deeper samples, representing the unconfined aquifer and the uppermost aquitard (RUM unit). The dataset includes five samples from Hanford formation gravels, three samples of Hanford formation sand, and five samples from the RUM. Not all analyses were run on all samples.

Bulk density of the Hanford formation ranged from 2,166 to 2,432 kg/m$^3$ (135.2 to 151.8 lb/ft$^3$). Bulk density of the RUM ranged from 1,700 to 1,964 kg/m$^3$ (106.1 to 122.6 lb/ft$^3$).

Vertical hydraulic conductivity of 16 samples of the Hanford formation gravels varied by five orders of magnitude, from 0.0012 to 25 m/d (0.0040 to 84 ft/d). The differences are not always explained by lithology of the formation. For example, two adjacent samples of sandy gravel from Well 199-F5-54 had results of 0.0019 and 6.2 m/d. A single sample of a sandy interval at the base of the Hanford formation had a very low vertical hydraulic conductivity, 0.00045 m/d (0.0015 ft/d). The vertical hydraulic conductivity of the RUM ranged from 0.000037 to 0.017 m/d (0.00012 to 0.057 ft/d).

When vertical hydraulic conductivity is considered as a group, some patterns emerge (summary rows of Table 3-7; Figure 3-29). The average for Hanford Site gravels was 4.9 m/d (16 ft/d), while the average for the RUM is much lower, 0.0066 m/d (0.022 ft/d).

Slug tests were performed in 10 100-F wells in 2010 (*Analysis of Slug Test Data at the 100-FR-3 Operable Unit* [ECF-100FR3-11-0146] Appendix C). Horizontal hydraulic conductivity of the Hanford formation aquifer ranged from 14 to 48 m/d (46 to 157 ft/d). This range was similar to results of 1992 slug tests (Table 3-10). The 2010 slug tests in RUM unit Wells 199-F5-43B and 199-F5-53 yielded hydraulic conductivity two orders of magnitude lower, 0.8 and 0.2 m/d (3 and 1 ft/d), respectively.

A constant-rate discharge test was conducted in RUM Well 199-F5-53 to determine horizontal hydraulic conductivity (*Aquifer Test Analyses for Wells 199-B2-15 and 199-F5-53* [ECF-HANFORD-11-0149], Appendix C). Variations in the river level during the test affected both the drawdown and the recovery period data. In addition, the data indicated systematic changes in the water level at the end of the test that may have been caused by small changes in the pumping rate. Because of these irregularities, standard methods of evaluating test results were not employed. Instead, an analogous method was used for estimating the transmissivity. The analogous methodology assumes that the transmissivity at one well can be used to estimate the transmissivity at another well if the well losses are equivalent between two wells, the specific capacities between the wells can be determined at equivalent pumping times, and the geology is similar between the two sites. Well 199-B2-15, located in 100-BC, was used as an analog for 199-F5-53. Both wells are completed in the first water producing zone below the top of the RUM, and both wells should have similar well efficiencies, given that the same materials and development processes were used when they were built (same screen length, screen slot, and filter pack). Results give an estimated horizontal hydraulic conductivity of 1.1 m/d (3.7 ft/d). This is higher than the estimate based on slug tests (0.2 m/d [0.7 ft/d]). Because of the interferences with the pumping test data, the slug test estimate is considered more reliable.

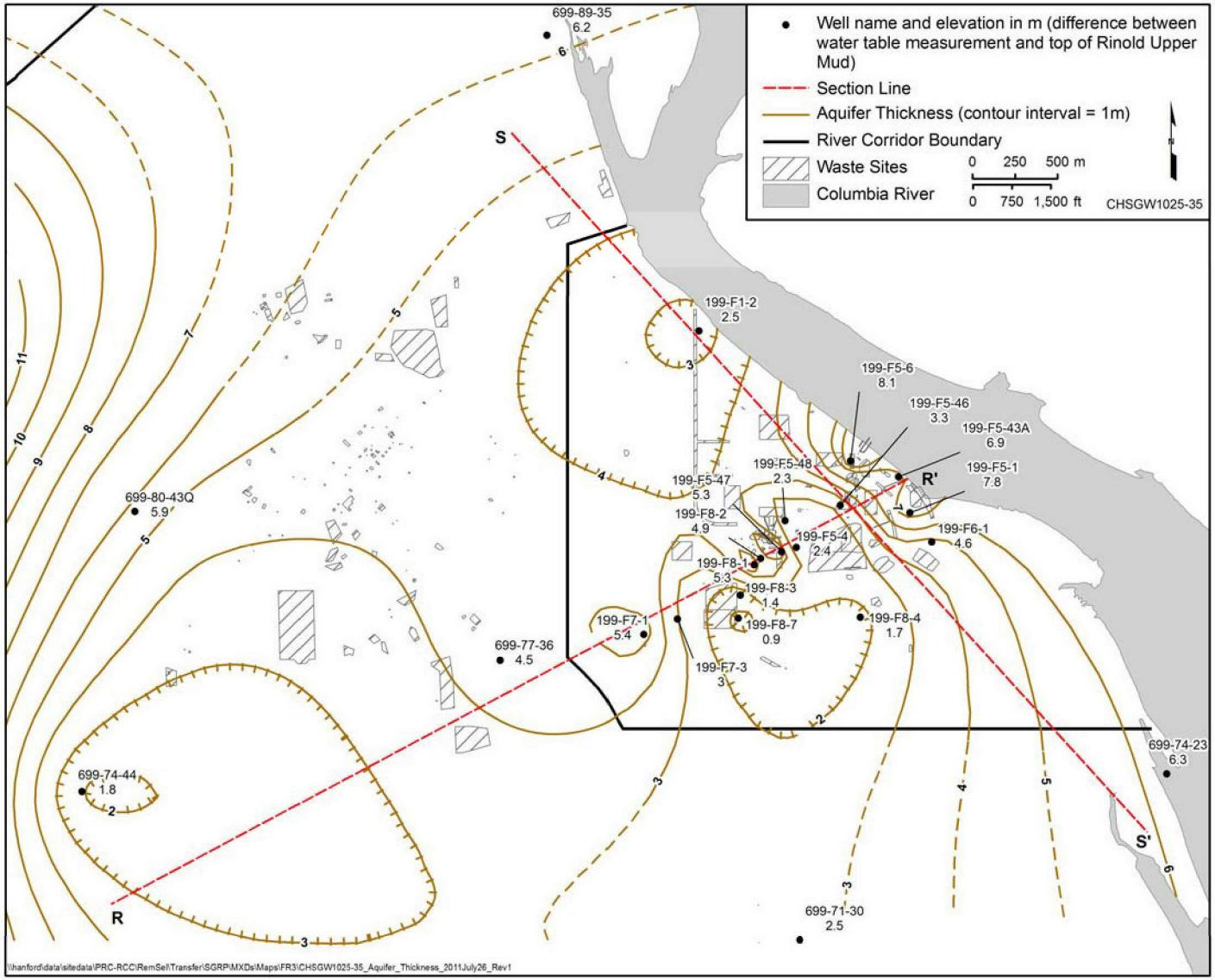
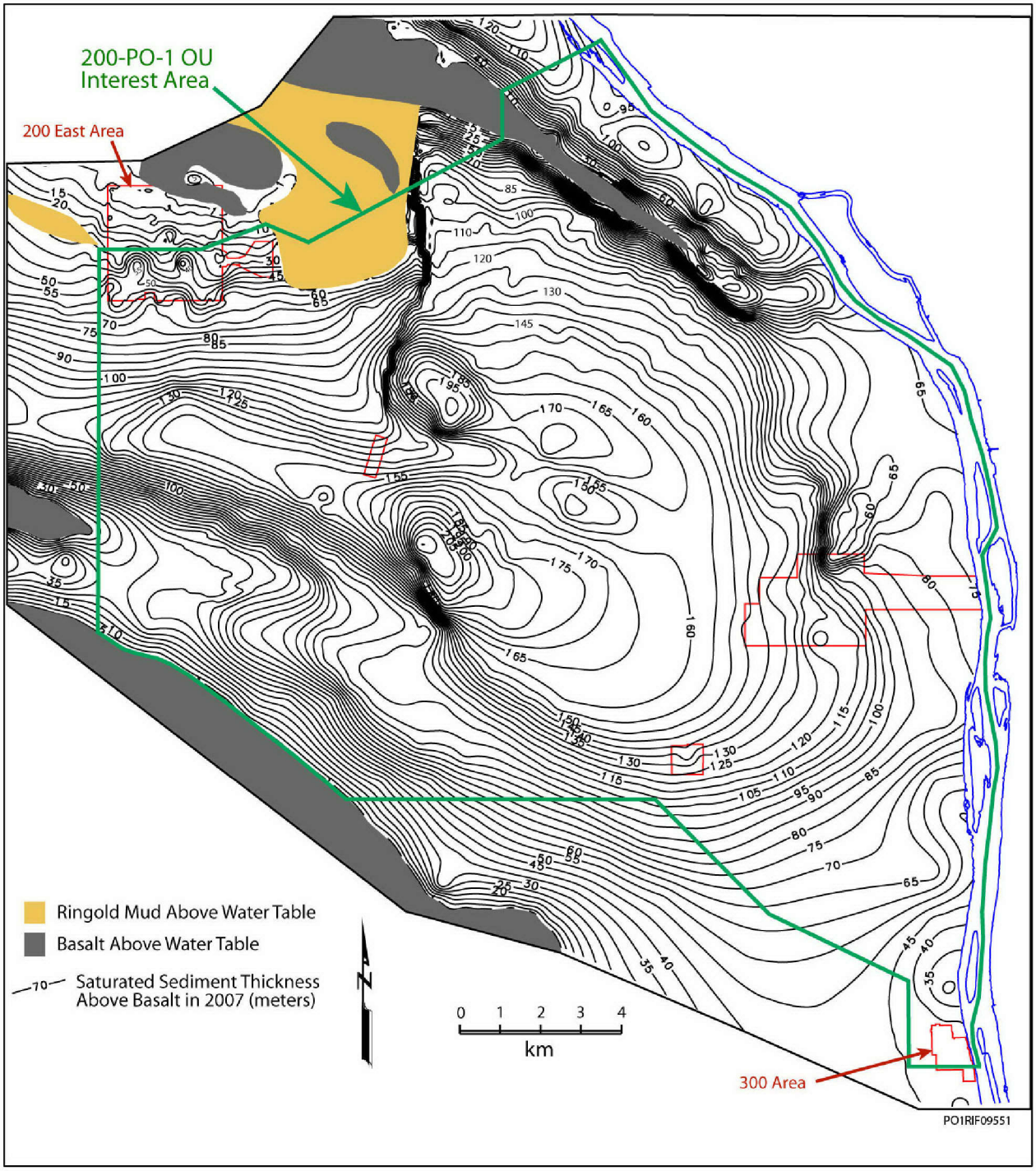



**Figure 3-27. Thickness of Unconfined Aquifer, 100-F**




Source: DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit.*

**Figure 3-28. Thickness of Suprabasalt Aquifer System, Southeastern Hanford Site**

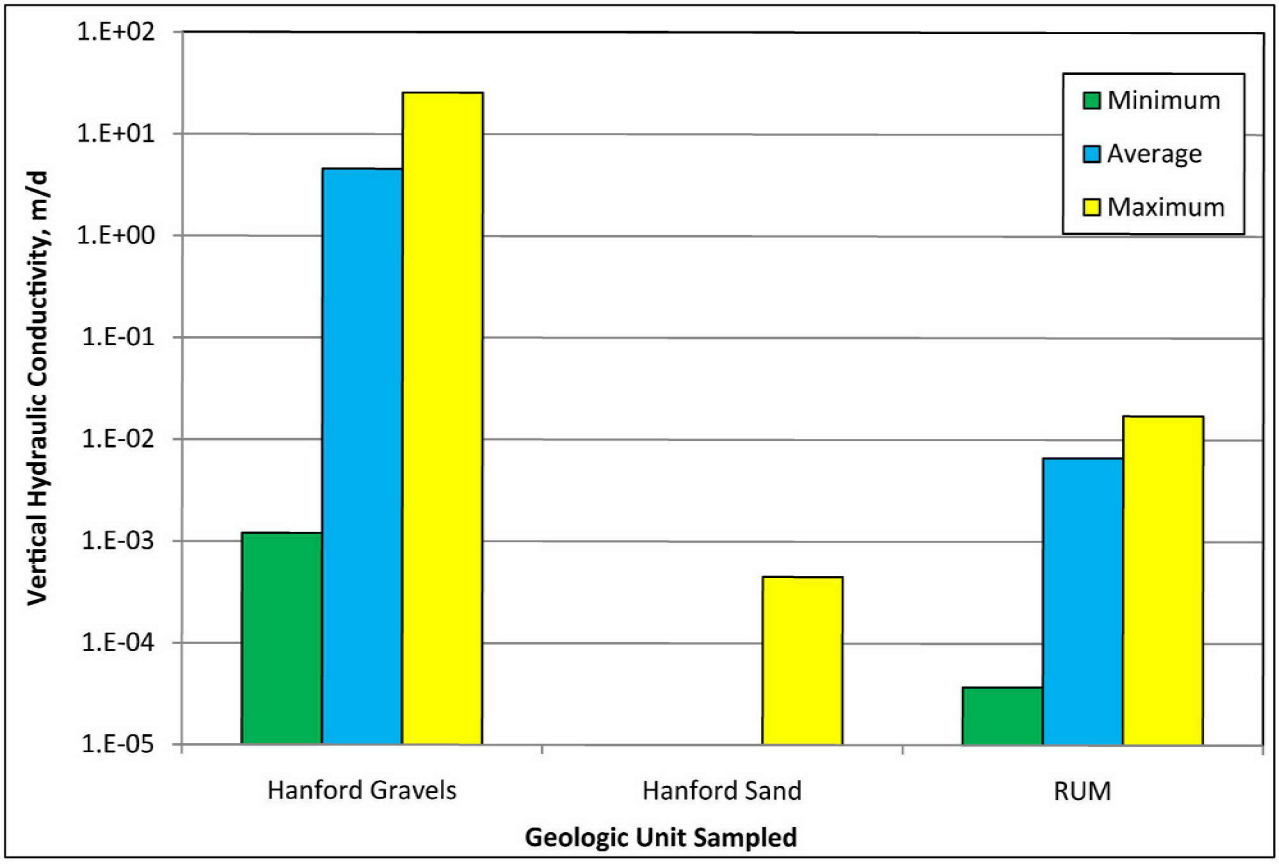



**Figure 3-29. Vertical Hydraulic Conductivity of Soil Samples from 100-F Monitoring Wells**

For 100-IU-2/IU-6, Figure 3-30 illustrates horizontal hydraulic conductivity values for the unconfined aquifer across the Hanford Site, as determined from pumping tests. The Hanford formation has high hydraulic conductivity ranging from 10 to 3,500 m/d (3 to 1,070 ft/d) (*Uncertainty Analysis Framework-Hanford Site-Wide Groundwater Flow and Transport Model* [PNNL-13641]). The highest values are in the paleochannel extending from the 200 East Area toward the southeast. Hydraulic conductivity of Ringold aquifers (primarily unit E) range from 0.1 to 560 m/d (0.30 to 1,840 ft/d). Horizontal hydraulic conductivity of fine-grained units (RUM unit; upper Ringold) is much lower than the unconfined aquifer, ranging from 0.0003 to 0.03 m/d (0.001 to 0.10 ft/d).

### 3.6.3 Groundwater Flow

This section describes current and past directions of groundwater flow beneath 100-F/IU. Information gathered under the RI contributed to more detailed interpretations of hydraulic gradients and groundwater flow in 100-F. Results of a separate investigation defined areas of groundwater upwelling into the Columbia River near 100-F and portions of 100-IU-2/IU-6.

**Table 3-9. Bulk Density and Percent Moisture of 100-F Aquifer and Aquitard, from Laboratory Tests**

| Well | Date | Sample Interval Bottom | | Geology (from Borehole Logs) | Bulk Density, Wet | | Percent Moisture Wet Sample |
|---|---|---|---|---|---|---|---|
| | | m | ft | | $kg/m^3$ | $lb/ft^3$ | |
| 199-F5-52 | 8/6/2010 | 15.8 | 51.8 | Hf: gravelly sand | 2318 | 144.6 | 21.8 |
| | 8/13/2010 | 20.1 | 65.8 | Hf: gravel | 2196 | 137.0 | 11.2 |
| | 8/13/2010 | 20.1 | 65.8 | | | | 12.2 |
| | 8/16/2010 | 22.5 | 73.8 | RUM: mud | 1964 | 122.6 | 19.7 |
| | 8/16/2010 | 22.5 | 73.8 | | | | 24.9 |
| 199-F5-53 | 11/4/2010 | 12.2 | 40.1 | Hf: sandy gravel | 2432 | 151.8 | |
| | 11/11/2010 | 15.9 | 52.3 | Hf: sand | 2190 | 136.7 | 4.73 |
| | 11/11/2010 | 15.9 | 52.3 | | | | 13 |
| | 11/11/2010 | 17.6 | 57.6 | RUM: mud | | | 19.8 |
| | 11/11/2010 | 17.6 | 57.6 | | | | 19.7 |
| | 11/11/2010 | 17.6 | 57.6 | | | | 19.4 |
| | 11/11/2010 | 17.6 | 57.6 | | | | 11.5 |
| | 11/22/2010 | 25.7 | 84.3 | RUM: mud | 1920 | 119.8 | 30.8 |
| | 11/22/2010 | 25.7 | 84.3 | | | | 21.4 |
| | 11/29/2010 | 32.0 | 105.0 | RUM: mud | 1901 | 7.4 | 38.1 |
| | 11/29/2010 | 32.0 | 105.0 | | | | 24.8 |
| 199-F5-54 | 8/24/2010 | 15.1 | 49.6 | Hf: sandy gravel | 2379 | 148.4 | |
| | 8/26/2010 | 18.0 | 59.0 | Hf: gravelly sand | 2166 | 135.2 | 20 |
| | 8/26/2010 | 18.0 | 59.0 | | | | 23.6 |
| | 8/26/2010 | 20.2 | 66.4 | Hf: sand | | | 21.9 |
| | 8/26/2010 | 21.2 | 69.5 | Hf: sand | | | 13.9 |
| | 9/1/2010 | 23.6 | 77.4 | RUM: mud | 1700 | 106.1 | 35.1 |

Hf = Hanford formation
RUM = Ringold upper mud unit

Natural and artificial recharge are key drivers of the mobilization of contaminants in the vadose zone, and ultimately groundwater. Table 3-11 lists estimated recharge rates for the dominant soil types. Recharge rates may be as low as 1.5 mm/yr (0.059 in./yr) where mature vegetation is present, and as high as 52 mm/yr (2.0 in./yr) on disturbed soil. The most significant recharge sources are episodic meteorological events (i.e., storms and rapid snowmelts) (*Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment* [PNNL-14744]). Recharge rates vary seasonally with the highest rates occurring in the winter and spring.

### *3.6.3.1 100-F Groundwater Flow*

Water-level data from manual measurements and pressure transducers were evaluated to define horizontal and vertical hydraulic gradients. Water table maps are used to infer general directions of groundwater flow. Groundwater flows perpendicular to the water-table contours. In March 2010 (Figure 3-31), the Columbia River was at a moderate stage. Groundwater in 100-F flowed generally to the east and northeast, toward the river. In the southern part of 100-F there is a southward component of flow. During

periods of high river stage (e.g., early July 2010; Figure 3-32), the hydraulic gradient reverses near the river, and river water flows into the aquifer. Groundwater cannot flow under the Columbia River because the hydraulic head on the east side of the river is higher than on the Hanford Site.

**Table 3-10. Aquifer Properties Based on Slug Tests**

| Well Name | Geologic Unit | 1992 Tests[a] | 2010 Tests[b] |
|---|---|---|---|
| | | Hydraulic Conductivity (m/d) | Hydraulic Conductivity (m/d) |
| 199-F1-2 | Hanford | 36.6 | Not Tested |
| 199-F5-42 | Hanford | 24 | 18 |
| 199-F5-43A | Hanford | 38 | 26 |
| 199-F5-43B | RUM | Not Tested | 0.8 |
| 199-F5-44 | Hanford | 17 | 14 |
| 199-F5-45 | Hanford | 9 | Not Tested |
| 199-F5-46 | Hanford | 69 | 48 |
| 199-F5-47 | Hanford | 31 | 23 |
| 199-F5-48 | Hanford | 20 | Not Tested |
| 199-F5-52 | Hanford | Not Tested | 23 |
| 199-F5-53 | RUM | Not Tested | 0.2 |
| 199-F5-54 | Hanford | Not Tested | 34 |
| 199-F6-1 | Hanford | 21 | Not Tested |
| 199-F7-3 | Hanford | 43 | 20 |
| 199-F8-3 | Hanford | 63 | Not Tested |
| 199-F8-4 | Hanford | 11 | Not Tested |

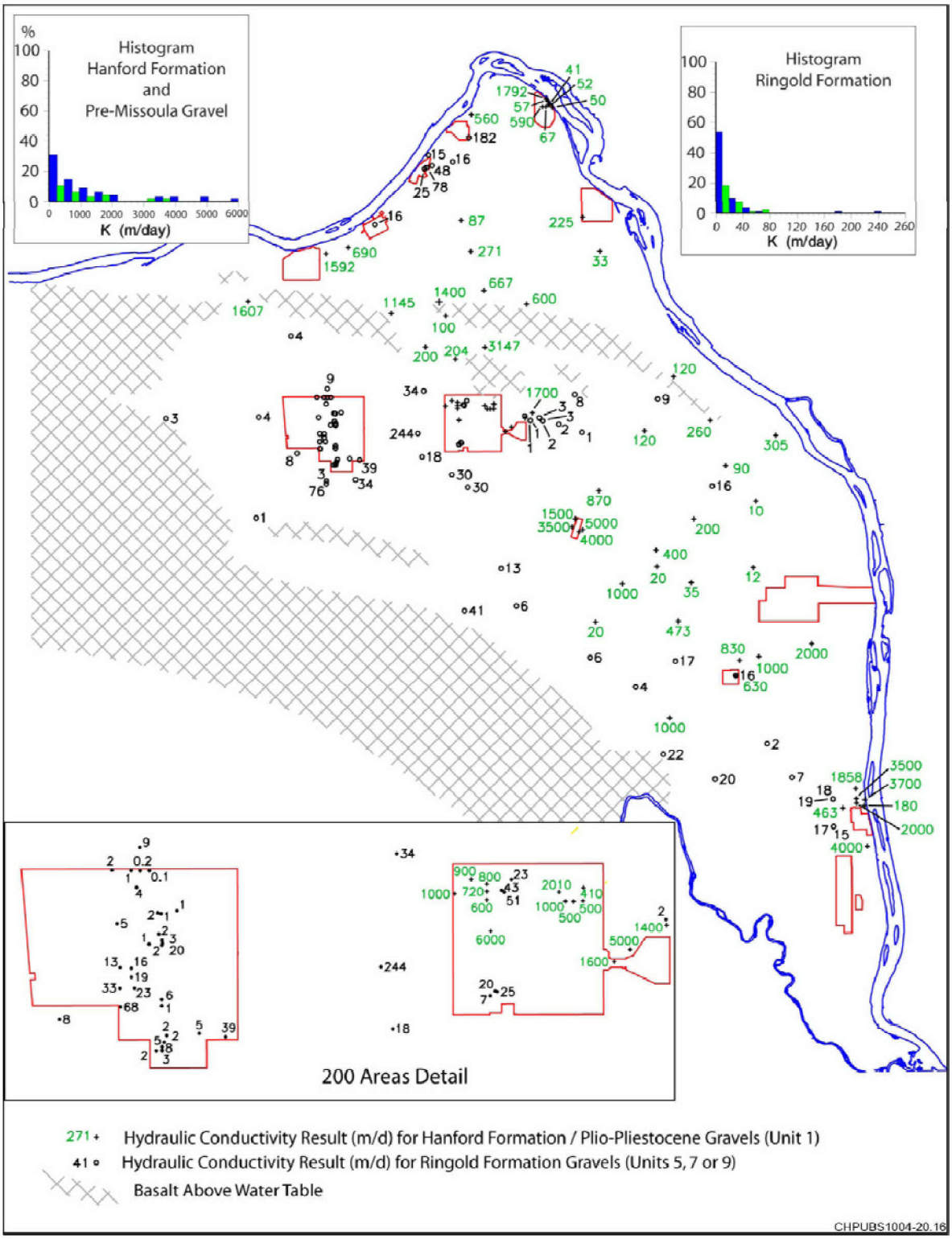
a. *Geology of the 100-FR-3 Operable Unit, Hanford Site South-Central Washington* (WHC-SD-EN-TI-221); Analyses per "A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells" (Bouwer and Rice, 1976) and "The Bouwer and Rice Slug Test – An Update" (Bouwer, 1989).

b. *Analysis of Slug Test Data at the 100-FR-3 Operable Unit* (ECF-100FR3-11-0146; Appendix C).

**Table 3-11. Estimated Recharge Rates for Dominant Soil Types**

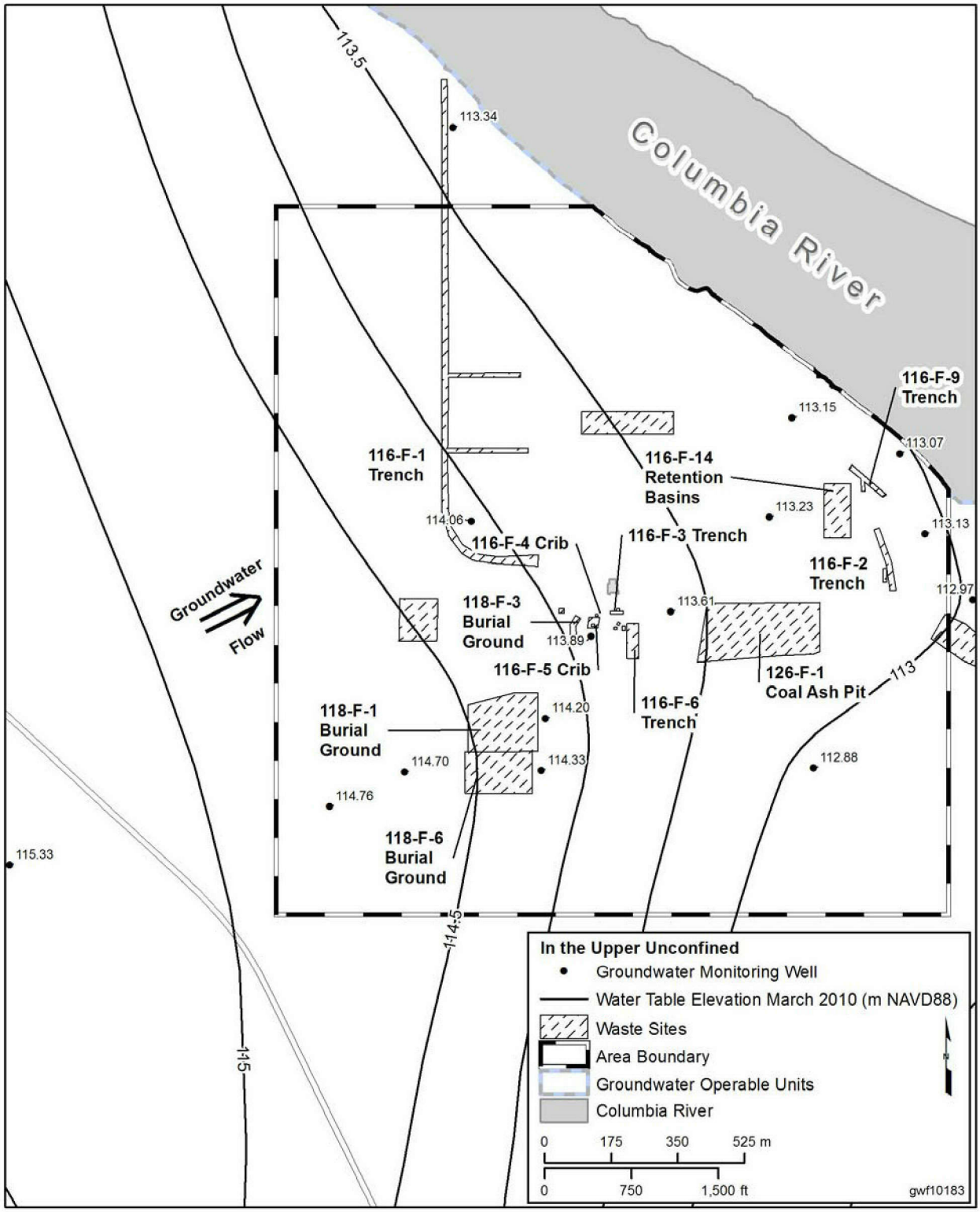
| Major Soil Type | No Vegetation | Mature Shrub-Steppe |
|---|---|---|
| Ephrata Sandy Loam | 17 mm/yr (0.67 in./yr) | 1.5 mm/yr (0.059 in./yr) |
| Burbank Loamy Sand | 52 mm/yr (2.0 in./yr) | 3.0 mm/yr (0.12 in./yr) |
| Rupert Sand | 44 mm/yr (1.7 in./yr) | 4.0 mm/yr (0.16 in./yr) |

Source: PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*.



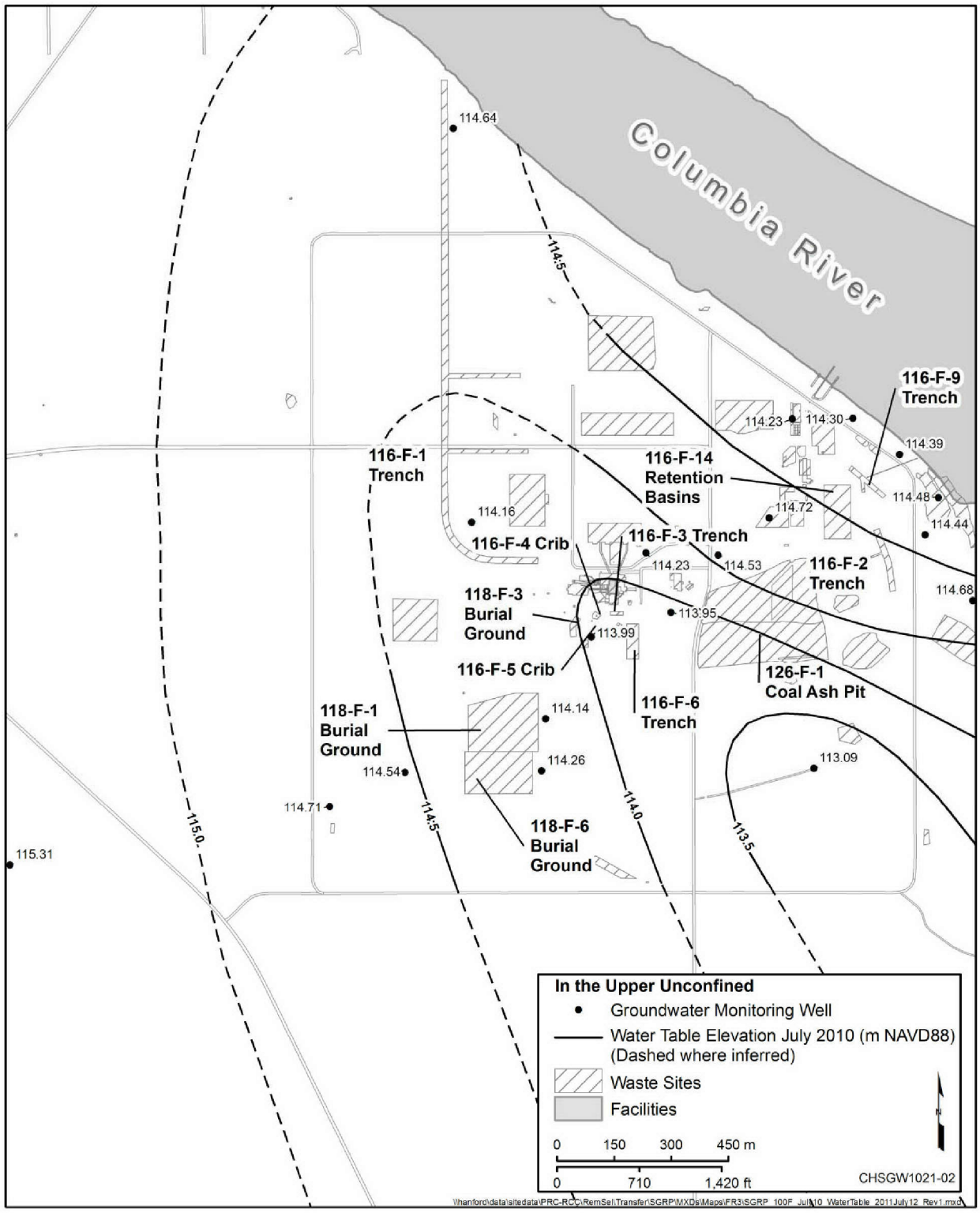

Source: PNNL-13641, *Uncertainty Analysis Framework – Hanford Site-Wide Groundwater Flow and Transport Model*.

**Figure 3-30. Hydraulic Conductivity Values Derived from Well Pumping Tests**




Sources: DOE/RL-2011-01, *Hanford Site Groundwater Monitoring Report for 2010*.
NAVD88, *North American Vertical Datum of 1988*.

**Figure 3-31. 100-F Water Table, March 2010**




Source: NAVD88, *North American Vertical Datum of 1988*.

**Figure 3-32. 100-F Water Table, July 2010**

To evaluate hydraulic gradients in more detail, water-level data were analyzed by trend-surface analysis (*Hydraulic Gradients in 100-FR-3, 2010 and 2011* [ECF-100FR3-12-0028] Appendix C). A plane was fitted to the water-level data using least squares regression. The slope of the fitted surface represents the hydraulic gradient magnitude, and the dip direction represents the direction of groundwater flow. Velocity was estimated using a form of the Darcy equation:

$$v = Ki/n_e$$

where:

v = average velocity

K = horizontal hydraulic conductivity

i = hydraulic gradient

$n_e$ = effective porosity

The axis of the water table "valley" of Figure 3-32 effectively divides 100-F into two flow regimes. In the northeastern, or near-river regime, the flow direction changes markedly with changing river stage. Flow is toward the east when the river is low and to the south-southeast when the river stage is high. In the southwestern or inland flow regime, the magnitude and direction of groundwater flow are more consistent.

In northeastern 100-F during low stage (February and September 2010), the gradient sloped to the northeast, perpendicular to the river. The maximum gradient was 0.0016 m/m in September 2010. December 2011 was a time of fairly low, but variable river stage. The gradient sloped toward the east-northeast. Using a median value for hydraulic conductivity (35 m/d or 110 ft/d), velocity ranged from 0.17 to 0.23 m/d (0.56 to 0.75 ft/d) during these periods of low river stage.

During high and moderately high river stage (early July 2010 and March 2011, respectively), the gradient reversed and sloped gently to the south or south-southwest. The July data set did not form a good plane; therefore, more uncertainty is associated with this estimate. The minimum gradient magnitude was 0.00035 m/m in March 2011. Using the median value for hydraulic conductivity, velocity was 0.14 m/d (0.46 ft/d) in March 2011 and 0.17 m/d (0.56 ft/d) in July 2010.

Groundwater flow in the inland (southwest) portion of 100-F was consistently to the east or east-northeast during the periods studied. The magnitude of the gradient varied little (0.0010to 0.0015 m/m). Using the median value for hydraulic conductivity, velocity ranged from 0.20 to 0.29 m/d (0.66 to 0.95 ft/d).

There are insufficient wells in southeastern 100-F to use trend-surface analysis in that area. Interpretation of water-level maps indicate the direction of flow in southeastern 100-F curves to the southeast (Figure 3-31).

Several kilometers southeast of 100-F the water table slopes very gently at elevations ranging from 112 to 111 m (364 to 367 ft). This is approximately the same elevation as the Columbia River at this location. Consequently, the average direction of groundwater flow in this region is approximately parallel to the river. The gradient in this region was calculated from water-level data from five wells in March 2010 (699-62-31, 699-63-25A, 699-64-27, 699-66-23, and 699-71-30; Figure 3-2) and three wells in March 2011 (699-71-30, 699-64-27, and 699-62-31). During both periods, the gradient sloped to the south-southeast at 0.0012 m/m, and velocity was estimated at 0.24 m/d (0.79 ft/d).

Table 3-12 and Figure 3-33 summarize results.

**Table 3-12. Hydraulic Gradients and Groundwater Velocity in 100-F**

| Region | Date | Gradient | Azimuth, degrees E of N | Velocity* m/d (ft/d) |
|---|---|---|---|---|
| North-eastern 100-F (near river) | Feb. 2010 | 0.00097 | 53 | 0.19 (0.62) |
| | July 2010 | 0.00085 | 202 | 0.17 (0.54) |
| | Sept. 2010 | 0.0016 | 43 | 0.23 (0.77) |
| | Mar. 2011 | 0.00035 | 170 | 0.14 (0.47) |
| | Dec. 2011 | 0.00087 | 74 | 0.17 (0.56) |
| South-western 100-F (inland) | Feb. 2010 | 0.0015 | 77 | 0.29 (0.96) |
| | July 2010 | 0.0013 | 83 | 0.24 (0.80) |
| | Sept. 2010 | 0.0012 | 95 | 0.23 (0.74) |
| | Mar. 2011 | 0.0012 | 90 | 0.23 (0.77) |
| | Dec. 2011 | 0.0010 | 98 | 0.20 (0.66) |
| South of 100-F | Mar. 2010 | 0.0012 | 157 | 0.24 (0.77) |
| | Mar. 2011 | 0.0012 | 159 | 0.24 (0.78) |

Note: Blue highlighting denotes reversed gradient.

Source: ECF-100FR3-12-0028, *Hydraulic Gradients in 100-FR-3, 2010 and 2011,* in Appendix C.

* Calculated by Darcy equation assuming hydraulic conductivity of 35 m/d (115 ft/d) and porosity of 18 percent.

Normal seasonal variability in the water table in 100-F is more than 3 m (10 ft) in wells near the river and decreases farther inland (Figure 3-34). Well 199-F7-1 shows notably little seasonal variability, just 0.11 m (0.36 ft) between October 2010 and late August 2011. During times of high river stage, water levels rise in the aquifer near the river, and a "valley" forms in the water table (Figure 3-32). Groundwater from east and west converges and moves toward the southeast, approximately parallel to the river. Flow may be influenced by a buried paleochannel of highly transmissive sediments.

Vertical gradients within the unconfined aquifer at 100-F (Hanford formation) have not been quantified. The aquifer is thin, and the vertical component of flow is probably insignificant.

Pressure transducers in well pair 199-F5-43A and -43B provide information on vertical gradients between the unconfined aquifer and the RUM. During a period of low river stage in fall 2010, the gradient fluctuated up and down (top panel of Figure 3-35). The overall difference in head between the two wells was negligible (0.004 m [0.013 ft] average), indicating no significant vertical gradient. During a period of high river stage in spring 2011, there was a consistently downward hydraulic gradient (bottom panel of Figure 3-35). The water level in the river was higher than in the unconfined aquifer, which was higher than in the RUM. During this period, the difference in head between the two wells averaged 0.07 m (0.23 ft), and the vertical gradient between the unconfined aquifer and the RUM averaged 0.0019 m/m.

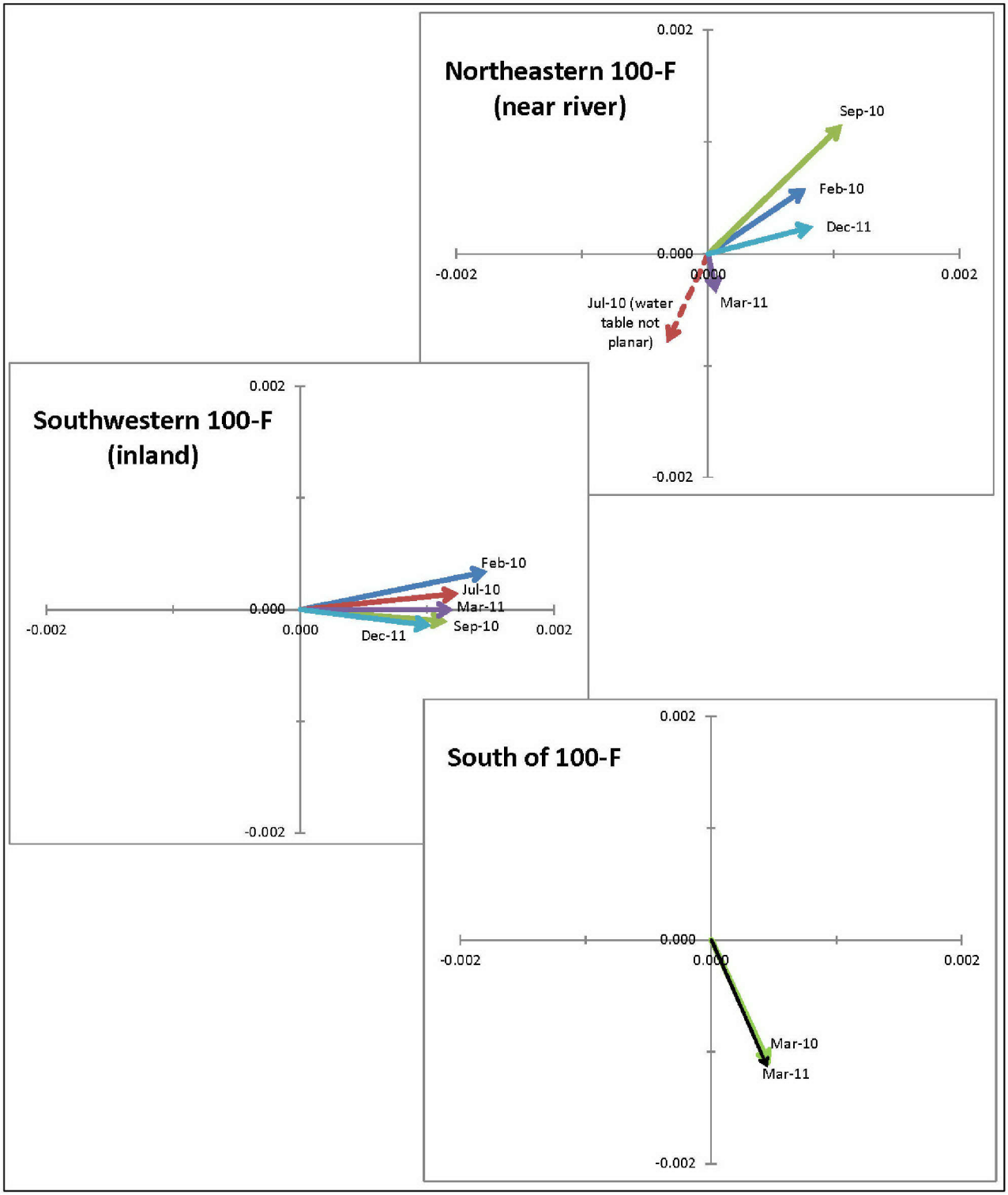



**Figure 3-33. Magnitude and Direction of Hydraulic Gradient in 100-F**

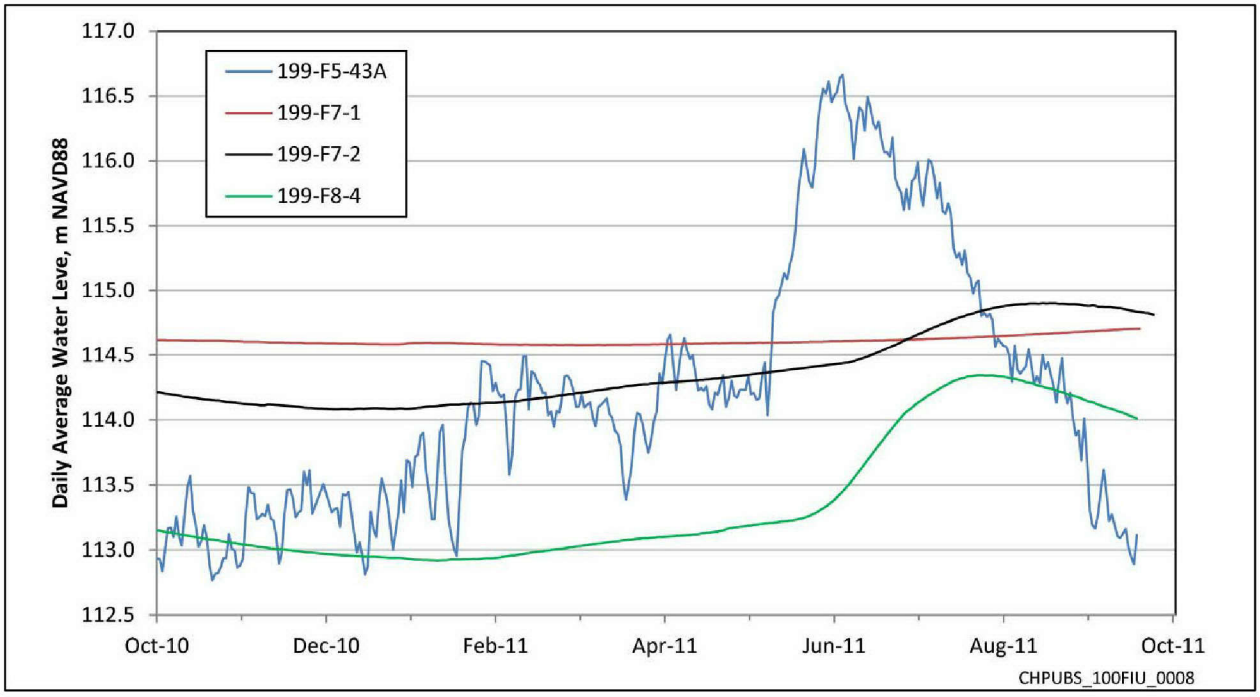



**Figure 3-34. Daily Average Water Levels in 100-F Monitoring Wells**

Manual water-level data from piezometers in Well 699-84-35A, north of 100-F, indicate a downward gradient from the Hanford formation to underlying Ringold sediments, and an upward gradient between the lower mud and overlying portions of the Ringold Formation (Figure 3-36). The gradient between the Hanford formation (piezometer O) and the middle of the Ringold Formation (piezometer R, beneath the RUM) is downward at 0.007 m/m. Piezometer P, screened at the base of the Ringold Formation in the lower mud, has the highest head. The gradient between this unit and overlying sediments is upward at 0.26 m/m.

Historical water-level data show the effects of artificial recharge at 100-F and elsewhere on the Hanford Site (Figure 3-37). Discharge of large volumes of liquid effluent created groundwater mounds beneath each of the 100 Area during the 1960s (*Hydrologic Information Summary for the Northern Hanford Site* [WHC-SD-EN-TI-023]). As the reactors were shut down in the late 1960s and the 1970s, the mounded water levels gradually declined, as illustrated by Well 699-77-36, located southwest of 100-F. The 100-F groundwater mound had a peak elevation of at least 118 m (387 ft) in the early 1960s, centered in eastern 100-F (e.g., Well 199-F5-1 on Figure 3-37). This mound created the potential for radial flow and spreading of groundwater contaminants. The mound had subsided by the 1970s. The increase in water levels in the mid-1990s shown in the hydrograph was a result of several years of high river stage (Section 3.3.1). The hydraulic effects of changes in river stage propagated inland rapidly through the highly permeable Hanford formation aquifer.

#### *3.6.3.2 100-IU-2/IU-6 Groundwater Flow*

Figure 3-38 is a water table map for the entire Hanford Site for March 2010. Groundwater flows west to east beneath the southern portion of 100-IU-2/IU-6, discharging to the Columbia River at the eastern edge of the Hanford Site. Some groundwater flows northward through the gap between Gable Mountain and Gable Butte, and then toward the river. This component of flow is evidenced by water levels and contaminant movement, and is being studied as part of the 200-BP-5 OU.

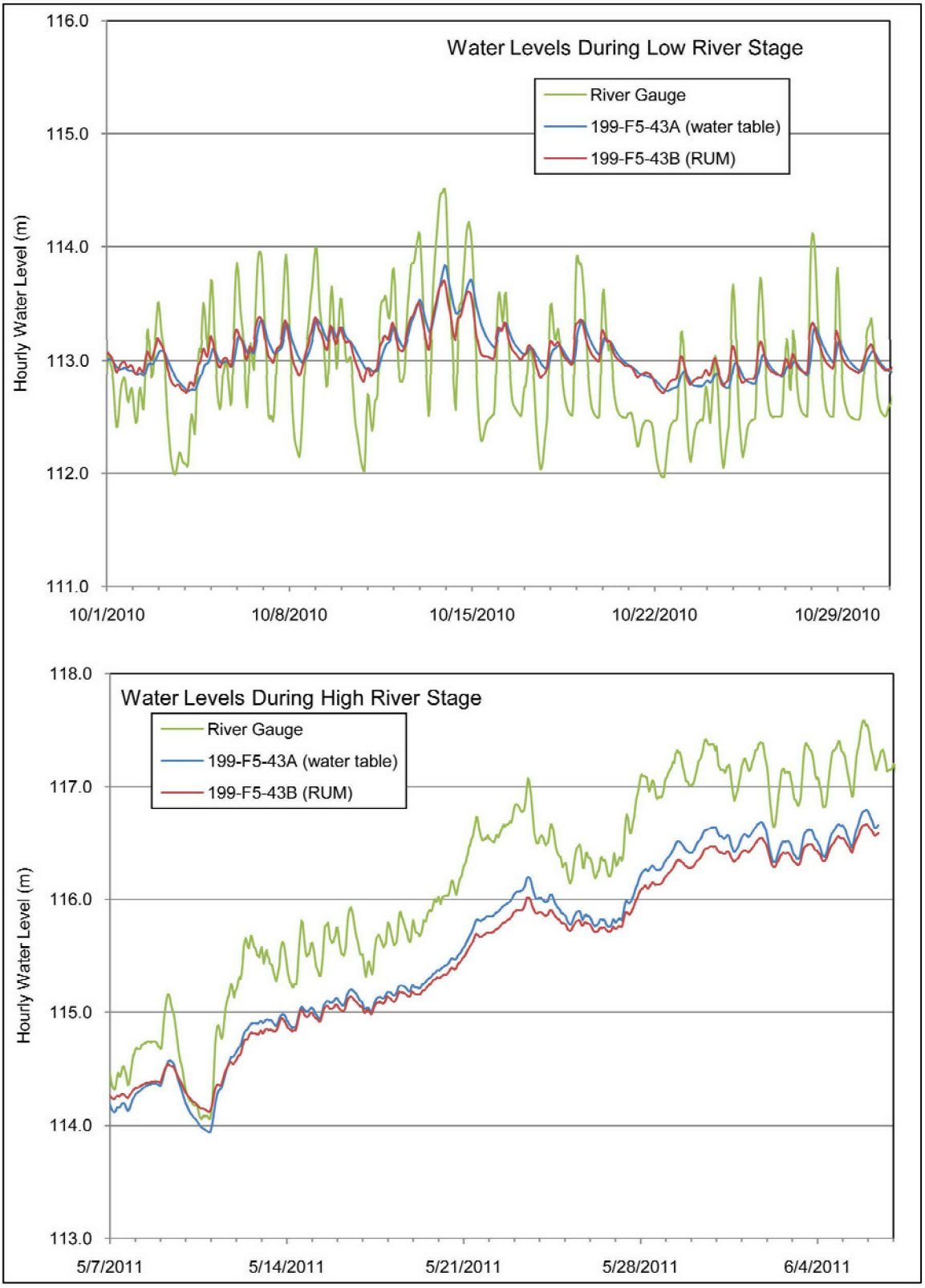



**Figure 3-35. Water Levels in Wells 199-F5-43A and 199-F5-43B, and 100-F River Stage**

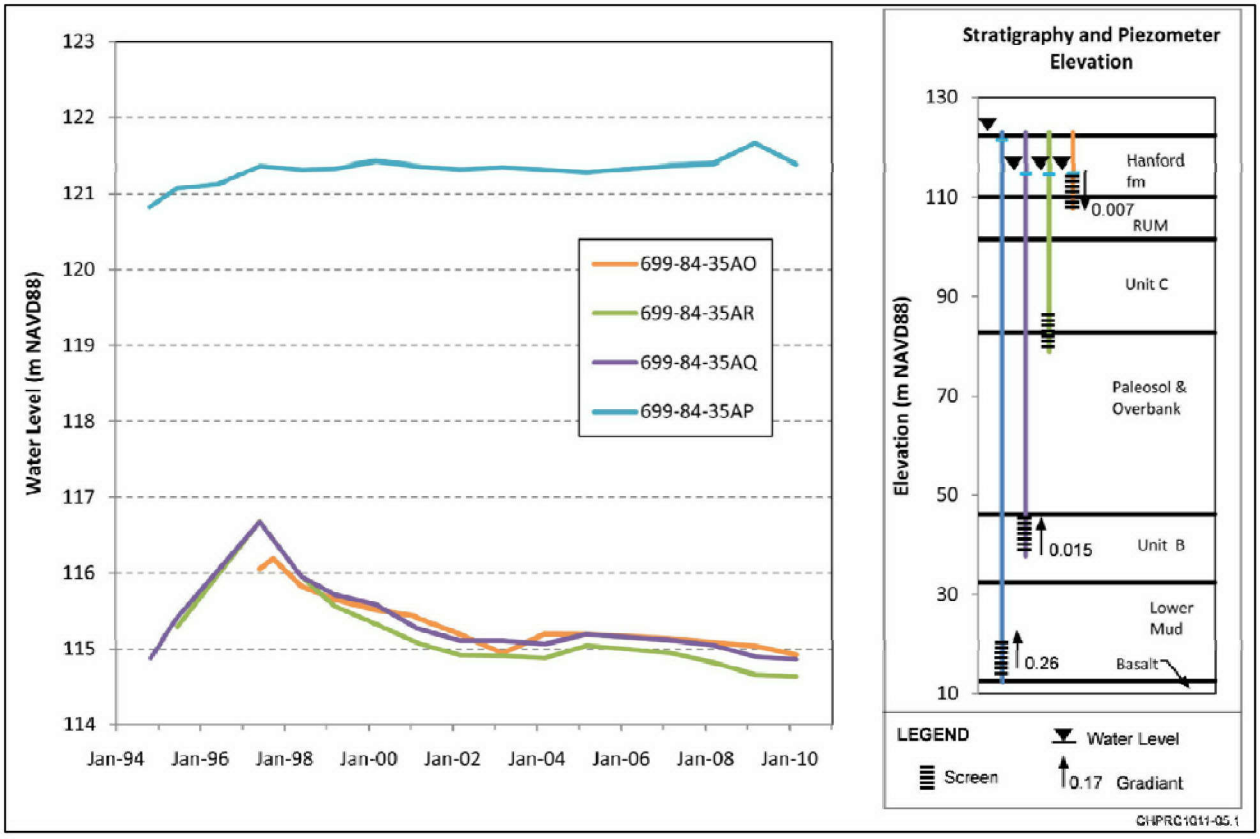



**Figure 3-36. Water Levels and Vertical Gradients in Piezometers near 100-F**

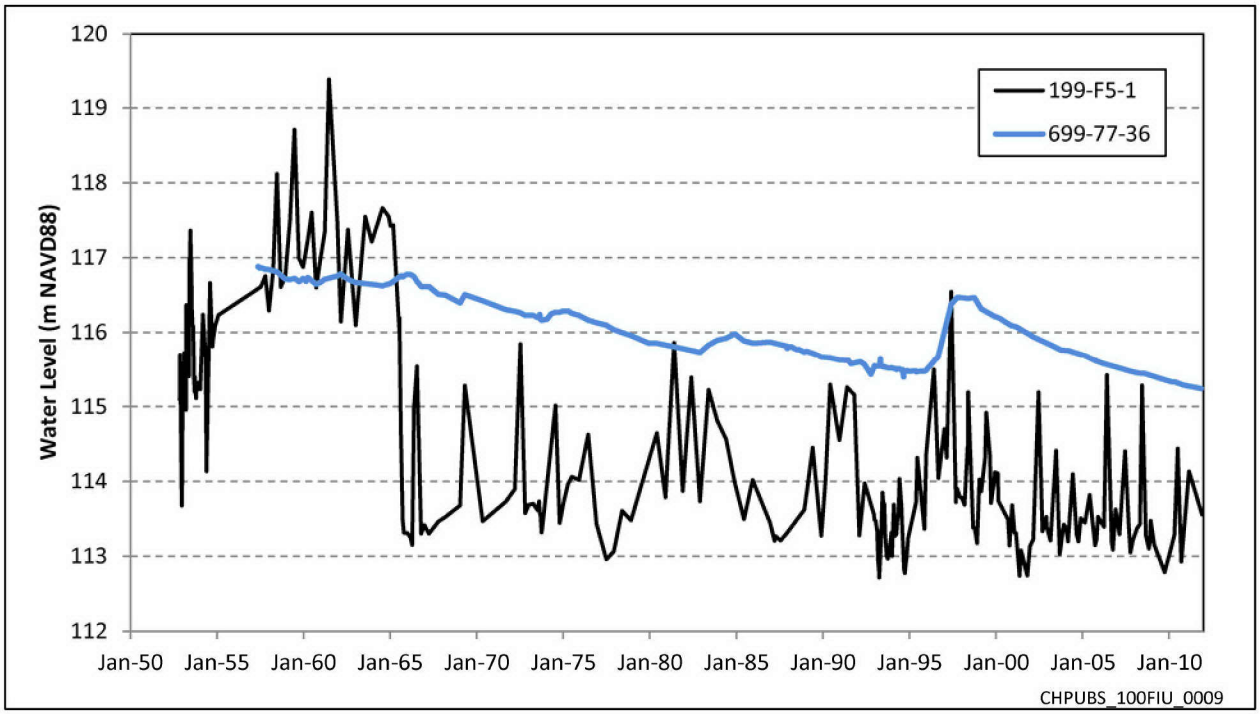
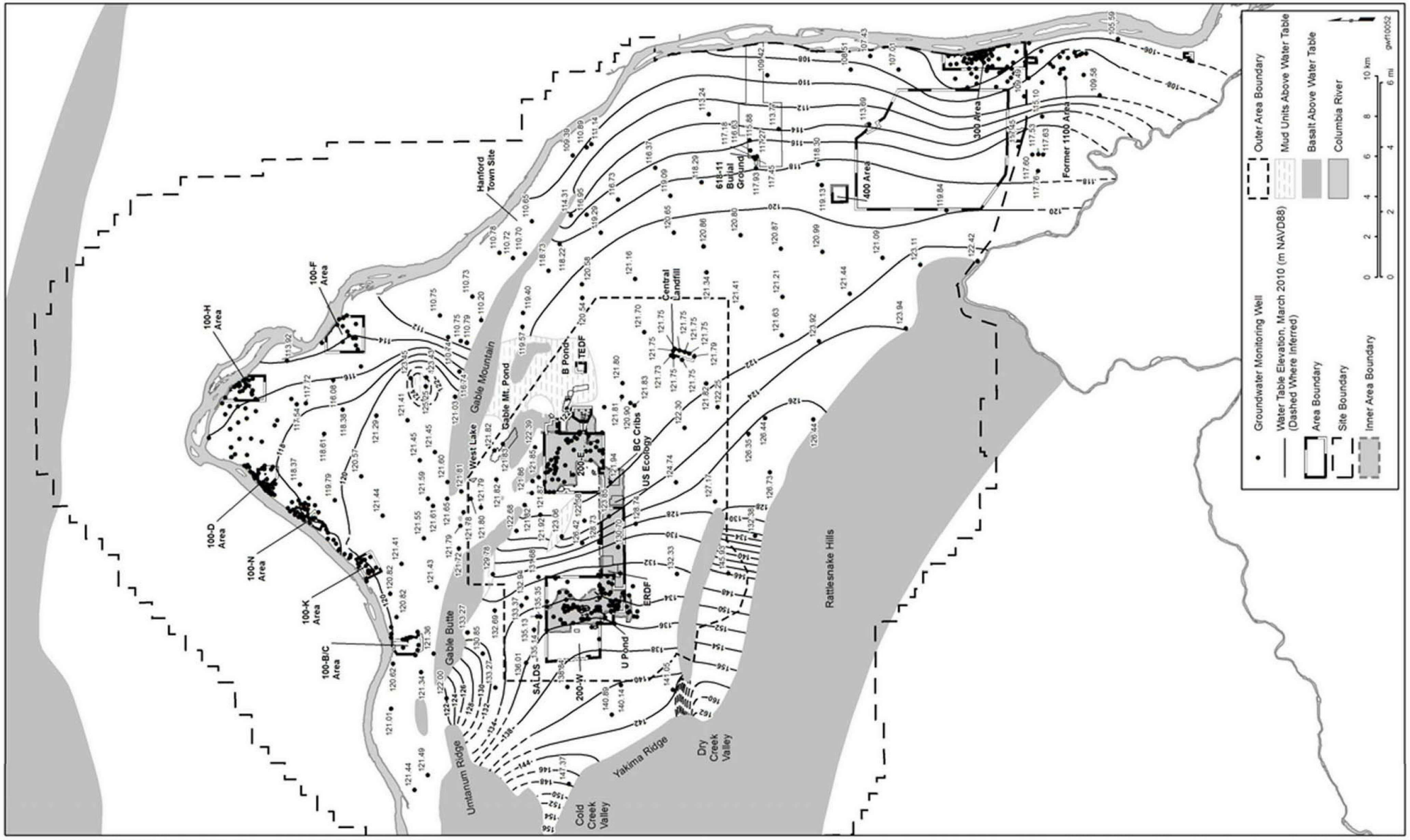



**Figure 3-37. Water Levels in Wells 199-F5-1 and 699-77-36, 1952 to 2011**




Source: DOE/RL-2011-01, *Hanford Site Groundwater Monitoring for 2010*.

**Figure 3-38. Hanford Site Water Table, March 2010**

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The topographic high formed by the Gable Mountain basalt structure constrained the path of the paleo-floods and the ancestral Columbia River. Consequently, flow was diverted around the Gable Mountain anticline, near the Hanford Townsite, creating extensive channeling that removed much of the Ringold Formation sediment and re-deposited high-permeability Cold Creek and Hanford formation sediment (200-PO-1 RI Report [DOE/RL-2009-85]). These highly permeable channels form preferential groundwater flow paths. The areal extent of this preferential groundwater flow region has expanded and contracted with time, depending on the elevation of the water table. During past decades, as groundwater mounding on the Central Plateau drove contaminants and raised groundwater levels (Figure 3-39), the areal extent of the plumes was much greater, spreading laterally downgradient and virtually unconstrained within saturated Hanford formation and Ringold Formation sediment toward the Columbia River. As the 200 Area liquid disposal sources were turned off in the mid-1990s, the groundwater flow rate and water table elevation showed a dramatic decrease. The dropping water table receded farther into the Ringold Formation, slowing the movement of groundwater and contamination to the river. Areas of higher permeability, where Cold Creek and Hanford formation sediment is still present at or below the water table, appear to provide the preferential groundwater flow path to the river.

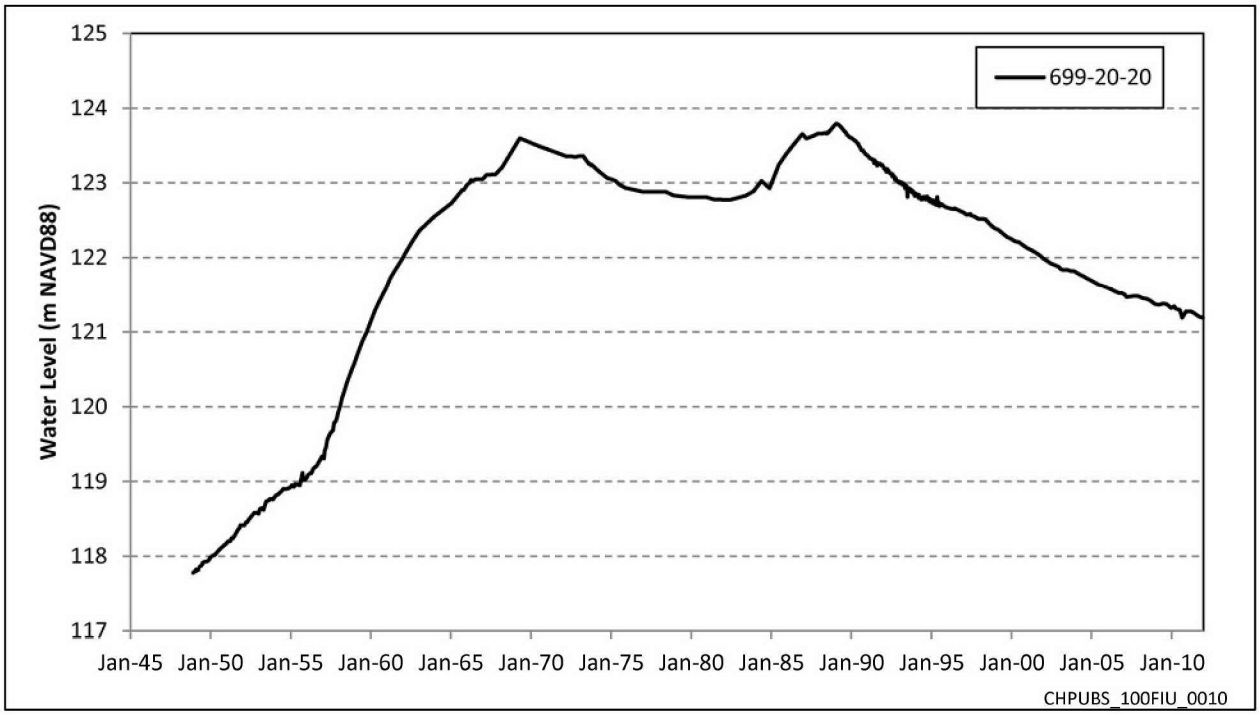



**Figure 3-39. Water Levels in Well 699-20-20, 1948 to 2011**

Vertical head differences in 100-IU-2/IU-6 south of Gable Mountain vary. Well 699-14-38, located south-southeast of the 200 East Area, monitors the top of basalt, the Ringold Formation, and the Hanford formation (Figure 3-40). The gradient between water in the basalt and the overlying Ringold Formation is upward at 0.017 m/m. The gradient between the Ringold Formation and Hanford formation also is upward, at 0.025 m/m. Wells 699-24-1S, -1P, -1Q, and -1R are a group of piezometers located east-southeast of the 200 East Area that monitor various intervals in the basalt, the Ringold Formation, and the Cold Creek unit (Figure 3-40). The vertical gradient is downward between the Ringold Formation and the underlying basalt (0.007 to 0.08 m/m). An upward gradient of 0.18 m/m exists between the Rattlesnake Ridge interbed and the shallower Levey interbed.

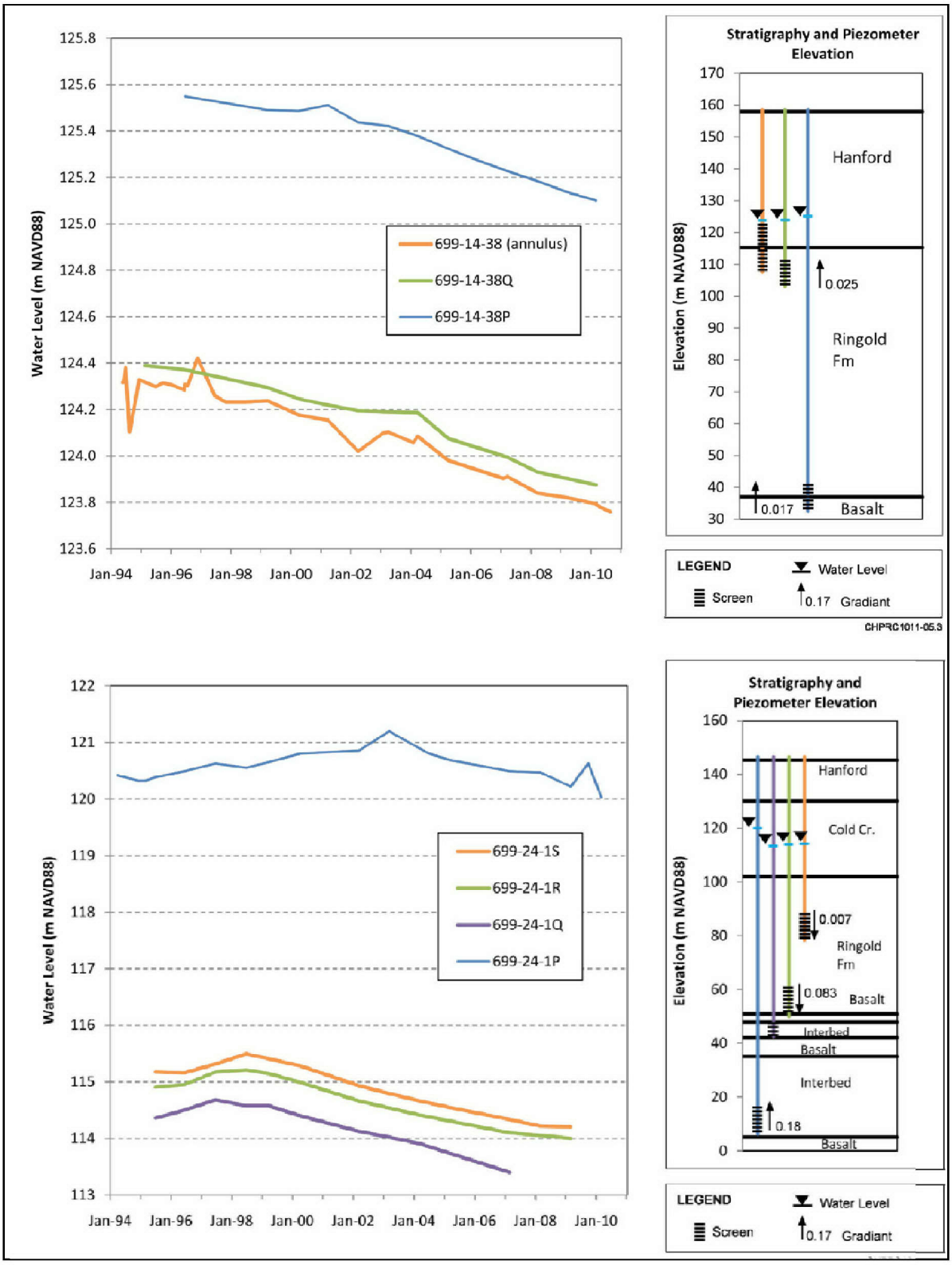



**Figure 3-40. Water Levels and Vertical Gradients in Piezometers Southeast of 200 East Area**

Groundwater velocity within the unconfined aquifer between the 200 East Area and the Columbia River (100-IU-2/IU-6) was estimated by inspection of arrival times of tritium concentration peaks at monitoring wells along an identified flow path downgradient of the source areas (200-PO-1 RI Report [DOE/RL-2009-85]). The estimated groundwater velocity during the period examined (1963 to 1996) ranged from about 250 to 625 m/yr (820 to 2050 ft/yr), with the higher velocity observed near the Columbia River where the hydraulic gradient is steeper (Table 3-13).

The apparent travel time for mobile contaminants originating within the southeast corner of the 200 East Area to reach the Columbia River was approximately 33 years (i.e., 1963 to 1996 for the observed tritium concentration peaks). This is probably a minimum travel time (i.e., it overstates groundwater contaminant migration rates compared to current conditions) for the following two reasons:

- The westernmost (i.e., upgradient) monitoring history for this observation was taken from Wells 699-34-41B and 699-31-31. Historical tritium monitoring in both of these wells was started when substantial tritium concentrations were already present in both wells. This would indicate that the actual peak concentration may have occurred before initiation of monitoring in those wells.

- The time period examined for this evaluation includes the historical operational period (e.g., 1960s and 1970s) when large groundwater mounds were present beneath the 200 Area, thus increasing the effective groundwater gradient across the Site. Under current conditions, the historic groundwater mounds are substantially diminished, and groundwater gradient across the Hanford Site is approaching pre-Hanford Site conditions with reduced groundwater velocity and resultant increased travel time from the Central Plateau to the Columbia River.

### 3.6.4 Zone of Surface Water/Groundwater Interaction

Groundwater flow on the Hanford Site near the Columbia River is influenced by river stage, which is directly controlled by the upstream Priest Rapids Dam. The rise and fall of river stage creates a dynamic zone of interaction between groundwater and river water, and influences flow patterns, transport rates, contaminant concentrations, and attenuation rates within the system (Figure 3-41; *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project* [PNNL-13674]). The Columbia River discharge and resultant river stage in the Hanford Reach vary substantially on a seasonal basis and even on a daily and hourly basis, depending on the operations of Priest Rapids Dam. At 100-F, Columbia River elevations vary up to 3 m (10 ft) in a year (Section 3.3.1).

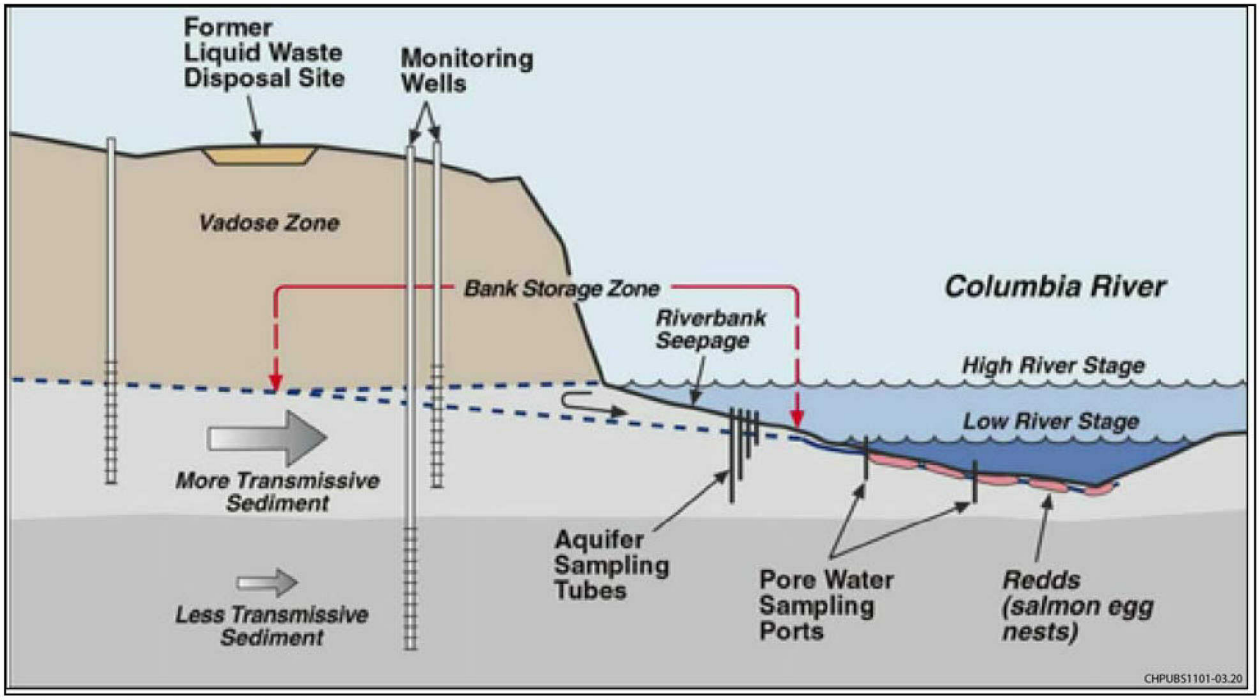
Physical, chemical, and biological processes that occur within the zone of interaction potentially alter the characteristics of groundwater nearing the Columbia River. Data suggest that physical processes are the primary influences on contaminant concentrations and fluxes where groundwater discharges into the river. Chemical processes may render contaminants less mobile as they adsorb to sediments or precipitate.

Water from the zone of interaction is a mixture of groundwater and river water. Specific conductance of groundwater from the inland portion of 100-F is greater than 800 µS/cm, while that of river water averages approximately 140 µS/cm. Samples from aquifer tubes and from wells nearest the river (199-F5-42 and 199-F5-43A) typically have specific conductance below 200 µS/cm, with some values indistinguishable from river water specific conductance. A few 100-F aquifer tubes have specific conductance above 200 µS/cm; these are typically tubes greater than 3 m (10 ft) deep. Specific conductance of samples from the 200-PO-1 shoreline segment (100-IU-2/IU-6) tend to be slightly higher, with locations in regional contaminant plumes as high as 300 µS/cm or more.

**Table 3-13. Estimated Groundwater Velocity in the Unconfined Aquifer, 100-IU-2/IU-6 South of Gable Mountain, Based on Arrival of Tritium Concentration Peaks**

| Relative Location | Wells inspected for Tritium Peaks, and Time Period | Estimated Groundwater Velocity, m/yr (ft/yr) |
|---|---|---|
| Near 200 East Area | 699-31-31 and 699-35-15A, 1963 to 1969 | 433 (1420) |
| Midway between 200 East and Columbia River | 699-26-15A and 699-35-9, 1969 to 1990 | 252 (827) |
| Near Columbia River | 699-37-E4, 1990 to 1996 | 625 (2050) |

Source: DOE/RL-2009-85, *Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit*.




Note: Modified from PNNL-13674, *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone integration Project*.

**Figure 3-41. Illustration of Zone of Interaction and River Bank Seepage**

Groundwater from the unconfined aquifer discharges to the Columbia River. Discharge of groundwater from the aquifer to the river is estimated to range from about 1.1 to 2.5 $m^3$/sec (39 to 99 $ft^3$/sec) for the entire Hanford Site (*Groundwater Data Package for Hanford Assessments* [PNNL-14753]).

Riverbank seep discharges to the river are visible during low river stage. Conversely, during high river stage, the seeps are submerged as river water infiltrates the riverbanks and forms either a layered system or a mixture during interaction with approaching groundwater. Data from the seeps and along the riverbank indicate that the riverbank storage water composition oscillates dramatically from nearly completely river water during high river stage to primarily groundwater during low river stage (*Zone of Interaction Between Hanford Site*

*Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project* [PNNL-13674]).

During 2008 through 2010, DOE conducted field sampling activities in support of an RI of Hanford Site releases to the Columbia River (Section 2.1.10.3). Results of the mapping phase of the study for 100-F and 100-IU-2/IU-6 are summarized in Sections 3.6.4.1 and 3.6.4.2, respectively. Subsequent phases of the study collected samples of pore water and analyzed them for Hanford Site contaminants. Sediment and surface water samples also were collected. Chapter 4 summarizes the results.

#### *3.6.4.1 Groundwater Discharge to Columbia River in 100-F*

During the upwelling study, specific conductance and temperature were measured at 64 locations along the 100-F section of the Columbia River. One small groundwater upwelling region was observed immediately adjacent to 100-F (Figure 3-42). There were no elevated temperature anomalies near 100-F, suggesting relatively low discharge rates. Groundwater upwelling areas were also observed in the 100-F slough area and near the beginning of the 100-F island complex (Figure 3-43). More prominent upwelling patterns were found across the river from 100-F. Relatively high temperature anomaly patterns coincided with the prominence of high specific conductance values in this region.

The maximum specific conductance in 100-F pore water was 858 µS/cm in sandy silt substrate in an inlet on the east shore near the base of a landslide off the White Bluffs. Specific conductance near the main 100-F Area ranged from 133 to 208 µS/cm. Specific conductance was higher farther downstream, greater than 400 µS/cm in some samples in the 100-F slough.

#### *3.6.4.2 Groundwater Discharge to Columbia River in 100-IU-2/IU-6*

During the upwelling study, specific conductance and temperature were measured at 80 sample locations throughout approximately 21 km (13 mi) of the river between the Hanford Townsite and Energy Northwest (Figures 3-44 through 3-47). Pore water specific conductance indicated the presence of broad areas of groundwater upwelling from the Hanford Townsite slough down to Energy Northwest. Most of these areas were not associated with significant temperature anomalies, indicating relatively low discharge rates. Groundwater upwelling was detected offshore in waters as deep as approximately 11 m (36 ft).

The maximum specific conductance was 684 µS/cm in a silty/cobble substrate approximately 2.6 km (1.6 mi) upstream of Savage Island. There were relatively few areas along the Hanford Site shorelines where elevated temperature anomaly patterns were distinctly observed.

### 3.6.5 Groundwater Chemistry

The diagrams of Figure 3-48 illustrate relative concentrations of major ions in groundwater samples from 100-F. General chemistry of 100-F groundwater is primarily a calcium-bicarbonate type. Some locations tend toward a sodium-bicarbonate type (e.g., 199-F5-43A and -43B). Ionic strength is greater in wells inland from the river (e.g., 199-F5-48, 199-F7-1, and 199-F8-4 on Figure 3-48).

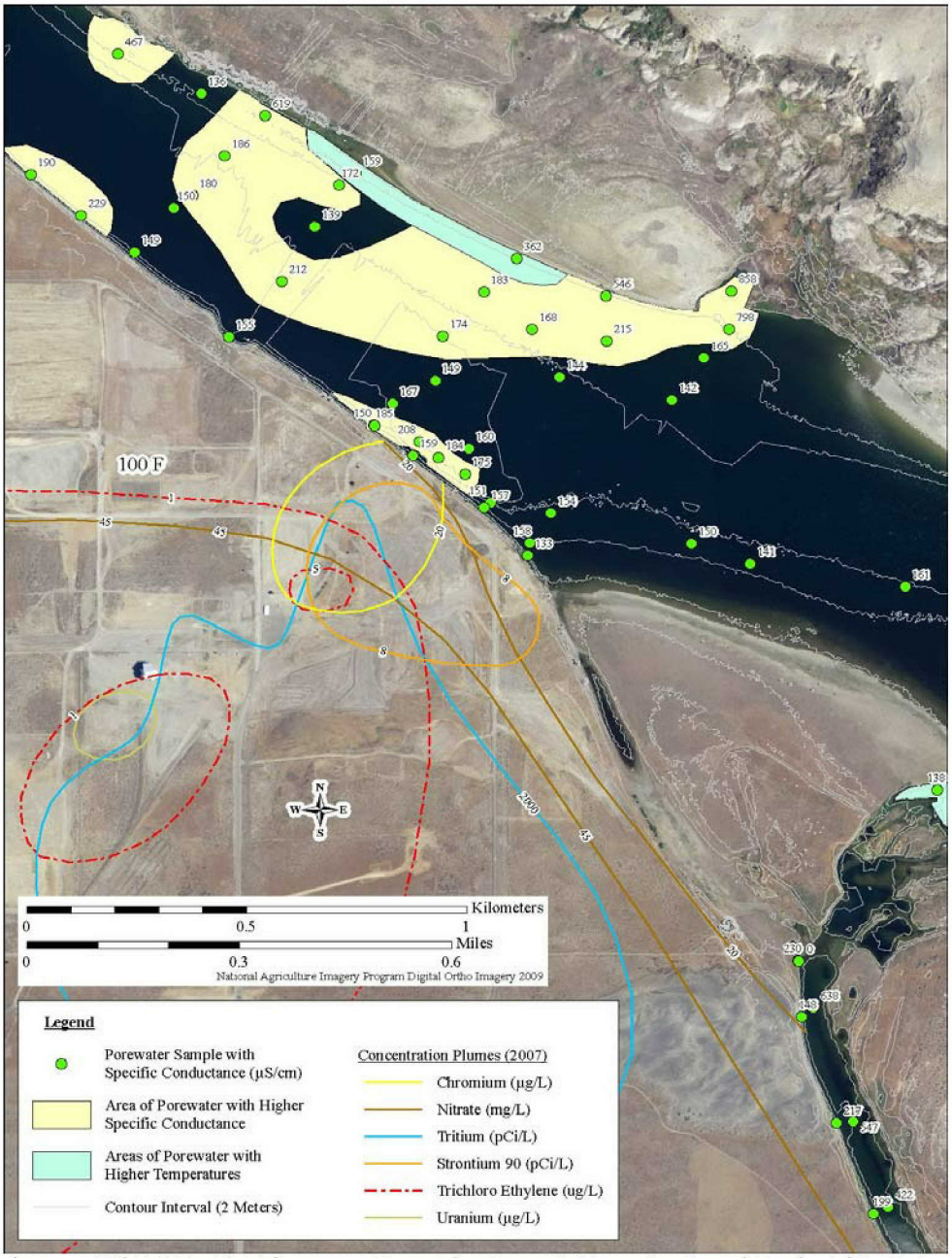
Groundwater pH in 100-F ranges from 7.1 to 8.0 and averages 7.6. Dissolved oxygen ranges from 2 to 10 mg/L. The lowest value measured in 2010 was 1.9 mg/L in Well 199-F7-1 in southwestern 100-F. Other wells in this region, which coincide with the trichloroethene plume, also have low dissolved oxygen (2.5 to 4 mg/L). Other wells with typically low dissolved oxygen (less than 5 mg/L) are not limited to a specific location within 100-F. Well 199-F5-43B, screened in the RUM unit, has low dissolved oxygen (less than 1 mg/L in 2000, the most recent data point).

Hardness of 100-F groundwater ranges from approximately 80 to 370 mg/L as $CaCO_3$. Wells near the Columbia River (e.g., 199-F5-43A) tend to have lower hardness. Groundwater is harder in wells in central

100-F (199-F5-48) and southwestern 100-F (199-F8-7). Well 199-F5-43B, screened in the confined Ringold but located near the river, has a relatively low hardness (104 mg/L).

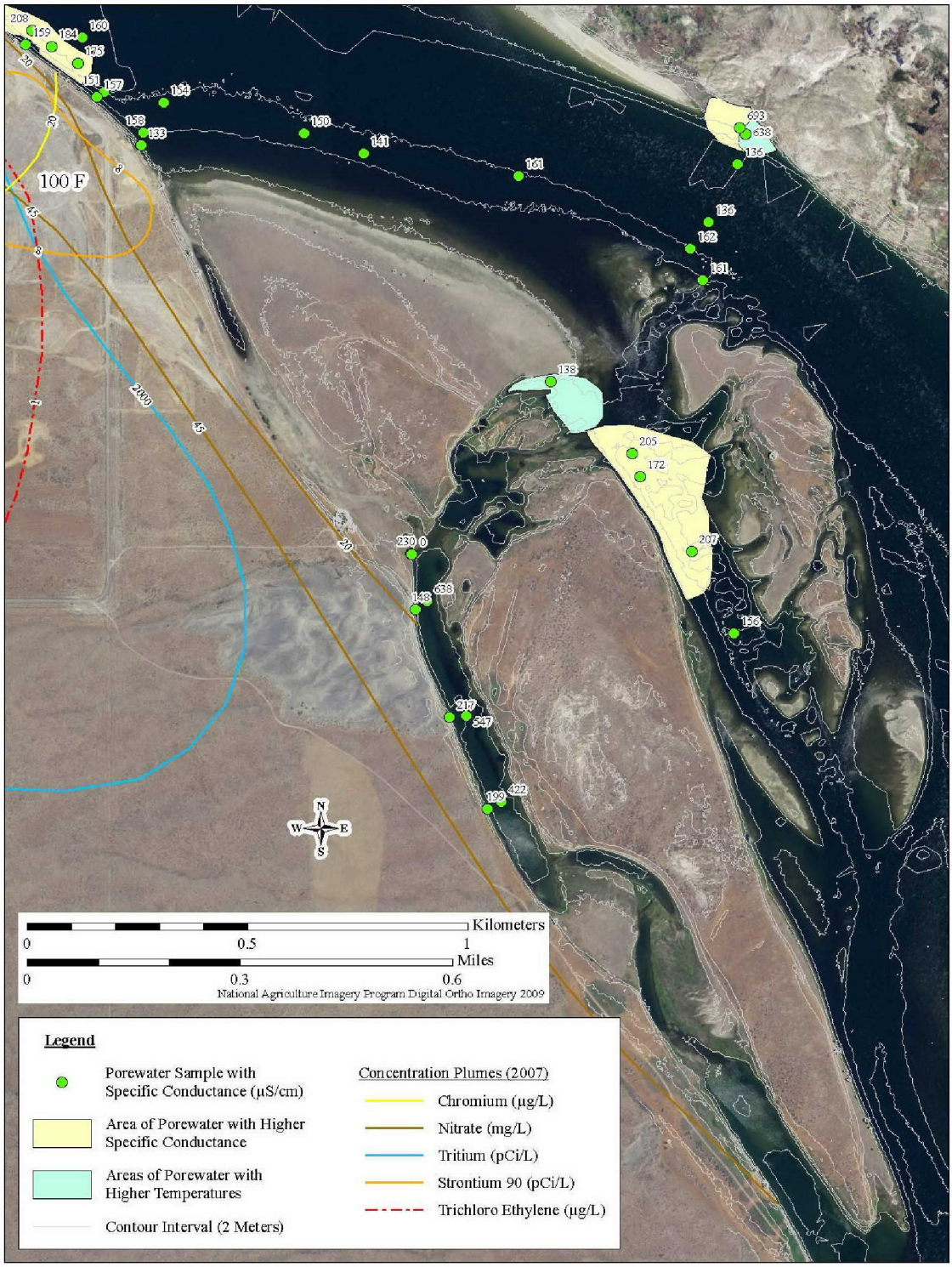
Groundwater in 100-IU-2/IU-6 is a calcium-bicarbonate type (Figure 3-49). Dissolved oxygen ranges from 8 to 10 mg/L and pH averages approximately 8. The groundwater is moderately hard (approximately 150 mg/L as $CaCO_3$).

Chapter 4 includes a discussion of groundwater contaminant chemistry.



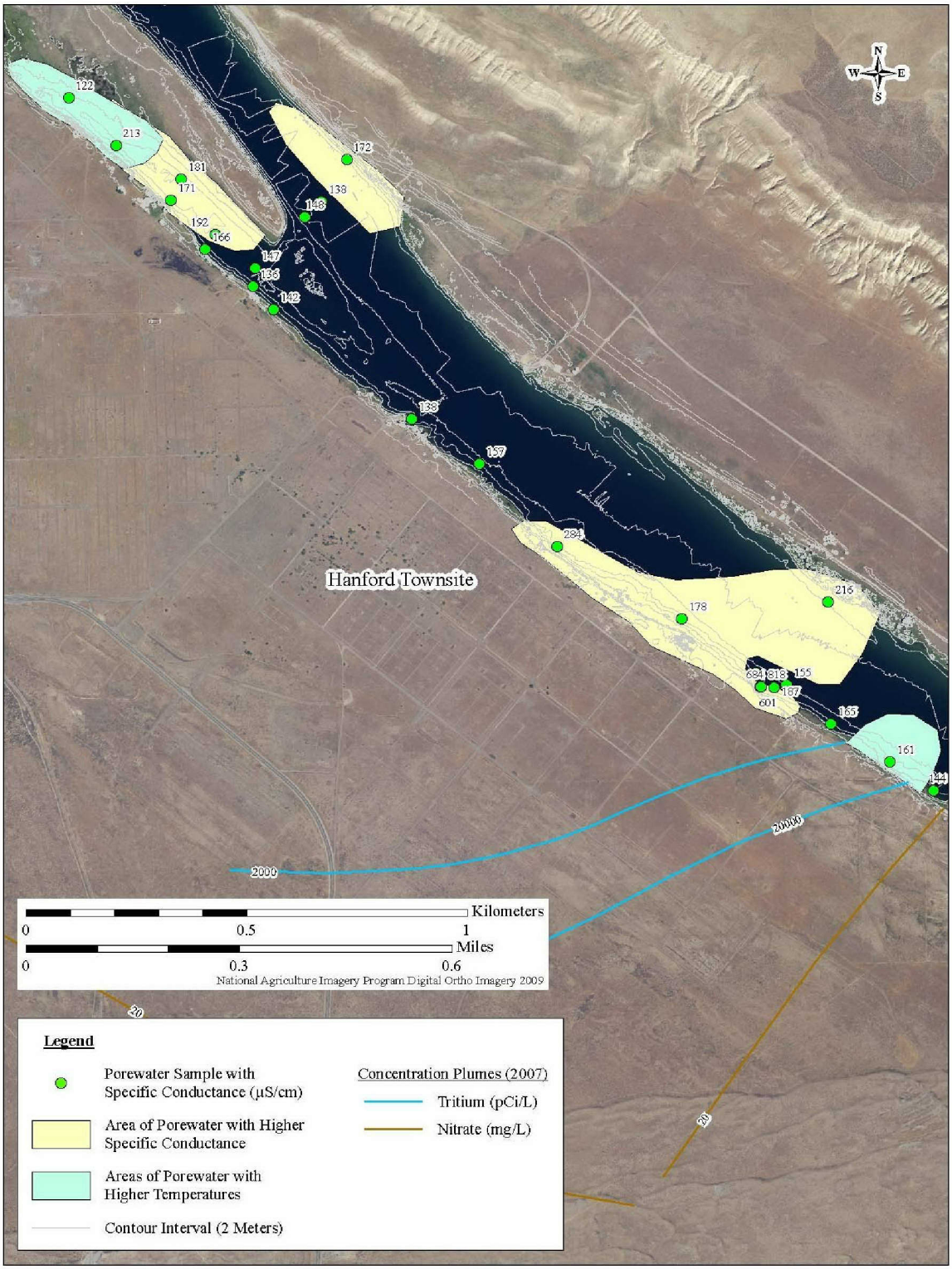

Source: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*.

**Figure 3-42. Pore Water Specific Conductance (µS/cm) and Temperature Anomaly Patterns near the 100-F Area, Upstream Portion**



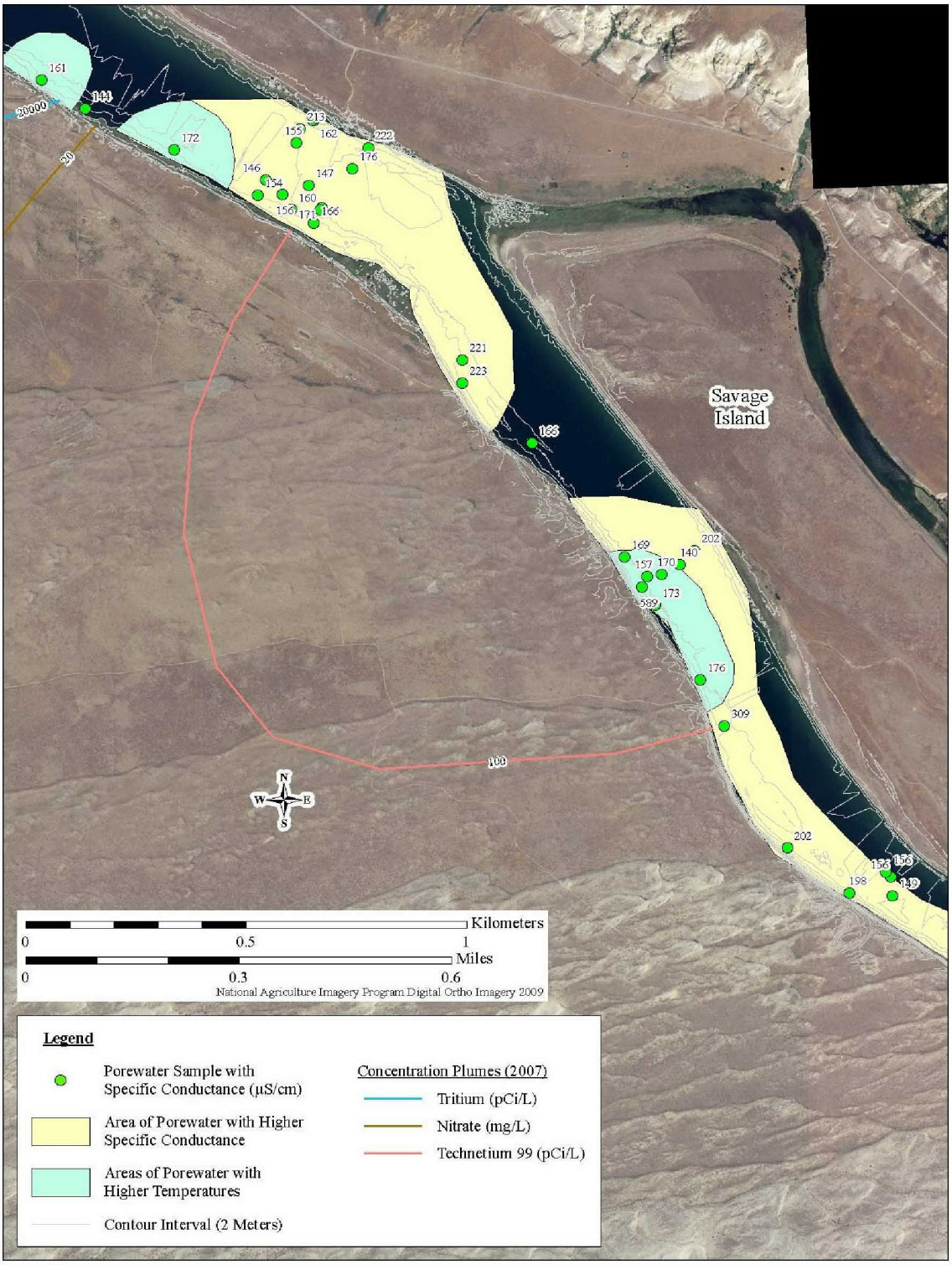

Source: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*.

**Figure 3-43. Pore Water Specific Conductance (µS/cm) and Temperature Anomaly Patterns near the 100-F Area, Downstream Portion**



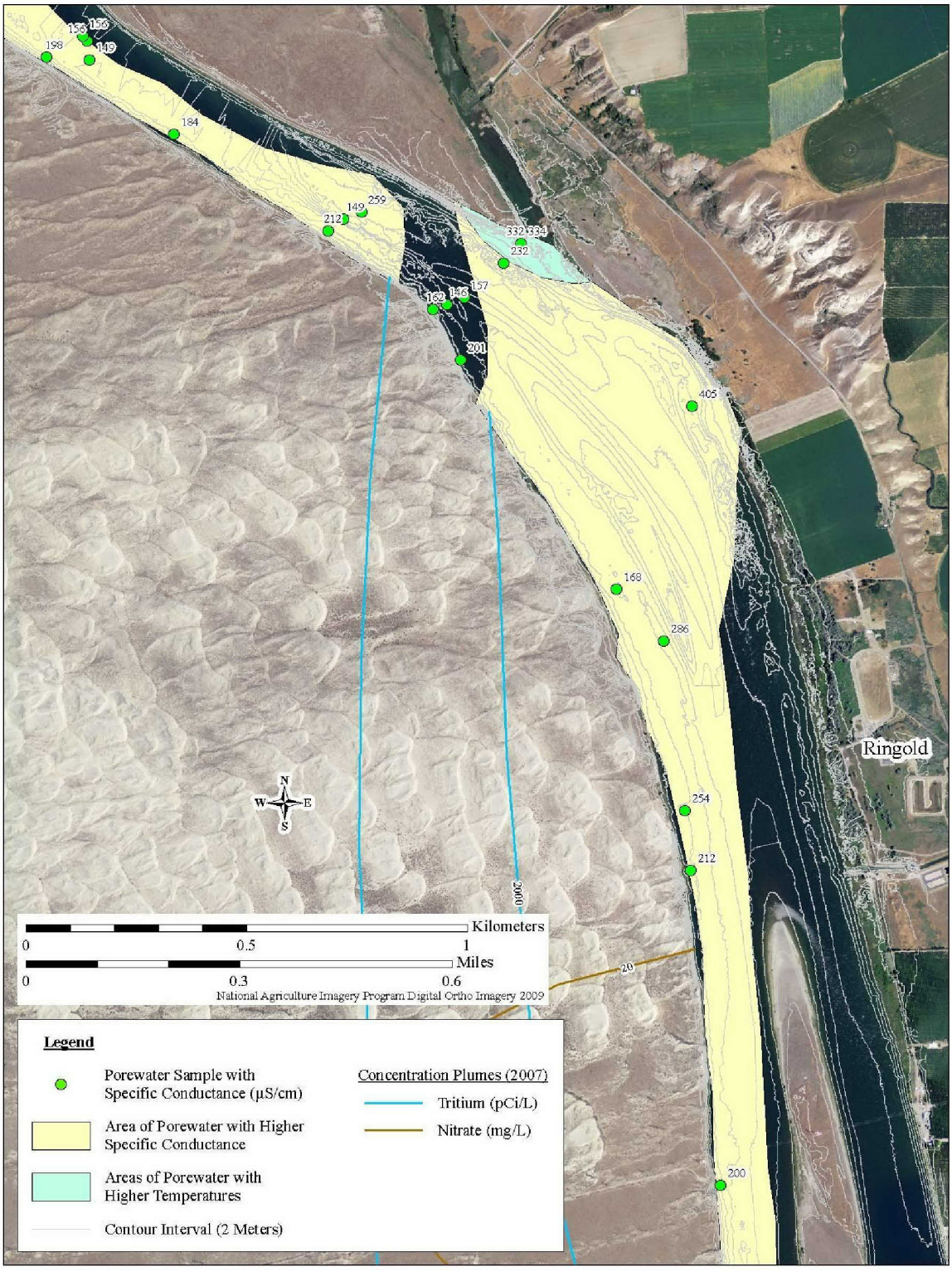

Source: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*.

**Figure 3-44. Pore Water Specific Conductance (µS/cm) and Temperature Anomaly Patterns near the Hanford Townsite, Segment 1**



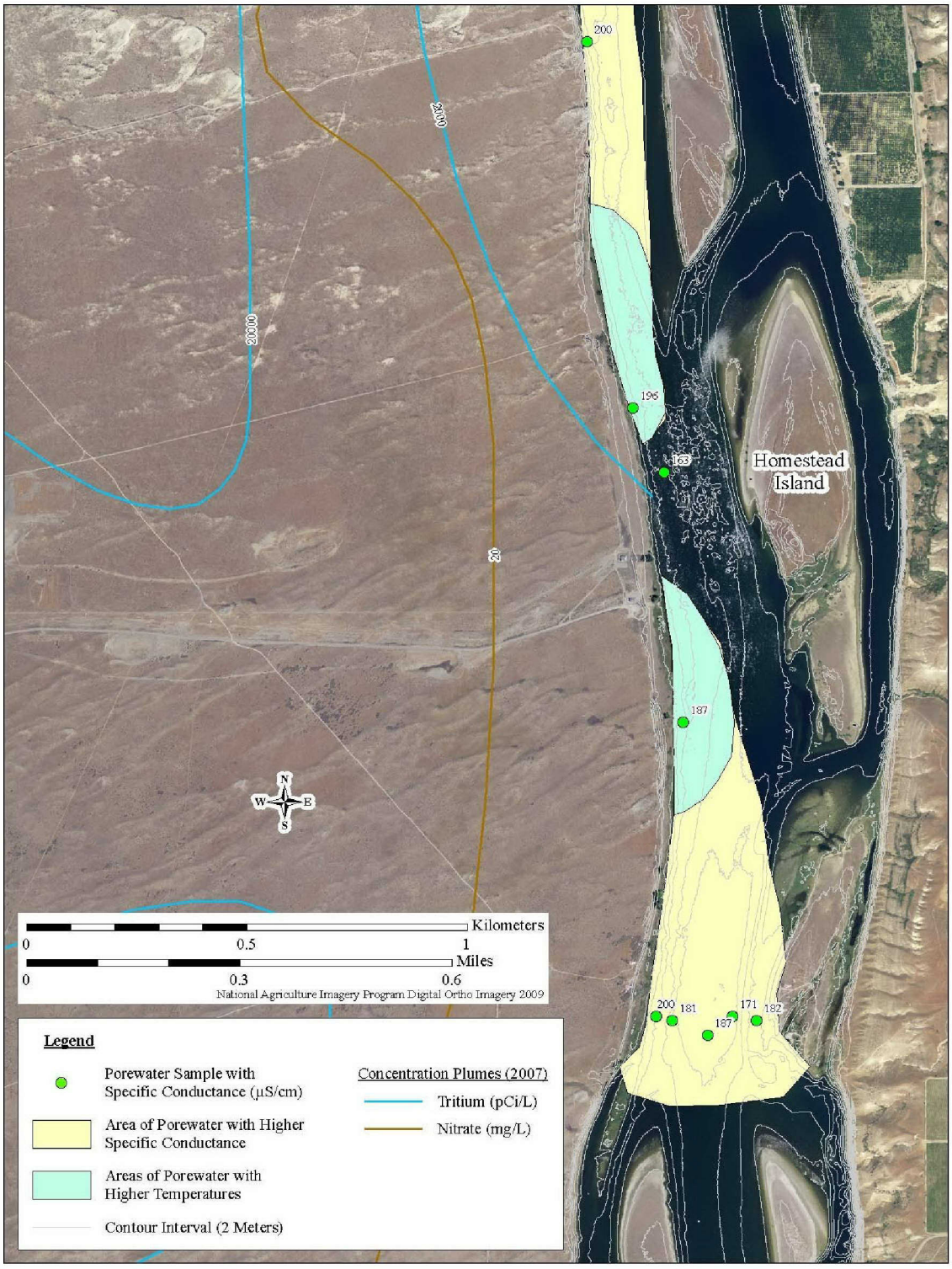

Source: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*.

**Figure 3-45. Pore Water Specific Conductance (µS/cm) and Temperature Anomaly Patterns near the Hanford Townsite, Segment 2**




Source: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling.*

**Figure 3-46. Pore Water Specific Conductance (µS/cm) and Temperature Anomaly Patterns near the Hanford Townsite, Segment 3**




Source: WCH-380, *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*.

**Figure 3-47. Pore Water Specific Conductance (µS/cm) and Temperature Anomaly Patterns near the Hanford Townsite, Segment 4**

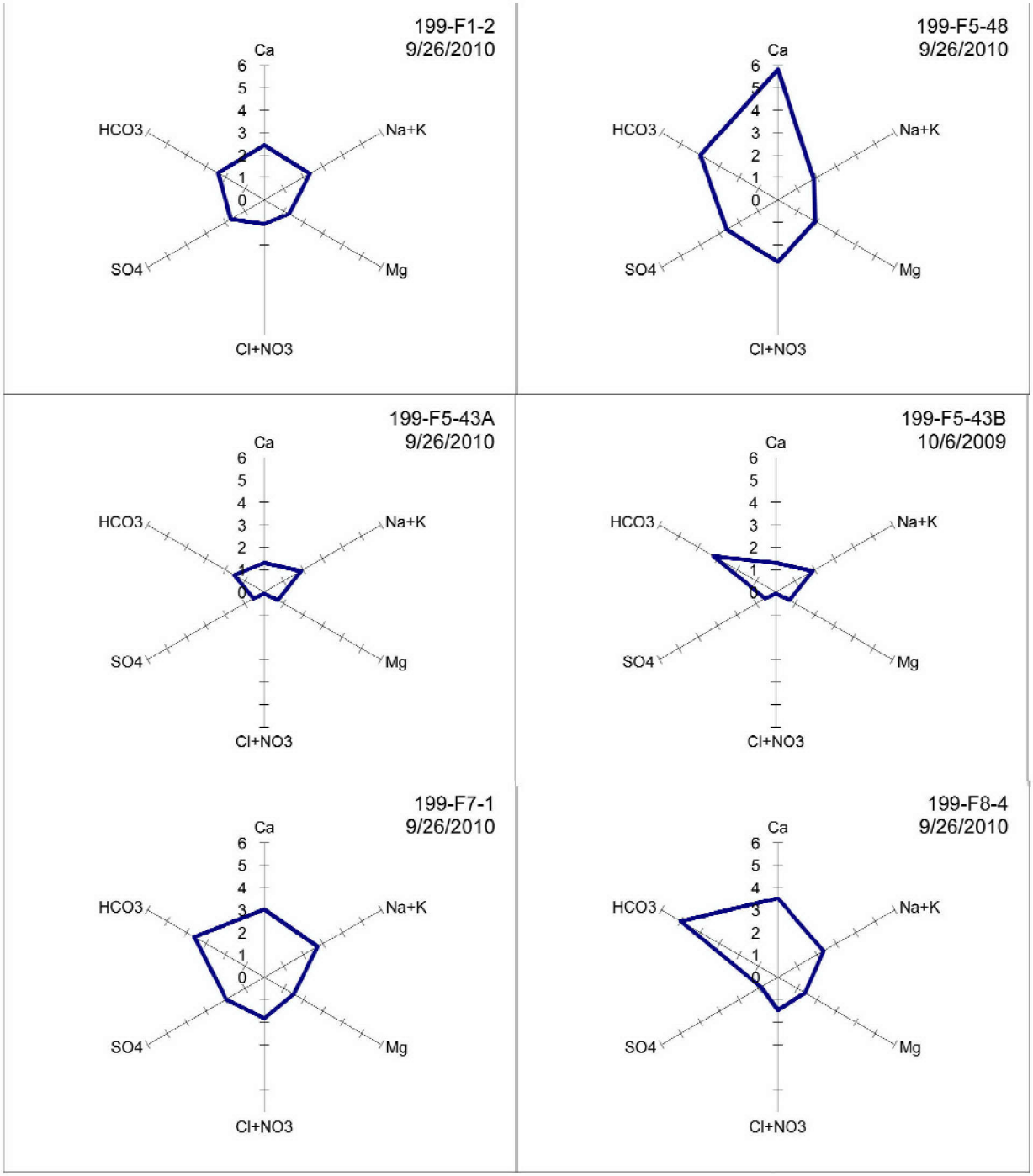



**Figure 3-48. General Groundwater Chemistry in 100-F**

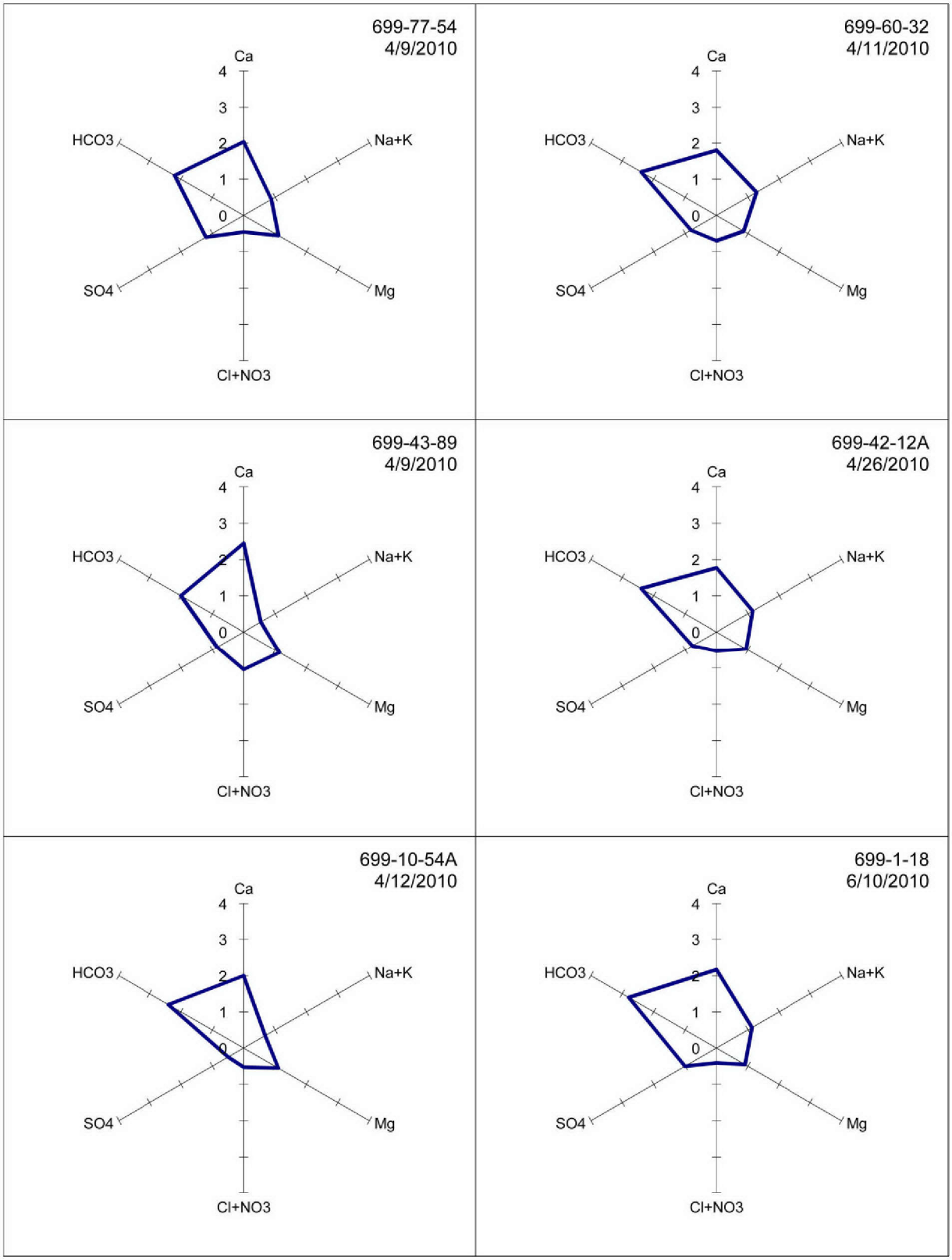



**Figure 3-49. General Groundwater Chemistry in 100-IU-2/IU-6**

## 3.7 Artificial Water Systems

The raw water supply for the 100 and 200 Areas is provided from the Columbia River through a series of pump houses, reservoirs, and pipelines from the River Corridor. Collectively, this important piece of the Hanford Site's infrastructure is known as the water export system (i.e., water distribution system). A large part of this system intersects the 100-F/IU portion of the River Corridor (Figure 3-50).

## 3.8 Demography and Land Use

*Demographics.* A detailed discussion of the population surrounding the Hanford Site, including adjacent counties and cities, is presented in the NEPA Characterization Report (PNNL-6415). The 2009 population estimate from the U.S. Census Bureau was that 47,530 people lived in the city of Richland, the closest population center to the Hanford Site. An estimated 58,650 people lived in Pasco and 67,810 people lived in Kennewick. Population groups near the Hanford Site include Native Americans and various ethnic minorities. Native American descendants living near the Hanford Site include members of the following federally recognized groups: the Confederated Tribes and Bands of the Yakama Nations, the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), Nez Perce Tribe, and Confederated Tribes of the Colville Reservation. Members of other unrecognized Tribes members, such as the Wanapum, also live in the area. There is no continuous human inhabitation immediately adjacent to 100-F/IU.

The economy in the region near the Hanford Site is driven by three major sectors: DOE and its contractors operating the Hanford Site; Energy Northwest, which operates the nuclear-powered Columbia Generating Station on land leased from DOE; and the agricultural community, including a substantial food-processing component. Additional employment sectors driving the local economy include "other major employers," such as non-DOE contractor employers in the region, tourism, and healthcare.

*Land Use.* The Columbia River is a critical resource for the people and ecology of the Pacific Northwest. The 50-mile stretch of the Columbia River flowing through the Hanford Site is referred to as the Hanford Reach. It is the only free-flowing stretch of the Columbia above Bonneville Dam in the United States. The river, islands, gravel bars, sloughs, riparian areas, and dune field of the Hanford Reach provide a variety of habitats that are now rare along the Columbia River. As one of the largest rivers in North America, its waters support a multitude of uses that are vital to the economic and environmental well-being of the region. The river is particularly important in sustaining the culture of Native Americans.

Land use in the River Corridor is currently controlled by DOE and the U.S. Fish and Wildlife Service (USFWS), which jointly manage this federally owned land to protect natural and cultural resources while conducting cleanup activities. Such management is consistent with *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, hereinafter called CLUP (DOE/EIS-0222-F), and the corresponding *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE/EIS-0222-SA-01) for the site. This approach also reflects the requirements of the USFWS management plan (*Hanford Reach National Monument, Final Comprehensive Conservation Plan and Environmental Impact Statement Adams, Benton, Grant and Franklin Counties, Washington* [USFWS, 2008]) for the Hanford Reach National Monument. Both DOE and the USFWS expect that this joint management of the Hanford Site will continue for many years and that the property will remain under federal ownership.

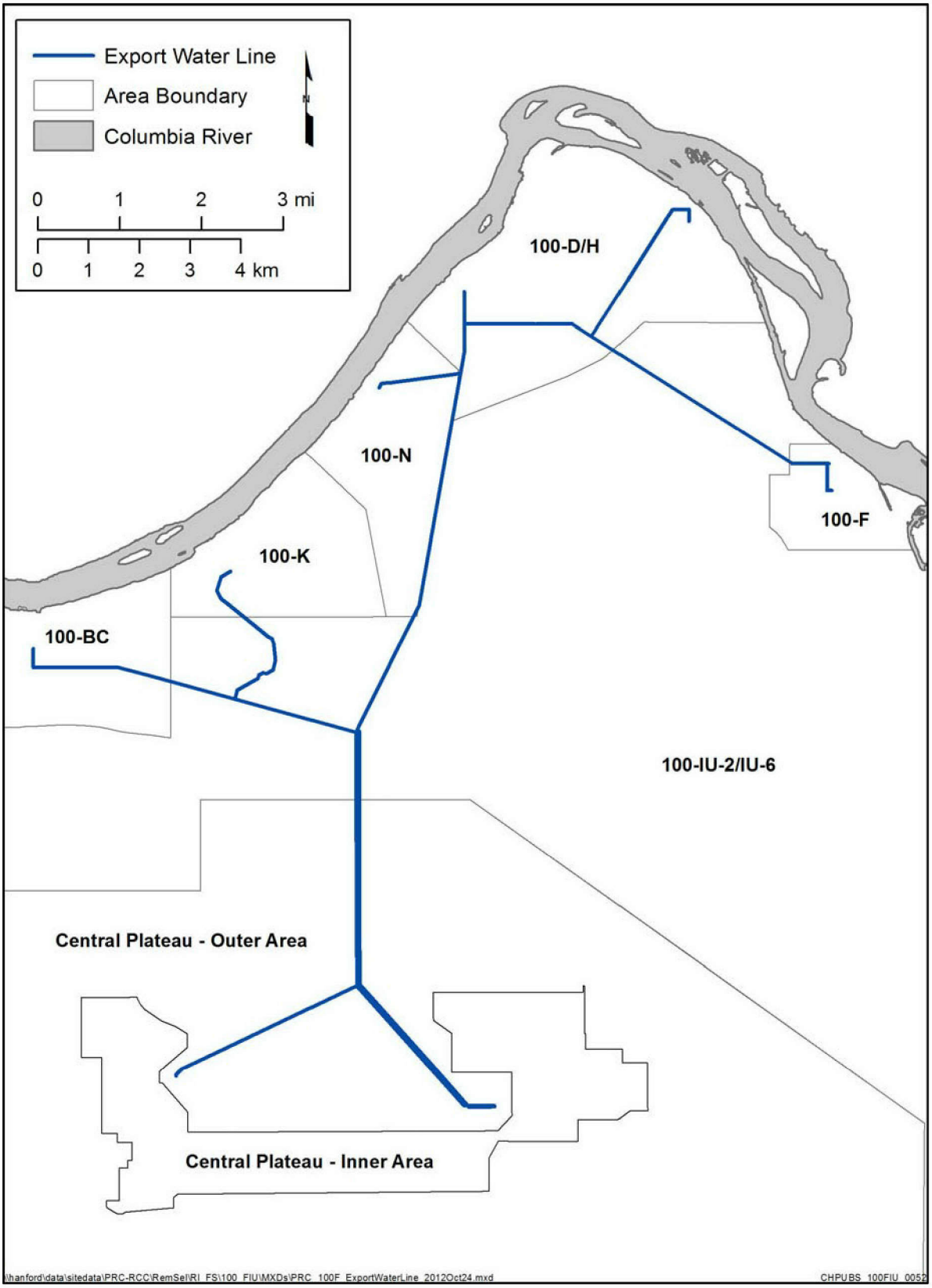



Figure 3-50. Water Export System

Interim action RODs for CERCLA cleanup activities in the river corridor recognized the reasonably anticipated future land use in the river corridor had not been well defined. Since the time the RODs were established, DOE has issued the Hanford CLUP (DOE/EIS-0222-F), and the Hanford Reach National Monument has been established. The interim action RODs define conservation and preservation as the future use of the lands along the river. In a memorandum (*Hanford Reach National Monument* [Clinton, 2000]), the President directed the Secretary of Energy to consult with the Secretary of the Interior on how best to protect the lands around the Hanford National Monument permanently. Much of the area contains shrub-steppe habitat and other areas of scientific and historic interests. The President specifically included the possibility of adding lands to the Hanford Reach National Monument as they are remediated (*Hanford Reach National Monument* [Clinton, 2000]). EPA and the state of Washington believe that the cleanup actions in the river corridor should also support the potential for future residential use.

When soil cleanup goals were initially established for the river corridor, the TPA (Ecology et al., 1989a) signatories agreed that it was appropriate to protect for a range of potential exposures in the future so that cleanup actions did not limit future use of the site. Such a goal addressed the interests of a number of Hanford Site stakeholders, including the Future Site Uses Working Group. Interim action cleanup requirements were based upon consideration of state MTCA (WAC 173-340) cleanup requirements for unrestricted surface use for chemical contaminants and a dose based standard of 15 mrem per year for radiological constituents based on DOE guidance for a residential exposure. For the purpose of establishing final cleanup requirements for the River Corridor cleanup, the TPA (Ecology et al., 1989a) agencies believe it is appropriate to continue to use the interim action ROD cleanup requirements, which have been updated to reflect revised MTCA (WAC 173-340) values and excess cancer risk for radiological constituents. Final cleanup values will also be established to protect groundwater and surface water resources and address ecological risk considerations.

Because the interim action cleanup values in river corridor RODs were developed to accommodate a variety of future land use options, the resultant cleanup actions will be protective of the reasonably foreseeable land uses that DOE and the USFWS anticipate for the River Corridor.

*Tribal Interests.* Tribal fishing rights are recognized on rivers within the lands ceded by treaty, including the Columbia River, which flows through the Hanford Site. In addition to fishing rights, the Tribes retain the privilege to hunt, gather roots and berries, and pasture horses and cattle on "open and unclaimed lands." It is the position of DOE that the Hanford Site, which was assembled from lands acquired from private owners and lands withdrawn from the public domain into a federal enclave with no public entry, is not open and unclaimed land. While reserving all rights to assert their respective positions, the Tribes are participants in DOE's land use planning process, and DOE considers Tribal Nation concerns in that process.

*Groundwater Use.* Groundwater in 100-F and most of 100-IU-2/IU-6 currently is extracted only for environmental monitoring. Water supply wells in 100-IU-2/IU-6 include drinking water wells 499-S1-8J, 499-S0-7, and 499-S0-8 in the 400 Area.

## 3.9 Ecology

The unique habitat of the Hanford Site is located in the mid-latitude, semi-arid Columbia Plateau with the last free-flowing section of the Columbia River flowing through it, supporting a rich diversity of plant and animal species (2009 Sitewide Environmental Report [PNNL-19455]). Species diversity is maintained through the long-standing management practices of DOE, which leaves most of the land area relatively undisturbed; only about 6 percent of Hanford Site land has been disturbed or is actively used by DOE for waste disposal and storage. Thus, the types of native terrestrial and aquatic ecological resources found on the Hanford Site are becoming increasingly rare throughout the Columbia Basin region. Preservation of these areas is important as agricultural, industrial, and residential development continues.

*Establishment of the Hanford Reach National Monument* (Presidential Proclamation 7319) placed high priority on shrub-steppe community habitat maintenance and enhancement for native species. Washington State has designated shrub-steppe communities as priority habitat because of their significance to a number of wildlife species and the scarcity of this habitat type. In addition, the U.S. Department of the Interior has identified native shrub and grassland steppe in Washington and Oregon as an endangered ecosystem.

The discussion in this section relies heavily on the RCBRA (DOE/RL-2007-21, Volume I). This document characterized the ecology of the River Corridor to support management practices for the River Corridor. In doing this, three key ecological study zones were identified: the upland, riparian, and near-shore river zones. Each ecological zone within the River Corridor supports a unique community of plants and animals, and this zone approach is reflected in this section.

*Upland Zone.* The upland zone is the largest zone and consists of land adjacent to the main channel of the Columbia River above the river high-water mark that extends inland from the Columbia River. Terrestrial, and generally dry, the upland zone is not influenced by river flow and depends on precipitation for its water supply.

*Riparian Zone.* The riparian zone extends from the point on the riverbank where upland vegetation is no longer dominant to the shoreline of the Columbia River. Typically narrow, the riparian zone varies in width, depending on the slope of the riverbank. The transition from the upland zone vegetation to riparian vegetation is generally abrupt. The vegetation that grows in the riparian zone along the river shoreline is thicker and taller than that in the upland area, attracting a broader range of wildlife species. The small mammals, birds, and reptiles common to the upland environment are also likely to inhabit the riparian environment (RCBRA [DOE/RL-2007-21, Volume I]).

*Near-Shore Aquatic Zone.* The near-shore aquatic zone consists of a narrow band of the Columbia River adjacent to the shoreline. The near-shore aquatic zone evaluated in this report extends from the low water mark on the shoreline to roughly 1.8 m (6 ft) in depth. The Columbia River Component evaluates environmental conditions for depths greater than 1.8 m (6 ft).The aquatic vegetation found in the near-shore zone supports aquatic insect populations, benthic taxa (species and organisms that live in or on the bottom of the river), birds, and fish.

Knowledge of the ecological setting is a compilation of ecological data obtained from multiple biological inventories of plant and wildlife species and ecological characterizations from the following reports:

- The NEPA Characterization Report (PNNL-6415) provides a detailed summary of the ecology, biological resources, and hydrology for the entire Hanford Site, with selected information grouped by major operational areas.
- *United States Department of the Interior Record of Decision Hanford Reach of the Columbia River: Final Environmental Impact Statement for Comprehensive River Conservation Study* (DOI, 1996) provides general information on the riparian and aquatic environments found within the Hanford Reach.
- *Literature Review of Environmental Documents in Support of the 100 Area and 300 Area River Corridor Baseline Risk Assessment* (hereinafter called the RCBRA Literature Review [PNNL-SA-41467]) provides detailed characterization data for the 100 Area and 300 Area, including comprehensive lists of plant and wildlife species occurring in or near the study area.

DOE has been conducting ecological characterization on the Hanford Site since the early 1970s, and environmental reports, (e.g., *Hanford Site Environmental Report for Calendar Year 2010* [PNNL-20548]) are produced annually. Other ecological reports pertaining to the River Corridor include Nature Conservancy surveys (*Biodiversity Inventory and Analysis of the Hanford Site: 1997 Annual Report* [Hall, 1998]; *Biodiversity Inventory and Analysis of the Hanford Site: 1994 Annual Report* [Pabst, 1995]; *Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999* [Soll et al., 1999]; *Biodiversity Inventory and Analysis of the Hanford Site: 1995 Annual Report* [Soll and Soper, 1996]) and *Vascular Plants of the Hanford Site* (PNNL-13688).

### 3.9.1 River Corridor Flora

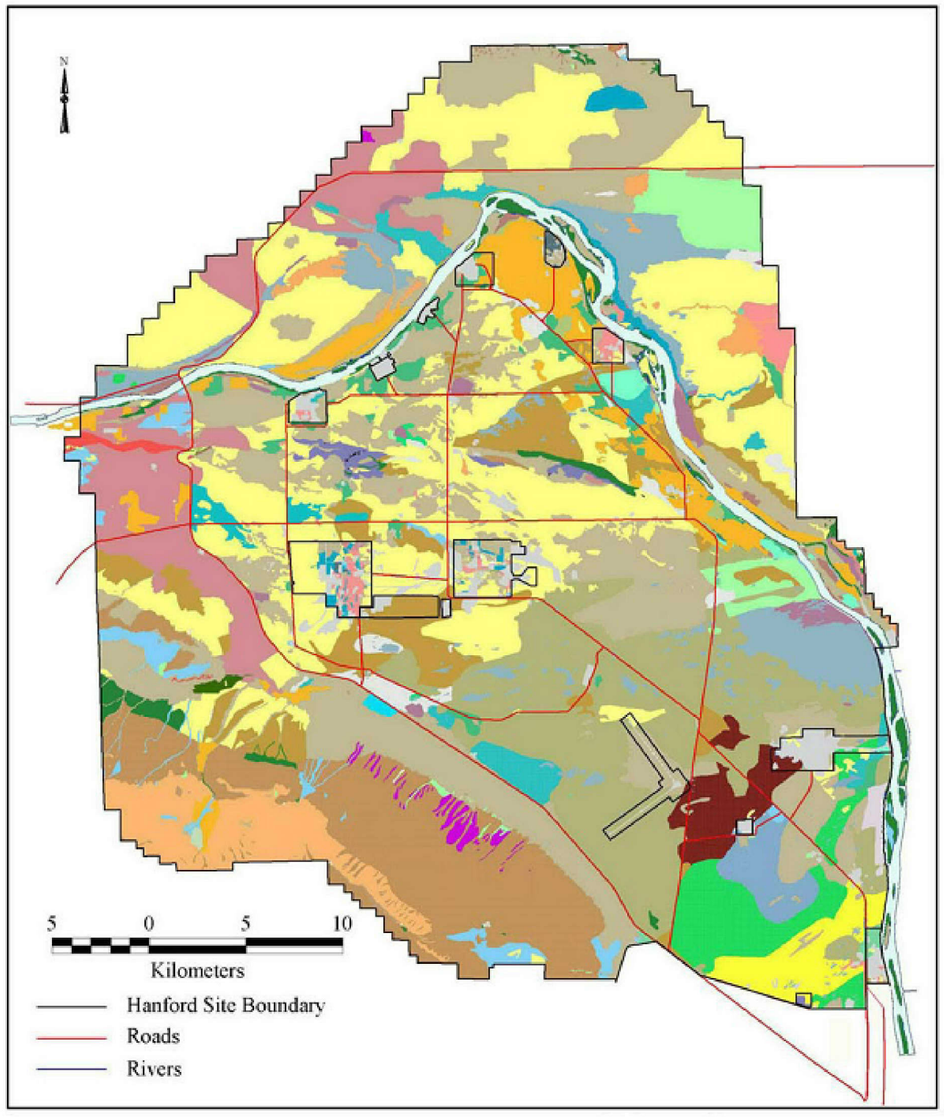
Historically, much of the River Corridor upland zone was a native shrub-steppe habitat. The most prevalent shrub was big sagebrush (*Artemisia tridentata*), with smaller quantities of rabbitbrush (*Chrysothamnus* and *Ericameria*), and an understory dominated by Sandberg's bluegrass (*Poa secunda* formerly *sandbergii*). During the Euro-American settlement of the area, a large portion of the area was disturbed by farming. Construction activities for the reactor projects further disturbed the vegetation and soil in the area. These two major changes in land use resulted in changes to the native plant community, creating areas that have been kept free of vegetation and areas that have partially recovered to various levels of plant succession (RCBRA [DOE/RL-2007-21, Volume I]).

The vegetation in the River Corridor upland zone operating areas is typically sparse and consists of early successional species such as cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola kali*), tumblemustard (*Sisymbrium altissimum*), and bur ragweed (*Ambrosia acanthicarpa*). Most operating areas, including waste sites, were historically maintained free of vegetation for contamination control, fire prevention, and maintenance purposes. Large areas of cheatgrass and exotic annual species present in the 100-D, 100-F, White Bluffs, and Hanford Townsite areas that resulted from pre-Hanford Site farming and homesteading are described as "abandoned old fields." More detailed descriptions of vegetation by reactor area can be found in the RCBRA Literature Review (PNNL-SA-41467). The 100-IU-2 and 100-IU-6 OUs, consist of large areas of undisturbed native habit. Figure 3-51 illustrates distribution of vegetation types before the 2000 wildfire. Figure 3-52 shows the burn area.

Vegetation found in riparian zones reflects the transition between aquatic and upland ecosystems. Changes to the composition of shoreline vegetation over time have been influenced by moderation in the river elevation changes controlled by the Priest Rapids Dam, approximately 18.5 km (10 mi) upstream of the Hanford Site. The transition from riparian to upland vegetation is abrupt as a result of the steepness of the shoreline. Dominant vegetation within the riparian zone includes mulberry (*Morus alba*), willow (*Salix*), Siberian elm (*Ulmus pumila*), northern wormwood (*Artemisia campestris*), sweet clover (*Melilotus alba* or *M. officinalis*), and reed canarygrass (*Phalaris arundinacea*) (RCBRA [DOE/RL-2007-21, Volume I]).

Vegetation in the near-shore river zone consists of macrophytes and periphyton. Macrophytes are sparse in the Columbia River because of strong currents, the rocky bottom, and frequently fluctuating water levels. Where macrophytes are found, they commonly include duckweed (*Lemna*) and the native rooted pondweeds *(Potamogeton* and *Elodea canadensis*). Macrophytes provide food and shelter for juvenile fish and spawning areas for some species of warm-water game fish. Since the late 1980s, Eurasian milfoil (*Myriophyllum spicatum*), an introduced macrophyte, has increased to nuisance levels and may encourage increased sedimentation of fine particulate matter. Periphyton communities develop on suitable solid substrate wherever there is sufficient light for photosynthesis and adequate currents to prevent sediment from covering the colonies.

Comprehensive lists of plants found on the Hanford Site are presented in the NEPA Characterization Report (PNNL-6415) and *Vascular Plants of the Hanford Site* (PNNL-13688).



Source: PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*.

Figure 3-51. Distribution of Vegetation Types and Area before the 2000 Fire

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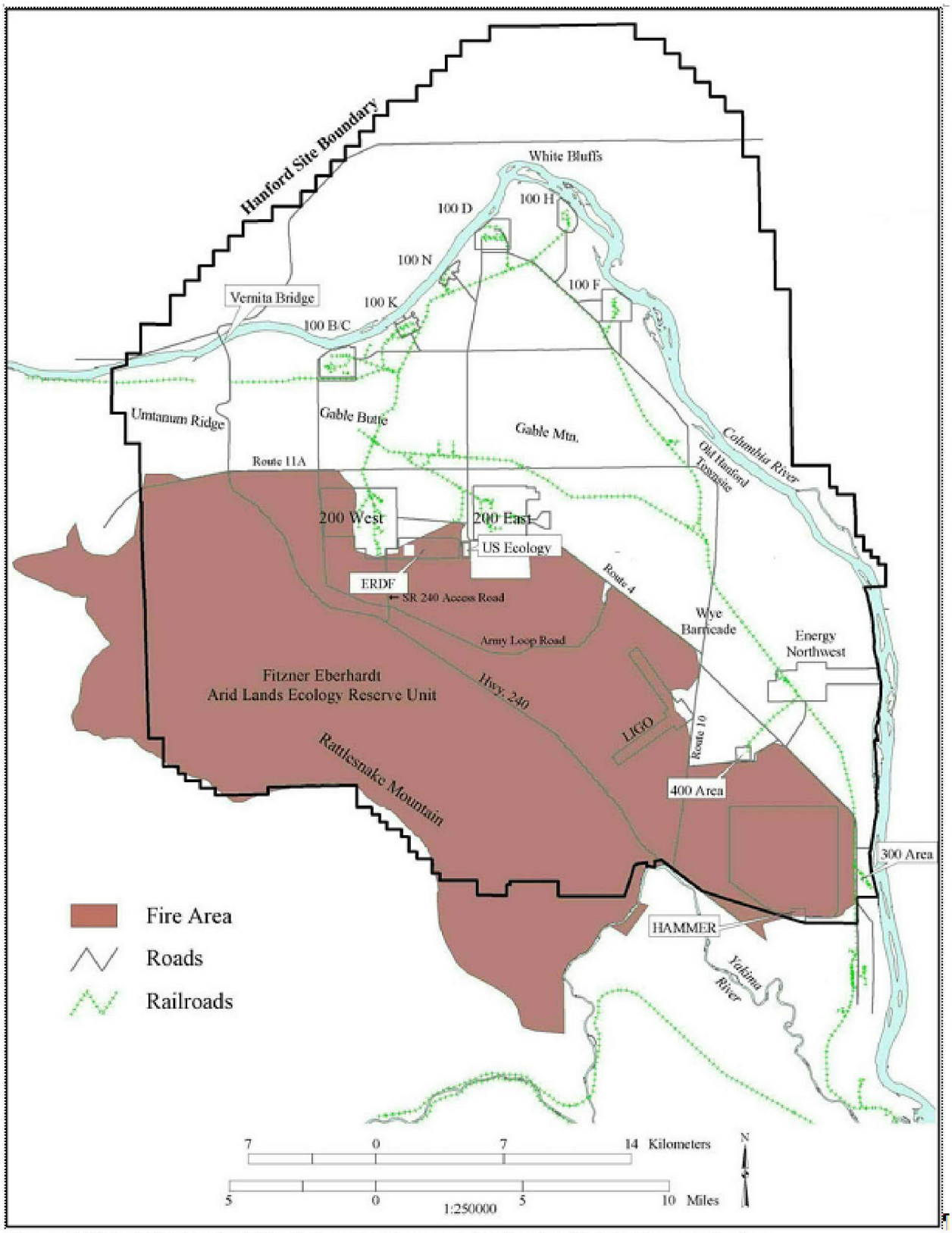
### 3.9.2 River Corridor Fauna

Wildlife use of habitat overlaps considerably between the riparian and upland zones. Use of the riparian zone is likely higher than that of the upland zone associated with the CERCLA waste sites because of its proximity to the Columbia River. River access results in greater species diversity and the presence of higher density and higher stature vegetation that remains productive over a longer period of time (RCBRA [DOE/RL-2007-21, Volume I]). Species lists have been compiled for the major classes of vertebrates that have been observed on the Hanford Site or within the Hanford Reach of the Columbia River and include 46 species of mammals, 145 species of birds, 10 species of reptiles, 5 species of amphibians, and more than 45 species of fish (NEPA Characterization Report [PNNL-6415]). As invertebrates are concerned, 1,509 species-level identifications have been completed, and the collection of 40,000 specimens has resulted in the identification of 43 new taxa and 142 new findings in the State of Washington (*Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999* [Soll et al., 1999]). The high diversity of insect species on the Hanford Site reflects the size, complexity, and relatively undisturbed quality of the shrub-steppe habitat. Appendix H presents an extensive list of species known or potentially occurring on the Hanford Site classified by habitat type.

Mammals of the upland environment that may be found in and adjacent to the 100 Area and 300 Area include the mule deer (*Odocoileus hemionus*), badger (*Taxidea taxus*), coyote (*Canis latrans*), Great Basin pocket mouse (*Perognathus parvus*), northern pocket gopher (*Thomomys talpoides*), black-tailed jackrabbit (*Lepus californicus*), and cottontail rabbit (*Sylvilagus nuttalii*) (*100 Areas CERCLA Ecological Investigations* [WHC-EP-0620]). The abundance of these species and the occurrence of others vary according to the soil type and vegetative community. While other large mammals, such as elk (*Cervus elaphus*), are infrequently observed in the 100 Area and 300 Area upland reactor areas, the number of individual large mammals present per unit area may increase as habitat quality and shrub cover improve through natural recovery and waste site restoration. Some mammals common to the upland environment are also likely to use and inhabit the riparian environment, including the western harvest mouse (*Reithrodontomys megalotis*), the Great Basin pocket mouse (*Perognathus parvus*), and the deer mouse (*Peromyscus maniculatus*) (*Synthesis of Ecological Data Collected in the Riparian and Riverine Environments of the Hanford Reach* [PNNL-14516], hereinafter called Synthesis of Riparian and Riverine Data). A complete list of mammals observed and expected in all habitats of the 100 Area is provided in *100 Areas CERCLA Ecological Investigations* (WHC-EP-0620). The NEPA Characterization Report (PNNL-6415) presents a complete listing of Hanford Site wildlife species.

Several species of birds present in the upland zone rely on structures such as buildings, fences, and utility poles for some of their habitat needs. Raptors, such as red-tailed hawks (*Buteo jamaicensis*), are present and frequently nest on buildings, utility poles and towers, and trees along the river. Nonvegetated areas provide nesting habitat for nighthawks (*Chordeiles minor*) and killdeer (*Charadrius vociferus*). Canada geese (*Branta canadensis*) use open cheatgrass areas for winter grazing. Following restoration, improvements in shrub coverage will provide important habitat for native shrub-steppe bird species such as the horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), savannah sparrow (*Passerculus sandwichensis*), loggerhead shrike (*Lanius ludovicianus*), and possibly sage sparrow (*Amphispiza belli*). Raptors will continue to be present, but as the shrubs develop and the open grassy areas shrink in size, wintering geese will likely avoid the area, preferring the cheatgrass areas associated with nearby abandoned farm fields and orchards. A list of bird species observed in the 100 Area is available in *100 Areas CERCLA Ecological Investigations* (WHC-EP-0620). A catalogue of Hanford Site avian species is presented in the NEPA Characterization Report (PNNL-6415).




Source: PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*.

Figure 3-52. Burned Area after 2000 Fire

Synthesis of Riparian and Riverine Data (PNNL-14516) provides information on bird populations with respect to riparian vegetation. Location data are available in the electronic Environmental Monitoring and Compliance Project database managed by PNNL. Research efforts have assessed winter bird populations in cottonwood/willow (*Populus/Salix*) communities of the Columbia River shoreline ("Bird Surveys in Cottonwood-Willow Communities in Winter" [Rickard, 1964]; "A Comparison of Winter Bird Populations After a Decade" [Rickard and Rickard, 1972]), quantified shorebird response to water fluctuations in the Columbia River near-shore environment ("Avian Interactions with Mid-Columbia River Water Level Fluctuations" [Books, 1985]), and evaluated habitat selection and use by spring migrant passerines ("Use of Riparian Habitats by Spring Migrant Land Birds in the Shrub-Steppe of Washington" [Duberstein, 1997]). The information gathered during these research efforts has been used to document the status and ecology of the Hanford Site's avian wildlife.

Common reptiles found in upland environments at the Hanford Site include the rattlesnake (*Crotalus viridis*), gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and side blotch lizard (*Uta stansburiana*) (*Habitat Types on the Hanford Site: Wildlife and Plant Species of Concern* [PNL-8942]; *A Synthesis of Ecological Data from the 100 Areas of the Hanford Site* [WHC-EP-0601]). A variety of snakes common to the upland areas may also use the riparian habitat. Other reptiles that may be found in the riparian zone include the western terrestrial garter snake (*Thamnophis sirtalis*) and the painted turtle (*Chrysemys picta*) (*Herpetofauna of the Hanford Nuclear Reservation, Grant, Franklin and Benton Counties, Washington* [Hallock, 1998]; and Synthesis of Riparian and Riverine Data [PNNL-14516]). Amphibians in the riparian and near-shore environments of the Hanford Reach include mostly Woodhouse's toads (*Bufo woodhousii*), but bullfrogs (*Rana catesbeiana*) and Great Basin spadefoot toads (*Scaphiopus intermontanus*) may also be present (Synthesis of Riparian and Riverine Data [PNNL-14516]).

The dominant ground-dwelling invertebrate species in the upland environment are harvester ants (*Pogonomyrmex owyheei*) and darkling beetles (family Tenebrionidae). Harvester ants can exist on vegetated and nonvegetated soil and have been documented on waste sites (*Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport* [PNL-2774]). Darkling beetles, however, rely on vegetative matter in the soil during their larval stage and therefore are not expected to occur in areas void of vegetation (*Darkling Beetle Populations (Tenebrionidae) of the Hanford Site in Southcentral Washington* [PNL-2465]). Areas that were not used as waste sites or have not been affected by Hanford Site operations likely have less soil disturbance and may support a more robust and diverse community of soil-dwelling fauna than previously disturbed or remediated sites.

More than 45 species of fish have been identified in the Hanford Reach of the Columbia River. Of these species, Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), Coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) use the river as a migration route to and from upstream spawning areas and are of the greatest economic importance. Other fish of importance to sport anglers are the native mountain whitefish (*Prosopium williamsoni*) and white sturgeon (*Acipenser transmontanus*). Introduced species like smallmouth bass (*Micropterus dolomieui*), black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), and walleye (*Stizostedion vitreum*) are also popular. Other large fish populations include introduced common carp (*Cyprinus carpio*) and native species such as redside shiner (*Richardsonius balteatus*) and large-scale suckers (*Catostomus macrocheilus*). Smaller fish, such as sculpin (*Cottus*), are associated with shoreline habitats and have small home ranges (RCBRA [DOE/RL-2007-21, Volume I]).

### 3.9.3 Threatened and Endangered Species

A variety of species are recognized by state or federal agencies as having special status based on the species' risk of extinction. Threatened and endangered species are considered at risk and, as such, these species were

not identified for sacrificial sampling and subsequent analyses for the risk assessment effort. Data for selected surrogate species were required for contaminant or biological characterization based on the guild in which the special status species were identified (Table 5-1 of *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL-2004-37]). The list of state and federally listed species of concern, including candidate, sensitive, and monitored species, thought or known to occur on the Hanford Site is updated regularly in the NEPA Characterization Report (PNNL-6415). No plants, invertebrates, reptiles, amphibians, or mammals on the federal list of threatened and endangered wildlife and plants are known to occur on the Hanford Site (RCBRA Literature Review [PNNL-SA-41467]).

Two species of federally listed endangered fish, the Upper Columbia River spring-run Chinook salmon and the steelhead, occur in the Hanford Reach. The spring-run Chinook salmon do not spawn in the Hanford Reach, but use it as a migration corridor. Steelhead spawning has been observed in the Hanford Reach. The bull trout is listed as threatened by the National Marine Fisheries Service, but is not considered a resident species and is rarely observed in the Hanford Reach (*100-B/C Pilot Project Risk Assessment Report* [DOE/RL-2005-40]).

DOE employs the following protective measures for endangered salmon and steelhead:

- Water diversions meet state screening criteria or appropriate administrative controls, including discharges that meet National Pollutant Discharge Elimination System (NPDES) permit requirements. Removal of native riparian or emergent vegetation is minimized. Where possible, construction projects do not simplify shoreline structures, and final construction produces banks at a 3:1 slope.

- Silt-loaded surface runoff is minimized along the shoreline, and disruptive activities in the river or on the shoreline are avoided from April to November.

Although the bald eagle has been removed from the list of federally endangered species, it is still protected under the *Bald and Golden Eagle Protection Act of 1940*. In addition, DOE has decided to continue to protect nest and roost sites on the Hanford Site under the *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (hereinafter called Bald Eagle Management Plan [DOE/RL-94-150]). Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 to 400 m (2,600 to 2,400 ft). The Washington State Department of Fish and Wildlife requires protection of roosting trees for bald eagle habitat and foraging areas ("Permanent Regulations," "Bald Eagle Protection Rules" [WAC 232-12-292]).

Tables 3-14 and 3-15 list those flora and fauna species that are listed by the State of Washington as being threatened or endangered including candidate, sensitive, and monitored species, thought or known to occur on the Hanford Site.

Table 3-14. Flora Threatened and Endangered Species List

| Scientific Name | Common Name | State Status | Federal Status |
|---|---|---|---|
| **Upland** | | | |
| *Oenothera caespitosa* | caespitose evening-primrose | SS | |
| *Orobanche californica* | California broomrape | SX | |
| *Astragalus columbianus* | Columbia milk-vetch | SS | FCo |
| *Nicotiana attenuata* | coyote tobacco | SS | |
| *Cuscuta denticulata* | desert dodder | ST | |
| *Camissonia pygmaea* | dwarf evening-primrose | SS | |

Table 3-14. Flora Threatened and Endangered Species List

| Scientific Name | Common Name | State Status | Federal Status |
|---|---|---|---|
| *Astragalus geyeri* | Geyer's milk-vetch | ST | |
| *Cryptantha leucophaea* | gray cryptantha | SS | FCo |
| *Aliciella leptomeria* | Great Basin gilia | ST | |
| *Lomatium tuberosum* | Hoover's desert parsley | SS | FCo |
| *Loeflingia squarrosa* var. *squarrosa* | loeflingia | ST | |
| *Cryptantha scoparia* | miner's candle | SS | |
| *Erigeron piperianus* | Piper's daisy | SS | |
| *Cistanthe rosea* | rosy pussypaws | ST | |
| *Calochortus macrocarpus* | sagebrush-mariposa lily | SE | |
| *Camissonia minor* | small-flower evening primrose | SS | |
| *Cryptantha spiculifera* | Snake River cryptantha | SS | |
| *Ribes cereum* | squaw currant | SE | |
| *Mimulus suksdorfii* | Suksdorf's monkey-flower | SS | |
| *Eriogonum codium* | Umtanum desert buckwheat | SE | FC |
| *Eatonella nivea* | white etonella | ST | |
| **Riparian** | | | |
| *Lipocarpha aristulata* | awned halfchaff sedge | ST | |
| *Eleocharis rostellata* | beaked spike-rush | SS | |
| *Hypericum majus* | Canadian St. John's-wort | SS | |
| *Anagallis minima* | chaffweed | ST | |
| *Ammannia robusta* | grand redstem | ST | |
| *Rotala ramosior* | lowland toothcup | ST | |
| *Rorippa columbiae* | persistantsepal yellowcress | SE | FCo |

Source: "List of Vascular Plants Tracked by the Washington Natural Heritage Program" (WNHP, 2011).

FC = Federal Candidate
FCo = Federal Species of Concern
SE = State Endangered
SS = State Sensitive
ST = State Threatened
SX = Possibly extinct or extirpated from Washington

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Table 3-15. Fauna Threatened and Endangered Species List

| Scientific Name | Common Name | State Status | Federal Status |
|---|---|---|---|
| **Birds** | | | |
| *Pelecanus erythrorhynchos* | American white pelican | SE | |
| *Haliaeetus leucocephalus* | bald eagle | SS | FCo |
| *Athene cunicularia* | burrowing owl | SC | FCo |
| *Gavia immer* | common loon | SS | |
| *Buteo regalis* | ferruginous hawk | ST | FCo |
| *Otus flammeolus* | flammulated owl | SC | |
| *Aquila chrysaetos* | golden eagle | SC | |
| *Centrocercus urophasianus* | greater sage grouse | ST | FC |
| *Melanerpes lewis* | Lewis' woodpecker | SC | |
| *Lanius ludovicianus* | loggerhead shrike | SC | FCo |
| *Accipiter gentilis* | northern goshawk | SC | FCo |
| *Falco peregrinus* | peregrine falcon | SS | FCo |
| *Amphispiza belli* | sage sparrow | SC | |
| *Oreoscoptes montanus* | sage thrasher | SC | |
| *Grus canadensis* | sandhill crane | SE | |
| *Aechmophorus occidenalis* | western grebe | SC | |
| **Mammals** | | | |
| *Lepus californicus* | black-tailed jackrabbit | SC | |
| *Sorex merriami* | Merriam's shrew | SC | |
| *Urocitellus townsendii (formerly Spermophilus townsendii)* | Townsend's ground squirrel | SC | FCo |
| *Urocitellus washingtoni (formerly (Spermophilus washingtoni)* | Washington ground squirrel | SC | FC |
| *Lepus townsendii* | white-tailed jackrabbit | SC | |
| **Reptiles/Amphibians** | | | |
| *Sceloporus graciosus* | northern sagebrush lizard | SC | FCo |
| *Masticophis taeniatus* | striped whipsnake | SC | |
| **Aquatics** | | | |
| *Salvelinus confluentus* | bull trout | SC | FT |
| *Anodonta californiensis* | California floater (mussel) | SC | FCo |
| *Oncorhynchus tshawtscha* | chinook salmon | SC | FE |
| *Rhinichthys falcatus* | leopard dace | SC | |
| *Catostormus platyrhynchus* | mountain sucker | SC | |
| *Lampetra tridentata* | Pacific lamprey | SM | FCo |

Table 3-15. Fauna Threatened and Endangered Species List

| Scientific Name | Common Name | State Status | Federal Status |
|---|---|---|---|
| *Oncorhynchus mykiss* | rainbow trout (steelhead) | SC | FT |
| *Lampetra ayresii* | river lamprey | SC | FCo |
| *Fisherola nuttalli* | shortface lanx (snail) | SC | |

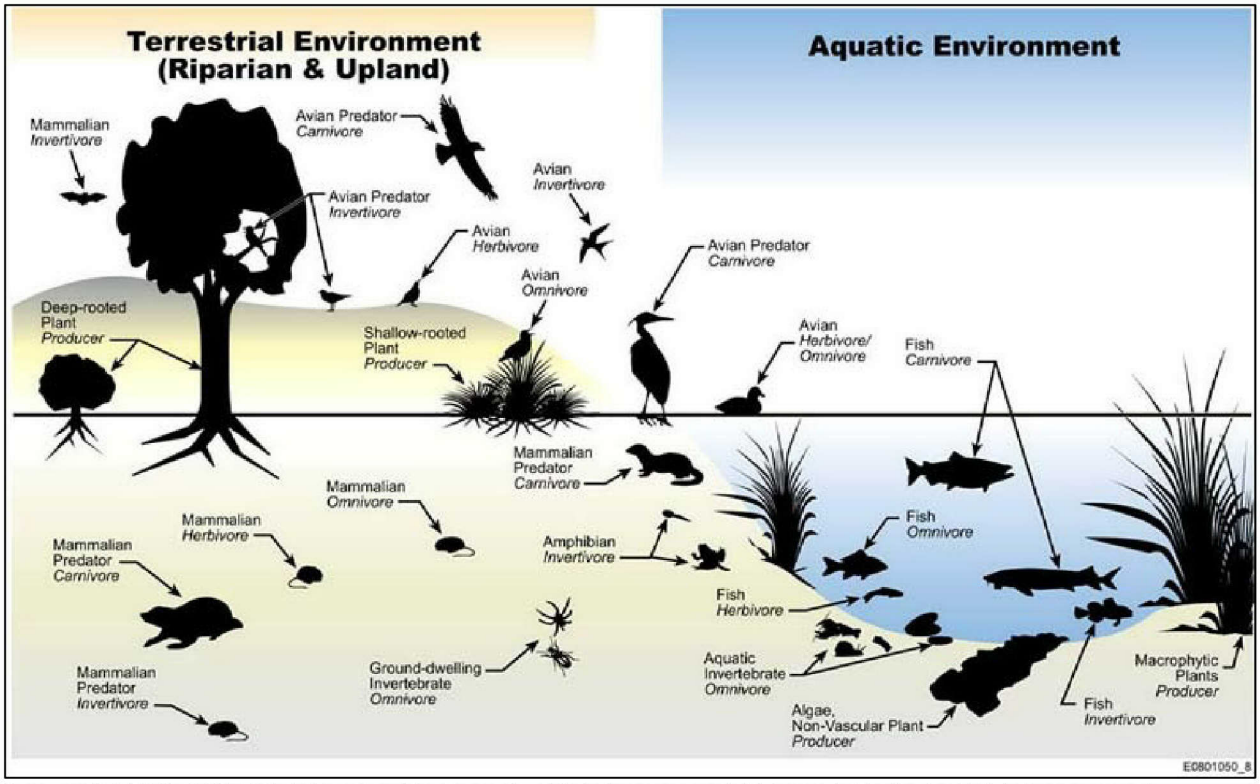
Source: "Species of Concern" (WDFW, 2011).

FC = Federal Candidate
FCo = Federal Species of Concern
FE = Federal Endangered
FT = Federal Threatened
SC = State Candidate
SE = State Endangered.
SM = State Monitored
SS = State Sensitive
ST = State Threatened

### 3.9.4 River Corridor Food Web and Receptors

Consideration of ecological receptors in the risk assessment requires an understanding of relationships among biotic community members. One such relationship, trophic transfer of contaminants, is an important element in ecological risk assessments. To develop a conceptual model based on trophic guilds, EPA recommends defining the functional ecosystem components with regard to their role in the food web (*Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final* [EPA/540/R-97-006], hereinafter called ERAGS). Given the complexity of trophic interactions, food webs are a simplification of the ecosystem showing broad relationships limited to trophic transfer. At a base level, some organisms prey on plants (herbivores), plants and animals (omnivores), or just animals (carnivores). More specific feeding classes exist within particular trophic categories. For example, considering the terrestrial environment, pollen-feeding animals may be relatively unimportant in terms of nutrient and energy transfer through the food web, but are important as plant pollinators. The same generalities are applicable to considerations of trophic linkages in the aquatic environment (e.g., many aquatic invertebrates consume periphyton and use this autotrophic component of the aquatic food web as a refuge from predation). Ultimately, depiction of trophic-level relationships from a functional perspective allows for ready identification of the feeding guilds most at risk from ingestion of contaminated plant and animal materials (RCBRA [DOE/RL-2007-21, Volume I]).

This framework is used to describe a simplified trophic structure for the ecological community of the RCBRA (Figure 3-53). For the most part, trophic linkages among aquatic and terrestrial biota are stronger within habitats than between habitats. In recognition of this, receptors are delineated into aquatic near-shore and terrestrial food webs. Some organisms can use both aquatic and terrestrial habitat. For example, bats and kingbirds are aerial insectivores that live on land and meet their dietary demands primarily through the consumption of emergent aquatic insects. The highest trophic level consists of avian predators that can traverse all environments.




Source: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*.

Figure 3-53. Ecological Food Web Represented by Simplified Feeding Guilds in the River Corridor

Hanford Site-specific receptors are recommended as surrogates for MTCA ("Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7490]) feeding guilds because they represent relevant ecological endpoints that also address management goals (*DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* [BHI-01757]). Receptor trophic-based guilds are representative of the upland, riparian, and near-shore environments, and include decomposers, producers, and consumers (herbivores, omnivores, insectivores, and carnivores). While categories such as omnivory and herbivory are useful constructs to simplify a complex ecosystem, it is important to note that animals do not typically restrict themselves to narrow food sources. Considerable dietary overlap exists among the middle trophic levels, because all species are, to some degree, opportunists. Other species are primarily insectivorous only at times when insects are abundant (*Washington Department of Fish and Wildlife's Priority Habitat and Species Management Recommendations, Vol. IV: Birds – Sage Sparrow* Amphispiza belli [WDFW, 2003]). Given the dietary overlap, it would be an artificial distinction to focus on a specific category; modeling specific diets (e.g., strict herbivory) is done to set the exposure bounds in trophic-transfer analyses.

## 3.10 Cultural Resources

The Hanford Site contains some of the most important archaeological sites in the region. Most of these sites are eligible for listing on the National Register of Historic Places (36 CFR 60). In addition, other natural resources and sacred sites important to the present Tribal Nations are preserved at the Hanford Site (*Data Compendium for the Columbia River Comprehensive Impact Assessment* [PNL-9785]). Restricted access for more than 50 years has minimized looting and vandalism of historic, cultural, and

archaeological sites. Furthermore, hydroelectric and agricultural developments have not destroyed these culturally significant sites, as has been experienced elsewhere in the Columbia River Basin.

Cultural surveys have been performed for 100-F and most of the River Corridor in 100-IU-2/IU-6. Much of the 600 Area has not been surveyed for cultural resources. Based on what is known, the 600 Area contains cultural resources associated Native American, Early Setters, and Cold War era cultural landscapes. Information specific to 100-F/IU included in this section is summarized from the NEPA Characterization Report (PNNL-6415).

Restricted access to the Hanford Site has facilitated the preservation of cultural sites. Furthermore, hydroelectric and agricultural development have not destroyed these culturally significant sites, as has been experienced elsewhere in the Columbia River Basin. Through the Cultural Resources Review process, DOE, contractor cultural resources specialists, Tribal Nation representatives, and project and site planners work together to protect resources important to the Native American community and other interested parties.

### 3.10.1 Prehistoric Archaeology

The 100-F Area and the river corridor to the south contain many cultural sites associated with the Native American cultural landscape (NEPA Characterization Report [PNNL-6415]). A nearly continuous string of camps and villages of the Wanapum extended from the Hanford Townsite upstream to the White Bluffs Townsite. Sites of particular importance include three that are eligible for listing in the NRHP: 45BN606, 45BN135, and site complex 45BN431, 432, and 433. Radiocarbon dates obtained from these sites through archaeological investigations provide a range of occupation extending from 8,860 to 270 years ago; however, the majority of dates occur after 3,000 years, suggesting an emphasis on relatively recent occupations. Analysis of artifacts and features indicate these were seasonal camps devoted primarily to shellfish, fish, mammal, and plant procurement and processing. In addition, a historic Wanapum cemetery is located near 100-F.

In other portions of 100-IU-2/IU-6, the Native American cultural landscape is characterized by the gathering of inland resources (such as quarry sites, hunting sites, religious use sites, and plant gathering sites) and riverine resources (such as fishing sites, open campsites, and root gathering).

### 3.10.2 Homestead and Townsite Era

Principal sites associated with the Early Settlers/Farming landscape in 100-F/IU include the White Bluffs townsite and ferry landing, the Hanford Townsite, the Chicago, Milwaukee, St. Paul, and Pacific Railroad line and associated whistle stops; early settler's farmsteads; and the Hanford Irrigation Canal and associated irrigation features (NEPA Characterization Report [PNNL-6415]).

The White Bluffs ferry landing was the upriver terminus of shipping during the mid-19$^{th}$ century. It was at this point that supplies for trappers, traders, and miners were off-loaded, and commodities from the interior were transferred from pack trains and wagons to riverboats. The first store and ferry of the mid-Columbia region were located at the ferry landing. A log cabin, thought to have been a blacksmith shop built during the late 19$^{th}$ century, still stands. The only remaining structure associated with the White Bluffs Townsite (near the railroad) is the First Bank of White Bluffs.

The Bruggemann Warehouse, located approximately 1.6 km (3 mi) west of 100-BC, is eligible for listing in the National Register. The Hanford Townsite, located downstream of 100-F, contains an electrical substation and a high school that became eligible for listing in 2002.

Archaeological remains of former farmsteads, ranches, and pre-1943 transportation routes are present in other parts of 100-IU-2/IU-6.

### 3.10.3 Manhattan Project and Cold War Era

Three Manhattan Project/Cold War era buildings/structures have been inventoried in this area, including the 105-F Reactor building (NEPA Characterization Report [PNNL-6415]). An assessment of the contents of 105-F was conducted to identify any artifacts that may have value as potential museum exhibits. Eleven industrial artifacts were identified and tagged, including a fuel scale, elevator control panel, two shop signs, four safety signs, a hardhat, graphite blocks, and vintage ceiling lights. All tagged artifacts were transferred to B Reactor or the Columbia River Exhibition of History, Science, and Technology (CREHST) museum in Richland, Washington, for inclusion into the Hanford Collection.

In 100-IU-2/IU-6, evidence of cultural resources associated with the Cold War Era landscape consists of anti-aircraft artillery sites, meteorological towers, and roads located in the 600 Area.

## 3.11 Summary of Physical Setting

The 100-F Area is in the northeastern portion of the Hanford Site, with the Columbia River flowing past on the northeast. The 100-IU-2/IU-6 OUs cover a broad area, including areas of the Hanford Site not in the reactor areas, the 300 Area, or the central portion of the Hanford Site. Together, 100-F and 100-IU-2/IU-6 encompass 38,000 ha (93,000 acres).

The Columbia River makes up the eastern boundary of 100-F/IU. Flow volume is controlled by Priest Rapids Dam, located upstream of the Hanford Site. Flow volumes typically peak from April through June during spring runoff and are lowest from September through October.

RI activities confirmed and refined what was known about 100-F hydrostratigraphy. The vadose zone comprises primarily Hanford formation gravels and is 0 to 15 m (0 to 49 ft) thick. Percent moisture of vadose zone samples from RI wells averaged 2.4 percent. In 100-IU-2/IU-6, vadose zone thickness ranges from near zero adjacent to the Columbia River to greater than 107 m (350 ft) in the central Hanford Site. The unconfined aquifer beneath 100-F comprises Hanford formation gravels. Its saturated thickness ranges from less than 1 m (3 ft) in southwestern 100-F to 8 m (25 ft) in eastern 100-F.

The hydrostratigraphy of 100-IU-2/IU-6 is variable because of the large area covered by these OUs. Beneath the western 100 Area, the unconfined aquifer is in Ringold unit E and the lower portion of the Hanford formation, and is up to 50 m (160 ft) thick. The unconfined aquifer generally thins toward the east, and is in the Hanford formation. Directly north of Gable Mountain, the water table is within the RUM unit, and there is no unconfined aquifer in the Hanford formation or Ringold unit E. South of Gable Mountain and Gable Butte, the water table may be in Ringold unit E, the Cold Creek unit, or the Hanford formation. Any of these units forms an aquifer when saturated.

Slug tests in the new 100-F RI wells yielded estimates of horizontal hydraulic conductivity of the Hanford formation ranging from 13 to 48 m/d (43 to 157 m/d). Horizontal hydraulic conductivity of the RUM unit was estimated to be 0.2 to 0.8 m/d (1 to 3 ft/d). Vertical hydraulic conductivity, as determined by laboratory tests of sediment samples, were highly variable and averaged 4.9 m/d (16 ft/d) in the Hanford gravels and 0.0066 m/d (0.022 ft/d) in the RUM.

The water table lies at a depth of 0 m (0 ft) adjacent to the river to greater than 107 m (350 ft) in the central Hanford Site. Beneath the portion of 100-F near the river, water table elevation varies by more than 3 m (10 ft) seasonally. In this region, groundwater flows toward the northeast during periods of low river stage and to the south or southwest during periods of high river stage. Estimated flow velocity ranges from 0.07 to 0.31 m/d (0.23 to 1.0 ft/d). Beneath the inland portion of 100-F, the water table shows little seasonal variation, and groundwater flows consistently to the east. The flow rate is estimated to be approximately 0.20 to 0.29 m/d (0.66 to 0.95 ft/d). Groundwater upwelling investigations show little

groundwater discharge to the Columbia River adjacent to 100-F. It appears that groundwater flows nearly parallel to the river channel for some distance south of 100-F.

Groundwater flows west to east beneath the southern portion of 100-IU-2/IU-6, discharging to the Columbia River at the eastern edge of the Hanford Site. Some groundwater flows northward through the gap between Gable Mountain and Gable Butte, and then toward the river. A groundwater upwelling study indicated broad areas of groundwater upwelling in the Columbia River from the Hanford Townsite slough down to Energy Northwest, but with relatively low discharge rates.

Natural recharge to the aquifer is low because of the Hanford Site's hot, arid or semi-arid climate. Historical artificial recharge came from liquid waste releases to the ground, spills, and ongoing leaks from facilities associated with the water supply. Water applied to control dust during facility demolition and waste site remediation is a recent potential source of artificial recharge.

Current land use in the Hanford Site's River Corridor consists of waste management, environmental monitoring, soil remediation, and conservation and restoration activities. Access is restricted to Hanford Site employees and contractors. DOE's reasonably anticipated future land use is predominantly conservation/preservation in the River Corridor.

The 100-F Area and near-shore portions of 100-IU-2/IU-6 are located in the Hanford Reach National Monument. The monument was created in part from the security buffer zone surrounding the Hanford Site, which has been untouched by development or agriculture since 1943.

The predominant plant community at 100-F/IU is sagebrush/Sandberg's bluegrass/cheatgrass. A relatively narrow riparian zone supports grasses, sedges, and scattered deciduous shrubs and trees.

Bull trout, spring-run Chinook salmon, and steelhead are included on federal threatened or endangered species lists and are candidates for state listing. The spring-run Chinook salmon do not spawn in the Hanford Reach, but use it as a migration corridor. Steelhead spawning has been observed in the Hanford Reach. Four bird species are state threatened or endangered species: the American white pelican, ferruginous hawk, greater sage grouse, and sandhill crane.

*Looking Ahead In This Document*

Chapter 3 described the physical setting of 100-F/IU, including the makeup of vadose zone materials, the groundwater, and the Columbia River.

Chapter 4 describes the contaminants resulting from 100-F/IU operations and their current extent in the environment. Contaminants can be harmful to HHE if there is contact with sufficient concentrations, mass, or radioactivity.

Chapter 5 describes and predicts fate and transport, that is, how these contaminants will migrate through the environment. The potential harm depends on specific receptors as well as exposure times and patterns that might bring receptors and contaminants into contact. The ways that the contaminants could come into contact with humans and the environment are called pathways. Chapter 6 addresses the human health pathway, and evaluates potential impacts. Chapter 7 addresses the biological receptor pathway and evaluates how plant, animal, bird, or invertebrate species might be affected.

Chapter 8 identifies technologies that could remove contaminants from the setting or interrupt these pathways. Chapter 9 develops and evaluates remedial alternatives using these technologies. Chapter 10 compares the alternatives that can best address the problem. This evaluation and comparison will support a remedial decision to implement actions to protect HHE.

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# 4 Nature and Extent of Contamination

Evaluation of the nature and extent of contamination describes the contaminant levels found in the environmental media in the study area. Levels of contamination are determined from recently collected RI data, data from RI of the Columbia River, data available from previous field investigations, completed interim remediation, interim action ongoing remediation, and operational process information. Reported concentrations of the various analytes are compared to background concentrations to determine if they represent a contaminant potentially released by Hanford.

Following the comparison to background levels, the contaminants are described in relation to their nature and extent. This chapter adds information about contaminants into the physical setting. This chapter also describes uncertainties associated with the data as they relate to the nature and extent of contamination.

This evaluation of the nature and extent of contamination is based on the long history of information for 100-F/IU and the new information collected during the RI to meet the data needs outlined in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) and 100-F/IU SAP (DOE/RL-2009-43). Many of the data collected during remediation that have been documented in CVPs and LFIs also are incorporated into this discussion of nature and extent of contamination.

*Highlights for 100-F*

- 144 of 149 waste sites have been remediated or are classified as not requiring remediation.
- Soil samples from boreholes were analyzed to determine vertical extent of contamination below the depth of remedial action at three waste sites. Several metals and radionuclides were detected at levels above background.
- Groundwater contamination is limited to the thin, unconfined aquifer beneath 100-F. Cr(VI), strontium-90, and TCE exceed water quality standards in relatively small groundwater plumes beneath 100-F; concentrations are generally declining. Tritium formerly exceeded the DWS but concentrations have declined.
- Disposal of animal waste contributed to a large nitrate plume that migrated south, parallel to the river, at concentrations above the DWS. Concentrations within the plume are steady or declining.
- Pore water from shallow sediment in the Columbia River is not contaminated at levels above AWQC or DWS.

*Highlights for 100-IU-2/IU-6*

- There are 251 waste sites identified, of which 115 are yet to be addressed.
- No groundwater contaminant plumes originate in 100-IU-2/IU-6. Contamination from other OUs is present in groundwater beneath portions of 100-IU-2/IU-6.
- Pore water from shallow sediment in the Columbia River is contaminated with tritium at levels above the DWS in one location where the Sitewide plume discharges to the river.

Information is also presented to describe the current understanding of contaminant releases from 100-F/IU to the Columbia River, biota, and air. This information is summarized from the Hanford Site Releases Data Summary (WCH-398), RCBRA (DOE/RL-2007-21), and *Hanford Site Environmental Report for Calendar Year 2008* (PNNL-18427).

Section 4.1 describes the Hanford Site background concentrations. Section 4.2 describes vadose zone contamination associated with areas investigated for the RI. Section 4.3 describes groundwater contamination. Sections 4.4 and 4.5 discuss Columbia River surface water/sediments and biota. Section 4.6 discusses ambient and atmospheric releases to the air. Section 4.7 provides a summary of the nature and extent of contamination in the vadose zone and groundwater.

*Types of Waste Sites*. Figures 1-6 through 1-8 in Chapter 1 show the locations of the former waste sites in 100-F that were the primary sources of the groundwater contaminants Cr(VI), strontium-90, TCE, and nitrate. Brief descriptions of the major types of waste sites and facilities that were formerly present in 100-F are provided below. Chapter 5, Section 5.2 discusses primary and secondary sources of contamination as part of the CSM for 100-F/IU.

- **Trenches**—Shallow, narrow, unlined liquid waste sites of variable length that were excavated into the land surface. Trenches received limited quantities of sludge and/or liquid waste (cooling water, contaminated water and sludge, sodium dichromate, fuel rupture effluent, and decontamination solutions [i.e., citric acid, nitric acid, and solvents]). Trenches typically were 15 to 40 m (50 to 130 ft) long, 3 to 5 m (10 to 17 ft) wide, and 2 to 6 m (6 to 20 ft) deep.

- **Cribs**—Subsurface liquid waste disposal sites for percolating wastewater into the ground without exposure to the atmosphere. The cribs typically were 3 m×3 m×3 m (10 ft×10 ft×10 ft) boxes, shored with wooden railroad ties, and filled with gravel. Early waste management practices used cribs to dispose of low-level radioactive waste and to provide a physical barrier against surface exposure. Cribs received contaminated water and sludge, contaminated process tube effluent, fuel storage effluent, spent laboratory solutions, and potassium borate solutions.

- **French drains**—Small, subsurface liquid waste disposal sites designed to percolate wastewater into the ground without exposure to the atmosphere. These sites were usually constructed with a 1 m (3 ft) diameter, open or gravel-filled pipe placed vertically to less than 5 m (16 ft) depth. French drains typically received low volumes of low-level radioactive waste for disposal.

- **Solid Waste Burial Grounds**—Areas used for near-surface disposal of solid waste containing radioactive and nonradioactive hazardous substances, construction debris from reactor modifications, contaminated construction equipment, contaminated dirt, irradiated reactor parts, and low-level radioactive combustible material.

- **Unplanned release sites**—Locations where waste was unintentionally released to the environment. Waste sites in this group are typically related to liquid waste spills.

- **Retention Basins**—Large, open, reinforced-concrete structures designed to temporarily hold cooling water from reactor operations. After cooling and decay of short-lived radionuclides, the water was discharged to the Columbia River. Although retention basins were not designed to dispose of water to the ground, they leaked substantially to the surrounding vadose zone.

- **Pipelines**—Closed transfer lines between facilities or structures that were used to transfer chemicals or waste effluents. Some pipelines leaked.

- **Experimental Animal Farm (EAF)**—A biological laboratory that examined the effects of radiation and radioactive contamination on animals and fish. Experiments produced contaminated solid and liquid wastes, including animal remains, dung, and urine that were disposed onsite.

*Analytical Data.* Nonradionuclide analytes in soil are reported in units of milligram per kilogram (mg/kg [equivalent to parts per million]). Radionuclides are reported in units of picocuries/gram (pCi/g).

Groundwater nonradionuclide analytes are reported in units of microgram per liter (µg/L [equivalent to parts per billion]) or milligrams per liter (mg/L [equivalent to parts per million], and radionuclides in groundwater are reported in pCi/L. Analytical results are included in Appendix D.

Filled symbols on vertical profile graphs in this chapter indicate detections during the analysis. Hollow symbols indicate that the analyte was not detected above limiting criteria. Limiting criteria are usually the method detection limit (MDL), instrument detection limit (IDL), or minimum detectable activity (MDA). For chemical constituents, the results are reported as the limiting criteria and flagged with a "U." Thus, a data point reported as "1.0 U mg/kg" means "less than 1.0 mg/kg."

As concentrations get closer to detection limits, precision and accuracy decline, primarily because of two factors: extrapolation beyond determined calibration curve boundaries, and increased noise-to-signal ratios from the instrument detection system. Consequently, results near the MDL/IDL are less precise and accurate than higher values. The estimated quantitation limit (EQL); sometimes referred to as the reporting limit (RL) or practical quantitation limit (PQL), is the lowest concentration that can be reliably quantified within specified limits of precision and accuracy under routine laboratory operating conditions. The EQL is generally 5 to 10 times greater than the MDL. The concentration range between the IDL/MDL and the EQL/RL is an analytical "gray zone" where the presence of an analyte can be detected but the analytical precision and accuracy of the values obtained are diminished. If an analyte is detected at a value less than the EQL/RL, but greater than or equal to the IDL/MDL, the detected concentration is flagged ("B" for most inorganic analytes, "J" for organics) to indicate the potential for diminished precision and accuracy.

Because detection limits for a given analyte can vary depending on many factors, it sometimes happens that a detected value is reported at a lower concentration than a nondetection (U-flagged) value. It is important that any laboratory-established detection be documented and reported to the best of the laboratory's capability. Not reporting the obtained value (even if potentially with a very large error bound) would be a functional corruption of the dataset. Requesting/requiring the laboratory to report nondetects to routine MDLs is not technically appropriate because it would negatively bias the interpretation of actual laboratory capabilities and the results thus reported. The apparent disparity in detected values reported at lower values than nondetect values (particularly when presented as plots) does not misrepresent the accuracy or usefulness of the data. If project-defined EQL/RL goals are met, this facet of the data will not negatively impact decision-making activities.

## 4.1 Background Concentrations

Background concentrations of chemical substances and radionuclides at the Hanford Site are those levels that are generally considered to be naturally occurring (i.e., not influenced by human activity), although anthropogenic occurrences may be considered background when they are not specifically related to a given waste site. Hanford Site background concentrations have been established for many but not all of the inorganic and radionuclides analytes for 100-F and 100-IU-2/IU-6, and none of the organic analytes. Some chemicals may be present in the environment, originating from both natural (background) and artificial conditions. Arsenic is an example of a chemical that naturally occurs in the environment, but may also be present as a result of pesticide applications (*Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* [EPA 540-R-01-003], hereinafter called CERCLA Soil Background Comparisons Guidance).

Section 4.1.1 describes pre-Hanford practices that affected background concentrations of lead and arsenic, and Section 4.1.2 describes Hanford Site soil background concentrations as determined by sampling. Groundwater background concentrations for 100-F/IU analytes were derived from *Hanford Site Background: Part 3, Groundwater Background* (DOE/RL-96-61). Section 4.3 presents groundwater background concentrations.

### 4.1.1 Historical Agricultural Activities

As discussed in Chapter 1, historical agricultural lands are present in the River Corridor, including 100-F/IU. Collocated within the historical orchard land areas are waste sites related to releases from Hanford Site operations (Figure 4-1). The persistence of residuals from lead arsenate that was applied as a pesticide before Hanford operations began is a concern that merits an assessment of potential impacts to HHE. Should contaminants associated with historical orchard lands (e.g., lead and arsenic) be present at any particular waste site, that contamination will not be remediated beyond the waste site footprint as part

of the 100-F/IU cleanup action. Any contaminants remaining outside the waste site footprint will be addressed as part of the RI for the 100-OL-1 OU. This approach will allow reclassification of individual waste sites that meet the cleanup standards (for non-orchard lands related contaminants) of the applicable decision area ROD while supporting the broad area investigation of historical orchard lands as part of the 100-OL-1 OU.

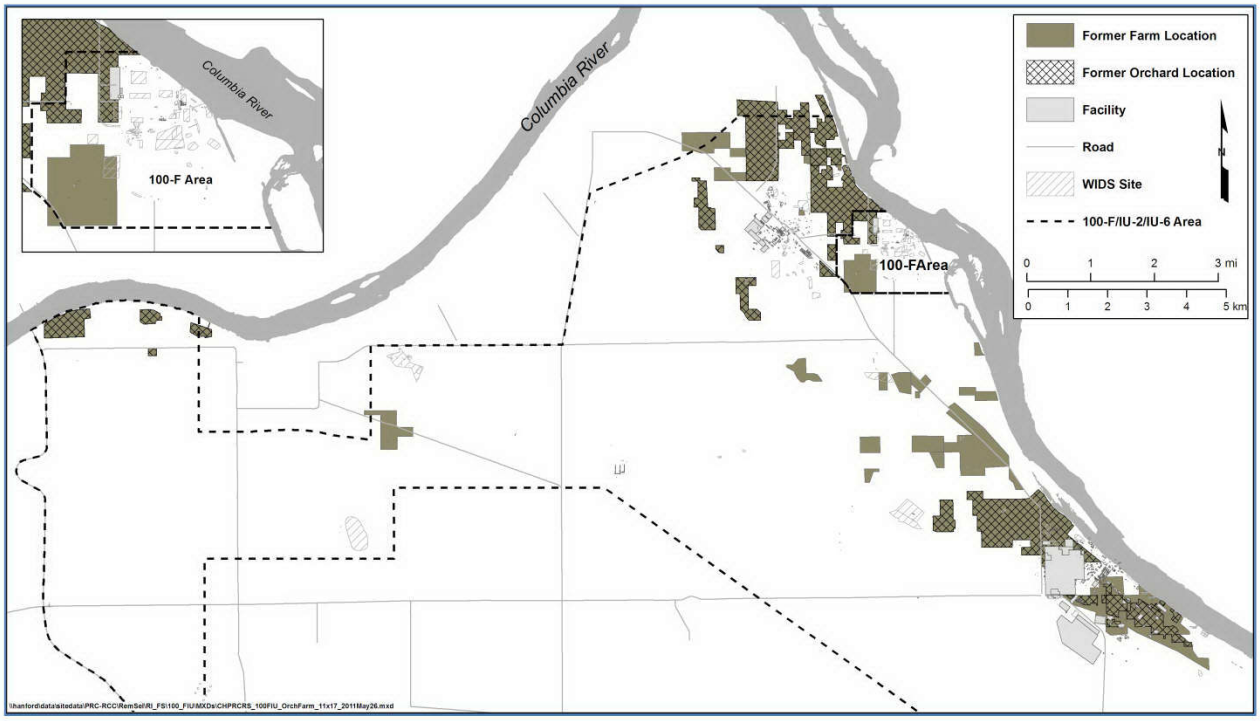


Figure 4-1. Locations of Former Orchards and Farms in 100-F/IU

Details for the handoff of actions between the River Corridor RODs and the 100-OL-1 OU investigations will be established in the RD/RA work plan documents associated with each decision area ROD. An example of this approach, as implemented for the interim action RODs, is provided by *Federal Facility Agreement and Consent Order Change Control Form: Modify Remedial Design Report/ Remedial Action Work Plan for the 100 Area (DOE/RL-96-17 Rev. 6) to add Section 3.6.10 Residual Pesticides from Agriculture Use* (TPA-CN-401).

### 4.1.2 Hanford Site Soil Background

The identification of background concentrations of constituents in soil and groundwater is important to determine which waste sites may require remedial action. These concentrations are also important because calculated PRGs can be less than background concentrations. Where PRGs are calculated to be less than background, the PRG is revised to reflect a background concentrations rather than the calculated value. CERCLA does not typically require cleanup to concentrations below background concentrations. As such, a constituent detected below background (i.e., 90$^{th}$ percentile in *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* (DOE/RL-92-24), hereinafter called Non-Rad Soil Background document, or *Hanford Site Background: Part 2, Soil Background for Radionuclides* (DOE/RL-96-12), hereinafter called Rad Soil Background document, is not considered a contaminant.

For anthropogenic radionuclides in depth-discrete soil samples (including strontium-90, cobalt-60, cesium-137, europium-154, europium-155, plutonium-238, and plutonium-239/240), anthropogenic

constituents were not excluded based on background concentration (i.e., all detects are presented, even if below background Hanford Site soil concentrations).

Table 4-1 lists the analytes for which soil background concentrations have been established. The table includes the 90th percentile concentration for each substance listed. For the purposes of this chapter, measured concentrations that exceed the 90th percentile level are considered to be indicative of potential contamination.

Table 4-1. Background Concentrations in Hanford Site Soil

| CAS Number | Analyte | Abbreviation | 90th Percentile | Reference |
|---|---|---|---|---|
| **Radionuclides (pCi/g)** | | | | |
| 10045-97-3 | Cesium-137[a] | Cs-137 | 1.05 | DOE/RL-96-12 |
| 10198-40-0 | Cobalt-60 | Co-60 | 0.00842 | DOE/RL-96-12 |
| 15585-10-1 | Europium-154 | Eu-154 | 0.0334 | DOE/RL-96-12 |
| 14391-16-3 | Europium-155 | Eu-155 | 0.0539 | DOE/RL-96-12 |
| 13981-16-3 | Plutonium-238 | Pu-238 | 0.00378 | DOE/RL-96-12 |
| 15117-48-3 | Plutonium-239/240[a] | Pu-239/240 | 0.0248 | DOE/RL-96-12 |
| 10098-97-2 | Strontium-90[a] | Sr-90 | 0.178 | DOE/RL-96-12 |
| 13966-29-5 | Uranium-233/234 | U-233/234 | 1.10 | DOE/RL-96-12 |
| 15117-96-1 | Uranium-235 | U-235 | 0.109 | DOE/RL-96-12 |
| 7440-61-1 | Uranium-238 | U-238 | 1.06 | DOE/RL-96-12 |
| **Nonradionuclides (mg/kg)** | | | | |
| 7440-36-0 | Antimony | Sb | 0.13 | ECF-HANFORD-11-0038 |
| 7440-38-2 | Arsenic | As | 6.47 | DOE/RL-92-24 |
| 7440-39-3 | Barium | Ba | 132 | DOE/RL-92-24 |
| 7440-41-7 | Beryllium | Be | 1.51 | DOE/RL-92-24 |
| 7440-43-9 | Cadmium | Cd | 0.56 | ECF-HANFORD-11-0038 |
| 7440-47-3 | Chromium (total) | Cr | 18.5 | DOE/RL-92-24 |
| 7440-48-4 | Cobalt | Co | 15.7 | DOE/RL-92-24 |
| 7440-50-8 | Copper | Cu | 22 | DOE/RL-92-24 |
| 7439-92-1 | Lead | Pb | 10.2 | DOE/RL-92-24 |
| 7439-93-2 | Lithium | Li | 33.5 | DOE/RL-92-24 |
| 7439-96-5 | Manganese | Mn | 512 | DOE/RL-92-24 |
| 7439-97-6 | Mercury | Hg | 0.01 | ECF-HANFORD-11-0038 |
| 7439-98-7 | Molybdenum | Mo | 0.47 | ECF-HANFORD-11-0038 |
| 7440-02-0 | Nickel | Ni | 19.1 | DOE/RL-92-24 |
| 7782-49-2 | Selenium[b] | Se | 0.78 | ECF-HANFORD-11-0038 |

Table 4-1. Background Concentrations in Hanford Site Soil

| CAS Number | Analyte | Abbreviation | 90th Percentile | Reference |
|---|---|---|---|---|
| 7440-22-4 | Silver | Ag | 0.17 | ECF-HANFORD-11-0038 |
| 7440-28-0 | Thallium | Tl | 0.18 | ECF-HANFORD-11-0038 |
| 7440-62-2 | Vanadium | V | 85.1 | DOE/RL-92-24 |
| 7440-66-6 | Zinc | Zn | 67.8 | DOE/RL-92-24 |
| 14797-55-8 | Nitrate | $NO_3^-$ | 52 | DOE/RL-92-24 |

Sources: DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides.*

DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*.

ECF-HANFORD-11-0038, *Soil Background Data for Interim Use at the Hanford Site.*

a. Cesium-137, strontium-90, and plutonium-239/240 are anthropogenic radionuclides whose background values only apply to surface soil samples.

b. The 90th percentile value for selenium is estimated because the majority of detections were below the minimum quantitation limit.

CAS = Chemical Abstracts Service

Additional analytes for which no background concentrations have been established are presented in subsequent sections. These analytes are included in target analyte lists for groundwater and vadose zone soil samples. For the purposes of this chapter, detection of these additional analytes is considered indicative of potential contamination.

Background concentrations for Hanford Site groundwater were derived from *Hanford Site Background: Part 3, Groundwater Background* (DOE/RL-96-61). Those values are presented in Section 4.3.

Investigations for collecting data and developing River Corridor background values in soil for selected metals were performed as part of the RI. Revised provisional background values for antimony, cadmium, mercury, selenium, silver, and thallium are presented in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038). This revised information is included in Table 4-1.

## 4.2 Vadose Zone Contamination

Within 100-F/IU, 400 waste sites (including subsites) have been identified. Primary and secondary sources of contamination and contaminated environmental media are described in Chapter 5, Section 5.2. For a historical perspective of investigations that have been conducted with regard to characterization of the vadose zone at 100-F, refer to Chapter 1, Table 1-3 for a list of applicable documents. Appendix E provides a summary of confirmation sampling results collected to support the determination for sites determined not to require remediation, a summary of the actions conducted under the interim action ROD at those sites determined to require remediation, and a summary of verification sampling results collected to assess the efficacy of the remedial actions conducted at those sites. This section specifically describes the nature and extent of existing contamination in the vadose zone at the areas investigated for the RI. Remedial actions conducted under the interim action ROD consisted of soil removal to the depths noted in Appendix E to remove contaminants exceeding the remediation requirements specified in the interim action ROD and vadose zone sampling at selected waste sites. Of the 400 waste sites identified under 100-F/IU, 280 sites were dispositioned under the interim action ROD (1 closed out, 132 interim closed out, 50 no action); were classified as “not accepted” (48 waste sites); or “rejected” (49 waste sites) under CERCLA. As of June 30, 2012, a total of 120 waste sites remained to be addressed, with 5 sites under

100-F and 115 sites under 100-IU-2/IU-6. The five sites remaining under 100-F included 100-F-57:2, 100-F-65, 100-F-59, 100-F-39, and 100-F-8:2. Chapter 5 evaluates contaminant fate and transport. Chapter 6 addresses the human health risk associated with the waste sites, and Chapter 7 discusses the ecological risk.

The description of soil contamination present at the sites sampled in accordance with the 100-F/IU RI work plan and SAP are described in this section based on data collected between 1993 and 2011 for constituents with concentrations that exceed background soil concentrations (Table 4-1). In Chapter 6, a concise description is presented to identify the occurrence of analytes detected above background at closed out, interim closed, and no action waste sites. Data generated from this investigation were integrated with analytical results from the following investigations:

- 100-FR-1 LFI (DOE/RL-93-82)
- *Cleanup Verification Package for the 116-F-14 Retention Basin* (CVP-2001-00009)
- *Cleanup Verification Package for the 118-F-1 Burial Ground* (CVP-2007-00001)
- *Cleanup Verification Package for the 118-F-8:1, 105-F Reactor Below-Grade Structures and Underlying Soils; the 118-F-8:3, 105-F Fuel Storage Basin Underlying Soils; and the 100-F-10 French Drain* (CVP-2003-00017)

A number of sites have radionuclide contamination above background at a depth greater than 4.6 m (15 ft) following implementation of the interim action ROD. These sites include the following:

- 100-F Reactor Cooling Water Effluent Underground Pipelines (100-F-19:1, 100-F-19:2, and 100-F-19:3)
- Sites that received reactor effluent: the 107-F Liquid Waste Disposal Trench (116-F-2), the 1608-F Liquid Waste Disposal Trench (116-F-6), Animal Waste Leaching Trench (116-F-9), and 107-F Retention Basin (116-F-14)
- 105-F Fuel Storage Basin sites (118-F-8:3 and 118-F-8:4)

In addition, four sites will be addressed using the allowable residual contamination level (ARCL) methodology (132-F-3, 132-F-4, 132-F-5, and 132-F-6). These sites will be evaluated for human health risk in Chapter 6.

Overburden material associated with two remediated waste sites report elevated concentrations of site-related radiological COPCs. The 116-F-4 waste site (overburden focused decision unit) had elevated concentrations of technetium-99 (1.5 pCi/g), cesium-137 (3.5 pCi/g), and strontium-90 (1.6 pCi/g). Similarly, the 100-F-26:14 waste site (overburden decision unit) had elevated concentrations of cesium-137 (2.0 pCi/g), europium-152 (1.4 pCi/g), and strontium-90 (0.37 pCi/g).

The 118-F-6 (shallow decision unit) contained strontium-90 at a concentration of 4.1 pCi/g and a field duplicate result of 3.04 pCi/g. An additional three samples were collected from the site with strontium-90 results of 0.519 pCi/g, 1.32 pCi/g, and 0.794 pCi/g. Although it is assigned to a shallow zone decision unit, the residual contamination is located at a depth greater up to 6.4 m (21 ft). This waste site, along with 116-F-4 and 100-F-26:14, warrants further evaluation in the human health risk assessment provided in Chapter 6.

It was noted that samples from four 600 Area sites contained elevated levels of lead or arsenic. Two of these sites (600-351 and 600-109) were located within known orchard areas, and the presence of both arsenic and lead at elevated concentrations is indicative of the use of lead arsenate in the orchards.

The 600-109 site is located within the boundaries of the former Hanford Trailer Camp Landfill. It will need to be evaluated as part of the 100-OL-1 OU.

Site 600-3 contained elevated levels of lead but not corresponding elevated arsenic concentrations. While this site does share part of its boundary with a former farmstead site, the neighboring location was not an orchard. The presence of lead but not a corresponding increase in arsenic does not match a lead arsenate fingerprint. Rather, it reflects the presence of lead sheeting at the site that has subsequently been removed under the interim remedial action, as documented in *Remaining Sites Verification Package for the 600-3, Hanford Townsite Excess Material Storage Yard/Paint Pit* (RSVP-2011-072). The presence of residual elevated lead concentrations (maximum focused sample concentration of 259 mg/kg, 95 percent UCL of 34.4 mg/kg in the east excavation area, and 95 percent UCL of 22.2 mg/kg in the staging pile area) is most likely attributed to residual contamination resulting from the historical use of the site.

Site 600-176 was the location of a paint disposal area and does not fall within the footprint of a former orchard location. The historical use of lead paint and subsequent disposal in this area is the likely contributor to elevated lead concentrations (95 percent UCL of 119 mg/kg) in the soil. The site has been remediated as documented in *Remaining Sites Verification Package for the 600-176, White Bluffs Paint Disposal Area* (RSVP-2011-029).

Site 600-202 was the location of four burn and burial pits within the Hanford Construction Camp municipal dump area and is not associated with the locations of any former orchards. The presence of elevated lead concentrations is not matched by the presence of arsenic; hence, it is not attributed to the use of lead arsenate. The site has subsequently been remediated as documented in *Remaining Sites Verification Package for the 600-202, Hanford Townsite Four Burn and Burial Pits* (RSVP-2011-030). The residual elevated lead concentration (maximum focused sample concentration of 278 mg/kg and a 95 percent UCL of 38.3 mg/kg in the staging pile area) is most likely attributed to the disposal and burning activities that took place in the pits.

Risk attributed to sites 600-3, 600-176, and 600-202 will be further evaluated in Chapters 5, 6, and 7.

Appendix D includes soil data collected during the RI and previous investigations. The soil analytical datasets applicable to RI waste sites include constituents characterized as having short half-lives (e.g., less than 3 years), common laboratory contaminants, essential nutrients, and essentially nontoxic substances. These constituents are commonly not discussed as detections and are primarily an artifact of the sampling and analysis process, not observed above background concentrations, or not a human health concern (i.e., nontoxic) per *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual [Part A]: Interim Final* (EPA/540/1-89/002), hereinafter called the risk assessment guide. Table 4-2 lists 100-F soil target analytes excluded from consideration.

Two boreholes, C7970 and C7971, were completed through the 116-F-14 Retention Basin and the 118-F-1 Burial Ground, respectively, to assess the nature and extent of contamination beneath selected remediated waste sites (data gap 2). An additional borehole, C7972, was completed in the boundary of the 118-F-8 Fuel Storage Basin to assess the nature and extent of contamination in the vadose zone around the F Reactor structure (data gap 3). Three groundwater monitoring wells were installed in the 100-F Area to better understand the mobility of contaminants through the vadose zone (data gap 7).

Table 4-2. 100-F Soil Analytes Excluded from Further Consideration

| Analyte | Exclusion Rationale | Daughters | Half-Life |
|---|---|---|---|
| **Radionuclides** | | | |
| Actinium-228 | Decayed daughter of Th-232/Ra-228; in equilibrium with parent; half-life less than 3 years | -- | 6.15 hours |
| Cerium-144 | Half-life less than 3 years | Pr-144m (1.2 m [4 ft]), Pr-144 (17.28 m [56.69 ft]), and Nd-144 (stable) | 284.6 days |
| Cesium-134 | Half-life less than 3 years | Ba-134 (stable) | 2.065 years |
| Cobalt-58 | Half-life less than 3 years | Ni-58 (stable) | 70.88 days |
| Iron-59 | Half-life less than 3 years | Co-59 (stable) | 44.51 days |
| Lead-212 | Decayed daughter of Th-232/Ra-228; in equilibrium with parent; half-life less than 3 years | -- | 10.6 hours |
| Lead-214 | Decayed daughter of Ra-226; in equilibrium with parent; half-life less than 3 years | -- | 26.8 minutes |
| Magnesium-54 | Half-life less than 3 years | Fe-54 (stable) | 612.2 days |
| Potassium-40 | Naturally occurring background radiation | -- | $1.28 \times 10^9$ years |
| Radium-224 | Decayed daughter of Th-232/Ra-228; in equilibrium with parent; half-life less than 3 years | -- | 3.66 days |
| Radium-226 | Only potential source from naturally occurring background radiation (insufficient in growth time for the Hanford Site introduced U as decay daughter of U-234/Th-230) | -- | $1.6 \times 10^3$ years |
| Radium-228 | Naturally occurring background radiation | -- | 5.76 years |
| Ruthenium-103 | Half-life less than 3 years | Rh-103m (56.12 m [184.12 ft]) and Rh-103 (stable) | 39.27 days |
| Ruthenium-106 | Half-life less than 3 years | Rh-106 (29.9 m [98.1 ft]) and Pd-106 (stable) | 1.020 years |
| Sodium-22 | Half-life less than 3 years | Ne-22 (stable) | 2.605 years |
| Thorium-228 | Naturally occurring background radiation (present in secular equilibrium with parent radium-228 isotope); half-life less than 3 years | -- | 1.91 years |

Table 4-2. 100-F Soil Analytes Excluded from Further Consideration

| Analyte | Exclusion Rationale | Daughters | Half-Life |
|---|---|---|---|
| Thorium-230 | Only potential source from naturally occurring background radiation (insufficient in growth time for the Hanford Site introduced U as decay daughter of U-234) | -- | $7.7 \times 10^4$ years |
| Thorium-232 | Naturally occurring background radiation | -- | $1.4 \times 10^{10}$ years |
| Thorium-234 | Decayed daughter of U-238; in equilibrium with parent; half-life less than 3 years | -- | 2.41 days |
| Tin-113 | Half-life less than 3 years | In-113m (1.658 hrs) and In-113 (stable) | 115.1 days |
| Uranium-240 | Half-life less than 3 years | -- | 14.1 hours |
| **Nonradionuclides** | | | |
| Calcium | Essential nutrient | -- | -- |
| Chloride | Essential nutrient | -- | -- |
| Iron | Essential nutrient | -- | -- |
| Magnesium | Essential nutrient | -- | -- |
| Sodium | Essential nutrient | -- | -- |
| Potassium | Essential nutrient | -- | -- |
| Phosphate | Essential nutrient | -- | -- |
| Ammonia | No soil toxicity information available | -- | -- |
| Bismuth | No soil toxicity information available | -- | -- |
| Zirconium | No soil toxicity information available | -- | -- |
| Acetone | Laboratory contaminant | -- | -- |
| bis(2-Ethylhexyl) phthalate | Laboratory contaminant | -- | -- |
| Diethyl phthalate | Laboratory contaminant | -- | -- |
| di-n-Butylphthalate | Laboratory contaminant | -- | -- |
| Methylene chloride | Laboratory contaminant | -- | -- |
| Toluene | Laboratory contaminant | -- | -- |

In addition to the data collected specifically in support of the RI, data are presented for the 100-F-59 riparian area, that includes the section of the former 128-F-2 Burn Pit that is below the Columbia River ordinary high water mark (OHWM) and a portion of the adjoining slough (further discussion is provided in Section 4.2.4).

Vertical profiles are used to show the distribution of contamination in the vadose zone. The profiles provide, as applicable, a visual depiction of analytes above background, sample depth, the waste site structure, depth of remedial action, stratigraphy, and the water table depth encountered at sampling. As such, the profiles show those analytes detected in borehole soil above background. The analytical results are plotted at the lower end of the sample intervals. Note that strontium and tin do not have established background values and, therefore, are reported wherever detections occurred.

### 4.2.1 116-F-14 Retention Basin

The 116-F-14 Retention Basin was a concrete-lined reservoir designed to temporarily hold reactor coolant water prior to discharge to the Columbia River. Following the reactor shutdown, the retention basin was decommissioned in stages from 1965 to 1999. Remedial excavation, conducted in 2000, extended to a depth greater than 4.6 m (15 ft) below the surrounding grade. Figure 4-2 shows the location of the boreholes. The COCs at the time of remediation included carbon-14, cesium-137, cobalt-60, europium-152, europium-154, europium-155, nickel-63, strontium-90, total chromium, and Cr(VI) (*Cleanup Verification Package for the 116-F-14 Retention Basin* [CVP-2001-00009]). The site was determined to meet interim closure requirements based on evaluation of the analytical results for shallow (0 to 4.6 m [15 ft]) and deep zone (greater than 4.6 m [15 ft]) cleanup verification samples (Table 4-3).

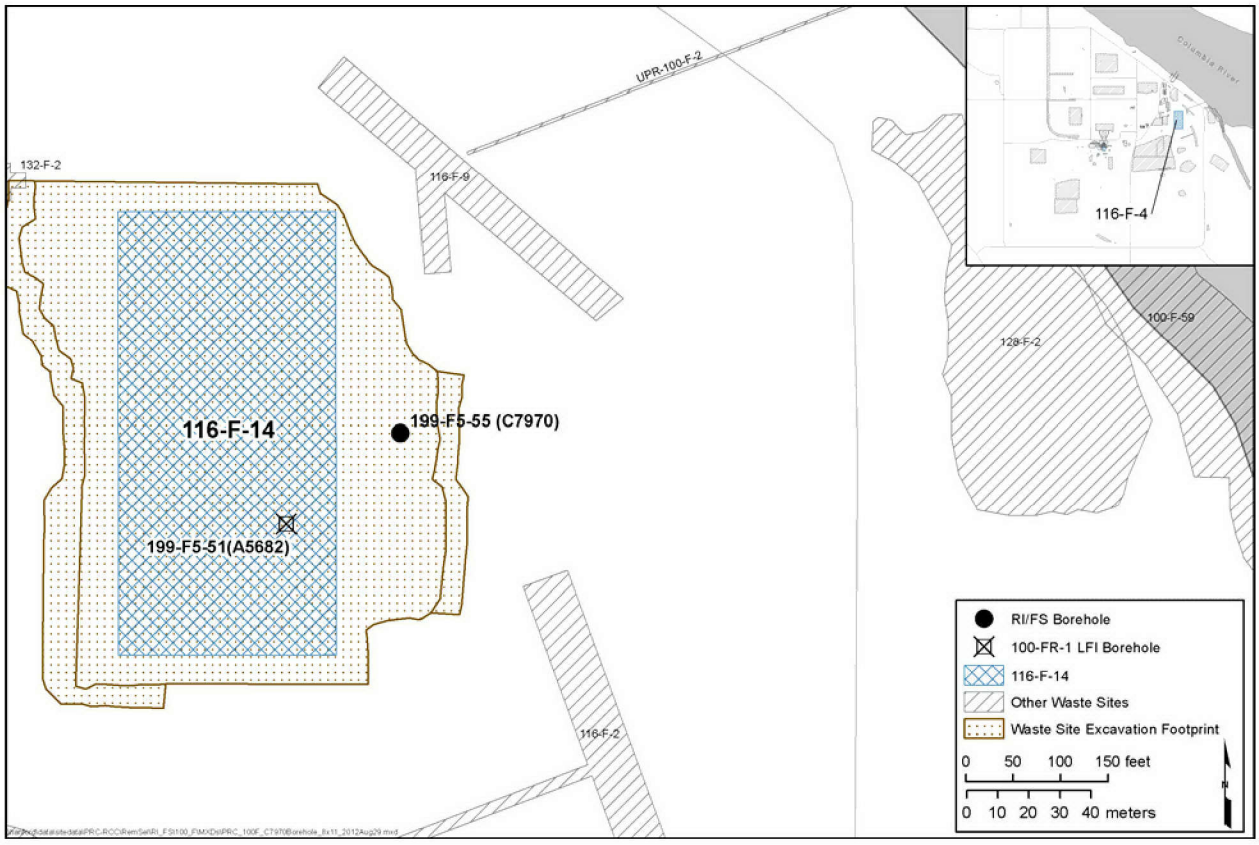


Figure 4-2. 116-F-14 Retention Basin Borehole Locations

The 116-F-14 waste site was selected for additional characterization to support the refinement of the CSM for contaminant distribution beneath selected remediated waste sites. In addition, the maximum residual concentration of Cr(VI) in the soil column associated with this waste site is 3.2 mg/kg. Data for analytes exceeding background levels are presented in Table 4-3. These data are based on soil samples collected

during the LFI, cleanup verification, and the RI. Vertical profiles for the analytes exceeding background are shown on Figures 4-3 and 4-4.

Thirty-one constituents were detected above background in soil samples associated with the 116-F-14 Retention Basin (Table 4-3). The LFI data included 10 radionuclides detected; however, 7 of the radionuclides were not detected below the depth of remedial action (exception: cesium-137, plutonium-238, and plutonium-239/240). In the RI samples (Figure 4-4), nine radionuclides were detected with the maximum activity for all radionuclides occurring at 6.9 m (22.7 ft) bgs. Below this depth, activity decreased for all radionuclides, and only cesium-137 and strontium-90 were detected at the water table.

Cr(VI) was detected across the soil column with the maximum concentration (3.23 mg/kg) occurring at 6.9 m (22.7 ft) bgs. The concentration decreased with depth; however, Cr(VI) was still present in soil collected from the bottom of the borehole (0.27 mg/kg at 14.9 m [48.9 ft]). The maximum concentration of total chromium (126 mg/kg) was detected at 6.9 m (22.7 ft) bgs and decreased with depth. However, there was an increase in total chromium in soil collected below the water table (13.6 m [44.7 ft]). Modeling of the vadose zone contaminant concentrations to assess whether the residual concentrations adversely impact the aquifer is discussed in Chapter 5. Nitrate (as N) and sulfate were detected above background across the soil column with maximum concentrations occurring at 8.3 m and 6.9 m (27.1 ft and 22.7 ft), respectively.

### 4.2.2 118-F-1 Burial Ground

The 118-F-1 Burial Ground received radioactive equipment and other miscellaneous solid waste from F Reactor operations, including dummy elements and irradiated process tubing, gun barrel tips, steel sleeves, and metal chips removed from the reactor. Remedial action, completed in 2006, consisted of the excavation of all buried material to a maximum depth of 5.5 m (18 ft) bgs. Figure 4-5 shows the location of the borehole and the excavation footprint of the 118-F-1 waste site. The COCs at the time of remediation included americium-241, carbon-14, cesium-137, cobalt-60, europium-152, europium-154, nickel-63, plutonium-238, plutonium-239/240, silver-108m, strontium-90, tritium, uranium-238, cadmium, lead, and mercury (*Cleanup Verification Package for the 118-F-1 Burial Ground* [CVP-2007-00001]). The site was determined to meet interim closure requirements based on evaluation of the analytical results for cleanup verification samples, summarized in Table 4-4.

The 118-F-1 waste site was selected for additional characterization to support the refinement of the CSM for contaminant distribution beneath selected remediated waste sites. In addition, the burial ground is being characterized because it is suspected of being the source of Cr(VI) and tritium groundwater contamination that was formerly observed in this area. Data for analytes exceeding background levels are presented in Table 4-4. These data are based on soil samples collected during the cleanup verification and the RI. Vertical profiles for the analytes exceeding background are shown on Figure 4-6.

Eleven constituents were detected above background in RI soil samples associated with the 118-F-1 Burial Ground (Table 4-4). The radionuclides previously identified in the cleanup verification samples were not detected in any of the RI samples. Nonradionuclides detected above background included arsenic, chromium, lead, lithium, mercury, molybdenum, nickel, strontium, tin, nitrate, and styrene. Chromium and nickel had maximum concentrations (66.2 mg/kg and 36.1 mg/kg, respectively) at 5.97 m (19.8 ft) bgs. Seven of the constituents were detected above background at the maximum extent of the borehole. Cr(VI) was not detected in any soil samples collected as part of the RI.

Table 4-3. 116-F-14 Retention Basin—Summary of Soil Data

| Analyte | Background | Concentration and Distribution | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cleanup Verification Data[a] | | | | 1992 LFI Borehole A5682 (Well 199-F5-51)[b] | | | | | RI Borehole C7970 (Well 199-F5-55)[c] | | | | |
| | | Shallow Zone[d] | | Deep Zone | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (7.5 m/24.5 ft bgs) | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (14.9 m/48.9 ft bgs, unless otherwise noted)[e] | |
| | | Original | Decayed | Original | Decayed | Original | Decayed | | Original | Decayed | Original | Decayed | | Original | Decayed |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[f]** | | | | | | | | | | | | | | | |
| Americium-241 | NA | -- | NA | -- | NA | 0.98 (1.5/5) | 0.95 | 2.1/7 | U | NA | -- | NA | NA | -- | NA |
| Carbon-14 | NA | U | NA | 8.6 | 8.6 | 28 (1.5/5) | 28 | 2.1/7 | U | NA | 48.8 (6.9/22.7) | 48.8 | 6.9/22.7 | U | NA |
| Cesium-137 | NA | 0.63 | 0.49 | 7.7 | 6.0 | 12 (2.1/7) | 8 | 7.5/24.5 | 1.5 | 1.0 | 4.49 (6.9/22.7) | 4.29 | 12.8/42.0 | U | NA |
| Cobalt-60 | NA | 0.075 | 0.018 | 7.5 | 1.8 | 53 (2.1/7) | 4 | 2.1/7 | U | NA | 3.88 (6.9/22.7) | 2.98 | 8.3/27.1 | U | NA |
| Europium-152 | NA | 1.8 | 1.0 | 150 | 85 | 940 (1.5/5) | 337 | 2.1/7 | U | NA | 170 (6.9/22.7) | 153 | 9.7/31.9 | U | NA |
| Europium-154 | NA | 0.19 | 0.08 | 14 | 6 | 130 (1.5/5) | 26 | 2.1/7 | U | NA | 12.9 (6.9/22.7) | 11.0 | 6.9/22.7 | U | NA |
| Europium-155 | NA | U | NA | U | NA | 6.6 (1.5/5) | 0.4 | 2.1/7 | U | NA | U | NA | NA | U | NA |
| Nickel-63 | NA | 6.0 | 5.6 | 420 | 389 | -- | NA | NA | -- | NA | 562 (6.9/22.7) | 554 | 8.3/27.1 | U | NA |
| Plutonium-238 | NA | -- | NA | -- | NA | 0.24 (7.5/24.5) | 0.20 | 7.5/24.5 | 0.24 | 0.20 | U | NA | NA | U | NA |
| Plutonium-239/240 | NA | -- | NA | -- | NA | 5.1 (1.5/5) | 5.1 | 7.5/24.5 | 0.035 | 0.035 | 2.50 (6.9/22.7) | 2.50 | 6.9/22.7 | U | NA |
| Strontium-90 | NA | 0.15 | 0.12 | 1.1 | 0.8 | 16 (1.5/5) | 10 | 1.5/5 | U | NA | 7.73 (6.9/22.7) | 7.37 | 14.9/48.9 | 3.25 | 3.10 |
| Tritium | NA | -- | NA | -- | NA | -- | NA | NA | -- | NA | 7.31 (6.9/22.7) | 6.53 | 6.9/22.7 | U | NA |
| **Nonradionuclides (mg/kg)** | | | | | | | | | | | | | | | |
| Antimony | 0.130 | -- | | -- | | U | | NA | U | | 0.441 (11.2/36.9) | | 13.6/44.7 | U | |
| Barium | 132 | -- | | -- | | 170 (1.5/5) | | 1.5/5 | 79.1 | | 96.4 (5.5/17.9) | | NA | 45.9 (<BG) | |
| Bismuth | NA | -- | | -- | | -- | | NA | -- | | 0.614 (5.5/17.9) | | 12.2/40.0 | U | |
| Boron | 3.89 | -- | | -- | | -- | | NA | -- | | 8.34 (5.5/17.9) | | 5.5/17.9 | U | |
| Cadmium | 0.563 | -- | | -- | | 1.5 (2.1/7) | | 2.1/7 | U | | 0.745 (6.9/22.7) | | 6.9/22.7 | 0.056 (<BG) | |
| Chromium | 18.5 | 24 | | 130 | | 124 (2.1/7) | | 7.5/24.5 | 35.3 | | 126 (6.9/22.7) | | 13.6/44.7 | 14.8 (<BG) | |
| Copper | 22 | -- | | -- | | 29.3 (2.1/7) | | 2.1/7 | 15.9 | | 18.2 (6.9/22.7) | | NA | 9.46 (<BG) | |
| Cr(VI) | 0 | 1.2 | | 6.2 | | -- | | NA | -- | | 3.23 (6.9/22.7) | | 14.9/48.9 | 0.27 | |
| Lead | 10.2 | -- | | -- | | 5 (0.6/2) | | NA | 2.6 | | 11.4 (6.9/22.7) | | 6.9/22.7 | 2.15 (<BG) | |
| Molybdenum | 0.470 | -- | | -- | | -- | | NA | -- | | 6.31 (13.6/44.7) | | 16.0/52.5 | 0.517 | |
| Nickel | 19.1 | -- | | -- | | 20.8 (7.5/24.5) | | 7.5/24.5 | 20.8 | | 24.3 (11.2/36.9) | | 11.2/36.9 | 7.08 (<BG) | |
| Nitrate (as N) | 11.7 | -- | | -- | | -- | | NA | -- | | 26.6 (8.3/27.1) | | 13.6/44.7 | 23.4 (13.6/44.7) | |
| Silver | 0.167 | -- | | -- | | 0.79 (5.7/18.6) | | 5.7/18.6 | U | | U | | NA | U | |

Table 4-3. 116-F-14 Retention Basin—Summary of Soil Data

| Analyte | Background | Concentration and Distribution | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cleanup Verification Data[a] | | | | 1992 LFI Borehole A5682 (Well 199-F5-51)[b] | | | | RI Borehole C7970 (Well 199-F5-55)[c] | | | | |
| | | Shallow Zone[d] | | Deep Zone | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (7.5 m/24.5 ft bgs) | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (14.9 m/48.9 ft bgs, unless otherwise noted)[e] | |
| | | Original | Decayed | Original | Decayed | Original | Decayed | | Original | Decayed | Original | Decayed | | Original | Decayed |
| Strontium | NA | -- | | -- | | -- | | -- | -- | | 63.5 (5.5/17.9) | | 14.9/48.9 | 19.9 | |
| Sulfate | 237 | -- | | -- | | 57 (2.1/7) | | NA | 8 | | 2170 (6.9/22.7) | | 13.6/44.7 | 381 (13.6/44.7) | |
| Tin | NA | -- | | -- | | -- | | -- | -- | | 2.14 (13.6/44.7) | | 14.9/48.9 | 1.91 | |
| Zinc | 67.8 | -- | | -- | | 87.4 (2.1/7) | | 2.1/7 | 39.2 | | 156 (6.9/22.7) | | 6.9/22.7 | 26.4 (<BG) | |
| Alpha-chlordane | NA | -- | | -- | | U | | NA | U | | 0.0079 (6.9/22.7) | | 8.3/27.1 | U (13.6/44.7) | |
| Beta-BHC | NA | -- | | -- | | U | | NA | U | | 0.0115 (8.3/27.1) | | 13.6/44.7 | 0.00272 (13.6/44.7) | |
| Gamma-BHC | NA | -- | | -- | | U | | NA | U | | 0.0031 (8.3/27.1) | | 8.3/27.1 | U (13.6/44.7) | |
| Gamma-chlordane | NA | -- | | -- | | -- | | NA | -- | | 0.0059 (6.9/22.7) | | 8.3/27.1 | U (13.6/44.7) | |
| Heptachlor epoxide | NA | -- | | -- | | U | | NA | U | | 0.0035 (8.3/27.1) | | 8.3/27.1 | U (13.6/44.7) | |

a. Verification sample results represent the 95% UCL concentration from the given decision unit(s). Values that are followed by (U) indicate that none of the data used for 95% UCL calculation were detected above the sample minimum detectable activity. Verification 95% UCL values were obtained from the 116-F-14 CVP (*Cleanup Verification Package for the 116-F-14 Retention Basin* [CVP-2001-00009]). The maximum depth of interim remedial action at 116-F-14 was 4.6 m (15 ft) bgs.

b. LFI borehole data obtained from *Limited Field Investigation Report for the 100-FR-1 Operable Unit* (DOE/RL-93-82) and HEIS. Six soil samples taken in 1993 for LFI investigation at 0.6, 1.5, 2.1, 4.0, 5.7, and 7.5 m (2, 5, 7, 13, 27.5, 18.6, and 24.5 ft) bgs (deeper end of interval reported). Total borehole depth was 8.1 m (26.6 ft) bgs.

c. Borehole data obtained from HEIS. The water table was encountered at 12.9 m (42.3 ft) bgs. Well was drilled to 15.2 m (50.0 ft) bgs.

d. Shallow zone value represents the excavation area, unless otherwise noted.

e. The maximum depth from which samples were collected is in the rewetted zone/aquifer.

f. Original radiological data presented in left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% UCL values obtained using U-flagged datasets is not decayed.

BG = background
bgs = below ground surface
CVP = cleanup verification package
HEIS = Hanford Environmental Information System
LFI = limited field investigation
NA = not applicable
UCL = upper confidence limit

1

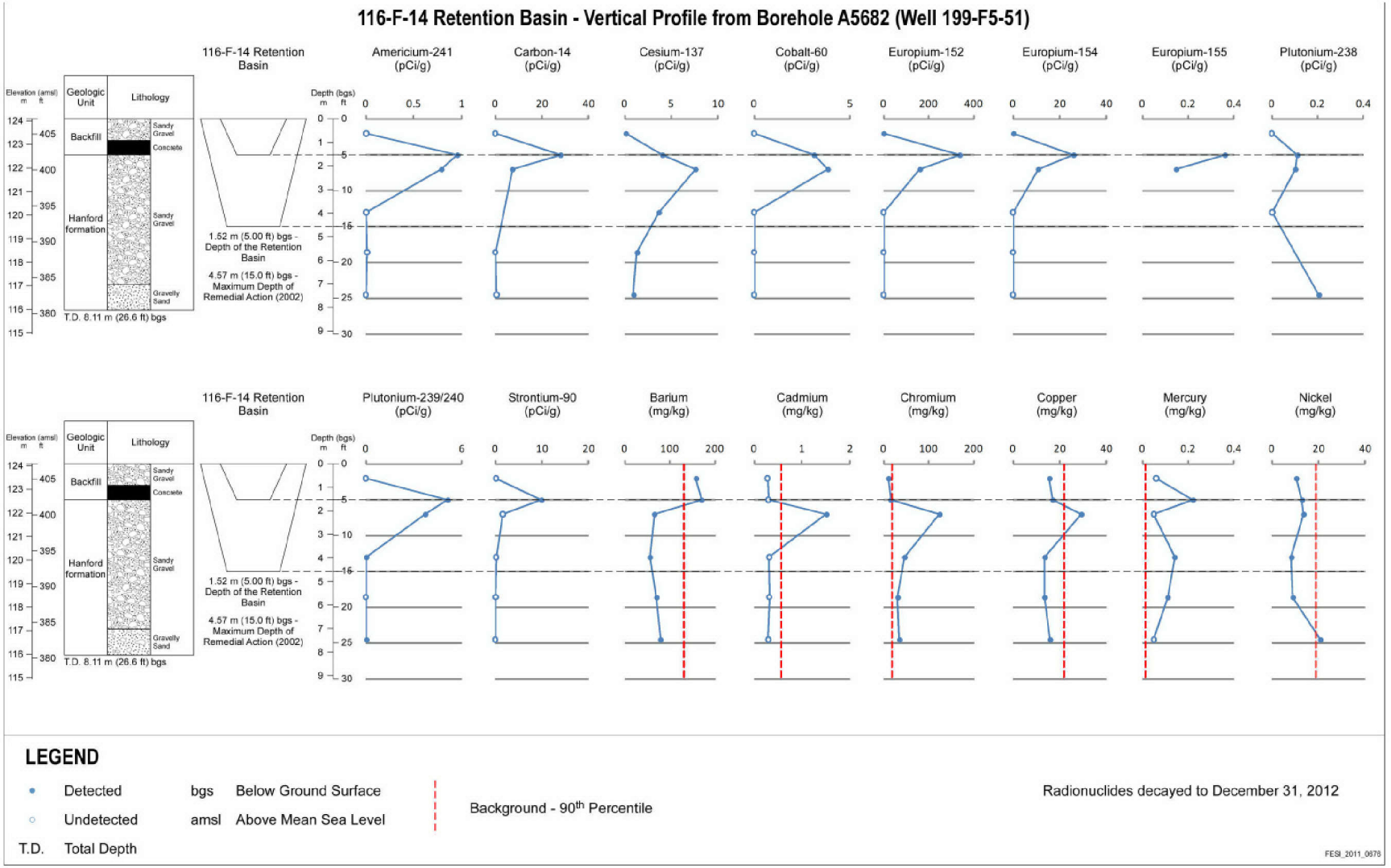


Figure 4-3. Vertical Profile from LFI Borehole 199-F5-51 through the 116-F-14 Retention Basin

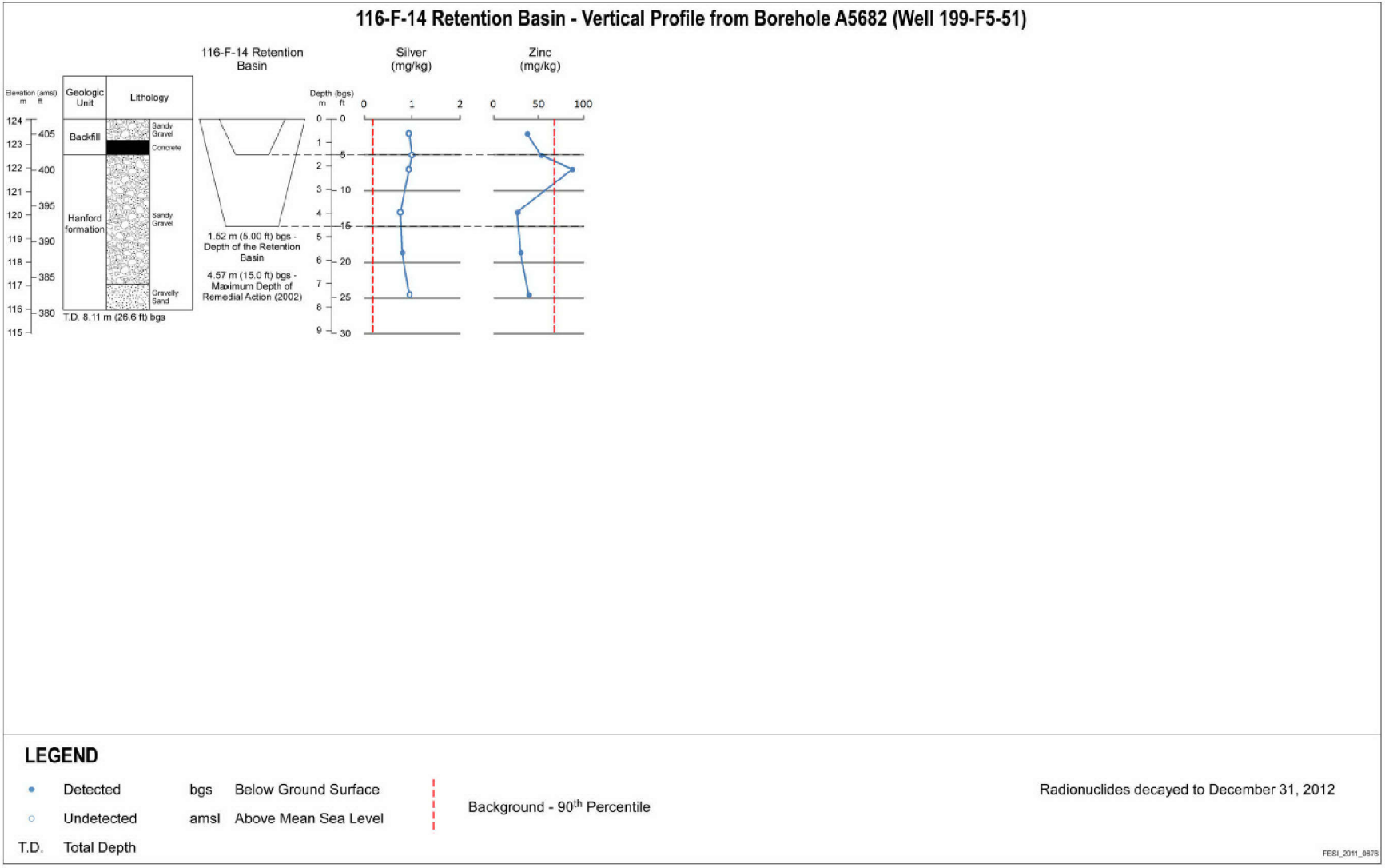


Figure 4-3. Vertical Profile from LFI Borehole 199-F5-51 through the 116-F-14 Retention Basin (cont.)

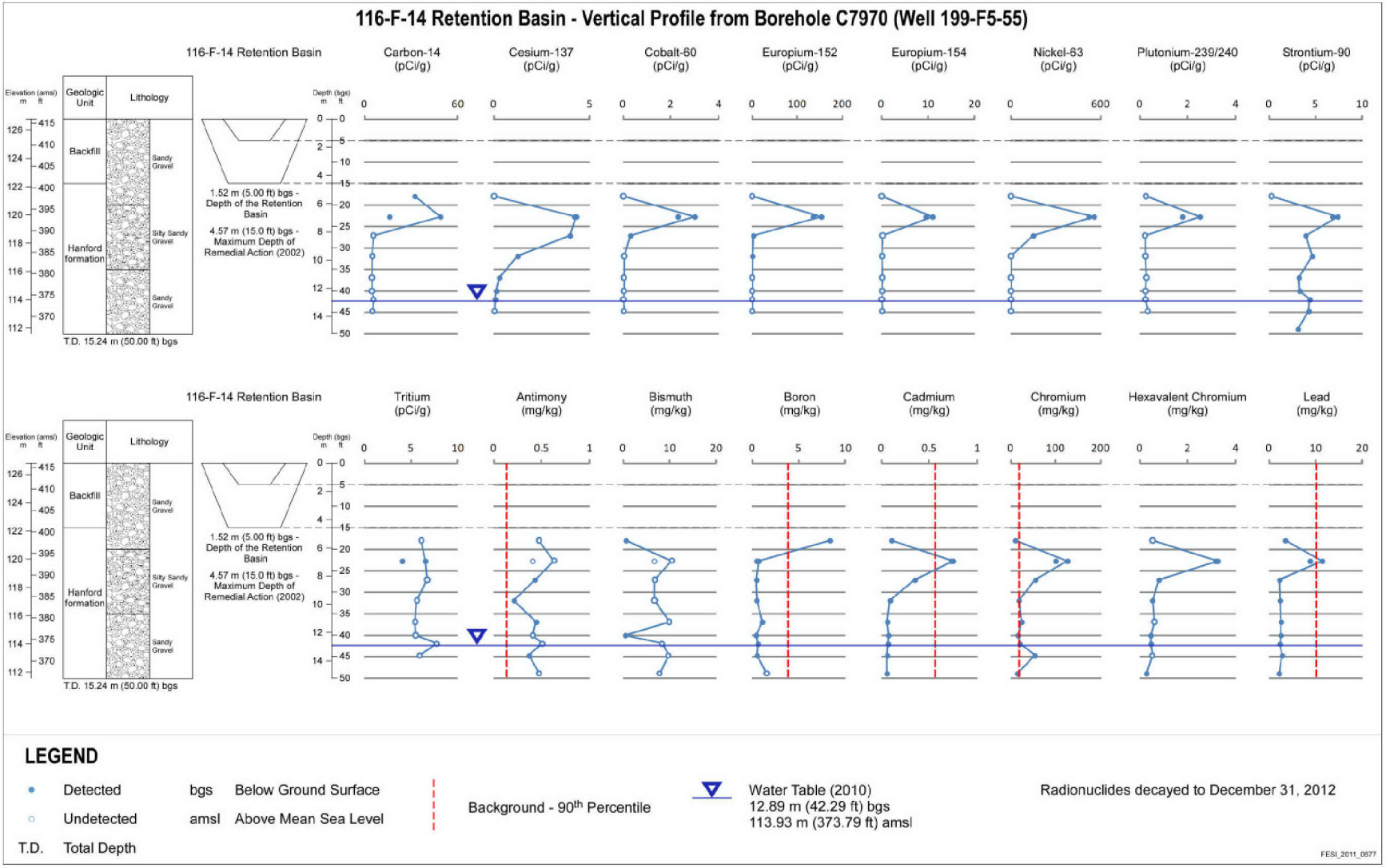


Figure 4-4. Vertical Profile from RI Borehole C7970 through the 116-F-14 Retention Basin

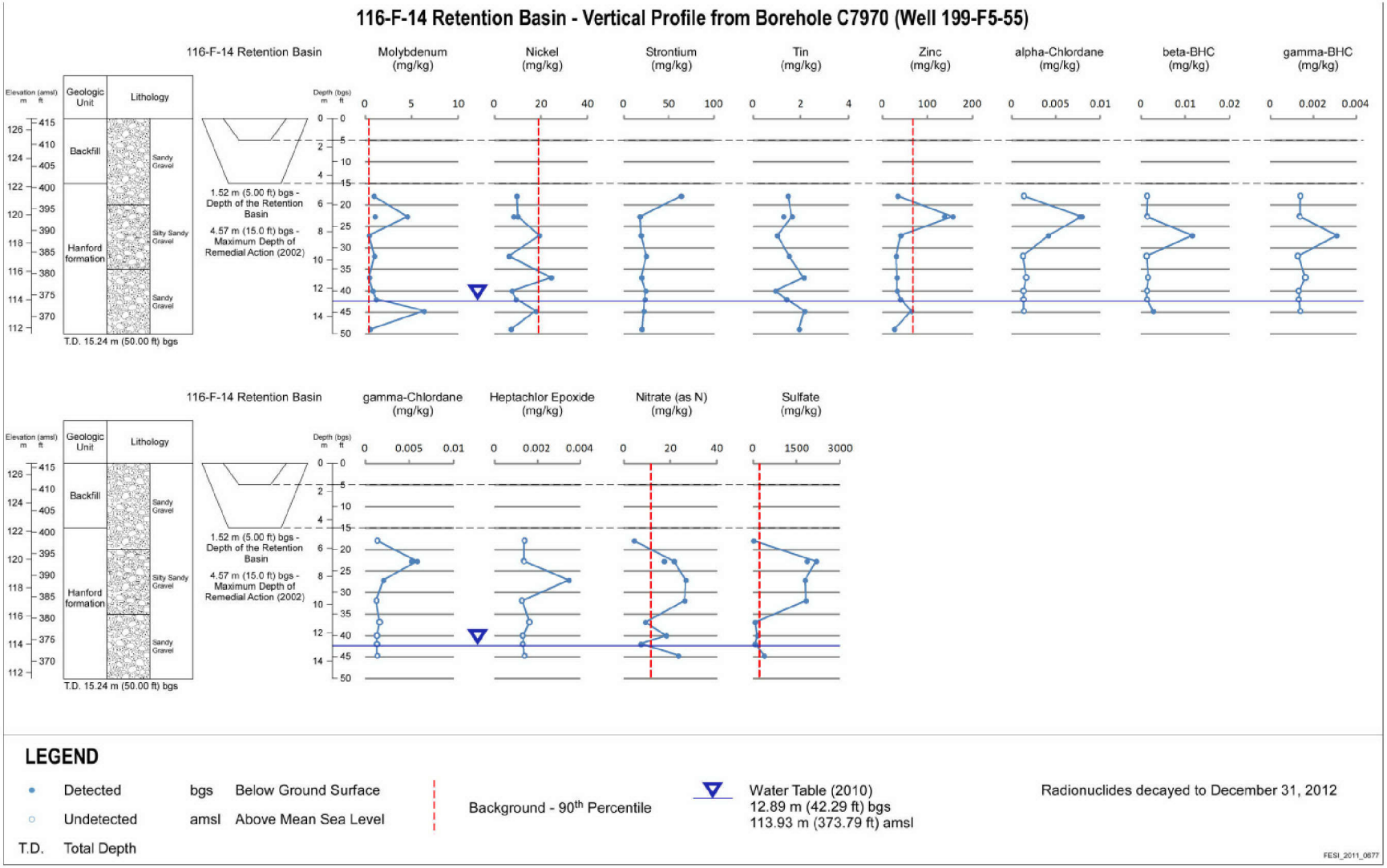


Figure 4-4. Vertical Profile from RI Borehole C7970 through the 116-F-14 Retention Basin (cont.)

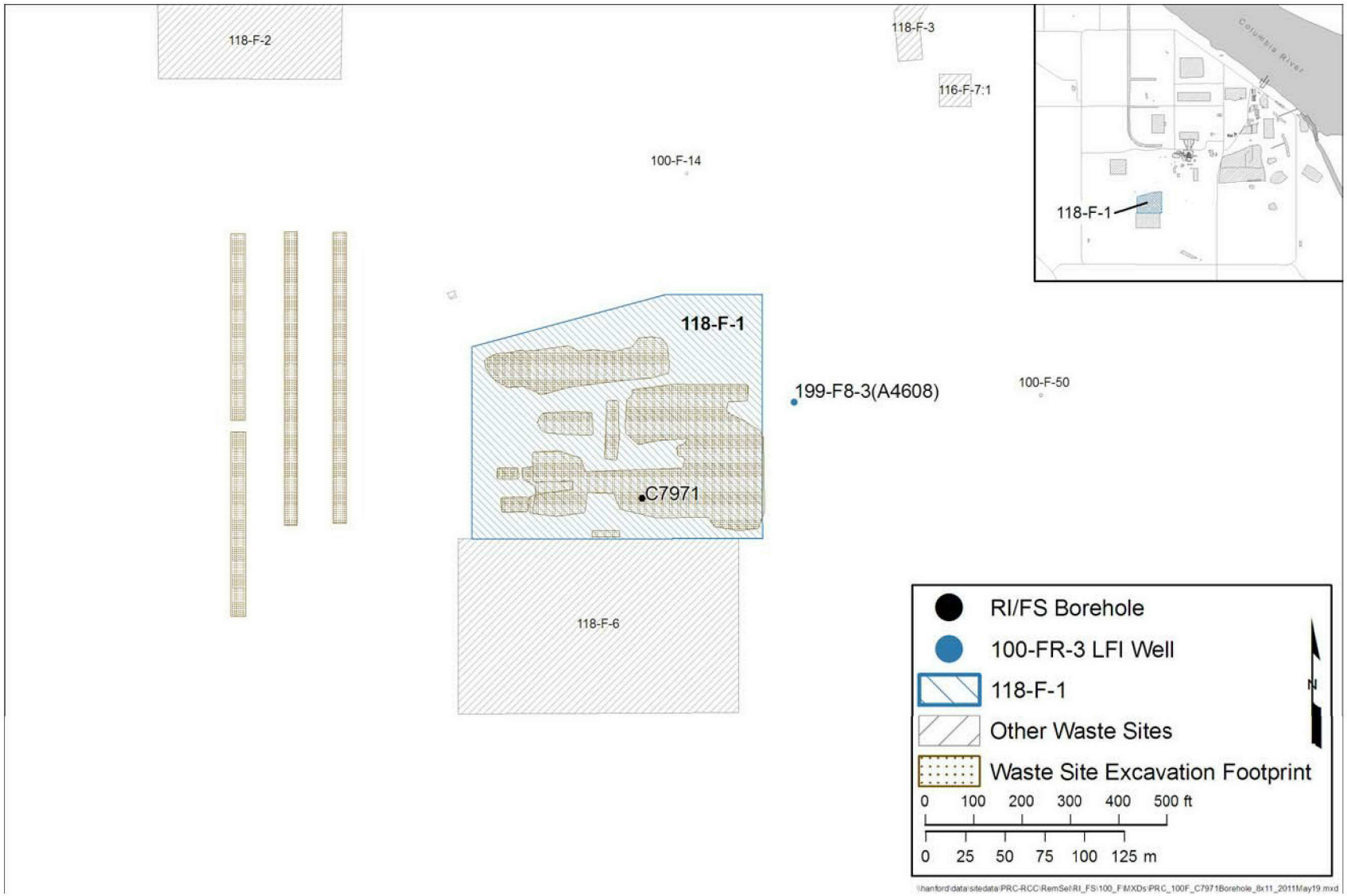


Figure 4-5. 118-F-1 Burial Ground Borehole Location and Excavated Footprint

Table 4-4. 118-F-1 Burial Ground—Summary of Soil Data

| Analyte | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] | | RI Borehole C7971[b] | | | | |
| | | Shallow Zone[c] | | Maximum Result with Corresponding Depth (ft bgs) | | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (9.6 m/31.5 ft bgs, unless otherwise noted)[d] | |
| | | Original | Decayed | Original | Decayed | | Original | Decayed |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[e]** | | | | | | | | |
| Americium-241 | NA | 0.23[f] | 0.23 | U | NA | NA | U | NA |
| Cesium-137 | NA | 0.45[g] | 0.39 | U | NA | NA | U | NA |
| Cobalt-60 | NA | 0.074[g] | 0.034 | U | NA | NA | U | NA |
| Europium-152 | NA | 0.14[g] | 0.10 | U | NA | NA | U | NA |
| Nickel-63 | NA | 4.4[g] | 4.2 | U | NA | NA | U | NA |
| Plutonium-239/240 | NA | 0.11 | 0.11 | U | NA | NA | U | NA |
| Silver-108m | NA | 0.017 | 0.017 | U | NA | NA | U | NA |
| Strontium-90 | NA | 0.38 | 0.33 | U | NA | NA | U | NA |
| **Nonradionuclides (mg/kg)** | | | | | | | | |
| Arsenic | 6.47 | -- | | 7.06 (9.6/31.5) | | 9.6/31.5 | 7.06 | |
| Chromium | 18.5 | -- | | 66.2[h] (6.0/19.8) | | 9.6/31.5 | 23.5 | |
| Lead | 10.2 | 18[g] | | 12.6 (9.6/31.5) | | 9.6/31.5 | 12.6 | |
| Lithium | 13.3 | -- | | 17.8 (9.6/31.5) | | 9.6/31.5 | 17.8 | |
| Mercury | 0.0131 | 0.45 | | 0.015 (8.7/28.5) | | 8.7/28.5 | 0.015 (8.7/28.5) | |
| Molybdenum | 0.470 | -- | | 1.11 (6.8/22.2) | | 8.7/28.5 | 0.244 (<BG) | |
| Nickel | 19.1 | -- | | 36.1[h] (6.0/19.8) | | 9.6/31.5 | 20.5 | |
| Nitrate (as N) | 11.7 | -- | | 18.7 (8.7/28.5) | | 8.7/28.5 | 18.7 (8.7/28.5) | |
| Strontium | NA | -- | | 67.8 (9.6/31.5) | | 9.6/31.5 | 67.8 | |
| Tin | NA | -- | | 2.63 (9.6/31.5) | | 9.6/31.5 | 2.63 | |
| Styrene | NA | -- | | 0.0013 (6.0/19.8) | | 6.0/19.8 | U (8.7/28.5) | |

Table 4-4. 118-F-1 Burial Ground—Summary of Soil Data

| Analyte | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] | | RI Borehole C7971[b] | | | | |
| | | Shallow Zone[c] | | Maximum Result with Corresponding Depth (ft bgs) | | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (9.6 m/31.5 ft bgs, unless otherwise noted)[d] | |
| | | Original | Decayed | Original | Decayed | | Original | Decayed |

a. Verification sample results represent the maximum 95% UCL concentration from the given decision unit(s). Values that are followed by (U) indicate that none of the data used for 95% UCL calculation were detected above the sample minimum detectable activity. Verification 95% UCL values were obtained from the 100-F/IU STOMP PRG Determination Calculation (*Cleanup Verification Package for the 118-F-1 Burial Ground* [CVP-2007-00001]). The maximum depth of interim remedial action at 118-F-1 was 5.5 m (18 ft) bgs.

b. Borehole data obtained from HEIS, the water table was encou+ntered at 8.0 m (26.2 ft) bgs. Borehole was drilled to 10.2 m (33.5 ft) bgs.

c. Shallow zone value represents the excavation area unless otherwise noted.

d. The maximum depth from which samples were collected is in the rewetted zone/aquifer.

e. Original radiological data presented in left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% UCL values obtained using U-flagged datasets is not decayed.

f. Shallow zone closeout value is from overburden.

g. Shallow zone closeout value is from waste sorting trench.

h. Results of chromium and nickel in B28VL9 collected at 6.0 m (19.8 ft) bgs indicate potential contamination from sampling artifacts. The maximum values of chromium and nickel from the borehole excluding this sample are 23.5 and 20.5 mg/kg, respectively, at 9.6 m (31.5 ft) bgs. Concentrations of chromium and nickel are 9.06 and 7.41 mg/kg, respectively, in the sample interval below B28VL9 collected at 6.8 m (22.2 ft) bgs. See anomalous metals discussion in Section 4.2.7.

BG = background
bgs = below ground surface
HEIS = Hanford Environmental Information System
NA = not applicable
PRG = preliminary remediation goal
RI = remedial investigation
STOMP = Subsurface Transport Over Multiple Phases
UCL = upper confidence limit

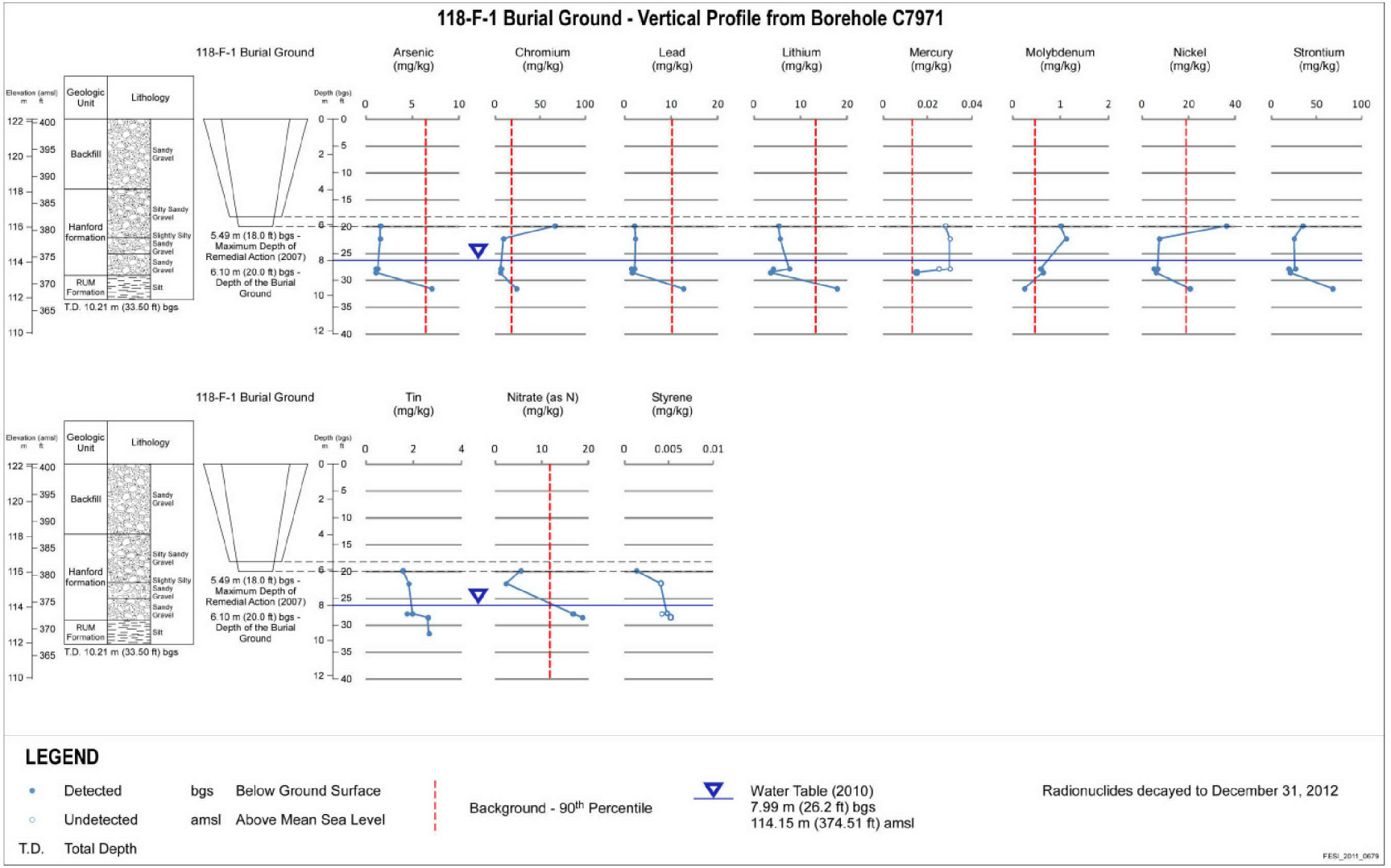


Figure 4-6. Vertical Profile from RI Borehole C7971 through 118-F-1 Burial Ground

### 4.2.3 118-F-8 Reactor Fuel Storage Basin

The 118-F-8 Reactor Fuel Storage Basin was the underwater collection, storage, and transfer facility for irradiated fuel elements discharged from the reactor. Remedial action, completed in 2003, consisted of the removal of the building structures, debris, and underlying contaminated soil to a maximum depth of 6.4 m (21 ft) bgs. Figure 4-7 shows the location of the borehole and the excavated footprint of the 118-F-8 waste site. The COCs at the time included americium-241, barium-133, carbon-14, cesium-137, cobalt-60, europium-152, europium-154, europium-155, nickel-63, plutonium-238, plutonium-239/240, strontium-90, uranium-234, uranium-235, uranium-238, Cr(VI), barium, lead, mercury, and PCBs (*Cleanup Verification Package for the 118-F-8:1, 105-F Reactor Below-Grade Structures and Underlying Soils; the 118-F-8:3, 105-F Fuel Storage Basin Underlying Soils; and the 100-F-10 French Drain* [CVP-2003-00017]). The site was determined to meet interim closure requirements based on evaluation of the analytical results for cleanup verification samples, summarized in Table 4-5.

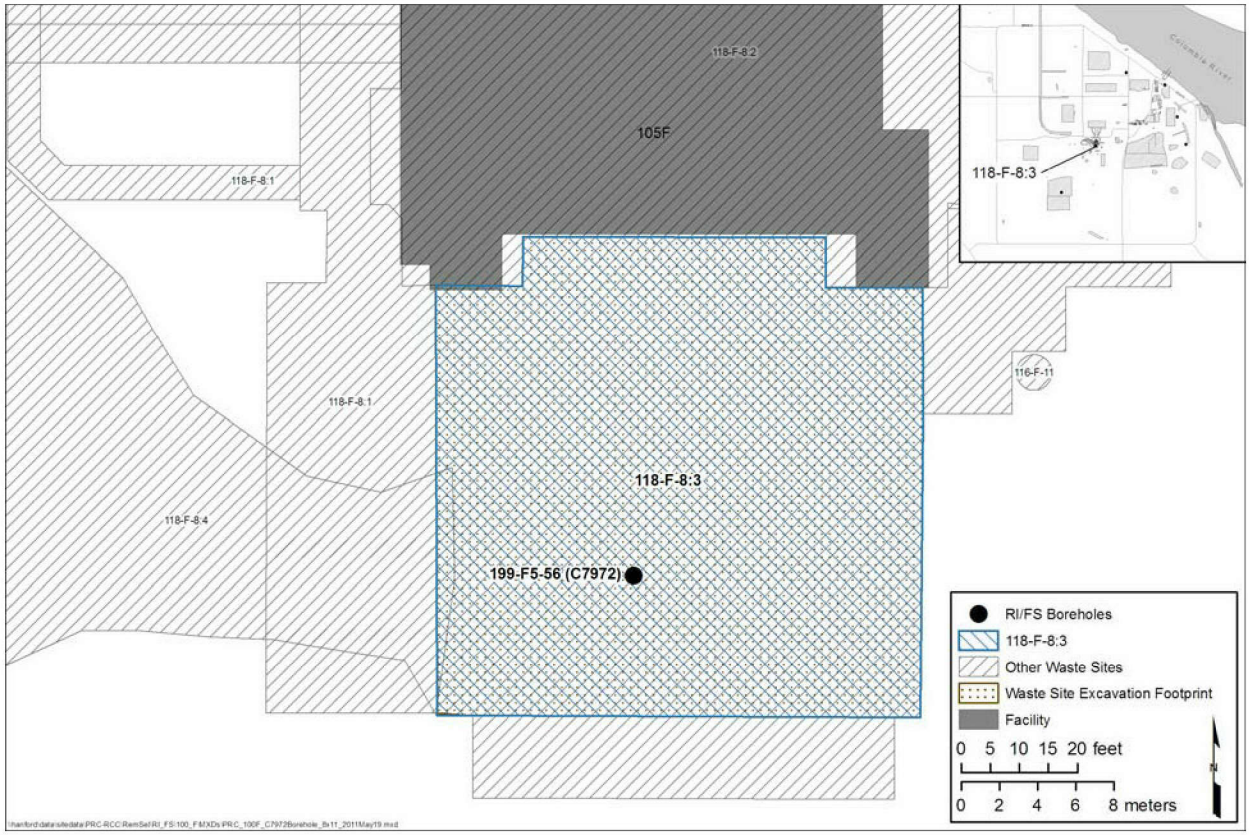


Figure 4-7. 118-F-8 Reactor Fuel Storage Basin Borehole Location and Excavated Footprint

The 118-F-8 Fuel Storage Basin was selected for additional characterization to support the refinement of the CSM for contaminant distribution beneath and around reactor structures. In addition, the fuel storage basin is being characterized because residual contamination may extend beyond the depth of remedial action. Data for analytes exceeding background levels are presented in Table 4-5. These data are based on soil samples collected during the cleanup verification and RI. Vertical profiles for the analytes exceeding background are shown on Figure 4-8.

Table 4-5. 118-F-8 Reactor Fuel Storage Basin—Summary of Soil Data

| Analyte | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] | | RI Borehole C7972 (Well 199-F5-56)[b] | | | | |
| | | Deep Zone[c] | | Maximum Result with Corresponding Depth (ft bgs) | | Extent of Detection Above BG (ft bgs) | Result at Maximum Sample Depth (15.5 m/50.9 ft bgs, unless otherwise noted)[d] | |
| | | Original | Decayed | Original | Decayed | | Original | Decayed |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[e]** | | | | | | | | |
| Americium-241 | NA | 1.93 | 1.90 | U | NA | NA | U | NA |
| Carbon-14 | NA | 33.9 | 33.9 | U | NA | NA | U | NA |
| Cesium-137 | NA | 151 | 120 | 2.11 (8.2/26.8) | 2.02 | 8.2/26.8 | U | NA |
| Cobalt-60 | NA | 10.4 | 2.8 | 0.039 (8.2/26.8) | 0.03 | 8.2/26.8 | U | NA |
| Europium-152 | NA | 108 | 64.6 | 0.758 (8.2/26.8) | 0.68 | 8.2/26.8 | U | NA |
| Europium-154 | NA | 13.7 | 6.1 | 0.099 (8.2/26.8) | 0.084 | 8.2/26.8 | U | NA |
| Nickel-63 | NA | 362 | 338 | 3.38 (7.2/23.6) | 3.33 | 8.2/26.8 | U | NA |
| Plutonium-238 | NA | 0.275 | 0.254 | U | NA | NA | U | NA |
| Plutonium-239/240 | NA | 7.27 | 7.27 | U | NA | NA | U | NA |
| Strontium-90 | NA | 87.5 | 68.8 | 1.62 (8.2/26.8) | 1.54 | 13.7/45.0 | U | NA |
| Tritium | NA | 0.408 | 0.233 | U | NA | NA | U | NA |
| **Nonradionuclides (mg/kg)** | | | | | | | | |
| Antimony | 0.130 | -- | | 0.668 (13.7/45.0) | | 15.5/50.9 | 0.474 | |
| Bismuth | NA | -- | | 0.48 (13.7/45.0) | | 13.7/45.0 | U | |
| Chromium | 18.5 | -- | | 36.5 (9.6/31.4) | | 11.0/36.1 | 14.4 (<BG) | |
| Cr(VI) | NA | 1.4 | | U | | NA | U | |
| Mercury | 0.0131 | 0.40 | | U | | NA | U | |
| Molybdenum | 0.470 | -- | | 2.69 (11.0/36.1) | | 13.7/45.0 | 0.356 (<BG) | |
| Nickel | 19.1 | -- | | 20.3 (9.6/31.4) | | 9.6/31.4 | 11.5 (<BG) | |
| Nitrate | 52.3 | -- | | 86.4 (7.2/23.6) | | 13.7/45.0 | 15.1 (<BG) – (13.7/45.0) | |

Table 4-5. 118-F-8 Reactor Fuel Storage Basin—Summary of Soil Data

| Analyte | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] | | RI Borehole C7972 (Well 199-F5-56)[b] | | | | |
| | | Deep Zone[c] | | Maximum Result with Corresponding Depth (ft bgs) | | Extent of Detection Above BG (ft bgs) | Result at Maximum Sample Depth (15.5 m/50.9 ft bgs, unless otherwise noted)[d] | |
| | | Original | Decayed | Original | Decayed | | Original | Decayed |
| Strontium | NA | -- | | 34.8 (9.6/31.4) | | 15.5/50.9 | 24.7 | |
| Sulfate | 237 | -- | | 2600 (13.7/45.0) | | 13.7/45.0 | 2600- (13.7/45.0) | |
| Thallium | 0.185 | -- | | 0.265 (13.7/45.0) | | 13.7/45.0 | U | |
| Tin | NA | -- | | 2.11 (7.2/23.6) | | 15.5/50.9 | 1.26 | |
| Alpha-BHC | NA | -- | | 0.0016 (12.8/42.0) | | 12.8/42.0 | U (13.7/45.0) | |
| Aroclor-1254 | NA | 0.38 | | U | | NA | U (13.7/45.0) | |

a. Verification sample results represent the maximum 95% UCL concentration from the given decision unit(s). Values that are followed by (U) indicate that none of the data used for 95% UCL calculation were detected above the sample minimum detectable activity. Verification 95% UCL values were obtained from *Cleanup Verification Package for the 118-F-8:1, 105-F Reactor Below-Grade Structures and Underlying Soils; the 118-F-8:3, 105-F Fuel Storage Basin Underlying Soils; and the 100-F-10 French Drain* (CVP-2003-00017). The maximum depth of interim remedial action at 118-F-8:3 was 6.4 m (21 ft) bgs.

b. Borehole data obtained from HEIS. The water table was encountered at 13.2 m (43.45 ft) bgs. Borehole was drilled to 15.5 m (50.9 ft) bgs.

c. Deep zone sample results represent soil below the former fuel storage basin.

d. The maximum depth from which samples were collected is in the rewetted zone/aquifer.

e. Original radiological data presented in left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% UCL values obtained using U-flagged datasets is not decayed.

BG = background

bgs = below ground surface

HEIS = Hanford Environmental Information System

RI = remedial investigation

UCL = upper confidence limit

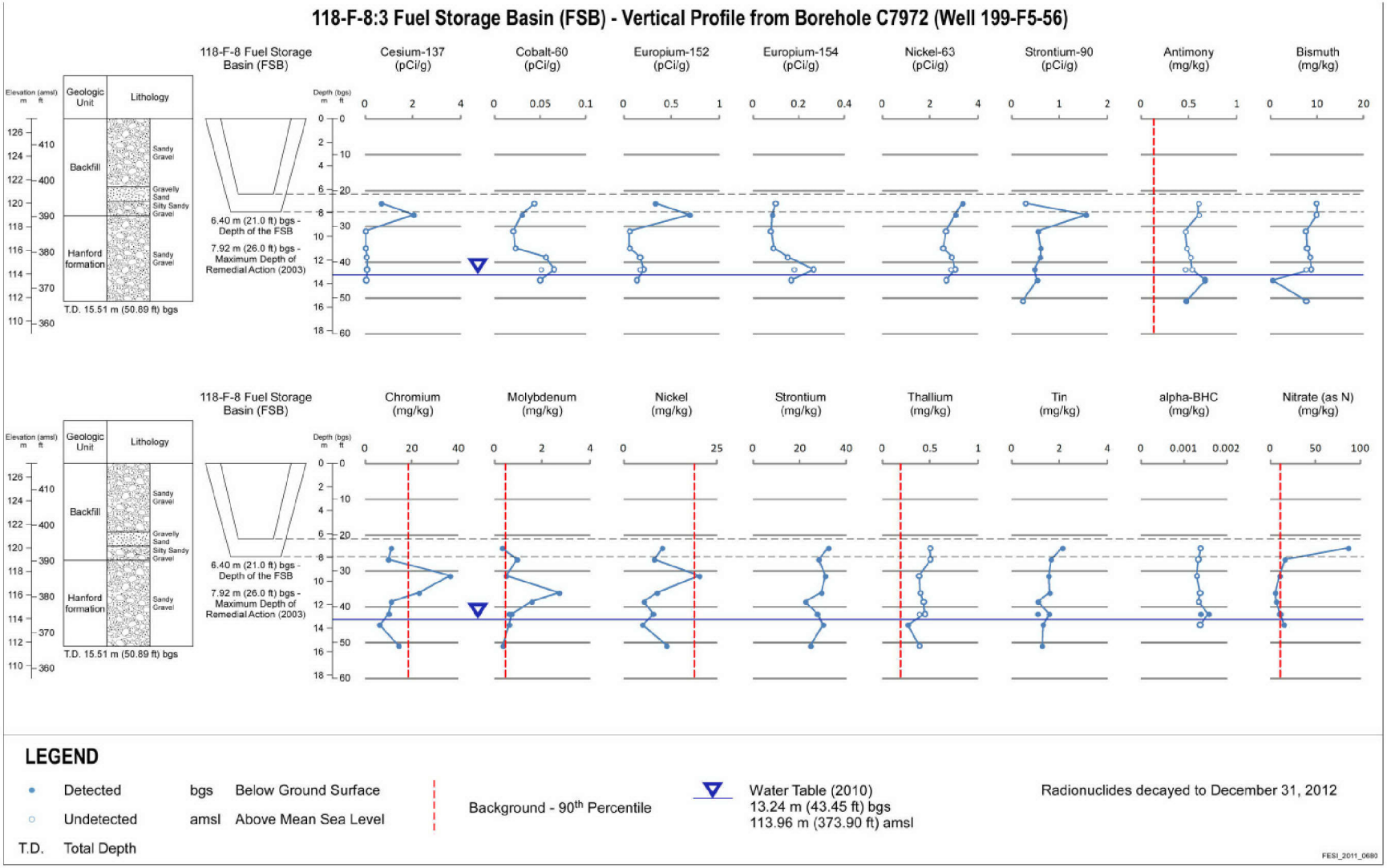


Figure 4-8. Vertical Profile from RI Borehole C7972 through 118-F-8 Reactor Fuel Storage Basin

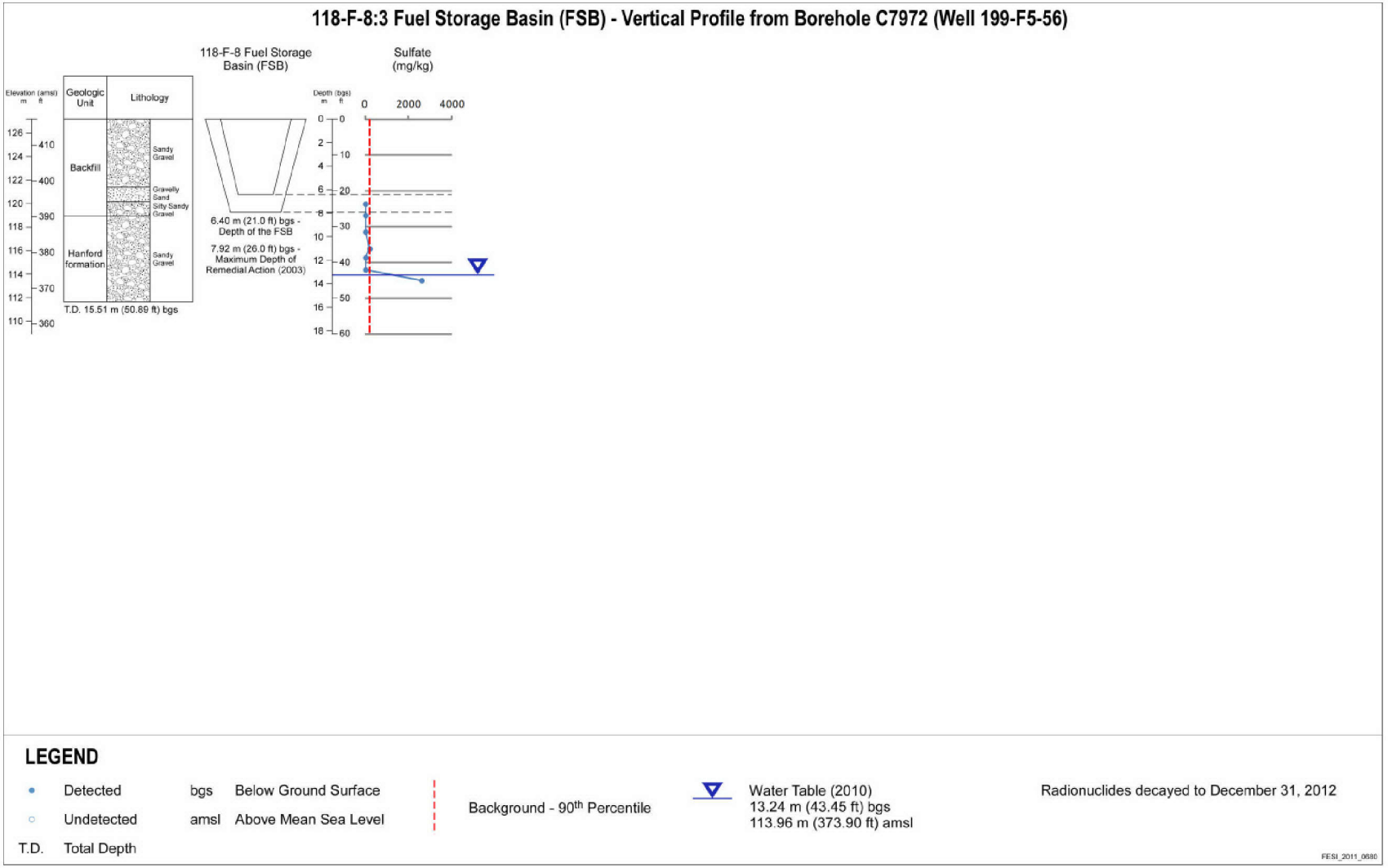


Figure 4-8. Vertical Profile from RI Borehole C7972 through 118-F-8 Reactor Fuel Storage Basin (cont.)

Seventeen constituents were detected above background in RI soil samples associated with the 118-F-8 Fuel Storage Basin (Table 4-5). Six radionuclides were detected in soil samples; however, five of the six radionuclides were not detected deeper than 8.2 m (26.8 ft) bgs. Only strontium-90 was present across the vadose zone to the water table (13.2 m [43.45 ft] bgs). The maximum chromium and nickel concentrations (36.5 mg/kg and 20.3 mg/kg, respectively) were detected at 9.6 m (31.4 ft) bgs. With the exception of sulfate (maximum concentration 2,600 mg/kg at 13.7 m [45 ft] bgs), nonradionuclide concentrations decreased with depth across the vadose zone. Cr(VI) was not detected in any soil samples collected as part of the RI.

### 4.2.4 100-F-59 Riparian Area Contamination Originating from 128-F-2 Burn Pit

The 100-F-59 waste site, which is a riparian area contamination originating from 128-F-2, includes the section of the former 128-F-2 Burn Pit that is below the Columbia River OHWM and a portion of the adjoining slough. Figure 4-9 is a historical photo showing the former burn pit during high water flow with the downstream slough inundated by the river. Figure 4-10 shows the upland portion of the remediated 128-F-2 Burn Pit area site and the general location of 100-F-59, with the shoreline area that is below the OHWM inundated by the river.

Figure 4-9. Historical Aerial Photograph Showing 128-F-2 Burn Pit Area and Slough

Figure 4-10. Aerial Photograph Identifying General Locations of 100-F-59 and 128-F-2 Waste Sites

Initial remediation of the 128-F-2 Burn Pit was performed from August through October 2005. Additional excavation was conducted in February 2007 to remove shoreline contamination extended below the OHWM. Final sampling results indicated the riparian area below the OHWM did not meet soil RAGs for multiple metals. The elevated metals were generally located within the southern (downstream) half of the excavation. To determine the nature and extent of contamination, additional characterization sampling of riparian areas upriver, downriver, and surrounding the excavation was performed in January 2008. Three sampling areas were identified, as shown on Figure 4-11. Within each of the three sampling areas, one location was selected for collection of samples at depths of 0.3, 0.6, and 0.9 m (1, 2, and 3 ft) bgs.

- The Near Waste Site area surface soil samples were collected at a distance of 2 and 10 m (7 and 33 ft) from the eastern edge of the contaminated 128-F-2 Burn Pit area at eight locations. Two additional surface samples were collected upriver of the waste site to provide localized soil concentrations.

- The North Shore area surface soil sample locations were in areas of rapid elevation changes and vegetation zones along two transects located 60 and 120 m (195 to 395 ft) from the southeast boundary of the 128-F-2 Burn Pit area below the OHWM. The surface samples were located at 0.5 m (1.6 ft) elevation increments with a total of eight elevations sampled.

- The Slough Area surface soil sample locations were located within the downstream slough, with samples collected at every 0.5 m (1.6 ft) elevation change over a distance of approximately 450 m (1475 ft). Three of the seven samples were collected in the area of lowest elevation, which extends approximately 170 m (385 ft) along the slough.

Figure 4-11. Aerial Photograph Identifying General Sampling Area Locations Outside of the 128-F-2 Burn Pit Waste Site

Table 4-6 presents the maximum results from the portion of 128-F-2 Burn Pit area below the OHWM and the three sampling areas. Characterization sample results showed that most metal concentrations decreased outside of the contaminated 128-F-2 Burn Pit area. Elevated metal results were primarily located in areas immediately downstream from, and adjacent to, the contaminated area. Metal concentrations in the North Shore samples were generally lower than that measured in the other areas. The contaminated section of 128-F-2 Burn Pit area below the OHWM was administratively separated from the original site and combined with an adjoining portion of the slough area to create the 100-F-59 waste site. Samples from the upland area of 128-F-2 Burn Pit area met soil RAGs and the upland portion of the 128-F-2 Burn Pit area site were reclassified as interim closed.

Table 4-6. Summary of 100-F-59 Waste Site and Surrounding Sediment Data

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | | Maximum Result with Corresponding Depth in Each Sediment Sample Area[a] | | | |
| | Soil Background (mg/kg) | Former 128-F-2 Burn Pit Area Below OHWM | Near Waste Site | Slough Area | North Shore |
| **Radionuclides (pCi/g)** | | | | | |
| Cesium-137 | 1.1 | U | -- | 0.207 (<BG) | -- |
| **Nonradionuclides (mg/kg)** | | | | | |
| Antimony | 0.130 | 3.8 | 1.4 | 2.4 | 1.3 |
| Arsenic | 6.5 | 37.1 | 13.7 (0.6 m/2 ft) | 7.5 | 10.2 [b] |
| Barium | 132 | 786 | 207 (0.6 m/2 ft) | 176 (0.9 m/3 ft) | 102 (0.9 m/3 ft) (<BG) |
| Boron | 3.89 | 0.98 (<BG) | 3.1 (<BG) | 3.3 (<BG) | 4.0 |
| Cadmium | 0.563 | 2.5 | 1.7 | 0.72 | 1.2 |
| Chromium | 18.5 | 671 | 335 | 371 | 23.1 (0.9 m/3 ft) |
| Cobalt | 15.7 | 33.9 | 12.9 (0.6 m/2 ft) (<BG) | 10.7 (0.6 m/2 ft) (<BG) | 10.2 (0.9 m/3 ft) (<BG) |
| Copper | 22 | 68.2 | 178 | 31.5 | 43.5 |
| Cr(VI) | NA | 12.4 | 1.8 (0.9 m/3 ft) | 4.3 | 1.3 |
| Lead | 10.2 | 160 | 109 | 54.4 | 99.4 |
| Manganese | 512 | 5740 | 797 (0.6 m/2 ft) | 290 (<BG) | 290 (<BG) |
| Mercury | 0.33 | 0.06 | 0.11 | 0.12 | 0.13 |
| Molybdenum | 0.470 | 7.4 | 1.6 (0.6 m/2 ft) | 3.8 | 1.5 |
| Nickel | 19.1 | 92.9 | 39.2 (0.6 m/2 ft) | 24.5 | 16.2 (0.9 m/3 ft) (<BG) |
| Silver | 0.167 | U | 2.3 | 0.31 | 0.44 |
| Vanadium | 85.1 | 124 | 65.7 (0.6 m/2 ft) (<BG) | 112 | 89.9 (0.9 m/3 ft) |

Table 4-6. Summary of 100-F-59 Waste Site and Surrounding Sediment Data

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | | Maximum Result with Corresponding Depth in Each Sediment Sample Area[a] | | | |
| | Soil Background (mg/kg) | Former 128-F-2 Burn Pit Area Below OHWM | Near Waste Site | Slough Area | North Shore |
| Zinc | 67.8 | 806 | 401 | 212 | 396 |
| Benzo(a)pyrene | NA | 0.019 | -- | -- | -- |
| Benzo(b)fluoranthene | NA | 0.021 | -- | -- | -- |
| Benzo(ghi)perylene | NA | 0.022 | -- | -- | -- |
| Benzo(k)fluoranthene | NA | 0.020 | -- | -- | -- |
| Chrysene | NA | 0.018 | -- | -- | -- |
| Indeno(1,2,3-cd)pyrene | NA | 0.019 | -- | -- | -- |
| Aroclor-1260 | NA | 0.40 | -- | -- | -- |
| Aldrin | NA | 0.00072 | U | -- | -- |
| Alpha-BHC | NA | 0.0018 | U | -- | -- |
| beta-1,2,3,4,5,6-Hexachlorocyclohexane | NA | 0.00072 | U | -- | -- |
| Delta-BHC | NA | 0.0009 | U | -- | -- |
| 4,4'-DDD | NA | 0.0053 | 0.0025 | -- | -- |
| 4,4'-DDE | NA | 0.00040 | 0.019 | -- | -- |
| 4,4'-DDT | NA | 0.0087 | U | -- | -- |
| Dieldrin | NA | 0.0026 | U | -- | -- |
| Endosulfan I | NA | 0.00047 | U | -- | -- |
| Endosulfan II | NA | 0.0092 | U | -- | -- |
| Endosulfan sulfate | NA | 0.0089 | U | -- | -- |
| Endrin | NA | 0.00087 | U | -- | -- |
| Endrin aldehyde | NA | 0.0085 | U | -- | -- |
| gamma-BHC (Lindane) | NA | 0.0007 | U | -- | -- |
| gamma-Chlordane | NA | 0.0024 | U | -- | -- |
| Methoxychlor | NA | 0.0089 | U | -- | -- |

Table 4-6. Summary of 100-F-59 Waste Site and Surrounding Sediment Data

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | | Maximum Result with Corresponding Depth in Each Sediment Sample Area[a] | | | |
| | Soil Background (mg/kg) | Former 128-F-2 Burn Pit Area Below OHWM | Near Waste Site | Slough Area | North Shore |

a. All samples were collected at the surface, unless otherwise noted.

b. The maximum arsenic result was measured in both the 0 and 0.3 m (0 and 1 ft) samples at the same location.

-- = no data
BG = background
NA = not applicable
OHWM = ordinary high water mark

### 4.2.5 Soil Samples from Monitoring Wells

Soil samples were collected from three wells to evaluate contaminant fate and transport across the vadose zone and in the unconfined aquifer (Figure 3-1). These groundwater wells are not associated with a waste site, but rather are located at specific areas to address data needs 4, 6, and 7 (Table 2-1). 199-F5-52 (C7790) was completed to define the extent of Cr(VI) in groundwater, 199-F5-54 (C7792) was completed to define the extent of strontium-90 in groundwater, and 199-F5-53 (C7791) was completed to collect geochemical and hydrogeologic data to evaluate near-shore area groundwater contaminant fate and transport. Soil samples were collected from 4.6 m (15 ft) above the water table to 1.5 m (5 ft) below the water table. Low levels of several metals, including Cr(VI), were detected in soil samples from Well 199-F5-52 (Table 4-7 and Figure 4-12). In Well 199-F5-53, soil samples collected near the water table had higher concentrations of cesium-137, strontium-90, chromium, and molybdenum (Table 4-8 and Figure 4-13). No Cr(VI) was detected in the soil at Well 199-F5-53. Few results from Well 199-F5-54 exceeded background concentrations in soil (Table 4-9 and Figure 4-14).

Table 4-7. Well 199-F5-52 (C7790) Summary of Soil Data

| Analyte | Concentration and Distribution[a] | | | |
|---|---|---|---|---|
| | Background | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (15.8/51.8 ft bgs)[b] |
| **Nonradionuclides (mg/kg)** | | | | |
| Antimony | 0.130 | 0.429 (8.2/27.0) | 11.9/39.0 | U |
| Chromium | 18.5 | 96.6 (9.5/31.3) [c] | 13.7/44.9 | 13.3 (<BG) |
| Cr(VI) | NA | 0.23 (15.8/51.8) | 15.8/51.8 | 0.23 |
| Molybdenum | 0.470 | 2.29 (13.0/42.6) | 15.8/51.8 | 0.617 |
| Nickel | 19.1 | 49 (9.5/31.3) [c] | 9.5/31.3 | 10.1 (<BG) |

Table 4-7. Well 199-F5-52 (C7790) Summary of Soil Data

| Analyte | Concentration and Distribution[a] | | | |
|---|---|---|---|---|
| | Background | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (15.8/51.8 ft bgs)[b] |
| Strontium | NA | 36.5 (9.5/31.3) | 15.8/51.8 | 29.7 |

a. Analytical data obtained from HEIS. The water table was encountered at 13.6 m (44.8 ft) bgs. Borehole was drilled to a total depth of 22.5 m (73.8 ft) bgs.

b. The maximum depth from which samples were collected is in the rewetted zone/aquifer.

c. Results of chromium and nickel in B26T20 collected at 9.5 m (31.3 ft) bgs indicate contamination from sampling artifacts in the samples. The maximum values of chromium and nickel from the borehole excluding this sample are 24.1 and 13.9 mg/kg, respectively, at 11.9 m (39.0 ft) bgs. Concentrations of chromium and nickel are less than background in the sample intervals above and below the B26T20 sample interval. See anomalous metals discussion in Section 4.2.7.

1

Table 4-8. Well 199-F5-53 (C7791) Summary of Soil Data

| Analyte | Concentration and Distribution[a] | | | |
|---|---|---|---|---|
| | Background | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (14.0 m/45.9 ft bgs)[b] |
| **Radionuclides (pCi/g)[c]** | | | | |
| Cesium-137 | NA | 0.351 (11.6/38.0) | 12.2/40.1 | U |
| Strontium-90 | NA | 0.751 (12.2/40.1) | 12.2/40.1 | U |
| **Nonradionuclides (mg/kg)** | | | | |
| Antimony | 0.130 | 0.206 (11.6/38.0) | 11.6/38.0 | U |
| Chromium | 18.5 | 49.2 (11.6/38.0) | 11.6/38 | 11.5 (<BG) |
| Molybdenum | 0.470 | 3.63 (11.6/38.0) | 14.0/45.9 | 0.821 |
| Strontium | NA | 34.9 (7.7/25.1) | 14.0/45.9 | 22.1 |
| Thallium | 0.185 | 0.305 (12.2/40.1) | 12.2/40.1 | U |
| Tin | NA | 2.24 (10.7/35.0) | 14.0/45.9 | 2.17 |

a. Analytical data obtained from HEIS. The water table was encountered at 11.7 m (38.5 ft) bgs. Borehole was drilled to a total depth of 35.4 (116.1 ft) bgs.

b. The maximum depth from which samples were collected is in the rewetted zone/aquifer.

c. Radionuclide analytical data not decayed.

2

Table 4-9. Well 199-F5-54 (C7792) Summary of Soil Data

| Analyte | Concentration and Distribution[a] | | | |
|---|---|---|---|---|
| | Background | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (15.1 m/49.6 ft bgs)[b] |
| **Nonradionuclides (pCi/g)[c]** | | | | |
| Strontium-90 | NA | 0.287 (11.8/38.6) | 11.8/38.6 | U |
| **Nonradionuclides (mg/kg)** | | | | |
| Antimony | 0.130 | 0.242 (12.5/41.0) | 15.1/49.6 | 0.224 |
| Chromium | 18.5 | 62.8 (12.5/41.0) | 12.5/41.0 | 10.2 (<BG) |
| Cr(VI) | NA | 0.31 (11.8/38.6) | 11.8/38.6 | U |
| Molybdenum | 0.470 | 12.1 (12.5/41.0) | 15.1/49.6 | 0.789 |
| Strontium | NA | 43.7 (7.3/24.1) | 15.1/49.6 | 16.6 |
| Tin | NA | 1.84 (12.5/41.0) | 13.2/43.3 | U |

a. Borehole data obtained from HEIS. The water table was encountered at 13.2 m (43.3 ft) bgs. Borehole was drilled to a total depth of 23.6 m (77.4 ft) bgs.

b. The maximum depth from which samples were collected is in the rewetted zone/aquifer.

c. Radionuclide analytical data not decayed.

### 4.2.6 Summary of Limited Field Investigation Data

Collection of vadose zone characterization data began in the early 1990s within 100-F. Many of these data have been discussed in the previous sections. For completeness, this section summarizes LFI data that were not specifically linked to the data gaps and waste site efforts identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4).

The data described below were collected in support of the characterization of specific waste sites either from test pits excavated within the footprint of the waste site, or from boreholes drilled through the waste site with vadose zone samples collected at specified depths as described in the 100-FR-1 LFI (DOE/RL-93-82). The 100-FR-3 LFI (DOE/RL-93-83) also provided information on the lateral and vertical depth of contamination. A few of the boreholes were drilled along the periphery of 100-F, thereby providing data about the possible extent of contamination around 100-F. For those test pits and boreholes that were sampled within the boundary of a waste site, the data presented herein represent analytes that remain in place based on the depth of remediation of the listed waste site. A review of the data indicates that analytes were detected above background concentrations at the following locations:

- 116-F-1: Lewis Canal – 116-F-1B Test Pit
- 116-F-1: Lewis Canal – 116-F-1C Test Pit
- 116-F-3: 105-F Storage Basin Trench – Test Pit
- 116-F-9: Animal Waste Leaching Trench – 116-F-9D Test Pit

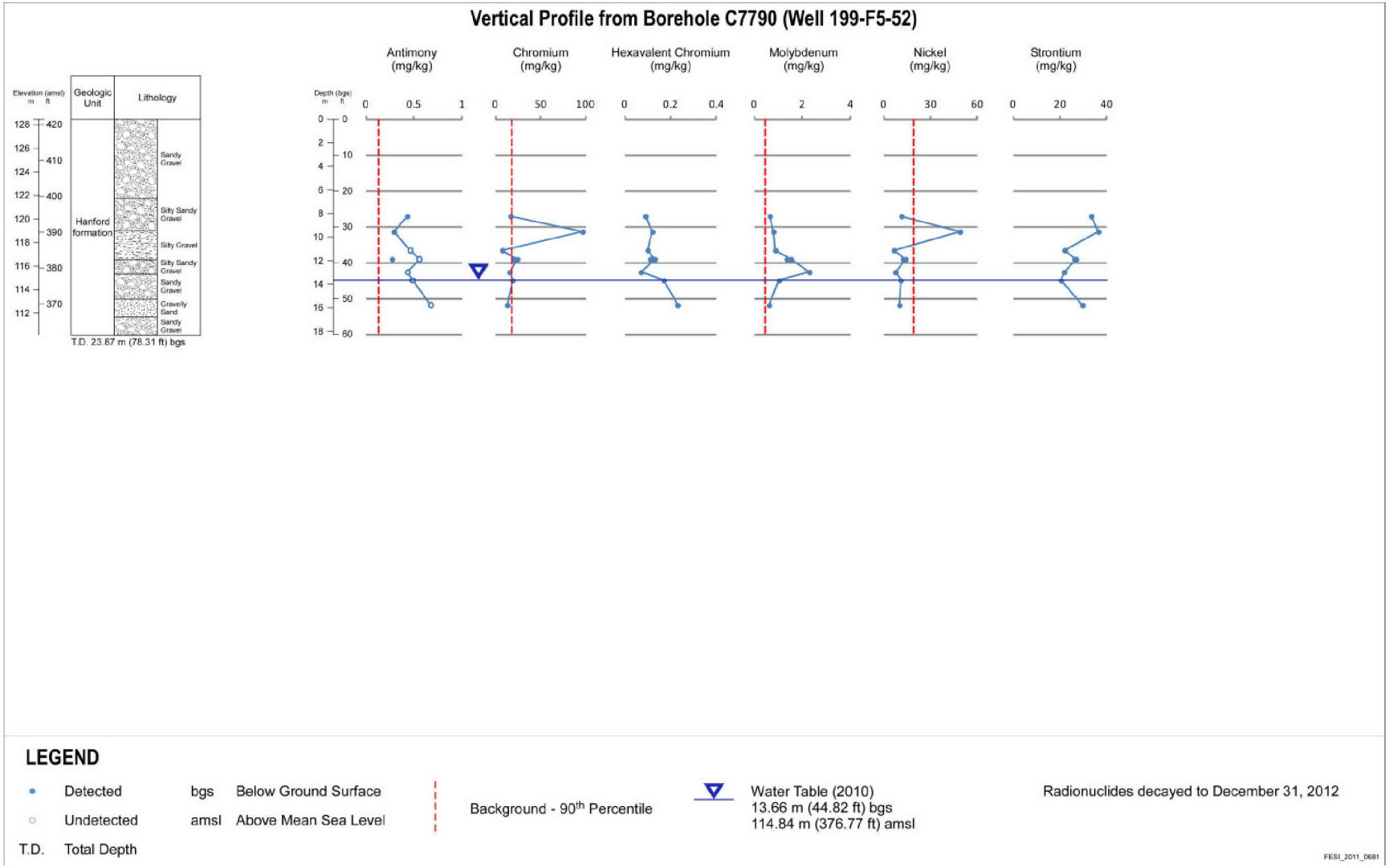


Figure 4-12. Vertical Profile from RI Well C7790 (199-F5-52)

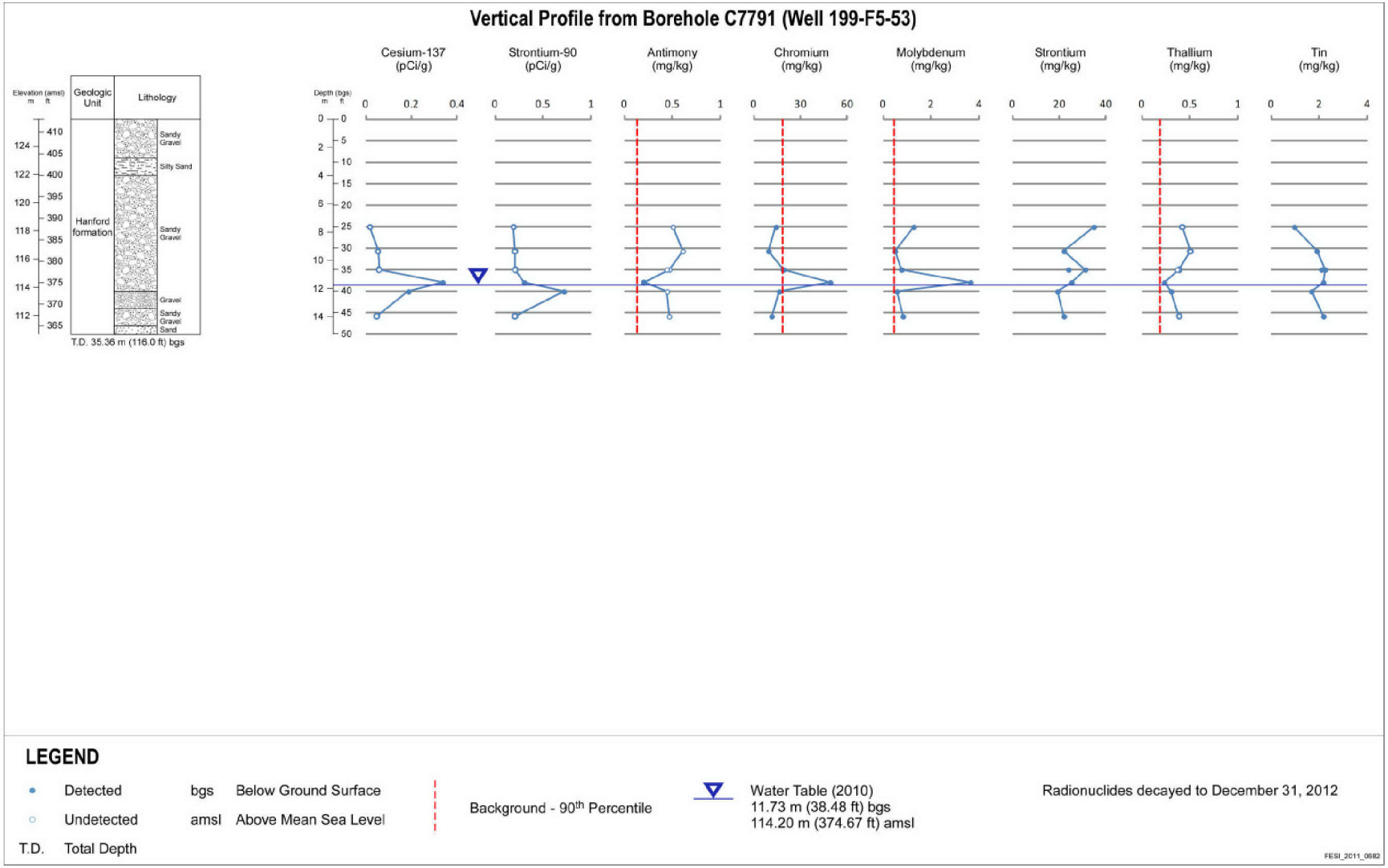


Figure 4-13. Vertical Profile from RI Well C7791 (199-F5-53)

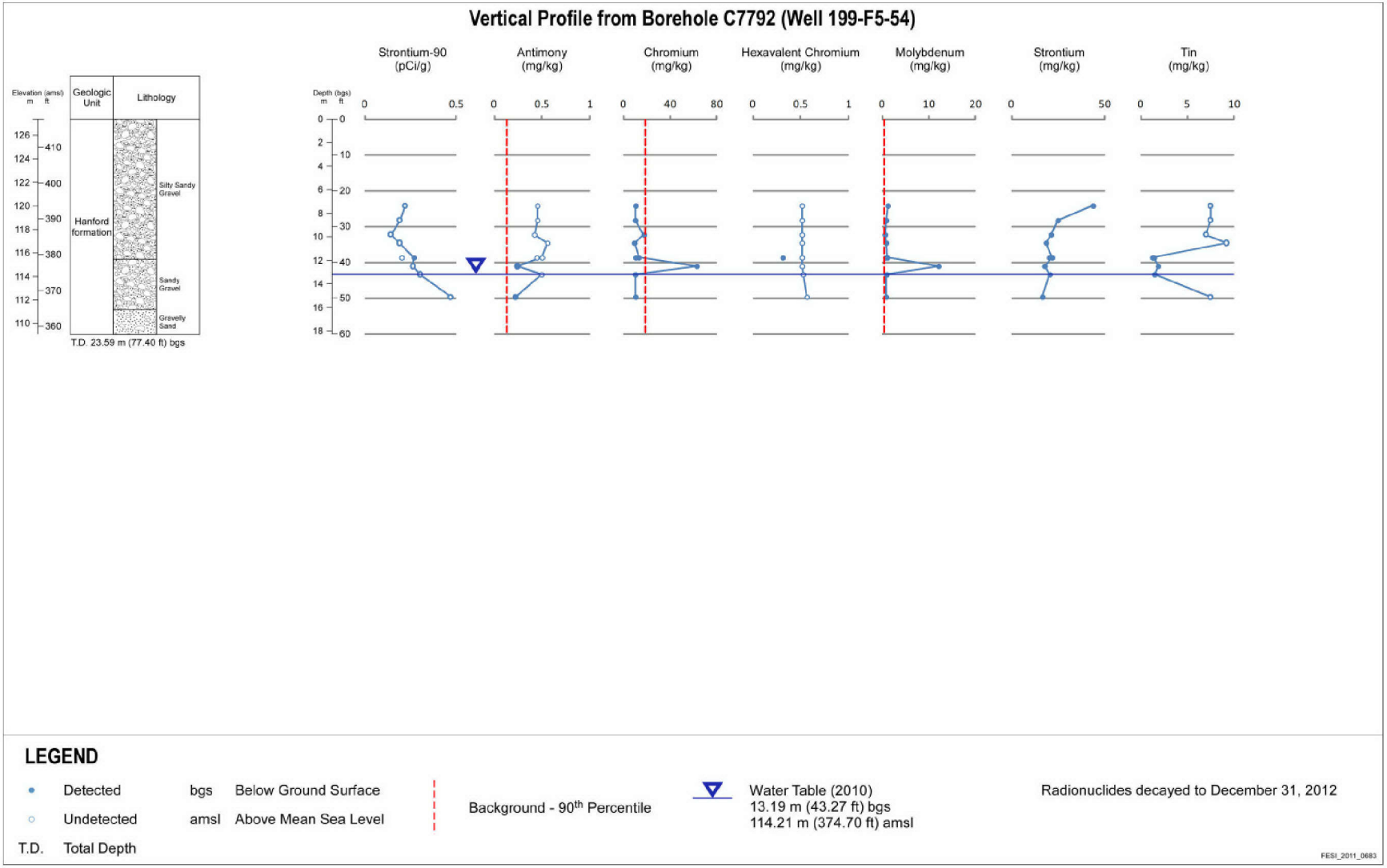


Figure 4-14. Vertical Profile from RI Well C7792 (199-F5-54)

- 116-F-1: Lewis Canal – Borehole 199-F1-2
- 116-F-1: Lewis Canal – Borehole 199-F4-2
- 128-F-2: 100-F Burning Pit – Borehole 199-F5-42
- 100-F-54: 100-F Animal Farm Pastures – Borehole 199-F5-46
- 116-F-6: 1608-F Liquid Waste Disposal Trench – Borehole 199-F5-47
- 116-F-2: 107-F Liquid Waste Disposal Trench – Borehole 199-F5-49
- 116-F-9: Animal Waste Leaching Trench – Borehole 199-F5-50
- 116-F-14: 107-F Retention Basin – Borehole 199-F5-51
- 116-F-4: 105-F Pluto Crib – Borehole 199-F8-5
- 116-F-6: 1608-F Liquid Waste Disposal Trench – Borehole 199-F8-6
- Near 100-F-26 and 100-F-41: 100-F Water Treatment Facility Underground Pipelines and 100-F Service Water Pipelines, respectively – Borehole 199-F5-48
- Near 118-F-5: PNL Sawdust Pit – Borehole 199-F6-1
- West of 118-F-6: PNL Solid Waste Burial Ground – Borehole 199-F7-3
- East of 118-F-1: Minor Construction Burial Ground No. 2 – Borehole 199-F8-3
- 100-F northeast perimeter fence – Borehole 199-F5-43A
- 100-F northeast perimeter fence – Borehole 199-F5-43B
- 100-F northeast perimeter fence – Borehole 199-F5-44
- South wall of the 1722F Area Shop – Borehole 199-F5-45
- 100-F southeast corner – Borehole 199-F8-4

LFI locations are shown on Figure 4-15. Tables 4-10, 4-11, and 4-12 provide summaries of the organic, inorganic, and radionuclide data, respectively. The summary provides the maximum concentration for each analyte that exceeds the background concentrations provided in Table 4-1 and the depth at which the maximum concentration was encountered. If the site has been remediated, the result represents the maximum concentration encountered below the depth of remediation. For radionuclide data, both the original concentration as determined by the laboratory and the data corrected for decay to December 31, 2012 are provided.

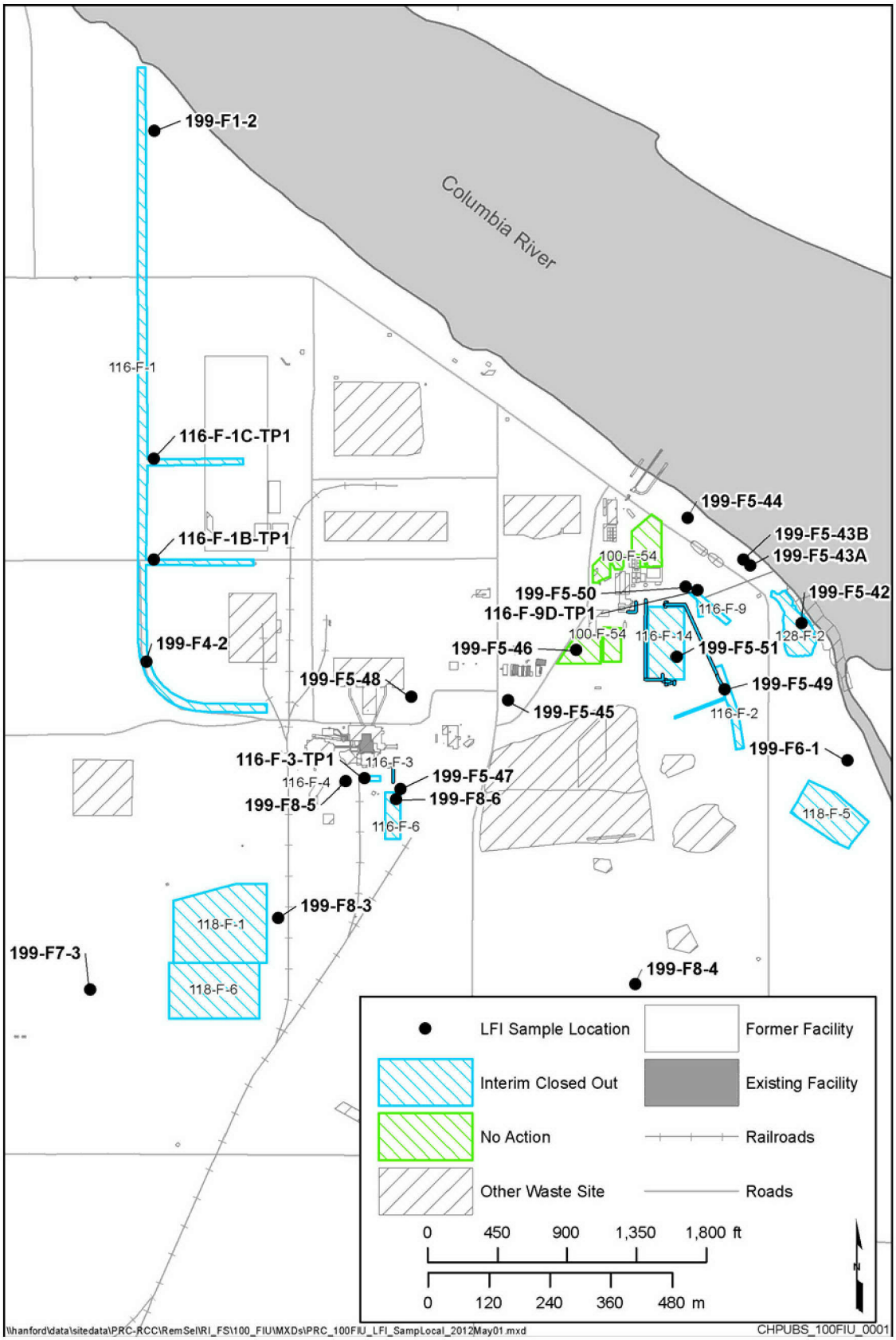


Figure 4-15. Limited Field Investigation Sample Locations

Table 4-10. Summary of Additional LFI Data—100-F Organics

| Location | Waste Site | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2-Butanone | | 2-Hexanone | | 2-Pentanone | | 4-Methyl-2-Pentanone | | Acetone | | alpha-Chlordane | | Benzene | | Bis(2-Ethylhexyl)phthalate) | | Chloroform | |
| Test Pit 1 | 116-F-1 | | | 2 | 4.6/15 | 1 | 4.6/15 | | | 13 | 4.6/15 | | | | | 54 | 3.1/10 | | |
| Test Pit 1 | 116-F-1 | 6 | 0.3/1 | 3 | 0.3/1 | 2 | 0.3/1 | 2 | 0.3/1 | 9 | 0.3/1 | | | | | 470 | 0.3/1 | | |
| Test Pit 1 | 116-F-3 | | | | | | | | | 10 | 5.2/17 | | | | | 45 | 5.2/17 | | |
| Test Pit 1 | 116-F-9 | | | | | | | | | 7 | 6.1/20 | 6.1 | 6.1/20 | | | 84 | 6.1/20 | | |
| 199-F4-2 | 116-F-1 | | | | | | | | | 10 | 6.9/22.5 | | | | | | | | |
| 199-F5-42 | 128-F-2 | | | | | | | | | 33 | 8.2/27 | | | | | 120 | 8.2/27 | | |
| 199-F5-43A | — | 5 | 4.3/14 | | | | | | | 81 | 10.4/34 | | | | | 68 | 10.4/34 | | |
| 199-F5-43B | — | | | | | | | | | 26 | 17.4/57 | | | | | | | | |
| 199-F5-44 | — | | | | | | | | | 24 | 12.0/39.5 | | | | | 100 | 12.0/39.5 | | |
| 199-F5-45 | — | | | | | | | | | | | | | | | | | | |
| 199-F5-46 | 100-F-54 | | | | | | | | | 76 | 11.3/37 | | | | | 23 | 10.2/33.5 | | |
| 199-F5-47 | 116-F-6 | | | | | | | 2 | 12.5/41 | 29 | 15.8/52 | | | | | | | | |
| 199-F5-48 | 100-F-41,-26 | | | | | | | | | | | | | | | 73 | 11.3/37 | | |
| 199-F5-49 | 116-F-2 | | | | | | | | | | | | | | | | | | |
| 199-F5-50 | 116-F-9 | 23 | 7.6/25 | | | | | | | 12 | 7.6/25 | | | | | | | | |
| 199-F5-51 | 116-F-14 | 2 | 7.5/24.5 | | | | | 3 | 7.5/24.5 | 46 | 5.7/18.6 | | | | | 100 | 5.7/18.6 | 9 | 7.5/24.5 |
| 199-F6-1 | 118-F-5 | | | | | | | | | 32 | 8.2/27 | | | | | 21 | 12.8/42 | | |
| 199-F7-3 | 118-F-6 | | | | | | | | | 46 | 7.3/24 | | | | | 46 | 3.7/12 | | |
| 199-F8-3 | 118-F-1 | | | | | | | | | 21 | 9.8/32 | | | | | | | | |
| 199-F8-4 | — | | | | | | | | | 16 | 14.5/47.5 | | | | | | | | |
| 199-F8-5 | 116-F-4 | | | | | | | | | 11 | 6.3/20.8 | | | | | 96 | 6.3/20.8 | | |
| 199-F8-6 | 116-F-6 | | | | | | | | | 15 | 6.4/21 | | | 2 | 6.4/21 | 72 | 5.2/17 | | |
| | | Diethylphthalate | | Di-n-butylphthalate | | Di-n-octylphthalate | | Methylene Chloride | | Methyl Isocyanate | | Tetrachloroethene | | Toluene | | trans-Chlordane | | Trichloroethene | |
| Test Pit 1 | 116-F-1 | | | 55 | 0.3/1 | | | 2 | 1.5/5 | | | | | 42 | 0.3/1 | | | | |
| Test Pit 1 | 116-F-1 | | | 69 | 1.5/5 | | | 12 | 0.3/1 | | | 1 | 0.3/1 | 57 | 0.3/1 | | | 2 | 0.3/1 |
| Test Pit 1 | 116-F-3 | | | 77 | 5.2/17 | | | | | | | | | 7 | 5.2/17 | | | | |
| Test Pit 1 | 116-F-9 | | | 57 | 6.1/20 | | | | | | | | | | | 4.1 | 6.1/20 | | |
| 199-F4-2 | 116-F-1 | | | 150 | 4.9/16 | | | 3 | 4.9/16 | | | | | 36 | 6.9/22.5 | | | | |

Table 4-10. Summary of Additional LFI Data—100-F Organics

| Location | Waste Site | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) | Maximum (µg/kg) | Depth (m/ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2-Butanone | | 2-Hexanone | | 2-Pentanone | | 4-Methyl-2-Pentanone | | Acetone | | alpha-Chlordane | | Benzene | | Bis(2-Ethylhexyl)phthalate) | | Chloroform | |
| 199-F5-42 | 128-F-2 | | | | | | | 4 | 8.2/27 | | | | | 2 | 6.7/22 | | | | |
| 199-F5-43A | — | | | | | | | | | 14 | 10.4/34 | | | | | | | | |
| 199-F5-43B | — | | | | | | | 5 | 17.4/57 | | | | | 6 | 17.4/57 | | | | |
| 199-F5-44 | — | | | | | | | 5 | 12.0/39.5 | | | | | 2 | 12.0/39.5 | | | | |
| 199-F5-45 | — | | | | | | | 2 | 11.3/37 | | | | | 11 | 14.3/47 | | | | |
| 199-F5-46 | 100-F-54 | 270 | 16.2/53 | | | | | 15 | 10.2/33.5 | | | | | 4 | 16.2/53 | | | | |
| 199-F5-47 | 116-F-6 | 690 | 15.8/52 | | | | | 4 | 15.8/52 | | | | | 13 | 12.5/41 | | | | |
| 199-F5-48 | 100-F-41,-26 | 340 | 13.4/44 | | | | | | | | | | | 6 | 15.7/51.5 | | | | |
| 199-F5-49 | 116-F-2 | | | 71 | 9.8/32 | | | 2 | 9.8/32 | | | | | 4 | 9.8/32 | | | | |
| 199-F5-50 | 116-F-9 | | | 74 | 7.6/25 | | | 3 | 7.6/25 | | | | | | | | | | |
| 199-F5-51 | 116-F-14 | 2600 | 7.5/24.5 | 160 | 5.7/18.6 | | | 4 | 8.2/27 | | | | | 2 | 5.7/18.6 | | | | |
| 199-F6-1 | 118-F-5 | | | 27 | 12.8/42 | | | 46 | 12.8/42 | | | | | | | | | | |
| 199-F7-3 | 118-F-6 | | | 39 | 2.0/6.5 | | | 37 | 7.3/24 | | | | | 3 | 2.0/6.5 | | | | |
| 199-F8-3 | 118-F-1 | | | 48 | 9.8/32 | | | | | | | | | 2 | 5.2/17 | | | | |
| 199-F8-4 | — | | | | | | | | | | | | | 2 | 11.9/39 | | | | |
| 199-F8-5 | 116-F-4 | | | 280 | 6.3/20.8 | 170 | 4.8/15.6 | 3 | 6.3/20.8 | | | | | 3 | 6.3/20.8 | | | | |
| 199-F8-6 | 116-F-6 | | | | | | | | | | | | | 1 | 6.4/21 | | | | |

1

Table 4-11. Summary of Additional LFI Data—100-F Metals

| Location | Waste Site | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Aluminum | | | Antimony | | | Barium | | | Cadmium | | | Chromium | | | Copper | | | Fluoride | | |
| Test Pit 1 | 116-F-1 | | | | | | | | | | | | | | | | | | | | | |
| Test Pit 1 | 116-F-1 | | | | | | | | | | 0.563 | 0.65 | 0.3/1 | 18.5 | 23.3 | 0.3/1 | | | | | | |
| Test Pit 1 | 116-F-9 | | | | | | | | | | | | | | | | | | | | | |
| 199-F1-2 | 116-F-1 | | | | | | | | | | | | | 18.5 | 31.8 | 6.7/22 | 22 | 23.8 | 6.7/22 | 2.81 | 3.0 | 7.3/24 |
| 199-F5-42 | 128-F-2 | | | | | | | | | | | | | | | | 22 | 23.7 | 6.7/22 | | | |
| 199-F5-43A | — | | | | | | | | | | | | | 18.5 | 21.9 | 5.8/19 | | | | | | |
| 199-F5-43B | — | 11800 | 13200 | 17.4/57 | | | | | | | | | | 18.5 | 24 | 17.4/57 | 22 | 31.6 | 17.4/57 | | | |
| 199-F5-44 | — | | | | | | | | | | | | | 18.5 | 44.2 | 12.0/39.5 | | | | | | |
| 199-F5-45 | — | | | | | | | | | | | | | | | | | | | 2.81 | 3.0 | 11.3/37 |
| 199-F5-46 | 100-F-54 | | | | | | | | | | | | | 18.5 | 26.1 | 10.2/33.5 | | | | 2.81 | 3.0 | 16.1/53 |
| 199-F5-47 | 116-F-6 | | | | 0.13 | 3.3 | 11.0/36 | | | | | | | | | | | | | | | |
| 199-F5-48 | 100-F-41,-26 | | | | | | | | | | | | | | | | | | | 2.81 | 4.0 | 11.3/37 |
| 199-F5-49 | 116-F-2 | | | | | | | 132 | 338 | 6.7/22 | | | | 18.5 | 30.5 | 5.1/16.8 | | | | | | |
| 199-F5-50 | 116-F-9 | | | | | | | | | | | | | | | | | | | 2.81 | 3.1 | 7.6/25 |
| 199-F5-51 | 116-F-14 | | | | | | | | | | | | | 18.5 | 35.3 | 7.5/24.5 | | | | | | |
| 199-F7-3 | 118-F-6 | | | | | | | | | | | | | 18.5 | 37 | 3.7/12 | | | | 2.81 | 3.0 | 2.0/6.5 |
| 199-F8-3 | 118-F-1 | 11800 | 15200 | 9.8/32 | 0.13 | 3.2 | 5.2/17 | | | | | | | | | | | | | | | |
| 199-F8-4 | — | 11800 | 15900 | 14.5/47.5 | | | | | | | | | | | | | 22 | 32.9 | 14.5/47.5 | 2.81 | 3.0 | 11.9/39 |
| 199-F8-5 | 116-F-4 | | | | | | | | | | | | | | | | | | | | | |
| 199-F8-6 | 116-F-6 | | | | | | | | | | | | | | | | | | | | | |
| | | Lead | | | Manganese | | | Mercury | | | Nickel | | | Silver | | | Sulfate | | | Zinc | | |
| Test Pit 1 | 116-F-1 | 10.2 | 13.1 | 0.3/1 | | | | 0.0131 | 0.56 | 3.1/10 | | | | 0.167 | 0.98 | 4.6/15 | | | | | | |
| Test Pit 1 | 116-F-1 | 10.2 | 13.8 | 0.3/1 | | | | 0.0131 | 0.69 | 0.3/1 | | | | 0.167 | 1.3 | 0.3/1 | | | | 67.8 | 142 | 0.3/1 |
| Test Pit 1 | 116-F-9 | | | | | | | 0.0131 | 0.09 | 6.1/20 | | | | 0.167 | 1.4 | 6.1/20 | 237 | 240 | 6.1/20 | | | |
| 199-F1-2 | 116-F-1 | | | | | | | | | | | | | | | | | | | | | |
| 199-F5-42 | 128-F-2 | | | | | | | | | | | | | | | | | | | | | |
| 199-F5-43A | — | | | | | | | | | | | | | 0.167 | 0.56 | 5.8/19 | | | | | | |
| 199-F5-43B | — | 10.2 | 11.4 | 17.4/57 | | | | | | | 19.1 | 23.8 | 17.4/57 | 0.167 | 0.66 | 17.4/57 | | | | | | |

Table 4-11. Summary of Additional LFI Data—100-F Metals

| Location | Waste Site | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) | Bkgd (mg/kg) | Maximum (mg/kg) | Depth (m/ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Aluminum | | | Antimony | | | Barium | | | Cadmium | | | Chromium | | | Copper | | | Fluoride | | |
| 199-F5-44 | — | | | | | | | | | | 19.1 | 21.0 | 12.0/39.5 | | | | | | | | | |
| 199-F5-45 | — | | | | | | | | | | | | | | | | | | | | | |
| 199-F5-46 | 100-F-54 | | | | | | | | | | | | | | | | | | | | | |
| 199-F5-47 | 116-F-6 | | | | | | | 0.0131 | 0.05 | 11.0/36 | | | | 0.167 | 1.3 | 15.8/52 | | | | | | |
| 199-F5-48 | 100-F-41,-26 | | | | | | | | | | | | | | | | | | | | | |
| 199-F5-49 | 116-F-2 | | | | | | | 0.0131 | 0.23 | 5.1/16.8 | | | | | | | | | | | | |
| 199-F5-50 | 116-F-9 | | | | | | | | | | | | | 0.167 | 1.0 | 7.6/25 | | | | | | |
| 199-F5-51 | 116-F-14 | | | | | | | 0.0131 | 0.11 | 5.7/18.6 | 19.1 | 20.8 | 7.5/24.5 | 0.167 | 0.79 | 5.7/18.6 | | | | | | |
| 199-F7-3 | 118-F-6 | | | | | | | 0.0131 | 0.5 | 2.0/6.5 | 19.1 | 20.2 | 3.7/21.8 | | | | | | | | | |
| 199-F8-3 | 118-F-1 | 10.2 | 13.0 | 9.8/32 | 512 | 581 | 9.8/32 | | | | | | | 0.167 | 1.4 | 6.7/22 | | | | | | |
| 199-F8-4 | — | | | | | | | | | | | | | 0.167 | 1.2 | 14.5/47.5 | | | | | | |
| 199-F8-5 | 116-F-4 | | | | | | | | | | | | | 0.167 | 0.65 | 7.9/26 | | | | | | |
| 199-F8-6 | 116-F-6 | | | | | | | | | | | | | 0.167 | 0.9 | 6.4/21 | | | | | | |

Table 4-12. Summary of Additional LFI Data—100-F Radionuclides

| Location | Waste Site | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Americium-241 | | | Carbon-14 | | | Cesium-137 | | | Cobalt-60 | | | Europium-152 | | | Europium-154 | | | Europium-155 | | |
| Test Pit 1 | 116-F-1B | | | | | | | 0.19 | 0.12 | 0.3/1.0 | | | | | | | | | | | | |
| Test Pit 1 | 116-F-1C | | | | | | | 0.088 | 0.056 | 0.3/1.0 | | | | | | | | | | | | |
| Test Pit 1 | 116-F-3 | | | | | | | | | | | | | 0.82 | 0.29 | 5.2/17 | | | | | | |
| Test Pit 1 | 116-F-9D | | | | | | | 0.13 | 0.08 | 6.1/20 | 0.055 | 0.004 | 6.1/20 | 0.14 | 0.05 | 6.1/20 | | | | | | |
| 199-F4-2 | 116-F-1 | | | | 180 | 180 | 4.9/16.0 | | | | | | | | | | | | | | | |
| 199-F5-43B | — | 0.84 | 0.81 | 17.4/57 | | | | | | | | | | | | | | | | | | |
| 199-F5-44 | — | | | | | | | 0.10 | 0.06 | 8.5/28 | | | | | | | | | | | | |
| 199-F5-49 | 116-F-2 | 0.012 | 0.012 | 10.2/33.5 | 240 | 239 | 5.1/16.8 | 31 | 20 | 5.1/16.8 | 6.8 | 0.5 | 5.1/16.8 | 190 | 68 | 5.1/16.8 | 17.0 | 3.4 | 5.1/16.8 | 0.65 | 0.04 | 5.1/16.8 |
| 199-F5-50 | 116-F-9 | | | | | | | | | | | | | | | | | | | | | |
| 199-F5-51 | 116-F-14 | 0.25 | 0.24 | 5.1/16.8 | | | | 2.1 | 1.3 | 5.7/16.8 | | | | | | | | | | | | |
| 199-F6-1 | Near 118-F-5 | | | | | | | | | | | | | | | | | | | | | |
| 199-F7-3 | Near 118-F-6 | | | | | | | | | | | | | | | | | | | | | |
| 199-F8-3 | Near 118-F-1 | | | | | | | | | | | | | | | | | | | | | |
| 199-F8-5 | 116-F-4 | 0.053 | 0.051 | 6.3/21 | | | | 0.72 | 0.46 | 6.3/20.8 | | | | | | | | | | | | |
| 199-F8-6 | 116-F-6 | | | | | | | 0.16 | 0.10 | 5.2/17 | | | | 1.6 | 0.6 | 5.2/17 | 0.14 | 0.03 | 5.2/17 | | | |
| | | Gross Alpha | | | Gross Beta | | | Plutonium-238 | | | Plutonium-239/240 | | | Strontium-90 | | | Uranium-235 | | | Uranium-238 | | |
| Test Pit 1 | 116-F-1B | | | | | | | | | | | | | | | | | | | | | |
| Test Pit 1 | 116-F-1C | | | | | | | | | | | | | | | | | | | | | |
| Test Pit 1 | 116-F-3 | | | | | | | | | | 0.95 | 0.95 | 5.2/17 | | | | | | | | | |
| Test Pit 1 | 116-F-9D | | | | | | | | | | | | | 6.3 | 3.9 | 6.1/21 | | | | | | |
| 199-F4-2 | 116-F-1 | | | | | | | | | | | | | | | | | | | | | |
| 199-F5-43B | — | | | | | | | | | | | | | | | | | | | 1.3 | 1.3 | 17.4/57 |
| 199-F5-44 | — | | | | | | | | | | | | | | | | | | | | | |
| 199-F5-49 | 116-F-2 | | | | | | | 0.022 | 0.019 | 5.1/16.8 | 1.3 | 1.3 | 5.1/16.8 | 3.2 | 2.0 | 5.1/16.8 | 0.37 | 0.37 | 8.1/26.5 | | | |
| 199-F5-50 | 116-F-9 | | | | | | | | | | | | | 19 | 12 | 7.6/25 | | | | | | |
| 199-F5-51 | 116-F-14 | 5.8 | — | 5.7/18.6 | | | | 0.24 | 0.20 | 7.5/24.5 | 0.035 | 0.035 | 7.5/24.5 | | | | | | | | | |
| 199-F6-1 | Near 118-F-5 | 4.7 | — | 12.8/42 | 30 | — | 12.8/42 | | | | | | | | | | | | | | | |
| 199-F7-3 | Near 118-F-6 | 4.7 | — | 3.7/12 | 24 | — | 7.3/24 | | | | | | | | | | | | | | | |

Table 4-12. Summary of Additional LFI Data—100-F Radionuclides

| Location | Waste Site | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) | Maximum (pCi/g) | Decayed (pCi/g) | Depth (m/ft) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Americium-241 | | | Carbon-14 | | | Cesium-137 | | | Cobalt-60 | | | Europium-152 | | | Europium-154 | | | Europium-155 | | |
| 199-F8-3 | Near 118-F-1 | 5.9 | — | 9.8/32 | | | | | | | | | | | | | | | | | | |
| 199-F8-5 | 116-F-4 | | | | | | | | | | 0.027 | 0.027 | 6.3/20.8 | | | | | | | | | |
| 199-F8-6 | 116-F-6 | | | | | | | | | | 0.096 | 0.096 | 5.2/17 | 4.4 | 2.7 | 5.2/17 | | | | | | |

Note:All radionuclide results are decay-corrected to 12/31/2012.

### 4.2.7 Anomalous Metal Concentrations in Selected 100-F RI Samples

Some of the chromium and nickel results appear anomalous when compared to other results from neighboring intervals in the same boring, duplicate sample results, and analyses performed in support of the batch leach tests. A trend of elevated chromium and nickel results occurs primarily in a ratio between 1.5 to 2.2, chromium:nickel. The ratio between the metals generally decreases as the analytical result approaches background values of chromium (18.2 mg/kg) and nickel (19.1 mg/kg). Table 4-13 presents data for the corresponding wells and intervals in 100-F boreholes that show the elevated chromium and nickel results potentially attributable to stainless steel contamination, and the relative ratios of chromium:nickel in these samples.

Table 4-13. Elevated Metal Concentrations in 100-F Area RI Samples

| Borehole ID | Interval | Sample | Chromium (mg/kg) | Nickel (mg/kg) | Ratio Chromium:Nickel |
|---|---|---|---|---|---|
| C7971 | I-001 | B28VL9 | 66.2 | 36.1 | 1.83 |
| C7790 (Well 199-F5-52) | I-002 | B26T20 | 96.6 | 49.0 | 1.97 |

Steel drilling and sampling equipment introduces the potential for false positive chromium and nickel results. The discussion of elevated concentrations of the other metals in the presence of chromium is predicated on the fact that these metals are all components of various alloys of steel. The shoes that are used on the split spoons are made of 4140 alloy steel, the split spoons are DOM 520 steel, and the stainless steel liners that are periodically used are 304 stainless.

Given that the DOM 520 steel does not contain any chromium, molybdenum, or nickel, it can be discounted as a source of the elevated concentrations. The 4140 alloy steel contains between 0.80 and 1.10 percent by weight of chromium and 0.15 to 0.25 percent molybdenum. For the 304 stainless, chromium is much more prevalent, ranging from 18 to 20 percent and also contains nickel at 8 to 12 percent.

Results from borehole C7790 (Well 199-F5-52), Interval I-002, illustrate the potential stainless steel contamination with elevated chromium (96.6 mg/kg) and nickel (49.0 mg/kg) (Table 4-14). This well is not located near an existing waste site. Chromium and nickel results in this sample collected at 9.5 m (31.3 ft) bgs are approximately four times that of the next highest concentration borehole sample for chromium and nickel (24.1 and 13.9 mg/kg, respectively, in sample B26T30 at 11.9 m [39 ft] bgs). No samples other than B26T20 from this borehole show nickel to exceed background (19.2 mg/kg). Given this information, it is probable that stainless steel is causing elevated chromium and nickel results in Interval 2.

Table 4-14. Borehole C7790, Interval 2 (Sample B26T20) Chromium and Nickel Results Relative to Neighboring Interval Sample Results

| Interval | Sample | Sample Depth (ft) | Chromium (total) | Nickel |
|---|---|---|---|---|
| | | | mg/kg | mg/kg |
| C7790; I-001 | B26T18 | 27.0 | 16.9 | 11.4 |
| C7790; I-002 | B26T20 | 31.3 | 96.6 | 49.0 |
| C7790; I-003 | B26T22 | 36.5 | 7.80 | 6.58 |
| C7790; I-004 | B26T30 | 39.0 | 24.1 | 13.9 |
| C7790; I-004 Duplicate | B26T25 | 39.0 | 21.2 | 12.5 |

### 4.2.8 Soil Gas from 1995 Limited Field Investigation

In 1995, a supplemental LFI was conducted for the 100-FR-3 OU to determine the extent and potential source of trichloroethene groundwater contamination. The study included an assessment of soil gas in the vicinity of the plume. Results of that study are summarized in Section 4.3.2.

### 4.2.9 Summary of Vadose Zone Contamination

As identified in Chapter 1, 286 waste sites have been evaluated with respect to the nature and extent of contamination in 100-F/IU. 133 of these sites are identified as requiring further action. Approximately 81 of these sites are anticipated to have actions completed under the interim action ROD. As of June 30, 2012, over 1,354,000 metric tons (1,492,000 tons) of contaminated material has been removed from 100-F. At IU-2/IU-6, the field activities completed have resulted in the removal of 424,000 metric tons (467,000 tons) of contaminated material for treatment, as appropriate, and disposal. This extensive work has had a significant impact on the nature and extent of vadose zone contamination, and the remaining contamination is the focus of this discussion.

100-F/IU waste site LFI, CVP/RSVP, and RI data are presented in Appendix D. In addition, CVP data for interim closed out waste sites are presented in Appendix E. The following observations can be made about RI soil data:

- Radiological contamination was detected at Wells C7791 (199-F5-53) and C7792 (199-F5-54). Cesium-137 and strontium-90 were the only anthropogenic radionuclides detected and were only detected in the deep vadose zone (within less than 1.5 m [5 ft] of the water table).
- Anthropogenic radiological contamination was also detected in boreholes C7970, C7971, and C7972, including gamma-emitting radionuclides (cobalt-60, cesium-137, europium-152, and europium-154), beta emitters (carbon-14, nickel-63, strontium-90, and tritium), and plutonium-239/240. Uranium isotopes were analyzed for and detected in boreholes C7971 and C7972 at or below background concentrations.
- Cr(VI) was detected at borehole C7970. The highest concentration (3.23 mg/kg) occurred at 6.92 m (22.7 ft) bgs and then decreased with depth.
- Cr(VI) was detected at Wells C7790 (199-F5-52) and C7792 (199-F5-54) near the water table.
- Total chromium was detected above background at all boreholes and wells, and concentrations ranged from 36.5 mg/kg at borehole C7972 to 126 mg/kg at borehole C7970.

## 4.3 Groundwater Contamination

This section describes the nature and extent of contaminants in groundwater beneath 100-F and 100-IU-2/IU-6. The RI tasks have produced additional data to help refine knowledge of the nature and extent of these contaminants in 100-F. The 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) identified the following four data needs associated with obtaining a better understanding of the nature and extent of contamination in groundwater.

*Data Need 4: The nature and extent of contamination in the unconfined aquifer above cleanup standards has not been fully defined in all areas or for all COPCs.* These data are needed to identify groundwater contaminants and define the extent of contamination horizontally and vertically.

*Data Need 5: Contaminant concentrations entering the Columbia River are not well known.* These data are needed to monitor contaminant concentrations over time and with depth near the river.

*Data Need 6: The fate and transport of contaminants beneath the unconfined aquifer has not been evaluated sufficiently.* These data are needed to evaluate the integrity of the aquitard unit and contaminant fate and transport within the aquitard.

*Data Need 7: Data are needed for a better understanding of hydrogeological conditions, aquifer surface water interactions, and contaminant mobility through the vadose zone.* Geological characterization, physical, and hydraulic property data are needed to support modeling and analysis.

*Data Need 8: Data are needed to reduce the uncertainty in spatial and temporal distribution of groundwater contamination.* As a result of the uncertainties identified in the RCBRA (DOE/RL-2007-21), the Integrated Work Plan (DOE/RL-2008-46) added activities that would help reduce uncertainties, verify conclusions of the HHRA presented in the RCBRA (DOE/RL-2007-21, Volume II), and ensure that contaminants were not inadvertently overlooked based on the use of the existing groundwater data set. Section 3.6.5.1 of the Integrated Work Plan (DOE/RL-2008-46) identifies the following activities to reduce uncertainties:

- Identify existing and/or install new monitoring wells that are spatially representative of the groundwater. This set of wells will represent locations where a receptor potentially could contact groundwater.
- Conduct multiple rounds of sampling to obtain temporal representation of the unconfined aquifer from influence of river stage. Additional rounds of sampling at spatially representative monitoring wells will represent current groundwater conditions and capture the influence of river fluctuations on COPC concentrations.
- Analyze all spatially representative monitoring wells for a focused list of groundwater COPCs identified for each round of sampling. Analyzing each of the monitoring wells for COPCs will provide a dataset that is representative of potential releases to the groundwater.
- Evaluate sample results from characterization activities to support final remedial action decisions for groundwater.

Section 4.3.1 presents a comprehensive interpretation of the results of sampling conducted to address data needs for spatial and temporal distribution of contaminants as identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4), using groundwater data from wells sampled over a five-year period from January 2007 through December 2011. Effects on contaminant concentrations and distributions from changes in Columbia River stage are also discussed. Sections 4.3.2 through 4.3.4 present further information about the distribution and trends in groundwater contaminants.

Groundwater data discussed in this section are available via the DOE 2012 Environmental Dashboard application and included in Appendix D.

### 4.3.1 Spatial/Temporal Groundwater Evaluation

The groundwater monitoring program analyzed 37 COPCs for 100-F and 34 COPCs for IU-2/IU-6 as identified in the 100-F/IU SAP (DOE/RL-2009-43). The COPCs were analyzed in samples collected from pre-existing monitoring wells (Figures 4-16 and 4-17).

At 100-F, 19 wells were sampled in May 2010 (high river stage), July 2010 (intermediate river stage), and late September to late November 2010 (low river stage) to define spatial and temporal distribution of groundwater contamination to address Data Gap 8. At 100-IU-2/IU-6, 36 wells were sampled between April 2010 and December 2010 to define spatial and temporal distribution of groundwater contamination to address Data Gap 8. Variations in the river's elevation do not directly affect groundwater conditions

within the IU-2/IU-6 well network. For 100-F, these sampling times are evaluated with respect to the temporal changes in the aquifer and the degree to which the intervals capture varying aquifer conditions related to fluctuations in the Columbia River elevations.

Along the River Corridor of the Hanford Site, seasonal variations in river stage may affect aquifer conditions by causing temporary changes in the water table. These changes affect groundwater flow directions and rates, and sometimes affect contaminant concentrations. For example, high river elevations may cause an influx of clean water from the river, lowering contaminant concentrations in wells near the river. When the aquifer further inland experiences the high river elevation as a pressure pulse, the higher water table may impact a contaminated section of unsaturated sediments, causing concentrations to increase. Conversely, when the river stage is at the lowest levels, the flow direction near the river is approximately toward the river, causing contaminant plumes to migrate toward the river. Farther inland, contaminant concentrations in the aquifer may decrease because contaminated soils are above the water table and not contributing to groundwater chemistry. To characterize the dynamic groundwater conditions and associated contaminant concentrations adequately, sampling was scheduled during periods when the river elevation and water table were expected to be high, low, and intermediate.

River stage in 100-F varies seasonally by approximately 3 m (10 ft), resulting in water-table fluctuations of several meters (Figure 3-8). The daily average elevations depict a cyclic pattern that reflects operation of upstream dams and reservoirs used for flood control, hydroelectric production, and salmon spawning programs. The highest river stage generally occurs from May through July, and the lowest river stage occurs from September through October and sometimes into November. The intervals between the maximum and minimum river elevations from approximately December through April and July through August are periods when the aquifer is in transition. The change from low to high elevations occurs gradually over about four months. The change from high to low levels is sharper, occurring over a two-month interval in July and August.

The actual sampling intervals are compared to 100-F river stage in Figure 4-18. The May 2010 sampling event was intended to represent high river stage conditions. However, as illustrated in Figure 4-18, the major increase in river stage occurred after the sampling event. The "transitional" sampling event occurred in July 2010, and the low water table event from late September to late November. Two of the three sampling events (May and July 2010) were completed within 30 days to minimize effects from dynamic river fluctuations. However, the 30-day schedule was not met for the low river stage sampling event (Table 2-13 in Chapter 2). The analytical data are presented in Appendix D, incorporated into the historical summary statistics, and included in the contaminant distribution discussions. Further evaluations of this data set, including the evaluations of COPCs, are presented in Chapter 6.

#### 4.3.1.1 Spatial/Temporal Groundwater Evaluation for 100-F

This section evaluates the nature and extent of historical COPCs in groundwater based on data collected between January 11, 2007, and December 7, 2011 for wells screened in the unconfined aquifer. Section 4.3.2 presents additional information about the nature and extent of the contaminants retained as groundwater COPCs based on the results of the groundwater risk assessment.

Groundwater data for 100-F/IU were compiled and statistically analyzed, and the results are presented in Table 4-15. This table presents the summary statistics for each analyte identified as a COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) and the 100-F/IU SAP (DOE/RL-2009-43). This table also lists the background concentrations in Hanford Site groundwater (*Hanford Site Background: Part 3, Groundwater Background* [DOE/RL-96-61]), where available, and the lowest action level for each contaminant and its basis.

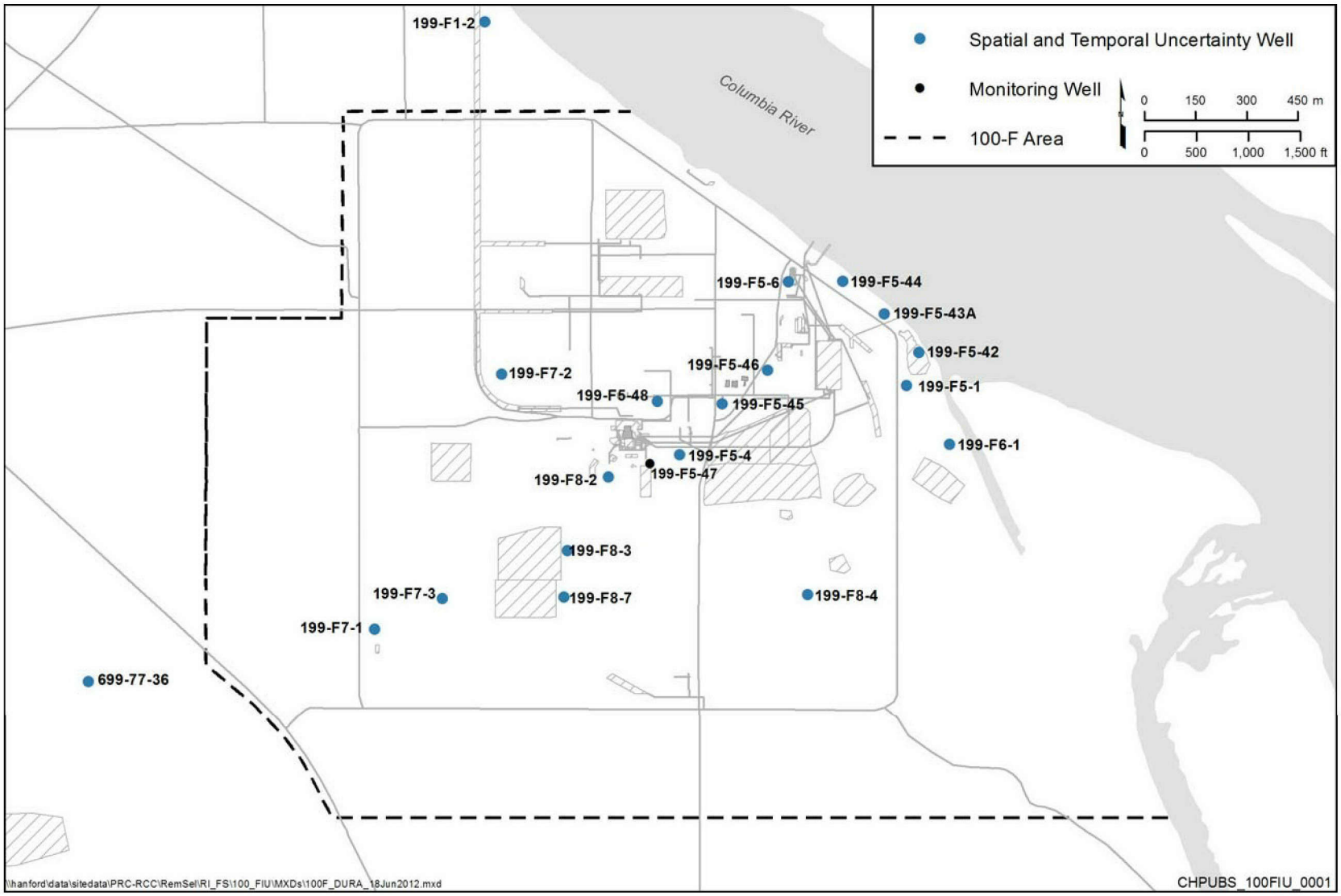


Figure 4-16. Groundwater Monitoring Well Network for 100-F Groundwater Summary Statistics

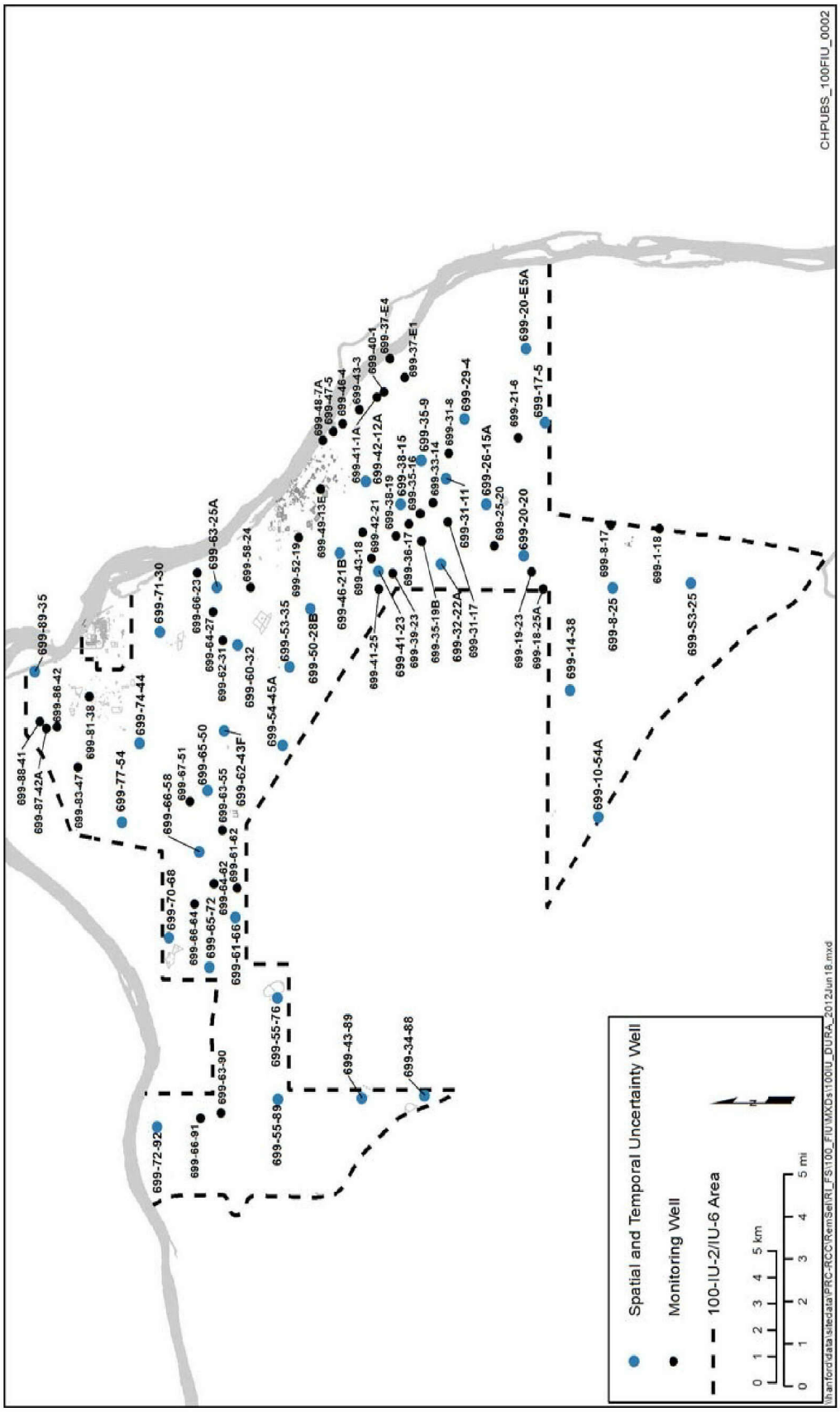


Figure 4-17. Monitoring Well Locations within the 100-IU-2 and 100-IU-6 Groundwater Area

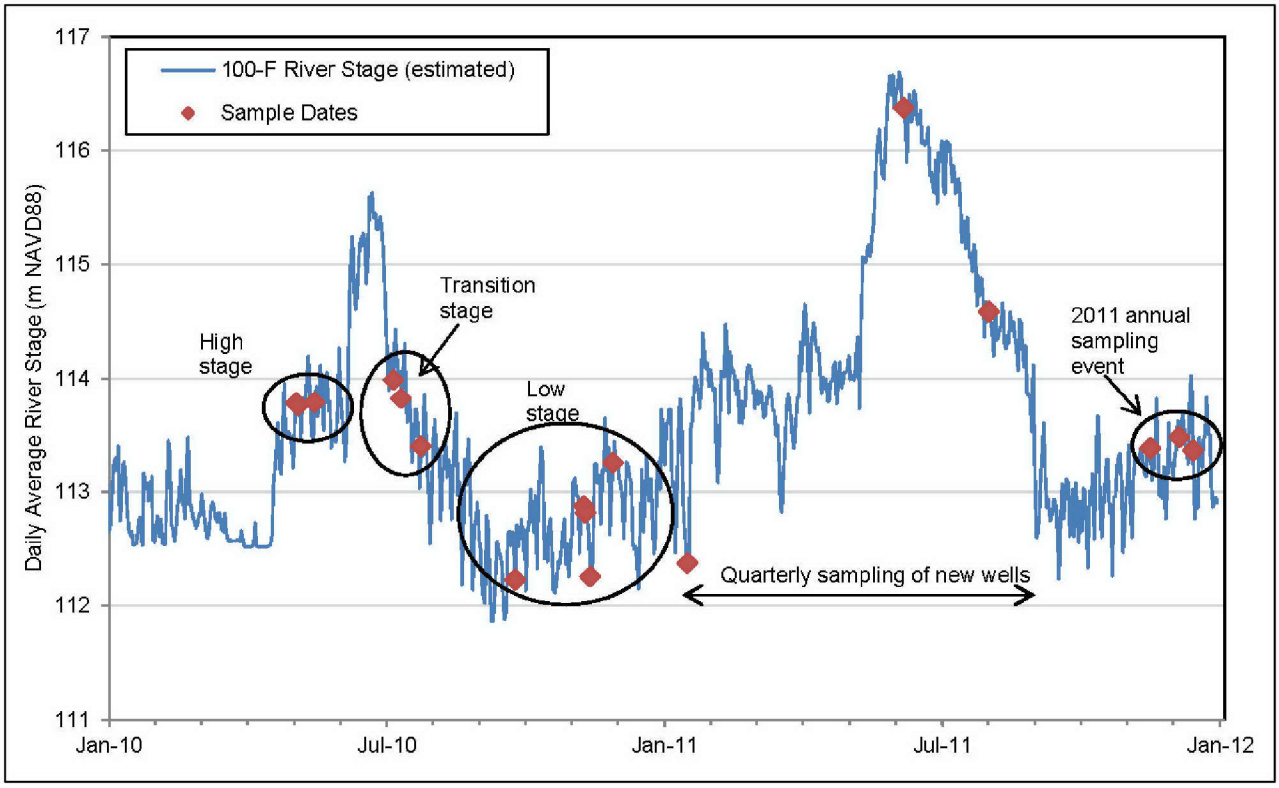


Figure 4-18. Groundwater Sampling Intervals during Low, Transitional, and High River Stages at 100-F

For the purpose of COPC identification, action levels are screening levels derived from chemical-specific ARARs and/or risk-based concentrations using default exposure assumptions. It should be noted that some of the exposure pathways in these screening levels are incomplete.

The sources of action levels from federal regulations are:

- 40 CFR 141, "National Primary Drinking Water Regulations," MCLs, secondary MCLs, and nonzero MCLGs established under the *Safe Drinking Water Act of 1974* (SDWA)
- *National Recommended Water Quality Criteria* (EPA, 2009a), Ambient Water Quality Criteria (AWQC) established under Section 304 of the *Clean Water Act of 1977*
- "Water Quality Standards" (40 CFR 131) for states not complying with Section 303 of the *Clean Water Act of 1977*

The sources of the action levels from Washington State regulations are:

- "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)
- "Groundwater Cleanup Standards" (WAC 173-340-720)
- "Surface Water Cleanup Standards" (WAC 173-340-730)
- "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)" (WAC 246-290-310)

While surface water and AWQC standards are considered for the identification of action levels, it must be noted that these standards only apply for groundwater where it enters the Columbia River. For the upland parts of groundwater, only drinking water standards are applicable.

The following evaluation specifically identifies when the action level is a DWS or an AWQC.

The evaluation presented in this section focuses on the following:

- Analytes that are identified as COPCs in the groundwater risk assessment provided in Section 6.3 and that warrant further evaluation in the FS
- Analytes identified as historical COPCs in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) as a result of uncertainties resulting from limitations in the analytical data (inadequate MDLs or anomalous results). Analytical data used in the groundwater risk assessment provided in Section 6.3 and data from a larger population of wells sampled over a longer sampling timeframe were evaluated to determine these analytes do not warrant further evaluation in the FS.

*100-F COPCs Warranting Evaluation in the FS.* Section 6.3 identifies Cr(VI), nitrate, strontium-90, and trichloroethene as COPCs that warrant further evaluation in the FS.

Cr(VI) was detected in 39 percent of the unfiltered samples and 47 percent of the filtered groundwater samples. Concentrations ranged from 2.3 to 92 µg/L in unfiltered samples and from 2.2 to 93 µg/L in filtered samples. All MDLs were less than the AWQC of 10 µg/L (AWQC values in groundwater are of interest at points where groundwater discharges to surface water). Cr(VI) concentrations above the AWQC were reported as follows:

- Four of seven sample results from 199-F5-44 (less than 2 to 12 µg/L)
- Two of six sample results from 199-F5-45 (7.6 to 21 µg/L)
- All seven sample results from 199-F5-46 (20 to 93 µg/L)
- A single sample result from 199-F5-47 (11 µg/L)
- All nine sample results from 199-F5-48 (11 to 16 µg/L)
- Six of seven sample results from 199-F5-6 (less than 2 to 61 µg/L)

Nitrate was detected 99 percent of the unfiltered samples and was not analyzed for in filtered samples. Nitrate concentrations ranged from 0.912 to 139 mg/L and were above the DWS in 58 percent of the detected results. Nitrate above the DWS was reported at 12 of the 20 wells evaluated.

Trichloroethene was detected in 51 percent of the unfiltered samples and was not analyzed for in filtered samples. Trichloroethene concentrations above the DWS of 5 µg/L were reported as follows:

- Two of four sample results from 199-F5-45 (2.5 to 7.9 µg/L)
- All six sample results from 199-F7-1 (9.7 to 20 µg/L)
- One of six sample results from 199-F7-2 (2.6 to 5.5 µg/L)
- All six sample results from 199-F7-3 (5 to 10 µg/L)
- All six sample results from 699-77-36 (8.5 to 13 µg/L)

Table 4-15. 100-F Groundwater Summary Statistics

| Analyte Name | Filtered | Units | Number of Results | Number of Detects | Frequency of Detects (%) | Min Non-Detect | Max Non-Detect | Min Detect | Max Detect | Mean Detect | Median Detect | Background 90th Percentile | No. of Detects > Background | Action Level (EQL) | No. of Detects >Action Level (>EQL) | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Radionuclides** | | | | | | | | | | | | | | | | |
| Americium-241 | N | pCi/L | 57 | 4 | 7 | -0.18 | 0.19 | 0.060 | 0.080 | 0.070 | 0.070 | 7.70E-05 | 4 | 15 | -- | 40 CFR 141 - Federal MCL |
| Carbon-14 | N | pCi/L | 57 | 9 | 16 | -12 | 7.8 | 9.0 | 71 | 26 | 13 | -- | -- | 2,000 | -- | 40 CFR 141.66 |
| Cesium-137 | N | pCi/L | 58 | 0 | 0 | -1.3 | 2.3 | -- | -- | -- | -- | 8.6 | -- | 200 | -- | 40 CFR 141 - Federal MCL |
| Cobalt-60 | N | pCi/L | 58 | 0 | 0 | -2.5 | 2.5 | -- | -- | -- | -- | 0.023 | -- | 100 | -- | 40 CFR 141 - Federal MCL |
| Europium-154 | N | pCi/L | 58 | 0 | 0 | -5.8 | 6.0 | -- | -- | -- | -- | 70 | -- | 60 | -- | 40 CFR 141 - Federal MCL |
| Gross alpha | N | pCi/L | 98 | 42 | 43 | -3.1 | 5.5 | 1.9 | 12 | 6.0 | 5.5 | -- | -- | 15 | -- | 40 CFR 141 - Federal MCL |
| Gross beta | N | pCi/L | 97 | 88 | 91 | 1.8 | 8.0 | 2.4 | 51 | 14 | 10 | 3.1 | 87 | -- | -- | 40 CFR 141 - Federal MCL |
| Iodine-129 | N | pCi/L | 58 | 0 | 0 | -2.04 | 0.16 | -- | -- | -- | -- | 9.00E-07 | -- | 1.0 | -- | 40 CFR 141 - Federal MCL |
| Plutonium-238 | N | pCi/L | 57 | 3 | 5 | -1.7 | 0.28 | 0.26 | 0.30 | 0.28 | 0.29 | 4.99E-04 | 3 | 15 | -- | 40 CFR 141 - Federal MCL |
| Plutonium-239/240 | N | pCi/L | 57 | 5 | 9 | -0.044 | 1.1 | 0.061 | 0.67 | 0.35 | 0.40 | -- | -- | 15 | -- | 40 CFR 141 - Federal MCL |
| Strontium-90 | N | pCi/L | 83 | 25 | 30 | -8.4 | 1.5 | 0.36 | 26* | 7.1 | 5.3 | 0.0010 | 25 | 8.0 | 6 | 40 CFR 141 - Federal MCL |
| Technetium-99 | N | pCi/L | 58 | 5 | 9 | -11 | 3.1 | 9.0 | 40 | 19 | 16 | 0.83 | 5 | 900 | -- | 40 CFR 141 - Federal MCL |
| Thorium-230 | N | pCi/L | 57 | 0 | 0 | -0.13 | 0.23 | -- | -- | -- | -- | -- | -- | 15 | -- | 40 CFR 141 - Federal MCL |
| Tritium | N | pCi/L | 103 | 62 | 60 | -90 | 320 | 200 | 15,000 | 2,048 | 1,550 | 119 | 62 | 20,000 | -- | 40 CFR 141 - Federal MCL |
| **VOCs** | | | | | | | | | | | | | | | | |
| 1,1-Dichloroethene | N | µg/L | 84 | 0 | 0 | 0.083 | 1.0 | -- | -- | -- | -- | -- | -- | 0.057 (2) | -- (0) | 40 CFR 131 -- Human Health Water + Organism |
| 1,2-Dichloroethane | N | µg/L | 84 | 2 | 2 | 0.1 | 1 | 0.33 | 0.82 | 0.58 | 0.58 | -- | -- | 0.38 (5) | 1 (0) | Clean Water Act -- Human Health Water + Organism |
| 1,4-Dioxane | N | µg/L | 60 | 1 | 2 | 7.6 | 7.6 | 20 | 20 | 20 | 20 | -- | -- | 4.0 | 1 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Carbon tetrachloride | N | µg/L | 84 | 0 | 0 | 0.12 | 1.0 | -- | -- | -- | -- | -- | -- | 0.23 (1) | -- (0) | Clean Water Act -- Human Health Water + Organism |
| Chloroform | N | µg/L | 84 | 30 | 36 | 0.10 | 1.0 | 0.11 | 1.9 | 0.34 | 0.20 | -- | -- | 1.4 (5) | 2 (0) | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Styrene | N | µg/L | 57 | 9 | 16 | 0.07 | 0.074 | 0.10 | 0.52 | 0.20 | 0.14 | -- | -- | 100 | -- (0) | 40 CFR 141 - Federal MCL |
| Tetrachloroethene | N | µg/L | 84 | 4 | 5 | 0.18 | 1.0 | 0.44 | 3.6 | 1.5 | 0.92 | -- | -- | 0.081 (5) | 4 (0) | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Trichloroethene | N | µg/L | 84 | 43 | 51 | 0.21 | 1.0 | 0.25 | 20 | 6.3 | 4.7 | -- | -- | 0.49 (5) | 42 (21) | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Vinyl chloride | N | µg/L | 84 | 0 | 0 | 0.084 | 1.0 | -- | -- | -- | -- | -- | -- | 0.025 (5) | -- (0) | Clean Water Act -- Human Health Water + Organism |
| **Anions** | | | | | | | | | | | | | | | | |
| Fluoride | N | µg/L | 112 | 76 | 68 | 46 | 88 | 49 | 682 | 266 | 210 | 1,047 | -- | 960 | -- | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Nitrate | N | µg/L | 112 | 111 | 99 | 274 | 274 | 912 | 139,000 | 57,238 | 58,900 | 26,871 | 76 | 45,000 | 64 | 40 CFR 141 - Federal MCL |

Table 4-15. 100-F Groundwater Summary Statistics

| Analyte Name | Filtered | Units | Number of Results | Number of Detects | Frequency of Detects (%) | Min Non-Detect | Max Non-Detect | Min Detect | Max Detect | Mean Detect | Median Detect | Background 90th Percentile | No. of Detects > Background | Action Level (EQL) | No. of Detects >Action Level (>EQL) | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sulfate | N | µg/L | 112 | 111 | 99 | 130 | 130 | 8,830 | 136,000 | 62,962 | 51,100 | 47,014 | 59 | 250,000 | -- | 40 CFR 141 - Federal MCL |
| **Metals** | | | | | | | | | | | | | | | | |
| Aluminum | N | µg/L | 57 | 19 | 33 | 10 | 10 | 6.1 | 90 | 22 | 12 | 7.1 | 16 | 50 | 3 | 40 CFR 141 - Federal MCL |
| Aluminum | Y | µg/L | 56 | 5 | 9 | 5 | 10 | 4.6 | 23 | 13 | 12 | 7.1 | 4 | 50 | -- | 40 CFR 141 - Federal MCL |
| Antimony | N | µg/L | 110 | 2 | 2 | 0.30 | 60 | 38 | 44 | 41 | 41 | 55 | -- | 5.6 | 2 | Clean Water Act -- Human Health Water + Organism |
| Antimony | Y | µg/L | 110 | 2 | 2 | 0.30 | 60 | 4.1 | 52 | 28 | 28 | 55 | -- | 5.6 | 1 | Clean Water Act -- Human Health Water + Organism |
| Arsenic | N | µg/L | 57 | 48 | 84 | 0.80 | 0.80 | 0.68 | 12 | 4.6 | 3.7 | 7.9 | 7 | 0.018 | 48 | Clean Water Act -- Human Health Water + Organism |
| Arsenic | Y | µg/L | 56 | 47 | 84 | 0.80 | 0.80 | 0.82 | 11 | 4.7 | 3.9 | 7.9 | 10 | 0.018 | 47 | Clean Water Act -- Human Health Water + Organism |
| Beryllium | N | µg/L | 110 | 0 | 0 | 0.050 | 4.0 | -- | -- | -- | -- | 2.3 | -- | 4.0 | -- | 40 CFR 141 - Federal MCL |
| Beryllium | Y | µg/L | 110 | 0 | 0 | 0.050 | 4.0 | -- | -- | -- | -- | 2.3 | -- | 4.0 | -- | 40 CFR 141 - Federal MCL |
| Cadmium | N | µg/L | 110 | 0 | 0 | 0.055 | 4.0 | -- | -- | -- | -- | 0.92 | -- | 0.25 | -- | Clean Water Act -- Freshwater CCC |
| Cadmium | Y | µg/L | 110 | 1 | 0.9 | 0.10 | 4.0 | 0.059 | 0.059 | 0.059 | 0.059 | 0.92 | -- | 0.25 | -- | Clean Water Act -- Freshwater CCC |
| Chromium | N | µg/L | 110 | 79 | 72 | 1.0 | 13 | 1.3 | 98 | 14 | 7.6 | 2.4 | 77 | 65 | 1 | Clean Water Act -- Freshwater CCC |
| Chromium | Y | µg/L | 110 | 77 | 70 | 1.0 | 13 | 1.0 | 93 | 12 | 5.9 | 2.4 | 72 | 65 | 1 | Clean Water Act -- Freshwater CCC |
| Cobalt | N | µg/L | 110 | 16 | 15 | 0.050 | 5.0 | 0.099 | 13 | 2.2 | 0.16 | 0.92 | 3 | 2.6 | 3 | WAC 173-340-730(3)(b)(iii)(A) and (B) |
| Cobalt | Y | µg/L | 110 | 25 | 23 | 0.10 | 5.0 | 0.069 | 13 | 1.2 | 0.16 | 0.92 | 2 | 2.6 | 2 | WAC 173-340-730(3)(b)(iii)(A) and (B) |
| Copper | N | µg/L | 110 | 44 | 40 | 0.10 | 6.0 | 0.225 | 7.2 | 1.6 | 0.73 | 0.81 | 21 | 9.0 | -- | Clean Water Act -- Freshwater CCC |
| Copper | Y | µg/L | 110 | 38 | 35 | 0.20 | 6.0 | 0.217 | 6.9 | 1.6 | 0.61 | 0.81 | 15 | 9.0 | -- | Clean Water Act -- Freshwater CCC |
| Cr(VI) | N | µg/L | 75 | 29 | 39 | 2.0 | 3.7 | 2.3 | 92 | 15 | 11 | -- | -- | 10 | 16 | WAC 173-201A |
| Cr(VI) | Y | µg/L | 60 | 28 | 47 | 2.0 | 2.0 | 2.2 | 93 | 14 | 8.8 | -- | -- | 10 | 13 | WAC 173-201A |
| Lead | N | µg/L | 57 | 1 | 1.8 | 0.10 | 0.20 | 0.21 | 0.21 | 0.21 | 0.21 | 0.92 | -- | 2.1 | -- | WAC 173-201A |
| Lead | Y | µg/L | 56 | 0 | 0 | 0.10 | 0.20 | -- | -- | -- | -- | 0.92 | -- | 2.1 | -- | WAC 173-201A |
| Lithium | N | µg/L | 57 | 38 | 67 | 4.0 | 4.0 | 4.0 | 53 | 19 | 15 | 11 | 24 | 32 | 6 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Lithium | Y | µg/L | 56 | 37 | 66 | 4.0 | 4.0 | 4.0 | 54 | 19 | 14 | 11 | 25 | 32 | 6 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Manganese | N | µg/L | 110 | 15 | 14 | 3.3 | 6.0 | 4.2 | 135 | 19 | 8.7 | 39 | 1 | 50 | 1 | 40 CFR 141 - Federal MCL |
| Manganese | Y | µg/L | 110 | 5 | 5 | 2.5 | 6.0 | 5.6 | 126 | 36 | 15 | 39 | 1 | 50 | 1 | 40 CFR 141 - Federal MCL |
| Mercury | N | µg/L | 57 | 0 | 0 | 0.050 | 0.10 | -- | -- | -- | -- | 0.0030 | -- | 0.012 | -- | 40 CFR 131 -- Freshwater CCC |
| Mercury | Y | µg/L | 56 | 0 | 0 | 0.016 | 0.10 | -- | -- | -- | -- | 0.0030 | -- | 0.012 | -- | 40 CFR 131 -- Freshwater CCC |
| Nickel | N | µg/L | 110 | 16 | 15 | 4.0 | 67 | 4.0 | 36 | 12 | 6.2 | 1.6 | 16 | 52 | -- | Clean Water Act -- Freshwater CCC |

Table 4-15. 100-F Groundwater Summary Statistics

| Analyte Name | Filtered | Units | Number of Results | Number of Detects | Frequency of Detects (%) | Min Non-Detect | Max Non-Detect | Min Detect | Max Detect | Mean Detect | Median Detect | Background 90th Percentile | No. of Detects > Background | Action Level (EQL) | No. of Detects >Action Level (>EQL) | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nickel | Y | µg/L | 110 | 16 | 15 | 4.0 | 67 | 4.0 | 30 | 11 | 5.0 | 1.6 | 16 | 52 | -- | Clean Water Act -- Freshwater CCC |
| Selenium | N | µg/L | 57 | 39 | 68 | 0.30 | 0.60 | 0.64 | 5.4 | 2.6 | 2.6 | 11 | -- | 5.0 | 1 | Clean Water Act -- Freshwater CCC |
| Selenium | Y | µg/L | 56 | 38 | 68 | 0.60 | 0.60 | 0.63 | 5.4 | 2.7 | 2.7 | 11 | -- | 5.0 | 3 | Clean Water Act -- Freshwater CCC |
| Thallium | N | µg/L | 57 | 0 | 0 | 0.050 | 0.55 | -- | -- | -- | -- | 1.7 | -- | 0.24 | -- | Clean Water Act -- Human Health Water + Organism |
| Thallium | Y | µg/L | 56 | 1 | 1.8 | 0.050 | 0.10 | 1.1 | 1.1 | 1.1 | 1.1 | 1.7 | -- | 0.24 | 1 | Clean Water Act -- Human Health Water + Organism |
| Zinc | N | µg/L | 110 | 20 | 18 | 4.0 | 9.0 | 4.0 | 21 | 11 | 9.7 | 22 | -- | 91 | -- | WAC 173-201A |
| Zinc | Y | µg/L | 110 | 17 | 15 | 4.0 | 9.6 | 4.0 | 22 | 9.8 | 7.8 | 22 | -- | 91 | -- | WAC 173-201A |

Note: Groundwater data from 100-F wells screened in the unconfined aquifer and sampled between January 2007 and December 2011. See Figure 4-16 for wells included. Data from temporary wells 199-F5-55 and 199-F5-56 were not included in this evaluation. In 2011, the maximum strontium-90 concentrations in 199-F5-55 and 199-F5-56 were 285 pCi/L and 80 pCi/L, respectively (Section 4.3.2).

Sources: 40 CFR 131, "Water Quality Standards."

40 CFR 141, "National Primary Drinking Water Regulations."

40 CFR 141.66, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels for Radionuclides."

*Clean Water Act of 1977*.

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

WAC 173-340-730, "Model Toxics Control Act—Cleanup," "Surface Water Cleanup Standards."

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Strontium-90 was detected in 30 percent of the unfiltered samples and was not analyzed for in filtered samples. Concentrations ranged from 0.36 to 26 pCi/L[1] and exceeded the DWS of 8 pCi/L in 24 percent of the detected results. Concentrations above the DWS were reported as follows:

- All five sample results from 199-F5-1 (12 to 26 pCi/L)
- One of six sample results from 199-F5-46 (less than 0.99 to 8.3 pCi/L)

*100-F Historical COPCs.* Historical COPCs are those analytes that were identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4), or those analytes for which a maximum concentration exceeding an action limit was reported during the spatial and temporal sampling (Section 6.3). The following descriptions include radionuclides, VOCs, anions, and metals.

*Radionuclides.* Americium-241, carbon-14, plutonium-238, plutonium-239/240, technetium-99, and tritium were identified as historical COPCs in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). Gross alpha was not identified as a COPC but was subsequently added per Step 4 of the Integrated 100 Area RI/FS Work Plan (DOE/RL-2008-46). Although these radionuclides were detected at concentrations below their DWS, limited analytical results were available for evaluation during preparation of the work plan to determine their presence or absence in 100-F groundwater. All samples included in the evaluation for americium-241, carbon-14, plutonium-238, and plutonium-239/240 were collected as part of the spatial and temporal sampling activities of the RI. As shown in Table 4-15, all results for these seven radionuclides were less than their DWS. Detected concentrations were greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration when available (Table 4-15). Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, americium-241, carbon-14, plutonium-238, plutonium-239/240, technetium-99, and tritium are not retained as COPCs to be further evaluated in the FS.

Cesium-137, cobalt-60, europium-154, iodine-129, and thorium-230 were identified as historical COPCs in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). Limited analytical results were available for evaluation to determine their presence or absence in 100-F groundwater. For cesium-137, cobalt-60, europium-154, and iodine-129, all but one sample included in this evaluation were collected as part of the spatial and temporal sampling activities of the RI. For thorium-230, all samples included in this evaluation were collected as part of the spatial and temporal sampling activities of the RI. These five radionuclides were not detected in any samples, and all MDLs were less than their respective DWS (Table 4-15). Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, cesium-137, cobalt-60, europium-154, iodine-129, and thorium-230 are not retained as COPCs to be further evaluated in the FS.

Gross beta was not identified as a historical COPC in the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4) but was subsequently added per Step 4 of the Integrated 100 Area RI/FS Work Plan (DOE/RL-2008-46). Gross beta is considered an indicator parameter, and its presence is generally associated with the presence of beta emitting isotopes such as technetium-99 and strontium-90. Gross beta concentrations are greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 3.1 pCi/L. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, gross beta is not retained as a COPC to be further evaluated in the FS.

*Volatile Organic Compounds.* 1,1-Dichloroethene was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the action level, and most MDLs were greater than the action level. The action level for 1,1-dichloroethene is 0.057 µg/L

[1] Data from temporary wells 199-F5-55 and 199-F5-56 were not included in this evaluation. In 2011, the maximum strontium-90 concentrations in 199-F5-55 and 199-F5-56 were 285 pCi/L and 80 pCi/L, respectively (Section 4.3.2).

based on the "Water Quality Standards" (40 CFR 131) Human Health Water + Organism value; however, it defaults to the EQL of 2 µg/L listed in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All results were less than detection limits. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, 1,1-dichloroethene is not retained as a COPC to be further evaluated in the FS.

1,2-Dichloroethane is included in the nature and extent evaluation, but it was not identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). 1,2-Dichloroethane was detected above the action level of 0.38 µg/L in samples collected for the RI. The action level for 1,2-dichloroethane is 0.38 µg/L based on the *National Recommended Water Quality Criteria* (EPA, 2009a), "Human Health Water + Organism" value; however, it defaults to the EQL of 5 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All results (detected concentrations and MDLs) are less than the EQL. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, 1,2-dichloroethane is not retained as a COPC to be further evaluated in the FS.

1,4-Dioxane is included in the nature and extent evaluation, but it was not identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). It was detected above the action level of 4.0 µg/L in a single sample collected for the RI. A concentration of 20 µg/L was reported at Well 199-F8-7; two subsequent sampling rounds were reported as not detected. All MDLs were reported as 7.6 µg/L, which is above the action level. Although all 1,4-dioxane results (detected concentrations and MDLs) are above the action level, this analyte is not associated with a Hanford site release and results suggest it is not associated with a trend. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, 1,4-dioxane is not retained as a COPC to be further evaluated in the FS.

Carbon tetrachloride was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the action level, and most MDLs were greater than the action level. Carbon tetrachloride was not detected in any samples. The action level for carbon tetrachloride is 0.23 µg/L based on the *National Recommended Water Quality Criteria* (EPA, 2009a), "Human Health Water + Organism" value; however, it defaults to the EQL of 1 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, carbon tetrachloride is not retained as a COPC to be further evaluated in the FS.

Chloroform was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and most MDLs were greater than the action level. The action level for chloroform is 1.4 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; however, it defaults to the EQL of 5 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All results were less than the EQL. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, chloroform is not retained as a COPC to be further evaluated in the FS.

Styrene was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because all MDLs were above the action level. All results were less than the DWS of 100 µg/L. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, styrene is not retained as a COPC to be further evaluated in the FS.

Tetrachloroethene was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the action level and most MDLs were greater than the action level. The action level for tetrachloroethene is 0.081 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; however, it defaults to the EQL

of 5 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All results were less than the EQL. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, tetrachloroethene is not retained as a COPC to be further evaluated in the FS.

Vinyl chloride was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because all MDLs were above the action level. Vinyl chloride was not detected in any samples. The action level for vinyl chloride is 0.025 µg/L based on the *National Recommended Water Quality Criteria* (EPA, 2009a), "Human Health Water + Organism" value; however, it defaults to the EQL of 5 µg/L listed in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, vinyl chloride is not retained as a COPC to be further evaluated in the FS.

*Anions.* Fluoride was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level. All fluoride results were less than the action level of 960 µg/L. Fluoride results were also less than the Hanford Site 90$^{th}$ percentile (unfiltered) concentration of 1,047 µg/L. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, fluoride is not retained as a COPC to be further evaluated in the FS.

Sulfate was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the secondary DWS. All sulfate results were less than the secondary DWS of 250 mg/L. Sulfate concentrations were greater than the Hanford Site 90$^{th}$ percentile (unfiltered) background concentration of 47 mg/L. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, sulfate is not retained as a COPC to be further evaluated in the FS.

*Metals.* Aluminum is included in the nature and extent evaluation, but it was not identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). Aluminum was detected above the secondary DWS of 50 µg/L in samples collected for the RI. All samples included in this evaluation were collected as part of the spatial and temporal sampling activities of the RI. Aluminum concentrations ranged from 6.1 to 90 µg/L in unfiltered samples and from 4.6 to 23 µg/L in filtered samples. A single aluminum concentration exceeding the secondary DWS was reported in an unfiltered sample at Well 199-F8-7; aluminum concentrations for the corresponding filtered sample as well as for the previous two sampling rounds were all below the action level. Aluminum is naturally present in aquifer sediment, and the exceedance was probably the result of suspended sediment in the sample. Aluminum concentrations in filtered and unfiltered samples are greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 7.1 µg/L. Based on the results of this evaluation and the groundwater risk assessment presented in Section 6.3, aluminum is not retained as a COPC to be further evaluated in the FS.

Antimony was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and most MDLs were greater than the action level. Samples collected for purposes other than the RI were analyzed using Method 6010. The only detected concentrations were reported by this method, and the filtered and unfiltered concentrations ranged from 4.1 to 52 µg/L, three of which exceed the action level of 5.6 µg/L. The MDLs reported by Method 6010 ranged from 4 to 60 µg/L, almost all of which exceed the action level. Antimony results (detected concentrations and MDLs) reported by Method 6010 are not accurate at concentrations at or near the action level. The samples collected for the RI were analyzed using the trace methods identified in the 100-F/IU SAP (DOE/RL-2009-43). All RI samples were reported as not detected, and the MDLs were less than the action level of 5.6 µg/L. Antimony concentrations in unfiltered and filtered samples were less than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 55 µg/L. Based on the

results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, antimony is retained as a COPC and warrants further evaluation in the FS.

Arsenic was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. All samples included in this evaluation were collected as part of the spatial and temporal sampling activities of the RI. Arsenic concentrations ranged from 0.68 to 12 µg/L in unfiltered samples and from 0.82 to 11 µg/L in filtered samples (Table 4-15). Minimum, maximum, and 90$^{th}$ percentile values for Hanford Site (filtered) background concentrations of arsenic are 0.5, 8.8, and 7.9 µg/L, respectively. Arsenic was consistently reported above the 90$^{th}$ percentile background concentration at the following wells:

- Five of six sample results at 199-F1-2 (3.6 to 9.7 µg/L)
- All six sample results at 199-F7-1 (9.4 to 12 µg/L)

A single arsenic detection was reported above the 90$^{th}$ percentile background concentration at the following wells:

- One of six sample results at 199-F5-48 (0.8U to 9.9 µg/L)
- One of six sample results at 199-F7-2 (6.1 to 8.1 µg/L)
- One of six sample results at 199-F7-3 (5.8 to 8.6 µg/L)
- One of six sample results at 699-77-36 (7.7 to 9.0 µg/L)

The results of this evaluation indicate that arsenic was detected in RI groundwater samples above the EQL of 4 µg/L and above the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 7.9 µg/L. However, arsenic concentrations are within or only slightly above the range observed in background wells. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, arsenic is not retained as a COPC for further evaluation in the FS.

Beryllium was identified as a COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level. Beryllium was not detected in any unfiltered or unfiltered samples and all MDLs were less than or equal to the action level of 4 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, beryllium is not retained as a COPC for further evaluation in the FS.

Cadmium was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. Samples collected for purposes other than the RI were analyzed by Method 6010. MDLs for these results ranged from 0.9 to 4 µg/L, which are higher than the action level of 0.25 µg/L. No detected results were reported by Method 6010. Cadmium results (detected concentrations and MDLs) reported by Method 6010 are not accurate at concentrations at or near the action level. Samples collected for the RI were analyzed using the trace methods identified in the 100-F/IU SAP (DOE/RL-2009-43). All cadmium results for RI samples were less than the action level of 0.25 µg/L and less than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 0.92 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, cadmium is retained as a COPC for further evaluation in the FS.

Chromium was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level. Total chromium concentrations above the AWQC of 65 µg/L were reported in the unfiltered sample (98 µg/L) and the filtered sample (93 µg/L) during the same sampling round at Well 199-F5-46. The remaining ten chromium results at this location were below the AWQC with concentrations ranging from 21 to 42 µg/L. Chromium concentrations in filtered and

unfiltered samples are greater than the Hanford Site 90th percentile (filtered) background concentration of 2.4 µg/L. Total chromium in 100-F groundwater represents Cr(VI), which is retained as a COPC for further evaluation in the FS.

Cobalt was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the action level, and MDLs were greater than the action level. Concentrations ranged from 0.07 to 13 µg/L. Samples collected for purposes other than the RI were analyzed by Method 6010. MDLs for these results ranged from 4 to 5 µg/L. These MDLs and the nine detected concentrations reported by Method 6010 are above the action level of 2.6 µg/L. The detected results reported by Method 6010 were flagged with "B" or "C" laboratory qualifiers. A "B" qualifier indicates that an analyte was detected at a value less than the contract- required detection limit but greater than or equal to the MDL. A "C" qualifier indicates that the analyte was detected in both the sample and the associated QC blank, and the sample concentration was less than or equal to five times the blank concentration. Cobalt results (detected concentrations and MDLs) reported by Method 6010 are not accurate at concentrations at or near the action level. Samples collected for the RI were analyzed using the trace methods identified in the 100-F/IU SAP (DOE/RL-2009-43). MDLs for these samples ranged from 0.05 to 0.22 µg/L. All MDLs and detected results reported by the trace methods were below the action level of 2.6 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, cobalt is retained as a COPC for further evaluation in the FS.

Copper was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. All copper results were less than the AWQC of 9.0 µg/L. Copper concentrations in filtered and unfiltered samples are greater than the Hanford Site 90th percentile (filtered) background concentration of 0.81 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, copper is not retained as a COPC for further evaluation in the FS.

Lead was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. All samples included in this evaluation were collected as part of the spatial and temporal sampling activities of the RI. All lead results were less than the AWQC of 2.1 µg/L. The unfiltered lead concentration was less than the Hanford Site 90th percentile (filtered) background concentration of 0.92 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, lead is not retained as a COPC for further evaluation in the FS.

Lithium is included in the nature and extent evaluation, but it was not identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). All samples included in this evaluation were collected as part of the spatial and temporal sampling activities of the RI. Lithium results above the action level were reported at Wells 199-F5-4 (38 and 39 µg/L), 199-F5-45 (36 and 38 µg/L), 199-F5-48 (36 and 37 µg/L), 199-F8-3 (53 and 54 µg/L), 199-F8-4 (34 and 35 µg/L), and 199-F8-7 (41 and 43 µg/L). The exceedances occurred in both filtered and unfiltered samples from a single sampling round at each of these wells. Lithium concentrations for the previous and subsequent sampling rounds were all below the action level. Lithium is not associated with a Hanford Site release, and its infrequent presence does not suggest a trend. Lithium concentrations in filtered and unfiltered samples are greater than the Hanford Site 90th percentile (unfiltered) background concentration of 11.3 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, lithium is not retained as a COPC for further evaluation in the FS.

Manganese was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the secondary DWS of 50 µg/L. One filtered and one unfiltered sample

from Well 199-F8-7 exceeded the secondary DWS with measured concentrations up to 135 µg/L. These concentrations were greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 39 µg/L. The elevated concentrations were from the first samples from this well, and subsequent results were lower. Drilling activities can temporarily increase the solubility of manganese. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, manganese is not retained as a COPC for further evaluation in the FS.

Mercury was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the AWQC, and MDLs were greater than the AWQC. All samples included in this evaluation were collected as part of the spatial and temporal sampling activities of the RI. Mercury was not detected in groundwater samples. The action level for mercury is 0.012 µg/L based on the AWQC; however, it defaults to the EQL of 0.5 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, mercury is not retained as a COPC for further evaluation in the FS.

Nickel was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the AWQC. All nickel results were less than the AWQC of 52 µg/L. Nickel concentrations in filtered and unfiltered samples are greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 1.6 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, nickel is not retained as a COPC for further evaluation in the FS.

Selenium was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the AWQC, and MDLs were greater than the AWQC. All samples included in this evaluation were collected as part of the spatial and temporal sampling activities of the RI. Four samples were reported with concentrations greater than or equal to the AWQC of 5 µg/L. However, all selenium concentrations in filtered and unfiltered samples are less than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 11 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, selenium is not retained as a COPC for further evaluation in the FS.

Thallium was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. The action level for thallium is 0.24 µg/L based on the *National Recommended Water Quality Criteria* (EPA, 2009a) "Human Health for Consumption of Water plus Organism;" however, it defaults to the EQL of 2 µg/L identified in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All thallium results were less than the EQL. The filtered thallium concentration is less than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 1.7 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, thallium is not retained as a COPC for further evaluation in the FS.

Zinc was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the AWQC. All zinc results were less than the AWQC of 91 µg/L. Zinc concentrations in filtered and unfiltered samples were less than or equal to the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 22 µg/L. Based on the results of this evaluation and the results of the groundwater risk assessment presented in Section 6.3, zinc is not retained as a COPC for further evaluation in the FS.

*Summary of the 100-F Groundwater Evaluation.* Table 4-16 summarizes the outcome of the analysis. Contaminants that warrant further evaluation in the FS are Cr(VI), nitrate, strontium-90, and trichloroethene.

Gross beta concentrations were greater than the Hanford Site 90$^{th}$ percentile background concentration in some 100-F monitoring wells, reflecting the presence of strontium-90. Total chromium concentrations above the AWQC of 65 µg/L were reported in samples associated with a single sampling round in one well. Total chromium in 100-F groundwater reflects the presence of Cr(VI).

Uncertainties identified for the COPCs in the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4) were generally associated with limitations in the analytical methods selected for analysis. Action levels for some of the metals and VOCs require methods that can measure the analyte at low levels and require the use of analytical methods that can detect analytes at trace levels. Use of Method 6010 for metals resulted in the introduction of uncertainties for antimony, cadmium, and cobalt because of low sensitivity of the method at low concentrations. Analytical results from Method 6010 are not adequate for determining the presence of antimony, cadmium, or cobalt at or near the action level.

Table 4-16. Summary of 100-F Groundwater Contaminant Evaluation

| Category | Constituent |
|---|---|
| Contaminant of potential concern[a] (contaminants that warrant further evaluation in FS) | Cr(VI), nitrate, strontium-90, trichloroethene |
| Detected at levels above action level and background | Gross beta[b], chromium[d] |
| Detected above action level only in samples analyzed by Method 6010 | Antimony, cadmium, cobalt |
| Detected above action level, but isolated instances and/or suspect data | 1,4-dioxane, aluminum, lithium |
| Detected in groundwater but below action level, EQL, or background concentrations | Gross alpha, americium-241, carbon-14, plutonium-238, plutonium-239/240, technetium-99, tritium, 1,2-dichloroethane, chloroform, styrene, tetrachloroethene, fluoride, sulfate, antimony, arsenic[c], cadmium, cobalt, copper, lead, manganese, nickel, selenium, thallium, zinc |
| Not detected in groundwater | Cesium-137, cobalt-60, europium-154, iodine-129, thorium-230, 1,1-dichloroethene, carbon tetrachloride, vinyl chloride, beryllium, mercury |

Based on evaluation of data collected January 2007 through December 2011.

a. See discussion in Section 4.3.3.

b. Gross beta indicates presence of strontium-90 or technetium-99. See results for those radionuclides.

c. Some concentrations slightly above background levels

d. Total chromium because of Cr(VI) (Section 4.3.3)

#### *4.3.1.2 Groundwater Evaluation for 100-IU-2/IU-6.*

There are a number of groundwater OUs across the Hanford Site. These groundwater OUs are the result of releases from Central Plateau and River Corridor sources. Because a groundwater OU does not exist, this RI evaluates whether additional OUs are needed to address groundwater contamination sources from 100-IU-2/IU-6.

This evaluation of nature and extent of COPCs in groundwater was based on samples collected between January 23, 2007, and December 15, 2011, from wells screened in the unconfined aquifer. Section 4.3.4 presents additional information about the nature and extent of groundwater contamination in 100-IU-2/IU-6.

Groundwater data for 100-IU-2/IU-6 were compiled and statistically analyzed, and the results are presented in Table 4-17. This table presents the summary statistics for each analyte identified as a COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) and the 100-F/IU SAP (DOE/RL-2009-43). The table also lists the background concentrations in Hanford Site groundwater (*Hanford Site Background: Part 3, Groundwater Background* [DOE/RL-96-61]), where available, and the lowest action level for each contaminant.

Figure 4-17 provides the locations of the wells included in the nature and extent evaluation. Many of the wells in 100-IU-2/IU-6 were drilled decades ago, and may have carbon steel casing with perforations instead of fabricated well screens. Some "wells" were drilled for geologic characterization and were not intended to be used for groundwater monitoring. Although these were not sampled for the RI, all of the data were considered in this evaluation. Results from some boreholes may not be representative of groundwater quality in the unconfined aquifer.

*100-IU-2/IU-6 Historical COPCs.* Historical COPCs are those analytes that were identified in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4), or those analytes for which a maximum concentration exceeding an action level (see beginning of Section 4.3.1.1 for definition of an action level) was reported during the spatial and temporal sampling.

The following descriptions include radionuclides, VOCs, anions, metals, and other analytes.

*Radionuclides.* Tritium was detected in 63 percent of the samples at concentrations ranging from 230 to 97,000 pCi/L. Tritium was reported above the DWS of 20,000 pCi/L in 26 monitoring wells. The Sitewide tritium plume is within the 200-PO-1 groundwater OU.

Iodine-129 was detected in 32 percent of the samples at concentrations ranging from 0.17 to 6.3 pCi/L. MDAs were below the DWS for 93 percent of the results. As with tritium, the Sitewide iodine-129 plume is within the 200-PO-1 groundwater OU. Iodine concentrations are greater than the Hanford Site 90$^{th}$ percentile background concentration of 0.0000009 pCi/L.

Americium-241, carbon-14, radium-228, strontium-90, and technetium-99 were identified as historical COPCs in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). Gross alpha was not identified as a historical COPC but was subsequently added per Step 4 of the Integrated Work Plan (DOE/RL-2008-46). Although these radionuclides were detected at concentrations below their DWS, limited analytical results were available for evaluation during preparation of the work plan to determine their presence or absence in 100-IU-2/IU-6 groundwater. All samples included in the evaluation for americium-241 carbon-14, and radium-228 were collected as part of the spatial and temporal sampling activities of the RI, as well as an additional sampling round at Well 699-20-E5A. As shown in Table 4-17, all results for these six radionuclides were less than the DWS. Detected concentrations are greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration when available (Table 4-17).

Cesium-137, cobalt-60, europium-152, europium-154, and europium-155 were identified as historical COPCs in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). They were not detected in any samples, and all MDLs were less than their respective DWS (Table 4-17).

Table 4-17. 100-IU-2/IU-6 Groundwater Area Summary Statistics

| Analyte Name | Filtered | Units | Number of Results | Number of Detects | Frequency of Detects (%) | Minimum Non-Detect | Maximum Non-Detect | Minimum Detect | Maximum Detect | Mean Detect | Median Detect | Background 90th Percentile | Detects > Background | Action Level (EQL) | Detects > Action Level (>EQL) | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Radionuclides** | | | | | | | | | | | | | | | | |
| Americium-241 | N | pCi/L | 109 | 5 | 5 | -0.24 | 2.1 | 0.081 | 0.13 | 0.099 | 0.090 | 7.70E-05 | 5 | 15 | -- | 40 CFR 141 - Federal MCL |
| Carbon-14 | N | pCi/L | 109 | 16 | 15 | -3.7 | 7.8 | 8.2 | 16 | 11 | 11 | -- | -- | 2,000 | -- | 40 CFR 141.66 |
| Cesium-137 | N | pCi/L | 152 | 0 | 0 | -3.4 | 2.4 | -- | -- | -- | -- | 8.6 | -- | 200 | -- | 40 CFR 141 - Federal MCL |
| Cobalt-60 | N | pCi/L | 152 | 0 | 0 | -2.2 | 6.9 | -- | -- | -- | -- | 0.023 | -- | 100 | -- | 40 CFR 141 - Federal MCL |
| Europium-152 | N | pCi/L | 152 | 0 | 0 | -6.4 | 11 | -- | -- | -- | -- | 222 | -- | 200 | -- | 40 CFR 141 - Federal MCL |
| Europium-154 | N | pCi/L | 152 | 0 | 0 | -6.4 | 16 | -- | -- | -- | -- | 70 | -- | 60 | -- | 40 CFR 141 - Federal MCL |
| Europium-155 | N | pCi/L | 152 | 0 | 0 | -11 | 8.9 | -- | -- | -- | -- | 5.9 | -- | 600 | -- | 40 CFR 141 - Federal MCL |
| Gross alpha | N | pCi/L | 176 | 72 | 41 | -2.3 | 6.4 | 1.1 | 14 | 3.2 | 2.7 | -- | -- | 15 | -- | 40 CFR 141 - Federal MCL |
| Gross beta | N | pCi/L | 177 | 160 | 90 | -0.31 | 4.7 | 2.2 | 110 | 30 | 14 | 3.1 | 159 | -- | -- | 40 CFR 141 - Federal MCL |
| Iodine-129 | N | pCi/L | 199 | 63 | 32 | -1.4 | 5.6 | 0.17 | 6.3 | 2.0 | 0.77 | 9.00E-07 | 63 | 1.0 | 29 | 40 CFR 141 - Federal MCL |
| Radium-228 | N | pCi/L | 109 | 1 | 1 | -1.2 | 1.9 | 2.4 | 2.4 | 2.4 | 2.4 | -- | -- | 5.0 | -- | 40 CFR 141 - Federal MCL |
| Strontium-90 | N | pCi/L | 171 | 3 | 2 | -11 | 4.7 | 2.0 | 4.7 | 3.1 | 2.5 | 0.0010 | 3 | 8.0 | -- | 40 CFR 141 - Federal MCL |
| Technetium-99 | N | pCi/L | 164 | 77 | 47 | -15 | 7.7 | 6.7 | 170 | 88 | 97 | 0.83 | 77 | 900 | -- | 40 CFR 141 - Federal MCL |
| Tritium | N | pCi/L | 241 | 153 | 63 | -220 | 190 | 230 | 97,000 | 29,108 | 29,000 | 119 | 153 | 20,000 | 81 | 40 CFR 141 - Federal MCL |
| **VOCs** | | | | | | | | | | | | | | | | |
| 1,1-Dichloroethene | N | µg/L | 168 | 2 | 1 | 0.045 | 1.0 | 0.14 | 0.14 | 0.14 | 0.14 | -- | -- | 0.057 (2) | 2 (0) | 40 CFR 131 – Human Health Water + Organism |
| Benzene | N | µg/L | 168 | 6 | 4 | 0.032 | 1.0 | 0.069 | 35 | 6.4 | 0.27 | -- | -- | 0.80 (1.5) | 2 (2) | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Carbon tetrachloride | N | µg/L | 168 | 1 | 0.6 | 0.039 | 1.0 | 5.4 | 5.4 | 5.4 | 5.4 | -- | -- | 0.23 (1) | 1 (1) | Clean Water Act – Human Health Water + Organism |
| Chloroform | N | µg/L | 168 | 29 | 17 | 0.048 | 1.0 | 0.071 | 0.79 | 0.25 | 0.14 | -- | -- | 1.4 (5) | -- (0) | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Tetrachloroethene | N | µg/L | 168 | 1 | 0.6 | 0.065 | 1.0 | 0.48 | 0.48 | 0.48 | 0.48 | -- | -- | 0.081 (5) | 1 (0) | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Trichloroethene | N | µg/L | 168 | 22 | 13 | 0.037 | 1.0 | 0.35 | 11 | 2.5 | 1.1 | -- | -- | 0.49 (1) | 15 (13) | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Vinyl chloride | N | µg/L | 168 | 2 | 1 | 0.032 | 1.0 | 0.68 | 3.9 | 2.3 | 2.3 | -- | -- | 0.025 (5) | 2 (0) | Clean Water Act – Human Health Water + Organism |
| **Anions** | | | | | | | | | | | | | | | | |
| Fluoride | N | µg/L | 255 | 238 | 93 | 20 | 1,500 | 21 | 1,050 | 316 | 285 | 1,047 | 1 | 960 | 1 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Nitrate | N | µg/L | 255 | 245 | 96 | 137 | 7,080 | 602 | 101,000 | 21,343 | 20,400 | 26,871 | 76 | 45,000 | 9 | 40 CFR 141 - Federal MCL |

Table 4-17. 100-IU-2/IU-6 Groundwater Area Summary Statistics

| Analyte Name | Filtered | Units | Number of Results | Number of Detects | Frequency of Detects (%) | Minimum Non-Detect | Maximum Non-Detect | Minimum Detect | Maximum Detect | Mean Detect | Median Detect | Background 90th Percentile | Detects > Background | Action Level (EQL) | Detects > Action Level (>EQL) | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Metals** | | | | | | | | | | | | | | | | |
| Aluminum | N | µg/L | 113 | 26 | 23 | 5.0 | 10 | 5.5 | 506 | 90 | 29 | 7.1 | 25 | 50 | 9 | 40 CFR 141 - Federal MCL |
| Aluminum | Y | µg/L | 113 | 5 | 4 | 5.0 | 10 | 5.4 | 52 | 21 | 11 | 7.1 | 4 | 50 | 1 | 40 CFR 141 - Federal MCL |
| Antimony | N | µg/L | 203 | 3 | 1.5 | 0.30 | 60 | 42 | 58 | 50 | 51 | 55 | 1 | 5.6 | 3 | Clean Water Act – Human Health Water + Organism |
| Antimony | Y | µg/L | 214 | 2 | 1 | 0.30 | 60 | 4.6 | 55 | 30 | 30 | 55 | -- | 5.6 | 1 | Clean Water Act – Human Health Water + Organism |
| Arsenic | N | µg/L | 137 | 120 | 88 | 0.40 | 0.80 | 1.0 | 16 | 5.4 | 4.9 | 7.9 | 20 | 0.018 | 120 | Clean Water Act – Human Health Water + Organism |
| Arsenic | Y | µg/L | 138 | 119 | 86 | 0.40 | 1.6 | 0.83 | 15 | 5.5 | 5.2 | 7.9 | 20 | 0.018 | 119 | Clean Water Act – Human Health Water + Organism |
| Cadmium | N | µg/L | 203 | 3 | 1.5 | 0.055 | 4.1 | 0.50 | 4.9 | 2.0 | 0.55 | 0.92 | 1 | 0.25 | 3 | Clean Water Act – Freshwater CCC |
| Cadmium | Y | µg/L | 214 | 1 | 0.5 | 0.055 | 4.1 | 4.6 | 4.6 | 4.6 | 4.6 | 0.92 | 1 | 0.25 | 1 | Clean Water Act – Freshwater CCC |
| Cobalt | N | µg/L | 203 | 24 | 12 | 0.050 | 5.0 | 0.12 | 10 | 2.6 | 0.59 | 0.92 | 8 | 2.6 | 7 | WAC 173-340-730(3)(b)(iii)(A) and (B) |
| Cobalt | Y | µg/L | 214 | 40 | 19 | 0.050 | 5.0 | 0.074 | 23 | 2.8 | 0.21 | 0.92 | 15 | 2.6 | 12 | WAC 173-340-730(3)(b)(iii)(A) and (B) |
| Copper | N | µg/L | 203 | 43 | 21 | 0.097 | 6.0 | 0.20 | 118 | 5.3 | 0.92 | 0.81 | 24 | 9.0 | 4 | Clean Water Act – Freshwater CCC |
| Copper | Y | µg/L | 214 | 19 | 9 | 0.097 | 6.0 | 0.22 | 15 | 2.2 | 0.52 | 0.81 | 5 | 9.0 | 1 | Clean Water Act – Freshwater CCC |
| Cr(VI) | N | µg/L | 127 | 36 | 28 | 2.0 | 3.7 | 2.2 | 24 | 8.5 | 7.2 | -- | -- | 10 | 11 | WAC 173-201A |
| Cr(VI) | Y | µg/L | 118 | 32 | 27 | 2.0 | 3.7 | 2.4 | 23 | 8.5 | 5.9 | -- | -- | 10 | 9 | WAC 173-201A |
| Iron | N | µg/L | 203 | 176 | 87 | 18 | 38 | 9.8 | 18,900 | 806 | 137 | 570 | 35 | 300 | 59 | 40 CFR 141 - Federal MCL |
| Iron | Y | µg/L | 214 | 108 | 50 | 9.0 | 38 | 9.2 | 18,100 | 651 | 47 | 570 | 9 | 300 | 13 | 40 CFR 141 - Federal MCL |
| Lead | N | µg/L | 134 | 51 | 38 | 0.10 | 0.20 | 0.10 | 13 | 1.4 | 0.47 | 0.92 | 15 | 2.1 | 9 | WAC 173-201A |
| Lead | Y | µg/L | 134 | 16 | 12 | 0.10 | 0.20 | 0.11 | 4.7 | 0.90 | 0.38 | 0.92 | 3 | 2.1 | 2 | WAC 173-201A |
| Manganese | N | µg/L | 203 | 100 | 49 | 4.0 | 6.0 | 4.0 | 1,160 | 72 | 24 | 39 | 35 | 50 | 32 | 40 CFR 141 – Federal MCL |
| Manganese | Y | µg/L | 214 | 71 | 33 | 2.5 | 6.0 | 4.4 | 1,220 | 76 | 20 | 39 | 22 | 50 | 18 | 40 CFR 141 – Federal MCL |

Table 4-17. 100-IU-2/IU-6 Groundwater Area Summary Statistics

| Analyte Name | Filtered | Units | Number of Results | Number of Detects | Frequency of Detects (%) | Minimum Non-Detect | Maximum Non-Detect | Minimum Detect | Maximum Detect | Mean Detect | Median Detect | Background 90th Percentile | Detects > Background | Action Level (EQL) | Detects > Action Level (>EQL) | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mercury | N | µg/L | 112 | 0 | 0 | 0.050 | 0.10 | -- | -- | -- | -- | 0.0030 | -- | 0.012 | -- | 40 CFR 131 – Freshwater CCC |
| Mercury | Y | µg/L | 111 | 0 | 0 | 0.050 | 0.10 | -- | -- | -- | -- | 0.0030 | -- | 0.012 | -- | 40 CFR 131 – Freshwater CCC |
| Nickel | N | µg/L | 203 | 14 | 7 | 4.0 | 67 | 4.0 | 44 | 11 | 6.0 | 1.6 | 14 | 52 | -- | Clean Water Act – Freshwater CCC |
| Nickel | Y | µg/L | 214 | 12 | 6 | 4.0 | 67 | 4.0 | 34 | 10 | 6.8 | 1.6 | 12 | 52 | -- | Clean Water Act – Freshwater CCC |
| Thallium | N | µg/L | 134 | 1 | 0.8 | 0.050 | 0.10 | 0.89 | 0.89 | 0.89 | 0.89 | 1.7 | -- | 0.24 | 1 | Clean Water Act – Human Health Water + Organism |
| Thallium | Y | µg/L | 134 | 3 | 2 | 0.050 | 0.10 | 0.068 | 1.0 | 0.38 | 0.077 | 1.7 | -- | 0.24 | 1 | Clean Water Act – Human Health Water + Organism |
| Zinc | N | µg/L | 203 | 101 | 50 | 4.0 | 9.0 | 4.0 | 7,780 | 392 | 11 | 22 | 33 | 91 | 22 | WAC 173-201A |
| Zinc | Y | µg/L | 214 | 80 | 37 | 4.0 | 9.6 | 4.0 | 7,980 | 408 | 11 | 22 | 28 | 91 | 19 | WAC 173-201A |
| **Other Analytes** | | | | | | | | | | | | | | | | |
| Total petroleum hydrocarbons - diesel range | N | µg/L | 111 | 5 | 5 | 70 | 70 | 74 | 19,000 | 3,925 | 180 | -- | -- | 500 | 1 | WAC 173-340-720(3)(b) Table 720-1 |

Note: Groundwater data from 100-IU-2/IU-6 wells screened in the unconfined aquifer and sampled between January 2007 and December 2011. See Figure 4-17 for wells included.

Sources: 40 CFR 131, "Water Quality Standards."

40 CFR 141, "National Primary Drinking Water Regulations."

40 CFR 141.66, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels for Radionuclides."

*Clean Water Act of 1977*.

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

WAC 173-340-730, "Model Toxics Control Act—Cleanup," "Surface Water Cleanup Standards."

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Gross beta was not identified as a historical COPC in the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4) but was subsequently added per Step 4 of the Integrated Work Plan (DOE/RL-2008-46). Gross beta is considered an indicator parameter, and its presence is generally associated with the presence of beta emitting isotopes such as technetium-99 and strontium-90. Gross beta concentrations were greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 3.1 pCi/L.

*Volatile Organic Compounds*. 1,1-Dichloroethene was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because, although it was not detected, most MDLs were greater than the action level. The action level for 1,1-dichloroethene is 0.057 µg/L based on the 40 CFR 131 Human Health Water + Organism value; however, it defaults to the EQL of 2 µg/L listed in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All results were less than the EQL.

Benzene was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the action level, and most MDLs were greater than the action level. The action level for benzene is 0.8 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; however, it defaults to the EQL of 1.5 µg/L listed in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. Concentrations above the EQL of 1.5 µg/L were reported at Wells 699-37-E1 (2.6 µg/L) and 699-39-23 (35 µg/L); both are the only benzene results reported at each location. Both of these wells were drilled in 1980 for geologic characterization and were not intended to become monitoring wells. No construction information is available, and the results may not be representative of groundwater quality in the unconfined aquifer. The benzene result reported at 699-37-E1 (2.6 µg/L) was flagged with an "H" review qualifier, indicating the laboratory holding time was exceeded before the sample was analyzed. The benzene result reported at 699-39-23 (35 µg/L) was flagged with a "B" laboratory qualifier, indicating the analyte was detected in both the associated QC blank and in the sample. The detections reported above the EQL of 1.5 µg/L are not believed to be representative of groundwater quality in the unconfined aquifer.

Carbon tetrachloride was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the action level, and most MDLs were greater than the action level. The action level for carbon tetrachloride is 0.23 µg/L based on the *National Recommended Water Quality Criteria* (EPA, 2009a), "Human Health Water + Organism" value; however, it defaults to the EQL of 1 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. A single detection of carbon tetrachloride was reported above the EQL at Well 699-54-45A (5.4 µg/L). The value is flagged Y (suspected error), and the other two sample results at this well were reported as nondetects. The results of this evaluation indicate that carbon tetrachloride has been detected in groundwater at low frequencies. The single detected concentration was reported above the EQL of 1 µg/L but is flagged as a suspected error.

Chloroform was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because MDLs were greater than the action level. The action level for chloroform is 1.4 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; however, it defaults to the EQL of 5 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All chloroform results were less than the EQL.

Tetrachloroethene was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the action level, and most MDLs were greater than the action level. The action level for tetrachloroethene is 0.081 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; however, it defaults to the EQL

of 5 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All tetrachloroethene results were less than the EQL.

Trichloroethene was detected in 13 percent of the samples. The action level for trichloroethene is 0.49 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; however, it defaults to the EQL of 1 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. Trichloroethene concentrations greater than or equal to the EQL of 1 µg/L were reported as follows:

- All three sample results from 699-65-72 (1 to 1.3 µg/L)
- All three sample results from 699-70-68 (1.1 to 1.7 µg/L)
- One of three sample results from 699-71-30 (0.45 to 1.4 µg/L)
- Two of three sample results from 699-83-47 (less than 1 to 1.1 µg/L)
- All four samples from 699-77-54 (8.9 to 11 µg/L)

Sections 4.3.2 and 4.3.4 provide additional information about trichloroethene in 100-F/IU.

Vinyl chloride was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because all MDLs were above the action level. The action level for vinyl chloride is 0.025 µg/L based on the *National Recommended Water Quality Criteria* (EPA, 2009a), "Human Health Water + Organism" value; however, it defaults to the EQL of 5 µg/L listed in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All chloroform results were less than the EQL.

*Anions.* Fluoride was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level. A single detection of fluoride (1,050 µg/L) above the action level was reported at Well 699-25-20; it was the only fluoride result reported at this location. This borehole was drilled in 1981 for geologic characterization and was not intended to be used for groundwater monitoring. Minimum, maximum, and 90$^{th}$ percentile values for Hanford Site background concentrations of fluoride are 267, 5,850, and 1,047 µg/L, respectively. A single sample from the 100-F data set was above the action level and the Hanford Site 90$^{th}$ percentile concentration. This result may not be representative of groundwater quality in the unconfined aquifer and is within the range of naturally occurring concentrations.

Nitrate was detected in 96 percent of the samples at concentrations ranging from 0.602 to 101 mg/L. Nitrate concentrations above the DWS were reported as follows:

- Both sample results from 699-62-31 (85.4 and 93.4 mg/L)
- All three sample results from 699-64-27 (46 to 49.6 mg/L)
- All four sample results from 699-71-30 (97.4 to 101 mg/L)

The nitrate contamination in these wells is attributed to sources in 100-F (Section 4.3.2).

*Metals.* Aluminum was detected above the secondary DWS of 50 µg/L in samples collected for the RI. It is included in the nature and extent evaluation, but it was not identified as a historical COPC in the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4). Aluminum concentrations ranged from 5.5 to 506 µg/L in unfiltered samples and from 5.4 to 52 µg/L in filtered samples. Aluminum concentrations exceeding the secondary DWS (50 µg/L) were reported as follows:

- Two of six sample results at 699-14-38 (less than 10 to 151 µg/L)
- One of six sample results at 699-17-5 (less than 10 to 159 µg/L)

- One of eight sample results at 699-20-E5A (less than 10 to 417 µg/L)
- Three of six sample results at 699-53-35 (less than 10 to 506 µg/L)
- Two of six sample results at 699-54-45A (less than 10 to 274 µg/L)

Aluminum is naturally present in aquifer sediment. The exceedances of the secondary DWS in unfiltered samples mostly likely reflect sediment particles in the samples; only one filtered sample had a concentration above the secondary DWS. Aluminum concentrations in filtered and unfiltered samples are greater than the Hanford Site 90$^{th}$ percentile (unfiltered) background concentration of 7.1 µg/L.

Antimony was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. Samples collected for purposes other than the RI were analyzed using Method 6010. All five detected concentrations were reported by this method, and the filtered and unfiltered concentrations ranged from 4.6 to 58 µg/L, four of which exceed the action level of 5.6 µg/L. The MDLs reported by Method 6010 ranged from 4 to 60 µg/L, almost all of which exceed the action level. Antimony results (detected concentrations and MDLs) reported by Method 6010 are not accurate at concentrations at or near the action level. For samples analyzed using the trace methods identified in the 100-F/IU SAP (DOE/RL-2009-43), all results were reported as nondetects, and the MDLs ranged from 0.3 to 1.1 µg/L, which are less than the action level of 5.6 µg/L. A single antimony concentration in an unfiltered sample was reported greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 55 µg/L.

Arsenic was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. Minimum, maximum, and 90$^{th}$ percentile values for Hanford Site (filtered) background concentrations of arsenic are 0.5, 8.8, and 7.9 µg/L, respectively. Arsenic concentrations ranged from 1.0 to 16 µg/L in unfiltered samples and from 0.83 to 15 µg/L in filtered samples. Arsenic was reported above the 90$^{th}$ percentile background concentration as follows:

- All six sample results at 699-20-20 (12 to 14 µg/L)
- Four of six sample results at 699-26-15A (7.7 to 8.8 µg/L)
- All six sample results at 699-29-4 (8.2 to 9.1 µg/L)
- All six sample results at 699-60-32 (12 to 14 µg/L)
- All six sample results at 699-62-43F (14 to 16 µg/L)
- All six sample results at 699-65-50 (9.1 to 11 µg/L)
- All six sample results at 699-89-35 (7.9 to 8.2 µg/L)

The results of this evaluation indicate that arsenic has been detected in groundwater, but only slightly above the 90$^{th}$ percentile background concentration.

Cadmium was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. Samples collected for purposes other than the RI were analyzed by Method 6010 with MDLs that ranged from 0.9 to 4.1 µg/L, higher than the action level of 0.25 µg/L. Two cadmium concentrations (4.6 and 4.9 µg/L) were reported by Method 6010 and were flagged with a "B" lab qualifier, indicating the analyte was detected at a value less than the contract-required detection limit but greater than or equal to the MDL. Cadmium results (detected concentrations and MDLs) reported by Method 6010 are not accurate at concentrations at or near the action level. For samples analyzed using the trace method identified in the 100-F/IU SAP (DOE/RL-2009-43), all but two results were less than the AWQC. Cadmium was detected twice above the AWQC (0.50 and 0.55 µg/L) at Well 699-54-45A; the other four sample results were

nondetects at this location. Cadmium concentrations in samples analyzed by the trace method are below the Hanford Site 90th percentile (filtered) background concentration of 0.92 µg/L.

Cr(VI) was detected in 28 percent of the unfiltered samples and 27 percent of the filtered samples. Concentrations ranged from 2.2 to 24 µg/L in unfiltered samples and from 2.4 to 23 µg/L in filtered samples. Concentrations above the AWQC were reported as follows:

- All six sample results from 699-62-43F (12 to 13 µg/L)
- All eight sample results from 699-77-54 (21 to 24 µg/L)
- Six of seven sample results from 699-87-42A (9 to 15 µg/L)

Well 699-62-43F is located approximately 6.9 km (4.3 mi) from the river; Well 699-77-54 is located approximately 3.6 km (2.3 mi) away from the river; and Well 699-87-42A is located approximately 2.8 km (1.7 mi) from the river. Cr(VI) concentrations are not likely to discharge directly to the river from these locations. Although all monitoring wells within the plume area were compared to the AWQC, only groundwater discharging to the Columbia River would need to meet this standard. Section 4.3.4 discusses these Cr(VI) detections and their possible source.

Cobalt was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the action level, and MDLs were greater than the action level. Samples collected for purposes other than the RI were analyzed by Method 6010. All results reported by Method 6010 were above the action level of 2.6 µg/L. Ten of the 15 detected results reported by Method 6010 were flagged with a "B" lab qualifier, indicating the analyte was detected at a value less than the contract-required detection limit but greater than or equal to the MDL. Cobalt results (detected concentrations and MDLs) reported by Method 6010 are not accurate at concentrations at or near the action level. For samples analyzed using the trace method identified in the 100-F/IU SAP (DOE/RL-2009-43), all but four results were less than the action level. Those four results were from Well 699-54-45A. Cobalt concentrations in filtered and unfiltered samples were greater than the Hanford Site 90th percentile (filtered) background concentration of 0.92 µg/L.

Copper was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the AWQC, and MDLs were greater than the AWQC. Copper concentrations above the AWQC of 9 µg/L were reported as follows:

- Two of six sample results at 699-54-45A (less than 0.2 to 11 µg/L)
- One of four sample results at 699-63-55 (less than 5.0 to 20 µg/L)
- Two of four sample results at 699-67-51 (less than 6.0 to 118 µg/L)

Copper results greater than the AWQC are generally associated with the unfiltered sample. Copper concentrations in filtered and unfiltered samples are greater than the Hanford Site 90th percentile (filtered) background concentration of 0.81 µg/L.

Iron was detected above the secondary DWS of 300 µg/L in samples collected for the RI. Iron is included in the nature and extent evaluation but was not identified as a COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4). Detections of iron in unfiltered samples above the secondary DWS were reported in 59 monitoring wells. Iron concentrations in filtered and unfiltered samples are greater than the Hanford Site 90th percentile (unfiltered) background concentration of 570 µg/L. Iron affects aesthetic qualities relating to public acceptance of drinking water. These regulations are not federally enforceable, but are intended as guidelines for states. Because the action level is based on a secondary DWS, iron concentrations in groundwater are compared to the AWQC of 1,000 µg/L. Iron was infrequently detected above the AWQC at two well locations (699-61-62 and 699-67-51). Iron is naturally present in aquifer

sediment and is a component of well casings and screens. Its presence above the secondary DWS in groundwater samples included in this evaluation most likely reflects well construction and not ambient groundwater quality.

Lead was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the AWQC, and MDLs were greater than the AWQC. Lead concentrations above the AWQC of 2.1 µg/L were reported as follows:

- Two of six sample results at 699-17-5 (less than 0.2 to 13 µg/L)
- Two of eight sample results at 699-20-E5A (less than 0.2 to 7.2 µg/L)
- Both sample results at 699-37-E1 (2.1 to 2.3 µg/L)
- Three of six sample results at 699-50-28B (less than 0.2 to 4.6 µg/L)
- Two of six sample results at 699-54-45A (less than 0.2 to 8.5 µg/L)
- One of six sample results at 699-8-25 (less than 0.2 to 3.3 µg/L)

Lead results greater than the AWQC are generally associated with the unfiltered sample. The lead concentrations in unfiltered and filtered samples are greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 0.92 µg/L.

Manganese was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the secondary DWS. Detections of manganese in unfiltered samples above the secondary DWS were reported in 22 monitoring wells. Many of the wells with exceedances were drilled in 1980 or 1981 for geologic characterization. Water samples have low dissolved oxygen content, which increases the solubility of metals such as manganese. Results are not believed to represent groundwater quality in the unconfined aquifer. Concentrations in filtered and unfiltered samples are greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 39 µg/L. Manganese affects aesthetic qualities relating to public acceptance of drinking water. These regulations are not federally enforceable, but are intended as guidelines for states. Because the action level is based on a secondary DWS, manganese concentrations in groundwater are compared to the "Surface Water Cleanup Standards" (WAC 173-340-730) level of 907 µg/L. All manganese results were less than 907 µg/L.

Mercury was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected infrequently above the AWQC, and MDLs were greater than the AWQC. Mercury was not detected in any groundwater samples. The AWQC for mercury is 0.012 µg/L; however, it defaults to the EQL of 0.5 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the AWQC. All MDLs are less than the EQL.

Nickel was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the AWQC. With the exception of 13 MDLs reported at a concentration of 67 µg/L, all remaining results were less than the AWQC. Nickel concentrations in filtered and unfiltered samples were greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 1.6 µg/L.

Thallium was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the action level, and MDLs were greater than the action level. The action level for thallium is 0.24 µg/L based on *National Recommended Water Quality Criteria* (EPA, 2009a) "Human Health for Consumption of Water plus Organism;" however, it defaults to the EQL of 2 µg/L identified in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All results were less than the EQL. The thallium concentrations in unfiltered and filtered samples are less than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 1.7 µg/L.

Zinc was identified as a historical COPC in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) because it was detected above the AWQC of 91 µg/L. Zinc concentrations above the AWQC were reported as follows:

- Both sample results at 699-31-8 (407 and 426 µg/L)
- Both sample results at 699-37-E1 (126 and 462 µg/L)
- All six sample results at 699-50-28B (235 to 411 µg/L)
- All six sample results at 699-54-45A (1,000 to 5,450 µg/L)
- All six sample results at 699-58-24 (2,110 to 7,980 µg/L)
- All four sample results at 699-62-31 (1,220 to 3,670 µg/L)
- One of four sample results at 699-63-55 (less than 4 to 387 µg/L)
- Two of nine sample results at 699-64-62 (17 to 206 µg/L)
- All six sample results at 699-66-58 (445 to 590 µg/L)
- All six sample results at 699-81-38 (221 to 482 µg/L)

Zinc concentrations in filtered and unfiltered samples were greater than the Hanford Site 90$^{th}$ percentile (filtered) background concentration of 22 µg/L. Zinc is naturally present in aquifer sediment and is a component of some well casings and screens. Its presence above the AWQC in groundwater samples included in this evaluation most likely reflects well construction and not ambient groundwater quality.

*Total Petroleum Hydrocarbons-diesel range.* Total petroleum hydrocarbons – diesel range was identified as a historical COPC in the 100-F/IU SAP (DOE/RL-2009-43). A single total petroleum hydrocarbon – diesel range concentration above the action level of 500 µg/L was reported at Well 699-37-E1. It is the only result reported at this location. This borehole was drilled in 1980 for characterization purposes and was not intended to become a monitoring well. No construction information is available. Samples from this borehole are not representative of groundwater quality in the unconfined aquifer.

*Conclusions from 100-IU-2/IU-6 Groundwater Evaluation.* Table 4-18 summarizes the outcome of the analysis. Groundwater contaminants include iodine-129, nitrate, trichloroethene, and tritium. These contaminants are not associated with 100-IU-2/IU-6 waste sites and originated in other operable units with the possible exception of trichloroethene which is being addressed by the 100-FR-3 Groundwater OU. Therefore, no additional groundwater OU is determined to be necessary.

Other uncertainties identified for the COPCs in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4) were generally associated with limitations in the analytical methods selected for analysis. Action levels for many of the metals and VOCs require methods that can measure the analyte at low levels and require the use of analytical methods that can detect analytes at trace levels. The analytical dataset evaluated for this evaluation represented 5 years of data from all of the monitoring wells currently in use. The analysis provided above identified when uncertainties were associated with data quality issues or limitations associated with the analytical method used.

### 4.3.2 Groundwater Contaminant Plumes in 100-F

Defining contaminant plumes was part of the work scope designed to fill data gap 4. Data from RI wells were combined with data from existing wells to refine knowledge of the nature and extent of groundwater contamination in 100-F. Appendix D includes groundwater data, which are also available online via the DOE 2012 Environmental Dashboard Application.

Table 4-18. Summary of 100-IU-2/IU-6 Groundwater Contaminant Evaluation

| Category | Constituent |
|---|---|
| Contaminant of potential concern[a] | Iodine-129, nitrate, trichloroethene, tritium |
| Detected at levels above action level and background | Cr(VI) [a], Gross beta[b] |
| Detected at levels above action levels only in samples analyzed by Method 6010 | Antimony, cadmium, cobalt |
| Detected at levels above action level and background; non-representative results | Aluminum, copper, iron, lead, manganese, zinc |
| Detected above action level, but isolated instances and/or suspect data | Benzene, carbon tetrachloride, fluoride, total petroleum hydrocarbons-diesel range |
| Detected in groundwater but below action level, EQL, or background concentrations | Gross alpha, americium-241, carbon-14, radium-228, strontium-90, technetium-99, 1,1-dichloroethene, chloroform, tetrachloroethene, vinyl chloride, arsenic[c], nickel, thallium |
| Not detected in groundwater | Cesium-137, cobalt-60, europium-152, europium-154, europium-155, mercury |

Based on evaluation of data collected January 2007 through December 2011.

a. See discussion in Section 4.3.4.

b. Gross beta indicates presence of strontium-90 or technetium-99. See results for those radionuclides.

c. Some concentrations slightly above background.

Nitrate, strontium-90, and trichloroethene exceed DWS, and Cr(VI) exceeds AWQC in the unconfined aquifer. Table 4-19 lists plume areas based on 2011 interpretations for each of these contaminants. Tritium concentrations formerly exceeded the DWS. The following sections discuss the current distribution of these contaminants in groundwater.

Table 4-19. 100-F Plume Area (2011)

| Constituent | Contour Level | Area km$^2$ (mi$^2$) |
|---|---|---|
| Cr(VI) | 10 µg/L | 0.17 (0.066) |
| Strontium-90 | 8 pCi/L | 0.072 (0.028) |
| Nitrate | 45 mg/L | 10.6 (4.09) |
| Trichloroethene* | 5 µg/L | 0.70 (0.27) |

Source: *Hanford Site Groundwater Monitoring for 2011* (DOE/RL-2011-118).

* Plume is not well defined by available data. Plume area is uncertain.

Contaminant plume maps presented in this section include:

- Cr(VI), strontium-90, nitrate, and trichloroethene maps for two of the three periods sampled for RI spatial and temporal assessment: spring (May) and fall (September through November) 2010. The spring event was intended to represent high river stage conditions. However, as illustrated in Figure 4-18, the major increase in river stage occurred after the sampling event. The fall sampling event represented low river stage conditions.

- Cr(VI), strontium-90, nitrate, and trichloroethene plume maps representing average concentrations for 2011, as prepared for the Hanford Site groundwater annual report. The comprehensive, annual sampling event for 100-F occurred in December 2011 (Figure 4-18). Selected wells were sampled more than once in 2011.

#### 4.3.2.1 Cr(VI) in 100-F Groundwater

Groundwater samples may be analyzed for Cr(VI) or for total chromium, which includes hexavalent and trivalent. Dissolved chromium in Hanford Site groundwater is virtually all hexavalent (*Speciation and Transport Characteristics of Chromium in the 100D/H Areas of the Hanford Site* [WHC-SD-EN-TI-302]). Filtered, total chromium data effectively represent Cr(VI) (*Hanford Site Groundwater Monitoring for Fiscal Year 2007* [DOE/RL-2008-01]). Trend plots in this section include both filtered, total chromium, and Cr(VI) data because Cr(VI) data were not available for many wells in the past.

Former sources of Cr(VI) in 100-F included facilities near the reactor building, trenches and retention basins near the Columbia River, and pipelines from the reactor building to these near-river facilities, primarily in northern and eastern 100-F. The current distribution of Cr(VI) in groundwater (Figures 4-19 through 4-21) shows no obvious relation to the locations of the former sources. The contamination apparently migrated and attenuated before most of the groundwater monitoring wells were installed in the early 1990s. The waste sites have been remediated, and concentrations in groundwater are expected to continue to decline with time.

Data from RI wells helped refine the Cr(VI) plume outline from previous estimates. Figures 4-19 and 4-20 illustrate the plume based on data collected in spring and fall 2010. Concentrations in the core of the plume (Wells 199-F5-6 and 199-F5-46) were higher in spring, when river stage was moderately high, than in fall, when river stage was low. However, it is unlikely that the increase was caused by the higher water levels. Cr(VI) concentrations in 199-F5-6, which is close to the river, usually vary inversely with river stage, but in May 2010 the opposite was observed. Concentrations in 199-F5-46, farther inland, show no obvious correlation to river stage. Cr(VI) concentrations are declining overall throughout the plume. Figure 4-21 illustrates the plume in 2011. Only 2 of 17 wells had concentrations above 20 µg/L in 2011.

Three wells located near the 116-F-14 retention basins and the 116-F-9 trench had chromium concentrations above 20 µg/L at least once in 2010 or 2011. The top panel of Figure 4-22 shows the Cr(VI) trends in those three wells since 1992; the bottom panel shows detail for recent years. Well 199-F5-46 had the highest concentrations historically, and concentrations have declined since monitoring began in the early 1990s. The concentration in this well briefly increased to more than 90 µg/L in May 2010. The concentration declined to approximately 20 µg/L in July and remained at that level for the remainder of 2010 and 2011. Well 199-F5-45 is the farthest inland of the three wells. Concentrations ranged from 10 to 20 µg/L in 2010. Concentrations have declined overall since 2003 in Well 199-F5-6, which is located closest to the river of the three wells shown.

Cr(VI) levels are low in 100-F Area aquifer tubes (Figure 4-23). Figure 4-24 shows Cr(VI) concentrations in the only aquifer tubes with concentrations above 10 µg/L in recent years. The maximum concentrations in 2009 were 14.7 µg/L in tube C6303 (near the known groundwater plume; see Figure 3-1 for location) and 11.3 µg/L in tube 75-D (approximately 2 km [1.2 mi] downstream; see Figure 2-2 for location). Concentrations in both of these tubes were below 10 µg/L in 2011. No known chromium sources are located near aquifer tube 75-D, so it is likely that the contamination moved southward from 100-F.

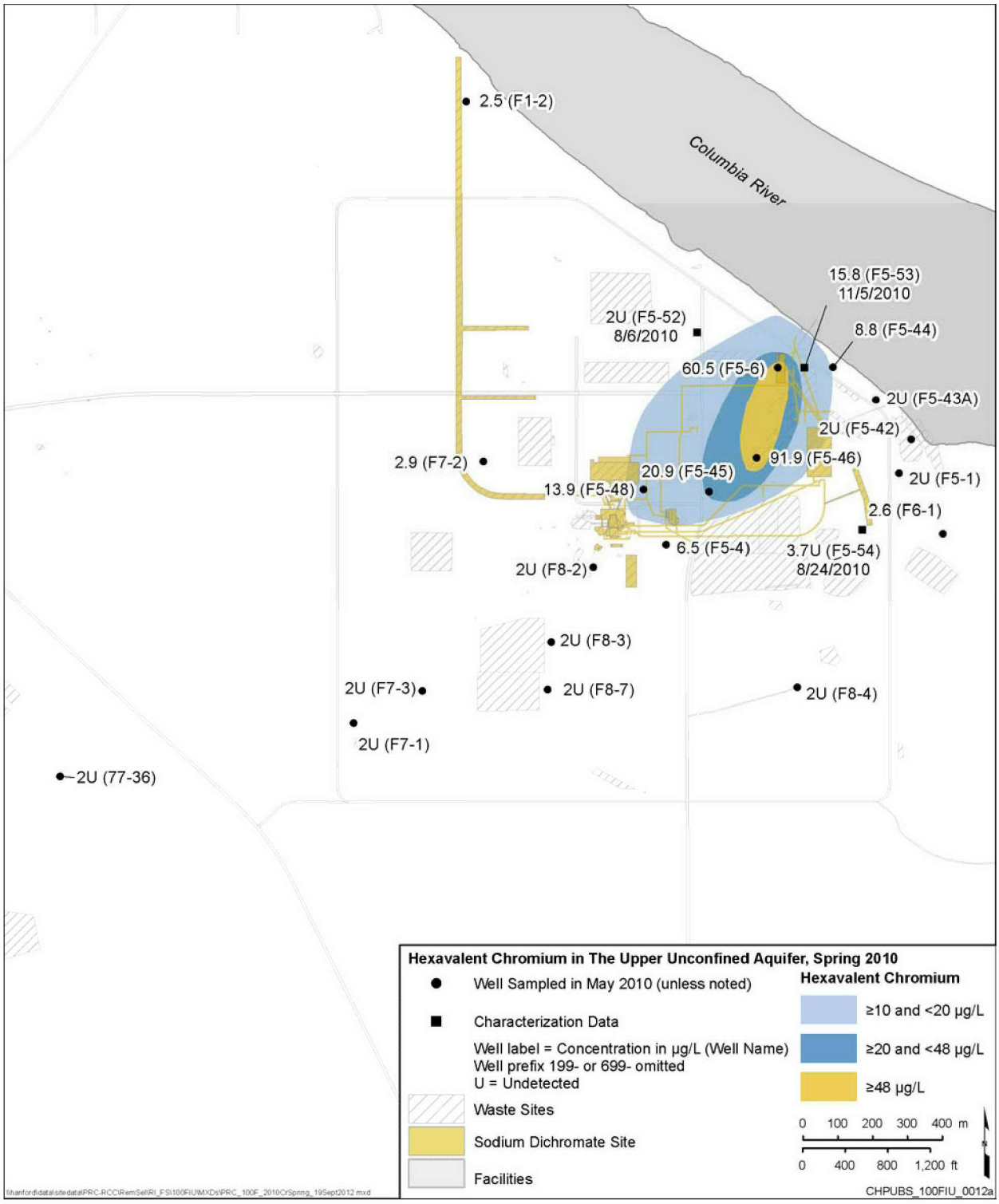



Figure 4-19. Hexavalent Chromium in 100-F Unconfined Aquifer, Spring 2010

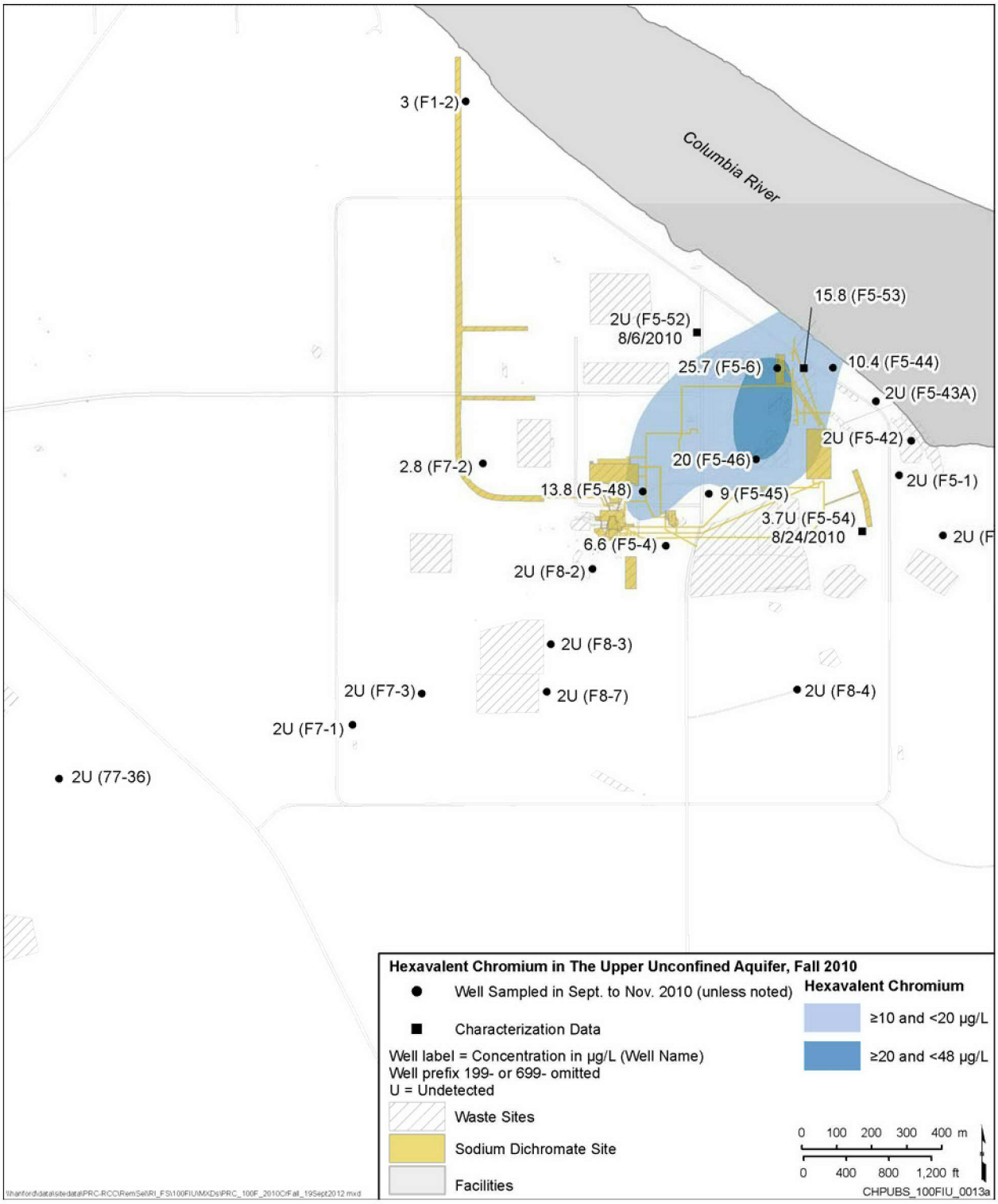



Figure 4-20. Hexavalent Chromium in 100-F Unconfined Aquifer, Fall 2010

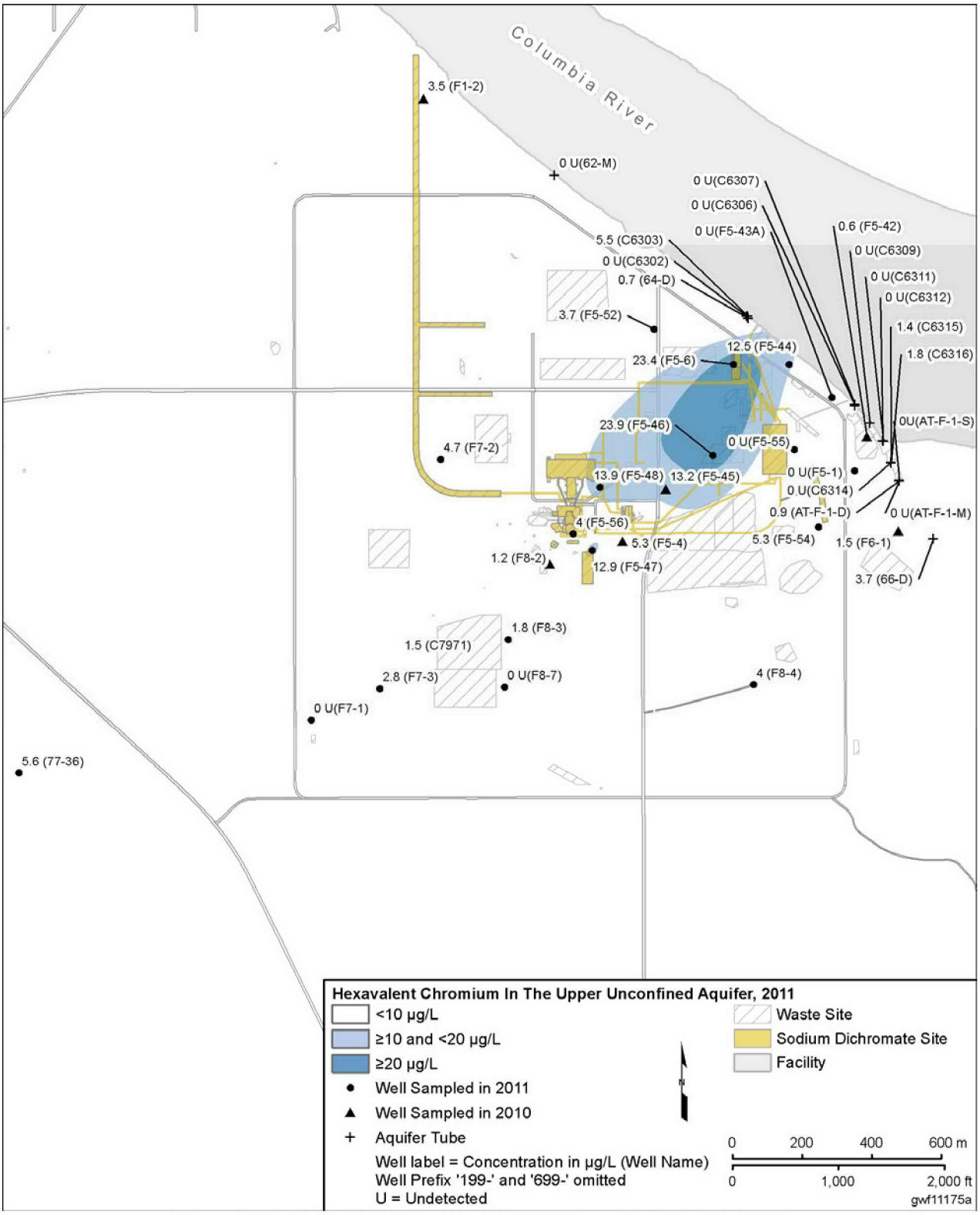



Figure 4-21. Hexavalent Chromium in 100-F Unconfined Aquifer, 2011

#### 4.3.2.2 Nitrate in 100-F Groundwater

Past sources of nitrate contamination included the experimental animal farm (for example, 116-F-9 animal leach trench; 118-F-6 burial ground) and various septic tanks and leach fields located throughout 100-F (Figure 1-6). These sites have been remediated. Pre-Hanford Site agriculture is another potential source of nitrate contamination. Groundwater studies in the Yakima Valley have recently identified agriculture-related nitrate contamination in private wells (*Lower Yakima Valley Groundwater Quality Preliminary Assessment and Recommendations Document* [Ecology Publication No. 10-10-009]). Concentrations two to three times the DWS have been observed in shallow wells.

A nitrate plume in groundwater extends southward approximately 5 km (3.1 mi) from 100-F (Figures 4-25 through 4-27). The plume distribution within 100-F Area was virtually identical in the three time periods shown. Data are sparse south of 100-F, so this part of the plume is open to various interpretations. The fact that this plume migrated southward, instead of east toward the river like the Cr(VI) plume, can be explained by the location of some of the nitrate sources in southern 100-F. The groundwater in southern 100-F flows to the east and southeast, and then turns toward the south and south-southeast (Figure 3-33; Section 3.6.3). Groundwater flow in northeastern 100-F, where primary Cr(VI) sources were located, varies with river stage but is dominantly toward the east.

In recent years, the highest nitrate concentrations were observed in Well 199-F5-47, located in central 100-F. Concentrations have increased in this well since 2007 (Figure 4-28). However, in general, concentrations within the nitrate plume are steady or declining (for example, Well 199-F7-3). Characterization samples collected while drilling Well 199-F5-54 showed nitrate concentrations near 150 mg/L in the upper portion of the aquifer and concentrations declining with depth. Vertical distribution of contaminants is discussed in greater detail in Section 4.3.4.

Nitrate concentrations in some 100-F aquifer tubes are above background levels but below the DWS. The concentration increased to 41 mg/L in 2009 in aquifer tube 62-M (north of 100-F; Figure 4-28), which was the highest concentration observed at that location to date. Located upstream from this tube, monitoring Well 199-F1-2 has nitrate concentrations at approximately 30 mg/L. Aquifer tube 75-D, located south of the 100-F Area, historically had nitrate levels just above the DWS. Concentrations declined below the DWS in 2009 and 2011.

#### 4.3.2.3 Strontium-90 in 100-F Groundwater

Major sources of strontium-90 included the 116-F-14 Retention Basin and the 116-F-2 Trench, located in northeastern 100-F. The current groundwater plume remains in the vicinity of these sites (Figures 4-29 through 4-31). Concentrations in 2010 and 2011 continued to exceed the 8 pCi/L DWS in Well 199-F5-1, located near the 116-F-2 Trench. Concentrations are declining in this well (Figure 4-32). Concentrations declined below the DWS for the first time in 2009 in Well 199-F5-46 and remained below the standard in 2010 and 2011. High and low river stage had no significant impact on the plume.

Two new temporary wells were sampled in December 2011 and had the highest strontium-90 concentrations in 100-F groundwater. These boreholes were installed in former waste sites to characterize the vadose zone and were completed as monitoring wells to obtain representative groundwater samples. Well 199-F5-55, in the center of the strontium-90 plume at the 116-F-14 Retention Basin, had a maximum concentration of 285 pCi/L. The next nearest downgradient well, 199-F5-1, has much lower concentrations (12 to 19 pCi/L).

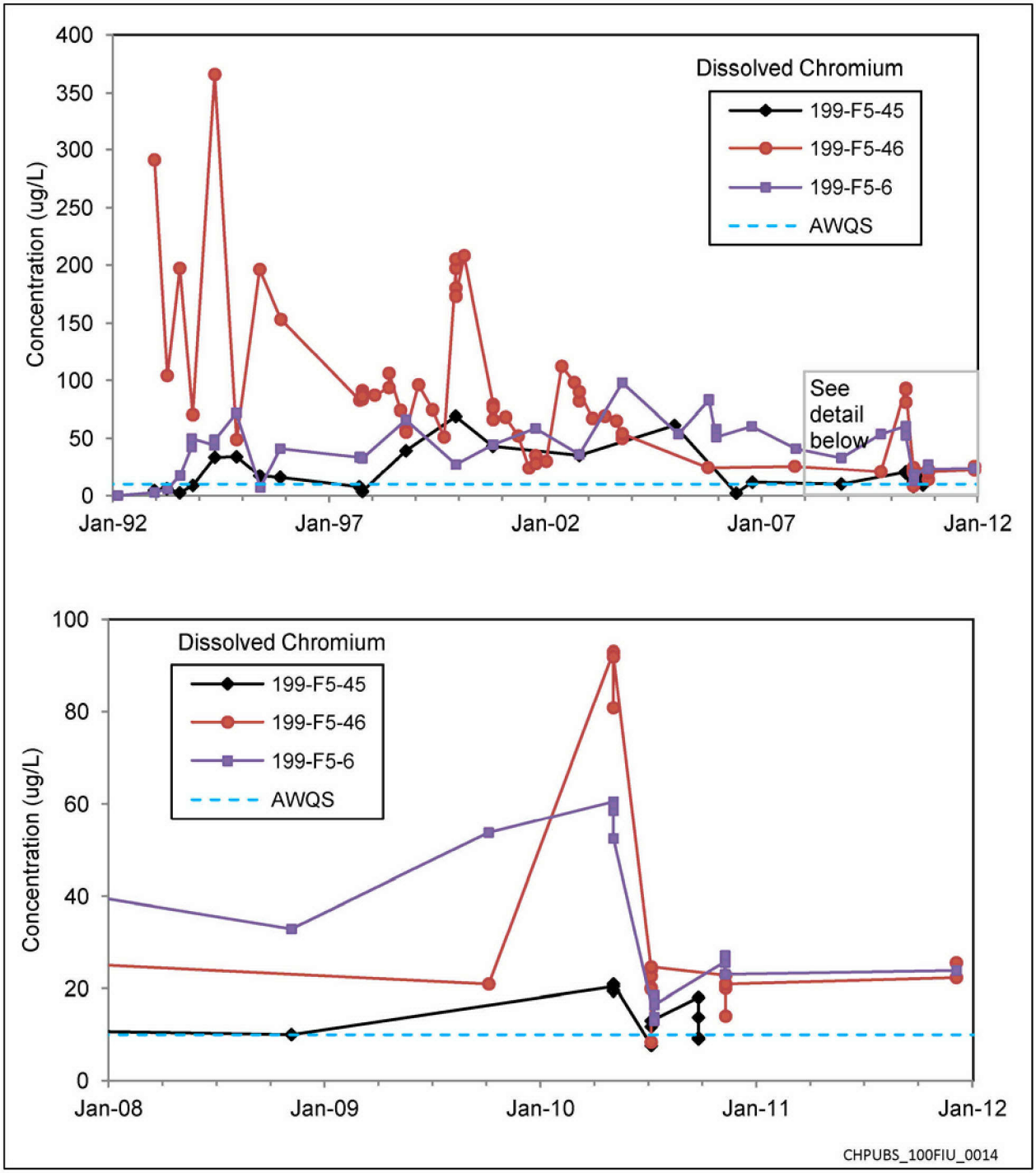



Figure 4-22. Dissolved Chromium Trends in Wells Monitoring Eastern 100-F

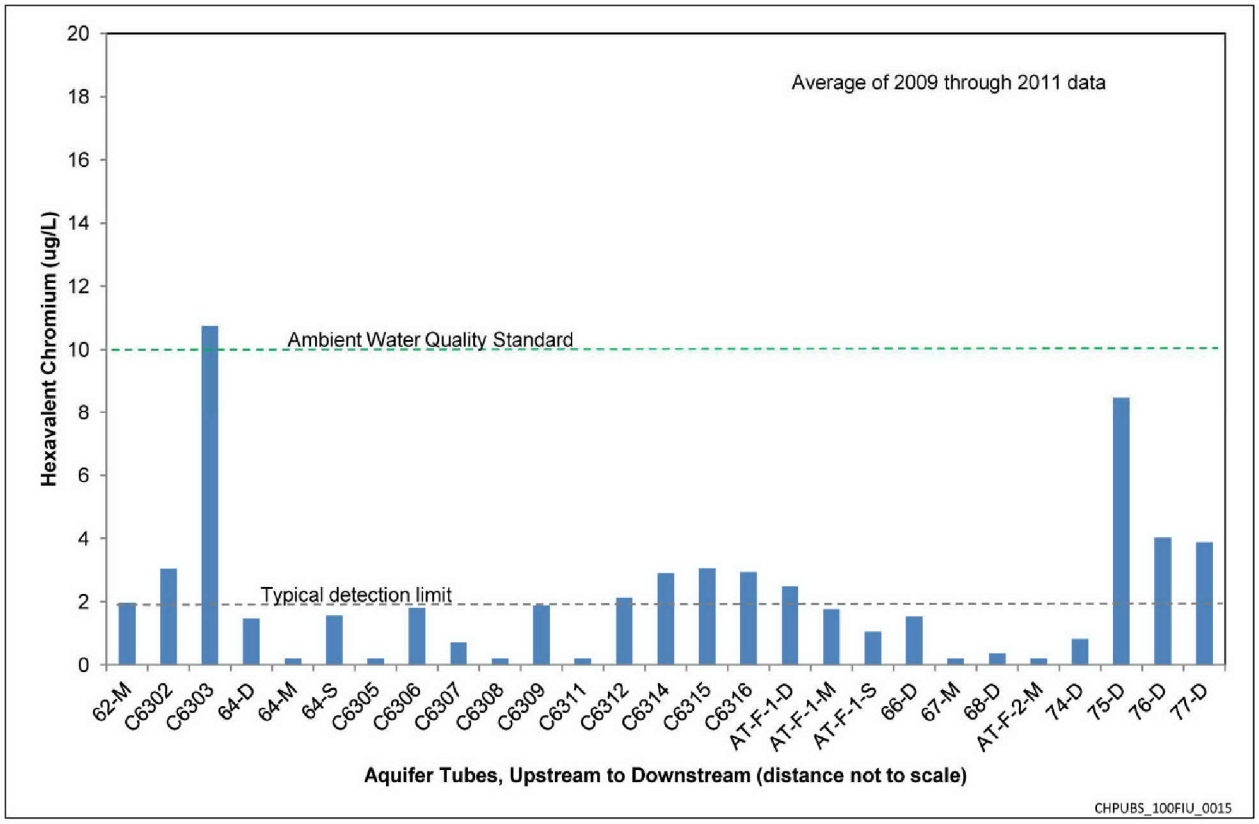



Figure 4-23. Hexavalent Chromium in 100-F Aquifer Tubes

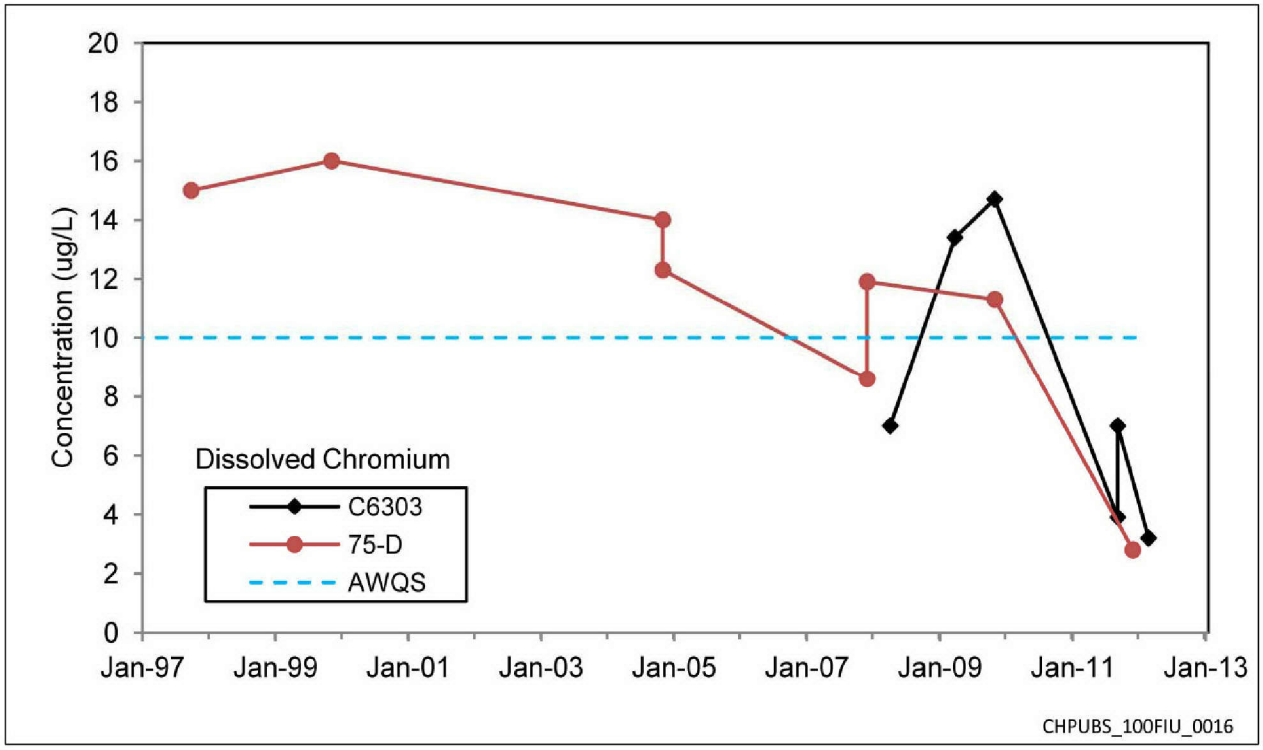



Figure 4-24. Dissolved Chromium Trends in 100-F Aquifer Tubes

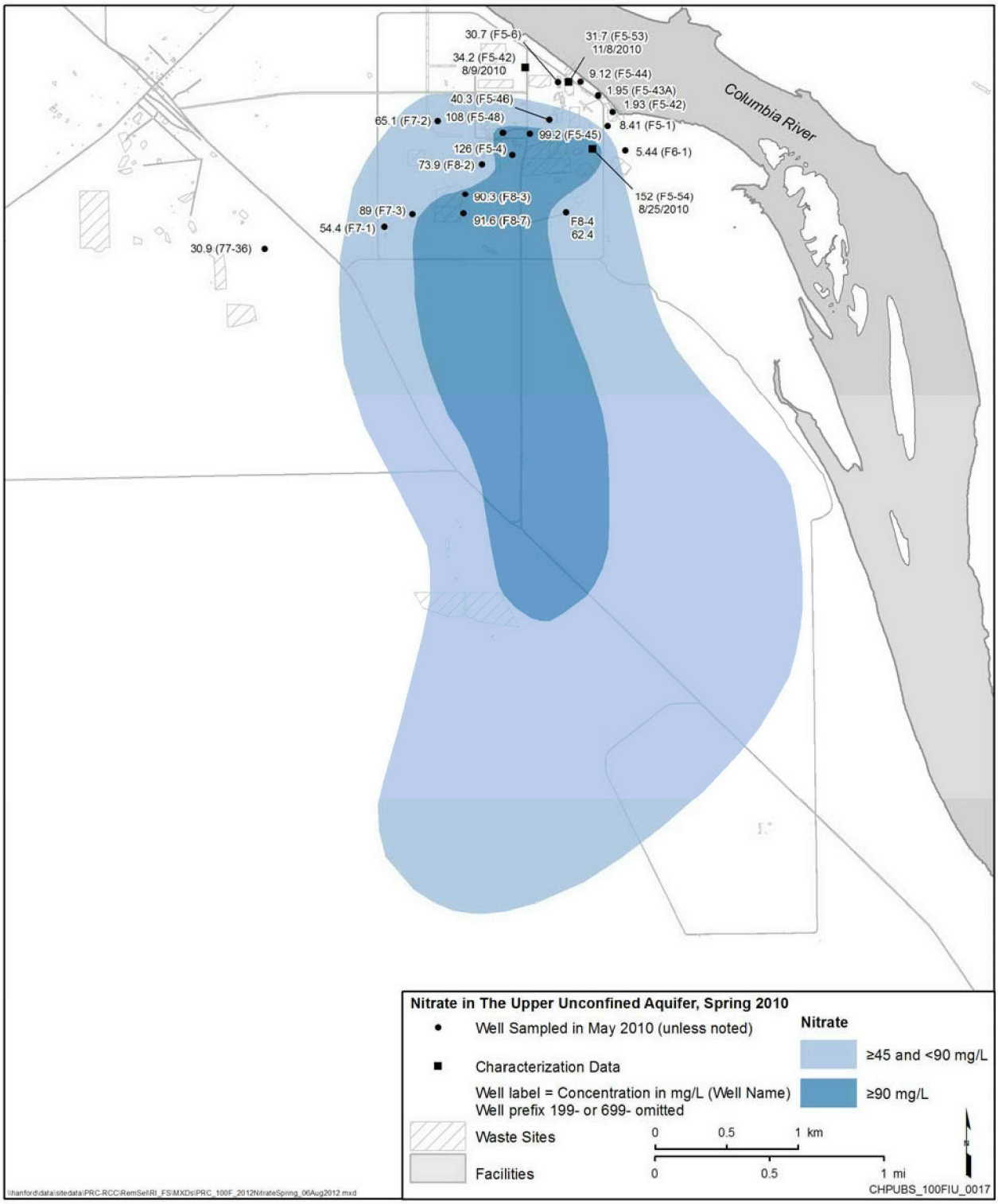



Figure 4-25. Nitrate in 100-F Unconfined Aquifer, Spring 2010

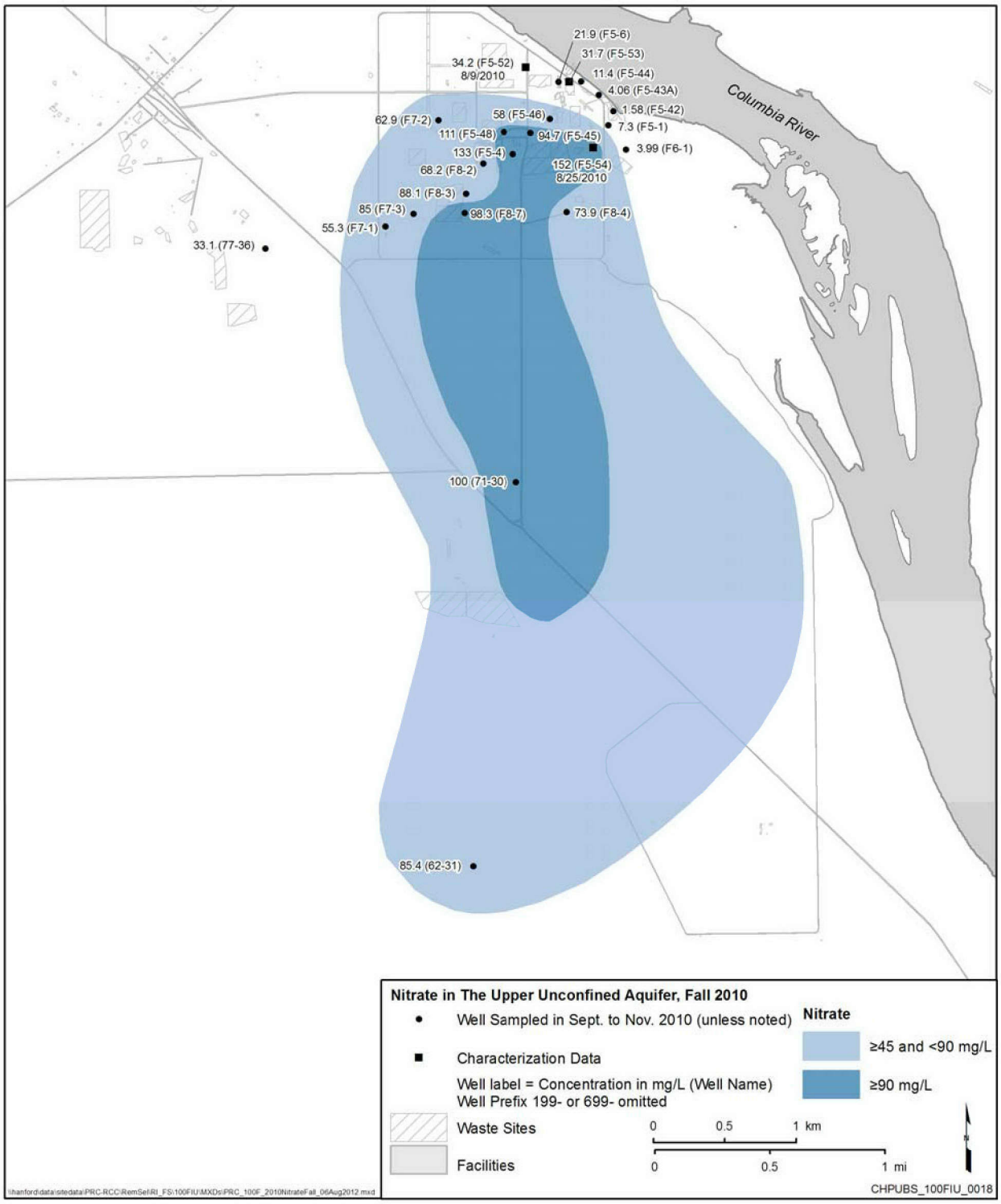



Figure 4-26. Nitrate in 100-F Unconfined Aquifer, Fall 2010

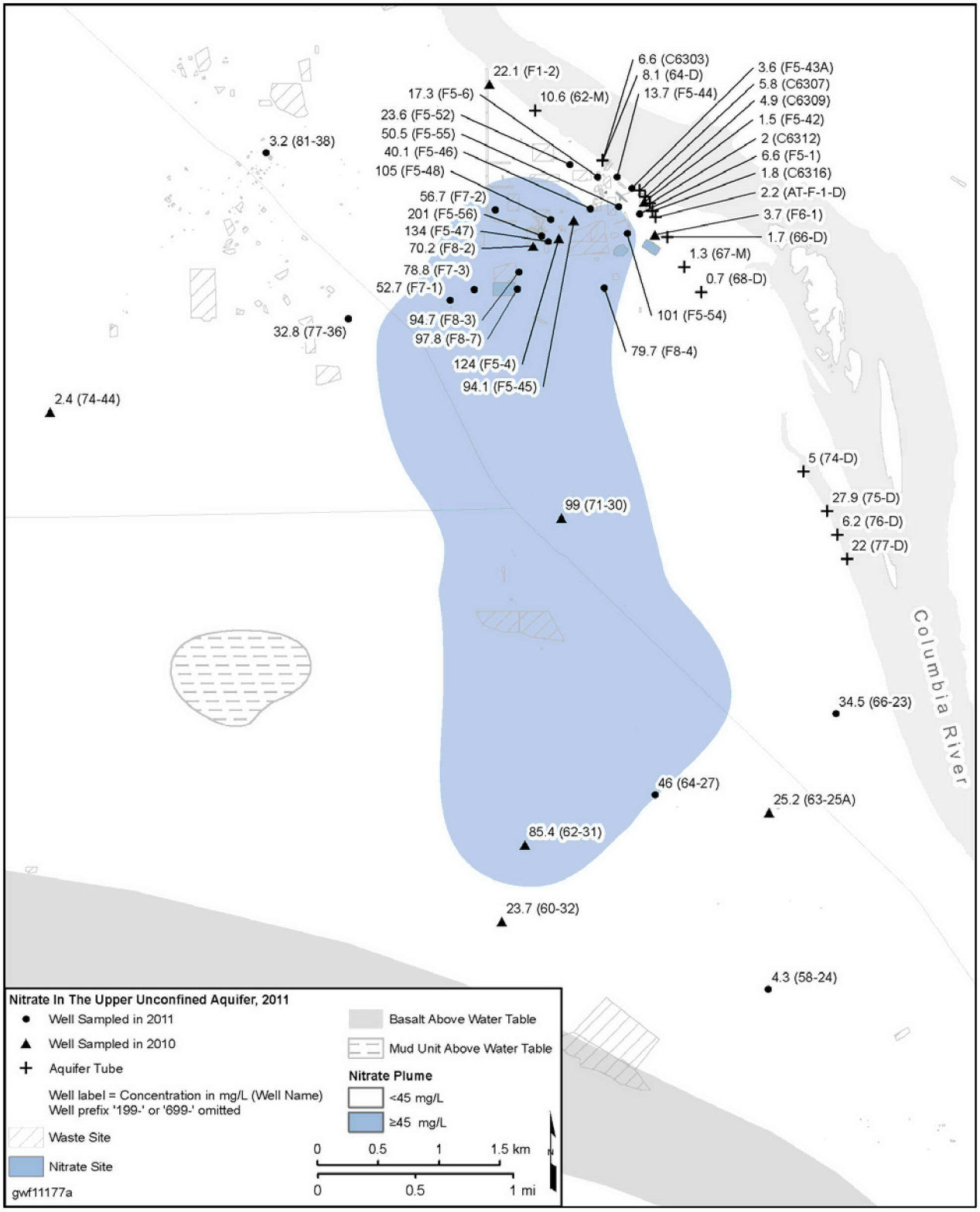



Figure 4-27. Nitrate in 100-F Unconfined Aquifer, 2011

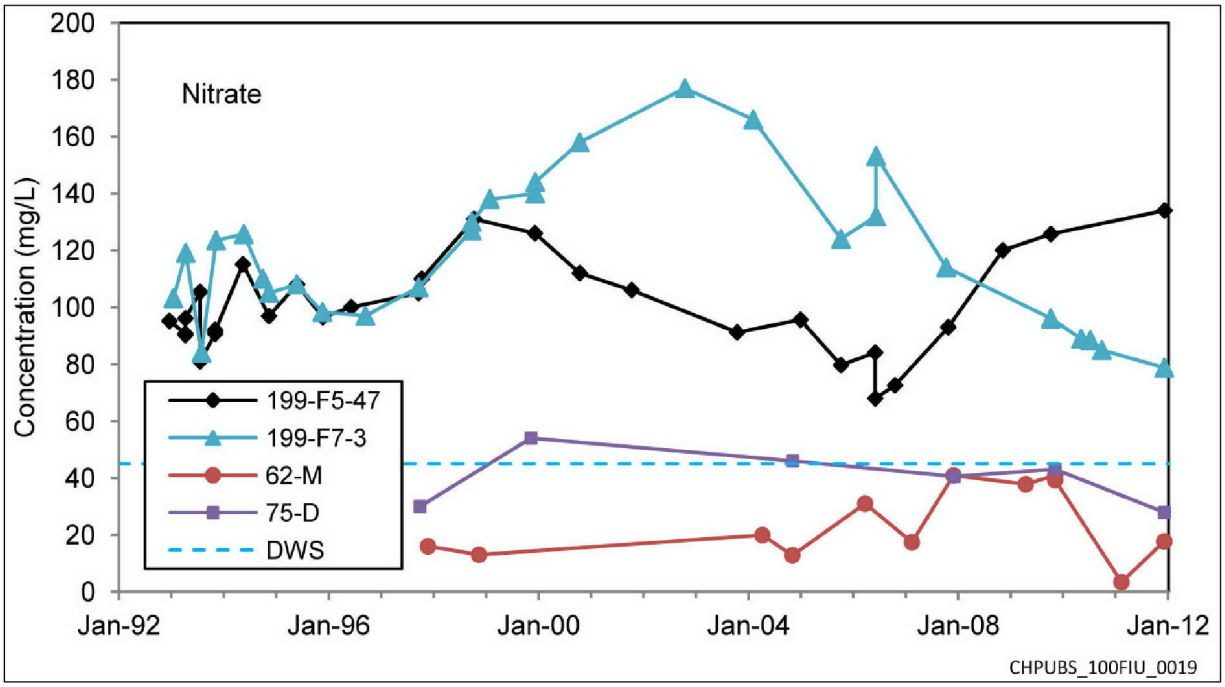



Figure 4-28. Nitrate Trends in 100-F Wells and Aquifer Tubes

Temporary Well 199-F5-56, near the F Reactor building, had a concentration of 80 pCi/L in December 2011. This is the only well in this part of 100-F with strontium-90 concentrations above the drinking water standard. Nearby wells historically had strontium-90 concentrations ranging from less than the detection limit up to approximately 7 pCi/L, and strontium-90 is no longer analyzed at some of these wells. The contamination detected in 199-F5-56 is evidently part of a small, local plume.

Duplicate groundwater samples from characterization borehole C7971 in the 118-F-1 Burial Ground had strontium-90 concentrations of 7.99 and 8.5 pCi/L in February 2011. Downgradient Well 199-F8-3 had a non-detect concentration, and 199-F8-7 had a concentration of 5.5 pCi/L.

#### *4.3.2.4 Trichloroethene in 100-F Groundwater*

Trichloroethene concentrations exceed the DWS (5 µg/L) in several wells in southwestern 100-F, and sporadically in wells in central 100-F (Figures 4-33 through 4-35). Only three wells exceed the DWS in southwestern 100-F. The lack of wells to the south creates uncertainty in the interpretation, and the plume probably extends farther south than can be interpreted based on available data. In 2010, trichloroethene was detected in Well 699-71-30, located approximately 2 km south of 100-F, at concentration up to 1.4 µg/L. This suggests that a plume extends southward at concentrations below the DWS. The orientation of the nitrate plume, with much higher concentrations, illustrates the overall direction of contaminant migration in this region to the south-southeast.

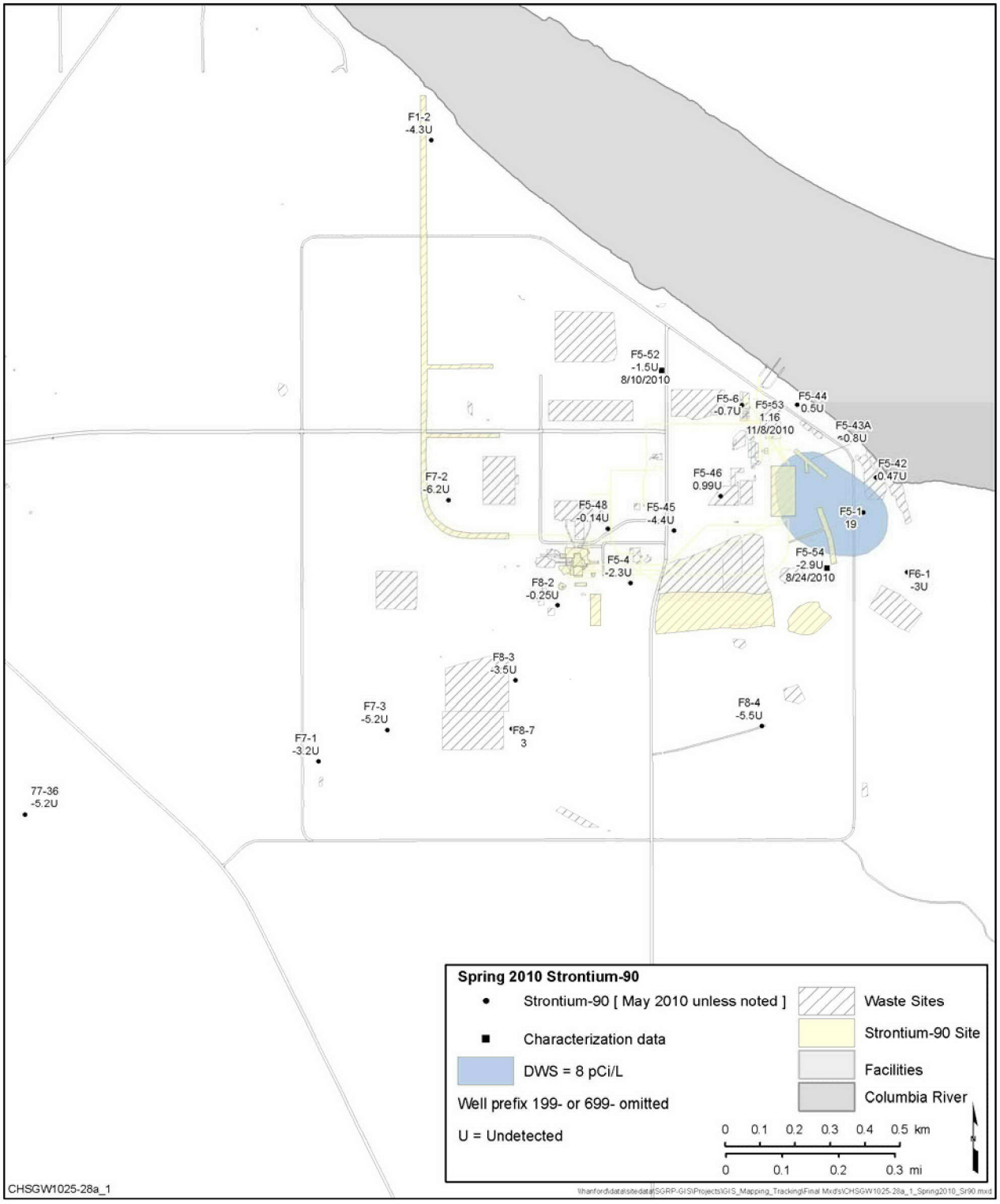



Figure 4-29. Strontium-90 in 100-F Unconfined Aquifer, Spring 2010

Figure 4-30. Strontium-90 in 100-F Unconfined Aquifer, Fall 2010

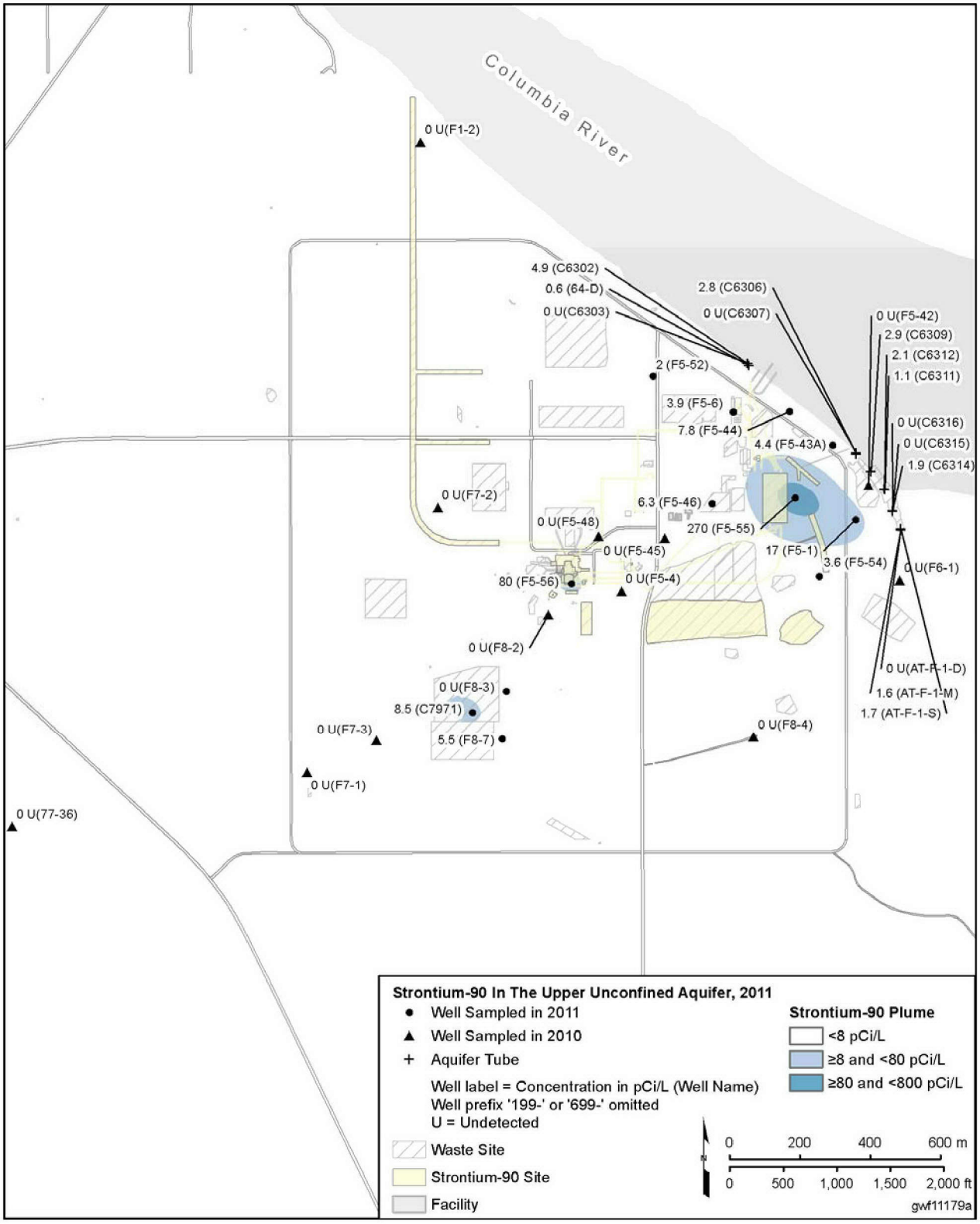



Figure 4-31. Strontium-90 in 100-F Unconfined Aquifer, 2011

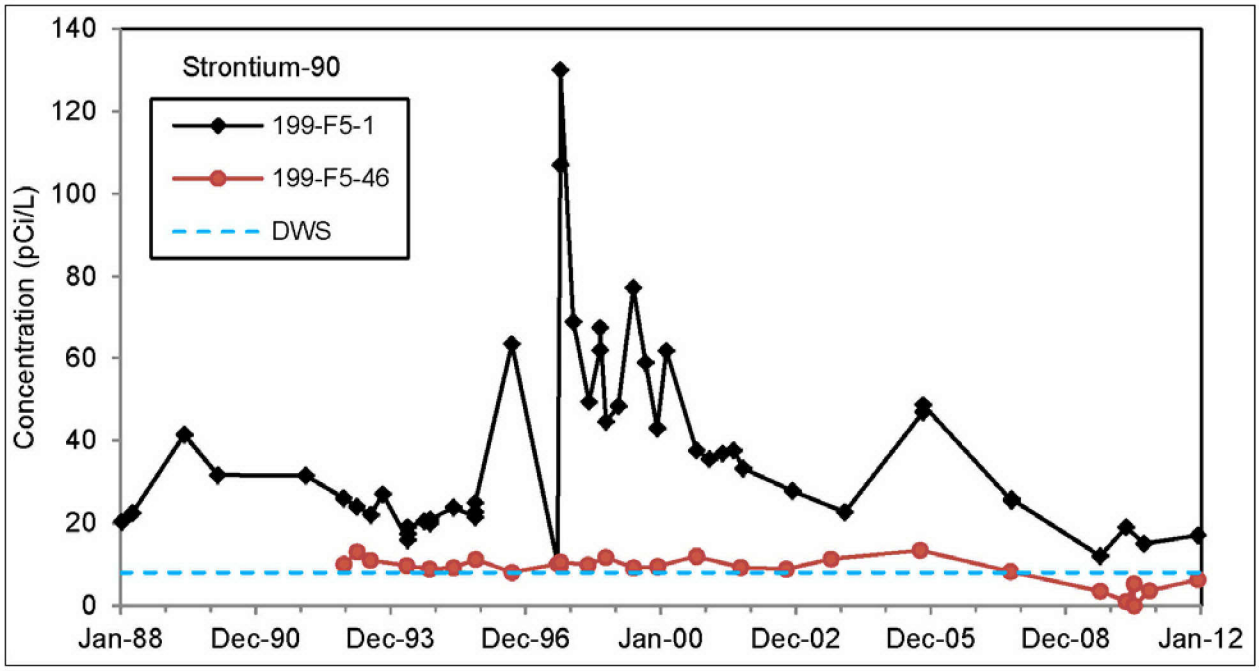



Figure 4-32. Strontium-90 Trends in Wells 199-F5-1 and 199-F5-46

In 1995, DOE conducted a soil vapor investigation in the southwest 100-F trichloroethene plume, as part of a supplemental LFI (*100-FR-3 Groundwater/Soil Gas Supplemental Limited Field Investigation Report* [DOE/RL-95-99]). A total of 40 soil gas samples and 41 groundwater samples were collected from a sampling grid using a hydraulic probe driver. The study identified a region of soil gas containing concentrations of trichloroethene up to 77 ppb by volume, and a region of groundwater contamination with concentrations up to 52 µg/L (Figure 4-36). The general region where trichloroethene was detected in soil gas corresponded to the general region of shallow groundwater contamination. The study concluded that the trichloroethene may have dissolved into the groundwater as the water moved through a region of vadose zone contamination. The study did not identify a source for the trichloroethene. Recently the 600-127 waste site, located just west of 100-F, was remediated (Figure 4-36 shows location). Process knowledge of this former facility suggests that it may have contributed to the trichloroethene plume. Temporary sampling points C8218, C8219, C8220, C8221, and C8222, similar to aquifer tubes, were driven into the excavated 600-127 waste site to collect groundwater from the top of the aquifer. Trichloroethene was below or near detection limits in all samples. The maximum concentration was 2.30 µg/L, flagged "J" indicating it is an estimate. Total petroleum hydrocarbons (diesel range) and vinyl chloride were undetected.

From southwestern 100-F, groundwater flows to the east until it gets close to the Columbia River. It then turns south-southeast, parallel to the river (Figures 3-31 and 3-33). Figure 4-37 illustrates trichloroethene concentrations in three wells in southwestern 100-F. The trends show movement of a portion of the plume toward the east and an overall decline in concentrations. Wells 199-F7-1 and 199-F7-3 are screened across the entire aquifer thickness (less than 3 m [10 ft] in this location). The highest concentration in 2009 through 2011 was 20 µg/L in Well 199-F7-1.

Wells in some other portions of 100-F also detect trichloroethene at concentrations that fluctuate around the DWS. In central 100-F, Wells 199-F5-4, 199-F5-45, 199-F5-46, 199-F5-48 and 199-F7-2 had trichloroethene concentrations in 2010 and 2011 that ranged from less than 1 to 7.9 µg/L. Well 199-F8-4 in southeastern 100-F has concentrations near the detection limit (1 µg/L).

The 100-F aquifer tubes are no longer sampled for trichloroethene. Samples from previous years showed no detections.

#### 4.3.2.5 *Tritium in 100-F Groundwater*

Tritium concentrations beneath 100-F have not exceeded the DWS (20,000 pCi/L) in recent years. At lower concentrations, a plume extends to the southeast from the southern part of 100-F.

Historically, only Wells 199-F5-4 and 199-F8-3 have had tritium concentrations above the DWS (Figure 4-38). Concentrations in Well 199-F5-4, in central 100-F, have been below the DWS since the late 1980s. Concentrations in Well 199-F8-3 (southwestern 100-F) spiked to approximately 180,000 pCi/L in the mid-1990s. The concentration spikes preceded waste site remediation. In December 2011, the tritium concentration in Well 199-F8-3 was 12,000 pCi/L.

Tritium concentrations in 100-F aquifer tubes range from below detection limits to approximately 1,000 pCi/L.

### 4.3.3 Vertical Distribution of Contaminants in 100-F Groundwater

The unconfined aquifer beneath 100-F is only 1 to 8 m (3 to 25 ft) thick. Vertical stratification of contamination within the unconfined aquifer is of less concern here than in areas with a thick aquifer. Many of the monitoring wells in 100-F are screened across the entire aquifer.

The base of the unconfined aquifer in 100-F comprises a thick sequence of fine-grained sediments of the Ringold Formation that is continuous beneath the region (Figures 3-9 and 3-11). This unit includes the informally named RUM and deeper paleosols and overbank deposits. Groundwater in water-bearing zones of the RUM (Wells 199-F5-43B and 199-F5-53) is not contaminated. Deeper aquifers (Ringold unit A and basalt-confined aquifers) are not monitored in 100-F but can be inferred to be uncontaminated because of the lack of contamination in the RUM and an upward hydraulic gradient.

Sources of information about vertical distribution of groundwater contaminants in 100-F include the following:

- Characterization data collected during installation of wells in 2010
- Monitoring data from Well 199-F5-43A, screened at the top of unconfined aquifer, and Well 199-F5-43B, screened in the RUM
- Monitoring data from Well 199-F5-53, screened in the RUM, and nearby Wells 199-F5-6 and 199-F5-44, screened in the unconfined aquifer
- Aquifer tube clusters screened at various depths in the unconfined aquifer

During drilling of new monitoring wells, water samples were collected every 1.5 m (5 ft) through the thickness of the unconfined aquifer and analyzed for COPCs. These were the first comprehensive data collected to define vertical distribution of contaminants through the entire aquifer thickness.

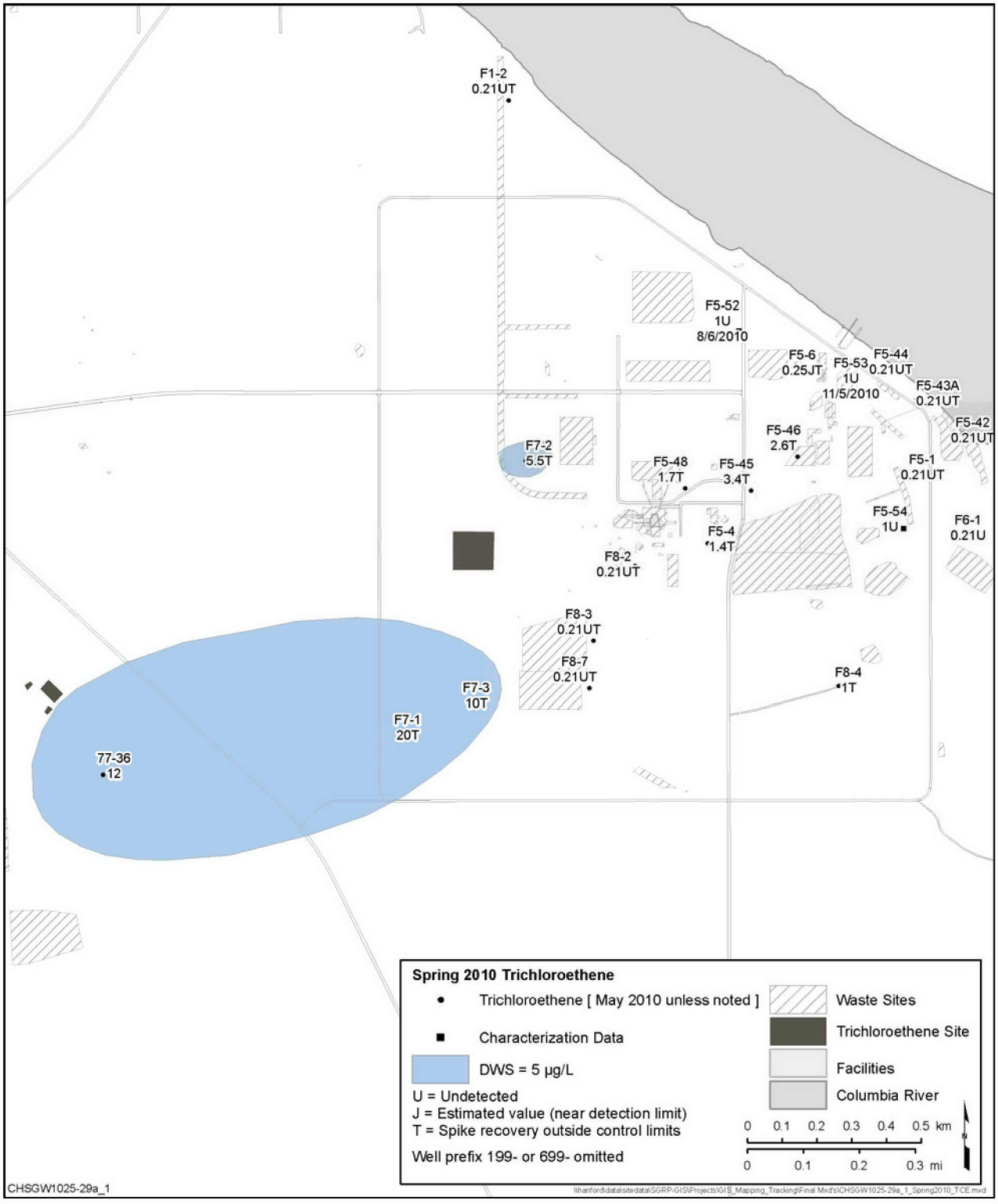



Figure 4-33. Trichloroethene in 100-F Unconfined Aquifer, Spring 2010

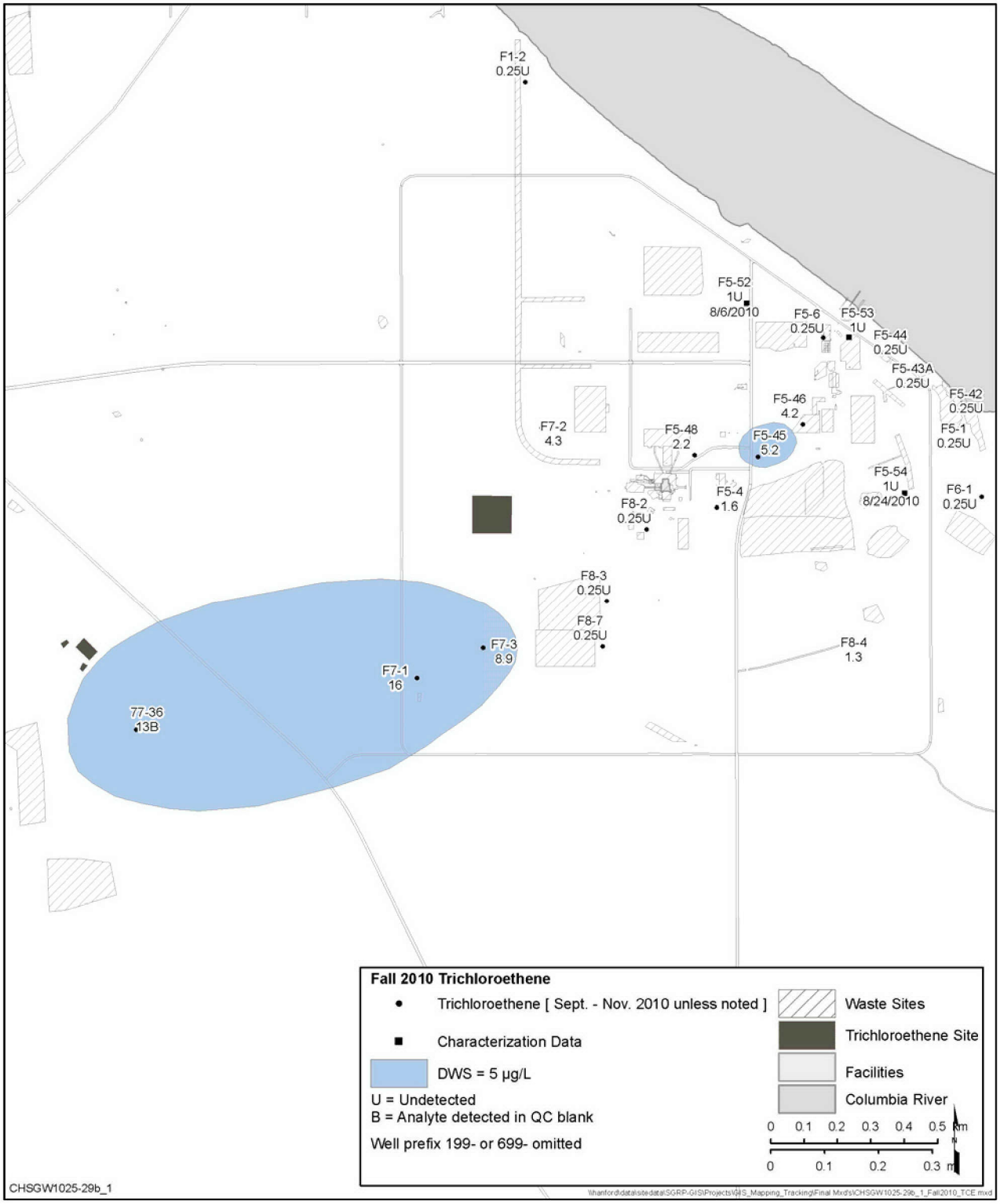



Figure 4-34. Trichloroethene in 100-F Unconfined Aquifer, Fall 2010

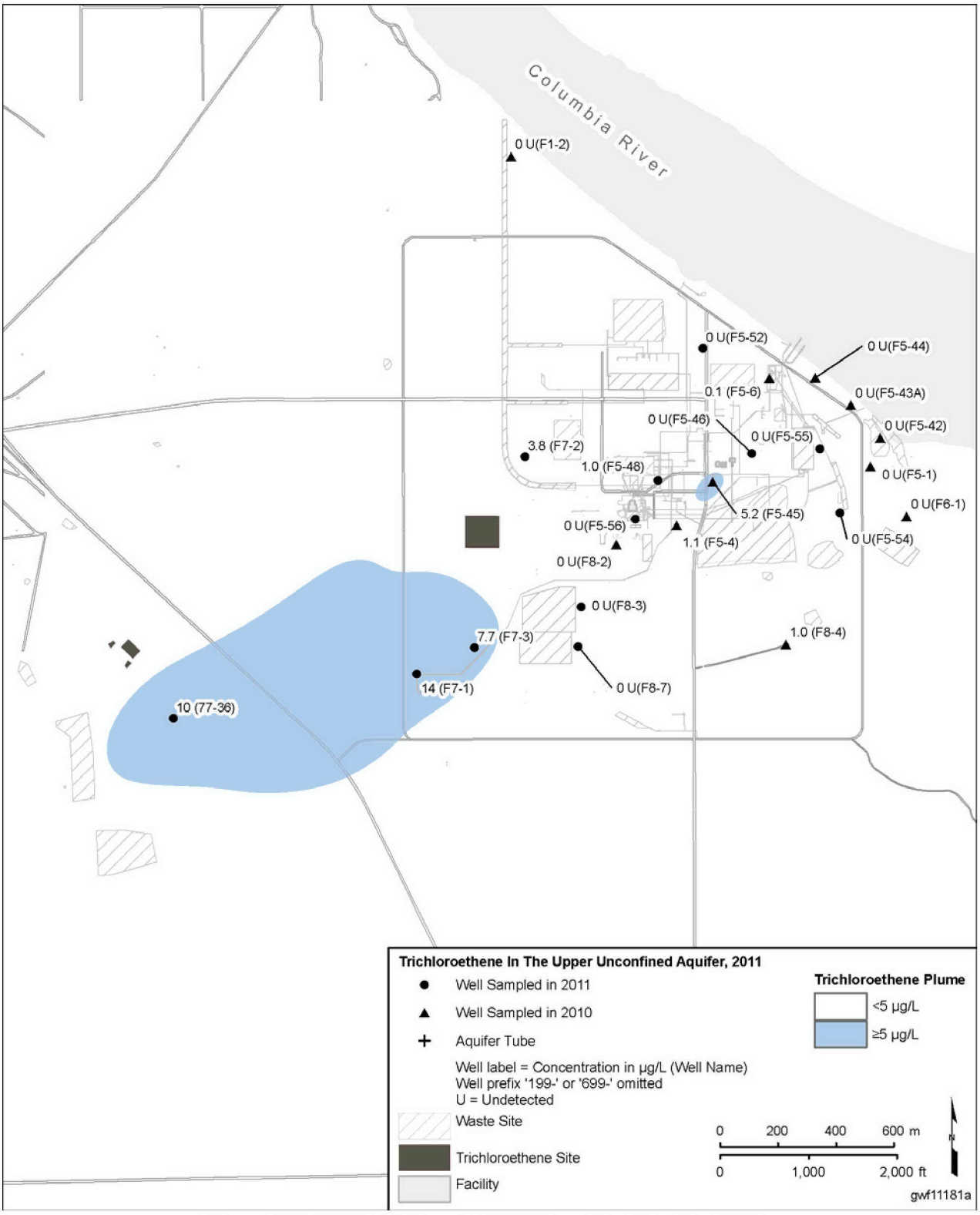
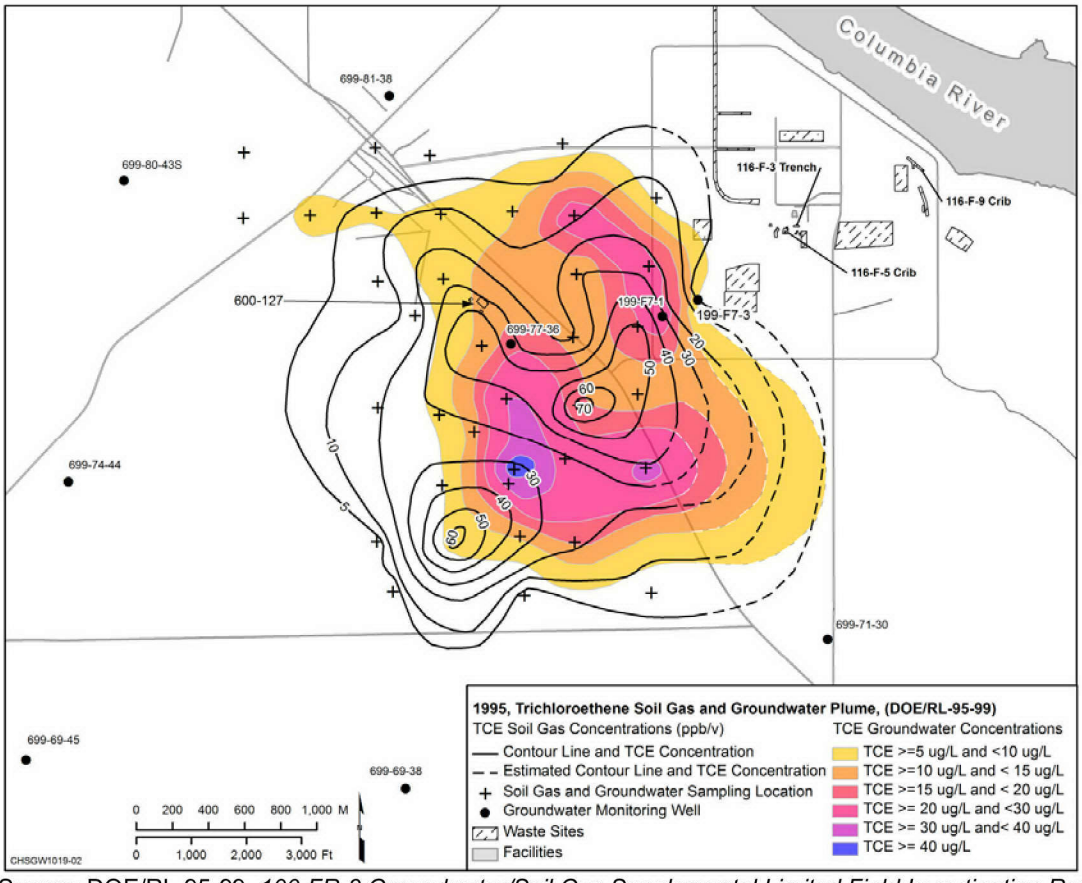



Figure 4-35. Trichloroethene in 100-F Unconfined Aquifer, 2011




Source: DOE/RL-95-99, *100-FR-3 Groundwater/Soil Gas Supplemental Limited Field Investigation Report*.

Figure 4-36. Trichloroethene Plume in Soil Gas and Groundwater, Based on 1995 Limited Field Investigation

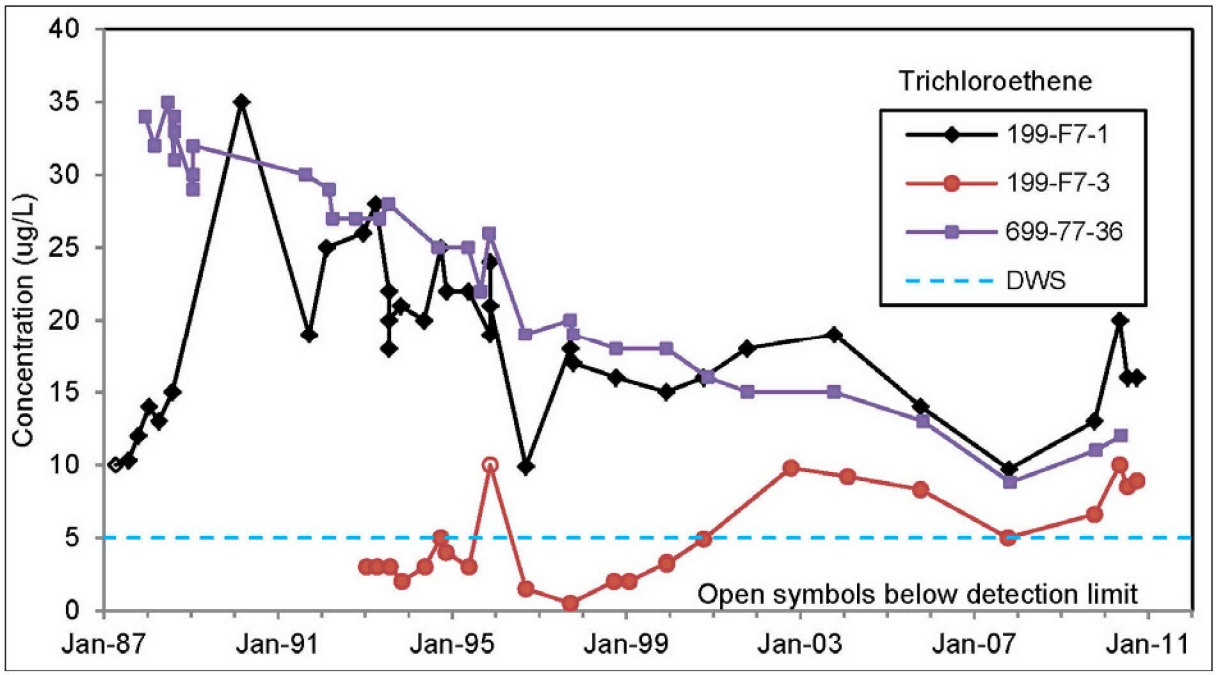



Figure 4-37. Trichloroethene Trends in Wells in Southwestern 100-F

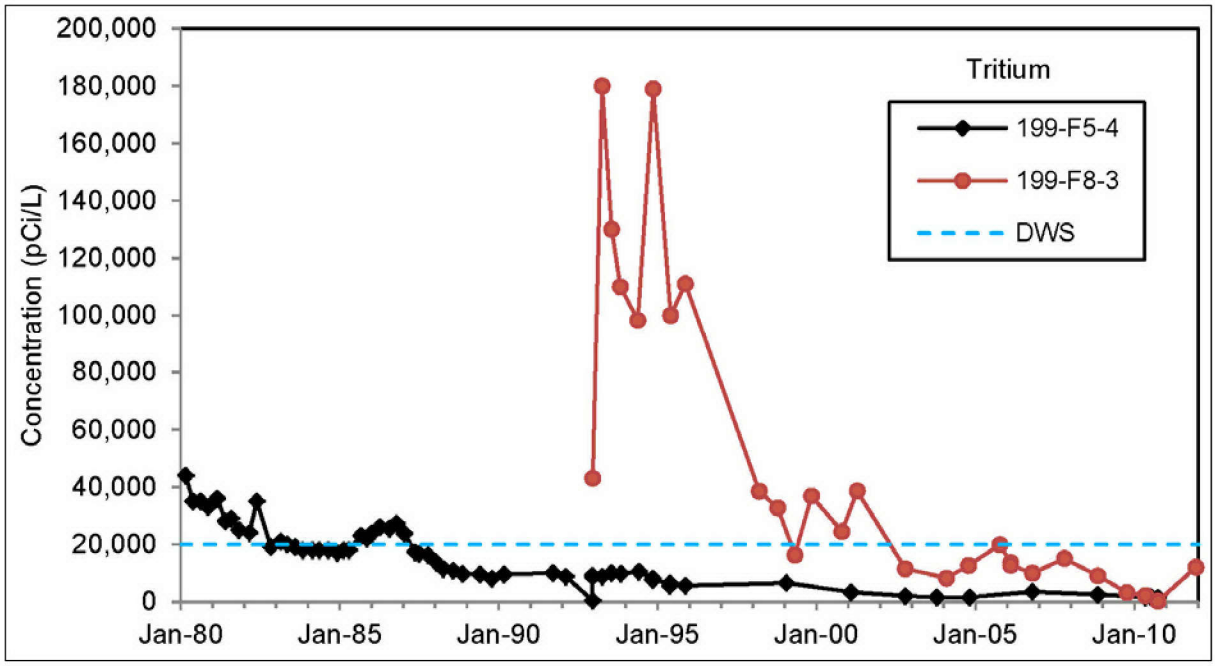



Figure 4-38. Tritium Trends in Wells 199-F5-4 and 199-F8-3

Cr(VI) concentrations decreased with depth in the only well where chromium was present. Nitrate decreased with depth in the well with the highest concentrations. No other significant variability with depth was observed, as discussed in the following sections.

#### *4.3.3.1 Vertical Distribution of Groundwater Contamination in Well 199-F5-52 (C7790)*

This well is located in northern 100-F and was intended to delimit the Cr(VI) plume. The aquifer is 6.4 m (21 ft) thick at this location, and four groundwater samples were collected during drilling. Figure 4-39 shows the vertical distribution of selected constituents in groundwater. Cr(VI), strontium-90, and trichloroethene were not detected in any characterization samples. Nitrate, gross alpha, gross beta, and tritium concentrations all were low and did not vary significantly with depth.

#### *4.3.3.2 Vertical Distribution of Groundwater Contamination in Wells 199-F5-6, 199-F5-44, and 199-F5-53*

Well 199-F5-53 (C7791) was drilled within the Cr(VI) and strontium-90 plumes in eastern 100-F and screened in a water-bearing unit of the RUM. Figure 4-40 shows the vertical distribution of selected constituents in groundwater. The unconfined aquifer was 4.8 m (16 ft) thick at this location, and only two unconfined groundwater samples were collected. One groundwater sample was collected from a water-bearing unit in the RUM. No water table wells are located immediately adjacent to Well 199-F5-53. Well 199-F5-6 is located approximately 80 m (260 ft) to the west (inland) and Well 199-F5-44 is located approximately 80 m (260 ft) to the east (near the river). Specific conductance in 199-F5-53 is intermediate between that of the nearby wells, reflecting the relative degree of mixing between groundwater and river water.

The groundwater sample from Well 199-F5-53, collected from approximately 1.5 m (5 ft) below the water table, had a maximum Cr(VI) concentration of 15.8 µg/L. The next sample, from 1.5 m (5 ft) deeper, had no detectable Cr(VI). Samples from the RUM had no detectable Cr(VI) or total chromium. Cr(VI) concentrations in nearby monitoring Well 199-F5-6 ranged from 14 to 60 µg/L in 2010. Concentrations in Well 199-F5-44, located nearer the river, averaged 10 µg/L in 2010.

Nitrate concentrations in the unconfined aquifer ranged from 20 to 32 mg/L, approximately the same as in nearby Well 199-F5-6. The concentration in the RUM was very low (less than 1 mg/L).

Strontium-90 was detected in one sample from the unconfined aquifer at 1.16 ± 0.45 pCi/L, but a split sample had no detectable strontium-90 (-4.6 ± 3.1 pCi/L). Strontium-90 is detected at levels below the DWS in nearby wells. No strontium-90 was detected in the RUM at Well 199-F5-53.

Trichloroethene was not detected in characterization samples from the unconfined aquifer and the RUM in Well 199-F5-53.

Gross alpha was not detected, and gross beta concentrations were less than 10 pCi/L. Tritium ranged from 510 to 3,500 pCi/L in the unconfined aquifer, with large variability between two duplicate samples. Tritium was not detected in the RUM.

#### *4.3.3.3 Vertical Distribution of Groundwater Contamination in Well 199-F5-54*

This well is located in eastern 100-F and was intended to delimit the strontium-90 plume on the south side. The unconfined aquifer is approximately 8.4 m (27 ft) thick at this location, and five groundwater samples were collected during drilling.

Strontium-90 was not detected in any characterization samples. Cr(VI) was not detected, and total chromium levels were less than 5 µg/L (Figure 4-41). Nitrate concentrations exceeded the DWS in all samples, but concentrations declined with depth. Gross alpha and gross beta concentrations also declined with depth. Tritium concentrations were below the DWS and increased with depth. Specific conductance decreased with depth, from 1,019 to 476 µS/cm.

#### *4.3.3.4 Vertical Distribution of Groundwater Contamination in Wells 199-F5-43A and 199-F5-43B*

Well 199-F5-43A monitors the unconfined aquifer and adjacent Well 199-F5-43B monitors a water-producing zone in the RUM. The shallow well typically has strontium-90 detections of 2 to 4 pCi/L. No strontium-90 is detected in the deeper well. Nitrate concentrations are higher in the shallow well (2 to 4 mg/L compared to 0.2 mg/L in the deep well). Chromium, tritium, and trichloroethene concentrations are near or below detection limits in both wells. Specific conductance is higher in the deeper well (approximately 360 µS/cm compared to 150 to 200 µS/cm in the shallow well).

#### *4.3.3.5 Vertical Distribution of Groundwater Contamination in Aquifer Tubes*

Aquifer tubes in 100-F (Figure 2-1 shows location) have screen depths ranging from 3 to 10 m (10 to 30 ft) bgs. The elevations of most of these screens are likely in the unconfined aquifer, with others possibly in the RUM.[2] Not all of the tubes are sampled routinely. At the sites where multiple depths are sampled, Cr(VI) concentrations are lowest in the shallowest tubes, which are most affected by mixing with river water. This mixing is evident from lower specific conductance in these tubes.

Table 4-20 lists strontium-90 concentrations from 100-F aquifer tubes where multiple depths were sampled in 2009 through 2011. Concentrations are near or below detection limits in all tubes and data are limited. The highest concentrations (maxima greater than 5 pCi/L) are observed in tubes C6302, C6309, and AT-F-1-M, which have screens at depths of 2.6 to 5.5 m (8.5 to 18 ft). The aquifer is approximately 6 to 8 m (20 to 26 ft) thick at this location.

Multiple-depth data for nitrate are not available in 100-F aquifer tubes.

[2] Geologic samples are not collected during installation of aquifer tubes, which are driven into the sediment. Consequently, the geologic formations are inferred from nearby monitoring wells.

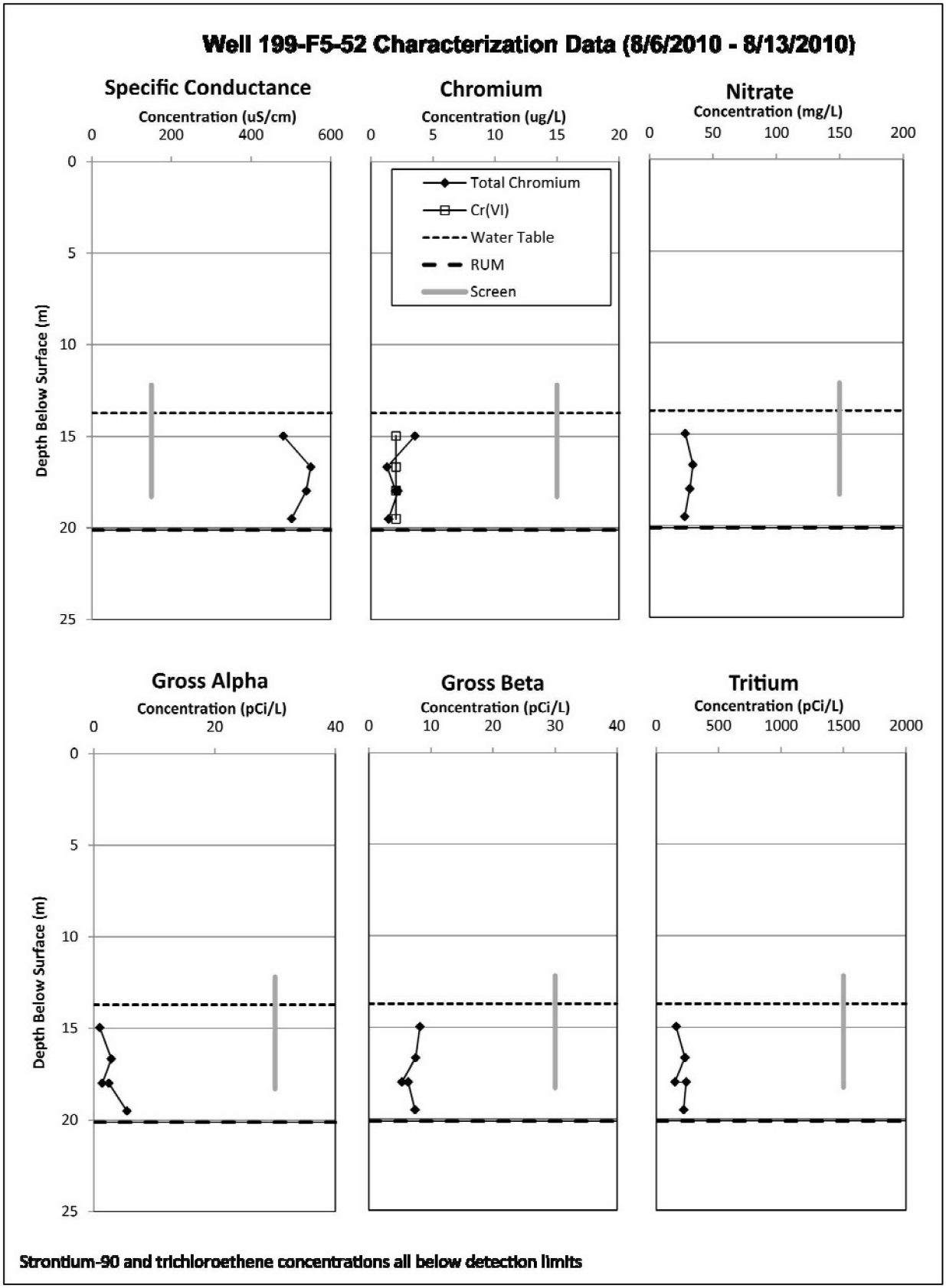



Figure 4-39. Vertical Distribution of Contaminants in Well 199-F5-52

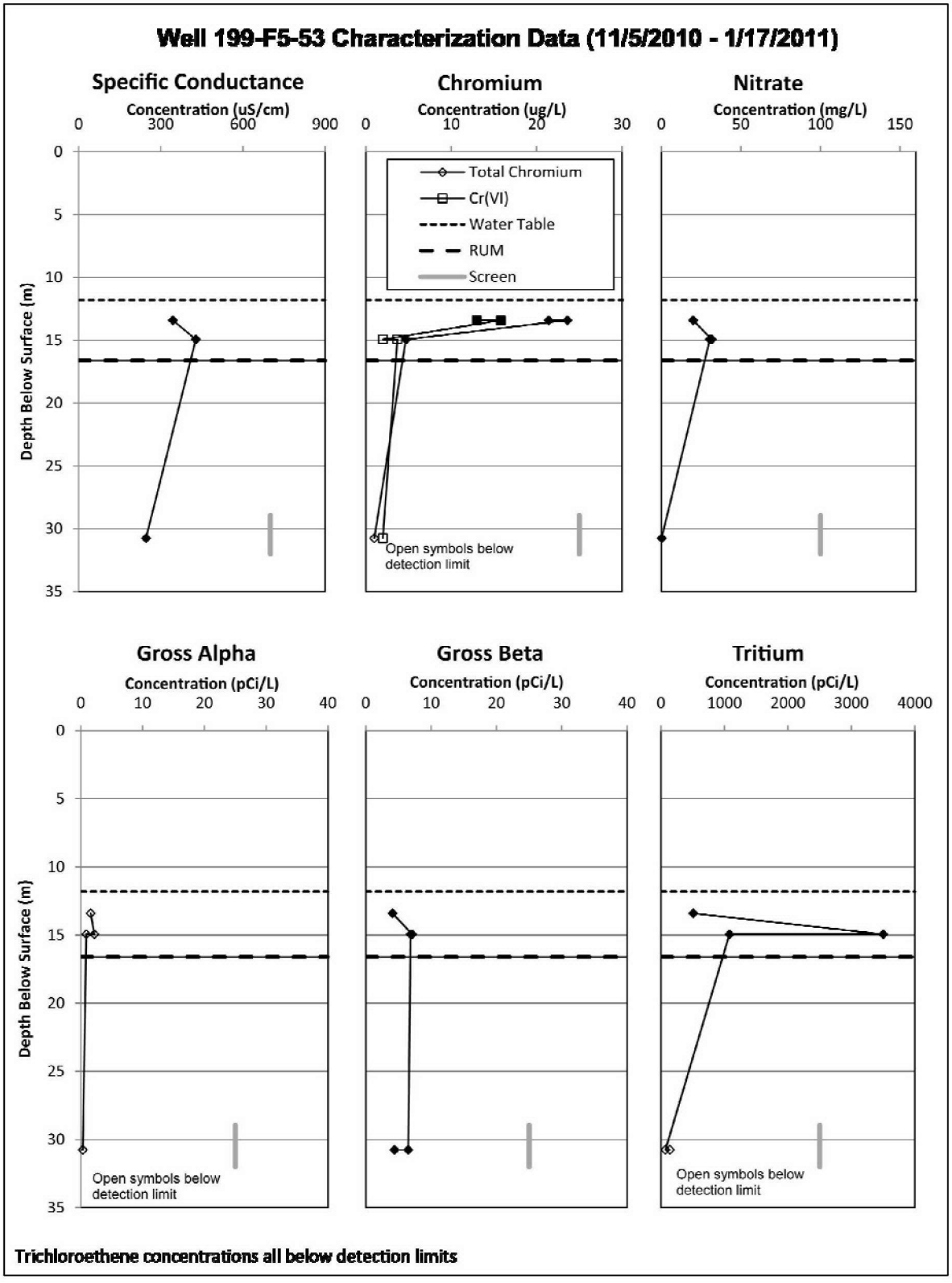



Figure 4-40. Vertical Distribution of Contaminants in Well 199-F5-53

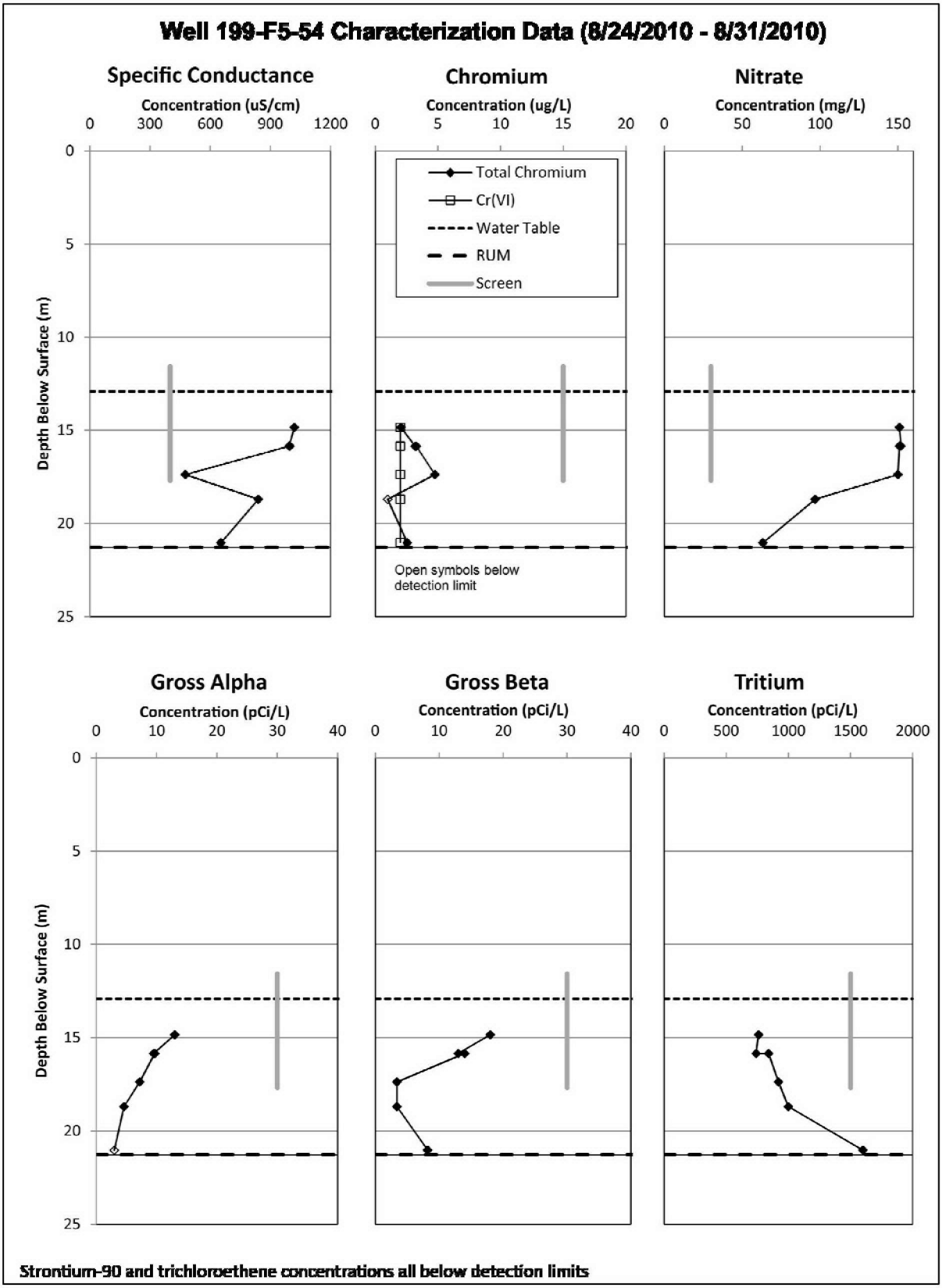



Figure 4-41. Vertical Distribution of Contaminants in Well 199-F5-54

Table 4-20. Strontium-90 Concentrations in 100-F Aquifer Tubes, 2009-2011

| Tube | Depth Below Ground Surface (m) | Depth Below Ground Surface (ft) | Number of Samples 2009-2011 | Strontium-90 Concentration (pCi/L) Minimum | Maximum | Average |
|---|---|---|---|---|---|---|
| C6302 | 2.58 | 8.5 | 3 | U | 5.4 | 3.4 |
| C6303 | 4.06 | 13.3 | 3 | U | U | U |
| 64-S | 2.29 | 7.5 | 1 | U | U | U |
| 64-M | 5.18 | 17.0 | 1 | U | U | U |
| 64-D | 8.23 | 27.0 | 5 | U | 2.7 | 1.1 |
| C6305 | 2.65 | 8.7 | 2 | U | U | U |
| C6306 | 4.37 | 14.3 | 3 | U | 2.8 | 1.2 |
| C6307 | 4.99 | 16.4 | 3 | U | U | U |
| C6308 | 2.85 | 9.4 | 2 | U | 2.8 | 1.4 |
| C6309 | 4.93 | 16.2 | 3 | 2.9 | 5.8 | 4.2 |
| C6311 | 2.96 | 9.7 | 3 | U | 1.1 | 0.9 |
| C6312 | 4.84 | 15.9 | 3 | U | 2.3 | 1.1 |
| C6314 | 3.53 | 11.6 | 3 | U | 1.9 | 0.6 |
| C6315 | 5.59 | 18.4 | 3 | U | U | U |
| C6316 | 8.31 | 27.3 | 5 | U | U | U |
| AT-F-1-S | 3.15 | 10.3 | 3 | U | 1.7 | 0.56 |
| AT-F-1-M | 5.51 | 18.1 | 3 | 1.6 | 5.4 | 3.5 |
| AT-F-1-D | 7.96 | 26.1 | 5 | U | U | U |
| 66-D | 8.56 | 28.1 | 2 | U | U | U |

Note: Shading indicates multi-depth clusters.
U = Not detected

### 4.3.4 Groundwater Contaminant Plumes in 100-IU-2/IU-6

Groundwater in 100-IU-2/IU-6 is contaminated with tritium and I-129 (Figure 4-42), but the sources of those contaminants are in the 200 Areas; remediation is addressed in 200 Area documents. A nitrate plume from 200 Area sources also coincides with the tritium and I-129 plumes, but concentrations in the 100-IU-2/IU-6 portion are below the DWS, except where the 100-F nitrate plume extends into a portion of 100-IU-2/IU-6. Because wells on the Hanford Site are monitored at different periods and frequencies, the plumes in Figure 4-42 are based on annual average concentrations.

Three wells in the northern portion of 100-IU-2/IU-6 have elevated concentrations (approximately 10 to 25 µg/L) of either dissolved total chromium or Cr(VI) (Figure 4-43). Wells 699-62-43F and 699-65-50 are located near Gable Mountain, and Well 699-77-54 is located east of the 100-K Area (see Figure 4-17 for well locations). It is likely that the chromium contamination originated in 100-K in years past, when groundwater mounds altered flow directions. In the 1950s and 1960s hydraulic head in 100-K

was much higher than in the 600 Area or 100-F (Figure 4-44), which could have pushed 100-K contaminants eastward toward Well 699-77-54.

Four wells in the 600 Area between 100-K and 100-F detect traces of trichloroethene; the source of contamination is unknown. Well 699-77-54 has the highest concentrations, from 9 to 11 µg/L (Figure 4-45). Nearby Wells 699-83-47, and 699-71-52 also have detected trichloroethene, but at concentrations below the DWS (see Figure 3-2 for well locations). Like the Cr(VI), this contamination may have originated in 100-K. Well 699-71-30, located south of 100-F, has detected traces of trichloroethene that relate to the plume in southwestern 100-F (Section 4.3.2.4).

Most of the monitoring wells in 100-IU-2/IU-6 are screened in the upper portion of the unconfined aquifer. The deeper wells show that groundwater contamination is either not detected at depth, or that concentrations are much lower than that found near the water table (*Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* [DOE/RL-2010-11]).

### 4.3.5 Soil Chemistry in Aquifer and Aquitard

Section 4.2.5 summarized analytical results for soil above or near the water table in groundwater monitoring wells. Samples were also collected from the RUM. Table 4-21 summarizes soil chemistry data from these samples, compared to Hanford Site soil background. The background values represent soil in the vadose zone, so they are not directly applicable to soil from below the water table. Background values are used here only for general perspective on concentrations measured in soil samples in the 100-F wells.

Constituents with concentrations above background included several metals and cobalt-60. In several cases, QC or data validation indicates some question about the data (indicated in the footnotes of Table 4-21). Some other results were very close to detection limits and may not be quantifiable. Most of the exceedances were from Well 199-F5-53 (location shown on Figure 3-1).

No soil background has been established for Cr(VI). Concentrations were below detection limits except one sample from Well 199-F5-52 (0.230 mg/kg at 15.8 m [51.8 ft] bgs) and one from Well 199-F5-53 (0.144 mg/kg at 25.7 m [84.3 ft] bgs), but a split sample had no detectable Cr(VI)). Both detections were flagged B (near detection limits).

## 4.4 Columbia River Water and Sediments

Hanford Site surface water and sediment investigations include annual environmental monitoring (2010 Sitewide Environmental Report [PNNL-20548]), and recent RIs (Field Summary Report [WCH-380]; Hanford Site Releases Data Summary [WCH-398]). This section summarizes results from those reports, and presents results of additional pore water sampling conducted in February 2011.

### 4.4.1 Remedial Investigation of Hanford Site Releases to the Columbia River

In recent years, DOE has studied Hanford Site releases to the Columbia River via groundwater discharge (upwelling) into the river. As discussed in Section 2.1.7, field sampling activities were conducted in 2008 through 2010 in support of a RI of Hanford Site releases to the Columbia River (Field Summary Report [WCH-380]; Hanford Site Releases Data Summary [WCH-398]). Section 3.6.4 describes DOE's upwelling study and how it defined areas where groundwater discharges to the Columbia River. During another phase of that study (Phase IIb), samples were collected from the pore water and analyzed for primary contaminants of concern: (Cr(VI) for 100-F and tritium for the Hanford Townsite). In the final phase of the study (Phase III), pore water, river water, and river sediment were collected and analyzed for a comprehensive list of analytes. This study was followed up by additional pore water sampling as part of the RI/FS (100-F/IU-2/IU-6 SAP [DOE/RL-2009-43]). This section summarizes results of all these sampling activities.

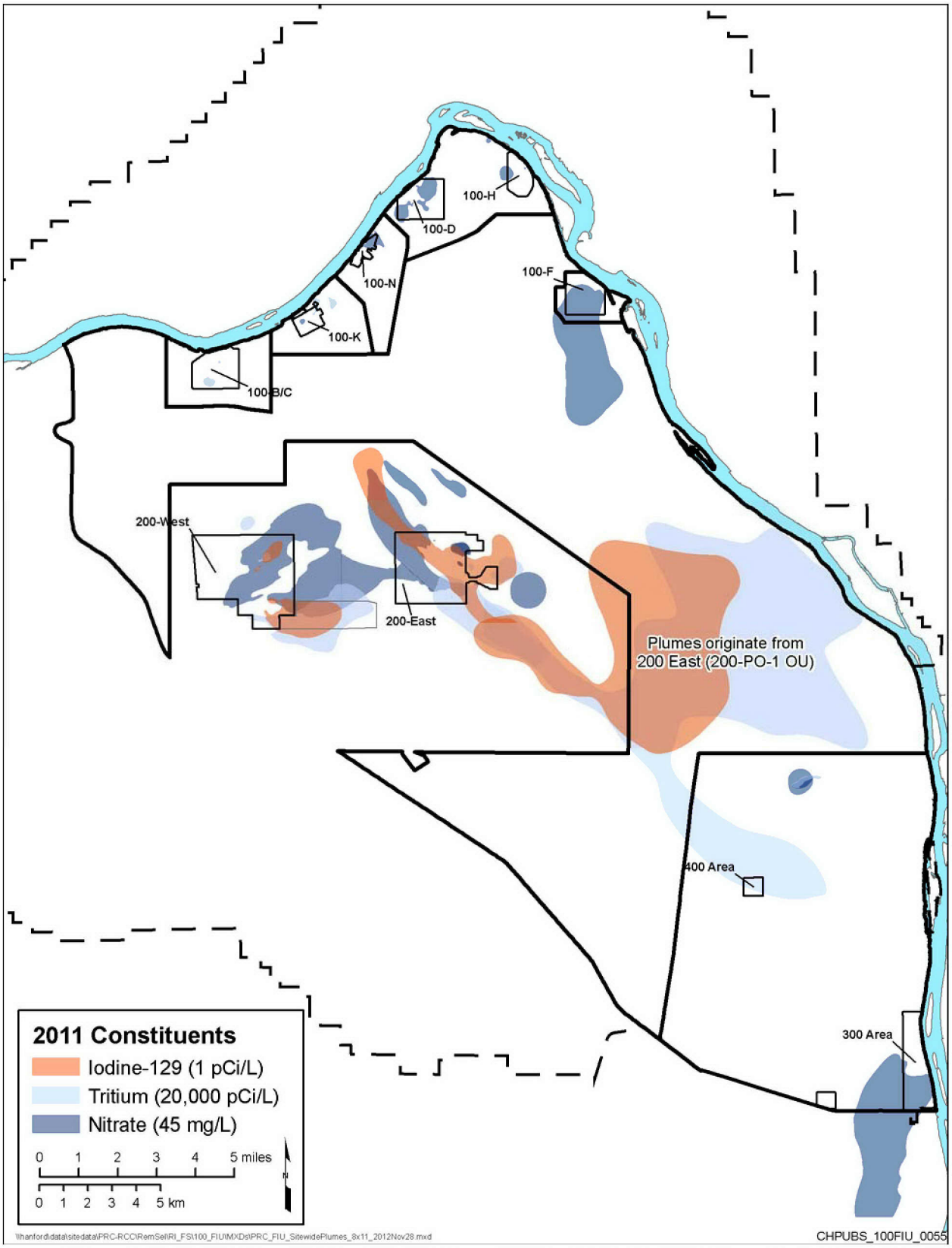



Figure 4-42. Distribution of Iodine-129, Nitrate, and Tritium in Hanford Site Groundwater, 2011

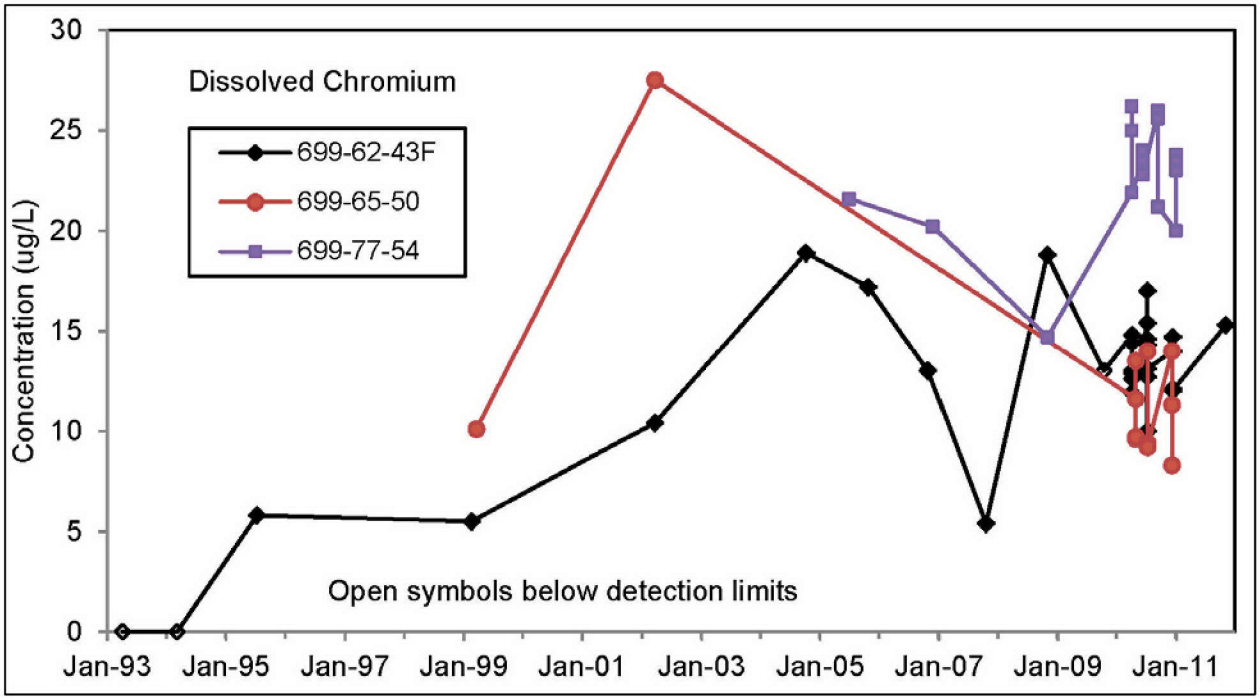



Figure 4-43. Dissolved Chromium Trends in 600 Area Wells

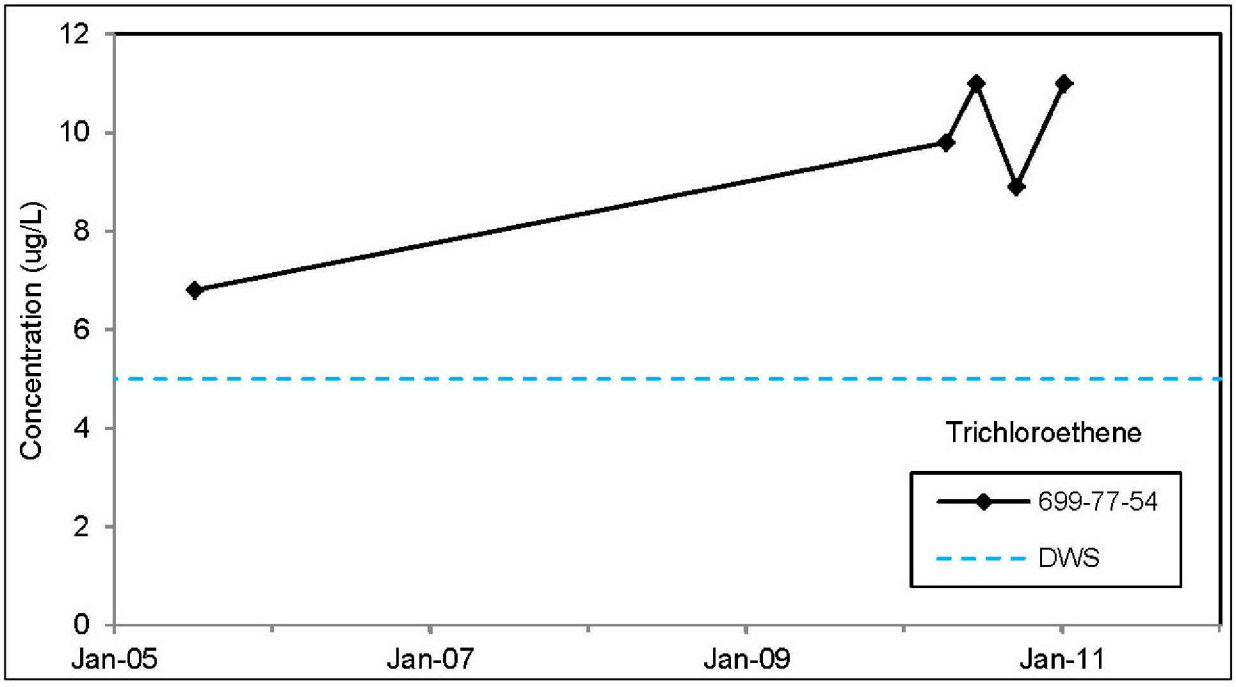



Figure 4-44. Trichloroethene Trend in Well 699-77-54

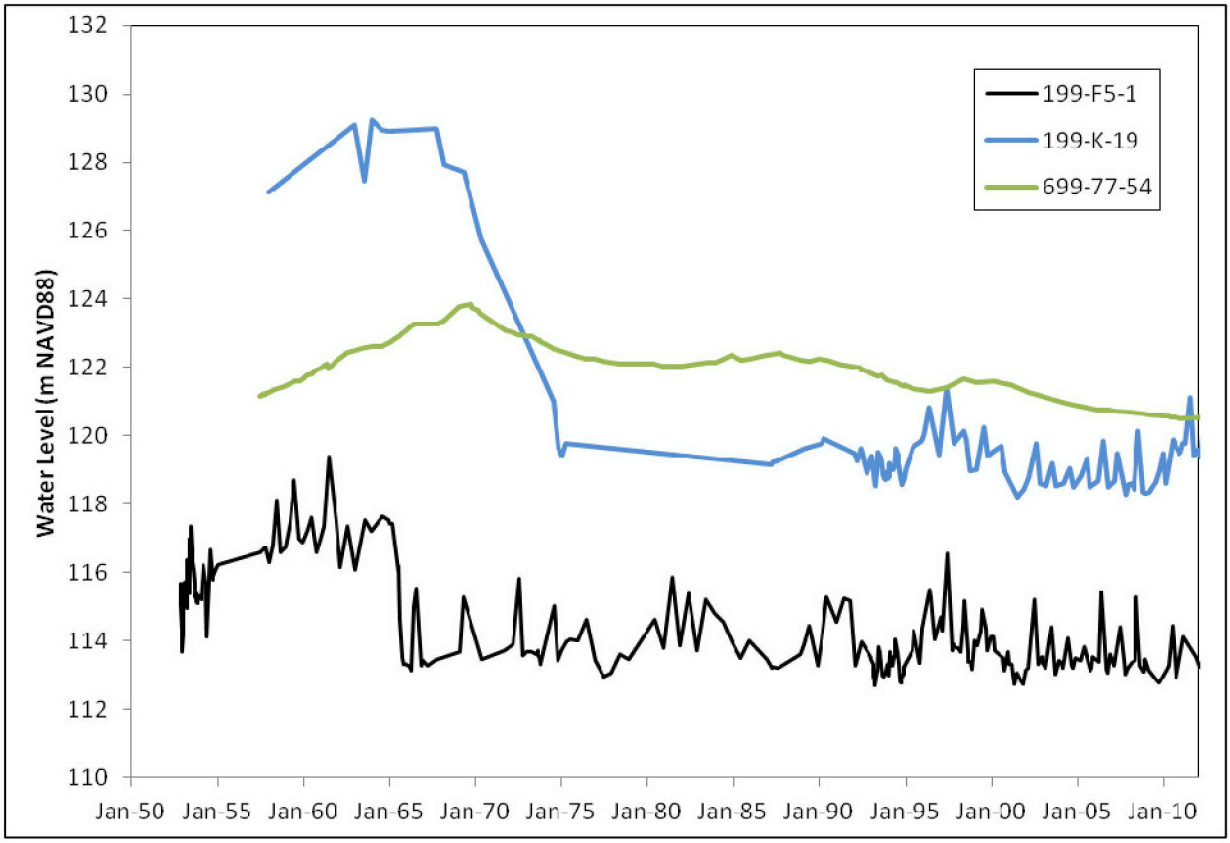



Figure 4-45. Water Levels in Wells in100-F (199-F5-1), 100-K (199-K-19), and 600 Area Between (699-77-54)

Table 4-21. Soil Chemistry Data Greater than Background from New Monitoring Wells, Samples Collected from the RUM Unit

| Well | Constituent[a,b] | Number Samples | Number Above Background | Background (mg/kg or pCi/g)[b] | Max. Conc. (mg/kg or pCi/g) | Depth Below Top of RUM (m) |
|---|---|---|---|---|---|---|
| 199-F5-52 | Selenium | 3 | 1 | 0.78 | 0.957[c] | 2.39 |
| 199-F5-53 | Arsenic | 15 | 1 | 6.47 | 9.02 | 15.4 |
| | Chromium | 15 | 5 | 18.5 | 23.8 | 0.96 |
| | Copper | 7 | 2 | 22.0 | 36.7[d] | 0.96 |
| | Lead | 15 | 1 | 10.2 | 12.5 | 15.4 |
| | Manganese | 7 | 3 | 512 | 981[e] | 9.09 |
| | Nickel | 7 | 1 | 19.1 | 25.6 | 0.96 |
| | Selenium | 15 | 3 | 0.78 | 1.91[f] | 0.96 |
| 199-F5-54 | Co-60 | 6 | 1 | 0.00842 | 0.041±0.033 | 2.29 |

Table 4-21. Soil Chemistry Data Greater than Background from New Monitoring Wells, Samples Collected from the RUM Unit

| Well | Constituent[a,b] | Number Samples | Number Above Background | Background (mg/kg or pCi/g)[b] | Max. Conc. (mg/kg or pCi/g) | Depth Below Top of RUM (m) |
|---|---|---|---|---|---|---|

a. Constituents evaluated: antimony, arsenic, beryllium, cadmium, cesium-137, chromium, cobalt-60, copper, europium-152, europium-154, Cr(VI), lead, manganese, nickel, selenium, silver, strontium-90, thallium, vanadium, and zinc (*Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study* [DOE/RL-2009-44], Table 2-12). Only those constituents with a result over background (see Table 4-1) are listed here.

b. Background concentration not available for Cr(VI); not detected except one sample from Well 199-F5-52 (230 µg/kg) and one from 199-F5-53 (144 µg/kg, but split was not detected). Both detections near detection limit (flagged "B").

c. Value flagged "B" indicating close to detection limit.

d. Duplicate sample had lower copper concentration (16.8 mg/kg) that did not exceed background.

e. Duplicate sample had lower manganese concentration (19.0 mg/kg) that did not exceed background.

f. Two highest values have validation qualifiers of "U".

Conclusions of the studies are that pore water, surface water, and river sediment at 100-F are not contaminated. Pore water at the Hanford Townsite (100-IU-2/IU-6) is contaminated with tritium from a groundwater plume originating in the 200 East Area.

#### *4.4.1.1 100-F Surface Water and Sediments*

Cr(VI) concentrations in Columbia River pore water at 100-F are below the AWQC of 10 µg/L and are not detectable in most cases. Table 4-22 lists Cr(VI) and total chromium data from pore water samples collected during Phase IIb (November 2009), Phase III (February 2010), and follow-up sampling in early 2011. Figures 2-3 and 2-6 in Chapter 2 show sampling locations.

Table 4-22. Chromium Concentrations in Pore Water at 100-F

| Sampling Site Station Number | Nov. 2009 Phase IIb | Feb. 2010 Phase III | | | Feb. 2011 | |
|---|---|---|---|---|---|---|
| | Cr(VI) (µg/L) | Cr(VI) (µg/L) | Total Cr, Unfiltered (µg/L) | Total Cr, Filtered (µg/L) | Cr(VI) (µg/L) | Total Cr (µg/L) |
| J100F1 | 3.7 U | -- | -- | -- | -- | -- |
| J100F2 | 3.7 U | - | -- | -- | -- | -- |
| J100F4 | 3.7 U | - | -- | -- | -- | -- |
| T100F2A | 8.0 | 20.0 J | 9.18 | 4.01 | 2 U | 1.12 B |
| T100F2C | 3.7 U | -- | -- | -- | -- | -- |
| T100F2D | 3.7 U | -- | -- | -- | -- | -- |
| J100F10 | 3.7 U | -- | -- | -- | -- | -- |
| T100F2E | 3.7 U | -- | -- | -- | -- | -- |
| J100F11 | 3.7 U | 7.4 U | 34.40 | 4.81 | -- | -- |

Table 4-22. Chromium Concentrations in Pore Water at 100-F

| Sampling Site Station Number | Nov. 2009 Phase IIb | | Feb. 2010 Phase III | | | Feb. 2011 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cr(VI) (µg/L) | | Cr(VI) (µg/L) | Total Cr, Unfiltered (µg/L) | Total Cr, Filtered (µg/L) | Cr(VI) (µg/L) | | Total Cr (µg/L) | |
| J100F14 | 3.7 | U | -- | -- | -- | -- | | -- | |
| J100F16A | 3.7 | U | -- | -- | -- | -- | | -- | |
| T100F4J1 | 3.7 | U | -- | -- | -- | -- | | -- | |
| J100F18 | 3.7 | U | -- | -- | -- | -- | | -- | |
| T100F4E | 3.7 | U | -- | -- | -- | -- | | -- | |
| J100F33* | 3.7 | UR | -- | -- | -- | -- | | -- | |
| T100F5J1 | 3.7 | U | -- | -- | -- | -- | | -- | |
| T100F5E | 3.7 | U | -- | -- | -- | -- | | -- | |
| J100F23 | 3.7 | U | -- | -- | -- | -- | | -- | |
| J100F25 | 3.7 | U | -- | -- | -- | -- | | -- | |
| F1 Transect 1 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F1 Transect 2 | -- | | -- | -- | -- | 2 | U | 2.13 | B |
| F1 Transect 3 | -- | | -- | -- | -- | 2 | U | 1.03 | B |
| F1 Transect 4 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F1 Transect 4 SPLIT | -- | | -- | -- | -- | 2.7 | | -- | |
| F1 Transect 5 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F1 Transect 5 DUP | -- | | -- | -- | -- | 2 | U | 1 | U |
| F1 Transect 6 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F1 Transect 7 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F1 Transect 8 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F1 Transect 9 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F1 Transect 10 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F2 Transect 1 | -- | | -- | -- | -- | 2 | U | 1.21 | B |
| F2 Transect 2 | -- | | -- | -- | -- | 2 | U | 1.12 | B |
| F2 Transect 3 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F2 Transect 4 | -- | | -- | -- | -- | 2 | U | 3.86 | B |
| F2 Transect 5 | -- | | -- | -- | -- | 2 | U | 1 | U |
| F2 Transect 6 | -- | | -- | -- | -- | 2 | U | 1 | U |

Table 4-22. Chromium Concentrations in Pore Water at 100-F

| Sampling Site Station Number | Nov. 2009 Phase IIb | Feb. 2010 Phase III | | | Feb. 2011 | |
|---|---|---|---|---|---|---|
| | Cr(VI) (µg/L) | Cr(VI) (µg/L) | Total Cr, Unfiltered (µg/L) | Total Cr, Filtered (µg/L) | Cr(VI) (µg/L) | Total Cr (µg/L) |
| F2 Transect 7 | -- | -- | -- | -- | 2 U | 1 U |
| F2 Transect 8 | -- | -- | -- | -- | 2 U | 1 U |
| F2 Transect 9 | -- | -- | -- | -- | 2 U | 1.6 B |
| F2 Transect 10 | -- | -- | -- | -- | 2 U | 1.22 B |

B = Value is above method detection limit but below contract detection limit
J = estimated value; high RPD (36.7%) on batch duplicate
R = result invalid (rejected)
U = Not detected
-- = not sampled
* Sample date July 2009

Nineteen pore water sample locations were successfully sampled for Cr(VI) in Phase IIb near 100-F. Only one of 19 pore water Cr(VI) results was reported above the detection limit of 3.7 µg/L. This result was 8 µg/L.

Two sample locations were selected for Phase III sampling of pore water, surface water, and sediment near 100-F. Again, Cr(VI) was detected in pore water at only one station (the same one with detectable Cr(VI) in Phase IIb), this time at 20 µg/L. The result has a data validation qualifier of "J" because of unacceptably high variability in a batch duplicate. Total chromium concentrations from the same location were much lower (9.2 and 4.0 µg/L in unfiltered and filtered samples, respectively), which also suggests a problem with the Cr(VI) result. Co-contaminants were analyzed in the two samples collected during Phase III. Strontium-90 was detected at both sites, at 2.3 and 1.5 pCi/L. Nitrate was detected at 8.0 and 3.1 mg/L; both results had a validation qualifier of "J." Tritium and uranium were not detected. The samples were not analyzed for organics. Surface water and sediment samples had no detectable Cr(VI) or strontium-90 during Phase III.

Additional, follow-up pore water sampling was conducted in February 2011 (*Columbia River Pore Water Sampling in 100-F Area, February 2011* [SGW-49575]). Out of 20 locations sampled, only one had detectable Cr(VI) at 2.7 µg/L, and a split sample from the same location had no detectable Cr(VI). The site that had detectable Cr(VI) in the earlier sampling events had no detectable Cr(VI) (Table 4-22). Total chromium results from the February 2011 sampling were consistent with the Cr(VI) results.

#### *4.4.1.2 Hanford Townsite Surface Water and Sediments*

Columbia River pore water at the old Hanford Townsite is contaminated with tritium at levels above the 20,000 pCi/L DWS at some locations. Twenty-nine locations were sampled for tritium during Phase IIb (Figures 2-5, 2-7, and 2-8 in Chapter 2) and seven of these had detectable tritium concentrations (ranging from 408 to 64,600 pCi/L; Table 4-23). The locations with the highest reported concentrations, which exceeded the DWS, were found near aquifer tube C6353, which has tritium concentrations of a similar magnitude.

A total of five sample locations were selected for Phase III sampling near the Hanford Townsite. Tritium was detected in pore water over a range of 6,240 to 65,200 pCi/L, consistent with measurements obtained

during Phase IIb. Nitrate concentrations in pore water were below the 45 mg/L DWS (maximum 35.7 mg/L).

Table 4-23. Tritium, Chromium, and Nitrate Concentrations in Columbia River Pore Water at the Hanford Townsite

| Station | River Mile | Nov. 2009 – Jan. 2010 Phase IIb | Feb. 2010 Phase III | | | | |
|---|---|---|---|---|---|---|---|
| | | Tritium (pCi/L) | Tritium (pCi/L) | Cr(VI) (µg/L) | Total Cr, Unfiltered (µg/L) | Total Cr, Filtered (µg/L) | Nitrate (mg/L) |
| JHTS40 | 349.58 | -- | 10,400 J | 7.4 U | 5.2 | 2.4 | 27.4 D J |
| JHTS30 | 351.77 | 15.7 U J | -- | -- | -- | -- | -- |
| JHTS29 | 352.65 | 85.7 U J | -- | -- | -- | -- | -- |
| JHTS38 | 353.82 | 242 U J | -- | -- | -- | -- | -- |
| JHTS28 | 354.62 | 127 U J | -- | -- | -- | -- | -- |
| JHTS26 | 355.17 | 228 U J | -- | -- | -- | -- | -- |
| JHTS24 | 356.13 | 152 U J | -- | -- | -- | -- | -- |
| JHTS23 | 356.54 | -68 U J | -- | -- | -- | -- | -- |
| JHTS21 | 356.58 | 28 U J | -- | -- | -- | -- | -- |
| JHTS19 | 357.38 | 31,500 J | 27,800 J | 13.0 | 10.4 | 3.0 | 33.5 D J |
| JHTS18 | 357.54 | 5,920 J | 6,240 J | 14.0 | 7.1 | 4.0 U J | 14.0 D J |
| JHTS33 | 357.85 | 64,600 J | 65,200 J | 21.0 | 15.0 | 2.8 | 35.7 D J |
| JHTS17 | 357.97 | 11,800 J | -- | -- | -- | -- | -- |
| JHTS15 | 358.26 | 185 U J | -- | -- | -- | -- | -- |
| JHTS11 | 358.91 | 286 U J | -- | -- | -- | -- | -- |
| JHTS9 | 359.90 | 3,470 J | 7,430 J | 15.0 | 2.1 | 0.6 B | 1.03 J |
| JHTS8 | 360.26 | 408 J | -- | -- | -- | -- | -- |
| JHTS4 | 361.23 | 239 U J | -- | -- | -- | -- | -- |
| JHTS2 | 362.41 | 6.5 U J | -- | -- | -- | -- | -- |

B = Near detection limit

J = The reported value is an estimate. Analyte was analyzed for and detected, but has potentially larger associated error factors in the result.

D = Analyte was identified in an analysis at a secondary dilution factor

U = Not detected

-- = not sampled

Pore water sample results for Cr(VI) ranged from 13 to 21 µg/L at four locations along the Hanford Site side of the river, opposite Savage Island. This was unexpected because there are no known chromium plumes reported in this area. Total chromium in filtered samples was lower, however (less than 5 µg/L). This suggests that the Cr(VI) results may have been biased high. Tritium was found in surface water at concentrations ranging from 255 to 989 pCi/L.

#### *4.4.1.3 Sampling in the Vicinity of 100-F and Hanford Townsites*

Samples of sediment, surface water, and island soil were also obtained at selected areas as a means of developing a better understanding of the nature and extent of potential contaminants released from the Hanford Site, and to support the subsequent human health and ecological risk assessments.

Sediment and soil samples were obtained at the White Bluffs Townsite, upriver from 100-F. Shallow sediment and shoreline sediment samples were taken along the Franklin Country shoreline opposite 100-F at locations conducive to sediment deposition in the river. Additional samples were taken along the west bank of the river, near Island 8 and Island 9 and the 100-F slough.

In the area of the Hanford Townsite downriver to just north of the 300 Area, a number of supplemental samples were obtained. This included the Hanford Townsite slough, the areas along both sides of Savage Island, the shoreline along the Ringold Springs recreational area, and islands such as Homestead and Wooded islands.

Analysis of these samples was completed and the results are presented in the Hanford Site Releases Data Summary [WCH-398]. The overall evaluation of the human health and ecological risk represented by all of the data collected as part of fulfilling the scope defined in the Columbia River RI Work Plan (DOE/RL-2008-11) is presented in the CRC (DOE/RL-2010-117). This includes an evaluation of all of the data collected throughout the Hanford Reach and downstream to McNary Dam. A summary of the analytical results for samples collected in the vicinity of the 100-F and Hanford Townsites is provided in Table 4-24.

### 4.4.2 Sitewide Environmental Monitoring of Surface Water and Sediments

DOE conducts environmental monitoring on the Hanford Site, including surface water and associated sediment. The following information is summarized from the 2010 Sitewide Environmental Report (PNNL-20548).

Samples of surface water and sediment are collected upstream from the Hanford Site at Priest Rapids Dam, downstream from the Site at the City of Richland, and at several locations on the Site. A cross-river transect is sampled at the Hanford Townsite. River water is not sampled at 100-F. Columbia River water samples collected at Priest Rapids Dam and the City of Richland were analyzed for gamma-emitting radionuclides, tritium, strontium-90, technetium-99, uranium isotopes, and plutonium isotopes.

*Shoreline Springs*. Shoreline springs (seeps) represent areas where groundwater discharges to the Columbia River. DOE routinely samples springs and associated sediments along the Hanford Reach. This section summarizes results of monitoring seeps at 100-F and 100-IU-2/IU-6 (the location of the former Hanford Townsite). Table 4-25 lists maximum concentrations for radionuclides, metals, and nitrate in spring water from 100-F and the Hanford Townsite over the period 2005 through 2010.

Only one spring from the 100-F segment of shoreline was flowing enough for sampling in recent years: SF-207-1, located approximately 2 km (1.6 mi) downstream from 100-F between aquifer tube sites 74 and 75. Highlights of the data include the following:

- Dissolved chromium concentrations have exceeded the AWQC (Figure 4-46). Concentrations are similar to those in nearby aquifer tube 75-D (Figure 4-24). The contamination is assumed to have moved downgradient from 100-F in the past.

- Gross alpha concentration exceeded the 15 pCi/L DWS in 2006 but have been below the standard since then (Figure 4-47). Some of the data are flagged "F" in the HEIS, indicating they are undergoing further review. Isotopic uranium data show a similar trend, with a maximum of 20 pCi/L.

- Gross beta concentration also peaked in 2006 (Figure 4-47). Strontium-90 was not detected in 2006. The beta activity may have been caused by technetium-99; the seep was not sampled for that constituent.

- Nitrate concentrations exceeded the DWS twice since 1999 (Figure 4-48). Concentrations in nearby aquifer tubes are similar, reflecting the presence of the large nitrate plume in groundwater (Section 4.3.3.2).

Several springs at the Hanford Townsite are sampled routinely. Concentrations of Sitewide groundwater contaminants tritium and nitrate are declining overall, but tritium concentrations remain above the DWS (Figures 4-49 and 4-50).

*Columbia River Water*. Radionuclide concentrations monitored in Columbia River water were low throughout 2010 and similar to previous years. Statistical analyses were performed to determine whether concentrations downstream from the Hanford Site were greater than those upstream from the Site.

The maximum tritium concentration in river water at the Hanford Townsite in 2010 was 160 ± 28 pCi/L (2010 Sitewide Environmental Report [PNNL-20548]). The highest uranium concentration was 0.45 ± 0.079 pCi/L. Strontium-90 was not detected.

Statistical analyses indicated that downstream tritium and uranium concentrations were higher than upstream concentrations. The average tritium concentration in Columbia River water collected at the City of Richland (29 ± 17 pCi/L) was higher than at Priest Rapids Dam (19 ± 4.6 pCi/L), but was only 0.1 percent of the Washington State ambient surface water quality standard of 20,000 pCi/L. Average total uranium concentration measured at the City of Richland (0.66 ± 0.099 pCi/L) also was higher than at Priest Rapids Dam (0.49 ±0.085 pCi/L). The primary source of uranium discharging to the Columbia River at the Hanford Site is the 300 Area, a short distance upstream from the City of Richland. No plutonium was detected in filtered river water samples in 2010. Statistical comparisons for strontium-90, gross alpha, and gross beta concentrations at Priest Rapids Dam and the City of Richland were not performed because most of the concentrations were less than detection limits.

Table 4-24. Summary of Analytical Results for Samples Collected in the Vicinity of 100-F and Hanford Townsite

| Analytical Class | Analyte Name | Number of Samples | Number of Detects | Minimum Detected Result | Maximum Detected Result | Units |
|---|---|---|---|---|---|---|
| **Surface Water Results** | | | | | | |
| Radionuclides | Cesium-137 | 17 | 2 | 20.7 | 49.9 | pCi/L |
| | Plutonium-239/240 | 17 | 1 | 0.234 | 0.234 | pCi/L |
| | Potassium-40 | 17 | 5 | 17,800 | 22,900 | pCi/L |
| | Radium-226 | 17 | 5 | 596 | 1,170 | pCi/L |
| | Radium-228 | 17 | 5 | 859 | 1,560 | pCi/L |
| | Thorium-230 | 17 | 5 | 0.148 | 0.25 | pCi/L |
| | Uranium-233/234 | 17 | 12 | 0.199 | 5.08 | pCi/L |
| | Uranium-235 | 17 | 4 | 0.119 | 0.347 | pCi/L |
| | Uranium-238 | 17 | 10 | 0.149 | 4.44 | pCi/L |
| Metals | Aluminum | 17 | 15 | 22.6 | 169 | µg/L |
| | Arsenic | 17 | 4 | 27.1 | 57.3 | µg/L |
| | Barium | 17 | 17 | 27.1 | 57.3 | µg/L |
| | Boron | 17 | 17 | 4.1 | 43.8 | µg/L |
| | Calcium | 17 | 17 | 16,900 | 68,400 | µg/L |
| | Chromium | 17 | 9 | 0.554 | 1.1 | µg/L |
| | Copper | 17 | 5 | 1.1 | 1.6 | µg/L |
| | Iron | 17 | 15 | 25.8 | 248 | µg/L |
| | Lead | 17 | 2 | 1.6 | 3.4 | µg/L |
| | Lithium | 17 | 11 | 1.4 | 19.3 | µg/L |
| | Magnesium | 17 | 17 | 4,210 | 34,600 | µg/L |
| | Manganese | 17 | 16 | 2.09 | 15.5 | µg/L |
| | Molybdenum | 17 | 14 | 0.789 | 4.01 | µg/L |
| | Nickel | 17 | 7 | 0.801 | 2.6 | µg/L |
| | Phosphorus | 17 | 11 | 9.4 | 47.6 | µg/L |
| | Potassium | 17 | 17 | 660 | 10,200 | µg/L |
| | Selenium | 17 | 3 | 3.1 | 3.7 | µg/L |
| | Silicon | 17 | 17 | 1,980 | 15,000 | µg/L |
| | Sodium | 17 | 17 | 2,140 | 49,000 | µg/L |
| | Strontium | 17 | 17 | 96.1 | 475 | µg/L |
| | Tin | 17 | 2 | 0.5 | 3.0 | µg/L |

Table 4-24. Summary of Analytical Results for Samples Collected in the Vicinity of 100-F and Hanford Townsite

| Analytical Class | Analyte Name | Number of Samples | Number of Detects | Minimum Detected Result | Maximum Detected Result | Units |
|---|---|---|---|---|---|---|
| | Titanium | 17 | 17 | 0.68 | 11.4 | µg/L |
| | Vanadium | 17 | 14 | 1.7 | 23.2 | µg/L |
| | Zinc | 17 | 9 | 3.3 | 13.1 | µg/L |
| Volatile Organic Compounds | Acetone | 10 | 1 | 3.15 | 3.15 | µg/L |
| | Methylene Chloride | 10 | 4 | 2 | 3 | µg/L |
| Semivolatile Organic Compounds | Bis(2-ethylhexyl) phthalate | 11 | 7 | 0.6 | 5 | µg/L |
| | Di-n-butylphthalate | 11 | 6 | 0.6 | 0.9 | µg/L |
| Pesticides | Gamma-BHC | 11 | 1 | 0.014 | 0.014 | µg/L |
| Total Petroleum Hydrocarbons | Diesel Range | 11 | 2 | 74 | 75 | µg/L |
| | Motor Oil | 11 | 1 | 151 | 151 | µg/L |
| **Upwelling Surface Water Results** | | | | | | |
| Radionuclides | Tritium | 5 | 4 | 255 | 989 | pCi/L |
| | Uranium-233/234 | 5 | 3 | 0.203 | 0.34 | pCi/L |
| | Uramium-238 | 5 | 2 | 0.203 | 0.22 | pCi/L |
| Metals | Aluminum | 5 | 3 | 19.8 | 27.1 | µg/L |
| | Barium | 5 | 5 | 23.9 | 27.8 | µg/L |
| | Boron | 5 | 5 | 5.68 | 10.5 | µg/L |
| | Calcium | 5 | 5 | 19,300 | 20,400 | µg/L |
| | Chromium | 5 | 2 | 0.608 | 6.44 | µg/L |
| | Iron | 5 | 5 | 12.9 | 222 | µg/L |
| | Lithium | 5 | 4 | 5.73 | 12.9 | µg/L |
| | Magnesium | 5 | 5 | 4,720 | 5,120 | µg/L |
| | Manganese | 5 | 5 | 1.36 | 3.23 | µg/L |
| | Molybdenum | 5 | 5 | 0.59 | 0.951 | µg/L |
| | Nickel | 5 | 2 | 0.824 | 1.23 | µg/L |
| | Phosphorus | 5 | 3 | 10.8 | 11.5 | µg/L |
| | Potassium | 5 | 5 | 485 | 1050 | µg/L |
| | Silicon | 5 | 5 | 1,980 | 2,440 | µg/L |
| | Sodium | 5 | 5 | 2,060 | 2,620 | µg/L |
| | Strontium | 5 | 5 | 102 | 113 | µg/L |

Table 4-24. Summary of Analytical Results for Samples Collected in the Vicinity of 100-F and Hanford Townsite

| Analytical Class | Analyte Name | Number of Samples | Number of Detects | Minimum Detected Result | Maximum Detected Result | Units |
|---|---|---|---|---|---|---|
| | Tin | 5 | 1 | 1.16 | 1.16 | µg/L |
| | Titanium | 5 | 5 | 0.886 | 0.994 | µg/L |
| | Vanadium | 5 | 5 | 4.4 | 5.6 | µg/L |
| | Zinc | 5 | 1 | 4.44 | 4.44 | µg/L |
| Anions | Chloride | 5 | 4 | 1,110 | 1,300 | µg/L |
| | Fluoride | 5 | 4 | 60 | 60 | µg/L |
| | Nitrate | 5 | 5 | 0.72 | 1560 | mg/L |
| | Nitrite | 5 | 1 | 1.56 | 1.56 | mg/L |
| | Nitrate/Nitrite | 5 | 4 | 0.24 | 340 | mg/L |
| | Sulfate | 5 | 5 | 10,800 | 72,400 | µg/L |
| **Pore water Results** | | | | | | |
| Radionuclides | Strontium-90 | 2 | 2 | 1.49 | 2.33 | pCi/L |
| | Technetium-99 | 3 | 3 | 32.5 | 130 | pCi/L |
| | Tritium | 36 | 12 | 408 | 65,200 | pCi/L |
| Cr(VI) | Cr(VI) | 7 | 5 | 13 | 21 | µg/L |
| **Sediment Results** | | | | | | |
| Radionuclides | Carbon-14 | 124 | 1 | 3.26 | 3.26 | pCi/g |
| | Cesium-137 | 131 | 87 | 0.015 | 0.348 | pCi/g |
| | Co-60 | 131 | 4 | 0.023 | 0.071 | pCi/g |
| | Eu-152 | 131 | 9 | 0.076 | 0.27 | pCi/g |
| | Potassium-40 | 131 | 130 | 2.16 | 21.3 | pCi/g |
| | Lead-212 | 131 | 6 | 0.153 | 0.76 | pCi/g |
| | Plutonium-238 | 131 | 1 | 0.041 | 0.041 | pCi/g |
| | Plutonium-239/240 | 131 | 4 | 43 | 0.093 | pCi/g |
| | Radium-226 | 131 | 131 | 0.146 | 1.02 | pCi/g |
| | Radium-228 | 131 | 131 | 0.254 | 1.93 | pCi/g |
| | Strontium-90 | 126 | 2 | 0.315 | 0.418 | pCi/g |
| | Technetium-99 | 128 | 2 | 5.04 | 5.08 | pCi/g |
| | Thorium-228 | 131 | 120 | 0.241 | 1.96 | pCi/g |
| | Thorium-230 | 131 | 107 | 0.235 | 3.01 | pCi/g |
| | Thorium-232 | 131 | 126 | 0.218 | 2.14 | pCi/g |

Table 4-24. Summary of Analytical Results for Samples Collected in the Vicinity of 100-F and Hanford Townsite

| Analytical Class | Analyte Name | Number of Samples | Number of Detects | Minimum Detected Result | Maximum Detected Result | Units |
|---|---|---|---|---|---|---|
| | Tritium | 5 | 1 | 11.3 | 11.3 | pCi/g |
| | Uranium-233/234 | 131 | 128 | 0.218 | 2.33 | pCi/g |
| | Uranium-235 | 131 | 13 | 0.032 | 0.107 | pCi/g |
| | Uranium-238 | 131 | 126 | 0.253 | 2.05 | pCi/g |
| Metals | Aluminum | 130 | 130 | 2,310 | 13,600 | mg/kg |
| | Antimony | 130 | 38 | 0.204 | 0.862 | mg/kg |
| | Arsenic | 130 | 130 | 1.35 | 12.0 | mg/kg |
| | Barium | 130 | 130 | 29.6 | 107 | mg/kg |
| | Beryllium | 130 | 130 | 0.077 | 0.794 | mg/kg |
| | Bismuth | 130 | 1 | 1.29 | 1.29 | mg/kg |
| | Boron | 130 | 129 | 0.428 | 1.65 | mg/kg |
| | Cadmium | 130 | 129 | 0.10 | 1.83 | mg/kg |
| | Calcium | 130 | 130 | 1,530 | 25,000 | mg/kg |
| | Chromium | 130 | 130 | 3.94 | 131 | mg/kg |
| | Cobalt | 130 | 130 | 1.45 | 7.32 | mg/kg |
| | Copper | 130 | 130 | 4.01 | 42.0 | mg/kg |
| | Iron | 130 | 130 | 4,340 | 27,200 | mg/kg |
| | Lead | 130 | 130 | 2.04 | 91.6 | mg/kg |
| | Lithium | 130 | 130 | 2.34 | 11.2 | mg/kg |
| | Magnesium | 130 | 130 | 1490 | 5160 | mg/kg |
| | Manganese | 130 | 130 | 63.6 | 573 | mg/kg |
| | Mercury | 130 | 42 | 0.009 | 0.100 | mg/kg |
| | Molybdenum | 130 | 124 | 0.074 | 1.97 | mg/kg |
| | Nickel | 130 | 130 | 2.94 | 16.2 | mg/kg |
| | Phosphorus | 130 | 130 | 204 | 735 | mg/kg |
| | Potassium | 130 | 130 | 439 | 1470 | mg/kg |
| | Selenium | 130 | 3 | 0.317 | 2.02 | mg/kg |
| | Silicon | 130 | 130 | 241 | 1940 | mg/kg |
| | Sodium | 130 | 130 | 61.7 | 300 | mg/kg |
| | Strontium | 130 | 130 | 11.5 | 54.4 | mg/kg |

Table 4-24. Summary of Analytical Results for Samples Collected in the Vicinity of 100-F and Hanford Townsite

| Analytical Class | Analyte Name | Number of Samples | Number of Detects | Minimum Detected Result | Maximum Detected Result | Units |
|---|---|---|---|---|---|---|
| | Thallium | 130 | 4 | 0.169 | 0.258 | mg/kg |
| | Tin | 130 | 45 | 0.336 | 6.92 | mg/kg |
| | Uranium | 130 | 1 | 4.46 | 4.46 | mg/kg |
| | Vanadium | 130 | 130 | 10.2 | 79.9 | mg/kg |
| | Zinc | 130 | 130 | 21.8 | 565 | mg/kg |
| Volatile Organic Compounds | Acetone | 58 | 5 | 0.0037 | 0.0085 | mg/kg |
| | Methylene Chloride | 58 | 31 | 0.0017 | 0.0084 | mg/kg |
| Semivolatile Organic Compounds | Bis(2-ethylhexyl) phthalate | 58 | 3 | 0.15 | 0.22 | mg/kg |
| | Di-n-butylphthalate | 58 | 2 | 0.061 | 0.065 | mg/kg |
| Pesticides | Aldrin | 58 | 2 | 0.00057 | 0.0014 | mg/kg |
| | alpha-BHC | 58 | 3 | 0.0006 | 0.0059 | mg/kg |
| | Beta-1,2,3,4,5,6-Hexachloro-cyclohexane | 58 | 2 | 0.0015 | 0.0027 | mg/kg |
| | Endosulfan Sulfate | 58 | 1 | 0.00033 | 0.00033 | mg/kg |
| | gamma-Chlordane | 58 | 2 | 0.00067 | 0.0033 | mg/kg |
| Total Petroleum Hydrocarbons | Diesel Range | 53 | 6 | 0.88 | 14.6 | mg/kg |
| | Motor Oil | 53 | 40 | 6.1 | 96.2 | mg/kg |
| **Island Soil Results** | | | | | | |
| Radionuclides | Cesium-137 | 20 | 19 | 0.044 | 0.354 | pCi/g |
| | Potassium-40 | 20 | 20 | 14.6 | 18.1 | pCi/g |
| | Radium-226 | 20 | 20 | 0.541 | 0.921 | pCi/g |
| | Radium-228 | 20 | 20 | 0.647 | 1.78 | pCi/g |
| | Strontium-90 | 20 | 1 | 1.81 | 1.81 | pCi/g |
| | Thorium-228 | 20 | 18 | 0.454 | 2.66 | pCi/g |
| | Thorium-230 | 20 | 16 | 0.346 | 1.82 | pCi/g |
| | Thorium-232 | 20 | 18 | 0.518 | 1.90 | pCi/g |
| | Uranium-233/234 | 20 | 20 | 0.406 | 1.11 | pCi/g |
| | Uranium-235 | 20 | 5 | 0.041 | 0.059 | pCi/g |
| | Uranium-238 | 20 | 20 | 0.291 | 1.07 | pCi/g |
| Metals | Aluminum | 20 | 20 | 6,290 | 10,700 | mg/kg |
| | Antimony | 20 | 3 | 0.529 | 0.612 | mg/kg |

Table 4-24. Summary of Analytical Results for Samples Collected in the Vicinity of 100-F and Hanford Townsite

| Analytical Class | Analyte Name | Number of Samples | Number of Detects | Minimum Detected Result | Maximum Detected Result | Units |
|---|---|---|---|---|---|---|
| | Arsenic | 20 | 20 | 2.95 | 7.94 | mg/kg |
| | Barium | 20 | 20 | 55 | 101 | mg/kg |
| | Beryllium | 20 | 20 | 0.181 | 0.364 | mg/kg |
| | Bismuth | 20 | 9 | 0.48 | 1.18 | mg/kg |
| | Boron | 20 | 20 | 1.03 | 2.16 | mg/kg |
| | Cadmium | 20 | 20 | 0.156 | 1.05 | mg/kg |
| | Calcium | 20 | 20 | 2,700 | 5,080 | mg/kg |
| | Chromium | 20 | 20 | 13.9 | 20.9 | mg/kg |
| | Cobalt | 20 | 20 | 4.32 | 7.13 | mg/kg |
| | Copper | 20 | 20 | 8.53 | 39.4 | mg/kg |
| | Cr-VI | 20 | 1 | 0.14 | 0.14 | mg/kg |
| | Iron | 20 | 20 | 14,300 | 24,200 | mg/kg |
| | Lead | 20 | 20 | 5.16 | 60.2 | mg/kg |
| | Lithium | 20 | 20 | 7.24 | 12.2 | mg/kg |
| | Magnesium | 20 | 20 | 3,840 | 5,790 | mg/kg |
| | Manganese | 20 | 20 | 205 | 377 | mg/kg |
| | Mercury | 20 | 16 | 0.010 | 0.038 | mg/kg |
| | Molybdenum | 20 | 20 | 0.230 | 0.968 | mg/kg |
| | Nickel | 20 | 20 | 12.6 | 18.4 | mg/kg |
| | Phosphorus | 20 | 20 | 536 | 944 | mg/kg |
| | Potassium | 20 | 20 | 1,060 | 2,070 | mg/kg |
| | Silicon | 20 | 20 | 570 | 1,860 | mg/kg |
| | Sodium | 20 | 20 | 109 | 342 | mg/kg |
| | Strontium | 20 | 20 | 19.3 | 34.7 | mg/kg |
| | Tin | 20 | 5 | 0.499 | 0.874 | mg/kg |
| | Titanium | 20 | 20 | 616 | 973 | mg/kg |
| | Uranium | 20 | 1 | 2.12 | 2.12 | mg/kg |
| | Vanadium | 20 | 20 | 30.8 | 59.3 | mg/kg |
| | Zinc | 20 | 20 | 39.1 | 327 | mg/kg |
| Semivolatile Organic Compounds | Bis(2-ethylhexyl) phthalate | 8 | 1 | 0.25 | 0.25 | mg/kg |

Table 4-24. Summary of Analytical Results for Samples Collected in the Vicinity of 100-F and Hanford Townsite

| Analytical Class | Analyte Name | Number of Samples | Number of Detects | Minimum Detected Result | Maximum Detected Result | Units |
|---|---|---|---|---|---|---|
| Pesticides | 4,4'-DDE | 8 | 2 | 0.0022 | 0.0046 | mg/kg |
| | 4,4'-DDT | 8 | 1 | 0.0055 | 0.0055 | mg/kg |
| Total Petroleum Hydrocarbons | Diesel Range | 8 | 1 | 1.62 | 1.62 | mg/kg |
| | Motor Oil | 8 | 7 | 5.72 | 30.1 | mg/kg |

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Table 4-25. Sitewide Environmental Monitoring Results for Shoreline Springs in 100-F and Hanford Townsite

| Constituent, units | 100-F | | Hanford Townsite | |
|---|---|---|---|---|
| | No. Samples | Maximum Concentration, 2005-2010 | No. Samples | Maximum Concentration, 2005-2010 |
| **Radionuclides** | | | | |
| Gross alpha, pCi/L | 5 | **28** ± 8.8 | 18 | 14 ± 5.6 |
| Gross beta, pCi/L | 5 | 43 ± 9.6 | 18 | 47 ± 12 |
| Iodine-129, pCi/L | 0 | No data | 12 | Not detected |
| Strontium-90, pCi/L | 5 | 0.12 ± 0.050 | 0 | No data |
| Technetium-99, pCi/L | 0 | No data | 18 | 68 ± 3.9 |
| Tritium, pCi/L | 5 | 1,400 ± 190 | 18 | **53,000** ± 3,300 |
| Uranium (total), pCi/L | 5 | 20 ± 2.1 | 18 | 5.6 ± 0.69 |
| **Dissolved Metals (Filtered Samples)** | | | | |
| Antimony, µg/L | 7 | 0.22 | 21 | 0.34 |
| Arsenic, µg/L | 7 | 2.2 | 21 | 4.0 |
| Cadmium, µg/L | 7 | 0.12 | 21 | 0.028 |
| Chromium*, µg/L | 7 | **16** | 21 | 2.7 |
| Copper, µg/L | 7 | 0.58 | 21 | 0.70 |
| Lead, µg/L | 7 | 0.36 | 21 | 0.29 |
| Nickel, µg/L | 7 | 2.6 | 21 | 1.4 |
| Silver, µg/L | 7 | 0.0050 | 21 | 0.015 |

Table 4-25. Sitewide Environmental Monitoring Results for Shoreline Springs in 100-F and Hanford Townsite

| Constituent, units | 100-F | | Hanford Townsite | |
|---|---|---|---|---|
| | No. Samples | Maximum Concentration, 2005-2010 | No. Samples | Maximum Concentration, 2005-2010 |
| Thallium, µg/L | 7 | 0.013 | 21 | 0.019 |
| Zinc, µg/L | 7 | 4.2 | 21 | 2.7 |
| **Anions** | | | | |
| Nitrate (as $NO_3$), mg/L | 7 | **46** | 21 | 23 |

Source: *Hanford Site Environmental Report for Calendar Year 2010* (PNNL-20548), Table 8.5.3 and C.10.

Notes: Values in bold exceed water quality standards.

* Dissolved chromium is considered to represent Cr(VI).

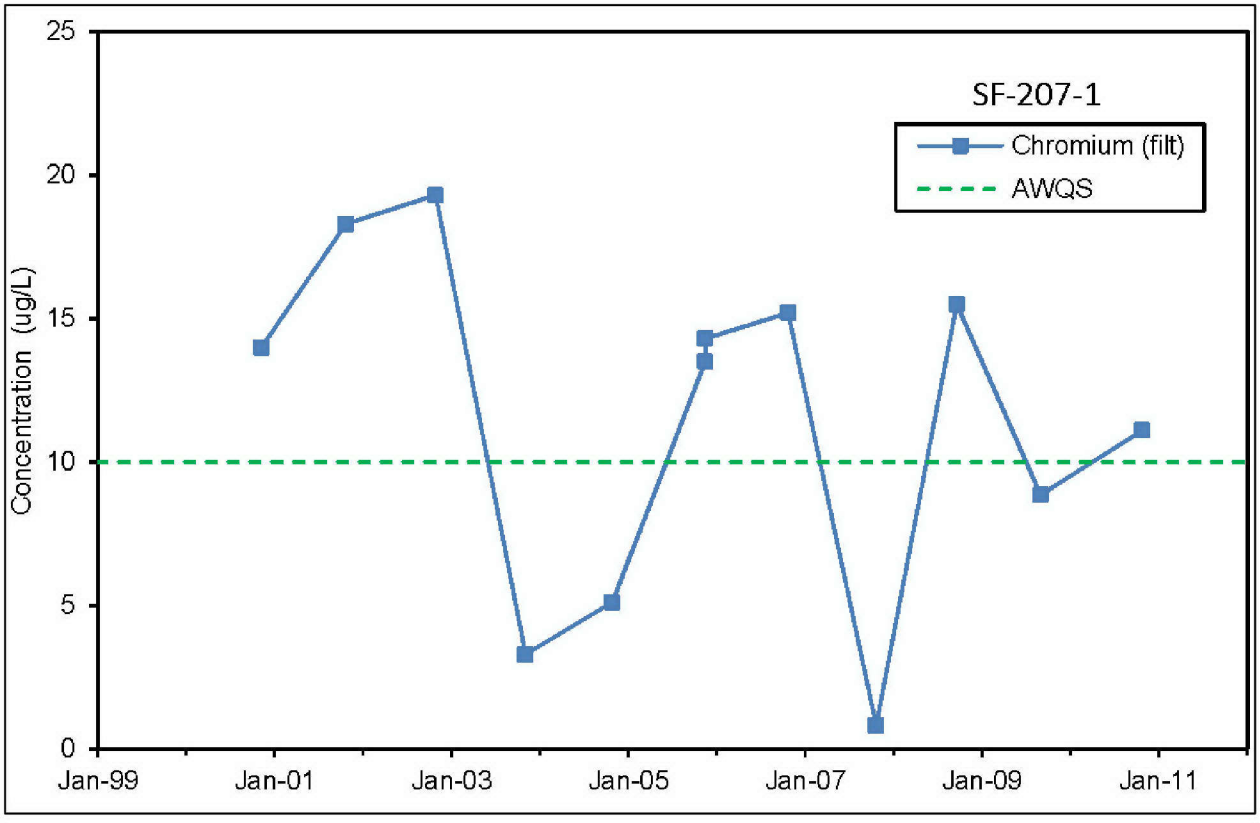



Figure 4-46. Dissolved Chromium Trend in 100-F Seep 207-1

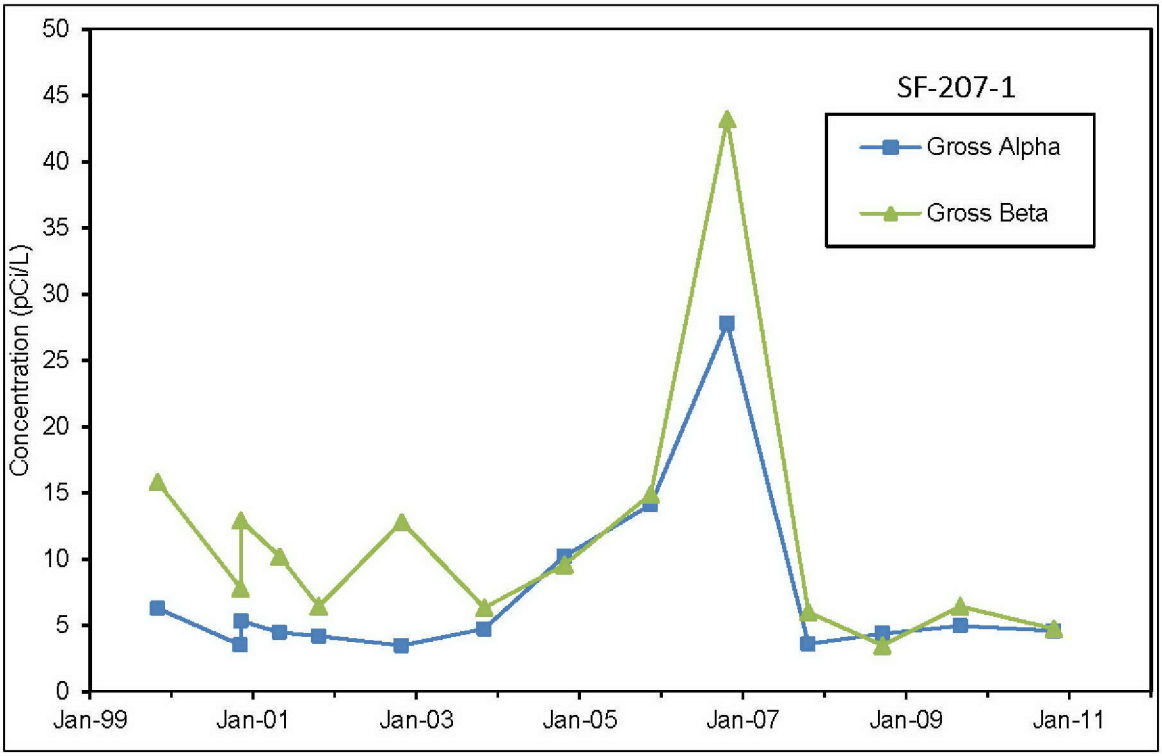



Figure 4-47. Gross Alpha and Gross Beta Trends in 100-F Seep 207-1

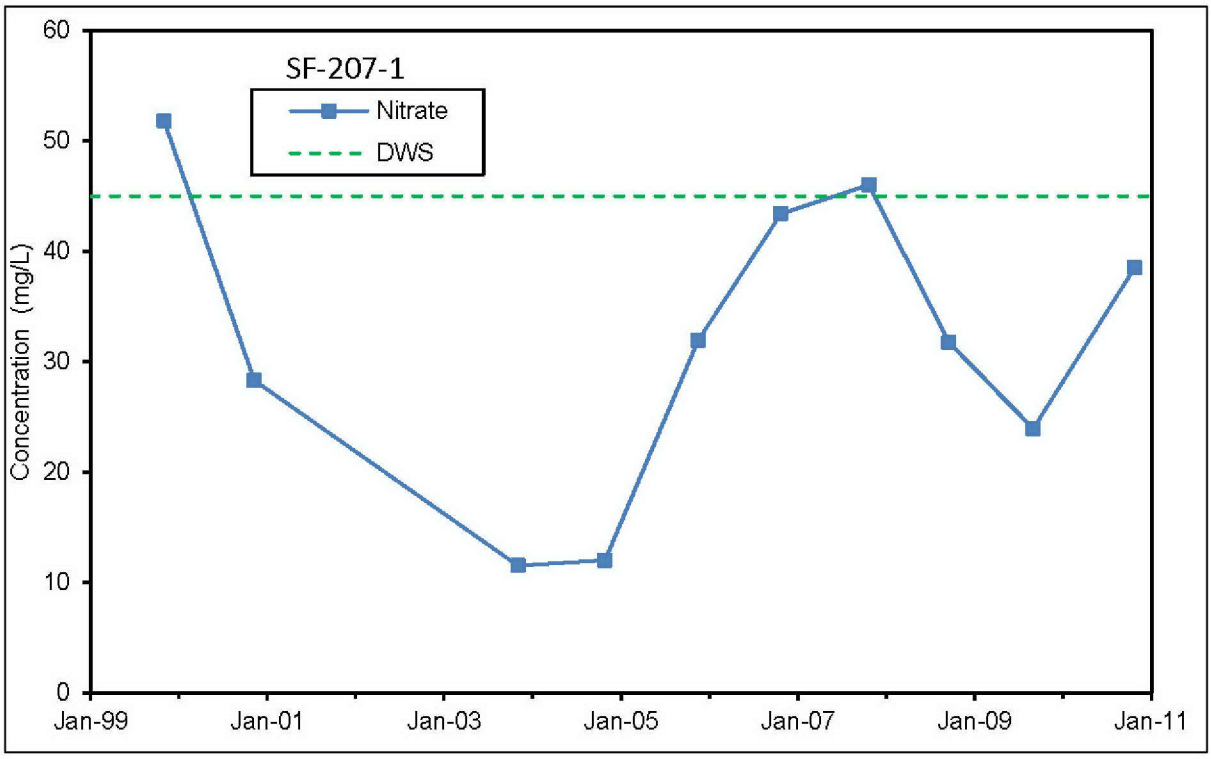



Figure 4-48. Nitrate Trend in 100-F Seep 207-1

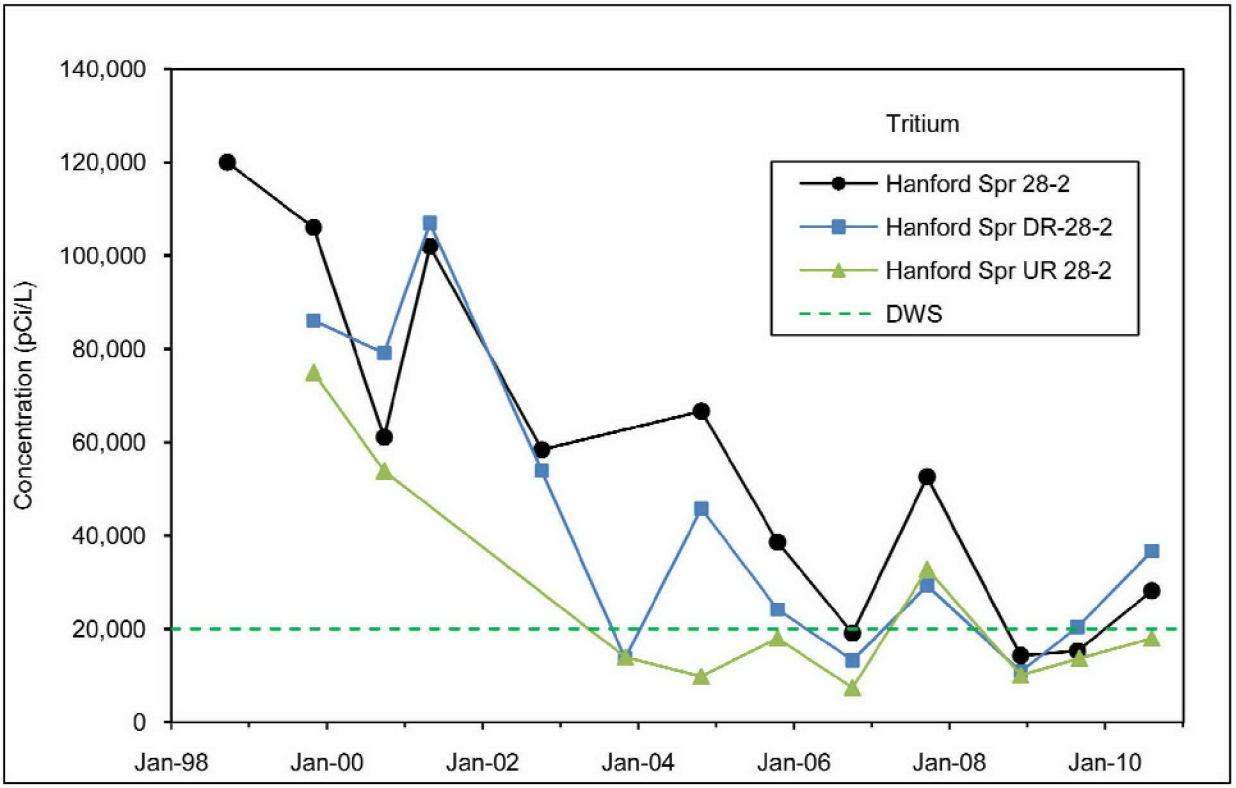



Figure 4-49. Tritium Trends in Seeps at the Hanford Townsite

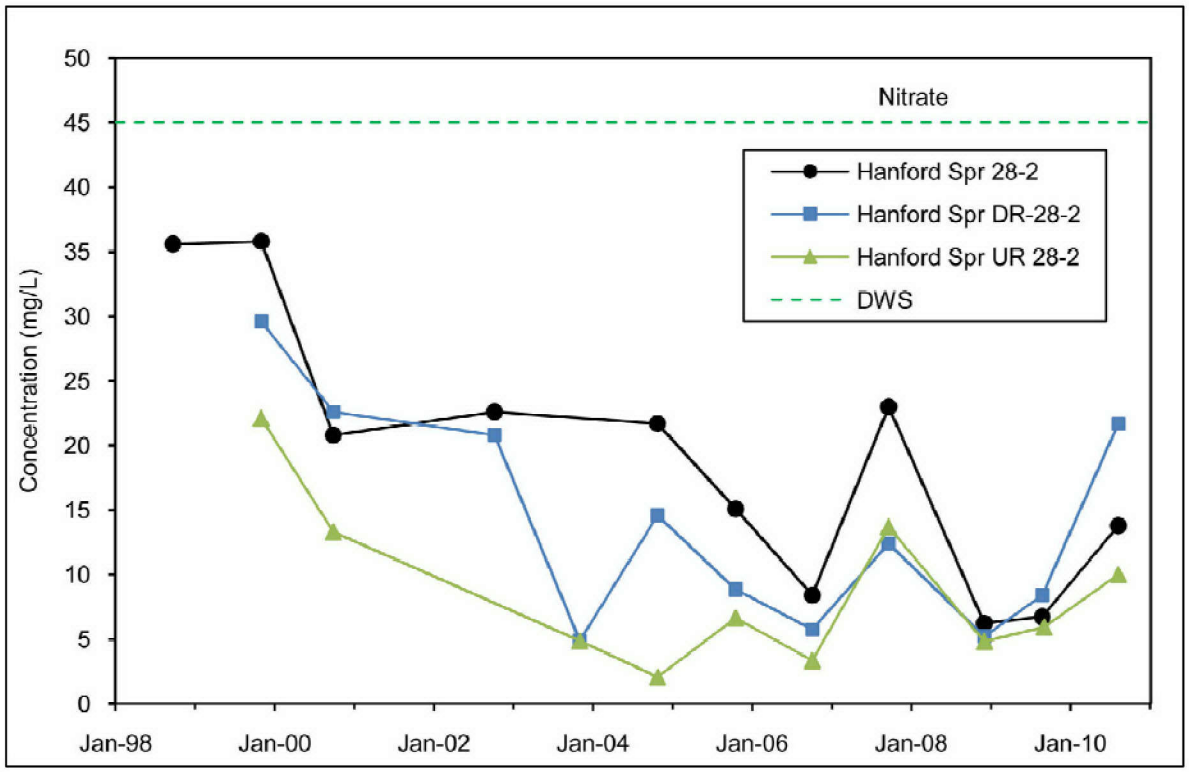



Figure 4-50. Nitrate Trends in Seeps at the Hanford Townsite

All metal and anion concentrations in river water, including dissolved chromium, were less than the AWQC in 2010.

The U.S. Geological Survey sampled Columbia River water at the Vernita Bridge (upstream from the Hanford Site) and the City of Richland in 2010. These data provided no indication of any deterioration of water quality along the Hanford Reach of the Columbia River. Median concentrations of dissolved chromium were similar for water samples collected near the Vernita Bridge and City of Richland and were well below the AWQC.

*River Sediment.* Some constituents in liquid effluents previously discharged to the Columbia River on the Hanford Site may have become associated with particles that accumulated in riverbed sediment, particularly in slack-water areas and in the reservoirs upstream from the dams. Fluctuations in the river flow may redistribute these contaminated sediments. Upper-layer sediment in the Columbia River downstream from the Hanford Site contains low concentrations of radionuclides and metals of Hanford origin, as well as contaminants from mining, agriculture, and atmospheric fallout. Periodic sediment sampling confirms that concentrations are low and that no significant changes in concentrations have occurred.

Sediment samples were collected upstream from the Hanford Site at the Priest Rapids Dam reservoir and downstream from the Site at McNary Dam. Sediment samples were also collected within the Hanford Site from slack-water areas where fine-grained material is known to deposit (for example, the White Bluffs, 100-F Area, and Hanford Sloughs), and from the publicly accessible City of Richland shoreline. Radionuclides consistently detected in river sediment upstream, adjacent to, and downstream from the Hanford Site in 2005 through 2010 included beryllium-7, potassium-40, cesium-137, uranium isotopes, and plutonium isotopes. The concentrations of all other radionuclides, including strontium-90, were below detection limits for most samples. Cesium-137 and plutonium isotopes exist in worldwide fallout as well as in effluent from Hanford Site facilities. Beryllium-7, potassium-40, and uranium isotopes occur naturally in the environment. Uranium isotopes also are present in irrigation water from fertilized crops and in Hanford Site groundwater. Results of sediment monitoring do not indicate the Hanford Site contributes significantly to these constituents in sediment.

Detectable amounts of most metals were found in all river sediment samples. Maximum and average concentrations of most metals were higher for sediment collected in the reservoir upstream from Priest Rapids Dam than in sediment from either the Hanford Reach or McNary Dam. The concentrations of cadmium, lead, nickel, and zinc differed the most between locations and may be associated with upstream mining activity.

## 4.5 Biota

This section summarizes ecological sampling or biological monitoring data that have been collected for 100-F/IU. Biota data are useful to understand biological receptors, which are evaluated in Chapter 7.

Biota data from two environmental sampling projects conducted at the Hanford Site were reviewed and summarized for this section: the Surface Environmental Surveillance Project (SESP) and the RCBRA. The SESP is a multimedia environmental surveillance project. The primary goal of the SESP is to measure concentrations of radionuclides and chemicals in environmental media to demonstrate compliance with applicable environmental quality standards and public exposure limits, and assess environmental impacts. Results of contaminant monitoring of plants and animals in 2010 are published in the 2010 Sitewide Environmental Report (PNNL-20548, Section 8.10) and summarized below. The findings from the SESP are summarized further in the evaluation presented in Appendix L.

*Vegetation Sampling Near Hanford Site Facilities and Operations.* Sixty-two vegetation samples were collected on the Hanford Site in 2010, mainly in the 200 Areas. Fifteen were collected from 100-IU-2/IU-6. No samples were collected in 100-F. In general, radionuclide concentrations in vegetation samples collected from, or adjacent to, waste disposal facilities in 2010 were higher than concentrations in samples collected farther away, including concentrations measured offsite. Generally, the predominant radionuclides were activation and fission products in the 100 Areas, fission products in the 200 Areas, and uranium in the 300 Area.

*Monitoring of Fish and Wildlife for Hanford Site-Produced Contaminants.* In 2010, roadkill deer, roadkill elk, fish, and rabbits were collected from locations on the Hanford Site as part of routine monitoring for site-produced contaminants. Of these animals, only deer were collected from sites within 100-IU-2/IU-6, and none were collected from 100-F. Strontium-90 was detected in bone samples from deer and elk on the Hanford Site and also from background locations elsewhere in the northwest. Other radionuclides were either not detected or below background concentrations.

Fish tissue has been a part of monitoring at the Hanford Site for many years, resulting in a variety of species and fish tissue in the database of historical samples. Within the historical fish tissue dataset, there is considerable inconsistency in species evaluated, tissue type (whole body, fillet, skin on, skin off, etc.), and analytes. Additionally, multiple collection and analysis approaches, as well as variability in species life spans, are believed to have introduced significant variability in analytical results. Fish tissue sampling was part of the CRC HHRA (DOE/RL-2010-117, Volume II). The Columbia River RI Work Plan (DOE/RL-2008-11), DQOs process (*Data Quality Assessment Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-381) and SAP (*Sampling and Analysis Instructions for the Remedial Investigation of Hanford Site Releases to the Columbia River* (WCH-286) for the CRC (DOE/RL-2010-117, Volume II) defined a consistent sampling and analysis approach among species, tissue types, and analytes. Therefore, fish tissue data from only 2009 to 2010 were used in the CRC HHRA (DOE/RL-2010-117, Volume II); the 2009 to 2010 program focused on target fish species intended to be most representative of the exposure scenarios identified for the CRC HHRA (DOE/RL-2010-117, Volume II):

- Common carp (*Cyprinus carpio*)
- Mountain whitefish (*Prosopium williamsoni*)
- Walleye (*Stizostedion vitreum*)
- Smallmouth bass (*Micropterus dolomieui*)
- Bridgelip sucker (*Catostomus columbianus*)
- White sturgeon (Acipenser transmonatnus)

These six fish species are year-round resident fish that reflect a range of trophic levels and have a higher rate of harvest and consumption among the local population. As described in the Columbia River RI Work Plan (DOE/RL-2008-11), salmon were not sampled as part of this study because they spend most of their life cycle in the ocean as opposed to the Hanford Site Study Area.

For all species except sturgeon, fish tissue samples were composite samples composed of tissue from approximately five fish. Generally, five samples of each fish species were collected from each area, and each sample included separate fillet, carcass (which included the head and skeleton of the fish), and combined liver and kidney tissue for analysis. For carp, sufficient tissue mass was available to obtain separate liver and kidney samples. Fillet samples for all of these species except sturgeon were prepared with the skin on, because skin for these types of fish is often left on during preparation, and consumed. Sturgeon samples were not composited, and thus samples represent tissue from individual fish. Sturgeon fillet samples were collected with the skin off, and separate liver and kidney samples were prepared.

*River Corridor Baseline Risk Assessment.* Biota data are also summarized from ecological samples collected to support the RCBRA ERA (DOE/RL-2007-21, Volume I). The primary goal of the RCBRA ecological risk assessment is to evaluate current and potential future risks to the environment posed by releases of hazardous substances (RCBRA (DOE/RL-2007-21, Volume I). The RCBRA appraises relevant sources of contamination, exposure pathways, and contaminants for several environmental media and receptors including surface soil, vegetation, soil invertebrates, small mammals, and birds. Measurement included radionuclides, metals, anions, semivolatile organic compounds, herbicides, and pesticides, as well as physical properties (pH, moisture, particle size, etc.) in selected media. The RCBRA sampling and analytical specifications are documented in the RCBRA SAP (DOE/RL-2005-42).

The locations of the RCBRA (DOE/RL-2007-21) biota samples summarized in this section are shown on Figure 4-51. The river level is shown at high water stage. Samples collected at lower river stages may appear to have been collected in the river when, in fact, the area would have been exposed at the time. The majority of the RCBRA environmental samples were collected in 2006 and 2007. The various terrestrial species of plants and animals collected and the tissues analyzed are summarized as follows:

- Perennial vegetation:
  - Unique local plants: mulberry and apricot leaves and shoots
  - Dominant shrub: current year's growth, stems and leaves (combined)
  - Dominant grass: current year's growth, stems and leaves (combined)
  - Dominant tree: current year's growth, stems and leaves (combined)
  - Balsam root: leaves, roots
- Terrestrial invertebrate: whole-body composites
- Mouse: whole-body composites, kidney, and liver (combined)
- Deer: antler, bones, and muscle
- Bird: bones, muscle, organs, and crop

Appendix H shows a summary of plant tissue samples collected for the SESP and RCBRA projects. Samples collected for RCBRA (DOE/RL-2007-21) were analyzed for radioactive and nonradioactive constituents. The samples collected for SESP were analyzed for radionuclides and total uranium only. The table also shows a summary of plant tissue samples collected from several reference areas (unaffected areas) as a part of the RCBRA project (DOE/RL-2007-21). The reference samples were analyzed for the same suite of analytes as the RCBRA (DOE/RL-2007-21) study site samples. The plant tissue sample results from the 100-F/IU study sites are within the range of the results for the reference area samples.

Appendix H shows a summary of invertebrate tissue samples collected for the RCBRA (DOE/RL-2007-21) project in the F/IU Area. The samples were analyzed for metals, selected radionuclides, and organic compounds. Results for the radionuclides are below or very near the detection levels. Although metals were detected in many of the samples, data were within acceptable range.

Appendix H shows a summary of mouse muscle and organ tissue samples collected for the RCBRA (DOE/RL-2007-21) project in the F/IU Area. The samples were analyzed for metals, radionuclides, and organic compounds. The results for the organics and radionuclides are below or very near the detection levels. Although metals were detected in many of the samples, data were within acceptable range.

Appendix H shows a summary of eastern kingbird, pheasant, and quail bone, muscle, organ, and crop tissue samples collected for the RCBRA (DOE/RL-2007-21) project in the F/IU Area. The samples were analyzed for metals, radionuclides, and organic compounds. The results are below or very near the detection levels; therefore, data were within acceptable range.

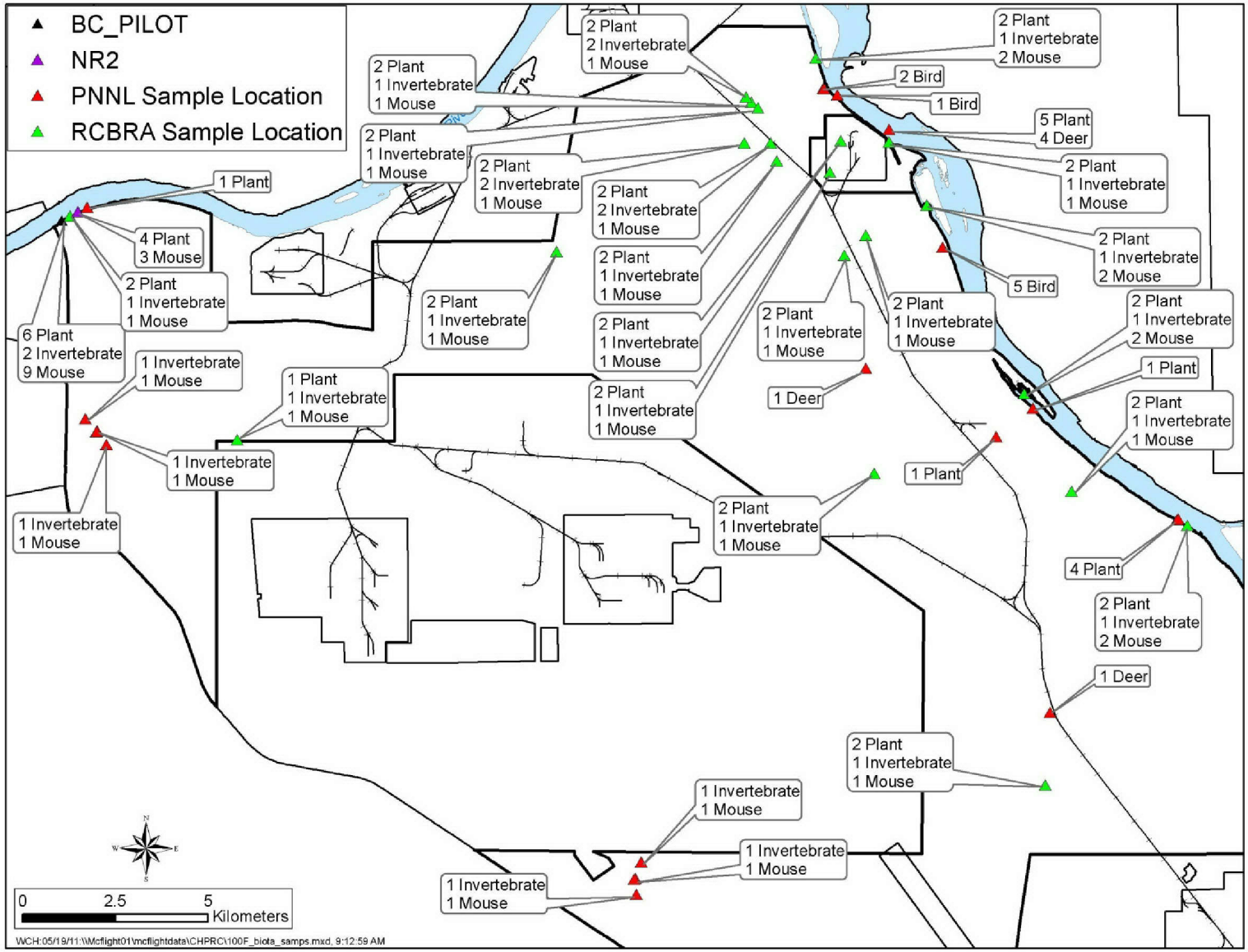



Figure 4-51. Terrestrial Biota Sampling Locations in 100-F/IU

## 4.6 Air

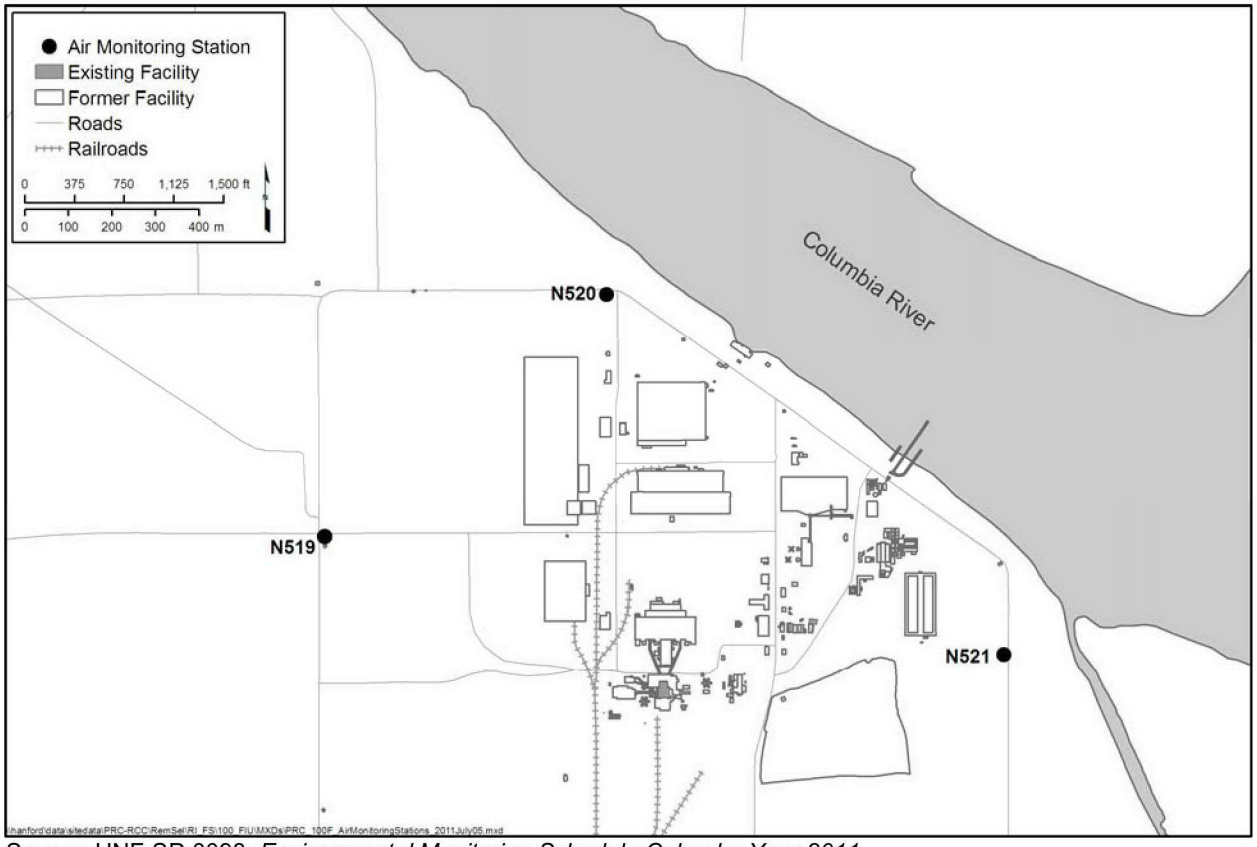
Atmospheric releases of radioactive materials from Hanford Site facilities and operations to the surrounding region are potential sources of human exposure. On the Hanford Site, radioactive constituents in the air are monitored onsite near facilities and operations, at Sitewide locations away from facilities, and offsite around the Hanford Site perimeter, as well as in nearby and distant communities. As discussed in Section 2.1.6, DOE monitors radionuclide airborne emissions from site facilities through several programs. The Near-Facility Environmental Monitoring Program measures concentrations of radionuclides in the ambient air on the Hanford Site near facilities and operations. The Hanford Site Environmental Surveillance Program measures the ambient air at Site locations away from facilities, around the perimeter of the Site, and offsite in nearby and distant communities. Remediation projects under CERCLA may also establish additional monitoring stations specific to their needs. In addition, emissions from stacks, vents, or other types of point sources are monitored individually by analyzing samples extracted from the outflow at each point of release. No point source releases are currently associated with the 100-F Area. The data collected by each program are used to assess the effectiveness of emission treatment and control systems and pollution management practices, and to determine compliance with state and federal regulatory requirements. Additional description of the ambient air sampling activities is available in the 2010 Sitewide Environmental Report (PNNL-20548).

*Ambient Air Monitoring Near Facilities and Operations.* Three ambient air monitoring stations are located at 100-F, established specifically for CERCLA site remediation support (Figure 4-52). Their locations have been established to provide the best tracking and trending of fugitive or diffuse emissions from the 100-F cleanup activities. As cleanup work progresses, station locations may be adjusted to provide for the best monitoring. Set points are established for the monitoring stations such that the regulatory agency would be informed if the 6-month composite sample results exceed 10 percent of EPA Table 2 ("National Emission Standards for Hazardous Air Pollutants" [40 CFR 61], "Compliance Procedures Methods for Determining Compliance with Subpart I " [Appendix E], Table 2) values. However, this has not occurred at 100-F. Results of ambient air concentration monitoring by the 100-F stations are provided in Section 5 of *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2010* (DOE/RL-2011-12).

*Sitewide and Offsite Ambient Air Monitoring.* During 2010, it was confirmed that there were no measureable impacts from 100-F Area to even the maximally exposed hypothetical member of the public. Overall fugitive or diffuse emissions from the Hanford Site, including the 100-F Area, are measured using a site network of ambient air samplers, separate from the near-facility monitors. A description of the perimeter network, operated under the Hanford Site Environmental Surveillance Program, and emissions measurements from the network are reported in Section 4 of *Radionuclide Air Emissions Report for the Hanford Site, Calendar Year 2010* (DOE/RL-2011-12). The effective dose equivalent to the Hanford Site maximally exposed individual resulting from routine and nonroutine fugitive or diffuse emissions at the Hanford Site in 2010 was 0.0081 mrem (0.000081 mSv). This is well within compliance to the overall ambient state standard of 10 mrem/yr EDE, per "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480).

## 4.7 Summary of Nature and Extent of Contamination

Understanding the nature and extent of contamination provides information critical to the risk assessment, the CSM, and helps identify the areas of contamination which will be addressed during development and comparison of remedial action alternatives. Data collected for the RI helped delimit contaminant concentrations in the vadose zone, groundwater, and pore water of the Columbia River. The operational history and the interim remediation process provide the framework for understanding the present nature and extent of contamination.




Source: HNF-SP-0098, *Environmental Monitoring Schedule Calendar Year 2011*.

Figure 4-52. Facility Air Monitoring Stations Located at 100-F Area

### 4.7.1 100-F Operational Period

Liquid and solid waste discharged during the reactor operational period represented the primary contaminant sources. These included cooling water conditioning and handling facilities, underground piping, liquid waste and solid waste storage and disposal sites, and unplanned releases (surface spills). Vadose zone soil and aquifer sediments impacted by releases represent potential secondary contaminant sources. Secondary sources can release contaminants to the environment long after discharges from primary contaminant sources have stopped.

Low-mobility contaminants, including many metals and radionuclides, sorbed to sediment grains in the vadose zone. These contaminants were found at the greatest concentrations within and near the areas of discharge. When little or no liquid effluent was discharged to a waste site, soil contamination remained in the shallow sediment. Most of this shallow contamination has been removed during remediation activities. Sufficiently high volumes of liquid discharged into a waste site expanded the depth of contamination in the vadose zone.

Strontium-90 is a slightly mobile contaminant in the subsurface and was present in several 100-F waste sites. Facilities producing biological waste materials contaminated with strontium-90 included the Experimental Animal Farm, formerly located in the northeast portion of 100-F near the 116-F-9 and 116-F-2 Trenches, and the radioecology laboratory. Strontium-90 also was present in discharges to the 116-F-9 Trench and in solid waste disposed at various burial grounds, including the 118-F-1 and 118-F-6 Burial Grounds. Strontium-90 sorbs to sediment grains in the vadose zone and in the aquifer, but also

migrated into groundwater, especially at sites with a significant driving force (for example, liquid effluent disposal).

Mobile and moderately mobile contaminants include nitrate, trichloroethene, and Cr(VI). During the period of reactor operations, large volumes of contaminated water were discharged to the soil via trenches, cribs, and leaks from pipelines and retention basins, primarily in eastern 100-F. Liquid effluent also was released through outfall piping to the Columbia River. During the operational period, large groundwater mounds helped spread mobile and moderately mobile contaminants in groundwater in a radial pattern. It is likely that groundwater carried these contaminants rapidly to the river, based on reactor operations and liquid discharge history. As early as September 1945, effluent springs began to appear along the riverbank in association with retention basin leakage. Multiple springs were identified along the 100-F shoreline during this period

Unlike the Cr(VI) contamination observed from processes at 100-D, apparently only relatively low concentration waste was discharged to the subsurface at 100-F because of the production facility design. There was a much longer period of using dry dichromate powder to mix corrosion control solutions for 105-F Reactor water treatment as compared to other 100 Area reactors; and the installation of newer equipment during the plant upgrades diminished the opportunity for leaks of the concentrated 70 percent solution. However, delivery of the 70 percent solution into the storage tanks at 185/190-F, waste site 100-F-57, was not completely efficient, and yellowish-stained soil around the storage tank location indicates some losses. The fraction of delivered 70 percent solution lost to the subsurface is not known. However, the current concentrations observed in groundwater do not indicate the presence of a highly concentrated, persistent source.

The Experimental Animal Farm was a source of nitrate contamination because it is a common component of animal urine and feces. A portion of the nitrate that reached groundwater near the animal pens was transported inland as a result of the groundwater mounding caused by reactor operations.

The source of trichloroethene contamination in and near 100-F has not been definitely identified, but is suspected to be one of a group of waste sites west of 100-F. It can be present as a gas in the vadose zone and as a dissolved species in soil moisture and groundwater.

### 4.7.2 100-F Post-Operations, Pre-Remediation

After reactor operations and liquid effluent disposal ceased, the driving force for infiltration decreased. For an undetermined period, water in the vadose zone continued to drain beneath the sites, but the volume was minor compared to the operational period. Infiltration of precipitation through contaminated vadose zone sediments carried some additional contamination to groundwater. Net infiltration of 17 to 52 mm/yr (0.67 to 2.0 in./yr) likely continued at nonvegetated waste sites. During this period, short-lived radionuclides continued to decay.

### 4.7.3 100-F Current Conditions

DOE began to remediate 100-F waste sites in the mid-1990s. Remediation generally included excavation to about 4.6 m (15 ft) bgs, which removed the most heavily contaminated vadose zone materials. Dust suppression water was used during demolition and remediation of waste sites, which may have temporarily mobilized some contaminants in the vadose zone. Once waste sites are revegetated, the plants consume the natural precipitation, limiting infiltration deep into the vadose zone. Some contaminants may remain dissolved in the unsaturated water content of the vadose zone, but the mass in this phase is likely to be low, given the relatively low moisture content of the vadose zone (Chapter 3).

Most of the contaminated vadose zone materials have been removed under the Interim Action ROD. As of June 2012, several waste sites continued to undergo interim remediation. A number of other sites have radionuclide contamination above background at a depth greater than 15 feet following implementation of the Interim Action ROD (Section 4.2). These sites, and four sites addressed using ARCL methodology, will be evaluated in Chapter 6.

Vadose zone sample data were gathered during the completion of the new RI boreholes and monitoring wells, and the results indicated the following:

- Anthropogenic radiological contamination was detected at boreholes C7970 (116-F-14 Retention Basin), C7971 (118-F-1 Burial Ground), and C7972 (118-F-8 Reactor Fuel Storage Basin), including gamma-emitting radionuclides (cobalt-60, cesium-137, europium-152, and europium-154), beta emitters (carbon-14, nickel-63, strontium-90, and tritium), and plutonium-239/240. Uranium isotopes were detected in boreholes C7971 and C7972 at or below background concentrations. Strontium-90 is also present in groundwater at these locations (discussed below).

- Radiological contamination was detected in soil samples from Wells 199-F5-53 and 199-F5-54. Strontium-90 and cesium-137 were the only anthropogenic radionuclides detected above background, and were only detected in the deep vadose zone (within less than 1.5 m [5 ft] of the water table). Strontium-90 was below or near the detection limit in water samples from Well 199-F5-53, and below the 8 pCi/L DWS in Well 199-F5-54.

- Cr(VI) was detected in soil samples from borehole C7970. The concentration was highest (3.23 mg/kg) at 6.92 m (22.7 ft) bgs and then decreased with depth. Cr(VI) was not detected in groundwater at this location.

- Cr(VI) was detected in soil samples from Wells 199-F5-52 and 199-F5-54 near the water table. Concentrations in groundwater are <10 µg/L.

- Total chromium was detected above background at all boreholes and wells, and concentrations ranged from 36.5 mg/kg at borehole C7972 to 126 mg/kg at borehole C7970.

Cr(VI), strontium-90, nitrate, and trichloroethene are in the 100-F groundwater. Key elements of the nature and extent of groundwater contamination include the following:

- Cr(VI) exceeds the 10 µg/L AWQC beneath a portion of eastern 100-F, with an estimated plume area of 0.17 $km^2$ (0.07 $mi^2$). Only two wells exceeded the 48 µg/L MTCA (WAC 173-340) standard at least once in 2009 through 2011. The plume is adjacent to the Columbia River (Figure 4-21), where groundwater flow varies from the east to the south. The AWQC applies in the Columbia River, which is the point of groundwater discharge. Concentrations in one aquifer tube near the plume exceeded the AWQC slightly in 2009 but dropped below that level in 2011. Cr(VI) concentrations in riverbed pore water do not exceed the AWQC.

- A strontium-90 plume with an area of 0.07 $km^2$ (0.03 $mi^2$ at greater than the 8 pCi/L DWS) underlies eastern 100-F. In 2010 and 2011, concentrations exceeded the DWS in one routine monitoring well and one new temporary well located within a former waste site; the maximum concentration was 285 pCi/L. This plume is adjacent to the Columbia River (Figure 4-31) where groundwater flow varies from the east to the south. However, strontium-90 has relatively low mobility and concentrations in aquifer tubes and pore water samples were below or near detection limits (below DWS). Another temporary well near the reactor building also has strontium-90 concentrations above the DWS.

- A nitrate plume underlies the southern half of 100-F and extends southward for a distance of approximately 2 km (1.2 mi). The plume has an area of 10.6 $km^2$ (4.1 $mi^2$ ) at greater than the 45 mg/L DWS (Figure 4-27). This plume is migrating to the east (beneath portions of 100-F) and south-southeast (in the region south of 100-F). Concentrations are stable overall, and ranged up to 200 mg/L in 2011. An aquifer tube and a shoreline seep downstream from 100-F formerly exceeded the DWS, but concentrations have declined.

- A trichloroethene plume in southwestern 100-F has an estimated area of 0.7 $km^2$ (0.27 $mi^2$) at greater than the 5 µg/L DWS (Figure 4-35), although portions of the plume boundary are not well defined. The maximum concentration in 2009 through 2011 was 20 µg/L, and concentrations are declining overall. Wells in other portions of 100-F also occasionally have trichloroethene concentrations above the DWS. The source of the trichloroethene groundwater plume has not been identified with certainty. Suspected waste sites have recently been remediated. Concentrations within the groundwater plume have been decreasing, and a concentrated residual source of trichloroethene is not suspected.

- Three RI wells provided information on contaminant distribution with depth in the thin, unconfined aquifer. One of the wells was located where concentrations at all depths were low and did not vary significantly with depth. A second well showed a decrease in Cr(VI) concentration with depth. The third well showed a decline in nitrate, gross alpha and gross beta concentrations with depth, and a modest increase in tritium concentrations with depth. Groundwater samples collected from the confined aquifers in the RUM do not show evidence of contamination.

As groundwater approaches the Columbia River, it enters a zone of interaction with river water. Flow paths in the zone of interaction vary with daily and seasonal fluctuations in river stage. River water infiltrates the banks when river stage is high, moves inland, and then reverses flow as the river stage subsides. Modeling suggests that there is a significant back-and-forth motion in the groundwater, effectively lengthening the flow path through the aquifer. A water molecule will experience numerous reversals in flow direction before it eventually reaches the water column in the river. This mechanism delays contamination from reaching the river and provides additional opportunity for contaminant attenuation by dilution, chemical reaction, or radioactive decay.

The water in the zone of interaction is a mixture of groundwater and river water, as evidenced by lower specific conductance in shallow aquifer tubes and, seasonally, in near-river monitoring wells. Mixing continues in the pore water of shallow river sediments. Recent studies show that specific conductance rapidly declines as the river rises.

Some of the groundwater from the unconfined aquifer eventually discharges to the Columbia River near 100-F and farther south. Groundwater flow under the river channel is prevented by higher hydraulic heads on the opposite side of the river. Columbia River pore water was sampled three times at 100-F. Results indicate that pore water and surface water meet water quality standards.

### 4.7.4 100-IU-2/IU-6

Waste sites and facilities in the 100-IU-2 and 100-IU-6 OUs were mainly associated with housing, staging equipment, and material for the project; most of the area was previously occupied by homesteads and farms. The area includes roads, railroads, a fire station, fuel stations, storage facilities, an old concrete batch plant site, storage vaults in the east end of Gable Mountain, and pre-Hanford Site farm sites and landfills (e.g., pre-1943 municipal and farm waste sites). Contamination in this area generally originated from light industrial chemical use and agriculture, rather than nuclear material production and chemical processing.

Remediation under the Interim Action ROD has been completed for a portion of 100-IU-2/IU-6 waste sites. Currently, 115 "accepted" waste sites remain, most of which are anticipated to be addressed under the Interim Action ROD. These waste sites were not the type that received concentrated or high-volume liquid waste that typically contributes to groundwater contamination.

Although the trichloroethene groundwater plume in southwest of 100-F may have originated from 100-IU-2/IU-6, no current source remains and the plume is further discussed in Section 4.7.3. No other groundwater contaminant plumes originate in 100-IU-2/IU-6, but contamination from other OUs is present, for example tritium from 200-PO-1. These constituents will be evaluated further in their respective OUs.

*Looking Forward in this Document*

Chapter 4 described the contaminants resulting from 100-F/IU operations and their current extent in the environment. Contaminants can be harmful to HHE if there is contact with sufficient concentrations, mass, or radioactivity.

Chapter 5 describes and predicts fate and transport; that is, how these contaminants will migrate through the environment. The potential harm depends on specific receptors as well as exposure times and patterns that might bring receptors and contaminants into contact. The ways that the contaminants could come into contact with people, plants, and animals are called pathways. Chapter 6 addresses the human health pathway, and evaluates potential impacts. Chapter 7 addresses the biological receptor pathway and evaluates how plant, animal, bird, or invertebrate species might be affected.

Chapter 8 identifies technologies that could remove contaminants from the setting or interrupt these pathways. Chapter 9 develops and evaluates remedial alternatives using these technologies. Chapter 10 compares the alternatives that can best address the problem. This evaluation and comparison will support a remedial decision to implement actions to protect HHE.

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# 5 Contaminant Fate and Transport

This chapter presents an evaluation of the anticipated behavior of COPCs present in vadose zone soil and groundwater at 100-F/IU. The evaluation includes an assessment of the behavior of residual contamination in vadose zone materials remaining following prior remediation that may function as secondary contaminant sources and describes how contaminants released to the environment may affect the underlying groundwater. The evaluation also includes an assessment of the behavior of selected COPCs already present in 100-F/IU groundwater. The conditions affecting contaminant behavior, modeling methods and results, and uncertainties are also discussed, concluding with a summary of the chapter as a whole.

The purpose of the fate and transport evaluation presented in this chapter is to describe the following:

1. The development of soil screening levels (SSLs) and PRGs for COPCs present in vadose zone soil at 100-F/IU and the application of these SSLs and PRGs to observed conditions to support the assessment of potential threats to groundwater and surface water.
2. How SSLs and PRGs are used to evaluate whether COPCs present at interim closed out waste sites may act as secondary sources of groundwater contamination.
3. The process that will be used to evaluate ongoing and future vadose zone remediation activities.
4. How existing Cr(VI), strontium-90, TCE, and nitrate groundwater contaminant plumes may behave in the future if no further action is taken at 100-F/IU.

Understanding contaminant fate and transport in the subsurface environment pathway is an important part of the RI/FS process (other transport mechanisms, including atmospheric transport, surface runoff, and biovector transport are possible pathways but not significant in the RI/FS based on nature and extent of contamination presented in

*Highlights*

- Disposal of large volumes of liquid effluent to the vadose zone during F Reactor operations between 1945 and 1965 resulted in accelerated transport of contaminants to deeper portions of the vadose zone and unconfined aquifer groundwater.
- Because liquid effluent discharges are no longer occurring, contaminant migration rates are now much slower. Many 100-F/IU contaminants have characteristics that limit their migration in the vadose zone. Cr(VI) and nitrate are the primary exceptions.
- A computer model was used to assess the fate and transport of COPCs in the vadose zone by developing a SSL and PRG for each COPC. The SSL identifies the allowable COPC concentration in soil that protects groundwater and surface water quality if irrigation were applied (SSL), while the PRG identifies the allowable concentration for a natural-based (native vegetation) recharge rate scenario.
- A total of 96 interim closed out waste sites in 100-F and 48 interim closed out waste sites in 100-IU-2/IU-6 were evaluated to assess the potential for groundwater and surface water impacts associated with leaching of vadose zone contaminants. Previous remediation was found to have achieved levels protective of applicable surface water and groundwater standards (measured at the waste site boundary) at nearly all of these sites.
- A computer model for the 100 Area was used to simulate the fate and transport of Cr(VI), strontium-90, TCE, and nitrate currently present in 100-FR-3 groundwater. The model simulations indicate (based on model predicted maximum concentrations):
  - Cr(VI) attenuates to concentrations less than its 10 µg/L surface water quality standard within 35 years.
  - Strontium-90 attenuates to concentrations below its 8 pCi/L MCL in 150 years.
  - TCE attenuates to concentrations below its 5 µg/L MCL within 45 years.
  - Nitrate attenuates to concentrations below its 45 mg/L MCL (expressed as nitrate) within 80 years.

Chapter 4). Projections of future contaminant behavior and concentrations at points of exposure are needed to assess potential threats to HHE. These projections are especially important for sites where contaminants are long-lived or where groundwater contaminant plumes may migrate beyond the area covered by a monitoring well network. Contaminant fate and transport in the vadose zone was simulated using a one-dimensional computer model. Contaminant fate and transport in groundwater was simulated over a 150-year period (years 2010 to 2160) using a three-dimensional computer model.

The information presented in this chapter was used to calculate SSLs and PRGs that are protective of groundwater and surface water quality for the conditions simulated. Remediated waste site COPC exposure point concentrations (EPCs) were compared to the SSLs and PRGs to identify waste sites requiring consideration in the FS for groundwater and surface water protection. The assumptions and model input parameters described are important for future waste site remediation efforts and assessing the achievement of remedial goals. The cleanup verification process, including demonstration of how remedial goals are achieved, involves comparing the waste site conceptual site model (CSM) to the generic CSM used to develop the SSLs and PRGs. To the extent a significant deviation in the two CSMs is observed, site-specific conditions can be used to evaluate the potential for a waste site to act as a source of groundwater contamination.

There are 96 interim closed out waste sites present in the 100-FR-1/FR-2 OUs and 48 interim closed out waste sites present in the 100-IU-2/IU-6 OUs. These waste sites were evaluated to determine whether further action might be needed for groundwater and surface water quality protection.

Without irrigation, there were no threats to groundwater quality or surface water quality in 100-F or 100-IU-2/IU-6. If irrigation of the land surface overlying waste sites were to occur, Cr(VI) present at 116-F-14 could pose a threat to surface water quality in 100-F.

No 100-IU-2/IU-6 waste sites were identified that could pose a threat to groundwater or surface water quality even if irrigation were applied.

In the case of Cr(VI) present in soil at the 116-F-14 waste site, site-specific modeling was used to determine that this COPC poses a potential threat to surface water quality under the irrigation recharge scenario. However, this analysis indicated that Cr(VI) at this site is not a potential threat to groundwater quality under any recharge scenario, or to surface water quality under the native recharge scenario.

## 5.1 Evaluation Process for Assessment of Groundwater and Surface Water Protection

The evaluation process used to assess whether there is potential for vadose zone contamination to affect groundwater and/or surface water quality followed a specific set of logical steps, as shown on Figure 5-1. This process is intended to determine whether there is potential for soil contaminants to migrate to the underlying groundwater and, subsequently, be discharged to surface water at concentrations that may pose a threat to human or ecological receptors. This evaluation does not include an assessment of potential effects due to direct contact with shallow or surface contamination. This evaluation is presented in Chapter 6 (human health) and Chapter 7 (ecological).

The activities associated with the evaluation process included the following steps:

1. The available data describing the nature and extent of residual contamination at a particular waste site were identified and assembled. This dataset may include laboratory analysis of soil samples collected from the vadose zone, field measurements of specific contaminant concentrations, qualitative and quantitative measurements of radionuclides present in the vadose zone, measurements of soil physical

properties (e.g., moisture and particle size distribution), and field observations made during drilling and/or excavation. The data were generated from process knowledge and operating history from specific waste site characterization activities (e.g., LFI and RI activities), or from completion and verification measurements associated with vadose zone interim action remediation.

2. The dataset for each waste site was then evaluated to develop a CSM.

3. The waste site CSM was then compared to the generic CSM, upon which the SSL and PRG values are based. If the known waste site conditions are similar to those used for the SSL and PRG simulations (i.e., 100:0 or 70:30 contaminant distributions, depending on individual contaminant soil:water distribution coefficients, or $K_d$ values), then the evaluation follows the SSL and PRG comparison pathway.

4. If known site conditions differ from the generic CSM, then the waste site is evaluated using a site-specific contaminant transport simulation. Conditions that may indicate that the generic CSM is not representative for the waste site include contaminant distribution in the vadose zone that differs from the default distribution (i.e., 100:0 or 70:30), and presence of a persistent groundwater plume near a waste site or operating area. Waste sites that are not represented by the default simulation scenarios are subsequently evaluated individually; that analysis is discussed later in this chapter.

5. EPCs for each COPC are calculated based on the site-specific data at hand. The EPC is calculated using either a 95 percent upper confidence level (UCL) on the mean or a maximum observed concentration (if insufficient data are available to derive a UCL).

6. The EPCs for each contaminant at a waste site are then compared to the SSL. The SSL represents a conservative groundwater or surface water protection value based on the assumption of an irrigation based recharge scenario. If the EPC is less than the SSL, then that contaminant is identified for no further action and the assessment moves to the next contaminant. Note that for surface water protection, the SSL is based on the groundwater concentration at the downgradient edge of the waste site (point of calculation), whereas the AWQC (which serves as a screening criterion to protect surface water from contamination in groundwater discharges) applies in the Columbia River. Dilution in groundwater from the point of calculation to the river, and in the river itself, is conservatively not included in this evaluation.

7. If the site-specific contaminant EPC is greater than the SSL, then the EPC is subsequently compared to the PRG for that contaminant. The PRG represents a protection value based on the reasonably anticipated future land use in the 100 Areas (i.e., conservation activities that do not include irrigated agriculture). If the EPC is greater than the SSL but less than the PRG, then the affected waste site is identified for application of institutional controls that will prevent irrigation in the future at the waste site. If the EPC is greater than the PRG, then the site may be evaluated for representativeness of the model. If found nonrepresentative, site-specific modeling can be applied to evaluate. If found representative, or site-specific results show exceedance, then the waste site is carried forward into the FS for identification of appropriate remedial alternatives to mitigate risks to groundwater and surface water posed by the vadose zone contamination.

If waste site conditions are not adequately represented by the generic CSM used for SSL and/or PRG development simulations, then the waste site and its affected contaminants are evaluated using a site-specific vadose zone transport simulation. This simulation uses the same general fate and transport modeling approach used for the SSL and PRG development, except that site-specific conditions are substituted where appropriate. The site-specific simulation also uses the Subsurface Transport Over Multiple Phases (STOMP) fate and transport code, and recharge rates with and without the assumed

application of irrigation. When the simulations are completed, they are evaluated using the same steps outlined above for default SSL and PRG values.

Site-specific modeling can be done in two ways. The modeling can be done by developing site-specific SSLs and PRGs similarly to development of the general area SSL/PRGs, but modifying the model scenario to reflect the site-specific conditions that vary in the selected site (such as for strontium-90, which was given a "site-specific" 100:0 initial contamination distribution for all sites based on observed deep contamination of this COPC at many sites despite its higher $K_d$ value). Alternately, a site-specific fate and transport simulation may be performed to assess the site-specific impacts to groundwater. The result of the site-specific evaluation is an assessment of the overall site conditions (such as was performed for site 116-F-14) to evaluate whether those conditions result in an unacceptable threat to groundwater or surface water.

## 5.2 100-F/IU Conceptual Site Model

The components of a CSM include contaminant sources, release mechanisms, transport processes, exposure pathways, and receptors. Sources, release mechanisms, and transport processes are discussed in this chapter. The physical settings (that contaminants are in and transported through) are discussed in Section 3.11. The nature and extent of contamination is summarized in Section 4.7. A final aspect of the CSM is the different exposure pathways through which humans, animals, and plants could potentially be impacted by the presence of contaminants in the environment. The exposure pathways and risk assessments for humans are described in Chapter 6, and the exposure pathways and risk assessments for biota are described in Chapter 7. This chapter (Chapter 5) focuses on subsurface fate and transport in the vadose zone and groundwater as a primary exposure pathway. This focus does not exclude other pathways (e.g., direct exposure) that are addressed elsewhere. However, the numerical modeling required to predict fate and transport of contaminants in the subsurface environment requires specialized modeling, which is the focus of this chapter.

The following subsections identify the primary sources of contamination in 100-F/IU, describe probable release mechanisms, and summarize the means by which contaminants are transported in the environment. In addition, processes that influence contaminant fate are described. The information presented in the following subsections lays the groundwork for the vadose zone contaminant transport assessment presented in Section 5.6 and the groundwater contaminant transport modeling presented in Section 5.7.

As presented in Chapters 1 through 4, waste material released from reactor operations and support facilities, including cooling water processing facilities, underground piping, liquid waste disposal sites, solid waste disposal sites, and surface spills were primary sources of contamination during operations and secondary sources may have developed in vadose zone and aquifer materials. Vadose zone soil and aquifer sediments impacted by releases represent potential secondary contaminant sources. Secondary sources can release contaminants to the environment long after discharges to primary contaminant sources have stopped.

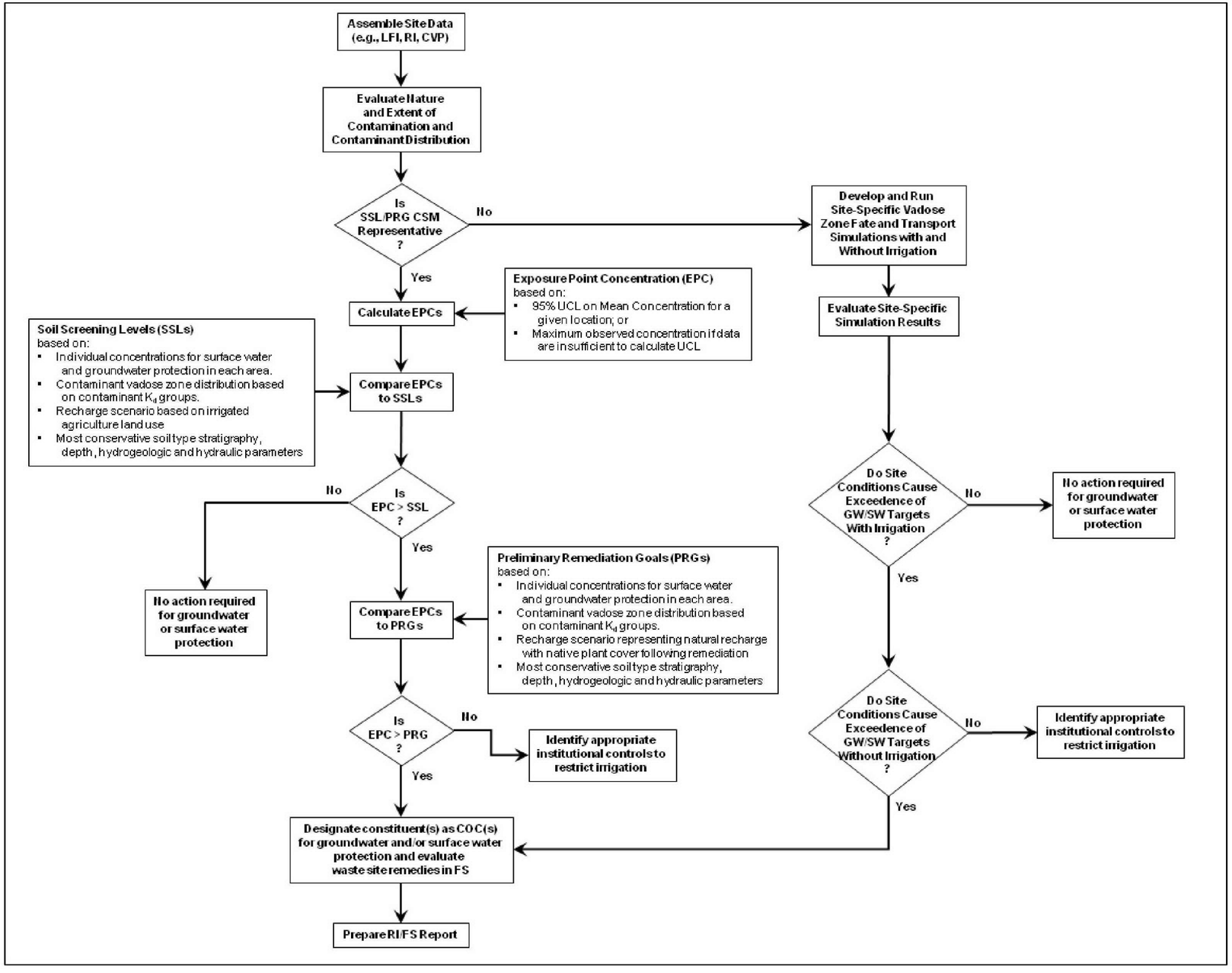


Figure 5-1. General Screening Process for Groundwater/Surface Water Protection at Sites with Measurement Data Describing Site Conditions

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Key elements influencing contaminant fate and transport in 100-F include the lasting effects of high-volume liquid waste disposal on vadose zone moisture levels and the water table, the development and behavior of secondary contaminant sources in the vadose zone, contaminated groundwater and surface water interaction, and the effect of river-stage fluctuations on contaminant entry to the Columbia River. Equally important are the differences in subsurface conditions that prevail today from those that existed during the 1945 to 1965 reactor operations period. These effects are graphically illustrated on Figure 5-2 and are summarized as follows:

- During the reactor operations period, large volumes of reactor cooling water containing Cr(VI) and radionuclides were temporarily stored in the 116-F-14 Retention Basin where the water (initially at or near boiling temperatures) thermally cooled and short-lived radionuclides decayed before discharge to the river. The cyclic heating and cooling of the retention basin and its associated pipelines exposed their materials of construction to significant thermal stresses. Over time, the liquid-effluent-handling infrastructure developed leaks, allowing effluent to seep into the vadose zone. Cooling water also overflowed from the retention basins directly into the spillways and the 116-F-2 Overflow Trench and 116-F-4 Crib.

- The volume of cooling water that seeped from the retention basins and trenches was large enough, and of sufficient duration, that large groundwater elevation mounds formed beneath these facilities (Figures 5-2 and 5-3). The groundwater elevation mound created a localized area with a radial groundwater flow pattern that transported contaminants inland, as well as toward the Columbia River.

- The 100-F Experimental Animal Farm (EAF) was located northeast of the F Reactor. Experiments conducted at this facility between 1945 and 1976 generated contaminated solid and liquid waste. Solid waste was placed in trenches and burial grounds, and liquid waste discharged to a sewer system that ultimately discharged to a spillway at the Columbia River. The EAF operations were likely a source of nitrate that migrated south possibly in response, at least in part, to the groundwater mounding resulting from high-volume cooling water discharge (Figure 5-3), although this migration path may also reflect other geologic aspects of the area south of 100-F.

- Contaminants were transported to various depths in the vadose zone and the unconfined aquifer commensurate with their relative mobility and with their volume of liquid effluent discharged. Highly mobile constituents such as nitrate and tritium were transported at essentially the same velocity as the water, while less mobile constituents (e.g., strontium-90) moved more slowly.

- Cr(VI) and other highly to moderately mobile contaminants were transported in the unconfined aquifer by the natural and groundwater mound-enhanced flow gradient, where they entered the Columbia River through upwelling along the river bottom and seeps along the riverbank.

- High-volume liquid effluent discharges to the retention basins and the overflow trench ceased when F Reactor operations ended in 1965. Once these discharges stopped, the groundwater elevation mound began to subside. By approximately 1970, the mound had largely dissipated.

- The depth of secondary contaminant sources may occur deeper beneath unremediated and remediated waste sites because of COPC sorption to vadose zone material. The concentrations of residual contaminants at remediated 100-F/IU waste sites were evaluated in CVP reports and were reported to be below the applicable interim action RAGs. This indicates that a majority of the secondary source materials have been removed from the 100-F/IU OU and are no longer potential sources of release or exposure.

- The construction, operation, and decommissioning of F Reactor operations support facilities resulted in the disturbance and removal of large areas of natural vegetative cover. These activities reduced evapotranspiration rates that, in turn, increased the amount of natural recharge infiltrating the ground surface.

- Chromium present in the vadose zone may occur in either the hexavalent (CrVI) or trivalent (CrIII) form. Most of the chromium that has migrated away from the primary source locations is expected to occur as Cr(VI). Most of the Cr(VI) is moderately mobile; however, some may sorb to mineral surfaces, precipitate in mineral phases with varying degrees of stability, or may be reduced to Cr(III) and form less mobile, less toxic, solid-phase precipitates (*Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* [PNNL-17674]).

- A portion of the vadose zone is periodically rewetted with daily and seasonal fluctuations in the Columbia River stage. Samples collected from the periodically rewetted zone during the 2010–2011 RI did not indicate the presence of significant secondary sources contributing to the persistence of Cr(VI) in unconfined aquifer groundwater.

- Groundwater flow and contaminant transport in the unconfined aquifer are affected by Columbia River-stage fluctuations. Spring runoff conditions increase the river's average daily elevation, which in turn pushes surface water inland and causes the groundwater elevation to rise at 100-F. During the late summer and early fall months, when low river-stage conditions prevail, groundwater flow toward the river dominates (Figure 5-2). Natural seeps occur along the shoreline, in the riparian zone, because of the declining river stage.

- From 2009 to 2011, the average concentration of Cr(VI) only exceeded the AWQC in one aquifer tube in 100-F. The highest individual measurement was 14.7 µg/L. Strontium-90 has not been detected in these samples at concentrations above the 8 pCi/L MCL. Because there is no AWQC for strontium-90, the Tri-Parties agreed to use the 8 pCi/L MCL in the 100-N Area to assess potential impacts to the Columbia River surface water quality.[1] The TCE plume is located inland and is not currently entering the river based on historical sampling of the aquifer tubes. Nitrate associated with the 100-FR-3 plume is not entering the river at concentrations greater than the MCL.[2]

The presence of COPCs in vadose zone soil and unconfined aquifer groundwater at 100-F resulted from discharges that primarily occurred between 1945 and 1965. The current distribution of COPCs was largely influenced by the design of the facilities that received liquid and solid waste, vadose zone and contaminant characteristics, and groundwater flow patterns. In addition, the current distribution of COPCs reflects the implementation of interim remedial actions that have removed contaminated vadose zone material from the 100-FR-3 OU. The presence of COPCs in vadose zone soil at 100-IU-2/IU-6 waste sites resulted from pre-Hanford agricultural practices and Hanford Site-related activities. The presence of COPCs in groundwater underlying the 100-IU-2/IU-6 OUs resulted primarily from groundwater transport of contaminants originating from the 200-BP-5 and 200-PO-1 Groundwater OUs, and in the case of nitrate, the 100-FR-3 OU as well.

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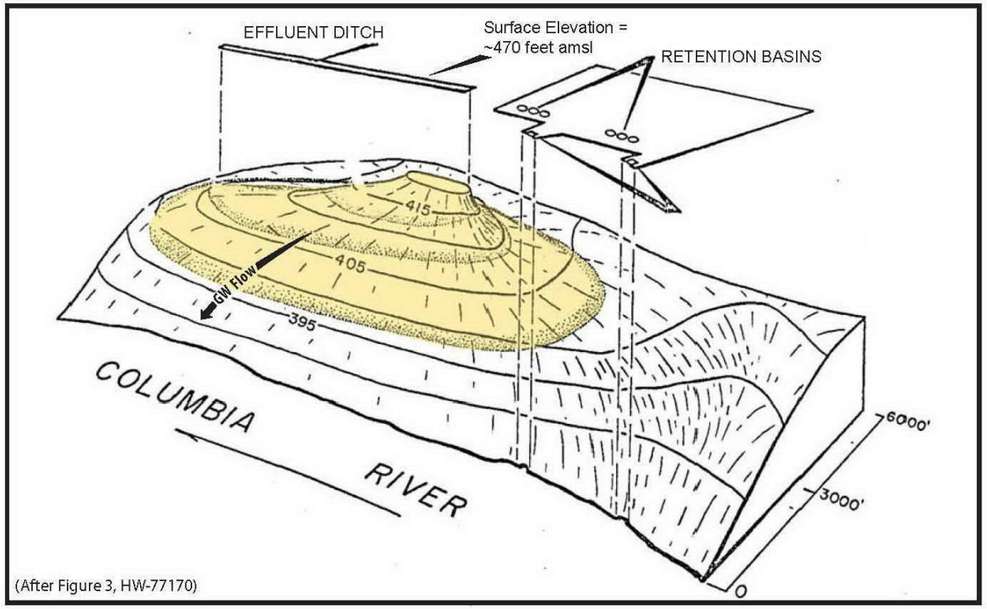
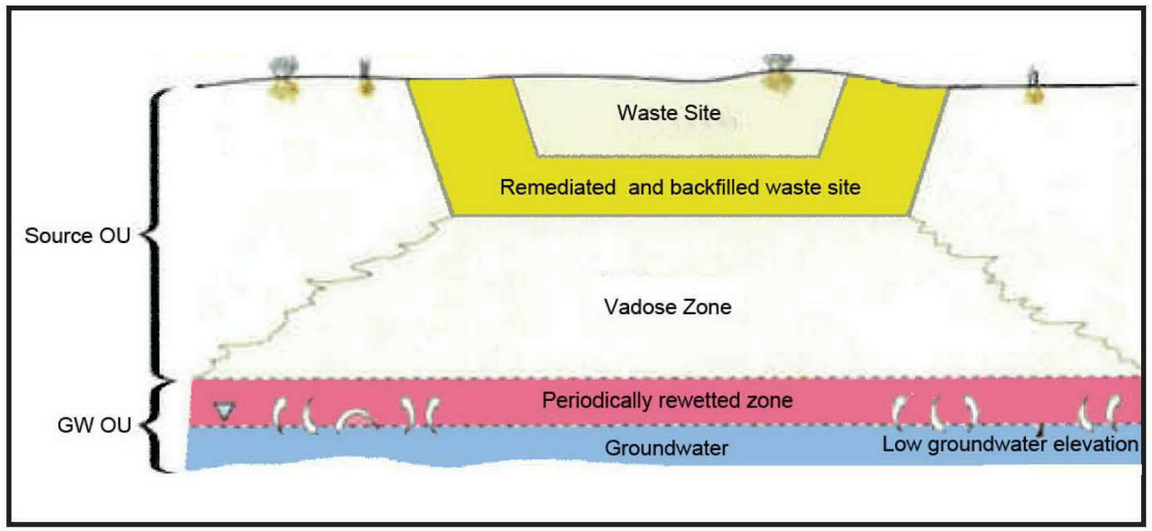
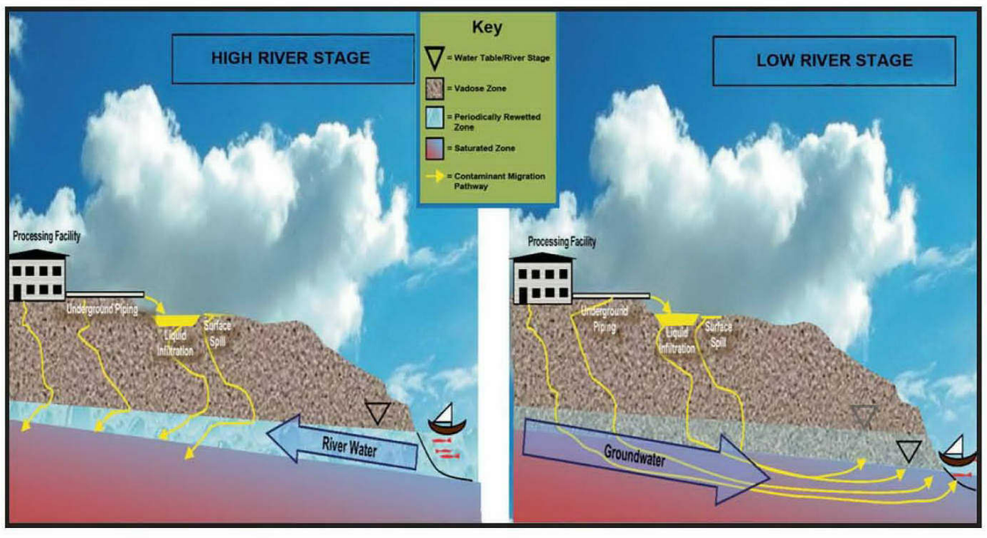
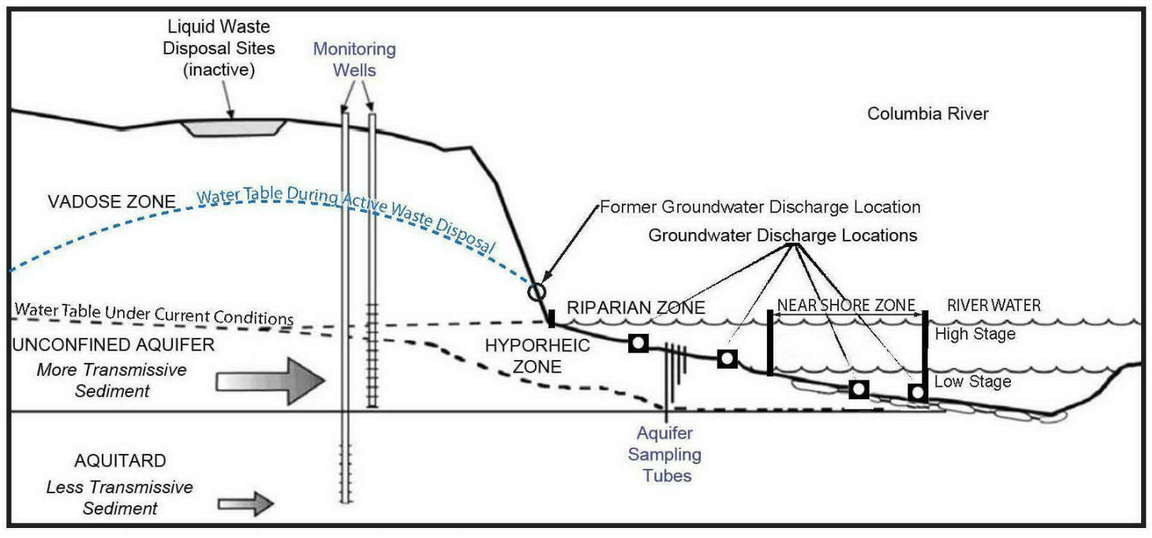
[1] Tri-Party Agreement Milestone M-016-110-T03, "Take Actions to Contain Sr-90 GW Plume at 100-NR-2 OU"—"DOE shall take actions necessary to contain the strontium-90 groundwater plume at the 100-NR-2 Operable Unit such that the default ambient water quality standard (8 pCi/L) for strontium-90 is achieved in the hyporheic zone and river water column."

[2] The DWS for nitrate is 45 mg/L expressed as nitrate ion ($NO_3^-$) or 10 mg/L expressed as nitrate-nitrogen ($NO_3$-N). All references to nitrate in this document are to the nitrate ion.




Source: HW-77170, *Status of the Ground Water Beneath Hanford Reactor Areas January,, 1962 toJanuary, 1963*.

Figure 5-2. Conceptual Overview of Contaminant Fate and Transport in 100-F

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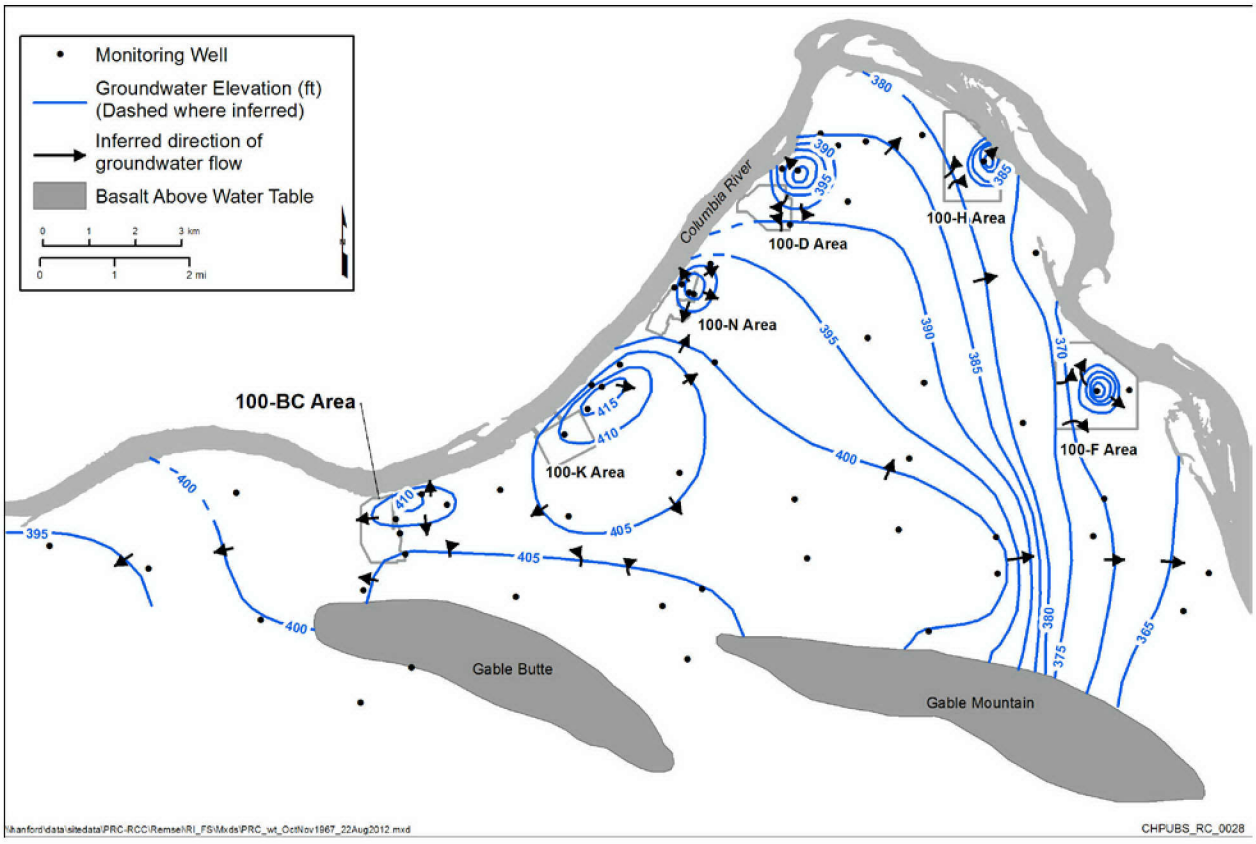



Source: WHC-SD-EN-TI-023, *Hydrologic Information Summary for the Northern Hanford Site*.

Figure 5-3. 100-F/IU Groundwater Mound during Operations

### 5.2.1 Contaminant Sources

The identified sources of contamination at 100-F/IU are categorized as primary and secondary sources. Primary sources are the process chemicals, working solutions, and radioactive and nonradioactive waste that were released into the environment during the period of 100-F/IU operations from 1945 and EAF operations until 1976.

Secondary sources consist of environmental media (e.g., soil, surface water, and groundwater) that were impacted by releases from primary sources. These media can retain sufficient levels of contaminants that can act as a reservoir for continuing releases to adjacent soil, surface water, groundwater, or air. Current and future remedial actions will focus on control of secondary contaminant sources that may result in either direct contact exposure to identified receptors, or release and transport to groundwater or surface water, where potential exposure may occur.

Historical releases of various liquid and solid waste resulted in contamination of the vadose zone and underlying groundwater. Contaminated groundwater migrated downgradient toward the Columbia River and entered the river through surface springs and direct interaction of groundwater with surface water in the river's hyporheic zone. Previously remediated waste sites may represent potential sources of contamination. These sites will be evaluated in the FS if they pose a threat to HHE.

### 5.2.2 Primary Sources

The contaminants detected at 100-F/IU originated from the historical operation of the water-cooled nuclear reactor (F Reactor) and its support infrastructure, as well as the EAF. The primary source was

the liquid waste generated during reactor operation (i.e., reactor cooling water, FSB water, and decontamination solutions). Reactor cooling water, obtained from the Columbia River, was conditioned before passing through the reactor. The conditioning process included solids removal and addition of sodium dichromate for corrosion protection. Contaminants potentially introduced into the cooling water as it passed through the reactor consisted of fuel materials, fission and activation products, and residual Cr(VI).

Reactor cooling water was by far the largest volume of primary source material at 100-F. Approximately 2.3 trillion L (608 billion gal) of coolant water passed through the reactor over its lifetime and was disposed either into the Columbia River or the vadose zone beneath the site. Other contaminants introduced into the cooling water as it passed through the reactor consisted of fuel materials, and fission and irradiation byproducts. Liquid effluent was released by direct discharge to the Columbia River via the 116-F-14 Retention Basin and the 1904-F Outfall Structure, and to the vadose zone through infiltration from cribs (116-F-4), and trenches (116-F-2). The large volumes of water released to the subsurface increased the potential for environmentally mobile chemicals and selected radionuclides (typically tritium and strontium-90) to be transported to groundwater. Other liquid primary sources included concentrated water treatment chemical solutions (e.g., high-concentration sodium dichromate solutions).

Solid waste associated with reactor operations included sludge from the FSB, solids generated from cooling water pre-treatment (e.g., crystalline sodium dichromate dihydrate), reactor components, and various other contaminated items. Waste generated from reactor operations may have been contaminated with radionuclides, chemicals, or both (i.e., mixed waste). The main source of solid waste was from reactor operations, and the most highly contaminated were the reactor components. These included aluminum spacers, lead-cadmium reactor neutron poison pieces, boron splines, graphite, process tubes, and lead. Sludge from the FSB and 116-F-14, and solids generated from cooling water pre-treatment comprised significant volumes of solid waste. Two reactor modification projects were responsible for much of the solid waste from F Reactor: the Ball 3X project and the tube replacement project.

Several hundred fuel cladding failures occurred over the lifetime of F Reactor, producing highly contaminated cooling water (*Historical Events—Reactors and Fuels Fabrication* [RL-REA-2247]). The most contaminated water was generally diverted to the soil column via trenches or cribs rather than retained (cooled) and disposed of in the river. Leaks and overflows were also sources of contamination to the vadose zone. Over the operating lifetime of the reactor facility, the retention basins and effluent piping developed leaks, releasing cooling water to the area in and around the basins, lines, and river shore at a rate as high as several thousand liters per minute. In May 1955, baffles in the retention basin broke loose and plugged the basin outlet. The cooling water overflow contaminated the immediate vicinity of the basin and drained to the Columbia River via a narrow trench near the northeast corner of the basin (*100-F Reactor Site Technical Baseline Report Including Operable Units 100-FR-1 and 100-FR-2* [WHC-SD-EN-TI-169]).

### 5.2.3 Secondary Sources

The release of contaminants from primary sources to the environment resulted in contaminated vadose zone soil beneath facilities and waste sites. This material represents a secondary source of contamination. Mobile contaminants present in vadose zone soil are subject to transport by leaching to groundwater, by groundwater to surface water, by overland flow, or by wind as particulates or vapors.

As of June 30, 2012, the majority of waste sites in 100-F/IU have undergone remediation, significantly reducing the potential for any remaining secondary sources. Other potential secondary sources that may be present include residual contamination in soil below remediated waste sites or within the unconfined aquifer sediments.

The evaluation of risks posed by secondary sources to HHE through direct exposure is discussed in Chapters 6 and 7, respectively. The potential for secondary sources to provide an ongoing source of contamination to groundwater is evaluated through the comparison of waste site contaminant EPCs to the SSLs and PRGs (Section 5.7) for groundwater and surface water protection.

The persistence of the Cr(VI), TCE, and nitrate groundwater plumes in the 100-FR-3 OU is attributed to the low horizontal hydraulic gradient and periodic hydraulic gradient reversals that occur along the river shoreline. These conditions slow plume migration and entry into the river while providing an inland groundwater/surface water mixing zone that reduces COPC concentrations before river discharge. In general, the RI characterization dataset did not identify any sources of Cr(VI), TCE, or nitrate in the vadose zone that would be expected to contribute to exceedances of groundwater or surface water standards under the reasonably anticipated future land use (conservation). Cr(VI) concentrations beneath remediated waste sites were generally low, with the highest concentration of 6.83 mg/kg occurring beneath the upgradient northeastern portion of 116-F-14 (former retention basin), although this site is not considered the source of this chromium plume in groundwater.

Under operating conditions at the F Reactor, strontium-90 was released with large volumes of high-temperature cooling water. These releases during operations resulted in transport of strontium-90 over greater distances and to lower depths in the vadose zone. After operations, the strontium-90 remained sorbed within the vadose zone.

Experiments conducted at the EAF between 1945 and 1976 generated contaminated solid and liquid waste. Solid waste was placed in trenches and burial grounds, and liquid waste discharged to the 116-F-16 Outfall and Trenches that is believed to be associated with the nitrate plume in this area.

### 5.2.4 Release Mechanisms

The primary release mechanisms were the reactor operation activities that resulted in the initial discharge of contaminants to the environment. Secondary release mechanisms are the processes that, under current and future conditions, redistribute contaminants from secondary sources to other environmental media.

#### *5.2.4.1 Primary Liquid Waste Release Mechanisms*

The primary release mechanisms for liquid waste at 100-F/IU included intentional or planned discharges, and UPRs. Planned releases fall into two groups:

- High-volume, low-concentration liquids (e.g., reactor cooling water) that were typically released directly to the Columbia River but were also sometimes discharged to engineered trenches
- Lower volume, higher concentration liquids (e.g., contaminated reactor cooling water generated during upset conditions) that were released to the land surface and allowed to infiltrate, or were discharged to engineered subsurface waste infiltration structures (e.g., cribs and covered trenches)

In addition, acids, solvents, and cleaning solutions used in reactor maintenance were discharged to cribs and trenches.

During F Reactor operations, high volumes of process effluent (including reactor cooling water, steam condensate, and FSB cooling/shielding water) were intentionally released via pipelines through retention basins to either Columbia River outfalls or trenches where the effluent was allowed to infiltrate into the vadose zone. In addition, liquid waste was intentionally released to the subsurface via cribs, trenches, French drains, and sewage disposal systems. Although trenches are surface features, their purpose was to facilitate rapid infiltration of wastewater into the vadose zone.

UPRs occurred during various material-handling transfers. Cooling water and other liquid waste were routinely transferred using underground pipelines, and releases occurred through leaks at joints caused by material failure due to corrosion, heat, or physical damage. Over the operating lifetime of F Reactor, leaks in the retention basins and effluent piping released cooling water to the area in and around the basin, lines, and river shore (*Radiological Characterization of the Retired 100 Areas* [UNI-946]). A significant release occurred when the retention basin overflowed in 1955, and cooling water contaminated the immediate vicinity of the basin and drained to the Columbia River. The sewer lines, septic tanks, and leaching fields that comprised the sanitary facilities at 100-F/IU were susceptible to leaks and failures and likely contributed to the nitrate contamination in the vadose zone and groundwater. Other probable sources of nitrate include fertilizer use on pre-Hanford Site agricultural lands and EAF animal waste.

A UPR occurred in March 1971 when the main sewer line between the EAF and the 141-C hog barn became plugged and overflowed, spilling washwater used to clean animal pens onto the surface adjacent to the building. In addition to animal waste, the washwater contained strontium-90 and plutonium-239, and contaminated approximately 148.6 $m^2$ (1,600 $ft^2$) of soil (*100-F Reactor Site Technical Baseline Report Including Operable Units 100-FR-1 and 100-FR-2* [WHC-SD-EN-TI-169]).

#### 5.2.4.2 Primary Dry Waste Release Mechanisms

Contaminants associated with dry solid waste were released to the environment through intentional disposal at waste sites or through unplanned spills of particulate material. Various types of solid waste, including contaminated reactor hardware and components, were placed directly in burial grounds. When this material interacted with water or air, contaminants may have transferred to other media through leaching or dissolution.

Dry granular or crystalline chemical materials (e.g., sodium dichromate dihydrate) or contaminated soil particulates may also have become windborne, suspended in surface runoff, or transferred to soil through physical contact with a contaminated surface. Intentional/planned releases of solid waste are believed to account for a large majority of historical dry waste releases to the environment.

#### 5.2.4.3 Secondary Release Mechanisms

Contaminated material present in the vadose zone or aquifer is a potential secondary source of some contaminants. Secondary sources remaining in pipelines and control structures in the form of pipe scaling, corrosion products, sludge, and sediment may be released through structural failure of the pipeline and exposure to infiltration. Secondary contaminant release mechanisms include the following:

- Volatilization to the atmosphere or soil gas (applicable to VOCs and tritium)
- Resuspension of particulates in air (applicable to all contaminants located at the soil surface)
- Transport in surface water runoff, both as dissolved constituents and suspended particles (applicable to all contaminants)
- Dissolution, desorption, and transport with infiltrating precipitation (applicable to soluble contaminants)
- Biotic uptake (applicable to all contaminants)
- Groundwater discharge to surface water and to the riparian ground surface in seeps and springs
- Release of reactor-related chemicals that could occur during facility demolition

### 5.2.5 Potential Routes of Migration

Contaminants released during F Reactor operations or those currently present as potential secondary sources have the ability to migrate through the air, vadose zone, groundwater, surface water, and biota uptake pathways. Each of these migration routes is discussed in the following subsections.

#### *5.2.5.1 Air*

Contaminants can potentially migrate to air as vapors or solid particles. The meteorological conditions summarized here are discussed in more detail in Chapter 3. In the 100 Areas and along the Columbia River, local winds are strongly influenced by near-river topography. At 100-F, the prevailing wind direction is from the west (NEPA Characterization Report [PNNL-6415])

During historical operations, contaminants were released through exhaust stack emissions before installation of the filtration system in 1960. These emissions distributed low-level radionuclide activity over a broad area (*100-F Reactor Site Technical Baseline Report Including Operable Units 100-FR-1 and 100-FR-2* [WHC-SD-EN-TI-169]). Without appropriate mitigation measures, strong winds can disperse contaminated surface soil while waste sites are exposed during excavation or demolition. Methods employed to minimize this hazard (e.g., mitigations taken as part of interim action ROD work) include applying dust-suppression water and soluble adhesives during remedial activities. Air monitoring is conducted during waste site remediation under approved site-specific air monitoring plans. Air monitoring programs conducted sitewide are summarized in Chapter 2. The majority of waste sites with the potential to act as a source of fugitive dust have already been remediated under interim remedial actions.

#### *5.2.5.2 Vadose Zone*

The stratigraphic unit relevant to contaminant transport in the vadose zone at 100-F is the Hanford formation. As described in Chapter 3, the Hanford formation consists of gravel with sandy interbeds; cobble-size clasts are common, and boulders may be present.

In the vadose zone, the downward movement of infiltrating water is inferred to be perpendicular to the orientation of the sedimentary bedding and lenses in the Hanford formation. Transient saturated conditions were present during reactor operations throughout the vadose zone beneath high-volume liquid effluent waste sites. Pressure head and vertical saturated hydraulic conductivity would have been the dominant factors controlling the downward movement of water and contaminants during this period.

Localized saturation of the vadose zone (resulting from the groundwater elevation mound beneath the 116-F-14 Retention Basin [Figure 5-3] and high-volume liquid effluent discharges to other waste sites, during reactor operations) altered the natural groundwater flow gradient. This change produced a localized area of radial groundwater flow with a preference toward the east and south (*Status of the Ground Water Beneath Hanford Reactor Areas January, 1962, to January, 1963* [HW-77170]). During this period, isotopic analysis of well and spring water was used to calculate an average horizontal groundwater-flow velocity ranging from 3.05 to 9.14 m/d (10 to 30 ft/d). Present-day flow velocities are much lower, ranging from 0.19 to 0.58 m/d (0.62 to 1.9 ft/d) along the shoreline and 0.20 m/d (0.66 ft/d) in the inland area.

In the Hanford Site's low rainfall, semiarid climate, the water-holding capacity of the soil (or matric potential) largely controls the movement of water through the soil and the corresponding rate of migration of mobile contaminants. Migration of contaminants through the vadose zone is currently slower than during reactor operations due to the cessation of liquid effluent discharges at the end of reactor operations and re-establishment of surface vegetation following remediation. Natural interbedding of gravel layers with finer textured sand and silt layers in the vadose zone produces capillary barriers that inhibit the

vertical movement of water under natural water infiltration rates. Vertical migration of contaminants within the soil pore spaces is therefore slowed under these conditions.

#### 5.2.5.3 Groundwater

As described in Section 3.6, the unconfined aquifer beneath 100-F lies within the Hanford formation gravels. The aquifer saturated thickness ranges from less than 1 m (3 ft) in the southern 100-F to 8 m (26 ft) in the eastern 100-F.

The groundwater flow system beneath 100-F is the primary contaminant transport pathway between the historical primary contaminant sources, current secondary sources, and the river. The characterization of 100 Area hydrogeology requires an understanding of surface water recharge sources, vadose zone characteristics, groundwater flow, and groundwater/surface water interactions. Both natural and anthropogenic recharge sources have influenced vadose zone water and groundwater flow patterns, as well as contaminant distribution in the subsurface underlying 100-F. The effects of natural processes on contaminant migration are ongoing, while the effects of anthropogenic-driven processes have diminished with the cessation of reactor operations.

Generally, natural groundwater flow patterns transport contaminants present in 100-F/IU groundwater east toward the river. Within the southeast portion of 100-F, a southeasterly flow component transports contaminants in a southeasterly direction. This flow component is evident in the configuration of the nitrate plume. Groundwater flow directions close to the Columbia River are influenced by the river stage. During the fall, when the river stage is relatively low, groundwater flow is toward the river. In the spring, when the river stage is high, the water table near the river flattens and river water may flow a limited distance inland into the aquifer. Seasonal high river stages are 3 m (10 ft) greater than seasonal low river stages. The river stage can also fluctuate several meters over short periods (i.e., hours to days) based on Columbia River dam operations. River-stage fluctuations influence groundwater elevations and flow directions several hundred meters inland from the river. The magnitude of the influence diminishes with increasing distance from the river.

#### 5.2.5.4 Surface Water

The Columbia River is the only natural surface water feature in 100-F/IU, except for the overland flow of seasonal seepage in the riparian zone. The routes of migration to the river include groundwater discharges upwelling to the riverbed, previous discharges to the river during operations, and overland flow of water discharged from seeps. Previous groundwater discharges to the Columbia River were observed as seeps on the riverbank that may have transported mobile contaminants (*Status of the Ground Water Beneath Hanford Reactor Areas January, 1962 to January, 1963* [HW-77170]). The Columbia River is the dominant aquatic ecosystem on the Hanford Site and supports a large and diverse population of plankton, benthic and lotic invertebrates, fish, and other ecological communities.

#### 5.2.5.5 Biotic Uptake

Plants may absorb contaminants through their roots. Animals may uptake contaminants from surface deposits, which could accumulate in their tissues. This exposure pathway is discussed in Chapter 7. Impacts from biotic uptake of Hanford Site contaminants is of particular concern in the riparian zone where contaminants may be found at the ground surface, within plants growing in contaminated soil, and where contaminated groundwater may seasonally discharge to the ground surface and flow overland to the river.

## 5.3 Contaminant Persistence

The persistence of contaminants determines how long they remain in the environment for transport to potential points of exposure. If a contaminant is persistent and mobile, it is more likely to be transported to the accessible environment (e.g., in the groundwater pathway from the vadose zone, to the groundwater, and eventually to the surface water). Persistence is defined by how long it takes a particular contaminant to be transformed into a less toxic or less available form, or how long it takes the contaminant to physically leave the affected area. Radionuclides undergo radioactive decay at varying rates specific to the individual nuclide. Chemicals may degrade abiotically through microbial mediated oxidation-reduction reactions or may be dispersed in a manner that reduces the mass and/or the concentration of the contaminant available for direct exposure. The following paragraphs discuss the persistence of selected 100-F/IU COPCs.

### 5.3.1 Nonradionuclide Chemical Constituents

The persistence or decay of chemical constituents at 100-F/IU is controlled by biological and geochemical oxidation-reduction processes, potential biological uptake, and physical processes (e.g., volatilization, dispersion, and dilution). The chemical constituents identified as COCs in this assessment were Cr(VI), TCE, and nitrate. These constituents are subject to a variety of transformational processes depending on the nature of environmental conditions present.

Cr(VI) is both relatively stable and persistent in the vadose zone and groundwater environments at 100-F. Chromium is typically present in the environment in one of two oxidation states: Cr(III) or Cr(VI). Cr(III) is typically precipitated in the environment as a low-solubility hydroxide molecule, $Cr(OH)_3$ and, as such, is not mobile and exhibits low mammalian toxicity. However, Cr(VI) is toxic and typically present under ambient conditions at 100-F as a soluble oxyanion, $Cr_2O_7^{-2}$ or $CrO_4^{-2}$, depending on concentration and pH. The ionic forms of Cr(VI) are relatively stable under the oxidation-reduction conditions typically present in soil and groundwater at 100-F, and as such, Cr(VI) tends to have moderate mobility under current conditions.

The primary source of Cr(VI) present in the subsurface environment was the sodium dichromate dihydrate used for corrosion control in reactor cooling water. This compound is acidic in its concentrated form; however, the dichromate, or chromate, ion can react with other metals in the environment to form compounds of lesser solubility. These compounds can include potassium dichromate (which is about one-tenth as soluble as sodium dichromate dihydrate) and lead chromate (which is essentially water-insoluble). The Cr(VI) ions can also be subject to chemical reduction under moderately reducing conditions, or upon reaction with reducing agents such as ferrous iron and sulfide. Ferrous iron is effective in reducing Cr(VI) to Cr(III), producing a very low-solubility hydroxide molecule (*Monitored Natural Attenuation of Inorganic Contaminants in Ground Water, Volume 2, Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium* [EPA/600/R-07/140]).

TCE found at relatively low concentrations in groundwater degrades very slowly under the oxidation conditions and dissolved oxygen concentrations currently present in 100-F groundwater (i.e., aerobic). TCE can be reductively dechlorinated by facultative[3] and obligate[4] anaerobic microorganisms under anoxic conditions or undergo abiotic transformation (*Identification and Characterization Methods for Reactive Minerals Responsible for Natural Attenuation of Chlorinated Organic Compounds in Ground*

[3] Can survive in both aerobic and anaerobic conditions.

[4] Can survive only in anaerobic conditions.

*Water* [EPA 600/R-09/115]). Additionally, TCE may volatilize from the land surface or surface water directly to the atmosphere. TCE dissolved in soil moisture or groundwater can partition to soil gas and then migrate to the atmosphere; however, gas exchange from the deep vadose zone (e.g., below a few meters bgs) or from groundwater accounts for only a small potential loss. Once in the atmosphere, TCE can be destroyed through photodegradation (sunlight). The potential for volatilization, abiotic, or biologically mediated degradation is dependent upon the specific physical and chemical properties of the environment where TCE occurs, the size and nature of the microbial populations, and the geochemical characteristic of the subsurface environment. The TCE present in 100-F/IU groundwater has persisted, indicating that naturally occurring transformation processes are slow in removing this constituent from the subsurface environment.

Nitrate is relatively stable under the aerobic conditions present at 100-F/IU and, therefore, will persist in most areas. Additionally, because it is not sorbed by vadose zone or aquifer sediments, nitrate is readily transported, as evidenced by the size of the nitrate plume present in 100-FR-3. Nitrate can be biodegraded through denitrification, in which the oxygen atoms in the nitrate molecule ($NO_3^-$) are removed by chemical reduction to produce nitrogen gas ($N_2$). Denitrification occurs under anaerobic conditions and in the presence of chemically reduced compounds such as organic carbon, ferrous iron, and sulfide minerals. The subsurface environment within 100-F/IU is characterized by aerobic conditions; therefore, denitrification, if present, is limited to localized zones that are not readily detected by the existing groundwater monitoring well network.

### 5.3.2 Radionuclide Constituents

Radionuclide persistence is controlled by the radioactive decay process that transforms the original radioisotope either into another isotope of the same element or into another element. The daughter product of radioactive decay may be a radionuclide or a stable isotope. Exclusive of their relative mobility in the environment, radionuclides with relatively long half-lives ($T_{1/2}$)[5] are of greater environmental concern than radionuclides with shorter $T_{1/2}$. This is due to the potential for constituents with longer half-lives to remain in the environment after release and to present a potential for exposure to human and ecological receptors either through direct exposure at or near the point of release, or through migration to distant exposure points. The only radionuclide identified as a COC for 100-F/IU was stronium-90 in soil and groundwater, with $T_{1/2}$ = 28.8 years. This radionuclide decays through beta emission to yttrium-90, which in turn decays by beta emission with a $T_{1/2}$ of 64 hours to stable zirconium.

In addition to radioactive decay, the persistence of a radionuclide in groundwater is affected by its individual chemical and physical behaviors. Strontium-90 will also behave as a metallic strontium molecule, with the exception that the isotope fraction will decay. In the environment, strontium-90 commonly remains as an exchangeable divalent cation. As such, it is not readily mobile and tends to be sorbed on soil particles near its point of release.

## 5.4 Vadose Zone Contaminant Migration Assessment

In addition to posing direct contact risk to future human or ecological receptors (discussed in Chapters 6 and 7, respectively), COPCs present in vadose zone soil may pose a threat to groundwater and surface water quality. Leaching of COPCs from secondary sources (contaminated soil) with subsequent transport by infiltrating water (from precipitation, dust suppression, irrigation, or septic drain field return flow) represents the primary vadose zone contaminant transport process for nonvolatile COPCs.

[5] For this RI/FS, half-life data was obtained from the Radiochemistry Society website (RS, 2012).

Contaminants released from the 100-F/IU primary and secondary sources were transported through the vadose zone and, in some cases, reached the water table. This section describes the factors affecting contaminant transport through the vadose zone. The most significant factors affecting subsurface contaminant migration are the type of surface cover and its effect on net infiltration or recharge rates; the physical, chemical, and hydraulic characteristics of the matrix; and the physical and chemical properties of the contaminant.

Once mobile contaminants reach groundwater, they travel in the direction of groundwater flow. Contaminated groundwater may migrate downgradient to upwell into the Columbia River. Additionally, groundwater may be seasonally discharged through seeps or springs to flow overland across the riparian zone to the river. Seasonal seeps and springs may be an ongoing contaminant source for the riparian zone.

The vadose zone contaminant migration assessment presented in this section focused on an evaluation of waste sites characterized during the LFI, the current RI, and sites where soil remediation is complete and CVP data describing post-remediation conditions are available (i.e., the "previously remediated sites"). This assessment provides a basis for confirming that previously characterized sites that were determined not to pose a potential threat to groundwater or surface water, and that sites remediated under the interim action ROD, do not pose a threat to groundwater or surface water.

### 5.4.1 Factors Affecting Contaminant Migration in the Vadose Zone

Contaminant migration from 100-F/IU waste sites through the vadose zone to the underlying aquifer is controlled by the driving forces and the interactions between the contaminants and sediments specific to 100-F/IU. The driving forces include gravity, matric potential gradients, recharge, and artificial discharge such as drainage from septic tank leach fields, pipe leaks, and tank leaks. The types, thicknesses, and properties of the sediments affect the rate and direction of solute and water movement in the vadose zone. The concentration of a contaminant in the groundwater and its concentration in Columbia River surface water, including the peak concentration, are dependent on the solute flux from the vadose zone, vadose zone thickness and properties, groundwater flux rates, travel distance, groundwater and river water mixing, and the sample location. The decay rate of each contaminant and its propensity to sorb to vadose zone or aquifer materials are important factors that control the peak concentration from which the SSL and PRG are calculated. Specific factors that affect contaminant transport in the vadose zone are discussed further in the following subsections.

#### *5.4.1.1 Infiltration and Recharge*

Net infiltration into the vadose zone is driven by competition between the processes of precipitation, evaporation, transpiration, runoff, and run-on. In semiarid and arid climates, downward water fluxes resulting from this competition are episodic and usually infrequent. However, this episodicity is damped with increasing depth. A number of studies have been conducted at the Hanford Site to ascertain representative long-term averages of the episodic fluxes (i.e., recharge rates), such as those compiled in *Vadose Zone Hydrogeology Data Package for Hanford Assessments* (PNNL-14702), hereinafter called Vadose Zone Hydrogeology Package.

The 100 Area-specific recharge rates described in the Vadose Zone Hydrogeology Package (PNNL-14702) vary with surface soil type and provide an estimate of the range of possible recharge rates for various land uses. Based on borehole geologic logs, four stratigraphic columns corresponding to the range of vadose zone thicknesses and lithologic composition present in 100-F, and four stratigraphic columns present in 100-IU-2/IU-6, were developed.

The long-term natural driving force for contaminant transport through the vadose zone is the downward movement of water. This movement is expressed as follows (*Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates* [PNNL-17841]):

- **Infiltration**—Refers to water usually resulting from precipitation that enters the ground. Enhanced infiltration may result where surface depressions act as terminals for overland flow.
- **Deep percolation or deep drainage**—Refers to water that has percolated or drained below the zone of evaporation and the influence of plant roots.
- **Recharge**—Refers to water that flows to the water table, and it is the primary mechanism for the transport of contaminants through the vadose zone to groundwater.

Direct measurement of naturally occurring recharge attributed to surface infiltration at the Hanford Site is not practical. Therefore, the measurement is made indirectly because the thickness of the vadose zone and the time scale required for water to travel from the surface to the water table would require long periods of observation. In place of direct measurements of recharge at the water table, measurements and analyses of deep drainage in the unsaturated zone are used to approximate the recharge. The terms can be equated as long as the climate, land use, and land cover remain the same. Consequently, the terms "deep percolation" or "deep drainage" are often used synonymously with "recharge."

Ample evidence exists that revegetation of disturbed land at the Hanford Site occurs both with and without human intervention. Data collected from the prototype Hanford barrier in the 200 East Area indicate that the sagebrush community begins to reduce net infiltration very soon after planting. The species richness of the plant community on the prototype Hanford barrier dropped from 35 in 1997 to 12 in 2007. The dominance of tall sagebrush (*Artemisia tridentate*) on the surface may continue to reduce the species richness on the surface (Figure 5-4).

Source: PNNL-17176, *200-BP-1 Prototype Hanford Barrier Annual Monitoring Report for Fiscal Years 2005 Through 2007.*

Figure 5-4. Prototype Hanford Barrier Cover in 2007 Dominated by Tall Sage (Artemisia tridentata) Covering Most of the Soil Surface, 13 Years after Plant Community Establishment

Grass cover has decreased from initial levels on the barrier surface, and it continued decreasing from 2004 to 2007. Cheatgrass (*Bromus tectorum*) and Russian thistle (*Salsola kali*) are nearly nonexistent on the barrier surface. The western and northern side slopes of the barrier, which were not planted with sagebrush, show less plant cover but higher species diversity than the barrier surface. This may be due to the influence of windblown material and seeds from adjacent land, or the lack of shrubs competing for resources. Insects and small mammals infest the barrier surface, which indicates that the restored barrier surface is beginning to function as a recovering ecosystem.

Numerous studies have estimated recharge rates for the vadose zone system at the Hanford Site under various surface cover conditions. Several such studies are summarized in Appendix B of *Recharge Data Package for Hanford Single-Shell Tank Waste Management Areas* (PNNL-16688), which cites the results of radioisotopic tracer studies that were used to estimate recharge rates under various soil types and vegetative covers. Tracer-method-based estimates in *Recharge Data Package for Hanford Single-Shell Tank Waste Management Areas* (PNNL-16688) for Burbank loamy sand or Ephrata sandy loam ranged from 1.2 mm/yr to 5.5 mm/yr under "sagebrush with sparse grass cover." The recharge rate affects the flow velocity/flux rate of water through the vadose zone. The flow velocity in the vadose zone is expected to have been greatest beneath the retention basin, French drains, trenches, and cribs during the operational period when percolation was greatest. The velocity of downward movement is expected to have decreased after the waste disposal ceased, as the subsurface water content profile began to equilibrate to new (bare soil) surface conditions. After waste disposal operations ended, alterations to the surface cover (including excavating contaminated soil, backfilling excavations with clean fill, and revegetating and stabilizing) began to alter and reduce the net infiltration rate to the vadose zone.

The recharge input values to the STOMP model for SSL (irrigation recharge scenario) and PRG (native vegetation recharge scenario) development were based on the vadose zone data package compiled in the Vadose Zone Hydrogeology Package (PNNL-14702). These data provided the basis for the recharge rates input to the sequential models used to calculate SSLs and PRGs. The first simulation, called the pre-2010 model, was used to establish the initial matric potential distribution in the vadose zone for the post-2010 model, which simulated the migration of water and contaminants to the underlying aquifer. The recharge rates, summarized in the following paragraphs, are discussed in detail in *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas* (ECF-HANFORD-12-0004) in Appendix F.

For the pre-2010 simulations, land use and recharge rates were assumed to change from a native shrub-steppe plant community (pre-operational) to bare soil (operational). Recharge rates for each type of land cover and each soil type were applied to the top boundary of the model for the year 0 to year 1944 (pre-operational) period. The pre-operational period is an arbitrarily long period used simply to establish a steady-state moisture profile for the specified recharge rate. The second period, which extends from 1944 to 2010, corresponds to the operational period and accounts for surface cover changes arising during the operational era and their influence on soil moisture conditions in the soil column.

Three recharge periods were specified for the post-2010 simulations to account for evolutionary changes in the surface cover (Table 5-1). Bare soil was assumed to continue to be the land cover above the waste site during the first recharge period spanning from 2010 to 2015. For the native vegetation recharge scenario, the second recharge period of 30 years (*Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection* [DOE/RL-2011-50]) represents a period where grasses and shrubs cover bare soil. The third recharge period represents the establishment of a mature shrub-steppe that continues for the remainder of the simulation period. Thus, recharge rates decrease over time in this native vegetation recharge scenario as the vegetation cover transitions from bare soil to a mature shrub-steppe state that is maintained thereafter.

Rates for the irrigation recharge scenario were estimated with the same approach used to assess interim remediation at 100 Area waste sites (100 Area RDR/RAWP [DOE/RL-96-17]). These site assessments used levels calculated from RESRAD simulations for radioactive contaminants of interest that assumed total recharge was a combination of irrigation and non-irrigation recharge rates. As the native vegetation recharge rates used in the RESRAD simulations were different from those adopted from the Vadose Zone Hydrogeology Package (PNNL-14702), the RESRAD equation for total recharge was solved to determine the rate attributable to irrigation alone. Based on that approach, the calculated non-irrigation total recharge rate was 11.6 mm/yr (0.5 in./yr), and the recharge attributable to irrigation alone was 68.4 mm/yr (2.7 in./yr). This irrigation rate was added to the native vegetation recharge rate to determine a recharge rate for the irrigation scenario for each soil type in the SSL and PRG simulations. The resulting recharge rates for native vegetation recharge and irrigation scenarios for each soil type are shown in Table 5-1.

The final SSL and PRG values were calculated assuming the most conservative set of input values. For the SSL calculation, the maximum recharge rate (irrigation recharge scenario) was applied for each soil type (Table 5-1) at 100-F/IU. For the PRG value calculation, the native vegetation recharge rate was applied for each soil type.

Table 5-1. Recharge Rate for Different Time Periods in STOMP Model Simulations

| Soil Type | Recharge Scenario | Recharge Rate (mm/yr) | | | | |
|---|---|---|---|---|---|---|
| | | **Historical[a]** | | **Predictive[b]** | | |
| | | **0 to 1944[c]** | **1944 to 2010[d]** | **2010 to 2015 (Period 1)[e]** | **2015 to 2045 (Period 2)[f]** | **2045 to 3010 (Period 3)[g]** |
| Ephrata sandy and stony loam | Native Vegetation | 1.5 | 17.0 | 17.0 | 3.0 | 1.5 |
| | Irrigation[h] | 1.5 | 17.0 | 17.0 | 71.4 | 69.9 |
| Burbank sandy loam | Native Vegetation | 3.0 | 52.0 | 52.0 | 6.0 | 3.0 |
| | Irrigation[h] | 3.0 | 52.0 | 52.0 | 74.4 | 71.4 |
| Rupert sand | Native Vegetation | 4.0 | 44.0 | 44.0 | 8.0 | 4.0 |
| | Irrigation[h] | 4.0 | 44.0 | 44.0 | 76.4 | 72.4 |

a. Historical simulations performed to obtain a coherent initial moisture condition to use for predictive simulations.

b. Predictive simulations performed using appropriate recharge scenarios representing alternative land uses (irrigation or native vegetation scenarios for irrigated agriculture or conservation, respectively).

c. Calendar years 0 to 1944 are simulated as an arbitrarily long period only for establishing a steady-state initial hydraulic condition.

d. Calendar years 1944 to 2010 are simulated with no vegetation to represent the Hanford Site operational era.

e. Period 1: Disturbed surface and no vegetation.

f. Period 2: Developing young shrub-steppe vegetation, progressing to mature shrub-steppe vegetation over a 30-year transition period.

g. Period 3: Mature shrub-steppe vegetation.

h. The irrigation scenario assumes conditions are identical to native vegetation scenario until 2015 when irrigation begins.

N/A = not applicable

#### 5.4.1.2 Stratigraphy

The characteristics of material in the vadose zone affecting contaminant mobility include particle size, permeability, and organic content of the lithologies present beneath the waste site. The primary mechanism for transport in the vadose zone is the flow of infiltrating water in response to gravitational and capillary forces. The pore networks (represented by grain-size distributions in each vertical lithologic sequence, the hydraulic and transport properties of each lithologic unit in the sequence, and the thickness of each lithologic unit) affect water flow and contaminant transport through the vadose zone. The unsaturated hydraulic conductivity of each lithologic unit varies with moisture content and, therefore, is a function of matric potential. The effects of the different lithologic units and variations in their individual thicknesses in the 100-F/IU SSL and PRG values were determined by running STOMP simulations for a number of stratigraphic columns that represent the range of conditions present at 100-F/IU.

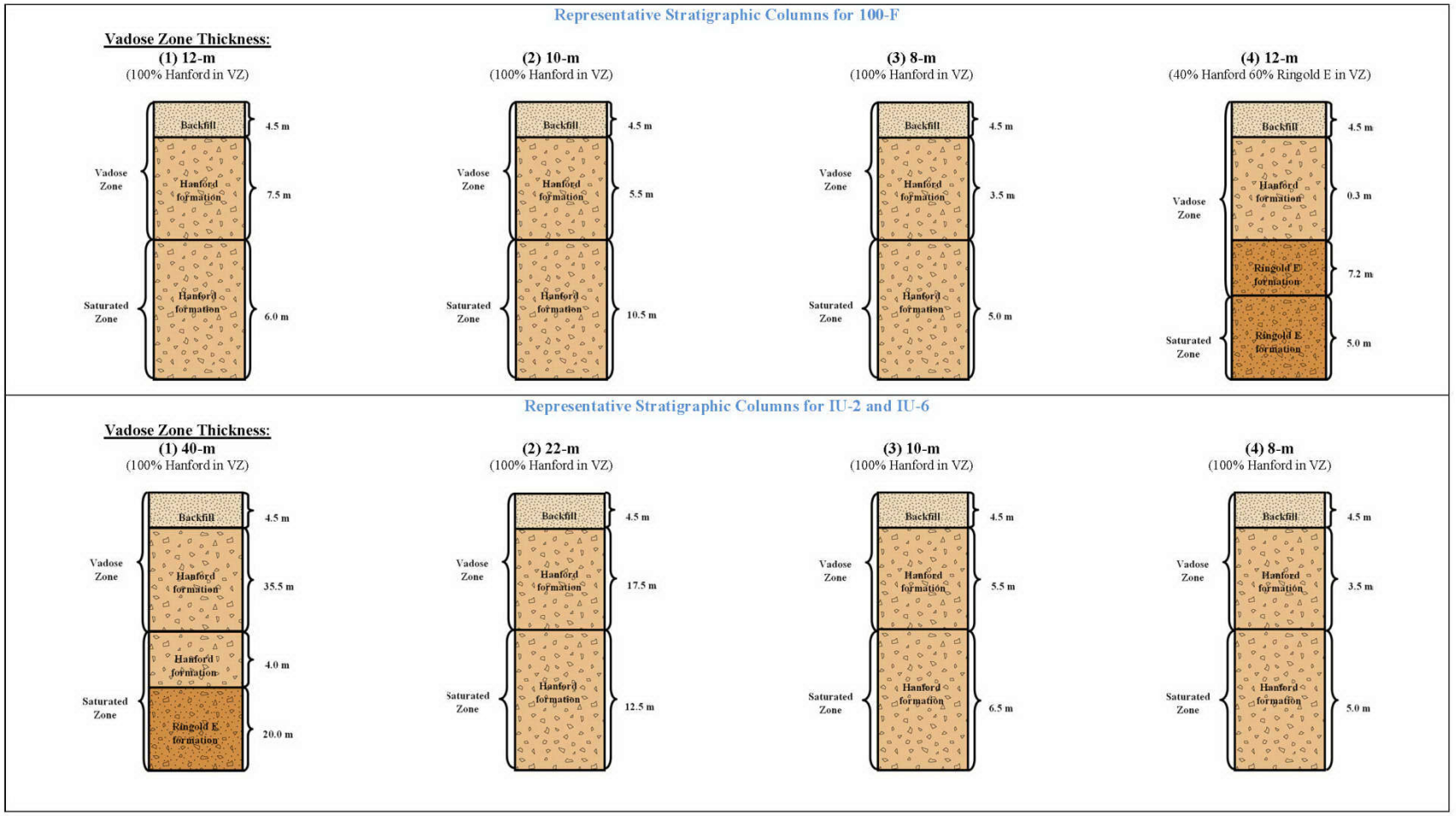
Representative 100-F/IU stratigraphic columns for the STOMP model simulations were developed from existing borehole logs. The lithologic unit present in the 100-F/IU vadose zone is the gravel-dominated Hanford formation. Due to its coarse texture and higher permeability, the Hanford formation transmits water and dissolved or particulate-bound contaminants more rapidly than most other lithologic units present at the Hanford Site. Existing borehole geologic logs were evaluated; four representative stratigraphic columns were developed for 100-F, and four stratigraphic columns were developed for 100-IU-2/IU-6 (Figure 5-5) to correspond with the range of vadose zone thicknesses (based on June 2008 [high groundwater elevation] conditions) and lithologic composition present. Each column was assumed to contain a clean backfill layer to represent conditions following interim remedial action completion. Backfill was assumed to replace the uppermost 4.6 m (15 ft) of native material in each column.

#### 5.4.1.3 Matric Potential

The matric potential is a measure of the attractive forces between water and porous or fractured materials that are important during variably saturated flow conditions (*Vadose Zone Processes* [Selker et al., 1999]). Moisture content and hydraulic conductivity are functions of matric potential. These functions are typically nonlinear and must be determined for each medium. The combination of matric potential gradients and gravity constitute the most important driving forces for vadose zone flow. The soil cover types discussed in the preceding section cause variations in the moisture and matric potential, in accordance with the net infiltration allowed by each cover type.

Like pressure head, matric potential can be measured in the field and the laboratory. In situ measurements of matric potential in the shallow Hanford Site vadose zone have been made using tensiometers and heat dissipation sensors installed in lysimeters, pits, and boreholes (*Compendium of Data for the Hanford Site (Fiscal Years 2004 to 2008) Applicable to Estimation of Recharge Rates* [PNNL-17841]; *Hydrologic Characterizations Using Vadose Zone Monitoring Tools: Status Report* [PNNL-14115]; and *Soil Water Balance and Recharge Monitoring at the Hanford Site – FY09 Status Report* [PNNL-18807]).

The nonlinear relationship between water content and matric potential, frequently called the moisture retention or characteristic curve, can usually be measured in the laboratory. The nonlinearity of the hydraulic conductivity and matric potential constitutive relation, termed "relative permeability," can typically be measured only over a small range of matric potential values. The remainder of the matric potential range must be inferred because the hydraulic conductivity can decrease several orders of magnitude for a much smaller decrease in matric potential.




Source: ECF-HANFORD-12-0004, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goalsfor 100 Area F and IU Source Areas*.

Figure 5-5. Representative Stratigraphic Columns for 100-F/IU STOMP Model Simulation

"A Closed-Form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils" (van Genuchten, 1980) alpha and *n* parameters used in the STOMP one-dimensional simulations were selected to represent materials from 100-F/IU and help define the relationship between moisture content in variably saturated media, the matric potential, and relative permeability. The inputs used in the simulations are described in detail in *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas* (ECF-HANFORD-12-0004) in Appendix F.

#### 5.4.1.4 Sorption

One of the single most important properties influencing contaminant mobility is the soil/water distribution coefficient, or $K_d$ value. This parameter is dependent on the relative abundance of different cations and anions in soil, soil pH, oxidation-reduction potential, cation exchange capacity, and the organic carbon content of the soil matrix. In general, organic constituents with lower molecular weights have lower $K_d$ values than those with higher molecular weights. The $K_d$ values for metals and metallic radionuclides are influenced by soil pH, cation exchange capacity, and the oxidation state of the metal.

Several metals of environmental concern (e.g., arsenic, chromium, and mercury) may occur in more than one oxidation state, such as trivalent (+3) and pentavalent (+5) arsenic; Cr(III) (+3) and Cr(VI) (+6); and monovalent (+1) and divalent (+2) mercury. The oxidation state and mineral speciation of these metals determine their relative mobility and toxicity. Cr(VI), originally released as high-solubility sodium dichromate dihydrate, is moderately mobile in soil and, therefore, moderately sorbed. However, Cr(VI) may also be present in soil as a relatively low-solubility mineral species such as potassium dichromate or lead chromate. Batch leach testing performed during the RI indicates that Cr(VI) present in vadose zone soil is moderately mobile ($K_d$ = 0.8 mL/g), suggesting that different mineral phases may be present. Cr(III)has low mobility and is generally present as a relatively insoluble precipitate such as chromium hydroxide $Cr(OH)_3$ (*Ground Water Issue Behavior of Metals in Soils* [EPA/540/S-92/018]).

Strontium-90 is assumed to exist as cationic species in the 100-F subsurface environment. Cationic species, which have higher $K_d$ values than anions, have moderate to low mobility. Cations are absorbed by clay minerals, oxides, and organic matter. Adsorption is pH-dependent, rising with increasing pH. Stronium-90 mobility is reduced through formation of precipitates with phosphate, carbonate, and hydroxide (*Ground Water Issue Behavior of Metals in Soils* [EPA/540/S-92/018]).

Table 5-2 summarizes the $K_d$ values and relative mobility for selected 100-F/IU COPCs. These contaminants are grouped by their relative mobility and $K_d$ values. With the exception of Cr(VI), the $K_d$ values used for the STOMP simulations were taken from *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the 100 Areas and 300 Area* (ECF-HANFORD-10-0442) in Appendix F. As described further in Section 5.5, batch leach testing was performed during the RI to develop a site-specific $K_d$ value for Cr(VI). The $K_d$ value for Cr(VI) is taken from batch leach testing as described and analyzed in *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area* (ECF-HANFORD-11-0165) in Appendix F.

*Highly Mobile COPCs.* Contaminants that are considered highly mobile move freely with the water in which they are dissolved, exhibiting limited interaction with the vadose zone soil or aquifer matrix that would retard their movement. Highly mobile contaminants are those that exhibit a $K_d$ of zero (no retardation), such as nitrate.

Table 5-2. Relative Mobility of Selected 100-F/IU Contaminants of Potential Concern

| Relative Mobility | Inorganics | Radionuclides | Organics |
|---|---|---|---|
| High | Nitrate | None | None |
| Moderate | Cr(VI) ($K_d$ = 0.8 mL/g) | None | Trichloroethene ($K_d$ = 0.094 mL/g) |
| Slight | None | Strontium-90 ($K_d$ = 25 mL/g) | Endrin ($K_d$ = 10.8 mL/g), heptachlor ($K_d$ = 9.53 mL/g) |
| Low | Cr(III) ($K_d$ = 200 mL/g) | None | None |

Source: ECF-HANFORD-10-0442, *Calculation of Nonradiological Soil Concentrations Protective of Groundwater Using the Fixed Parameter 3-Phase Equilibrium Partitioning Equation for the Protection of Groundwater for the 100 Areas and 300 Area*.

*Moderately Mobile COPCs.* Moderately mobile contaminants move readily with infiltrating water or groundwater but also exhibit a moderate degree of interaction with vadose zone soil and aquifer sediments. Sorptive processes generally tend to slow the rate of migration for these contaminants. A reduction in contaminant concentration with increasing depth occurs in the vadose zone and in groundwater with increasing distance downgradient from the point of entry. For the purpose of this analysis, moderately mobile contaminants are identified as those exhibiting $K_d$ values greater than 0 but less than 2. Both Cr(VI) and TCE are considered moderately mobile.

*Slightly Mobile COPCs.* Contaminants in the slightly mobile group exhibit a high degree of interaction with vadose zone soil and aquifer sediments and, as a result, migrate slowly through the vadose zone and aquifer. The concentration in soil decreases rapidly with increasing vadose zone depth, while the concentration in groundwater decreases with increasing distance from the point of entry. The decrease in concentration is due to the relatively large fraction of the contaminant that interacts with soil and becomes sorbed to the vadose zone and aquifer solids. The slightly mobile group includes contaminants that exhibit $K_d$ values greater than 1 but less than 30, such as strontium-90.

*Low-Mobility COPCs.* Contaminants with low mobility sorb strongly to vadose zone soil so no apparent migration occurs under natural recharge rates and infiltrating water near neutral pH conditions. Liquid waste sources with highly acidic or basic pH values, or those that contained complexing agents, may have transported these contaminants deeper into the vadose zone at the time of disposal, but their migration has since decreased as the liquid waste equilibrated with the vadose zone soil. These constituents are not expected to reach the water table, except at waste sites that discharge directly to the aquifer (deep injection/reverse wells), where the vadose zone is very thin, or where the effluent had acidic or caustic pH. Those contaminants that may have reached groundwater would not be expected to migrate much further in the aquifer. The low-mobility contaminants are identified as those that exhibit $K_d$ values greater than 30, such as Cr(III).

## 5.5 Batch Leach Tests

Because $K_d$ values are highly dependent on soil properties, batch leach tests were conducted during the RI, as described in the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4), to develop site-specific $K_d$ values for several metals, including Cr(VI) and strontium-90. Batch leach test samples were collected from a variety of locations in the saturated and unsaturated zones.

Batch leach tests were performed on soil and aquifer sediment samples using a leach procedure based on *Standard Test Method for Shake Extraction of Solid Waste with Water* (ASTM D3987-06). The procedure was performed using a 2 mm sieve to include the entire sand fraction based on the United States Department of Agriculture soil grain-size classification scheme. Where insufficient sample mass with less than 2 mm particle diameter was available based on actual field conditions, a 3/8 in. mesh screen was used instead. Demineralized water, pH-adjusted according to EPA's West Coast recommendation, was used as the leaching liquid. Selected soil samples were leached at soil-to-water weight ratios of 1:1, 1:2.5, and 1:5, with one test in each series duplicated.

Soil/water mixtures were placed in clean, water-tight sample containers (extraction vessels) and rotated end-over-end through the vessel centerline at a rate of about 30 rotations per minute for 18 hours. Following 18 hours of mixing, the soil/water slurry was filtered using a 0.45 µm filter. The leachate was analyzed for pH and conductivity. The leachate, after the 18-hour extraction period, and unfiltered soil were analyzed for arsenic, barium, cadmium, total chromium and Cr(VI), lead, selenium, and silver. Metals analysis for leachate and soil digestions was performed using Method 6010, 6020, or 200.8 for ICP metals, as applicable (bulk soil was digested using Method 3050B or 3051 for metals and Method 3060A for Cr[VI] to prepare for analysis). Separate aliquots of material were used for the bulk soil analysis and leaching tests.

The $K_d$ was calculated as the ratio of the contaminant sorbed to soil to the contaminant in solution by the following equation:

$$K_d = \frac{(C_S \times M_S) - (C_L \times V_L)}{M_S} \times \frac{1000}{C_L}$$

where:

$K_d$ = soil/water distribution coefficient (mL/g)
$C_S$ = contaminant concentration in bulk soil matrix before leaching (µg/g)
$M_S$ = dry mass of soil used for leaching (g)
$C_L$ = contaminant concentration in leachate (µg/L)
$V_L$ = liquid volume used for leaching (L)

The boring number, formation identification, sample depth intervals, and calculated $K_d$ values for the metals identified above are presented in Table 5-3. Calculated $K_d$ values for selenium and silver are not shown in the table because the soil samples had consistently nondetect concentrations. The complete datasets for vadose zone samples are provided in Appendix D.

For each vadose zone soil sample, four replicate samples were analyzed for total metal concentrations. The average of the four measurements was used in the calculation of $K_d$. If one or more of the four replicates was found to be below the reporting limit, the sample concentration was not considered reliable enough to report a $K_d$ value. This was done because the reporting limit varied among replicates, with the reporting limit for one replicate often being several times that of another. This variation precluded the use of surrogate values such as half-reporting limits because of the significant uncertainty introduced by the variable reporting limits. In most cases, more than one or all four replicates were below reporting limit. For duplicate samples, the larger $K_d$ of the two was reported in Table 5-3. In the common case, where an average soil concentration was calculated but the leachate water concentration was below reporting limit, that reporting limit was used in the calculation of a minimum $K_d$ value, and a greater than (>) sign was placed before the calculated $K_d$ value shown in Table 5-3.

Table 5-3. Summary of Batch Leaching Results for Samples Collected from the Saturated Zone in 100-FR-3

| Sample Location | Sample Depth (m bgs) | Constituent Measured | Batch Leach Ratio (g soil : mL water) | Calculated $K_d$ (mL/g) |
|---|---|---|---|---|
| Well 100-F5-54 | 74.9 to 77.4 | Arsenic | 1:1 | 43.8 |
| | | | 1:2.5 | 50.6 |
| | | | 1:5 | N/A |
| Well 100-F5-52 | 71.3 to 73.8 | Arsenic | 1:1 | 89.9 |
| | | | 1:2.5 | 61.9 |
| | | | 1:5 | 39.3 |
| Well 100-F5-53 | 52.3 | Arsenic | 1:1 | 12.1 |
| | | | 1:2.5 | 59.4 |
| | | | 1:5 | N/A |
| | 55.1 to 57.6 | Arsenic | 1:1 | N/A |
| | | | 1:2.5 | 68.6 |
| | | | 1:5 | N/A |
| | 55.1 to 57.6 | Arsenic | 1:1 | 112 |
| | | | 1:2.5 | 51.2 |
| | | | 1:5 | N/A |
| | | Lead | 1:1 | N/A |
| | | | 1:2.5 | N/A |
| | | | 1:5 | 70.8 |
| | 102.5 to 105 | Arsenic | 1:1 | 244 |
| | | | 1:2.5 | 91.5 |
| | | | 1:5 | 57.8 |
| | | Chromium (Total) | 1:1 | 511 |
| | | | 1:2.5 | 515 |
| | | | 1:5 | 499 |

bgs = below ground surface

$K_d$ = distribution coefficient

N/A = not applicable; the constituent was not detected in the batch leach extract for this sample aliquot and, therefore, a $K_d$ could not be calculated

### 5.5.1 Batch Leach Testing Data Evaluation

The batch leach test results were further evaluated to provide a basis for estimating a $K_d$ value to use in the vadose zone transport estimates for calculating the SSLs and PRGs. This data analysis included evaluation of uncertainty and a focused statistical analysis to recommend an area-wide conservative estimate for the Cr(VI) $K_d$ value.

In calculating $K_d$ using the equation above, it was assumed that each soil sample was 100 g, and the volumes of water used in the ratios were 100, 250, and 500 mL. Exact quantities of soil and water were not available from the laboratory, but the $K_d$ value is not very sensitive to slight variances from these assumed values. Given these uncertainties, along with laboratory analytical uncertainty, the reported $K_d$ values are considered accurate within approximately 30 percent.

Because of the nature of the procedure, these $K_d$ values are to be viewed as *desorption* distribution coefficients, as opposed to *adsorption* distribution coefficients. It is common to observe differences in $K_d$ between adsorption and desorption reactions, termed "hysteresis" ("Nonreversible Adsorption of Divalent Metal Ions [$Mn^{II}$, $Co^{II}$, $Ni^{II}$, $Cu^{II}$, and $Pb^{II}$] onto Goethite: Effects of Acidification, $Fe^{II}$ Addition, and Picolinic Acid Addition" [Coughlin and Stone, 1995]), with the desorption $K_d$ usually greater than the adsorption value.

Neither Cr(VI) nor strontium-90 was detected in the solid-phase samples or in any of the batch leach water extracts. No measurements useful for evaluating COPCs in groundwater were generated. A summary of the results of batch leaching of samples collected from the saturated zone is presented in Table 5-3. Only the results from samples exhibiting detectable constituents in the extracts are presented. The calculated $K_d$ values for arsenic, total chromium, and lead indicate that none of these constituents are substantially leachable. The high measured $K_d$ values are consistent with relatively high $K_d$ values used in the vadose zone and groundwater transport simulations.

### 5.5.2 Uncertainty in Batch Leach Testing Results

The results of batch leach testing using the method specified in the SAP are subject to some degree of uncertainty due to the test method and the computational approach used in calculating $K_d$. Specific areas of uncertainty identified during the data evaluation apply to the derivation of contaminant-specific $K_d$, as described in *Evaluation of Hexavalent Chromium Leach Test Data Conducted in Vadose Zone Sediment Samples from the 100 Area* (ECF-HANFORD-11-0165) in Appendix F. The following general conditions may produce some uncertainty in derivation of $K_d$ values from batch leach testing measurements:

- Differences in the pH of the extract solutions used to prepare the solid phase and liquid phase for analysis
- Dilution effects of batch leaching at differing solid to liquid ratios
- Variations in the linearity of the measured $K_d$ values
- Effects of coarse material (i.e., gravel fraction) on the $K_d$ in the geologic formation
- Potential dilution effects on the samples resulting from addition of potable water to boreholes during drilling

### 5.5.3 Development of Cr(VI) $K_d$ for Vadose Zone Simulations from Batch Leach Testing Results

The results of the batch leach testing for Cr(VI) were further evaluated to identify a single $K_d$ value to represent Cr(VI) behavior in the vadose zone model used for SSL and PRG development.

The results of leach tests are described in the following calculations:

- *100-K Remedial Investigation Distribution Coefficient Calculations* (0100K-CA-V0081); 100-K
- *100-B/C Remedial Investigation Distribution Coefficient Calculations* (0100X-CA-V0058); 100-BC
- *100-D and 100-H Remedial Investigation Distribution Coefficient Calculations* (0100X-CA-V0059); 100-D/H
- *100-F Remedial Investigation Distribution Coefficient Calculations*, (0100X-CA-V0060); 100-F

The calculations were analyzed to estimate a linear isotherm ($K_d$) value for residual Cr(VI) in the vadose zone. The assessment of $K_d$ relies on collected field data and the corresponding laboratory analysis outlined in *Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-44) to recommend a $K_d$ value for use in the 100 Areas. All methods used to calculate a $K_d$ value were outlined in the SAP for each respective River Corridor OU. The objective for this evaluation was to recommend a single $K_d$ value for use in the River Corridor, including the 100-F/IU. Details of the evaluation, including a historical evaluation of 100-F/IU column leaching tests, are described in *Evaluation of Hexavalent Chromium Leach Test Data Conducted in Vadose Zone Sediment Samples from the 100 Area* (ECF-HANFORD-11-0165) in Appendix F.

The large number of $K_d$ measurements and the lack of calculated $K_d$ correlation with possible explanatory parameters require use of a conservative value across the River Corridor for evaluating future fate and transport of residual Cr(VI) after interim remedial actions have been implemented for waste sites in the vadose zone. The evaluation of $K_d$ for the soil samples indicates that more than 90 percent of the values exceed 1.2 mL/g, and more than 95 percent of the values exceed 0.65 mL/g. If the $K_d$ values are adjusted for water used during the tests (normalizing the values to the smallest soil:water extract ratio), the $90^{th}$ percentile exceedance $K_d$ value drops to about 0.8 mL/g (here, a $90^{th}$ percentile exceedance means there is 0.9 probability that the $K_d$ value will be greater than or equal to 0.8 mL/g).

Based on the batch leach results for the 100 Area soil samples, a $K_d$ value of 0.8 mL/g was designated as a conservative estimate for calculating the Cr(VI) SSLs and PRGs in the vadose zone contaminant migration assessment. This value is subject to the uncertainties described in Section 5.5.2.

### 5.5.4 Other Leach Testing: Estimating Cr(VI) $K_d$

Multiple leach studies have been performed for the Cr(VI) present in 100-F soil, including batch leach evaluations (*Report for Batch Leach Analyses on Sediments at 100-FR-3 Operable Unit, Boreholes C7790, C7791, and C7792* [PNNL-20311]) and column leach studies (*Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* [PNNL-17674]). The results showed multiple categories of Cr(VI) with different leaching behaviors.

Cleanup verification activities to document completion of interim remedial actions for waste sites associated with the 100-F-19 reactor cooling water effluent pipelines were completed in 2001. A soil leachability study was conducted as part of this effort to assess the leaching potential of Cr(VI) and carbon-14 in 100-F soil. The leach testing methodology and results are documented in *Cleanup Verification Package for the 100-F-19:1 and 100-F-19:3 Reactor Cooling Water Effluent Pipelines, 100-F-34 Biology Facility French Drain, and 116-F-12 148-F French Drain*, Appendix D, *100-F Area Soil Hexavalent Chromium and Carbon-14 Leachability Study Summary Report* (CVP-2001-00002). Initial leachability testing showed that Cr(VI) remaining in the soil column is not readily mobilized based on the low concentrations of Cr(VI) and total chromium detected in the leachate.

## 5.6 Vadose Zone Modeling Methods and Results

Vadose zone transport simulations were performed using the STOMP computer code (*STOMP: Subsurface Transport Over Multiple Phases Version 2.0: Theory Guide* [PNNL-12030]). The STOMP code was selected to perform the simulations because it can adequately simulate the vadose zone features, events, and processes relevant to the SSL and PRG calculations for the 100 Areas while satisfying the criteria for numerical model code selection described in *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection* (DOE/RL-2011-50). The model development approach used to support this RI is documented in *Model Package Report: Vadose Zone Model for the River Corridor* (SGW-50776). The numerical approach for calculations made using this model is described in *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas* (ECF-HANFORD-12-0004), included in Appendix F.

A range of model input values were used for the simulations to account, to the extent possible, for the range of conditions observed or measured at representative locations within 100-F/IU. One-dimensional numerical models were constructed to represent the key facets of the conceptual model and were solved using STOMP. The STOMP-W (water) mode was used to solve the Richard's equation and the advection-dispersion equation that govern unsaturated water flow and dilute solute transport, respectively, under variably saturated conditions in porous media. The STOMP simulations predict contaminant concentration and the time to reach the peak concentration for the recharge rates and sediment types, thicknesses, and properties appropriate to 100-F/IU.

Conceptually, the model simulation represents a column of sediments that comprise the vadose zone underlain by an aquifer. Recharge-driven flow moves downward through the vadose zone, where it encounters contaminated soil that releases soluble contaminants for transport to the underlying aquifer, across which a hydraulic gradient drives horizontal groundwater flow. At the start of each vadose transport simulation, the vadose zone is composed of a cover of clean fill with constant thickness, as well as contaminated and uncontaminated sediments of varying thickness. The aquifer constitutes the base of the column with a thickness of 5 m (16.4 ft), so contaminant concentrations in a monitoring well with a 5 m (16.4 ft) long screen interval are simulated. Within the 100-F/IU (Figure 5-5), the vadose zone and saturated zones are composed of 4.5 m (15 ft) of backfill, as well as varying thickness of both Hanford formation and Ringold unit E sediments.

### 5.6.1 Initial Contaminant Distribution

Based on observations of contaminant distribution made using laboratory analysis of soil samples collected from RI borings and wells, the spatial distribution of contaminants was identified for use in the initial flow and transport simulations. Numerous contaminants were found to be distributed across the full vadose zone thickness, while others exhibited limited vertical distribution. Therefore, contaminants were grouped into two categories. The first category included contaminants with low $K_d$ (<2 mL/g) values, while the second category included contaminants with high $K_d$ (≥2 mL/g) values. The process used for identifying low $K_d$ and high $K_d$ range contaminants is presented in *Conceptual Basis for Distribution of Highly Sorbed Contaminants in 100 Areas Vadose Zone* (SGW-51818).

For low $K_d$ contaminants, a uniform unit-source concentration of 1 mg/kg was applied across the entire vadose zone below the clean backfill interval to a depth 0.5 m (1.6 ft) above the water table (i.e., the capillary fringe). This is referred to as the 100:0 initial source distribution. The unit-source concentration in the 0.5 m (1.6 ft) zone above the water table was not applied because capillary fringe and water table fluctuation effects across the periodically rewetted zone would result in boundary effects and extreme-concentration gradients. For the high $K_d$ contaminants, a uniform concentration unit-source of

1 mg/kg was applied in the upper 70 percent of the vadose zone below the clean backfill interval. This is referred to as the 70:30 initial source distribution.

An exception to the assignment of initial source distributions based on $K_d$ is made in the case of strontium-90 due to the observed distribution of significant concentrations of this COPC at depths greater than the upper 70 percent of the profile in several locations. This distribution is a legacy of the greater mobility of this contaminant in the operational era under different geochemical and hydraulic conditions. The effective mobility of strontium-90 during the operational period, involving large volumes of thermally hot fluids that saturated much of the vadose zone, is much higher than the mobility of residual strontium-90 in the vadose zone today and in future conditions. Accordingly, despite a $K_d$ value higher than the 2 mL/g threshold, the 100:0 initial source distribution is applied for evaluation of strontium-90.

The use of a unit-concentration source, typically 1 mg/kg, is a common practice in the simulation of multi-contaminant transport in a system where transport is controlled by $K_d$. The transport simulation results for individual contaminants can then be estimated by simply scaling the results for the unit-concentration source against the actual constituent concentration. Although the same contaminant distribution was applied to calculate both the SSLs and the PRGs, a different infiltration/recharge scenario was applied for each. The SSL simulation uses a conservative recharge scenario based on an assumed irrigated agriculture land use, whereas the PRG simulation uses a recharge scenario based on a recharge rate that accounts for re-establishment of a native plant population across the surface.

The initial simulation configuration assumes that interim remedial actions have been undertaken and that 4.6 m (15 ft) of clean backfill is present starting at the ground surface. This clean fill assumption is a default condition to the simulations and is not meant to represent conditions at any particular waste site where interim action excavations may have proceeded to greater or lesser depths.

### 5.6.2 Simulation Duration

As agreed during discussions with EPA, the STOMP simulations were limited to a maximum duration of 1,000 years. The peak contaminant concentration calculated within the 1,000-year simulation duration defines the SSL and PRG value.

### 5.6.3 Site-Specific Evaluation for 116-F-14

A site-specific simulation was developed and applied for the 116-F-14 Retention Basin to assess the potential for future groundwater impacts from leaching of Cr(VI) present in the deep vadose zone at this site. The results of sampling and analysis at the boring within the footprint of the retention basin revealed the presence of residual chromium distributed over the full thickness of the vadose zone below the depth of interim remedial action excavation and into the underlying aquifer. This boring (C7970) was completed as monitoring Well 199-F5-55.

A site-specific, one-dimensional modeling approach was selected, starting from the model used for general SSL/PRG calculation (described in Section 5.1) and refining for site-specific information (including stratigraphy and surface soil type) as follows. Site-specific modifications were made to the model to reflect the observed initial conditions at 116-F-14, with consideration given to spatial variability based on CVP data and review of the operational history of this waste site. A single, representative stratigraphic column (Column 1 on Figure 5-5) was selected as the most representative column for this site. Only the Rupert sand surface soil type was used (based on review of the prevalent surface soil at this location, based on soil mapping) in selecting recharge rates for the recharge scenarios. Based on indication of significant spatial variability in the distribution of Cr(VI) contamination at this site, and review of the operational history of this site, the modeling approach included a spatial variability treatment. The CVP peak concentrations were scaled to the vertical distribution of Cr(VI) contamination

obtained from RI borehole data to obtain a series of contamination profiles representing spatial variability at this waste site. Other model aspects used for these simulations remained as in the first-step model. A $K_d$ value of 0.8 mL/g was used for Cr(VI), and the irrigation recharge scenario and the native vegetation recharge scenario were both applied for the surface soil type prevalent at this location (Rupert sand) as upper-boundary conditions.

The maximum peak groundwater Cr(VI) concentrations simulated for each concentration initial profile, based on CVP data variability under each recharge scenario, were used to develop cumulative distributions of peak groundwater concentrations of Cr(VI) for contrast with the relevant protection levels, as shown on Figure 5-6. From the cumulative distributions shown on Figure 5-6 for the irrigation recharge scenario used as a basis for screening, the distribution of concentrations does not exceed the groundwater standard in all cases (100 percent of the area). However, under the irrigation recharge scenario, the distribution of peak groundwater concentrations does exceed the surface water standard for more than 60 percent of the area represented in this spatially distributed model evaluation. Thus, under site-specific modeling, it is found that this site fails the screening step (based on irrigation) for surface water protection. Note that this site-specific analysis takes no credit for attenuation mechanisms between the waste site location and the river in comparing to the surface water standard. For the native vegetation recharge scenario used to establish PRG values, 100 percent of the peak concentrations fall below the groundwater MCL (48 µg/L) standard, as well as below the surface water (10 µg/L) standard. This is strongly indicative that residual Cr(VI) contamination at this site will not cause exceedances of either the groundwater or surface water standards for expected land use (conservation with native vegetation). Therefore, based on these results, the site is not carried forward into the FS for alternatives analysis. However, it is noted that if the irrigation recharge scenario were used as a basis for PRG values (rather than native vegetation), then this site would be subject to consideration in the FS.

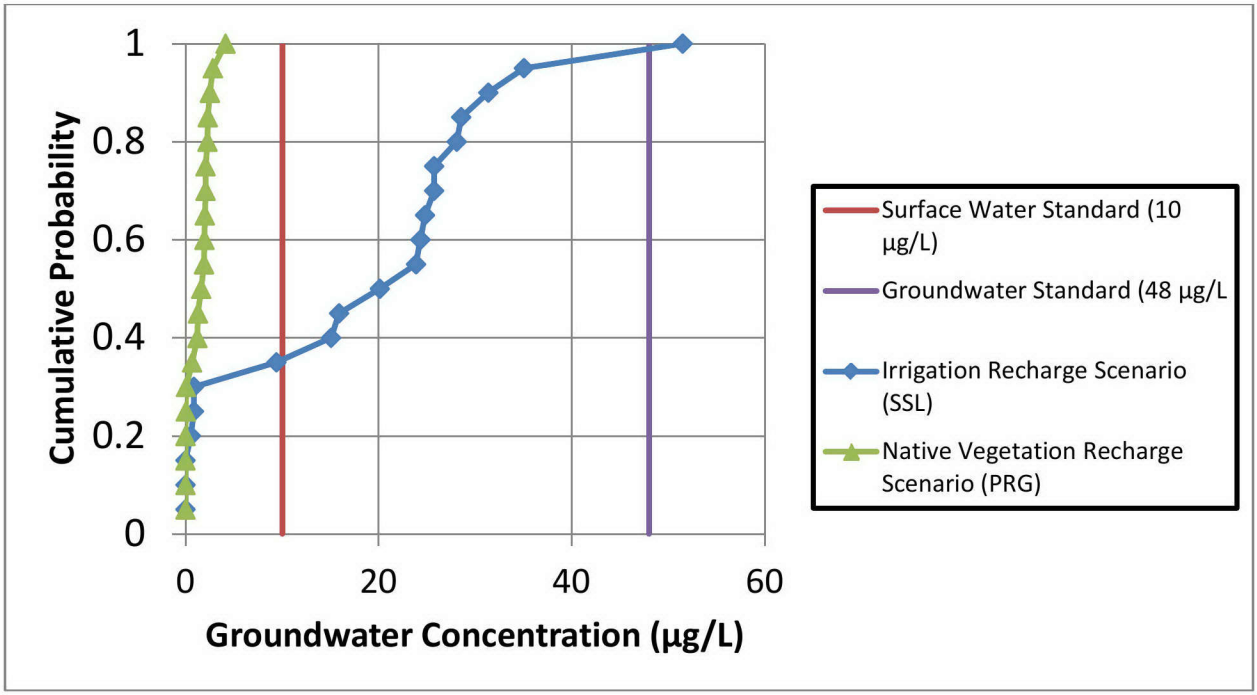



Figure 5-6. Cumulative Distribution of Predicted Peak Groundwater Concentration of Cr(VI) for Site-Specific Spatially Distributed Model of Site 116-F-14

It is noted that the 116-F-14 site has not constituted a source of Cr(VI) groundwater contamination to date based on review of groundwater monitoring annual reports from 1996 through 2011. Comparing water table maps from these annual reports with average dissolved chromium concentration in groundwater plume maps (e.g., *Hanford Site Groundwater Monitoring for Fiscal Year 2005* [PNNL-15670]; *Hanford Site Groundwater Monitoring for Fiscal Year 2008* [DOE/RL-2008-66]; *Hanford Site Groundwater Monitoring and Performance for 2009: Volumes 1 & 2* [DOE/RL-2010-11]; *Hanford Site Groundwater Monitoring Report for 2010* [DOE/RL-2011-01]; and *Hanford Site Groundwater Monitoring for 2011* [DOE/RL-2011-118]) shows that the chromium groundwater plume in 100-F is consistently upgradient and/or cross gradient from this waste site. Monitoring wells located downgradient of this waste site (e.g., groundwater Wells 199-F5-1, 199-F5-42, and 199-F5-54) consistently reported undetected chromium over these same years. The portion of the waste site overlying the chromium plume (at times) is over the most upgradient portion (northwestern corner) of the site; this would be inconsistent with the possibility that this site constitutes a source of to the current 100-F chromium groundwater plume.

## 5.7 Groundwater/Surface Water Protection SSL and PRG Development

SSLs and PRGs represent a data evaluation tool that provides a technical basis for identifying whether a previously remediated waste site, or a waste site to be remediated in the future, could pose a threat to groundwater or surface water quality. The SSL and PRG development process and results are described further in *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas* (ECF-HANFORD-12-0004) in Appendix F. A summary of the input parameters used with STOMP for these calculations is provided in Table 5-4.

Table 5-4. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for SSL and PRG Calculations, Source OUs in the 100-F, 100-IU-2, and 100-IU-6 Areas

| Input Parameter (units) | Input Parameter Value | | |
|---|---|---|---|
| **Simulation Duration** | | | |
| Simulation to establish initial hydraulic conditions (yr) | Calendar years 0 to 2010 (arbitrary long period to reach a steady state) | | |
| Simulation to predict contaminant transport (yr) | Calendar years 2010 to 3010 | | |
| **Upper Boundary Condition: Recharge (Deep Percolation) for Different Surface Soils [stepwise constant]** | | | |
| **Native vegetation recharge scenario** | **Ephrata sandy loam and stony loam** | **Burbank loamy sand** | **Rupert sand** |
| Recharge before 1944 (mm/yr) | 1.5 | 3.0 | 4.0 |
| Recharge 1944 to 2010 (mm/yr) | 17.0 | 52.0 | 44.0 |
| Recharge 2010 to 2015 (mm/yr) | 17.0 | 52.0 | 44.0 |
| Recharge 2015 to 2045 (mm/yr) | 3.0 | 6.0 | 8.0 |
| Recharge after 2045 (mm/yr) | 1.5 | 3.0 | 4.0 |
| **Irrigation recharge scenario** | **Ephrata sandy loam and stony loam** | **Burbank loamy sand** | **Rupert sand** |
| Recharge before 1944 (mm/yr) | 1.5 | 3.0 | 4.0 |
| Recharge 1944 to 2010 (mm/yr) | 17.0 | 52.0 | 44.0 |

Table 5-4. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for SSL and PRG Calculations, Source OUs in the 100-F, 100-IU-2, and 100-IU-6 Areas

| Input Parameter (units) | | Input Parameter Value | | |
|---|---|---|---|---|
| Recharge 2010 to 2015 (mm/yr) | | 17.0 | 52.0 | 44.0 |
| Recharge 2015 to 2045 (mm/yr) | | 71.4 | 74.4 | 76.4 |
| Recharge after 2045 (mm/yr) | | 69.9 | 71.4 | 72.4 |
| **Lateral Boundary Condition: Hydraulic Gradient (Saturated Portion)** | | | | |
| Hydraulic gradient (m/m) | 100-F | 0.0010 | | |
| | IU-2 | 0.0014 | | |
| | IU-6 | 0.0025 | | |
| **Hydraulic Parameters** | | | | |
| **100-F** | | **Vadose Zone** | | **Saturated Zone** |
| | **Backfill** | **Hanford formation** | **Ringold Formation** | **Hanford formation** | **Ringold Formation** |
| $n_T$ total porosity ($m^3/m^3$) | 0.276 | 0.280 | 0.280 | 0.280 | 0.280 |
| $n_D$ diffusive porosity ($m^3/m^3$) | 0.262 | 0.250 | 0.280 | 0.250 | 0.280 |
| $\alpha$ van Genuchten water retention function inverse air entry matric potential (1/cm) | 0.019 | 0.0145 | 0.008 | 0.0145 | 0.008 |
| $n$ van Genuchten water retention function exponential fitting parameter (dimensionless) | 1.400 | 1.48 | 1.66 | 1.48 | 1.66 |
| $s_r$ residual saturation (dimensionless) | 0.162 | 0 | 0.093 | 0 | 0.093 |
| $K_{s,h}$ saturated horizontal hydraulic conductivity (m/d) | 0.517 | 3.32 | 3.57 | 48.3 | 22.4 |
| $K_{s,v}$ saturated vertical hydraulic conductivity (m/d) | 0.517 | 0.332 | 0.357 | 4.83 | 2.24 |
| **IU-2 & IU-6** | | **Vadose Zone** | | **Saturated Zone** |
| | **Backfill** | **Hanford formation** | **Ringold Formation** | **Ringold Formation** |
| $n_T$ total porosity ($m^3/m^3$) | 0.276 | 0.280 | 0.280 | 0.280 |
| $n_D$ diffusive porosity ($m^3/m^3$) | 0.262 | 0.250 | 0.250 | 0.280 |

Table 5-4. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for SSL and PRG Calculations, Source OUs in the 100-F, 100-IU-2, and 100-IU-6 Areas

| Input Parameter (units) | Input Parameter Value | | | |
|---|---|---|---|---|
| $\alpha$ van Genuchten water retention function inverse air entry matric potential (1/cm) | 0.019 | 0.0145 | 0.0145 | 0.0080 |
| $n$ van Genuchten water retention function exponential fitting parameter (dimensionless) | 1.40 | 1.48 | 1.48 | 1.66 |
| $s_r$ residual saturation (dimensionless) | 0.162 | 0 | 0 | 0.093 |
| $K_{s,h}$ saturated horizontal hydraulic conductivity (m/d) | 0.517 | 3.31 | 97.6 | 22.4 |
| $K_{s,v}$ saturated vertical hydraulic conductivity (m/d) | 0.517 | 0.331 | 97.6 | 2.24 |
| **100-F, IU-2, & IU-6** | **Backfill** | **Hanford formation** | **Ringold Formation** | |
| $\rho_b$ bulk density (g/cm$^3$) | 1.94 | 1.91 | 1.90 | |
| $\rho_p$ particle density (g/cm$^3$) | Calculated from bulk density and porosity; $\rho_p = \rho_b / (1 - n_T)$ | | | |
| $m$ Mualem relative permeability function fitting parameter (dimensionless) | $m = (n-1)/n$ | | | |
| $\beta$ Mualem relative permeability function exponential term | 0.5 | | | |
| **Transport Parameters** | | | | |
| $D_m$ molecular diffusion (m$^2$/s) | Conventional model with $D_m = 0$ | | | |
| $\alpha_L$ longitudinal dispersivity (m) | 0 (dispersivity neglected; conservative assumption with regard to peak concentration) | | | |
| $\alpha_T/\alpha_L$ dispersivity anisotropy ratio (dimensionless) | Not applicable (one-dimensional model) | | | |

Table 5-4. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for SSL and PRG Calculations, Source OUs in the 100-F, 100-IU-2, and 100-IU-6 Areas

| Input Parameter (units) | Input Parameter Value |
|---|---|
| $K_d$ distribution coefficient (mL/g) | Twenty-six $K_d$ values over a range were simulated directly, and the results interpolated to provide values for specific contaminants based on their respective $K_d$. Higher values were estimated using regression.<br>The simulated $K_d$ values are: [0, 0.00001, 0.0001, 0.001, 0.01, 0.02, 0.04, 0.06, 0.08, 0.10, 0.20, 0.30, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90, 1, 2, 4, 8, 10, 12, 14, and 16].<br>The specific contaminant $K_d$ values for all contaminants evaluated (191 non-radionuclides and 28 radionuclides) are listed in ECF-HANFORD-12-0004 (found in Appendix F) in Attachment A, Tables A-1, A-2, A-3, and Attachment B, Tables B-1, B-2, and B-3. |

Notes: Sources for constitutive relationships:

- Mualem, 1976, "A New Model for Predicting the Hydraulic Conductivity of Unsaturated Porous Media."
- van Genuchten, M.Th., 1980, "A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils."

Details on the basis for all parameters in this table are found in Appendix F (*STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas* [ECF-HANFORD-12-0004]).

### 5.7.1 Identification of Peak Groundwater Concentrations

Peak groundwater concentrations were calculated along a portion of the model domain's downgradient boundary, corresponding to the top 5 m (16.4 ft) of the aquifer. The 5 m (16.4 ft) of aquifer thickness corresponds to a 5 m (16.4 ft) long monitoring well screen straddling the water table. The concentration was estimated conservatively by calculating it at the aquifer edge beneath the downgradient edge of the waste site footprint, from which the peak concentration and breakthrough time was determined for each contaminant.

Peak concentrations were calculated by running multiple STOMP simulations using a defined set of $K_d$ values. The $K_d$ dataset included 26 values ranging from 0 to 16 mL/g. Peak concentrations for $K_d$ values greater than 16 mL/g were estimated using regression analysis. No breakthrough was assumed if the estimated peak concentration within 1,000 years was calculated at less than 0.0001 µg/L (nonradionuclide COPCs) or 0.0001 pCi/L (radionuclide COPCs). "NR" was used to designate nonrepresentative results when no breakthrough was observed. For the PRG calculation (based on conservation land use), the breakthrough threshold is $K_d$ = 1 mL/g (i.e., NR is assigned for PRG values of analytes with $K_d$ values greater than 1 mL/g). For the SSL calculation (based on irrigation land use), the breakthrough threshold is 22 mL/g (i.e., NR is assigned for SSL values for analytes with $K_d$ values >22 mL/g).

Chemical SSLs protective of groundwater and surface water are presented in Table 5-5, and radionuclide SSLs protective of groundwater are presented in Table 5-6. Chemical PRGs protective of groundwater and surface water are presented in Table 5-7, and radionuclide PRGs protective of groundwater are presented in Table 5-8. Radionuclide SSLs and PRGs for protection of surface water were not calculated because AWQC for radionuclides have not been established. The final SSL and PRG value for a specific chemical or radionuclide constituent were selected from an array of values calculated for each of the eight different 100-F/IU soil stratigraphies (Figure 5-5). The final SSL and PRG values correspond to the minimum value calculated from the eight soil stratigraphies. If the minimum value calculated is less than the estimated quantitation limit (EQL), then the EQL was selected as the final SSL or PRG.

### 5.7.2 Comparison of Waste Site EPCs to SSLs

SSLs were developed to identify COPCs that may pose a threat to groundwater and surface water quality at previously characterized or remediated waste sites, or waste sites to be remediated in the future. The SSLs were derived using conservative assumptions that include an irrigation land use and a 100:0 waste profile for COPCs with $K_d$ values less than 2 (except strontium-90) and a 70:30 waste profile for COPCs with $K_d$ values greater than 2 (except strontium-90). The SSL represents the maximum concentration of a COPC in soil that is not expected to produce a concentration in groundwater at the downgradient boundary of the waste site exceeding the MCL, the MTCA groundwater cleanup level, or surface water AWQC within 1,000 years.

The waste site evaluation process included calculation of an EPC, based on a 95 percent UCL, for each COPC present at the waste site and comparing the EPC to the SSL (ECF-100FR1-11-0085, *Comparison of the 100-FR1 and 100-FR-2 Source Operable Unit Exposure Point Concentrations to Soil Screening Levels Protective of Groundwater and Soil Screening Levels Protective for Surface Water; Appendix G).* The following exclusion criteria were applied when comparing waste site EPCs to SSLs to eliminate contaminants that are unlikely to pose a threat:

- The contaminant is an essential nutrient (e.g., calcium, magnesium, potassium, and sodium) that is not excessively elevated above background or is not associated with the waste at a waste site.
- Radionuclides associated with background conditions and not attributable to waste site practices (e.g., potassium-40, radium-224, radium-226, radium-228, thorium-228, thorium-230, and thorium-232).
- Radionuclides with half-lives less than 3 years and that, upon decay, produce no significant daughter products.
- The maximum concentration of an inorganic analyte is less than or equal to the 90$^{th}$ percentile value of the background concentration.

If a waste site COPC EPC exceeded a SSL for groundwater or surface water protection, and was not eliminated by one of the exclusion criteria described above, it was carried forward to the PRG evaluation step (ECF-100-FR1-11-0086, *Comparison of the 100-FR-1 and 100-FR-2 Source Operable Unit Exposure Point Concentrations to Preliminary Remediation Goals Protective of Groundwater and Preliminary Remediation Goals Protective of Surface Water, Appendix G).*

#### *5.7.2.1 SSL Comparison Results*

The waste sites in 100-F with COPCs present at concentrations above groundwater protection SSLs (Table 5-9) included the following:

- 600-351. 2-(2-methyl-4-chlorophenoxy) propionic acid present in the shallow focused decision unit at an EPC of 2.3 mg/kg exceeded the groundwater protection SSL of 1.0 mg/kg.

The waste sites in 100-F with COPCs present at concentrations above surface water protection SSLs (Table 5-10) included the following:

- 100-F-19:1. Cr(VI) present in the deep decision unit at an EPC of 5.6 mg/kg exceeded the surface water protection SSL of 4.98 mg/kg.
- 116-F-14. Cr(VI) present in the deep decision unit at an EPC of 6.79 mg/kg was evaluated using site-specific modeling (Section 5.6.3) and has the potential to exceed the surface water protection standard.
- 118-F-7. Copper present in the staging pile area decision unit at an EPC of 552 mg/kg exceeded the surface water protection SSL of 329 mg/kg.

Table 5-5. Summary of 100-F/IU Soil Screening Levels Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection SSL (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection SSL (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 71-55-6 | 1,1,1-Trichloroethane | 0.14 | 200 | 0.005 | 21.9 | 102 | 183 | 930,000 | 102,000 | NR | NR |
| 79-34-5 | 1,1,2,2-Tetrachloroethane | 0.079 | 0.22 | 0.005 | 0.018 | 0.0812 | 0.145 | 0.17 | 0.014 | 0.0631 | 0.113 |
| 79-00-5 | 1,1,2-Trichloroethane | 0.075 | 0.77 | 0.005 | 0.0612 | 0.275 | 0.491 | 0.59 | 0.0471 | 0.212 | 0.378 |
| 75-34-3 | 1,1-Dichloroethane | 0.053 | 1,600 | 0.01 | 108 | 475 | 847 | 74,000 | 4,990 | 21,800 | 38,900 |
| 75-35-4 | 1,1-Dichloroethene | 0.065 | 7 | 0.01 | 0.521 | 2.32 | 4.13 | 0.057 | 0.01 | 0.0189 | 0.0337 |
| 120-82-1 | 1,2,4-Trichlorobenzene | 1.66 | 1.5 | 0.33 | 1.36 | 6.85 | 12.2 | 2 | 1.77 | 8.9 | 15.9 |
| 95-50-1 | 1,2-Dichlorobenzene | 0.379 | 600 | 0.33 | 150 | 734 | 1,310 | 420 | 105 | 514 | 916 |
| 107-06-2 | 1,2-Dichloroethane | 0.038 | 0.48 | 0.005 | 0.0288 | 0.122 | 0.218 | 0.38 | 0.0228 | 0.0966 | 0.172 |
| 540-59-0 | 1,2-Dichloroethene (Total) | 0.0396 | 72 | 0.005 | 4.39 | 18.7 | 33.4 | 2,100 | 128 | 547 | 976 |
| 78-87-5 | 1,2-Dichloropropane | 0.047 | 1.2 | 0.005 | 0.0785 | 0.34 | 0.607 | 0.5 | 0.0323 | 0.14 | 0.25 |
| 541-73-1 | 1,3-Dichlorobenzene | 0.434 | No Value | 0.33 | NA | NA | NA | 320 | 90.3 | 443 | 790 |
| 106-46-7 | 1,4-Dichlorobenzene | 0.616 | 8.1 | 0.005 | 3.17 | 15.6 | 27.8 | 22 | 8.44 | 41.6 | 74.2 |
| 93-76-5 | 2,4,5-T | 0.049 | 160 | --- | 10.5 | 45.7 | 81.5 | No Value | NA | NA | NA |
| 93-72-1 | 2,4,5-TP | 0.08 | 50 | --- | 4.14 | 18.7 | 33.4 | 10 | 0.827 | 3.74 | 6.68 |
| 95-95-4 | 2,4,5-Trichlorophenol | 1.6 | 800 | 0.33 | 693 | 3,480 | 6,210 | 490 | 421 | 2,120 | 3,780 |
| 88-06-2 | 2,4,6-Trichlorophenol | 0.381 | 4 | 0.33 | 0.999 | 4.89 | 8.72 | 1.4 | 0.352 | 1.72 | 3.07 |
| 94-75-7 | 2,4-D | 0.029 | 70 | --- | 3.84 | 15.7 | 28 | 100 | 5.48 | 22.5 | 40.1 |
| 94-82-6 | 2,4-DB | 0.1 | 128 | --- | 12 | 55.1 | 98.4 | 6,564 | 614 | 2,830 | 5,040 |
| 120-83-2 | 2,4-Dichlorophenol | 0.147 | 24 | 0.33 | 2.71 | 12.7 | 22.7 | 77 | 8.7 | 40.8 | 72.8 |
| 105-67-9 | 2,4-Dimethylphenol | 0.209 | 160 | 0.33 | 24.3 | 118 | 210 | 380 | 57.6 | 280 | 499 |
| 51-28-5 | 2,4-Dinitrophenol | 0.00001 | 32 | 0.825 | 1.28 | 4.52 | 8.07 | 69 | 2.75 | 9.75 | 17.4 |
| 121-14-2 | 2,4-Dinitrotoluene | 0.0955 | 0.28 | 0.33 | 0.33 | 0.33 | 0.33 | 0.11 | 0.33 | 0.33 | 0.33 |
| 606-20-2 | 2,6-Dinitrotoluene | 0.0692 | 16 | 0.33 | 1.22 | 5.47 | 9.76 | 120 | 9.02 | 40.3 | 71.9 |
| 78-93-3 | 2-Butanone | 0.00451 | 4,800 | 0.01 | 202 | 738 | 1,320 | 490,000 | 20,700 | 75,600 | 135,000 |
| 111-76-2 | 2-Butoxyethanol | 0.001 | 800 | --- | 32.3 | 115 | 206 | 82,044 | 3,310 | 11,800 | 21,100 |
| 91-58-7 | 2-Chloronaphthalene | 2.98 | 640 | 0.33 | 1,010 | 5,990 | 10,700 | 1,000 | 1,580 | 9,360 | 16,700 |
| 95-57-8 | 2-Chlorophenol | 0.388 | 40 | 0.33 | 10.2 | 50.1 | 89.4 | 81 | 20.7 | 102 | 181 |
| 591-78-6 | 2-Hexanone | 0.01498 | 40 | 0.02 | 1.91 | 7.39 | 13.2 | 3,400 | 163 | 634 | 1,130 |
| 91-57-6 | 2-Methylnaphthalene | 2.98 | 32 | 0.33 | 50.4 | 300 | 535 | 140 | 219 | 1,300 | 2,320 |
| 95-48-7 | 2-Methylphenol (cresol, o-) | 0.434 | 400 | 0.33 | 113 | 553 | 987 | 12,000 | 3,420 | 16,800 | 29,900 |
| 88-74-4 | 2-Nitroaniline | 0.0527 | 160 | 0.33 | 10.8 | 47.3 | 84.4 | 2,600 | 175 | 767 | 1,370 |

Table 5-5. Summary of 100-F/IU Soil Screening Levels Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection SSL (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection SSL (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 88-75-5 | 2-Nitrophenol | 0.297 | No Value | 0.66 | NA | NA | NA | No Value | NA | NA | NA |
| 91-94-1 | 3,3'-Dichlorobenzidine | 0.724 | 0.19 | 0.33 | 0.33 | 0.438 | 0.782 | 0.021 | 0.33 | 0.33 | 0.33 |
| 65794-96-9 | 3+4 Methylphenol (cresol, m+p) | No Value | No Value | 0.33 | NA | NA | NA | No Value | NA | NA | NA |
| 99-09-2 | 3-Nitroaniline | 0.0516 | 4.2 | 0.33 | 0.33 | 1.22 | 2.17 | 100 | 6.89 | 30.1 | 53.7 |
| 72-54-8 | 4,4'-DDD (Dichlorodiphenyldichloroethane) | 45.8 | 0.36 | 0.0033 | NR | NR | NR | 0.00031 | NR | NR | NR |
| 72-55-9 | 4,4'-DDE (Dichlorodiphenyldichloroethylene) | 86.4 | 0.26 | 0.0033 | NR | NR | NR | 0.00022 | NR | NR | NR |
| 50-29-3 | 4,4'-DDT (Dichlorodiphenyltrichloroethane) | 678 | 0.26 | 0.0033 | NR | NR | NR | 0.00022 | NR | NR | NR |
| 534-52-1 | 4,6-Dinitro-2-methylphenol | 0.6015 | 1.3 | 0.33 | 0.491 | 2.42 | 4.31 | 13 | 4.99 | 24.5 | 43.8 |
| 6607 | 4-Amino-3,5,6-trichloropicolinic acid | 0.039 | 500 | --- | 30.3 | 129 | 230 | 57,431 | 3,480 | 14,800 | 26,400 |
| 101-55-3 | 4-Bromophenylphenyl ether | No Value | No Value | 0.33 | NA | NA | NA | No Value | NA | NA | NA |
| 59-50-7 | 4-Chloro-3-methylphenol | 0.4918 | 1,600 | 0.33 | 508 | 2,500 | 4,450 | 31,000 | 9,680 | 4,7600 | 84,900 |
| 106-47-8 | 4-Chloroaniline | 0.0725 | 0.22 | 0.33 | 0.33 | 0.33 | 0.33 | 4.6 | 0.364 | 1.63 | 2.91 |
| 7005-72-3 | 4-Chlorophenylphenyl ether | 3.08 | No Value | 0.33 | NA | NA | NA | No Value | NA | NA | NA |
| 108-10-1 | 4-Methyl-2-pentanone | 0.0126 | 640 | 0.01 | 29.7 | 114 | 203 | 61,000 | 2,830 | 10,900 | 19,400 |
| 106-44-5 | 4-Methylphenol (cresol, p-) | 0.434 | 40 | --- | 11.3 | 55.3 | 98.7 | 1,500 | 413 | 2,030 | 3,610 |
| 100-01-6 | 4-Nitroaniline | 0.0516 | 4.4 | 0.33 | 0.33 | 1.28 | 2.28 | 81 | 5.43 | 23.7 | 42.3 |
| 100-02-7 | 4-Nitrophenol | 0.309 | 130 | 0.66 | 26.9 | 131 | 235 | 4,000 | 849 | 4,140 | 7,390 |
| 83-32-9 | Acenaphthene | 6.12 | 960 | 0.1 | 3,410 | 20,900 | 37,300 | 640 | 2,290 | 14,000 | 25,000 |
| 208-96-8 | Acenaphthylene | 5.03 | No Value | 0.1 | NA | NA | NA | No Value | NA | NA | NA |
| 67-64-1 | Acetone | 0.0006 | 7,200 | 0.02 | 289 | 1,030 | 1,840 | 740,000 | 29,700 | 106,000 | 189,000 |
| 309-00-2 | Aldrin | 48.7 | 0.0026 | 0.00165 | NR | NR | NR | 0.000049 | NR | NR | NR |
| 319-84-6 | Alpha-BHC | 1.76 | 0.014 | 0.00165 | 0.0135 | 0.0679 | 0.121 | 0.0026 | 0.00253 | 0.0127 | 0.0227 |
| 5103-71-9 | Alpha-Chlordane | 51 | 0.25 | 0.0165 | NR | NR | NR | 0.00057 | NR | NR | NR |
| 7429-90-5 | Aluminum | 1500 | 50 | 5 | NR | NR | NR | 87 | NR | NR | NR |
| 120-12-7 | Anthracene | 23.5 | 4,800 | 0.05 | NR | NR | NR | 8,300 | NR | NR | NR |
| 7440-36-0 | Antimony | 3.76 | 6 | 0.6 | 12.6 | 75.3 | 134 | 5.6 | 11.8 | 70.3 | 125 |
| 12674-11-2 | Aroclor-1016 | 107 | 0.5 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 11104-28-2 | Aroclor-1221 | 10.3 | 0.044 | 0.0165 | 0.283 | 1.58 | 2.85 | 0.000064 | 0.0165 | 0.0165 | 0.0165 |
| 11141-16-5 | Aroclor-1232 | 10.3 | 0.044 | 0.0165 | 0.283 | 1.58 | 2.85 | 0.000064 | 0.0165 | 0.0165 | 0.0165 |

Table 5-5. Summary of 100-F/IU Soil Screening Levels Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection SSL (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection SSL (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 53469-21-9 | Aroclor-1242 | 44.8 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 12672-29-6 | Aroclor-1248 | 43.9 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 11097-69-1 | Aroclor-1254 | 75.6 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 11096-82-5 | Aroclor-1260 | 822 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 7440-38-2 | Arsenic | 29 | 0.058 | 1 | NR | NR | NR | 0.018 | NR | NR | NR |
| 7440-39-3 | Barium | 25 | 2,000 | 0.5 | NR | NR | NR | 1000 | NR | NR | NR |
| 71-43-2 | Benzene | 0.062 | 0.8 | 0.005 | 0.058 | 0.257 | 0.459 | 1.2 | 0.0875 | 0.388 | 0.692 |
| 56-55-3 | Benzo(a)anthracene | 360 | 0.12 | 0.015 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 50-32-8 | Benzo(a)pyrene | 5500 | 0.012 | 0.015 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 205-99-2 | Benzo(b)fluoranthene | 803 | 0.12 | 0.015 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 191-24-2 | Benzo(ghi)perylene | 1950 | No Value | 0.03 | NA | NA | NA | No Value | NA | NA | NA |
| 207-08-9 | Benzo(k)fluoranthene | 1230 | 0.12 | 0.015 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 7440-41-7 | Beryllium | 790 | 4 | 0.2 | NR | NR | NR | 270 | NR | NR | NR |
| 319-85-7 | beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC) | 2.14 | 0.049 | 0.00165 | 0.0602 | 0.312 | 0.556 | 0.0091 | 0.0113 | 0.0584 | 0.104 |
| 108-60-1 | Bis(2-chloro-1-methylethyl)ether | 0.0392 | 0.63 | 0.33 | 0.33 | 0.33 | 0.33 | 37 | 2.27 | 9.7 | 17.3 |
| 111-91-1 | Bis(2-Chloroethoxy)methane | 0.00277 | 48 | 0.33 | 1.98 | 7.15 | 12.7 | 2,300 | 96.6 | 349 | 622 |
| 111-44-4 | Bis(2-chloroethyl) ether | 0.076 | 0.04 | 0.33 | 0.33 | 0.33 | 0.33 | 0.03 | 0.33 | 0.33 | 0.33 |
| 117-81-7 | Bis(2-ethylhexyl) phthalate | 110 | 6 | 0.33 | NR | NR | NR | 1.2 | NR | NR | NR |
| 7440-69-9 | Bismuth | No Value | No Value | 10 | NA | NA | NA | No Value | NA | NA | NA |
| 7440-42-8 | Boron | 3 | 3,200 | 2 | 5,070 | 30,200 | 53,800 | No Value | NA | NA | NA |
| 24959-67-9 | Bromide | No Value | No Value | 2.5 | NA | NA | NA | No Value | NA | NA | NA |
| 75-27-4 | Bromodichloromethane | 0.055 | 0.71 | 0.005 | 0.0486 | 0.213 | 0.381 | 0.27 | 0.0186 | 0.0817 | 0.146 |
| 75-25-2 | Bromoform | 0.13 | 5.5 | 0.005 | 0.582 | 2.71 | 4.83 | 4.3 | 0.452 | 2.1 | 3.75 |
| 74-83-9 | Bromomethane | 0.009 | 11 | 0.01 | 0.499 | 1.88 | 3.35 | 47 | 2.09 | 7.88 | 14.1 |
| 85-68-7 | Butylbenzylphthalate | 13.8 | 46 | 0.33 | 525 | 866 | 4,130 | 8.2 | 94 | 155 | 739 |
| 7440-43-9 | Cadmium | 30 | 5 | 0.2 | NR | NR | NR | 0.25 | NR | NR | NR |
| 7440-70-2 | Calcium | No Value | No Value | 100 | NA | NA | NA | No Value | NA | NA | NA |
| 86-74-8 | Carbazole | 3.39 | 4.4 | 0.33 | 7.94 | 47.3 | 84.4 | No Value | NA | NA | NA |
| 75-15-0 | Carbon disulfide | 0.046 | 800 | 0.005 | 51.3 | 222 | 396 | 13,000 | 852 | 3,690 | 6,580 |
| 56-23-5 | Carbon tetrachloride | 0.152 | 0.34 | 0.005 | 0.0389 | 0.183 | 0.326 | 0.23 | 0.0266 | 0.125 | 0.223 |

Table 5-5. Summary of 100-F/IU Soil Screening Levels Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection SSL (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection SSL (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 57-74-9 | Chlordane | 51 | 0.25 | 0.0165 | NR | NR | NR | 0.00057 | NR | NR | NR |
| 16887-00-6 | Chloride | 0 | 250,000 | 2 | 9,970 | 35,300 | 63,000 | 230,000 | 9,170 | 32,500 | 58,000 |
| 108-90-7 | Chlorobenzene | 0.22 | 100 | 0.005 | 15.7 | 76 | 136 | 130 | 20.4 | 98.8 | 176 |
| 75-00-3 | Chloroethane | 0.0217 | No Value | 0.01 | NA | NA | NA | No Value | NA | NA | NA |
| 67-66-3 | Chloroform | 0.053 | 1.4 | 0.005 | 0.0957 | 0.419 | 0.747 | 5.7 | 0.386 | 1.69 | 3.02 |
| 74-87-3 | Chloromethane | 0.006 | No Value | 0.01 | NA | NA | NA | No Value | NA | NA | NA |
| 7440-47-3 | Chromium | 200 | 100 | 0.2 | NR | NR | NR | 65 | NR | NR | NR |
| 218-01-9 | Chrysene | 200 | 1.2 | 0.1 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 156-59-2 | cis-1,2-Dichloroethylene | 0.036 | 70 | 0.005 | 4.11 | 17.3 | 30.8 | 2,300 | 137 | 577 | 1,030 |
| 10061-01-5 | cis-1,3-Dichloropropene | 0.027 | 0.44 | 0.005 | 0.0235 | 0.0957 | 0.171 | 0.34 | 0.0183 | 0.0744 | 0.133 |
| 7440-48-4 | Cobalt | 50 | 4.8 | 2 | NR | NR | NR | 2.6 | NR | NR | NR |
| PCB1242/1016 | Co-elution of Aroclor-1242 and Aroclor-1016 | No Value | No Value | --- | NA | NA | NA | No Value | NA | NA | NA |
| 7440-50-8 | Copper | 22 | 640 | 1 | 23,400 | 27,100 | 111,000 | 9 | 329 | 382 | 1,560 |
| 57-12-5 | Cyanide | 9.9 | 200 | --- | 1210 | 6,940 | 12,600 | 5.2 | 31.5 | 180 | 326 |
| 75-99-0 | Dalapon | 0.0027 | 200 | --- | 8.24 | 29.7 | 53.1 | 10,773 | 444 | 1,600 | 2,860 |
| 319-86-8 | Delta-BHC | 2.81 | No Value | 0.00165 | NA | NA | NA | No Value | NA | NA | NA |
| 53-70-3 | Dibenz[a,h]anthracene | 1,790 | 0.12 | 0.03 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 132-64-9 | Dibenzofuran | 11.3 | 16 | 0.33 | 122 | 235 | 1,140 | 1.7 | 13 | 25 | 122 |
| 124-48-1 | Dibromochloromethane | 0.063 | 0.52 | 0.005 | 0.0382 | 0.17 | 0.303 | 0.4 | 0.0294 | 0.13 | 0.233 |
| 1918-00-9 | Dicamba | 0.029 | 480 | --- | 26.3 | 108 | 192 | 24,613 | 1,350 | 5,530 | 9,860 |
| 60-57-1 | Dieldrin | 25.6 | 0.0055 | 0.0033 | NR | NR | NR | 0.000052 | NR | NR | NR |
| 60-29-7 | Diethylether | 0.009699 | 1,600 | --- | 72 | 272 | 485 | 96,000 | 4,320 | 16,300 | 29,100 |
| 84-66-2 | Diethylphthalate | 0.082 | 13,000 | 0.33 | 1,070 | 4,860 | 8,660 | 17,000 | 1,420 | 6,450 | 11,500 |
| 131-11-3 | Dimethyl phthalate | 0.0316 | No Value | 0.33 | NA | NA | NA | 270,000 | 15,200 | 62,700 | 112,000 |
| 84-74-2 | Di-n-butylphthalate | 1.57 | 1,600 | 0.33 | 1,360 | 6,820 | 12,200 | 2,000 | 1,700 | 8,530 | 15,200 |
| 117-84-0 | Di-n-octylphthalate | 83,000 | No Value | 0.33 | NA | NA | NA | No Value | NA | NA | NA |
| 88-85-7 | Dinoseb | 3.5 | 7 | --- | 13.3 | 78.9 | 141 | No Value | NA | NA | NA |
| 959-98-8 | Endosulfan I | 2.04 | 96 | 0.00165 | 116 | 587 | 1,050 | 0.056 | 0.0676 | 0.342 | 0.611 |
| 33213-65-9 | Endosulfan II | 2.04 | 96 | 0.0033 | 116 | 587 | 1,050 | 0.056 | 0.0676 | 0.342 | 0.611 |
| 1031-07-8 | Endosulfan sulfate | 2.04 | No Value | 0.0033 | NA | NA | NA | 0.93 | 1.12 | 5.69 | 10.1 |

Table 5-5. Summary of 100-F/IU Soil Screening Levels Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection SSL (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection SSL (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 72-20-8 | Endrin | 10.8 | 2 | 0.0033 | 14 | 75.6 | 136 | 0.0023 | 0.0161 | 0.087 | 0.157 |
| 7421-93-4 | Endrin aldehyde | 10.8 | No Value | 0.0033 | NA | NA | NA | 0.29 | 2.03 | 11 | 19.7 |
| 53494-70-5 | Endrin ketone | 9.72 | No Value | 0.0033 | NA | NA | NA | No Value | NA | NA | NA |
| 100-41-4 | Ethylbenzene | 0.2 | 4 | 0.005 | 0.588 | 2.85 | 5.08 | 16 | 2.32 | 11.3 | 20.1 |
| 107-21-1 | Ethylene Glycol | 0.001 | 16,000 | --- | 646 | 2,310 | 4,120 | 1,640,000 | 66,200 | 237,000 | NR |
| 206-44-0 | Fluoranthene | 49.1 | 640 | 0.05 | NR | NR | NR | 90 | NR | NR | NR |
| 86-73-7 | Fluorene | 7.71 | 640 | 0.03 | 2,850 | 17,400 | 31,100 | 1,100 | 4,890 | 30,000 | 53,500 |
| 16984-48-8 | Fluoride | 150 | 960 | 5 | NR | NR | NR | 16,000 | NR | NR | NR |
| 58-89-9 | Gamma-BHC (Lindane) | 1.35 | 0.08 | 0.00165 | 0.0587 | 0.295 | 0.527 | 0.019 | 0.014 | 0.0706 | 0.126 |
| 76-44-8 | Heptachlor | 9.53 | 0.019 | 0.00165 | 0.111 | 0.652 | 1.17 | 0.000079 | 0.00165 | 0.00265 | 0.00474 |
| 1024-57-3 | Heptachlor epoxide | 83.2 | 0.0048 | 0.00165 | NR | NR | NR | 0.000039 | NR | NR | NR |
| 118-74-1 | Hexachlorobenzene | 80 | 0.055 | 0.33 | NR | NR | NR | 0.00028 | NR | NR | NR |
| 87-68-3 | Hexachlorobutadiene | 53.7 | 0.56 | 0.33 | NR | NR | NR | 0.44 | NR | NR | NR |
| 77-47-4 | Hexachlorocyclopentadiene | 200 | 48 | 0.33 | NR | NR | NR | 40 | NR | NR | NR |
| 67-72-1 | Hexachloroethane | 1.78 | 3.1 | 0.33 | 3.09 | 15.5 | 27.7 | 1.4 | 1.38 | 6.95 | 12.4 |
| 18540-29-9 | Hexavalent Chromium | 0.8 | 48 | --- | 6[d] | 6[d] | 6[d] | 10 | 4.98 | 6[d] | 6[d] |
| 193-39-5 | Indeno(1,2,3-cd)pyrene | 3,470 | 0.12 | 0.03 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 7439-89-6 | Iron | 25 | 300 | 5 | NR | NR | NR | 300 | NR | NR | NR |
| 78-59-1 | Isophorone | 0.0468 | 46 | 0.33 | 2.97 | 12.9 | 23 | 8.4 | 0.542 | 2.35 | 4.19 |
| 7439-92-1 | Lead | 30 | 15 | 0.5 | NR | NR | NR | 2.1 | NR | NR | NR |
| 7439-93-2 | Lithium | 50 | 32 | 2.5 | NR | NR | NR | No Value | NA | NA | NA |
| 7439-95-4 | Magnesium | No Value | No Value | 75 | NA | NA | NA | No Value | NA | NA | NA |
| 7439-96-5 | Manganese | 50 | 50 | 5 | NR | NR | NR | 50 | NR | NR | NR |
| 7439-97-6 | Mercury | 30 | 2 | --- | NR | NR | NR | 0.012 | NR | NR | NR |
| 72-43-5 | Methoxychlor | 80 | 40 | 0.0165 | NR | NR | NR | 0.03 | NR | NR | NR |
| 75-09-2 | Methylene chloride | 0.01 | 5 | 0.005 | 0.226 | 0.855 | 1.53 | 4.6 | 0.208 | 0.787 | 1.4 |
| 7439-98-7 | Molybdenum | 20 | 80 | 2 | 2,470 | 2,780 | 11,800 | 1,300 | 39,900 | 45,100 | 192,000 |
| 108-38-3 | m-Xylene | 0.2 | 1,600 | --- | 236 | 1,150 | 2,050 | No Value | NA | NA | NA |
| 91-20-3 | Naphthalene | 1.19 | 160 | 0.1 | 108 | 543 | 969 | 4,900 | 3,330 | 16,800 | 29,900 |
| 7440-02-0 | Nickel | 65 | 100 | 4 | NR | NR | NR | 52 | NR | NR | NR |
| 14797-55-8 | Nitrate | 0 | 45,000 | 2.5 | 1,790 | 6,360 | 11,300 | 45,000 | 1,790 | 6,360 | 11,300 |

Table 5-5. Summary of 100-F/IU Soil Screening Levels Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection SSL (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection SSL (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 14797-65-0 | Nitrite | 0 | 3,300 | 2.5 | 132 | 466 | 832 | No Value | NA | NA | NA |
| 98-95-3 | Nitrobenzene | 0.119 | 16 | 0.33 | 1.61 | 7.46 | 13.3 | 17 | 1.71 | 7.92 | 14.1 |
| NO3-N | Nitrogen in Nitrate | 0 | 10,000 | 0.75 | 399 | 1,410 | 2,520 | 10,000 | 399 | 1,410 | 2,520 |
| NO2-N | Nitrogen in Nitrite | 0 | 1,000 | 0.75 | 39.9 | 141 | 252 | No Value | NA | NA | NA |
| NO2+NO3-N | Nitrogen in Nitrite and Nitrate | 0 | 10,000 | --- | 399 | 1,410 | 2,520 | 10,000 | 399 | 1,410 | 2,520 |
| 621-64-7 | n-Nitrosodi-n-dipropylamine | 0.024 | 0.013 | 0.33 | 0.33 | 0.33 | 0.33 | 0.005 | 0.33 | 0.33 | 0.33 |
| 86-30-6 | n-Nitrosodiphenylamine | 1.29 | 18 | 0.33 | 12.7 | 64.1 | 114 | 3.3 | 2.35 | 11.8 | 21.1 |
| 95-47-6 | o-Xylene | 0.24 | 1,600 | --- | 267 | 1,300 | 2,310 | No Value | NA | NA | NA |
| 87-86-5 | Pentachlorophenol | 0.592 | 0.73 | 0.33 | 0.33 | 1.35 | 2.41 | 0.27 | 0.33 | 0.501 | 0.894 |
| 85-01-8 | Phenanthrene | 16.7 | No Value | 0.05 | NA | NA | NA | No Value | NA | NA | NA |
| 108-95-2 | Phenol | 0.0288 | 2,400 | 0.33 | 131 | 537 | 959 | 10,000 | 547 | 2,240 | 4,000 |
| 14265-44-2 | Phosphate | No Value | No Value | 5 | NA | NA | NA | No Value | NA | NA | NA |
| 7723-14-0 | Phosphorus | 3.5 | 0.16 | 50 | 50 | 50 | 50 | No Value | NA | NA | NA |
| PO4-P | Phosphorus in phosphate | No Value | No Value | --- | NA | NA | NA | No Value | NA | NA | NA |
| 2023695 | Potassium | No Value | No Value | 400 | NA | NA | NA | No Value | NA | NA | NA |
| 129-00-0 | Pyrene | 68 | 480 | 0.05 | NR | NR | NR | 830 | NR | NR | NR |
| 7782-49-2 | Selenium | 5 | 50 | 1 | 141 | 861 | 1,540 | 5 | 14.1 | 86.1 | 154 |
| 7440-21-3 | Silicon | No Value | No Value | 2 | NA | NA | NA | No Value | NA | NA | NA |
| 7440-22-4 | Silver | 90 | 80 | 0.2 | NR | NR | NR | 2.6 | NR | NR | NR |
| 7440-23-5 | Sodium | No Value | No Value | 50 | NA | NA | NA | No Value | NA | NA | NA |
| 7440-24-6 | Strontium | 25 | 9,600 | 1 | NR | NR | NR | 26,000 | NR | NR | NR |
| 100-42-5 | Styrene | 0.91 | 100 | 0.005 | 56 | 282 | 502 | 38,000 | 21,500 | 108,000 | 193,000 |
| 14808-79-8 | Sulfate | 0 | 250,000 | 5 | 9,970 | 35,300 | 63,000 | No Value | NA | NA | NA |
| 127-18-4 | Tetrachloroethene | 0.27 | 0.081 | 0.005 | 0.0149 | 0.0727 | 0.13 | 0.39 | 0.0714 | 0.347 | 0.62 |
| 7440-28-0 | Thallium | 71 | 0.5 | 0.5 | NR | NR | NR | 0.24 | NR | NR | NR |
| 7440-31-5 | Tin | 130 | 9,600 | 10 | NR | NR | NR | 520 | NR | NR | NR |
| 108-88-3 | Toluene | 0.14 | 640 | 0.005 | 70.2 | 328 | 585 | 1,300 | 143 | 666 | 1,190 |
| TPHDIESEL | Total petroleum hydrocarbons - diesel range | No Value | 500 | --- | NA [e] | NA [e] | NA [e] | No Value | NA [e] | NA [e] | NA [e] |
| TPH/OILH | Total petroleum hydrocarbons - motor oil (high boiling) | No Value | 500 | --- | NA | NA [e] | NA [e] | No Value | NA [e] | NA [e] | NA [e] |
| 8001-35-2 | Toxaphene | 95.8 | 0.08 | 0.165 | NR | NR | NR | 0.0002 | NR | NR | NR |

Table 5-5. Summary of 100-F/IU Soil Screening Levels Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection SSL (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection SSL (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 156-60-5 | trans-1,2-Dichloroethylene | 0.038 | 100 | 0.005 | 5.99 | 25.4 | 45.4 | 140 | 8.39 | 35.6 | 63.5 |
| 10061-02-6 | trans-1,3-Dichloropropene | 0.027 | 0.44 | 0.005 | 0.0235 | 0.0957 | 0.171 | 0.34 | 0.0183 | 0.0744 | 0.133 |
| 126-73-8 | Tributyl phosphate | 1.89 | 9.51 | --- | 10.3 | 51.7 | 92.2 | 24.3 | 26.3 | 132 | 236 |
| 79-01-6 | Trichloroethene | 0.094 | 0.49 | 0.005 | 0.0442 | 0.203 | 0.361 | 2.5 | 0.225 | 1.03 | 1.84 |
| 75-69-4 | Trichloromonofluoromethane | 0.04389 | 2,400 | --- | 151 | 653 | 1,170 | 35,800 | 2,260 | 9,740 | 17,400 |
| 7440-61-1 | Uranium | 2 | 30 | --- | 35.9 | 180 | 321 | 780 | 930 | 4,670 | 8,330 |
| 7440-62-2 | Vanadium | 1,000 | 80 | 2.5 | NR | NR | NR | No Value | NA | NA | NA |
| 75-01-4 | Vinyl chloride | 0.019 | 0.061 | 0.005 | 0.005 | 0.012 | 0.0214 | 0.025 | 0.005 | 0.005 | 0.00881 |
| 1330-20-7 | Xylenes (total) | 0.23 | 1,600 | 0.01 | 258 | 1,250 | 2,240 | No Value | NA | NA | NA |
| 7440-66-6 | Zinc | 30 | 4,800 | 1 | NR | NR | NR | 91 | NR | NR | NR |

a. All analytes screening values default to the EQL when the calculated value is less than the EQL.

b. The calculated SSL for the analyte is considered nonrepresentative because breakthrough is not simulated within 1,000 years for in any of the representative stratigraphic columns, where breakthrough is defined as mass concentrations exceeding 0.0001 µg/L (the breakthrough threshold is $K_d$ = 22.0 mL/g for SSL values).

c. "NA" is applied when applicable water quality standard is not available to calculate the SSL or PRG values.

d. The SSL value was constrained to a maximum value of 6 mg/kg because the $K_d$ value used in the model was derived from experiments with soil concentration less than 6 mg/kg. Waste site 116-F-14 is evaluated for Cr(VI) using a site-specific model.

e. A STOMP-derived SSL is not calculated; a default screening level of 2,000 mg/kg obtained from WAC 173-340-900, Table 747-5, "Residual Saturation Screening Levels for TPH," will be used.

EQL = estimated quantitation limit
$K_d$ = distribution coefficient
NR = not recorded
PRG = preliminary remediation goal
SSL = soil screening level
STOMP = Subsurface Transport Over Multiple Phases

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Table 5-6. Summary of 100-F/IU Area Radionuclide Soil Screening Level Concentrations Protective of Groundwater Calculated with STOMP

| Radionuclide | Distribution Coefficient $K_d$ Value (mL/g) | Maximum Contaminant Level (pCi/L) | Half-Life (yr) | EQL (mg/kg) | Groundwater Protection SSL (pCi/g)[a,b,c] | | |
|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 |
| Americium-241 | 200 | 15 | 432 | 1 | NR | NR | NR |
| Carbon-14[d] | 0 | 2,000 | 5,730 | --- | 79.9 | 284 | 507 |
| Carbon-14[e] | 200 | 2,000 | 5,730 | --- | NR | NR | NR |
| Cesium-137 | 50 | 200 | 30 | 0.1 | NR | NR | NR |
| Cobalt-60 | 50 | 100 | 5.721 | 0.05 | NR | NR | NR |
| Curium-243 | 200 | 15 | 28.5 | --- | NR | NR | NR |
| Europium-152 | 200 | 200 | 13.3 | 0.1 | NR | NR | NR |
| Europium-154 | 200 | 60 | 8.8 | 0.1 | NR | NR | NR |
| Europium-155 | 200 | 600 | 4.96 | 0.1 | NR | NR | NR |
| Iodine-129 | 1 | 1 | 15,700,000 | --- | 0.612 | 3.08 | 5.5 |
| Neptunium-237 | 15 | 15 | 2,140,000 | --- | 209 | 842 | 1,500 |
| Nickel-63 | 30 | 50 | 96 | --- | NR | NR | NR |
| Niobium-94 | 200 | No Value | 20,300 | --- | NA | NA | NA |
| Plutonium-238 | 200 | 15 | 87.7 | 1 | NR | NR | NR |
| Plutonium-239 | 200 | 15 | 24,100 | 1 | NR | NR | NR |
| Plutonium-240 | 200 | 15 | 6,540 | 1 | NR | NR | NR |
| Plutonium-241 | 200 | 300 | 14 | --- | NR | NR | NR |
| Radium-226 | 200 | 5 | 1,600 | --- | NR | NR | NR |
| Radium-228 | 200 | 5 | 5.75 | 0.2 | NR | NR | NR |
| Strontium-90[f] | 25 | 8 | 29.12 | --- | 24,600 | 64,200 | 104,000 |
| Technetium-99 | 0 | 900 | 213,000 | --- | 35.9 | 127 | 227 |

Table 5-6. Summary of 100-F/IU Area Radionuclide Soil Screening Level Concentrations Protective of Groundwater Calculated with STOMP

| Radionuclide | Distribution Coefficient $K_d$ Value (mL/g) | Maximum Contaminant Level (pCi/L) | Half-Life (yr) | EQL (mg/kg) | Groundwater Protection SSL (pCi/g)[a,b,c] | | |
|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 |
| Thorium-228 | 200 | 15 | 1.91 | --- | NR | NR | NR |
| Thorium-230 | 200 | 15 | 77,000 | --- | NR | NR | NR |
| Thorium-232 | 200 | 15 | 14,100,000,000 | --- | NR | NR | NR |
| Tritium | 0 | 20,000 | 12.35 | --- | 1,660 | 7,460 | 13,300 |
| Uranium-233/234 | 2 | No Value | 244,500 | 1 | NA | NA | NA |
| Uranium-235 | 2 | No Value | 703,800,000 | 0.5 | NA | NA | NA |
| Uranium-238 | 2 | No Value | 4,468,000,000 | 1 | NA | NA | NA |

a. All analytes screening value defaults to the EQL when the calculated value is less than the EQL.

b. The calculated SSL for the analyte is considered non-representative because breakthrough is not simulated within 1,000 years for any of the representative stratigraphic columns, where breakthrough is defined as activity concentrations exceeding 0.0001 pCi/L (the breakthrough threshold is $K_d$ = 22.0 mL/g for SSL values).

c. "NA" is applied when applicable water quality standard is not available to calculate the SSL values.

d. Carbon-14 in liquid form, typically associated with reactor gas condensate.

e. Carbon-14 in solid form, typically associated with graphite.

f. Strontium-90 SSL is calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these operable units.

EQL = estimated quantitation limit

$K_d$ = distribution coefficient

NR = not recorded

SSL = soil screening level

Table 5-7. Summary of 100-F/IU Preliminary Remediation Goals Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection PRG (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection PRG (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 71-55-6 | 1,1,1-Trichloroethane | 0.14 | 200 | 0.005 | 66.5 | 184 | 328 | 930,000 | 308,000 | NR | NR |
| 79-34-5 | 1,1,2,2-Tetrachloroethane | 0.079 | 0.22 | 0.005 | 0.0483 | 0.144 | 0.256 | 0.17 | 0.0375 | 0.112 | 0.199 |
| 79-00-5 | 1,1,2-Trichloroethane | 0.075 | 0.77 | 0.005 | 0.163 | 0.487 | 0.868 | 0.59 | 0.125 | 0.374 | 0.667 |
| 75-34-3 | 1,1-Dichloroethane | 0.053 | 1,600 | 0.01 | 278 | 835 | 1,490 | 74,000 | 12,800 | 38,400 | 68,400 |
| 75-35-4 | 1,1-Dichloroethene | 0.065 | 7 | 0.01 | 1.36 | 4.09 | 7.29 | 0.057 | 0.0111 | 0.0333 | 0.0593 |
| 120-82-1 | 1,2,4-Trichlorobenzene | 1.66 | 1.5 | 0.33 | NR | NR | NR | 2 | NR | NR | NR |
| 95-50-1 | 1,2-Dichlorobenzene | 0.379 | 600 | 0.33 | 876 | 1,580 | 2,830 | 420 | 613 | 1,110 | 1,980 |
| 107-06-2 | 1,2-Dichloroethane | 0.038 | 0.48 | 0.005 | 0.0722 | 0.216 | 0.385 | 0.38 | 0.0571 | 0.17 | 0.304 |
| 540-59-0 | 1,2-Dichloroethene (Total) | 0.0396 | 72 | 0.005 | 11 | 33 | 58.9 | 2,100 | 322 | 964 | 1,720 |
| 78-87-5 | 1,2-Dichloropropane | 0.047 | 1.2 | 0.005 | 0.199 | 0.598 | 1.07 | 0.5 | 0.0819 | 0.246 | 0.439 |
| 541-73-1 | 1,3-Dichlorobenzene | 0.434 | No Value | 0.33 | NA | NA | NA | 320 | 608 | 1,010 | 1,810 |
| 106-46-7 | 1,4-Dichlorobenzene | 0.616 | 8.1 | 0.005 | 33.2 | 43.8 | 78 | 22 | 88.6 | 117 | 208 |
| 93-76-5 | 2,4,5-T | 0.049 | 160 | --- | 26.7 | 80.2 | 143 | No Value | NA | NA | NA |
| 93-72-1 | 2,4,5-TP | 0.08 | 50 | --- | 11.1 | 33.1 | 59.1 | 10 | 2.23 | 6.62 | 11.8 |
| 95-95-4 | 2,4,5-Trichlorophenol | 1.6 | 800 | 0.33 | NR | NR | NR | 490 | NR | NR | NR |
| 88-06-2 | 2,4,6-Trichlorophenol | 0.381 | 4 | 0.33 | 5.88 | 10.6 | 18.9 | 1.4 | 2.07 | 3.73 | 6.64 |
| 94-75-7 | 2,4-D | 0.029 | 70 | --- | 9.52 | 28 | 49.9 | 100 | 13.6 | 40 | 71.2 |
| 94-82-6 | 2,4-DB | 0.1 | 128 | --- | 33.8 | 97.9 | 175 | 6,564 | 1,730 | 5,020 | 8,950 |
| 120-83-2 | 2,4-Dichlorophenol | 0.147 | 24 | 0.33 | 8.36 | 22.9 | 40.9 | 77 | 26.8 | 73.5 | 131 |
| 105-67-9 | 2,4-Dimethylphenol | 0.209 | 160 | 0.33 | 91.1 | 219 | 391 | 380 | 216 | 520 | 928 |
| 51-28-5 | 2,4-Dinitrophenol | 0.00001 | 32 | 0.825 | 3.11 | 8.28 | 14.8 | 69 | 6.71 | 17.9 | 31.9 |
| 121-14-2 | 2,4-Dinitrotoluene | 0.0955 | 0.28 | 0.33 | 0.33 | 0.33 | 0.372 | 0.11 | 0.33 | 0.33 | 0.33 |
| 606-20-2 | 2,6-Dinitrotoluene | 0.0692 | 16 | 0.33 | 3.23 | 9.66 | 17.2 | 120 | 23.8 | 71.2 | 127 |
| 78-93-3 | 2-Butanone | 0.00451 | 4,800 | 0.01 | 494 | 1,340 | 2,400 | 490,000 | 50,600 | 138,000 | 246,000 |
| 111-76-2 | 2-Butoxyethanol | 0.001 | 800 | --- | 78.8 | 211 | 376 | 82,044 | 8,080 | 21,600 | 38,600 |
| 91-58-7 | 2-Chloronaphthalene | 2.98 | 640 | 0.33 | NR | NR | NR | 1,000 | NR | NR | NR |
| 95-57-8 | 2-Chlorophenol | 0.388 | 40 | 0.33 | 61.7 | 109 | 195 | 81 | 125 | 222 | 395 |
| 591-78-6 | 2-Hexanone | 0.01498 | 40 | 0.02 | 4.68 | 13.3 | 23.7 | 3,400 | 401 | 1,140 | 2,040 |
| 91-57-6 | 2-Methylnaphthalene | 2.98 | 32 | 0.33 | NR | NR | NR | 140 | NR | NR | NR |
| 95-48-7 | 2-Methylphenol (cresol, o-) | 0.434 | 400 | 0.33 | 760 | 1,270 | 2,260 | 12,000 | 23,000 | 38,400 | 68,400 |

Table 5-7. Summary of 100-F/IU Preliminary Remediation Goals Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection PRG (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection PRG (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 88-74-4 | 2-Nitroaniline | 0.0527 | 160 | 0.33 | 27.7 | 83.2 | 148 | 2,600 | 449 | 1,350 | 2,400 |
| 88-75-5 | 2-Nitrophenol | 0.297 | No Value | 0.66 | NA | NA | NA | No Value | NA | NA | NA |
| 91-94-1 | 3,3'-Dichlorobenzidine | 0.724 | 0.19 | 0.33 | 1.17 | 1.38 | 2.45 | 0.021 | 0.33 | 0.33 | 0.33 |
| 65794-96-9 | 3+4 Methylphenol (cresol, m+p) | No Value | No Value | 0.33 | NA | NA | NA | No Value | NA | NA | NA |
| 99-09-2 | 3-Nitroaniline | 0.0516 | 4.2 | 0.33 | 0.713 | 2.14 | 3.82 | 100 | 17.6 | 52.9 | 94.4 |
| 72-54-8 | 4,4'-DDD (Dichlorodiphenyldichloroethane) | 45.8 | 0.36 | 0.0033 | NR | NR | NR | 0.00031 | NR | NR | NR |
| 72-55-9 | 4,4'-DDE (Dichlorodiphenyldichloroethylene) | 86.4 | 0.26 | 0.0033 | NR | NR | NR | 0.00022 | NR | NR | NR |
| 50-29-3 | 4,4'-DDT (Dichlorodiphenyltrichloroethane) | 678 | 0.26 | 0.0033 | NR | NR | NR | 0.00022 | NR | NR | NR |
| 534-52-1 | 4,6-Dinitro-2-methylphenol | 0.6015 | 1.3 | 0.33 | 5.02 | 6.69 | 11.9 | 13 | 51 | 67.9 | 121 |
| 6607 | 4-Amino-3,5,6-trichloropicolinic acid | 0.039 | 500 | --- | 76 | 227 | 405 | 57,431 | 8,720 | 26,100 | 46,600 |
| 101-55-3 | 4-Bromophenylphenyl ether | No Value | No Value | 0.33 | NA | NA | NA | No Value | NA | NA | NA |
| 59-50-7 | 4-Chloro-3-methylphenol | 0.4918 | 1,600 | 0.33 | 4,000 | 6,110 | 10,900 | 31,000 | 76,200 | 116,000 | 208,000 |
| 106-47-8 | 4-Chloroaniline | 0.0725 | 0.22 | 0.33 | 0.33 | 0.33 | 0.33 | 4.6 | 0.964 | 2.88 | 5.14 |
| 7005-72-3 | 4-Chlorophenylphenyl ether | 3.08 | No Value | 0.33 | NA | NA | NA | No Value | NA | NA | NA |
| 108-10-1 | 4-Methyl-2-pentanone | 0.0126 | 640 | 0.01 | 72.8 | 206 | 367 | 61,000 | 6,940 | 19,600 | 34,900 |
| 106-44-5 | 4-Methylphenol (cresol, p-) | 0.434 | 40 | --- | 76 | 127 | 226 | 1,500 | 2,780 | 4,640 | 8270 |
| 100-01-6 | 4-Nitroaniline | 0.0516 | 4.4 | 0.33 | 0.749 | 2.25 | 4.01 | 81 | 13.9 | 41.7 | 74.3 |
| 100-02-7 | 4-Nitrophenol | 0.309 | 130 | 0.66 | 132 | 265 | 473 | 4,000 | 4,170 | 8,370 | 14,900 |
| 83-32-9 | Acenaphthene | 6.12 | 960 | 0.1 | NR | NR | NR | 640 | NR | NR | NR |
| 208-96-8 | Acenaphthylene | 5.03 | No Value | 0.1 | NA | NA | NA | No Value | NA | NA | NA |
| 67-64-1 | Acetone | 0.0006 | 7,200 | 0.02 | 705 | 1,890 | 3,360 | 740,000 | 72,300 | 193,000 | 345,000 |
| 309-00-2 | Aldrin | 48.7 | 0.0026 | 0.00165 | NR | NR | NR | 0.000049 | NR | NR | NR |
| 319-84-6 | Alpha-BHC | 1.76 | 0.014 | 0.00165 | NR | NR | NR | 0.0026 | NR | NR | NR |
| 5103-71-9 | Alpha-Chlordane | 51 | 0.25 | 0.0165 | NR | NR | NR | 0.00057 | NR | NR | NR |
| 7429-90-5 | Aluminum | 1,500 | 50 | 5 | NR | NR | NR | 87 | NR | NR | NR |
| 120-12-7 | Anthracene | 23.5 | 4,800 | 0.05 | NR | NR | NR | 8,300 | NR | NR | NR |
| 7440-36-0 | Antimony | 3.76 | 6 | 0.6 | NR | NR | NR | 5.6 | NR | NR | NR |
| 12674-11-2 | Aroclor-1016 | 107 | 0.5 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 11104-28-2 | Aroclor-1221 | 10.3 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 11141-16-5 | Aroclor-1232 | 10.3 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |

Table 5-7. Summary of 100-F/IU Preliminary Remediation Goals Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection PRG (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection PRG (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 53469-21-9 | Aroclor-1242 | 44.8 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 12672-29-6 | Aroclor-1248 | 43.9 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 11097-69-1 | Aroclor-1254 | 75.6 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 11096-82-5 | Aroclor-1260 | 822 | 0.044 | 0.0165 | NR | NR | NR | 0.000064 | NR | NR | NR |
| 7440-38-2 | Arsenic | 29 | 0.058 | 1 | NR | NR | NR | 0.018 | NR | NR | NR |
| 7440-39-3 | Barium | 25 | 2,000 | 0.5 | NR | NR | NR | 1,000 | NR | NR | NR |
| 71-43-2 | Benzene | 0.062 | 0.8 | 0.005 | 0.151 | 0.454 | 0.809 | 1.2 | 0.227 | 0.684 | 1.22 |
| 56-55-3 | Benzo(a)anthracene | 360 | 0.12 | 0.015 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 50-32-8 | Benzo(a)pyrene | 5,500 | 0.012 | 0.015 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 205-99-2 | Benzo(b)fluoranthene | 803 | 0.12 | 0.015 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 191-24-2 | Benzo(ghi)perylene | 1,950 | No Value | 0.03 | NA | NA | NA | No Value | NA | NA | NA |
| 207-08-9 | Benzo(k)fluoranthene | 1,230 | 0.12 | 0.015 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 7440-41-7 | Beryllium | 790 | 4 | 0.2 | NR | NR | NR | 270 | NR | NR | NR |
| 319-85-7 | beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC) | 2.14 | 0.049 | 0.00165 | NR | NR | NR | 0.0091 | NR | NR | NR |
| 108-60-1 | Bis(2-chloro-1-methylethyl)ether | 0.0392 | 0.63 | 0.33 | 0.33 | 0.33 | 0.508 | 37 | 5.71 | 17.1 | 30.5 |
| 111-91-1 | Bis(2-Chloroethoxy)methane | 0.00277 | 48 | 0.33 | 4.83 | 13 | 23.3 | 2,300 | 236 | 637 | 1,140 |
| 111-44-4 | Bis(2-chloroethyl) ether | 0.076 | 0.04 | 0.33 | 0.33 | 0.33 | 0.33 | 0.03 | 0.33 | 0.33 | 0.33 |
| 117-81-7 | Bis(2-ethylhexyl) phthalate | 110 | 6 | 0.33 | NR | NR | NR | 1.2 | NR | NR | NR |
| 7440-69-9 | Bismuth | No Value | No Value | 10 | NA | NA | NA | No Value | NA | NA | NA |
| 7440-42-8 | Boron | 3 | 3,200 | 2 | NR | NR | NR | No Value | NA | NA | NA |
| 24959-67-9 | Bromide | No Value | No Value | 2.5 | NA | NA | NA | No Value | NA | NA | NA |
| 75-27-4 | Bromodichloromethane | 0.055 | 0.71 | 0.005 | 0.125 | 0.376 | 0.67 | 0.27 | 0.0478 | 0.144 | 0.256 |
| 75-25-2 | Bromoform | 0.13 | 5.5 | 0.005 | 1.73 | 4.85 | 8.65 | 4.3 | 1.34 | 3.77 | 6.72 |
| 74-83-9 | Bromomethane | 0.009 | 11 | 0.01 | 1.22 | 3.4 | 6.06 | 47 | 5.12 | 14.3 | 25.5 |
| 85-68-7 | Butylbenzylphthalate | 13.8 | 46 | 0.33 | NR | NR | NR | 8.2 | NR | NR | NR |
| 7440-43-9 | Cadmium | 30 | 5 | 0.2 | NR | NR | NR | 0.25 | NR | NR | NR |
| 7440-70-2 | Calcium | No Value | No Value | 100 | NA | NA | NA | No Value | NA | NA | NA |
| 86-74-8 | Carbazole | 3.39 | 4.4 | 0.33 | NR | NR | NR | No Value | NA | NA | NA |
| 75-15-0 | Carbon disulfide | 0.046 | 800 | 0.005 | 130 | 390 | 695 | 13,000 | 2,160 | 6,480 | 11,600 |
| 56-23-5 | Carbon tetrachloride | 0.152 | 0.34 | 0.005 | 0.121 | 0.33 | 0.589 | 0.23 | 0.083 | 0.226 | 0.402 |

Table 5-7. Summary of 100-F/IU Preliminary Remediation Goals Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection PRG (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection PRG (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 57-74-9 | Chlordane | 51 | 0.25 | 0.0165 | NR | NR | NR | 0.00057 | NR | NR | NR |
| 16887-00-6 | Chloride | 0 | 250,000 | 2 | 24,300 | 64,700 | 115,000 | 230,000 | 22,400 | 59,500 | 106,000 |
| 108-90-7 | Chlorobenzene | 0.22 | 100 | 0.005 | 60 | 142 | 254 | 130 | 78 | 185 | 330 |
| 75-00-3 | Chloroethane | 0.0217 | No Value | 0.01 | NA | NA | NA | No Value | NA | NA | NA |
| 67-66-3 | Chloroform | 0.053 | 1.4 | 0.005 | 0.245 | 0.736 | 1.31 | 5.7 | 0.989 | 2.97 | 5.3 |
| 74-87-3 | Chloromethane | 0.006 | No Value | 0.01 | NA | NA | NA | No Value | NA | NA | NA |
| 7440-47-3 | Chromium | 200 | 100 | 0.2 | NR | NR | NR | 65 | NR | NR | NR |
| 218-01-9 | Chrysene | 200 | 1.2 | 0.1 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 156-59-2 | cis-1,2-Dichloroethylene | 0.036 | 70 | 0.005 | 10.3 | 30.6 | 54.5 | 2,300 | 343 | 1,020 | 1,820 |
| 10061-01-5 | cis-1,3-Dichloropropene | 0.027 | 0.44 | 0.005 | 0.0583 | 0.171 | 0.304 | 0.34 | 0.0453 | 0.133 | 0.236 |
| 7440-48-4 | Cobalt | 50 | 4.8 | 2 | NR | NR | NR | 2.6 | NR | NR | NR |
| PCB1242/1016 | Co-elution of Aroclor-1242 and Aroclor-1016 | No Value | No Value | --- | NA | NA | NA | No Value | NA | NA | NA |
| 7440-50-8 | Copper | 22 | 640 | 1 | NR | NR | NR | 9 | NR | NR | NR |
| 57-12-5 | Cyanide | 9.9 | 200 | --- | NR | NR | NR | 5.2 | NR | NR | NR |
| 75-99-0 | Dalapon | 0.0027 | 200 | --- | 20.1 | 54.3 | 96.8 | 10,773 | 1,080 | 2,920 | 5,210 |
| 319-86-8 | Delta-BHC | 2.81 | No Value | 0.00165 | NA | NA | NA | No Value | NA | NA | NA |
| 53-70-3 | Dibenz[a,h]anthracene | 1,790 | 0.12 | 0.03 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 132-64-9 | Dibenzofuran | 11.3 | 16 | 0.33 | NR | NR | NR | 1.7 | NR | NR | NR |
| 124-48-1 | Dibromochloromethane | 0.063 | 0.52 | 0.005 | 0.0996 | 0.299 | 0.534 | 0.4 | 0.0765 | 0.23 | 0.41 |
| 1918-00-9 | Dicamba | 0.029 | 480 | --- | 65.3 | 192 | 342 | 24,613 | 3,350 | 9,830 | 17,500 |
| 60-57-1 | Dieldrin | 25.6 | 0.0055 | 0.0033 | NR | NR | NR | 0.000052 | NR | NR | NR |
| 60-29-7 | Diethylether | 0.009699 | 1,600 | --- | 176 | 492 | 878 | 96,000 | 10,600 | 29,500 | 52,700 |
| 84-66-2 | Diethylphthalate | 0.082 | 13,000 | 0.33 | 2,900 | 8,590 | 15,300 | 17,000 | 3,850 | 11,400 | 20,400 |
| 131-11-3 | Dimethyl phthalate | 0.0316 | No Value | 0.33 | NA | NA | NA | 270,000 | 37,700 | 111,000 | 199,000 |
| 84-74-2 | Di-n-butylphthalate | 1.57 | 1,600 | 0.33 | NR | NR | NR | 2,000 | NR | NR | NR |
| 117-84-0 | Di-n-octylphthalate | 83,000 | No Value | 0.33 | NA | NA | NA | No Value | NA | NA | NA |
| 88-85-7 | Dinoseb | 3.5 | 7 | --- | NR | NR | NR | No Value | NA | NA | NA |
| 959-98-8 | Endosulfan I | 2.04 | 96 | 0.00165 | NR | NR | NR | 0.056 | NR | NR | NR |
| 33213-65-9 | Endosulfan II | 2.04 | 96 | 0.0033 | NR | NR | NR | 0.056 | NR | NR | NR |
| 1031-07-8 | Endosulfan sulfate | 2.04 | No Value | 0.0033 | NA | NA | NA | 0.93 | NR | NR | NR |

Table 5-7. Summary of 100-F/IU Preliminary Remediation Goals Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection PRG (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection PRG (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 72-20-8 | Endrin | 10.8 | 2 | 0.0033 | NR | NR | NR | 0.0023 | NR | NR | NR |
| 7421-93-4 | Endrin aldehyde | 10.8 | No Value | 0.0033 | NA | NA | NA | 0.29 | NR | NR | NR |
| 53494-70-5 | Endrin ketone | 9.72 | No Value | 0.0033 | NA | NA | NA | No Value | NA | NA | NA |
| 100-41-4 | Ethylbenzene | 0.2 | 4 | 0.005 | 2.17 | 5.28 | 9.41 | 16 | 8.58 | 20.8 | 37.2 |
| 107-21-1 | Ethylene Glycol | 0.001 | 16,000 | --- | 1,580 | 4,220 | 7,530 | 1,640,000 | 162,000 | NR | NR |
| 206-44-0 | Fluoranthene | 49.1 | 640 | 0.05 | NR | NR | NR | 90 | NR | NR | NR |
| 86-73-7 | Fluorene | 7.71 | 640 | 0.03 | NR | NR | NR | 1,100 | NR | NR | NR |
| 16984-48-8 | Fluoride | 150 | 960 | 5 | NR | NR | NR | 16,000 | NR | NR | NR |
| 58-89-9 | Gamma-BHC (Lindane) | 1.35 | 0.08 | 0.00165 | NR | NR | NR | 0.019 | NR | NR | NR |
| 76-44-8 | Heptachlor | 9.53 | 0.019 | 0.00165 | NR | NR | NR | 0.000079 | NR | NR | NR |
| 1024-57-3 | Heptachlor epoxide | 83.2 | 0.0048 | 0.00165 | NR | NR | NR | 0.000039 | NR | NR | NR |
| 118-74-1 | Hexachlorobenzene | 80 | 0.055 | 0.33 | NR | NR | NR | 0.00028 | NR | NR | NR |
| 87-68-3 | Hexachlorobutadiene | 53.7 | 0.56 | 0.33 | NR | NR | NR | 0.44 | NR | NR | NR |
| 77-47-4 | Hexachlorocyclopentadiene | 200 | 48 | 0.33 | NR | NR | NR | 40 | NR | NR | NR |
| 67-72-1 | Hexachloroethane | 1.78 | 3.1 | 0.33 | NR | NR | NR | 1.4 | NR | NR | NR |
| 18540-29-9 | Hexavalent Chromium | 0.8 | 48 | --- | 6[d] | 6[d] | 6[d] | 10 | 6[d] | 6[d] | 6[d] |
| 193-39-5 | Indeno(1,2,3-cd)pyrene | 3470 | 0.12 | 0.03 | NR | NR | NR | 0.0028 | NR | NR | NR |
| 7439-89-6 | Iron | 25 | 300 | 5 | NR | NR | NR | 300 | NR | NR | NR |
| 78-59-1 | Isophorone | 0.0468 | 46 | 0.33 | 7.53 | 22.6 | 40.3 | 8.4 | 1.37 | 4.12 | 7.35 |
| 7439-92-1 | Lead | 30 | 15 | 0.5 | NR | NR | NR | 2.1 | NR | NR | NR |
| 7439-93-2 | Lithium | 50 | 32 | 2.5 | NR | NR | NR | No Value | NA | NA | NA |
| 7439-95-4 | Magnesium | No Value | No Value | 75 | NA | NA | NA | No Value | NA | NA | NA |
| 7439-96-5 | Manganese | 50 | 50 | 5 | NR | NR | NR | 50 | NR | NR | NR |
| 7439-97-6 | Mercury | 30 | 2 | --- | NR | NR | NR | 0.012 | NR | NR | NR |
| 72-43-5 | Methoxychlor | 80 | 40 | 0.0165 | NR | NR | NR | 0.03 | NR | NR | NR |
| 75-09-2 | Methylene chloride | 0.01 | 5 | 0.005 | 0.552 | 1.55 | 2.76 | 4.6 | 0.508 | 1.42 | 2.54 |
| 7439-98-7 | Molybdenum | 20 | 80 | 2 | NR | NR | NR | 1,300 | NR | NR | NR |
| 108-38-3 | m-Xylene | 0.2 | 1,600 | --- | 874 | 2,120 | 3,790 | No Value | NA | NA | NA |
| 91-20-3 | Naphthalene | 1.19 | 160 | 0.1 | NR | NR | NR | 4,900 | NR | NR | NR |
| 7440-02-0 | Nickel | 65 | 100 | 4 | NR | NR | NR | 52 | NR | NR | NR |

Table 5-7. Summary of 100-F/IU Preliminary Remediation Goals Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection PRG (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection PRG (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 14797-55-8 | Nitrate | 0 | 45,000 | 2.5 | 4,370 | 11,600 | 20,800 | 45,000 | 4,370 | 11,600 | 20,800 |
| 14797-65-0 | Nitrite | 0 | 3,300 | 2.5 | 321 | 854 | 1,520 | No Value | NA | NA | NA |
| 98-95-3 | Nitrobenzene | 0.119 | 16 | 0.33 | 4.68 | 13.3 | 23.7 | 17 | 4.97 | 14.1 | 25.2 |
| NO3-N | Nitrogen in Nitrate | 0 | 10,000 | 0.75 | 972 | 2,590 | 4,620 | 10,000 | 972 | 2,590 | 4,620 |
| NO2-N | Nitrogen in Nitrite | 0 | 1,000 | 0.75 | 97.2 | 259 | 462 | No Value | NA | NA | NA |
| NO2+NO3-N | Nitrogen in Nitrite and Nitrate | 0 | 10,000 | --- | 972 | 2,590 | 4,620 | 10,000 | 972 | 2,590 | 4,620 |
| 621-64-7 | n-Nitrosodi-n-dipropylamine | 0.024 | 0.013 | 0.33 | 0.33 | 0.33 | 0.33 | 0.005 | 0.33 | 0.33 | 0.33 |
| 86-30-6 | n-Nitrosodiphenylamine | 1.29 | 18 | 0.33 | NR | NR | NR | 3.3 | NR | NR | NR |
| 95-47-6 | o-Xylene | 0.24 | 1,600 | --- | 1,070 | 2,460 | 4,390 | No Value | NA | NA | NA |
| 87-86-5 | Pentachlorophenol | 0.592 | 0.73 | 0.33 | 2.74 | 3.7 | 6.6 | 0.27 | 1.01 | 1.37 | 2.44 |
| 85-01-8 | Phenanthrene | 16.7 | No Value | 0.05 | NA | NA | NA | No Value | NA | NA | NA |
| 108-95-2 | Phenol | 0.0288 | 2,400 | 0.33 | 326 | 957 | 1,710 | 10,000 | 1,360 | 3,990 | 7,110 |
| 14265-44-2 | Phosphate | No Value | No Value | 5 | NA | NA | NA | No Value | NA | NA | NA |
| 7723-14-0 | Phosphorus | 3.5 | 0.16 | 50 | NR | NR | NR | No Value | NA | NA | NA |
| PO4-P | Phosphorus in phosphate | No Value | No Value | --- | NA | NA | NA | No Value | NA | NA | NA |
| 2023695 | Potassium | No Value | No Value | 400 | NA | NA | NA | No Value | NA | NA | NA |
| 129-00-0 | Pyrene | 68 | 480 | 0.05 | NR | NR | NR | 830 | NR | NR | NR |
| 7782-49-2 | Selenium | 5 | 50 | 1 | NR | NR | NR | 5 | NR | NR | NR |
| 7440-21-3 | Silicon | No Value | No Value | 2 | NA | NA | NA | No Value | NA | NA | NA |
| 7440-22-4 | Silver | 90 | 80 | 0.2 | NR | NR | NR | 2.6 | NR | NR | NR |
| 7440-23-5 | Sodium | No Value | No Value | 50 | NA | NA | NA | No Value | NA | NA | NA |
| 7440-24-6 | Strontium | 25 | 9,600 | 1 | NR | NR | NR | 26,000 | NR | NR | NR |
| 100-42-5 | Styrene | 0.91 | 100 | 0.005 | 1,030 | 1,080 | 1,920 | 38,000 | NR | NR | NR |
| 14808-79-8 | Sulfate | 0 | 250,000 | 5 | 24,300 | 64,700 | 115,000 | No Value | NA | NA | NA |
| 127-18-4 | Tetrachloroethene | 0.27 | 0.081 | 0.005 | 0.0647 | 0.141 | 0.252 | 0.39 | 0.309 | 0.676 | 1.2 |
| 7440-28-0 | Thallium | 71 | 0.5 | 0.5 | NR | NR | NR | 0.24 | NR | NR | NR |
| 7440-31-5 | Tin | 130 | 9,600 | 10 | NR | NR | NR | 520 | NR | NR | NR |
| 108-88-3 | Toluene | 0.14 | 640 | 0.005 | 213 | 589 | 1,050 | 1,300 | 432 | 1,200 | 2,130 |
| TPHDIESEL | Total petroleum hydrocarbons - diesel range | No Value | 500 | --- | NA[e] | NA[e] | NA[e] | No Value | NA[e] | NA[e] | NA[e] |
| TPH/OILH | Total petroleum hydrocarbons - motor oil (high boiling) | No Value | 500 | --- | NA[e] | NA[e] | NA[e] | No Value | NA[e] | NA[e] | NA[e] |

Table 5-7. Summary of 100-F/IU Preliminary Remediation Goals Protective of Groundwater and Surface Water Calculated with STOMP

| CAS No. | Analyte | 100 Areas $K_d$ Value Used to Calculate Groundwater Protection (mL/g) | Groundwater Standard (µg/L) | EQL (mg/kg) | Groundwater Protection PRG (mg/kg)[a,b,c] | | | Surface Water Standard (µg/L) | Surface Water Protection PRG (mg/kg)[a,b,c] | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 | | 100-F | 100-IU-2 | 100-IU-6 |
| 8001-35-2 | Toxaphene | 95.8 | 0.08 | 0.165 | NR | NR | NR | 0.0002 | NR | NR | NR |
| 156-60-5 | trans-1,2-Dichloroethylene | 0.038 | 100 | 0.005 | 15 | 44.9 | 80 | 140 | 21 | 62.8 | 112 |
| 10061-02-6 | trans-1,3-Dichloropropene | 0.027 | 0.44 | 0.005 | 0.0583 | 0.171 | 0.304 | 0.34 | 0.0453 | 0.133 | 0.236 |
| 126-73-8 | Tributyl phosphate | 1.89 | 9.51 | --- | NR | NR | NR | 24.3 | NR | NR | NR |
| 79-01-6 | Trichloroethene | 0.094 | 0.49 | 0.005 | 0.123 | 0.359 | 0.641 | 2.5 | 0.625 | 1.83 | 3.26 |
| 75-69-4 | Trichloromonofluoromethane | 0.04389 | 2,400 | --- | 382 | 1,150 | 2,040 | 35,800 | 5,700 | 17,100 | 30,500 |
| 7440-61-1 | Uranium | 2 | 30 | --- | NR | NR | NR | 780 | NR | NR | NR |
| 7440-62-2 | Vanadium | 1,000 | 80 | 2.5 | NR | NR | NR | No Value | NA | NA | NA |
| 75-01-4 | Vinyl chloride | 0.019 | 0.061 | 0.005 | 0.00745 | 0.0215 | 0.0384 | 0.025 | 0.005 | 0.00886 | 0.0158 |
| 1330-20-7 | Xylenes (total) | 0.23 | 1,600 | 0.01 | 1,010 | 2,370 | 4,220 | No Value | NA | NA | NA |
| 7440-66-6 | Zinc | 30 | 4,800 | 1 | NR | NR | NR | 91 | NR | NR | NR |

a. All analytes screening value defaults to the EQL when the calculated value is less than the EQL.

b. The calculated PRG for the analyte is considered non-representative because breakthrough is not simulated within 1,000 years in any of the representative stratigraphic columns, where breakthrough defined as mass concentrations exceeding 0.0001 µg/L (the breakthrough threshold is $K_d$ = 22.0 mL/g for PRG values).

c. "NA" is applied when applicable water quality standard is not available to calculate the SSL or PRG values.

d. The PRG value was constrained to a maximum value of 6 mg/kg because the $K_d$ value used in the model was derived from experiments with soil concentration less than 6 mg/kg. The Proposed Plan will recommend a PRG of 2.0 mg/kg based on the Interim Action Remedial Action Goal for surface water protection (*Remedial Design Report/Remedial Action Work Plan for the 100 Area* [DOE/RL-96-17]); modeling with site-specific information may be used to confirm protectiveness. Waste site 116-F-14 was evaluated with a site-specific model.

e. The PRG values for total petroleum hydrocarbons is a default screening level obtained from WAC 173-340-900, Table 747-5, "Residual Saturation Screening Levels for TPH."

CAS = Chemical Abstract Services
EQL = estimated quantitation limit
$K_d$ = distribution coefficient
NR = not recorded
PRG = preliminary remediation goal
SSL = soil screening level

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Table 5-8. Summary of 100-F/IU Area Radionuclide Preliminary Remediation Goals Protective of Groundwater Calculated with STOMP

| Radionuclide | Distribution Coefficient $K_d$ Value (mL/g) | Maximum Contaminant Level (pCi/L) | Half-Life (yr) | EQL (mg/kg) | Groundwater PRG (pCi/g)[a,b,c] | | |
|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 |
| Americium-241 | 200 | 15 | 432 | 1 | NR | NR | NR |
| Carbon-14[d] | 0 | 2,000 | 5,730 | --- | 195 | 518 | 924 |
| Carbon-14[e] | 200 | 2,000 | 5,730 | --- | NR | NR | NR |
| Cesium-137 | 50 | 200 | 30 | 0.1 | NR | NR | NR |
| Cobalt-60 | 50 | 100 | 5.721 | 0.05 | NR | NR | NR |
| Curium-243 | 200 | 15 | 28.5 | --- | NR | NR | NR |
| Europium-152 | 200 | 200 | 13.3 | 0.1 | NR | NR | NR |
| Europium-154 | 200 | 60 | 8.8 | 0.1 | NR | NR | NR |
| Europium-155 | 200 | 600 | 4.96 | 0.1 | NR | NR | NR |
| Iodine-129 | 1 | 1 | 15,700,000 | --- | NR | NR | NR |
| Neptunium-237 | 15 | 15 | 2,140,000 | --- | NR | NR | NR |
| Nickel-63 | 30 | 50 | 96 | --- | NR | NR | NR |
| Niobium-94 | 200 | No Value | 20,300 | --- | NA | NA | NA |
| Plutonium-238 | 200 | 15 | 87.7 | 1 | NR | NR | NR |
| Plutonium-239 | 200 | 15 | 24,100 | 1 | NR | NR | NR |
| Plutonium-240 | 200 | 15 | 6,540 | 1 | NR | NR | NR |
| Plutonium-241 | 200 | 300 | 14 | --- | NR | NR | NR |
| Radium-226 | 200 | 5 | 1,600 | --- | NR | NR | NR |
| Radium-228 | 200 | 5 | 5.75 | 0.2 | NR | NR | NR |
| Strontium-90[f] | 25 | 8 | 29.12 | --- | NR | NR | NR |
| Technetium-99 | 0 | 900 | 213,000 | --- | 87.5 | 233 | 415 |

Table 5-8. Summary of 100-F/IU Area Radionuclide Preliminary Remediation Goals Protective of Groundwater Calculated with STOMP

| Radionuclide | Distribution Coefficient $K_d$ Value (mL/g) | Maximum Contaminant Level (pCi/L) | Half-Life (yr) | EQL (mg/kg) | Groundwater PRG (pCi/g)[a,b,c] | | |
|---|---|---|---|---|---|---|---|
| | | | | | 100-F | 100-IU-2 | 100-IU-6 |
| Thorium-228 | 200 | 15 | 1.91 | --- | NR | NR | NR |
| Thorium-230 | 200 | 15 | 77,000 | --- | NR | NR | NR |
| Thorium-232 | 200 | 15 | 14,100,000,000 | --- | NR | NR | NR |
| Tritium | 0 | 20,000 | 12.35 | --- | 2,670 | 9,110 | 16,200 |
| Uranium-233/234 | 2 | No Value | 244,500 | 1 | NA | NA | NA |
| Uranium-235 | 2 | No Value | 703,800,000 | 0.5 | NA | NA | NA |
| Uranium-238 | 2 | No Value | 4,468,000,000 | 1 | NA | NA | NA |

a. All analytes screening value defaults to the EQL when the calculated value is less than the EQL.

b. The calculated PRG for the analyte is considered non-representative because breakthrough is not simulated within 1,000 years for any of the representative stratigraphic columns, where breakthrough is defined as activity concentrations exceeding 0.0001 pCi/L (the breakthrough threshold is $K_d$ = 22.0 mL/g for PRG values).

c. "NA" is applied when applicable water quality standard is not available to calculate the PRG values.

d. Carbon-14 in liquid form, typically associated with reactor gas condensate.

e. Carbon-14 in solid form, typically associated with graphite.

f. Strontium-90 PRG is calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 distributed throughout the vadose zone at some locations in these operable units.

EQL = estimated quantitation limit

$K_d$ = distribution coefficient

NR = not recorded

PRG = preliminary remediation goal

Table 5-9. 100-F Waste Sites with EPCs Greater than Groundwater Protection SSLs

| Waste Site/ Decision Unit | Analyte Group | Analyte Name | CAS No. | Units | EPC | STOMP 1-D 70:30/100:0 Contaminant Source Model SSL for Groundwater Protection [a] | Is EPC > SSL Protective of Groundwater? |
|---|---|---|---|---|---|---|---|
| 600-351_Shallow_ Focused | non-Rad | 2-(2-methyl-4-chlorophenoxy) propionic acid | 93-65-2 | µg/kg | 2,300 | 1,033 | No[b] |

a. ECF-HANFORD-12-0004, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas*. A 70:30 source distribution is used for analytes with $K_d \geq 2$ mL/g; a 100:0 source distribution is used for analytes with $K_d < 2$ mL/g. The SSL for all analytes defaults to the EQL when the calculated value is less than the EQL reported in DOE/RL-2009-43, *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*.

b. EPC exceeded SSL, but was dismissed upon further evaluation as follows: the calculated EPC of 2,300 µg/kg for 2-(2-methyl-4-chlorophenoxy) propionic acid is based on the maximum detected concentration. 2-(2-methyl-4-chlorophenoxy) propionic acid was detected in three of four soil samples where concentrations range between 2,200 and 2,300 µg/kg. All results were flagged with a "J" laboratory qualifier, indicating that the reported concentrations are considered estimates. The low-level detections of 2-(2-methyl-4-chlorophenoxy) propionic acid are likely associated with past herbicide application for weed control purposes. As such, 2-(2-methyl-4-chlorophenoxy) propionic acid was applied in accordance with its intended use and the not the result of a release. Therefore, 2-(2-methyl-4-chlorophenoxy) propionic acid is not retained as a COPC at this site.

CAS = Chemical Abstract Services
COPC = contaminant of potential concern
EPC = exposure point concentration
EQL = estimated quantitation limit
SSL = soil screening level
STOMP = Subsurface Transport Over Multiple Phases

Table 5-10. 100-F Waste Sites with EPCs Greater than Surface Water Protection SSLs

| Waste Site/Decision Unit | Analyte Group | Analyte Name | CAS No. | Units | Exposure Point Concentration | STOMP 1D 70:30/100:0 Contaminant Source Model SSL for Surface Water Protection[a] | Is EPC > SSL Protective of Surface Water? |
|---|---|---|---|---|---|---|---|
| 100-F-19:1_Deep | non-Rad | Cr(VI) | 18540-29-9 | µg/kg | 5,600 | 4,981 | No[b] |
| 116-F-14_Deep | non-Rad | Cr(VI) | 18540-29-9 | µg/kg | 6,787 | Exceeds[c] | Yes[c] |
| 118-F-7_Staging Pile Area | non-Rad | Copper | 7440-50-8 | µg/kg | 552,000 | 329,092 | No[d] |
| 128-F-2_Shallow | non-Rad | Endrin | 72-20-8 | µg/kg | 22 | 16 | No[e] |
| 128-F-2_Shallow | non-Rad | Heptachlor | 76-44-8 | µg/kg | 3.3 | 1.7 | No[f] |
| 1607-F7_Staging pile area_Focused | non-Rad | Heptachlor | 76-44-8 | µg/kg | 15 | 1.7 | No[g] |

a. ECF-HANFORD-12-0004, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for 100 Area F and IU Source Areas*. A 70:30 source distribution is used for analytes with Kd ≥ 2 mL/g; a 100:0 source distribution is used for analytes with Kd <2 mL/g. The SSL for all analytes defaults to the EQL when the calculated value is less than the EQL reported in DOE/RL-2009-43, *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*.

b. EPC exceeded SSL but was dismissed upon further evaluation as follows: the calculated EPC of 5,600 µg/kg for Cr(VI) is based on the maximum detected concentration. Cr(VI) was detected in two of seven soil samples where concentrations were reported at 3,400 and 5,600 µg/kg. The Cr(VI) concentration of 3,400 µg/kg was reported in the duplicate sample (B12VV2) but was not detected in the parent sample (B12VT7). Only one soil sample was reported above the SSL of 4,981 µg/kg. Therefore, the maximum Cr(VI) concentration overestimates the overall Cr(VI) concentration for the decision unit because all but one result was less than the SSL. Cr(VI) is not retained as a COPC at this site.

c. Evaluated using site-specific model and determined to pose a potential to exceed the surface water protection standard.

d. EPC exceeded SSL but was dismissed upon further evaluation as follows: the calculated EPC of 552,000 µg/kg for copper is based on the maximum detected concentration. Copper was detected in five soil samples (including one field duplicate). Four of five copper results ranged between 10.4 and 12.2 µg/kg was are below the SSL of 329,092 µg/kg. The single detection of copper above the SSL is likely associated with a copper fleck and is an overestimation of the overall copper concentration for the decision. As a result, copper is not retained as a COPC at this site.

e. EPC exceeded SSL but was dismissed upon further evaluation as follows: the calculated EPC of 22 µg/kg for endrin is based on the maximum detected concentration. Endrin was detected in three of 24 soil samples (including two field duplicates) where concentrations ranged between 7.7 and 22 µg/kg. Two soil samples were reported above the SSL of 16 µg/kg. The low-level detections of endrin are likely associated with past pesticide application. As such, endrin was applied in accordance with its intended use and the not the result of a release. Therefore, endrin is not retained as a COPC at this site.

Table 5-10. 100-F Waste Sites with EPCs Greater than Surface Water Protection SSLs

| Waste Site/Decision Unit | Analyte Group | Analyte Name | CAS No. | Units | Exposure Point Concentration | STOMP 1D 70:30/100:0 Contaminant Source Model SSL for Surface Water Protection[a] | Is EPC > SSL Protective of Surface Water? |
|---|---|---|---|---|---|---|---|

f. EPC exceeded SSL but was dismissed upon further evaluation as follows: the calculated EPC of 3.3 µg/kg for heptachlor is based on the maximum detected concentration. Heptachlor was detected in one of 24 soil samples (including two field duplicates). The single low-level detection of heptachlor is likely associated with past pesticide application. As such, heptachlor was applied in accordance with its intended use and the not the result of a release. Therefore, endrin is not retained as a COPC at this site.

g. EPC exceeded SSL but was dismissed upon further evaluation as follows: the calculated EPC of 15 µg/kg for heptachlor is based on the maximum detected concentration. Only one soil sample was collected and analyzed for heptachlor, the single detection was flagged with a "J" laboratory qualifier indicating that the reported concentration is considered an estimate. The low-level detection of heptachlor is likely associated with past pesticide application. As such, heptachlor was applied in accordance with its intended use and the not the result of a release. Therefore, heptachlor is not retained as a COPC at this site.

CAS = Chemical Abstract Services

COPC = contaminant of potential concern

EPC = exposure point concentration

EQL = estimated quantitation limit

SSL = soil screening level

STOMP = Subsurface Transport Over Multiple

- 128-F-2. Endrin and heptachlor present in the shallow decision unit at EPCs of 0.022 mg/kg and 0.003 mg/kg exceeded their respective surface water protection SSLs of 0.016 mg/kg and 0.0017 mg/kg.

- 1607-F7. Heptachlor present in the staging pile area focused decision unit at an EPC of 0.015 mg/kg exceeded the surface water protection SSL of 0.0017 mg/kg.

No interim remediated waste sites or sites that have been sampled to confirm achievement of interim action cleanup requirements in 100-IU-2/IU-6 with COPCs present had EPCs greater than their SSLs for protection of groundwater or surface water. A table presenting the comparison for all waste sites and COPCs is provided in Appendix F. Note that 115 additional waste sites in 100-IU-2/IU-6 remain to be addressed. Appendix E contains the list of possible COPCs for these 115 waste sites that will be evaluated during remedial action.

Further evaluation of the basis of EPCs for the exceedances of SSLs noted above follows:

- 600-351 shallow focused decision unit: The calculated EPC of 2,300 µg/kg for 2-(2-methyl-4-chlorophenoxy) propionic acid is based on the maximum detected concentration. 2-(2-methyl-4-chlorophenoxy) propionic acid was detected in three of four soil samples where concentrations range between 2,200 and 2,300 µg/kg. All results were flagged with a "J" laboratory qualifier indicating the reported concentrations are considered estimates. The low-level detections of 2-(2-methyl-4-chlorophenoxy) propionic acid are likely associated with past herbicide application for weed control purposes. As such, 2-(2-methyl-4-chlorophenoxy) propionic acid was applied in accordance with its intended use and the not the result of a release. Therefore, 2-(2-methyl-4-chlorophenoxy) propionic acid is not retained as a COPC at this site.

- 100-F-19:1 deep decision unit: The calculated EPC of 5,600 µg/kg for Cr(VI) is based on the maximum detected concentration. Cr(VI) was detected in two of seven soil samples where concentrations were reported at 3,400 and 5,600 µg/kg. The Cr(VI) concentration of 3,400 µg/kg was reported in the duplicate sample (B12VV2) but was not detected in the parent sample (B12VT7). Only one soil sample was reported above the SSL of 4,981 µg/kg. Therefore, the maximum Cr(VI) concentration overestimates the overall Cr(VI) concentration for the decision unit because all but one result was less than the SSL. Therefore, Cr(VI) is not retained as a COPC at this site.

- 118-F-7 staging pile area decision unit: The calculated EPC of 552,000 µg/kg for copper is based on the maximum detected concentration. Copper was detected in five soil samples (including one field duplicate). Four of five copper results ranged between 10.4 and 12.2 µg/kg, below the SSL of 329,092 µg/kg. The single detection of copper above the SSL is likely associated with a copper fleck and is an overestimation of the overall copper concentration for the decision. As a result, copper is not retained as a COPC at this site.

- 128-F-2 shallow decision unit: The calculated EPC of 22 µg/kg for endrin is based on the maximum detected concentration. Endrin was detected in 3 of 24 soil samples (including two field duplicates) where concentrations ranged between 7.7 and 22 µg/kg. Two soil samples were reported above the SSL of 16 µg/kg. The low-level detections of endrin are likely associated with past pesticide application. As such, endrin was applied in accordance with its intended use and the not the result of a release. Therefore, endrin is not retained as a COPC at this site.

- 128-F-2 shallow decision unit: The calculated EPC of 3.3 µg/kg for heptachlor is based on the maximum detected concentration. Heptachlor was detected in one of 24 soil samples (including two field duplicates). The single low-level detection of heptachlor is likely associated with past pesticide

application. As such, heptachlor was applied in accordance with its intended use and the not the result of a release. Therefore, endrin is not retained as a COPC at this site.

- 1607-F7 staging pile area decision unit: The calculated EPC of 15 µg/kg for heptachlor is based on the maximum detected concentration. Only one soil sample was collected and analyzed for heptachlor; the single detection was flagged with a "J" laboratory qualifier indicating that the reported concentration is considered an estimate. The low-level detection of heptachlor is likely associated with past pesticide application. As such, heptachlor was applied in accordance with its intended use and the not the result of a release. Therefore, heptachlor is not retained as a COPC at this site.

#### *5.7.2.2 PRG Comparison Results*

There were no interim remediated waste sites, or waste sites that have been sampled to confirm achievement of interim cleanup action requirements in 100-F, with COPCs present at concentrations above PRGs protective of groundwater and surface water.

One waste site in 100-IU-2/IU-6 (600-205) also initially failed for TPH. Further evaluation of the dataset revealed that a pre-remediation sample was erroneously included in the dataset for the site. Therefore, the reported TPH exceedance at this waste site was not confirmed.

## 5.8 Saturated Zone Modeling Methods and Results

A groundwater flow and contaminant transport model was constructed for the 100 Areas to simulate future contaminant migration and assist with developing remedial action alternatives for individual groundwater OUs. The model development and calibration process are documented in *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model* (SGW-46279). A summary of the model input parameters is provided in Table 5-11. Hydrogeologic model inputs for the simulations were derived from *Geohydrologic Data Package in Support of 100-FR-3 Modeling* (SGW-47040). The soil:water $K_d$ values for each COPC simulated (except for Cr[VI]) were obtained from *Selection and Traceability of Parameters to Support Hanford-Specific RESRAD Analyses: Fiscal Year 2008 Status Report* (PNNL-18564).

Table 5-11. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with Groundwater Flow and Transport Model Implemented in the MODFLOW and MT3DMS Codes for Groundwater OUs in the 100-F, 100-IU-2, and 100-IU-6 Areas

| Input Parameter (units) | Input Parameter Value | |
|---|---|---|
| **Simulation Duration** | | |
| Simulation of historic conditions (used for model calibration) | 6 years – January 2006 through December 2011<br>Monthly stress periods | |
| Simulation of future conditions | Flow | 151 years – January 2011 through December 2077.<br>Monthly stress periods for first 26 years followed by a single stress period of 125 years. |
| | Transport | Cr(VI), nitrate, and TCE for 76 years.<br>Strontium-90 for 201 years (last stress period extended to 175 years). |

Table 5-11. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with Groundwater Flow and Transport Model Implemented in the MODFLOW and MT3DMS Codes for Groundwater OUs in the 100-F, 100-IU-2, and 100-IU-6 Areas

| Input Parameter (units) | | Input Parameter Value | |
|---|---|---|---|
| **Upper Boundary Condition: Recharge** | | | |
| Recharge Boundary | | Recharge values reported in PNNL-14753 were uniformly scaled during the model calibration process to provide improved fit to measured groundwater elevations. Resulted in a single value for groundwater recharge of 12 mm/yr representing a spatial average of recharge throughout the model domain under present-day surface conditions (including artificial recharge sources such as 182-B and 182-D).[a] | |
| **Lateral Boundary Conditions** | | | |
| Constant Head Boundaries | | Used to represent time-variant hydraulic head distribution in model cells representing the Western Gap and the Gable Gap. | |
| General Head Boundaries | | Used to represent flow into and out of the model domain along the southeast model boundary between Gable Mountain and the Columbia River. Stress-period-specific, spatially variable values specified on the basis of a map of sitewide groundwater elevations representing typical groundwater level conditions in 2006-2008 and river-stage elevations for the same period. | |
| River Boundary | | River-stage data from six gauges located near each operable unit plus USGS Gauge 12472800 (located below Priest Rapids Dam) were processed and summarized to monthly average stage values for application in each stress period. | |
| **Lower Boundary Condition** | | | |
| No Flow Boundary | | The lower boundary of the model is a no-flow boundary, in keeping with the stratigraphy selected to choose relatively impermeable units (aquitard, basalt, or mud) to serve as the lower boundary. | |
| **Sources and Sinks** | | | |
| Pumping Stresses | | Historical | Extraction and injection rates for 100 Area pump-and-treat systems for January 2006 through December 2011 for the following systems: DR-5, HR-3, KX, KR4, and KW. |
| | | Predictive | Pumping stresses in predictive simulations were based on extraction/injection well configurations developed for each proposed alternative design in 100-F/IU. |
| **Hydraulic Parameters** | | | |
| | | **Full Model Domain** | |
| Specific yield (unitless) | | 0.10 | |
| Specific storage (1/day) | | 0.000005 | |
| | | **Hanford formation** | **Ringold Formation** |
| $K_h$ saturated horizontal hydraulic conductivity (m/d) | 100-F | Spatially variable; mean zonal value for portion of the 100 Area groundwater model in the 100-F Area: 30[b] | Not present in 100-F Area. |
| Vertical anisotropy ratio ($K_v/K_h$) | | 0.1 | |

Table 5-11. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with Groundwater Flow and Transport Model Implemented in the MODFLOW and MT3DMS Codes for Groundwater OUs in the 100-F, 100-IU-2, and 100-IU-6 Areas

| Input Parameter (units) | Input Parameter Value | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Transport Parameters** | | | | | | | | |
| **Contaminants of Concern →** | **Cr(VI)** | | **Nitrate** | | **Strontium-90** | | **TCE** | |
| Transport Parameters for Aqueous Phase ↓ | **Mobile Domain** | **Immobile Domain** | **Mobile Domain** | **Immobile Domain** | **Mobile Domain** | **Immobile Domain** | **Mobile Domain** | **Immobile Domain** |
| Porosity (unitless) | 0.18 | 0.045 | 0.18 | 0.045 | 0.18 | 0.045 | 0.18 | 0.045 |
| $K_d$ distribution coefficient (mL/g) | 0.0[c] | 0.3[c] | 0.0[c] | 0.0[c] | 7.0[c] | 39.0[c] | 0.0[d] | 0.025[d] |
| Radioactive decay half-life (years) [e] | N/A | | N/A | | 28.8 | | N/A | |
| Decay in water (1/day) [e] | 0 | | 0 | | 0.0000659 | | 0 | |
| Decay on soil (1/day) [e] | 0 | | 0 | | 0.0000659 | | 0 | |
| First-order dual-domain mass transfer rate (1/day) | 0.01 | | 0.01 | | 0.01 | | 0.01 | |
| $\rho_b$ bulk density (g/mL) | 1.72 | | | | | | | |
| Contaminants of Concern → | **Cr(VI)** | | **Nitrate** | | **Strontium-90** | | **TCE** | |
| Transport Parameters for Substrate (simulated for bioremediation of Cr(VI) and nitrate) ↓ | **Mobile Domain** | **Immobile Domain** | **Mobile Domain** | **Immobile Domain** | **Mobile Domain** | **Immobile Domain** | **Mobile Domain** | **Immobile Domain** |
| $K_d$ distribution coefficient (mL/g) | 0.0 | 0.0 | 0.0 | 0.0 | N/A | N/A | N/A | N/A |
| Decay in water (1/day) | 0.034657 [f] | | 0.034657 [f] | | -- | | -- | |
| Decay on soil (1/day) | 0 | | 0 | | -- | | -- | |
| First-order dual-domain mass transfer rate (1/day) | 0 | | 0 | | -- | | -- | |

Table 5-11. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with Groundwater Flow and Transport Model Implemented in the MODFLOW and MT3DMS Codes for Groundwater OUs in the 100-F, 100-IU-2, and 100-IU-6 Areas

| Input Parameter (units) | Input Parameter Value |
|---|---|

Note: Details on the basis for all parameters in this table are found in SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*.

Sources:

ECF-100FR3-11-0116, *Modeling of RI/FS Design Alternatives for 100-FR-3* (in Appendix F).

PNNL-14753, *Groundwater Data Package for Hanford Assessments*.

SGW-46279, *Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model*.

a. Recharge rate represents an average over a large area represented by the groundwater model with spatially distributed surface soil types and vegetative cover under present day conditions. This value is not directly comparable to recharge rates applied for vadose zone modeling of waste sites that represent a subset of the surface soil type and vegetation cover range applicable to the larger area groundwater model. The values used for the vadose zone models used to develop SSL and PRG values are within the range of recharge rates represented in the groundwater model for present day conditions.

b. Denotes calibrated value.

c. PNNL-18564, Table 6.9, sandy-gravel sediment type (distributed in the mobile and immobile domains based on the approximate ratio of the corresponding porosities).

d. From empirical calculation following PNNL-13560, *Assessment of Carbon Tetrachloride Groundwater Transport in Support of the Hanford Carbon Tetrachloride Innovative Technology Demonstration Program*, Equations 1 and 2, p. C-6, and assuming foc = 0.00028 and TCE solubility of 1,100 mg/L.

e. Decay values in water/soil correspond to radioactive half-life.

f. Decay values used to represent reduction/consumption/transformation of contaminant of concern resulting from instantaneous reaction with a specified stoichiometry under bioremediation alternatives.

$K_d$ = distribution coefficient
N/A = not applicable
PRG = preliminary remediation goal
SSL = soil screening level
TCE = trichloroethene
USGS = U.S. Geological Survey

### 5.8.1 Simulation Tools

The model domain and groundwater flow element were constructed using the U.S. Geological Survey's (USGS) MODFLOW code ("A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model" [McDonald and Harbaugh, 1988]). Model construction was supported by *User's Documentation for MODFLOW-96, an Update to the U.S. Geological Survey Modular Finite-Difference Ground-Water Flow Model* (Harbaugh and McDonald, 1996); *MODFLOW-2000, the U.S. Geological Survey Modular Ground-Water Model – User Guide to Modularization Concepts and the Ground-Water Flow Process* (Harbaugh et al., 2000); and "*MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model – The Ground-Water Flow Process*" (Harbaugh, 2005).

Contaminant plume migration was simulated using *MT3DMS: A Modular Three-Dimensional Multi-Species Transport Model for Simulation of Advection, Dispersion, and Chemical Reactions of Contaminants in Groundwater Systems; Documentation and User's Guide* (Zheng and Wang, 1999). This was supplemented with information from *MT3DMS v5.2: Supplemental User's Guide* (Zheng, 2006).

Particle Tracking was performed using *User's Guide for MODPATH/MODPATH-PLOT, Version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U.S. Geological Survey Finite-Difference Ground-Water Flow Model* (Pollock, 1994).

The MODFLOW code ("A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model" [McDonald and Harbaugh, 1988]) was selected because it has the capabilities, it is relatively simple to use, and it can be executed on a variety of computers and operating systems without modification. MODFLOW simulates groundwater flow using a block-centered, finite-difference grid. A finite-difference grid can simulate three-dimensional groundwater flow using one or more model layers that correspond to individual aquifers or aquitards, or that provide vertical contaminant discretization across thick aquifers and aquitards. Individual or multiple layers corresponding to aquifers can be simulated as unconfined (e.g., water table aquifers), confined, or convertible between unconfined and confined conditions.

The following subsections summarize the model development and deployment; additional details are presented in Appendix F (ECF-100-FR#-11-0116).

### 5.8.2 Model Construction

The groundwater flow model grid encompasses all 100 Area OUs. The model finite-difference grid is constructed so the north and northeast boundaries of the flow model parallel and abut the Columbia River. The model extends southward toward Gable Butte and Gable Mountain. The node-grid spacing is relatively coarse (about 100 m [328 ft]) throughout much of the domain, but more refined (15 m [49.2 ft]) within the 100 Area OU boundaries to provide for more detailed simulations.

#### *5.8.2.1 Layers*

The model is composed of four layers corresponding to the Hanford formation (always present in Layer 1) and Ringold unit E (typically represented by Layers 2 through 4, except east of 100-D where it is absent and, therefore, all model layers represent the Hanford formation). Throughout much of the western half of the model domain (including 100-K and 100-D), the water table lies within the Ringold unit E sands, whereas toward the east and north of the model domain (including 100-H and 100-F), the water table lies within the Hanford formation sands and gravels.

The base of the model (Layer 4) corresponds with the top of the RUM where present and the top of the basalt where the RUM is absent, which typically occurs in the southern portions of the model approaching Gable Butte. The geologic characterization compiled as part of the model data packages (*100-HR-3 Remedial Process Optimization Modeling Data Package* [SGW-40781]; *100-KR-4 Remedial Process Optimization Modeling Data Package* [SGW-41213]; *Geohydrologic Data Package in Support of 100-BC-5 Modeling* [SGW-44022]; and *Geohydrologic Data Package in Support of 100-FR-3 Modeling* [SGW-47040]) depicts the reasonably abrupt lateral transition from the Ringold unit E in the west and south of the model domain, to the Hanford formation sands and gravels in the east and north of the model domain, between 100-D and 100-H.

#### *5.8.2.2 Hydraulic Conductivity*

The principal aquifer property specified in the flow model is the spatially varying hydraulic conductivity of the saturated aquifer materials. The hydraulic conductivity distribution in the model was developed based on the information included in the model data packages and a pilot-point parameterization technique that was implemented in the model calibration process. Estimates of hydraulic conductivity compiled as part of the model data packages were tabulated and assigned to their corresponding aquifer unit. The mean value for the aquifer hydraulic conductivity in the portion of the 100 Area groundwater

model representing 100-FR-3 that resulted from the model calibration process is 30 m/d (98.4 ft/d) for the Hanford formation. Note that the Ringold Formation is not present in the 100-F Area.

#### 5.8.2.3 Recharge

An aerial recharge was specified based on information included in *Groundwater Data Package for Hanford Assessments* (PNNL-14753). An electronic version of the recharge package developed in the PNNL report was obtained, and the data spatially distributed across the model domain. Recharge rates were subsequently adjusted during the model calibration process. Based on the results of the model calibration, the recharge value was set equal to 12 mm/yr throughout much of the model domain. This natural recharge rate (12 mm/yr) appears to differ from natural recharge rates applied for vadose zone spatial recharge rate applied for the groundwater model is applicable to the large area represented by that model (encompassing all of the 100 Areas), which includes substantial variability in land surface soil types and vegetation cover. Moreover, this rate was calibrated to present day hydraulic conditions. In contrast, the recharge rates applied for vadose zone modeling apply to the smaller, local-scale waste site representations. For present day conditions (bare soil), the recharge rates for waste sites range from 17 to 52 mm/yr (see Table 5-4 for recharge rates under bare soil, 2010 through 2015). The groundwater model surface area averages recharge from these bare soil areas (e.g., waste sites) with larger areas of native vegetation cover with recharge rates ranging from 1.5 to 4.0 mm/yr (see Table 5-5 for recharge rates under mature shrub-steppe native vegetation cover, after 2045). Thus, the 12 mm/yr rate is consistent taken in context as a spatially averaged value over diverse land cover conditions for present-day conditions. Also note that the recharge rate applied to the groundwater model does not vary in time (as the vadose zone recharge rates do). This is because the groundwater model is applied to a much shorter time period for evaluation of remedial alternatives for which present-day recharge rates are sufficient, while the vadose zone modeling is applied to a much longer time period (1,000 years) to evaluate impact of residual contamination levels.

Artificial recharge conditions (e.g., surface reservoirs) were assigned recharge rates based on reported values (*In Situ Redox Manipulation (ISRM) Annual Report Fiscal Year 2007* [DOE/RL-2008-10]).

#### 5.8.2.4 Effective Porosity, Specific Yield, and River Conductance

Initial values for the aquifer layers were identified from published sources and subsequently revised during model calibration. The final values determined through the calibration process were 18 and 10 percent, respectively, for the Hanford formation and Ringold unit E layers. Both values are within the range of values documented in previous investigations for the Hanford Site (*Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report* [PNL-10886]). Riverbed conductance values were also determined during calibration, separately for the stretches of the Columbia River within each OU, to reflect the variability in geologic conditions.

#### 5.8.2.5 Model Calibration

The groundwater flow model was calibrated to data included in the model data packages for each OU through a combined manual and automated process. The model calibration was facilitated by the use of *PEST Model-Independent Parameter Estimation* (Doherty, 2010) and post-processing programs that calculate water-level responses to stresses. The model was calibrated to data from January 2006 to June 2009 and was validated with data from July 2009 to December 2010. The calibration step focused on the transient response of water levels to changing stresses and how they compare to values measured at wells in each OU. In addition, maps of simulated water-level contours were compared to actual contoured data included in published reports. The manual comparison step was performed to ensure that the simulated hydraulic gradient magnitude and direction agree with prior independent interpretations.

### 5.8.3 Contaminant Plume Migration Simulations—No Action

Contaminant transport simulations, based on current groundwater flow patterns and assuming no remedial action, were run for Cr(VI) (Figure 5-7), strontium-90 (Figure 5-8), TCE (Figure 5-9), and nitrate (Figure 5-10) for predictive simulations up to 75 years for Cr(VI), TCE, and nitrate, and 150 years for strontium-90. The southern distribution of the nitrate plume may reflect past hydraulic gradients during the operations period (Figure 5-3). These model simulations indicate that Cr(VI) may persist in 100-F/IU groundwater for up to 75 years, strontium-90 for up to 150 years, TCE for up to 75 years, and nitrate for up to 75 years. The modeling results are consistent with observed migration patterns for all four groundwater COPCs, which suggest very slow movement in groundwater and persistent concentrations for nearly 50 years since reactor operations ceased.

## 5.9 Uncertainties that Apply to Groundwater and Vadose Zone Modeling

This uncertainty discussion is based primarily on the current vadose zone and groundwater modeling objectives, and the use of these models to evaluate future conditions under no action remediation scenarios. Conservative assumptions are used in developing the vadose zone and saturated zone models for the purpose of excluding portions of the uncertainty ranges in model formulation and parameterization that may underestimate the risk to surface water and groundwater resources. That is to say, conservative assumptions are used to bias the model results towards more protective values for use in remedial action decision-making.

### 5.9.1 Uncertainty in the Conceptual Site Model

Conceptual site model uncertainty is often the main uncertainty when using models to predict future contaminant transport. Assumed values for vadose zone and aquifer physical properties, together with assumed values for contaminant transport properties, contribute to overall predictive uncertainty. Assumptions of spatially invariant material properties are often necessary to obtain best-estimate predictions, despite the recognition that the geological processes that deposited the soil materials produce stratified and heterogeneous sequences. Consequently, local variation in vadose and/or aquifer material properties can result in actual contaminant distributions that vary from the transport simulations.

It is assumed that effective porosity and saturated hydraulic conductivity values are constant within a given stratigraphic unit when calculating SSLs and PRGs protective of groundwater and of surface water, as well as in converting groundwater flux (Darcy velocity) calculated by MODFLOW to average linear groundwater velocity for use in MODPATH and MT3DMS fate and transport calculations. It is acknowledged that heterogeneities in the form of lenses, bar structures, and overbank deposits are prevalent at a scale smaller than the model grid size employed for the 100-F/IU vadose zone flow and groundwater flow models. Such features can lead to locally faster contaminant movement than predicted by models that assume spatially invariant properties, although over broad areas, the average values for predictions will be similar whether these small-scale heterogeneities are represented in the model. This is one reason why models make better predictions of bulk-averaged quantities than they make of values at specific point locations and times.

The effects of these local-scale heterogeneities result in uncertainties on predictions of groundwater and surface water protection. The chances of SSLs and PRGs being too high to be protective are minimized to the practical extent possible through use of conservatism, such as selecting the lowest SSL and PRG resulting from the set of STOMP simulations performed over the range of representative stratigraphies and surface soil types. In addition, the effects are minimized using predictions that the models are better suited to simulating (e.g., area-wide average values and area-wide changes in concentrations) than predictions that by their nature are greatly impacted by such uncertainty or variability (such as point

concentrations at specific locations and times). Inferences drawn from the model simulations should be drawn with consideration made for the nature of these model outputs.

### 5.9.2 Uncertainty in Contaminant Transport Parameters

Parameters that affect contaminant transport include the $K_d$ value of the contaminant and soil porosity. Soil porosity is variable throughout the soil column based on compaction and heterogeneity. The more porous the soil, the faster the contaminant can potentially move. Porosity values used in modeling assume the highest values for the soil types present, thereby over-representing the rate of movement through the vadose zone.

The $K_d$ value represents the propensity for an analyte to move through the soil instead of binding to it. A high $K_d$ value is typically found in contaminants such as PAHs, which are generally considered hydrophobic. The lower the $K_d$, the more likely it is that the contaminant will move with water through the vadose zone. A $K_d$ value can vary based on the water quality (ionic strength) and chemistry (e.g., pH), the concentration of the contaminant, the type of sorbent, and the availability of sorption sites within the soil matrix. The $K_d$ values used in evaluating the transport were primarily based on the assumption of dilute concentrations of contaminants in moisture within the vadose zone. The values tend to represent the more mobile $K_d$ conditions for a particular contaminant.

### 5.9.3 Uncertainties, Assumptions, and Limitations Specific to Vadose Modeling

Uncertainties based on the numerical equations used in modeling are expected to be small. *Regulatory Basis and Implementation of a Graded Approach to Evaluation of Groundwater Protection* (DOE/RL-2011-50) provides a summary evaluation of the comparisons of field data and results to the model simulations of similar conditions using STOMP. The evaluations indicate that the STOMP code adequately simulates the natural processes present in the 100 Areas.

Assumptions within the model input parameters have an effect on the simulation outcomes. The key assumptions used for 100-F/IU are as follows, with other assumptions presented in Appendix F:

- The vadose zone is considered homogeneous in nature within hydrostratigraphic units, without accounting for the presence of thin, finer grained material, which can retard the downward migration of contaminants.

- Based on current revegetation activities, revegetation of a waste site after remediation is typically occurring within one to two growing seasons. In the recharge scenarios used in modeling, revegetation of the area is assumed to start after 5 years, with bare soil present for the first 5 years. This assumption results in more water infiltrating to the vadose zone than may actually occur.

- The irrigation recharge scenario, used as the basis for calculation of SSL values, assumes the start of irrigated agriculture 5 years following remedial activity. Even if irrigated agriculture were to commence in the future, it would be unlikely to start as early as 5 years following remedial action. Consequently, SSL values calculated using the irrigation recharge scenario are overprotective because the high recharge rate applied under this scenario at this early time results in higher peak groundwater concentrations (especially for mobile constituents) than would be calculated for a later irrigation start.

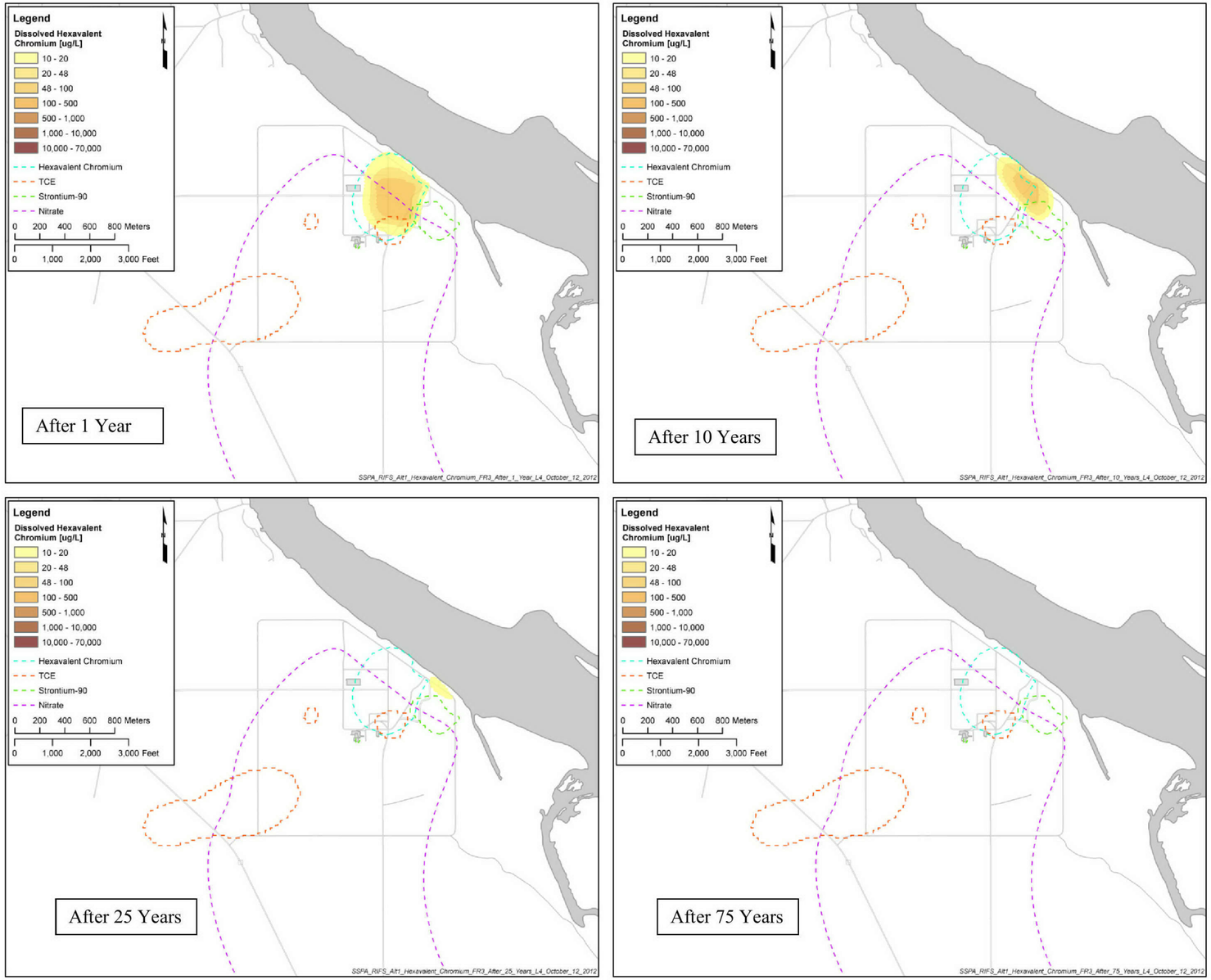


Figure 5-7. Model Simulated Cr(VI) Distribution in Unconfined Aquifer Groundwater

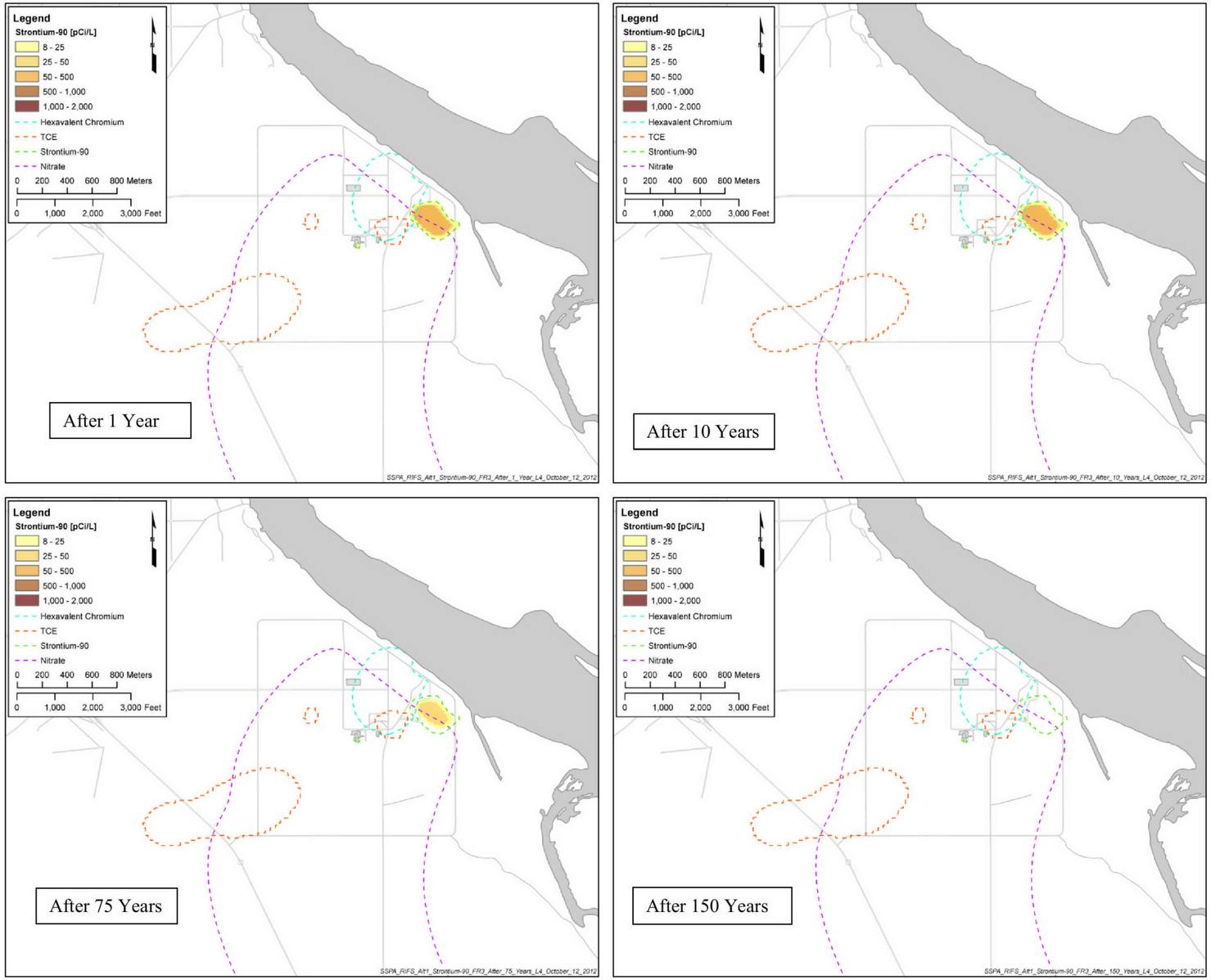


Figure 5-8. Model Simulation of Strontium-90 Distribution in Unconfined Aquifer Groundwater

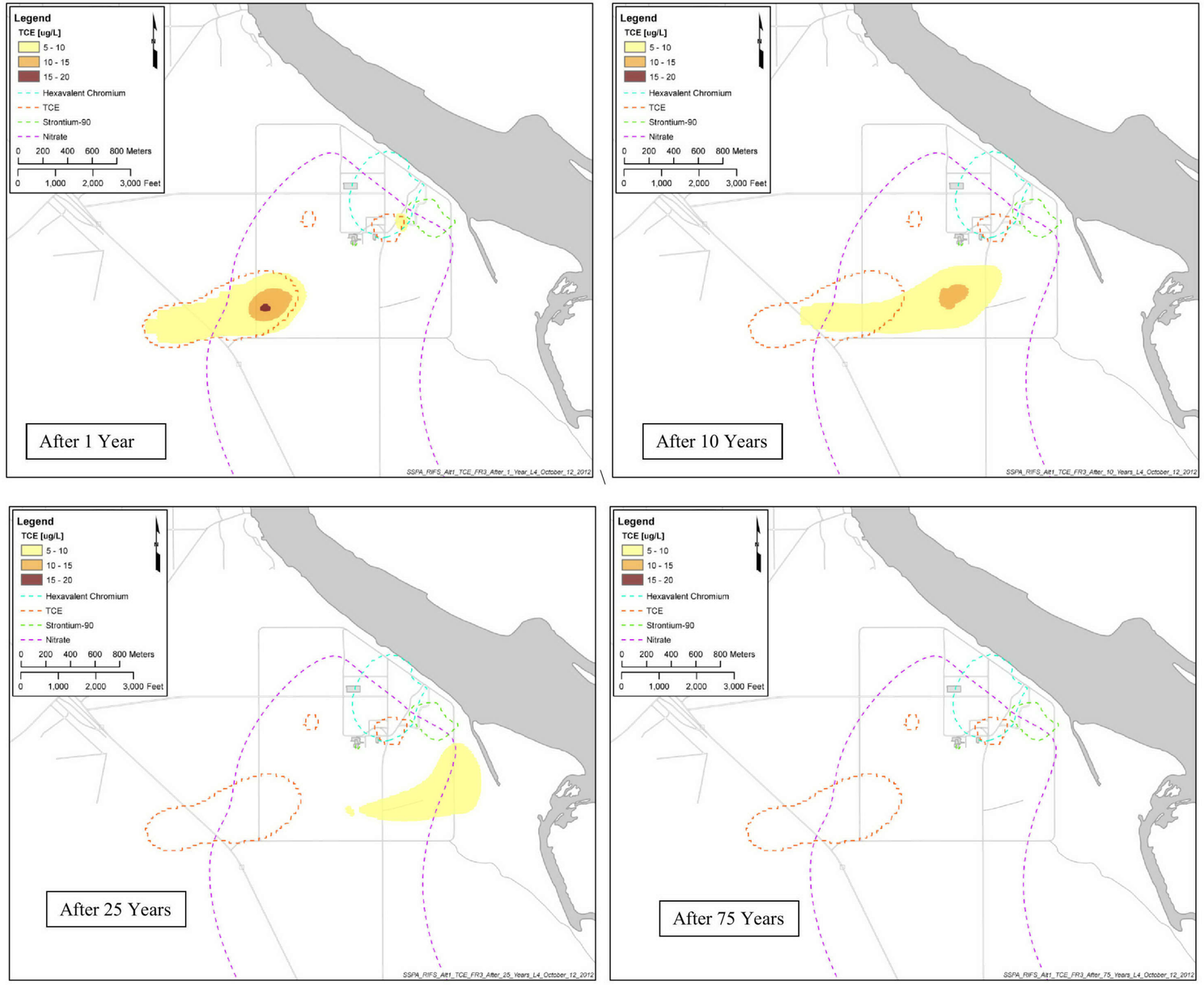


Figure 5-9. Model Simulation of TCE in Unconfined Aquifer Groundwater

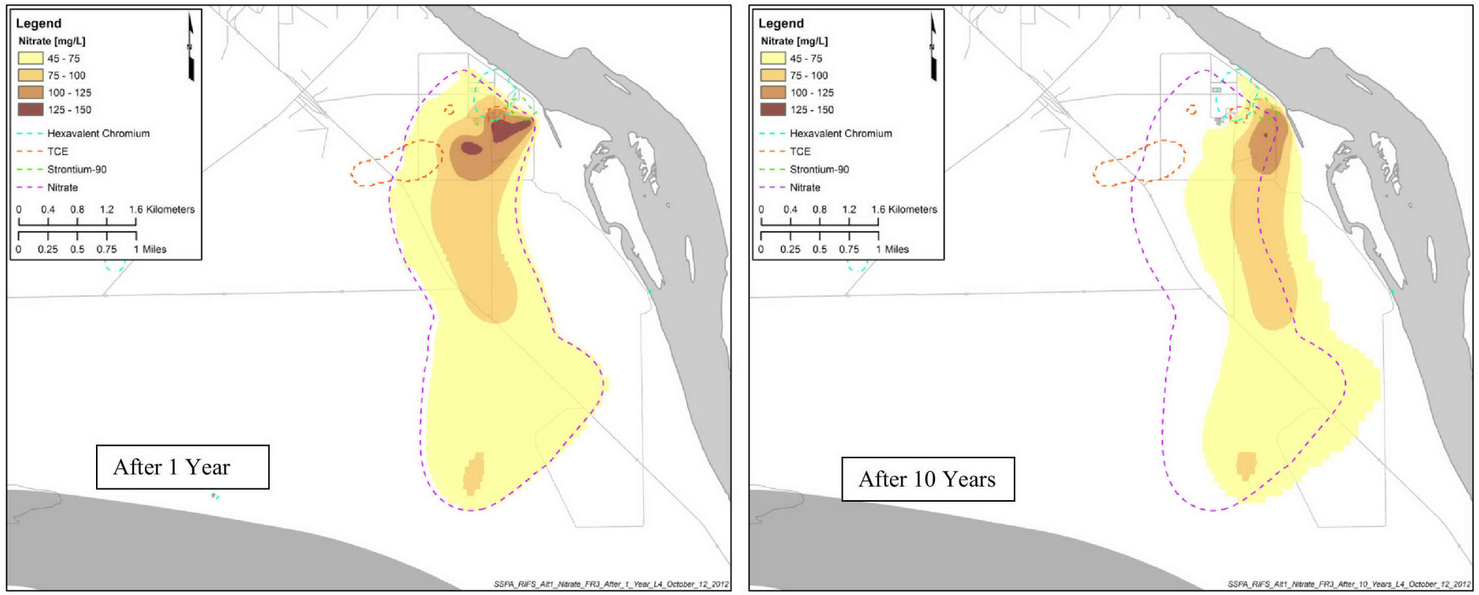


Figure 5-10. Model Simulation of Nitrate in Unconfined Aquifer Groundwater

- Groundwater is assumed to have negligible mixing with the Columbia River. In calculating the values for surface water protection, the point of calculation is in groundwater at the downgradient boundary of the waste site. No attenuation or decay of contaminants is assumed to occur between the downgradient boundary of the waste site and the river. This assumption results in higher SSL and PRG values, particularly those calculated for protection of surface water, than would be the case if a more realistic treatment of dilution and dispersion of contaminants during transport in the aquifer and mixing in the Columbia River had been included in the methodology.

- The native vegetation recharge scenario used in development of PRGs includes a progression from bare ground through a developing shrub-steppe plant community to a long-term, mature, shrub-steppe community. This surface cover may be subject to specific uncertainty because of the potential for wildfire effects. Wildfires occur periodically (and can be characterized by a recurrence frequency), and the effects of these events would likely result in a net increase of the long-term recharge rate to groundwater underlying affected areas. This effect is due to the removal of the mature plant communities at the ground surface (effectively to bare ground) in a fire event, followed by a plant recovery succession, and culminating in the mature shrub-steppe community if the time until the next fire event allows. The magnitude of this effect on average recharge rates is not quantified. The effect magnitude would depend on factors such as the fire event recurrence frequency, the intensity of individual fire events, and the recovery periods for specific plant communities. A typical fire cycle would include the fire year, during which the surface is assumed bare ground and recharge is maximized, followed by rapid establishment of cheatgrass (*Bromus tectorum*) over 1 to 2 years. Subsequent re-establishment of the young shrub-steppe community follows, with eventual development of the mature shrub-steppe. A realistic treatment of the fire cycle should address uncertainty in the fire recurrence frequency and moisture-holding capacity of the soil during frequent surface condition changes. To account for this uncertainty, the infiltration rates used in the vadose zone models are selected from the upper end of available rates based on about 30 years of field measurements (lysimeter studies) and long-term isotopic recharge studies that necessarily incorporate the effects of the history of all land surface changes at the measurement sites, including past wildfires. Moreover, a realistic treatment of the fire cycle should also address the transient changes in recharge resulting from rapid surface condition changes. Direct application of recharge rates measured for long-term, steady-state conditions to scenarios with frequent surface condition changes ignores the considerable moisture-retention capacity and plant water uptake potential (where plants recolonize following a disturbance) of the vadose zone. A demonstration of this process is shown by lysimetry measurements at the Hanford Site in "Variations in Water Balance and Recharge Potential at Three Western Desert Sites" (Gee et al., 1994). That study demonstrated that 3 years of increasing infiltration water was retained in the upper vadose zone following vegetation removal with maintenance of bare soil conditions, followed by rapid water removal through transpiration of recolonizing plants.

- The initial conditions for matric potential at the start of the flow and transport simulations represent a wetter vadose zone than is expected for such gravel-dominated sediments in a semiarid climate, thus allowing significantly higher water and solute flux values. This assumption is expected to result in more protective SSL and PRG values.

- The median hydraulic gradient value for each source area may be too large (by several fold) for waste sites near the Columbia River and may be several times too large for waste sites that are far inland from the river. This assumption is expected to result in varying impact of SSL and PRG values, rendering these more or less conservative for specific individual waste sites depending on their actual

location relative to the river. However, taken in context with other conservative assumption noted above, this is not expected to result in SSL or PRG values that are nonprotective.

- The assumption of a 5 m (16 ft) thick aquifer for calculating concentrations in the groundwater may be non-conservative for those waste sites at locations where the aquifer thickness is less than 5 m (16 ft). As noted in Section 3.4.2, the saturated thickness of the unconfined aquifer thins near the river. The mapping of aquifer thickness presented in Section 3.4.2 shows, for times of year with lower river stages (for example, September) that the 5 m (16 ft) assumption is, at least seasonally, not representative. The process for developing the representative stratigraphic columns for the 100-F waste sites (Section 5.4.1.2) that incorporated a 5 m (16 m) aquifer included consideration of the seasonal fluctuation in aquifer thickness; however, the conservatism was placed on minimizing the vadose zone thickness by using the highest annual water table. This was, at least for some portion of the year, non-representative with respect to dilution in the saturated zone.

### 5.9.4 Uncertainties, Assumptions, and Limitations Specific to Groundwater Modeling

Uncertainties based on the numerical equations used in modeling are expected to be small. A groundwater flow and contaminant transport model has been developed and calibrated for remedy design evaluation purposes in the 100 Areas. The model development and calibration is documented in a comprehensive modeling report (*Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model* [SGW-46279]).

The groundwater flow model grid encompasses all 100 Area OUs. The model finite-difference grid is constructed so the north and northeast boundaries of the flow model parallel and abuts the Columbia River. The model extends southward, toward Gable Butte and Gable Mountain. The grid spacing is relatively coarse (about 100 m [328 ft]) throughout much of the domain, but it is refined (15 m [49.2 ft]) in each 100 Area OU to support remedy evaluations.

Assumptions within the model input parameters have an effect on the simulation outcomes. The key assumptions used for 100-F/IU are as follows, with other assumptions and the specific input parameters presented in Appendix F:

- Predictive simulations were based on transient-state (i.e., time-varying) conditions in the aquifer that reflect water-level changes due to river-stage variation. The modeling period corresponds to 150 years (approximate CYs 2010 to 2160). For the period 2010 to 2035, the modeling period consists of a series of 12 monthly stress periods that are repeated in the same sequence. The stress periods correspond to monthly average river stages, each representing the average river stage for the particular calendar month over the period from 2006 to 2010 (excluding 2007 values, when the river-stage variation pattern was inconsistent with the other years). It is assumed that these conditions are representative of the typical conditions in the field and that future conditions will not vary significantly from these conditions.

- Groundwater flow is simulated as three-dimensional using four layers to represent the Hanford formation (always present in Layer 1) and Ringold unit E (typically represented by Layers 2 through 4). The base of the model is assumed to be the top of the RUM where present and the top of the basalt where the RUM is absent. At 100-F/IU, the water table fluctuates between Ringold unit E and the Hanford formation.

- The principal aquifer property specified in the flow model is the spatially varying hydraulic conductivity of the saturated aquifer materials. Estimates of hydraulic conductivity compiled as part of the model data package were tabulated and assigned to their corresponding aquifer unit.

- The mean values for the aquifer hydraulic conductivity that resulted from the model calibration process are 100 m/d (328 ft/d) for Ringold unit E and 100 m/d (328 ft/d) for the Hanford formation.

- Areal recharge from precipitation was specified based on information included in *Groundwater Data Package for Hanford Assessments* (PNNL-14753). An electronic version of the recharge package developed in this report was obtained, and the data were spatially distributed to the model grid cells and subsequently adjusted during model calibration. Based on the results of the model calibration, the recharge value was set equal to 12 mm/yr throughout much of the model domain (representing a spatial average of present day recharge conditions; consequently this value is not directly comparable to vadose zone simulation recharge rates for more limited spatial extent or other time periods).

- Effective porosity and specific yield values for the entire aquifer were identified from published sources and revised during the model calibration, and are equal to 18 and 10 percent, respectively. Both values are within the range of values documented in previous investigations for the Hanford Site (*Development of a Three-Dimensional Ground-Water Model of the Hanford Site Unconfined Aquifer System: FY 1995 Status Report* [PNL-10886]).

- The initial distribution of each COPC in groundwater within the 100-FR-3 OU was obtained using maximum sampled COC concentrations at each monitoring location during the period from 2009 through 2010. Uncertainties with estimating initial contaminant distribution in groundwater are primarily associated with the interpolation of individual sample contaminant concentration and the representativeness of individual samples with respect to the region surrounding the sample. The sample contaminant concentration is a minor contributor to overall uncertainty due to stringent quality controls applied by analytical laboratories. However, the representativeness in time and space of samples, together with the uncertainty associated with the interpolation of those point sample values to make a continuous distribution, are likely the greatest contributors to overall uncertainty in the initial contaminant distribution.

- It is assumed that no continuous source is present in the aquifer or vadose zone that would affect the contaminant distribution.

- The present-day nitrate plume distribution suggests that the model lacks some features, events, and processes that can explain how this plume migrated in a predominately southern direction to date. The model results predict future migration will be predominately toward the east. While past groundwater mounding can account for some of this southern migration, that event alone is inadequate to fully explain the plume migration to date. Well density is low and sampling is infrequent (annual only) in the southern reaches of this plume. While there is uncertainty in the model representation of the nitrate plume, there is sufficient information available to evaluate alternatives.

## 5.10 Summary of Contaminant Fate and Transport

Intentional and unintentional releases of liquid and solid waste associated with nuclear material production, and releases associated with the EAF, represent the primary contaminant sources at 100-F OUs. The releases associated with the reactor ended in 1965 and the EAF closed in 1976, but resulted in the presence of secondary contaminant sources in the vadose zone and contaminant plumes in unconfined aquifer groundwater. No 100-IU-2/IU-6 waste sites have been identified that could pose a threat to groundwater or surface water quality. Other transport mechanisms have been determined to pose no continuing risk based on the extensive remediation conducted to date.

The waste site EPCs for each remediated waste site and COPC were compared to the PRGs under the 100:0 and 70:30 waste site distribution scenarios. After excluding COPCs with peak concentration times greater than 1,000 years, no waste sites were identified with an EPC greater than groundwater and surface water protection PRG. This evaluation included site-specific modeling of Cr(VI) at 116-F-14. Results of that site-specific evaluation showed that this site would (1) not cause an exceedance of groundwater or surface water quality standards under the reasonably anticipated land use (conservation), (2) would not cause an exceedance of the groundwater protection standard under irrigated agriculture land use, but (3) could pose a risk of exceeding the surface water quality standard under irrigated agriculture land use. Comparison to the surface water quality standard did not account for attenuation mechanisms between the waste site and the river; this is conservatism in this analysis.

In the absence of groundwater remediation, groundwater contaminant plume simulations indicate that Cr(VI) is estimated to persist in groundwater at concentrations greater than the 10 µg/L surface water quality standard for up to 35 years. Strontium-90 is estimated to persist at concentrations above the 8 pCi/L MCL for up to 150 years. TCE is estimated to persist at concentrations above the 5 µg/L MCL for up to 45 years. Nitrate (expressed as nitrate) is estimated to persist at concentrations above the 45 mg/L MCL for up to 80 years. Note that these durations are based on model-predicted maximum concentrations ($C_{max}$); other statistics (e.g., 90$^{th}$ percentile or $C_{90}$) are attained in less time.

*Looking Ahead In This Document*

Chapter 5 described and predicted fate and transport, (i.e., how these contaminants will migrate through the environment). The potential risks depend on specific receptors, as well as exposure times and patterns that might bring receptors and contaminants into contact. The ways that the contaminants could encounter HHE are called “pathways.”

Chapter 6 addresses the human health pathway, and evaluates potential impacts. Chapter 7 addresses the biological receptor pathway and evaluates how plant, animal, bird, or invertebrate species might be affected. Chapter 8 identifies technologies that could remove contaminants from the setting or interrupt these pathways. Chapter 9 develops and evaluates remedial alternatives using these technologies. Chapter 10 compares the alternatives that can best address the problem. This evaluation and comparison will support a remedial decision to implement actions to protect HHE.

# 6 Human Health Risk Assessment

*Highlights*

- Principal soil contaminants identified at one or more waste sites through the risk assessment included radionuclides, metals, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons.
- The baseline risk assessment identified Cr(VI), nitrate, strontium-90, tritium, and trichloroethene as groundwater COPCs for evaluation of potential remedial technologies in the FS.
- Data and process knowledge indicate that human health PRGs would be exceeded at unremediated waste sites and provide the basis for action.

The integration of past and current HHRAs supports the development of remedial alternatives for waste sites and contaminated groundwater in the 100-F/IU area. These risk assessments have been integrated with the cleanups performed under the Interim Action RODs to identify the need for further remedial action and, if needed, to develop PRGs.

As described in the previous chapters, the remedial actions completed to date in the River Corridor were implemented primarily under Interim Action RODs. There is a requirement under CERCLA to perform a baseline risk assessment (BRA) to characterize current and potential threats to HHE before final action RODs for final remedies can be issued. The RCBRA (DOE/RL-2007-21) was prepared to address the regulatory requirement that a BRA be performed. The RCBRA (DOE/RL-2007-21, Volume II) is a comprehensive HHRA for the River Corridor considering relevant sources of contamination, exposure pathways, and contaminants to evaluate current and potential future risks posed by hazardous substance releases. The following is the purpose of the RCBRA (DOE/RL-2007-21, Volume II), as described in Section 1.1 of RCBRA (DOE/RL-2007-21, Volume II):

> *The purpose of the RCBRA is to characterize current and potential future risks to human health and the environment that may be posed by releases of hazardous substances in the River Corridor of the Hanford Site. DOE is required to assess human and ecological risk under CERCLA, Resource Conservation and Recovery Act of 1976 (RCRA), National Environmental Policy Act of 1969, and DOE orders. The "National Oil and Hazardous Substances Contingency Plan" (40 Code of Federal Regulations [CFR] 300), which implements CERCLA, specifically requires a site-specific baseline risk assessment to determine the need for action at sites, determine levels of contaminants that can remain onsite and still be protective, and provide a basis for comparing health effects of various cleanup alternatives (40 CFR 300.430[d][4]).*

Per the risk assessment guide (EPA/540/1-89/002), a BRA is an "analysis of the potential adverse health effects (current or future) caused by hazardous substance releases from a site in the absence of any actions to control or mitigate these releases (i.e., under an assumption of no action)."

The BRA is part of the CERCLA RI/FS process. The RI/FS is the methodology that the CERCLA program has established for characterizing the nature and extent of contamination associated with releases of hazardous substances to the environment; for assessing the potential risks posed by the environmental contamination to human and ecological receptors; and for developing and evaluating remedial options. Because the RI/FS is a process designed to support risk management decision making for CERCLA sites, the assessment of human health and environmental risk serves an essential role in the RI/FS process. The BRA provides information to assist in the development, evaluation, and selection of appropriate response alternatives. The results of the BRA are used for the following:

- Determine whether additional response action is necessary at a site.
- Support development of PRGs.

- Support selection of the "no action" remedial alternative where it is appropriate.
- Document the magnitude of risk and primary contributors (e.g., chemicals and exposure pathways) to risk at a site.

Interim Action RODs were written for River Corridor sites to allow cleanup activities to move forward as potential risks were identified. However, final remedy selection (development of Final Action RODs) must be completed in order for the NPL (40 CFR 300, Appendix B) CERCLA sites in the River Corridor to reach final closeout. One of the key evaluations needed to establish Final Action RODs for sites in the River Corridor was a BRA (*Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL-2004-37]). The RCBRA HHRA (DOE/RL-2007-21, Volume II) and the companion ERA (DOE/RL-2007-21, Volume I) provided an evaluation of ecological and human health risk from residual contamination at waste sites remediated under the Interim Action RODs and from potentially affected environmental media under various exposure scenarios. Unacceptable risks are present in the River Corridor at waste sites that are identified in the Interim Action RODs but have yet to be remediated. The determination of the presence of unacceptable risk and basis for action at yet-to-be remediated waste sites is supported by field investigation data as well as information gathered through implementation of the observational-approach soil cleanup actions in the River Corridor over the past 15 years. The site-specific risk information provided by the RCBRA (DOE/RL-2007-21) would be used to support Final Action RODs for the River Corridor.

## 6.1 Role of the RCBRA and the RI/FS Risk Assessment

The RCBRA (DOE/RL-2007-21) provided the following range of analyses:

- Assessment of residual risks for remediated waste sites using the unrestricted land use exposure scenario that was the basis for the RAGs for the Interim Action ROD cleanups in the 100 Areas
- Assessment of risks for several yet-to-be remediated waste sites using a broad range of exposure scenario
- Assessment of residual risks for remediated waste sites and broad areas[1] using a broad range of exposure scenarios

Portions of these analyses were considered in the HHRA approach used to develop soil PRGs that are presented in the RCBRA (DOE/RL-2007-21, Volume II). The following issues are addressed in this chapter as part of the integration of RCBRA (DOE/RL-2007-21) and the RI/FS, which will support the development of Final Action RODs for the 100-Area decision areas:

- Incorporation of PRG values from the RCBRA (DOE/RL-2007-21) for radioisotopes and chemicals based on updated regulatory guidance
- Inclusion of all decision units[2] associated with a remediated waste site
- Inclusion of analytical data from focused sampling designs

[1] The term "broad area" is used in the RCBRA (DOE/RL-2007-21) to refer to an exposure area that could potentially be as large as an individual Interim Action ROD decision area or as large as the entire River Corridor.

[2] The floor and sidewalls of an excavated waste site are divided into one or more decision units. A sample design is developed for each decision unit. See Section 6.2.2.2 for additional information.

- Analysis time frame (i.e., waste sites cleaned up after the analysis conducted in the RCBRA [DOE/RL-2007-21])
- Use of EPCs consistent with the waste site decision units (e.g., shallow zone, deep zone) and based on current EPA guidance

The following sections discuss the integration of the RCBRA (DOE/RL-2007-21) and the RI/FS risk assessment:

- Section 6.1.1 summarizes the evaluation of residual risks performed in the RCBRA for waste sites cleaned up under the interim action ROD. The results from this evaluation have been compared with the PRGs developed in the RCBRA (DOE/RL-2007-21) for use in the RI/FS.
- Section 6.1.2 describes the scenario that reflects unrestricted land uses in the River Corridor and their associated uncertainties and how they have been incorporated into the RI/FS.
- Section 6.1.3 describes how scenarios reflecting reasonably anticipated future land uses, presented in the RCBRA, have been incorporated into the RI/FS.
- Section 6.1.4 describes how other unrestricted land use scenarios (subsistence farmer and Native American resident) are used in the RCBRA (DOE/RL-2007-21).

The HHRA supporting the RI/FS is presented in two sections. Section 6.2 presents the methods and the results for the soil risk assessment and Section 6.3 presents the methods and results for the groundwater risk assessment. It should be noted that PRGs for the residential scenario used in the soil risk assessment incorporate exposure assumptions that were updated to reflect current EPA guidance as described in Section 6.1.2.

The soil risk assessment (Section 6.2) provides the data analysis (Section 6.2.1), estimated EPCs (Section 6.2.2), exposure assessment (Section 6.2.3), toxicity assessment (Section 6.2.4), risk characterization (Section 6.2.5), and the uncertainties assessment (Section 6.2.6).

The groundwater risk assessment supporting the RI/FS (Section 6.3) discusses findings and uncertainties of the RCBRA (DOE/RL-2007-21) (Section 6.3.1), as the Integrated Work Plan (DOE/RL-2008-46) adds activities that would help reduce uncertainties, verify conclusions, and ensure that no contaminants were inadvertently overlooked based on the use of the existing data set. The groundwater risk assessment involves the following steps: identification of COPCs (Section 6.3.2), exposure assessment (Section 6.3.3), toxicity assessment (Section 6.3.4), risk characterization (Section 6.3.5), risk characterization using action levels (Section 6.3.6), risk characterization results of the EPA tap water scenario (Section 6.3.7), and the uncertainties assessment (Section 6.3.8). The results of Section 6.3 will be used to identify COPCs, which represent contaminants that will be evaluated in the FS to define the COCs and guide the selection of remedial alternatives.

Section 6.4 presents conclusions of the riparian and near-shore environment from the RCBRA (Section 6.4.1) and conclusions from the CRC (Section 6.4.2). Section 6.5 presents a summary and conclusions for the soil risk assessment (Section 6.5.1) and the groundwater risk assessment (Section 6.5.2).

### 6.1.1 Evaluation of Residual Risks for Interim Action ROD Cleanups from the RCBRA

This section discusses the results of the screening level evaluation presented in Chapter 2 of the RCBRA (DOE/RL-2007-21, Volume II). It also compares the results from screening level evaluation to the methodology used to develop the interim action RAGs and describes how analytical data from

CVP/RSVP were used in the screening evaluation. Finally, the screening level risk results from the RCBRA (DOE/RL-2007-21, Volume II) are compared to the results of the soil risk assessment. The risk results from the evaluation are based on guidance and exposure assumptions that have been updated since the Interim Action RAGs were published. The methods used in the supplemental risk evaluation are described in Sections 6.1.2 and 6.1.3.

Chapter 2 of the RCBRA (DOE/RL-2007-21, Volume II) presents a screening-level assessment of residual cancer risks and noncancer hazards for the remediated waste sites using the exposure scenarios that were the basis of the residential RAGs for the Interim Action ROD cleanups in the 100 Areas. This assessment was done to provide information about the residual risks and noncancer hazards associated with post-interim action conditions at the remediated waste sites and help assess whether residual conditions are protective of human health.

Interim action ROD cleanups for the 100 Areas were based on an unrestricted scenario that was the basis for the RAGs. The Interim Action ROD residential scenario for radionuclides is a Rural Residential scenario that, in addition to direct contact, includes food chain exposure pathways (e.g., ingestion of homegrown produce, beef, and milk). The Interim Action ROD residential scenario for chemicals is based on the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]). The MTCA (WAC 173-340) Method B direct contact levels are based solely on incidental soil ingestion and do not address the food exposure pathways that were included for the radionuclide Rural Residential scenario[3]. The RAG for arsenic was based on the MTCA Method A soil cleanup level ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]). The RAG for lead was calculated using *Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children* (EPA/540/R-93/081).

CVPs or RSVPs were prepared to document completion of Interim Action ROD cleanup actions in accordance with the applicable decision document and support waste site reclassification. The screening-level calculations presented in Chapter 2 of the RCBRA (DOE/RL-2007-21, Volume II) use the Interim Action ROD risk assessment models, but differ from the calculations used in the CVPs and RSVPs to document the Interim Action ROD cleanups.

Forty-four waste sites from the 100-F/IU Source OUs were evaluated in the RCBRA (DOE/RL-2007-21, Volume II). One hundred additional waste sites with closeout verification data have been remediated at the 100-F/IU Source OU since 2005, and are not addressed in the RCBRA. An additional nine sites in the 100-F/IU Source OU have been remediated, but are included in another waste site's sampling and closeout documentation. From the RCBRA evaluation, residual cumulative cancer risks from chemicals evaluated in the RCBRA (DOE/RL-2007-21, Volume II) are less than $1 \times 10^{-5}$ using the Interim Action ROD residential scenario (i.e., MTCA [WAC 173-340] Method B unrestricted use scenario) with the exception of two waste sites (100-F-37 and 116-F-1). Residual cumulative cancer risks from radionuclides for all remediated waste sites are less than $1 \times 10^{-4}$ based on the Interim Action ROD Rural Residential scenario with the exception of the following four waste sites:

- 116-F-6
- 116-F-9
- 116-F-14
- UPR-100-F-2

[3] Note that for beryllium, cadmium, and Cr(VI), the Interim Action RAG for direct contact is based on the inhalation pathway.

The noncancer hazard indexes (HIs) for chemicals evaluated in the RCBRA (DOE/RL-2007-21) do not exceed a threshold of 1.0 at the 44 remediated waste sites. A summary of the risk assessment results for a residential scenario using approaches from both RCBRA (DOE/RL-2007-21, Volume II) and the RI/FS is provided in Table 6-1 through Table 6-3.

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Chemical Carcinogens

| Waste Site Name | RI/FS Decision Unit | Chemical Carcinogens and Cancer Risk Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Chemical Risk | RCBRA Chemical Risk Driver | RI/FS Chemical Risk | RI/FS Chemical Risk Driver |
| **100-F Source OU Waste Sites** | | | | | |
| 100-F-2 | Shallow | -- | -- | -- | -- |
| 100-F-7 | Shallow Focused | $4 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$) | $4.1 \times 10^{-6}$ | Arsenic ($4.1 \times 10^{-6}$) |
| 100-F-9 | Shallow Focused | $4 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$) | $3.9 \times 10^{-6}$ | Arsenic ($3.9 \times 10^{-6}$) |
| 100-F-11 | Shallow Focused | -- | -- | -- | -- |
| 100-F-12 | Shallow Focused | $4 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$) | $4.3 \times 10^{-6}$ | Arsenic ($4.2 \times 10^{-6}$) |
| 100-F-14 | Shallow Focused | $3 \times 10^{-6}$ | Arsenic ($3 \times 10^{-6}$) | $2.9 \times 10^{-6}$ | Arsenic ($2.9 \times 10^{-6}$) |
| 100-F-15 | Shallow | -- | -- | -- | -- |
| 100-F-16 | Shallow Focused | -- | -- | -- | -- |
| 100-F-18 | Shallow Focused | $3 \times 10^{-6}$ | Arsenic ($3 \times 10^{-6}$) | $2.6 \times 10^{-6}$ | Arsenic ($2.6 \times 10^{-6}$) |
| 100-F-19:1 | Shallow | -- | -- | -- | -- |
| 100-F-19:2 | Shallow | -- | -- | -- | -- |
| | Shallow Focused | Not Evaluated | Not Evaluated | -- | -- |
| 100-F-23 (RCBRA) 141-C (RI/FS) | Shallow | -- | -- | $6.3 \times 10^{-6}$ | Arsenic ($5.6 \times 10^{-6}$)-- |
| 100-F-24 | Shallow | -- | -- | -- | -- |
| 100-F-25 | Shallow | -- | -- | -- | -- |
| 100-F-26:1 | Shallow Focused | $5 \times 10^{-6}$ | Arsenic ($5 \times 10^{-6}$) | $5.4 \times 10^{-6}$ | Arsenic ($5.4 \times 10^{-6}$) |
| 100-F-26:2 | Shallow Focused | $3 \times 10^{-6}$ | Arsenic ($3 \times 10^{-6}$) | $3.2 \times 10^{-6}$ | Arsenic ($3.2 \times 10^{-6}$) |
| 100-F-26:5 | Shallow Focused | $3 \times 10^{-6}$ | Arsenic ($3 \times 10^{-6}$) | $3.5 \times 10^{-6}$ | Arsenic ($3.5 \times 10^{-6}$) |
| 100-F-26:7 | Shallow | $4 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$) | $2.9 \times 10^{-6}$ | Arsenic ($2.9 \times 10^{-6}$) |
| | Shallow Focused | Not Evaluated | Not Evaluated | $5.0 \times 10^{-6}$ | Arsenic ($5.0 \times 10^{-6}$) |
| 100-F-35 | Shallow | -- | -- | -- | -- |
| 100-F-37 | Shallow Focused | $3 \times 10^{-5}$ | Arsenic ($3 \times 10^{-5}$) | $2.6 \times 10^{-5}$ | Arsenic ($2.6 \times 10^{-5}$) |
| 100-F-38 | Shallow Focused | $4 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$) | $3.7 \times 10^{-6}$ | Arsenic ($3.6 \times 10^{-5}$) |

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Chemical Carcinogens

| Waste Site Name | RI/FS Decision Unit | Chemical Carcinogens and Cancer Risk Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Chemical Risk | RCBRA Chemical Risk Driver | RI/FS Chemical Risk | RI/FS Chemical Risk Driver |
| 116-F-1 | Shallow | $1 \times 10^{-5}$ | Arsenic ($1 \times 10^{-5}$) | $8.9 \times 10^{-6}$ | Arsenic ($8.9 \times 10^{-6}$) |
| 116-F-2 | Shallow | -- | -- | -- | -- |
| 116-F-3 | Shallow | -- | -- | -- | -- |
| 116-F-4 | Shallow Focused | -- | -- | -- | -- |
| 116-F-5 | Shallow | $3 \times 10^{-6}$ | Arsenic ($3 \times 10^{-6}$) | $2.6 \times 10^{-5}$ | Arsenic ($2.6 \times 10^{-5}$) |
| 116-F-6 | Shallow | -- | -- | -- | -- |
| 116-F-9 | Shallow | -- | -- | -- | -- |
| 116-F-10 | Shallow | -- | -- | -- | -- |
| 116-F-14 | Shallow | $4 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$) | $4.0 \times 10^{-6}$ | Arsenic ($4.0 \times 10^{-6}$) |
| 118-F-8:1 | Shallow | $1 \times 10^{-6}$ | None | $3.0 \times 10^{-8}$ | None |
| 1607-F2 | Shallow | -- | -- | -- | -- |
| 1607-F6 | Shallow | $8 \times 10^{-7}$ | None | $6.9 \times 10^{-7}$ | None |
| UPR-100-F-2 | Shallow | -- | -- | -- | -- |
| **100-IU-2 Source OU and 100-IU-6 Source OU Waste Sites** | | | | | |
| 600-107 | Shallow Focused | -- | -- | -- | -- |
| 600-128 | Shallow Focused | $3 \times 10^{-6}$ | Arsenic ($3 \times 10^{-6}$) | $3.3 \times 10^{-6}$ | Arsenic ($3.3 \times 10^{-6}$) |
| 600-131 | Shallow Focused | $5 \times 10^{-6}$ | Arsenic ($5 \times 10^{-6}$) | $4.8 \times 10^{-6}$ | Arsenic ($4.8 \times 10^{-6}$) |
| 600-132 | Shallow Focused | $4 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$) | $4.4 \times 10^{-6}$ | Arsenic ($3.9 \times 10^{-6}$) |
| 600-181 | Shallow Focused | $5 \times 10^{-6}$ | Arsenic ($5 \times 10^{-6}$) | $4.5 \times 10^{-6}$ | Arsenic ($4.5 \times 10^{-6}$) |
| 600-190 | Shallow Focused | $6 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$)<br>Aroclor-1254 ($2 \times 10^{-6}$) | $6.8 \times 10^{-6}$ | Arsenic ($3.8 \times 10^{-6}$)<br>Aroclor-1254 ($2.2 \times 10^{-6}$) |
| 600-204 | Shallow Focused | $4 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$) | $4.1 \times 10^{-6}$ | Arsenic ($4.1 \times 10^{-6}$) |
| 600-23 | Shallow | $7 \times 10^{-6}$ | Arsenic ($4 \times 10^{-6}$)<br>Aroclor-1254 ($3 \times 10^{-6}$) | $4.3 \times 10^{-6}$ | Arsenic ($4.3 \times 10^{-6}$) |
| | Shallow Focused | Not Evaluated | Not Evaluated | $6.4 \times 10^{-6}$ | Arsenic ($3.8 \times 10^{-6}$)<br>Aroclor-1254<br>($2.6 \times 10^{-6}$) |
| 628-1 | Shallow Focused | $5 \times 10^{-6}$ | Arsenic ($5 \times 10^{-6}$) | $4.5 \times 10^{-6}$ | Arsenic ($4.5 \times 10^{-6}$) |
| JA Jones | Shallow | -- | -- | -- | -- |
| | Shallow Focused | Not Evaluated | Not Evaluated | -- | -- |

Table 6-1. Summary of Residential Scenario Risk Assessment Results for Chemical Carcinogens

| Waste Site Name | RI/FS Decision Unit | Chemical Carcinogens and Cancer Risk Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Chemical Risk | RCBRA Chemical Risk Driver | RI/FS Chemical Risk | RI/FS Chemical Risk Driver |

Note: Chemical drivers shown have an associated risk greater than 1 × 10-6.

The risk value for the individual drivers is shown in parentheses after the name of the risk driver chemical.

Risks are based on reasonable maximum EPCs.

Source: RCBRA data: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*, Table 2-10.

RI/FS data: Tables G-27, G-48, and G-49 (Appendix G).

600-235 was evaluated in DOE/RL-2007-21, Volume II as 100-F/IU site; however, it has not been officially assigned to an OU and is therefore not included in this table or the RI/FS.

JA Jones was included in DOE/RL-2007-21, Volume II as a 300 Area OU waste site; however, it has subsequently been reassigned to the 100-IU-6 OU and is therefore included in this table and the 100-F/IU RI/FS.

Not Evaluated = Focused decision units were not evaluated in the RCBRA.

-- = carcinogenic COPCs were not identified

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Table 6-2. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens

| Waste Site Name | RI/FS Decision Unit | Noncancer Hazard Index and Noncancer Hazard Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Hazard Index | RCBRA Chemical Hazard Driver | RI/FS Hazard Index | RI/FS Chemical Hazard Driver |
| **100-F Source OU Waste Sites** | | | | | |
| 100-F-2 | Shallow | -- | -- | -- | -- |
| 100-F-7 | Shallow Focused | 0.12 | None | 0.89 | None |
| 100-F-9 | Shallow Focused | 0.12 | None | 0.95 | None |
| 100-F-11 | Shallow Focused | -- | -- | <0.01 | None |
| 100-F-12 | Shallow Focused | 0.11 | None | 1.01 | None |
| 100-F-14 | Shallow Focused | 0.09 | None | 1.06 | None |
| 100-F-15 | Shallow | 0.002 | None | <0.01 | None |
| 100-F-16 | Shallow Focused | 0.002 | None | <0.01 | None |
| 100-F-18 | Shallow Focused | 0.08 | None | 0.68 | None |
| 100-F-19:1 | Shallow | 0.002 | None | <0.01 | None |

Table 6-2. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens

| Waste Site Name | RI/FS Decision Unit | Noncancer Hazard Index and Noncancer Hazard Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Hazard Index | RCBRA Chemical Hazard Driver | RI/FS Hazard Index | RI/FS Chemical Hazard Driver |
| 100-F-19:2 | Shallow | 0.02 | None | 0.02 | None |
| | Shallow Focused | | | <0.01 | None |
| 100-F-23 (RCBRA) 141-C (RI/FS) | Shallow | -- | -- | 0.94 | None |
| 100-F-24 | Shallow | -- | -- | -- | -- |
| 100-F-25 | Shallow | 0.01 | None | <0.01 | None |
| 100-F-26:1 | Shallow Focused | 0.15 | None | 1.12 | None |
| 100-F-26:2 | Shallow Focused | 0.10 | None | 0.92 | None |
| 100-F-26:5 | Shallow Focused | 0.10 | None | 0.73 | None |
| 100-F-26:7 | Shallow | 0.11 | None | 0.93 | None |
| | Shallow Focused | Not Evaluated | Not Evaluated | 1.05 | None |
| 100-F-35 | Shallow | -- | -- | 0.01 | None |
| 100-F-37 | Shallow Focused | 0.77 | None | 0.77 | None |
| 100-F-38 | Shallow Focused | 0.14 | None | 0.97 | None |
| 116-F-1 | Shallow | 0.27 | None | 0.25 | None |
| 116-F-2 | Shallow | 0.01 | None | <0.01 | None |
| 116-F-3 | Shallow | 0.003 | None | <0.01 | None |
| 116-F-4 | Shallow Focused | 0.01 | None | <0.01 | None |
| 116-F-5 | Shallow | 0.08 | None | 1.71 | None |
| 116-F-6 | Shallow | 0.002 | None | <0.01 | None |
| 116-F-9 | Shallow | -- | -- | -- | -- |
| 116-F-10 | Shallow | 0.01 | None | <0.01 | None |
| 116-F-14 | Shallow | 0.12 | None | 0.45 | None |
| 118-F-8:1 | Shallow | 0.02 | None | 0.02 | None |
| 1607-F2 | Shallow | -- | -- | -- | -- |
| 1607-F6 | Shallow | 0.27 | None | 0.22 | None |
| UPR-100-F-2 | Shallow | -- | -- | -- | -- |
| **100-IU-2 Source OU and 100-IU-6 Source OU Waste Sites** | | | | | |
| 600-107 | Shallow Focused | -- | -- | -- | -- |
| 600-128 | Shallow Focused | 0.10 | None | 0.10 | None |

Table 6-2. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens

| Waste Site Name | RI/FS Decision Unit | Noncancer Hazard Index and Noncancer Hazard Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Hazard Index | RCBRA Chemical Hazard Driver | RI/FS Hazard Index | RI/FS Chemical Hazard Driver |
| 600-131 | Shallow Focused | 0.14 | None | 0.14 | None |
| 600-132 | Shallow Focused | 0.24 | None | 0.24 | None |
| 600-181 | Shallow Focused | 0.13 | None | 0.13 | None |
| 600-190 | Shallow Focused | 0.80 | None | 0.80 | None |
| 600-204 | Shallow Focused | 0.12 | None | 0.13 | None |
| 600-23 | Shallow | 0.95 | None | 0.16 | None |
| | Shallow Focused | Not Evaluated | Not Evaluated | 0.96 | None |
| 628-1 | Shallow Focused | 0.13 | None | 0.13 | None |
| JA Jones | Shallow | -- | -- | 0.02 | None |
| | Shallow Focused | Not Evaluated | Not Evaluated | <0.01 | None |

Note: Chemical drivers shown have an associated hazard quotient (HQ) greater than 1.

The HQ value for the individual drivers is shown in parentheses after the name of the risk driver chemical.

Hazard indices are based on reasonable maximum EPCs.

Source: RCBRA data: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*, Table 2-10.

RI/FS data: Tables G-27, G-48, and G-49 (Appendix G).

600-235 was evaluated in DOE/RL-2007-21, Volume II as 100-F/IU site; however, it has not been officially assigned to an OU and is therefore not included in this table or the RI/FS.

JA Jones was included in DOE/RL-2007-21, Volume II as a 300 Area OU waste site; however, it has subsequently been reassigned to the 100-IU-6 OU and is therefore included in this table and the 100-F/IU RI/FS.

Not Evaluated = Focused decision units were not evaluated in the RCBRA.

— = noncarcinogenic COPCs were not identified

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Table 6-3. Summary of Residential Scenario Risk Assessment Results for Radionuclides

| Waste Site Name | RI/FS Decision Unit | Radionuclides and Radiological Risk Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Radiological Risk | RCBRA Radiological Risk Driver | RI/FS Radiological Risk | RI/FS Radiological Risk Driver |
| **100-F Source OU Waste Sites** | | | | | |
| 100-F-2 | Shallow | $1 \times 10^{-5}$ | None | $8.0 \times 10^{-6}$ | None |
| 100-F-7 | Shallow Focused | -- | -- | -- | -- |
| 100-F-9 | Shallow Focused | -- | -- | -- | -- |
| 100-F-11 | Shallow Focused | -- | -- | -- | -- |
| 100-F-12 | Shallow Focused | -- | -- | -- | -- |
| 100-F-14 | Shallow Focused | -- | -- | $3.9 \times 10^{-7}$ | None |
| 100-F-15 | Shallow | -- | -- | -- | -- |
| 100-F-16 | Shallow Focused | -- | -- | $1.6 \times 10^{-8}$ | None |
| 100-F-18 | Shallow Focused | -- | -- | -- | -- |
| 100-F-19:1 | Shallow | $1 \times 10^{-5}$ | None | $2.2 \times 10^{-5}$ | None |
| 100-F-19:2 | Shallow | $5 \times 10^{-5}$ | None | $1.6 \times 10^{-5}$ | None |
| | Shallow Focused | Not Evaluated | Not Evaluated | -- | -- |
| 100-F-23 (RCBRA)<br>141-C (RI/FS) | Shallow | $5 \times 10^{-6}$ | None | $7.6 \times 10^{-5}$ | -- |
| 100-F-24 | Shallow | $7 \times 10^{-6}$ | None | $1.2 \times 10^{-6}$ | None |
| 100-F-25 | Shallow | $1 \times 10^{-5}$ | None | $6.0 \times 10^{-6}$ | None |
| 100-F-26:1 | Shallow Focused | $5 \times 10^{-6}$ | None | -- | -- |
| 100-F-26:2 | Shallow Focused | -- | -- | -- | -- |
| 100-F-26:5 | Shallow Focused | -- | -- | -- | -- |

Table 6-3. Summary of Residential Scenario Risk Assessment Results for Radionuclides

| Waste Site Name | RI/FS Decision Unit | Radionuclides and Radiological Risk Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Radiological Risk | RCBRA Radiological Risk Driver | RI/FS Radiological Risk | RI/FS Radiological Risk Driver |
| 100-F-26:7 | Shallow | -- | -- | -- | -- |
| | Shallow Focused | Not Evaluated | Not Evaluated | -- | -- |
| 100-F-35 | Shallow | $3 \times 10^{-5}$ | None | $9.1 \times 10^{-5}$ | None |
| 100-F-37 | Shallow Focused | -- | -- | -- | -- |
| 100-F-38 | Shallow Focused | -- | -- | -- | -- |
| 116-F-1 | Shallow | $4 \times 10^{-5}$ | None | $2.3 \times 10^{-5}$ | None |
| 116-F-2 | Shallow | $6 \times 10^{-5}$ | None | $3.5 \times 10^{-5}$ | None |
| 116-F-3 | Shallow | -- | -- | $9.8 \times 10^{-6}$ | None |
| 116-F-4 | Shallow Focused | $2 \times 10^{-5}$ | None | $1.3 \times 10^{-6}$ | None |
| 116-F-5 | Shallow | $1 \times 10^{-5}$ | None | $6.0 \times 10^{-6}$ | None |
| 116-F-6 | Shallow | $1 \times 10^{-4}$ | None | $8.5 \times 10^{-5}$ | None |
| 116-F-9 | Shallow | $1 \times 10^{-4}$ | Strontium-90 ($1 \times 10^{-4}$) | $6.7 \times 10^{-5}$ | None |
| 116-F-10 | Shallow | $9 \times 10^{-5}$ | None | $6.0 \times 10^{-5}$ | None |
| 116-F-14 | Shallow | $3 \times 10^{-4}$ | Europium-152 ($3 \times 10^{-4}$) | $1.3 \times 10^{-4}$ | None |
| 118-F-8:1 | Shallow | $7 \times 10^{-5}$ | None | $4.1 \times 10^{-5}$ | None |
| 1607-F2 | Shallow | $4 \times 10^{-5}$ | None | $1.8 \times 10^{-5}$ | None |
| 1607-F6 | Shallow | $1 \times 10^{-5}$ | None | $6.7 \times 10^{-6}$ | None |
| UPR-100-F-2 | Shallow | $1 \times 10^{-4}$ | None | $2.6 \times 10^{-5}$ | None |
| **100-IU-2 Source OU and 100-IU-6 Source OU Waste Sites** | | | | | |
| 600-107 | Shallow Focused | $3 \times 10^{-6}$ | None | $1.9 \times 10^{-6}$ | None |
| 600-128 | Shallow Focused | -- | -- | -- | -- |
| 600-131 | Shallow Focused | -- | -- | -- | -- |

Table 6-3. Summary of Residential Scenario Risk Assessment Results for Radionuclides

| Waste Site Name | RI/FS Decision Unit | Radionuclides and Radiological Risk Drivers | | | |
|---|---|---|---|---|---|
| | | RCBRA Radiological Risk | RCBRA Radiological Risk Driver | RI/FS Radiological Risk | RI/FS Radiological Risk Driver |
| 600-132 | Shallow Focused | -- | -- | -- | -- |
| 600-181 | Shallow Focused | -- | -- | -- | -- |
| 600-190 | Shallow Focused | -- | -- | -- | -- |
| 600-204 | Shallow Focused | -- | -- | -- | -- |
| 600-23 | Shallow | $7 \times 10^{-5}$ | None | -- | -- |
| | Shallow Focused | Not Evaluated | Not Evaluated | $7.7 \times 10^{-7}$ | None |
| 628-1 | Shallow Focused | -- | -- | -- | -- |
| JA Jones | Shallow | -- | -- | -- | -- |
| | Shallow Focused | Not Evaluated | Not Evaluated | -- | -- |

Note: Radionuclide drivers shown have an associated risk greater than 1× 10-4.

The risk value for the individual drivers is shown in parentheses after the name of the risk driver chemical.

Risks are based on reasonable maximum EPCs.

Source: RCBRA data: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment*, Table 2-10.

RI/FS data: Tables G-27, G-48, and G-49 (Appendix G).

600-235 was evaluated in DOE/RL-2007-21, Volume II as a 100-F/IU site; however, it has not been officially assigned to an OU and is therefore not included in this table or the RI/FS.

JA Jones was included in DOE/RL-2007-21, Volume II as a 300 Area OU waste site; however, it has subsequently been reassigned to the 100-IU-6 OU and is therefore included in this table and the 100-F/IU RI/FS.

Not Evaluated = Focused decision units were not evaluated in the RCBRA.

— = radionuclide COPCs were not identified

### 6.1.2 RI/FS Soil Risk Assessment (Unrestricted Land Use)

As shown in Table 6-1 through Table 6-3, the risk assessment results are similar between the RCBRA (DOE/RL-2007-21) and the RI/FS for the residential scenario. Differences in results are generally attributed to the COPC identification process, the method used to calculate EPCs, and the PRG value used for comparison. The soil risk assessment provided in this chapter supplements the RCBRA (DOE/RL-2007-21) because there are several key differences between the scope and purpose of the RCBRA and the scope and purpose of the RI/FS. Differences between the RCBRA (DOE/RL-2007-21) and the RI/FS in the methodologies used for assessing residual risks are described in Table 6-4; these

include methods for COPC identification, selection of exposure factors used for the interim action RAGs and PRGs, inclusion of all decision units associated with a waste site, and inclusion of analytical data from focused sampling designs. As a result of these differences, the evaluation provided in the RI/FS more directly supports the evaluation of remedial alternatives in the FS. Table 6-4 also provides the methods used for preparing the closeout documentation.

RAOs are narrative statements that define the extent to which waste sites require cleanup to protect HHE. Further, PRGs (also used as risk based screening levels [RBSLs]) are the numeric values that would be expected to achieve the RAOs presented in Chapter 8. The 100-F/IU Area PRGs are developed in the RCBRA (DOE/RL-2007-21) and presented in this chapter.

For the 100-F/IU Source OUs, the results of the soil risk assessment presented in this chapter will be used to determine whether additional remedial action may be necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as demonstrated by verification sampling and analysis. It is important to note that another objective of the soil risk assessment is to determine and affirm a basis for action. Although the RI/FS risk assessment and the RCBRA focus on the protection of HHE at waste sites that have been remediated, there are significant potential risks at unremediated sites that require continuation of cleanup actions. The risk-based screening evaluation for the residential scenario in this chapter provides information necessary to resolve the following questions and provides information needed to support final remedial decisions that will ensure protection of HHE:

- Are residual conditions for cleanup actions completed under the interim action RODs protective of HHE based on comparison to RBSLs calculated in accordance with current EPA guidance?
- Are there waste sites with a no action or interim closed out reclassification status that should be carried into the FS?
- What uncertainties are associated with the risk results that require a risk management decision?

Waste sites evaluated in the River Corridor were interimly closed out using RAGs related to direct contact soil exposure by human receptors. These RAGs are reported in the 100 Area RDR/RAWP (DOE/RL-96-17). The RAGs for radionuclides have not been revised since originally published in 1996. Interim RAGs in the 100 Area of the River Corridor (for direct contact) were based on a rural residential exposure scenario. The interim action ROD residential scenario for radionuclides is a Rural Residential scenario that, in addition to direct contact, includes food chain exposure pathways (e.g., ingestion of homegrown produce, beef, and milk). Since the 100 Area RDR/RAWP (DOE/RL-96-17) was originally published, EPA has published a change in policy associated with health protectiveness thresholds as well as updates in guidance associated with several exposure assumptions. PRGs presented in this chapter are consistent with the interim action RAGS and incorporate exposure assumptions that were updated to reflect current EPA guidance (Table 6-4).

The interim action ROD residential scenario for chemicals is based on the 2007 MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]). The MTCA (WAC 173-340) Method B levels are based solely on incidental soil ingestion and do not address the food exposure pathways that were included for the radionuclide Rural Residential scenario. The MTCA (WAC 173-340) Method B cleanup levels developed in this chapter are similar to those published in the most recent version of the 100 Area RDR/RAWP (DOE/RL-96-17) with the exception of those chemicals whose interim action RAG is based on the inhalation exposure route. For arsenic, lead, and total petroleum hydrocarbons, Table 740-1 Method A ("Tables" [WAC 173-340-900]) soil cleanup levels for unrestricted land use of 20 and 250 mg/kg were used for the RI/FS.

In addition to performing the risk-based screening evaluation, another purpose for updating the PRGs is to determine if the RAGs developed and reported in the 100 Area RDR/RAWP (DOE/RL-96-17) are protective when compared to current guidance. Chapter 8 provides a summary of the RAGs reported in the 100 Area RDR/RAWP (DOE/RL-96-17) in addition to the PRGs presented in this chapter.

### 6.1.3 RI/FS Soil Risk Assessment (Reasonably Anticipated Future Land Use Scenarios)

The RCBRA (DOE/RL-2007-21) evaluated risks for a range of exposure scenarios that represent a range of upper bound and reasonably anticipated receptors and activities. When soil cleanup levels were established initially for the River Corridor, the TPA (Ecology et al., 1989a) signatories agreed that it was appropriate to protect for a range of potential exposures in the future so that interim cleanup actions did not limit future use of the site. The resident Monument worker and the casual recreational user scenario represent reasonably anticipated future land use.

PRGs are presented in this section for both scenarios (resident Monument worker and the casual recreational user), as well as residential PRGs, for use in the risk-based screening evaluation. CVP and RSVP data are compared to these PRGs. When the total risk for a waste site is less than $1 \times 10^{-4}$ for radionuclides based on the residential scenario or $1 \times 10^{-5}$ for chemicals based on MTCA Method B levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]), then protection of the resident Monument worker and casual recreational user is also achieved. The results of these comparisons can be used in risk management decisions (presented in Section 6.2.5.5) and show that the total risk calculated for the Residential and the resident Monument worker scenarios are essentially identical. The Residential PRGs are slightly lower than the Resident Monument Worker PRGs because the Residential exposure scenario includes the food chain pathways.

The resident Monument worker scenario was evaluated in the RCBRA (DOE/RL-2007-21) as an occupational scenario and was applied on a local and broad area scale. In the RCBRA (DOE/RL-2007-21), the resident Monument worker spent a fraction of the day on the waste site as his residence (local area) and spent a fraction of the same day in a region as large as an individual interim action ROD decision area (comparable to an Operable Unit) and potentially as large as the entire River Corridor conducting work activities (broad area). To incorporate the use of this exposure scenario in the RI/FS process, the scenario was modified to assume that the broad area concentration was equal to the Reasonable Maximum Exposure (RME) broad area upland surface soil concentration reported in the RCBRA (DOE/RL-2007-21). The PRG value represents the concentration of soil the resident Monument worker is exposed to on the waste site (local area).

With the exception of the soil ingestion rate and exposure time, the exposure assumptions used to calculate the resident Monument worker local area PRGs are the same as those that would be used to provide an RME for the residential exposure scenario for the direct contact pathway. With the exception of the soil ingestion rate, the exposure assumptions used to calculate the resident Monument worker broad area risks are the same as those that would be used to provide an RME for the industrial worker exposure scenario defined in *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual Supplemental Guidance "Standard Default Exposure Factors" Interim Final* (OSWER Directive 9285.6-03). Some exposure assumptions were updated based on recent EPA guidance or modified to conform to recommended EPA methodology for calculation of PRGs. Exposure assumptions that were updated based on recent guidance include inhalation rates, particulate emission factors (PEFs), and the external gamma shielding factor. The exposure assumptions that were modified to correlate to standard PRGs equations include soil ingestion rates, indoor time fraction, onsite exposure time, and use of decay factors. These updates and modifications allow a numeric value to be developed to confirm that cleanup actions at the waste site are protective of reasonably anticipated future land uses. Table 6-5 summarizes the modifications made to the resident Monument worker exposure scenario for use as a PRG.

Table 6-4. Comparison of Methods and Assumptions Used for the Residential Scenario

| Parameter | Method Used in Closeout Documentation | Method Used in RCBRA | Method Used in RI/FS | Overall Effect on RI/FS |
|---|---|---|---|---|
| **Basis of PRG Values for Radioisotopes and Chemicals** | | | | |
| Residential PRG value for radioisotopes | Radionuclide cancer risk is evaluated using the Interim Action ROD rural residential exposure scenario reported in *Remedial Design Report/ Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17). Radionuclide RAGs were calculated based on a dose threshold of 15 mrem/yr. | Radionuclide cancer risk is evaluated using the Interim Action ROD rural residential exposure scenario reported in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* DOE/RL-96-17. Radionuclide RAGs were calculated based on a dose threshold of 15 mrem/yr. In the RCBRA (DOE/RL-2007-21), these RAGs were converted to RBSLs based on a risk threshold of $1 \times 10^{-4}$. (RCBRA [DOE/RL-2007-21], pg. 2-41).<br>The Interim Action ROD rural residential exposure scenario is considered a local area exposure scenario (located on a waste site). | Radionuclide cancer risk is evaluated using the residential exposure scenario. This exposure scenario is similar to the Interim Action ROD rural residential scenario but incorporates updates to reflect recent EPA guidance as identified below. | The residential scenario used in the RI/FS reflects updates in methodology (risk-based versus dose-based threshold) and recent recommendations in exposure assumptions. RBSL/PRG values differ slightly between the RAGs reported in the closeout documentation, RCBRA, and the RI/FS for key COPCs (gamma emitters and strontium-90). Risk-based PRG values reported in the RI/FS for gamma emitters and strontium-90 are slightly lower than the RAGs reported in closeout document and in the RCBRA (DOE/RL-2007-21). Risk-based PRG values reported in the RI/FS for some alpha emitters are greater than the RAGs reported in closeout document and in the RCBRA. |
| Updates to EPA guidance for residential PRG. | External gamma shielding factor is 0.8 (*Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals): Interim* [EPA/540/R-92/003]).<br>Outdoor time fraction is 0.2 (5 hours per day over 350 days per year) (*Hanford Guidance for Radiological Cleanup* [WDOH/320-015]).<br>Annual dose rate is 15 mrem/yr ("Radiation Site Cleanup Standards" [40 CFR 196]). | External gamma shielding factor is 0.7, which is based on the default value recommended in the RESRAD code.<br>Outdoor time fraction is 0.2 (5 hours per day over 350 days per year) (*Hanford Guidance for Radiological Cleanup* [WDOH/320-015]).<br>Target cancer risk value is $1 \times 10^{-4}$ (*Radiation Risk Assessment at CERCLA Sites: Q & A* [EPA/540/R/99/006]). | External gamma shielding factor is 0.4 (*Soil Screening Guidance for Radionuclides: User's Guide* [EPA/540-R-00-007]).<br>Outdoor time fraction is 0.12 (3 hours per day over 350 days per year) (*Exposure Factors Handbook Volume II – Food Ingestion Factors* [EPA/600/P-95/002Fb]).<br>Target cancer risk value is $1 \times 10^{-4}$ (*Radiation Risk Assessment At CERCLA Sites: Q & A* [EPA/540/R/99/006]). | Gamma shielding factor was revised from 0.7 to 0.4. The current assumption accounts for a 60 percent reduction in external exposure because of shielding from structures rather than a 30 percent reduction. Use of the updated assumption results in slightly less exposure and a less conservative PRG value (higher).<br>Outdoor time fraction was revised from 0.2 to 0.12. The current assumption assumes the resident spends 3 hours per day outside rather than 5 hours per day. Use of the updated assumption results in less exposure and a less conservative PRG value (higher).<br>The protective threshold value was updated from a dose-based value to a risk-based value. The overall outcome is that updated PRG values used in the RI/FS are slightly lower for beta- and gamma-emitting radioisotopes and higher for alpha-emitting radioisotopes. |
| MTCA (WAC 173-340) Method B Soil Cleanup Levels for unrestricted land use. | Separate MTCA (WAC 173-340) Method B levels were calculated for incidental soil ingestion and inhalation. | MTCA (WAC 173-340) Method B levels are based solely on incidental soil ingestion. | Separate MTCA (WAC 173-340) Method B levels were calculated for incidental soil ingestion and inhalation. | Chemicals that only report toxicity values for the inhalation exposure route are not included in the RCBRA (DOE/RL-2007-21) evaluation (beryllium, cadmium, cobalt, Cr(VI), and nickel). RAGs are reported for chemicals that only report toxicity values for the inhalation exposure route (beryllium, cadmium, cobalt, Cr(VI), and nickel). The RI/FS separately reports cancer risks and noncancer hazard indices for both incidental soil ingestion and inhalation exposure routes. |
| MTCA (WAC 173-340) Method B inhalation cleanup levels for unrestricted land use. | *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17) reports RAGs for beryllium, cadmium, Cr(VI) based on the inhalation exposure pathway, based on WAC 173-340-750(3).<br>A particulate emission factor (PEF) value of $1.0 \times 10^{7}$ $m^3/kg$ was used to convert air concentrations to soil concentrations. The PEF value of $1.0 \times 10^{7}$ $m^3/kg$ is based on the default mass loading factor in RESRAD. This is roughly two orders of magnitude smaller than EPA's default PEF of $1.4 \times 10^{9}$ $m^3/kg$. | MTCA (WAC 173-340) Method B inhalation cleanup levels were not evaluated in the RCBRA (DOE/RL-2007-21). | MTCA (WAC 173-340) Method B inhalation cleanup levels were calculated for the inhalation exposure route.<br>A PEF value of $7.3 \times 10^{10}$ $m^3/kg$ is used to convert air concentrations to soil concentrations. This PEF uses meteorological data from Boise, Idaho, and Hanford site-specific annual wind speed. The PEF of $7.3 \times 10^{10}$ $m^3/kg$ is within a factor of two of EPAs default PEF of $1.4 \times 10^{9}$ $m^3/kg$ published in *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (OSWER 9355.4-24). | Inhalation pathway cleanup levels that use a PEF value based on the default mass loading factor in RESRAD are lower values (more conservative) that those cleanup levels that are based on EPA Methodology. |

Table 6-4. Comparison of Methods and Assumptions Used for the Residential Scenario

| Parameter | Method Used in Closeout Documentation | Method Used in RCBRA | Method Used in RI/FS | Overall Effect on RI/FS |
|---|---|---|---|---|
| **Data Analysis** | | | | |
| Waste site decision units and analysis time frame | The floor and sidewalls of an excavated waste site are divided into one or more decision units. A sample design is developed for the decision unit. Sampling requirements for each decision unit is described in *100 Area Remedial Action Sampling and Analysis Plan* (DOE/RL-96-22). | For local area exposure scenarios (including the interim action ROD rural residential scenario), the RCBRA used only the CVP/RSVP data sets from shallow zone decision units. These data sets are from waste sites that were excavated /remediated through calendar year 2005.<br>The shallow zone decision unit is typically represented by soils from the excavation floor if at or above 4.6 m (15 ft) and any sidewalls from grade level (0 m [0 ft]) to a depth of 4.6 m (15 ft). | The RI/FS used CVP/RSVP data sets from all decision units associated with an excavated/remediated waste site through May 2011.<br>In addition to the shallow zone decision unit, the RI/FS evaluates the risk contribution from soils associated with the overburden, staging pile footprint area, and the deep zone decision units. | The RI/FS risk assessment is intended to supplement the analysis in Chapter 2 of the RCBRA (DOE/RL-2007-21).<br>The RI/FS risk assessment results will be used to identify waste sites that warrant evaluation of remedial alternatives in the FS. The RI/FS risk assessment can also be used to disposition the waste site from an interim status to final closure status when risk thresholds are not exceeded. |
| Statistical and focused sample designs | The layout and orientation of sampling designs are based on the size, shape, and depth of the site. The data sets from the sample design are used to confirm attainment of remedial action objectives. | When both focused and statistical samples exist for an analyte at a waste site, only the statistical samples were used to calculate the representative concentrations.<br>An uncertainty analysis was performed to evaluate the selection of focused and/or statistical samples has on the risk assessment results, representative concentrations for these waste sites are also calculated using the combined focused and statistical samples.<br>The statistical representative concentrations were compared to the combined focused and statistical samples and shown in Table C3-11 in Appendix C C-3, "Representative Concentrations." | The approach used to evaluate the data set for each sample design is the same as that used for the closeout documentation. | Evaluation of only the data from statistical sample designs when focused sample data are also collected has the potential to understate risk.<br>Frequently focused sample results are collected in areas with the highest potential for contamination to be present.<br>The RI/FS risk assessment results will be used to identify waste sites that warrant evaluation of remedial alternatives in the FS. The RI/FS risk assessment can also be used to disposition the waste site from an interim status to final closure status when risk thresholds are not exceeded. |
| COPC Identification | Closeout documentation did not incorporate a COPC identification step. All detected analytes with RAGs reported in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17) were evaluated in the closeout documentation. It should be noted that the RAGs listed in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17) do not include analytes that meet exclusion criteria. | COPC refinement process includes a number of complementary steps and criteria, including a pre-selected list of contaminants that were excluded and a list that were included, as determined and agreed upon among the Tri-Parties. Additional selection steps include evaluation of all data according to detection status, statistical comparisons of Hanford Site data to background and reference site data, and an analyte-specific evaluation.<br>Each interim action ROD area has a separate list of COPCs. | COPC identification uses the exclusion criteria defined in Section 6.2.1.3 of this Chapter. The inclusion list and other refinement steps used in the RCBRA (DOE/RL-2007-21) were not incorporated into the RI/FS.<br>When a COPC was detected at least once in a waste site decision unit (and it did not meet the exclusion criteria) it was carried into all risk calculations. | COPC refinement in RCBRA often included analytes that were not detected at the waste site. The inclusion of analytes that were not detected at a waste site decision unit results in an overstatement of risk.<br>The method used to identify COPCs in the RI/FS is similar to the method used in the closeout documentation. The RI/FS and closeout documentation did not evaluate analytes that met exclusion criteria.<br>Although two different COPC identification processes were used in the RCBRA and the RI/FS, similar risk drivers were identified in the risk characterization step of the analysis as shown in Table 6-1 through 6-3. |

Table 6-4. Comparison of Methods and Assumptions Used for the Residential Scenario

| Parameter | Method Used in Closeout Documentation | Method Used in RCBRA | Method Used in RI/FS | Overall Effect on RI/FS |
|---|---|---|---|---|
| EPCs | The primary statistical calculation to support closeout documentation was the 95 percent UCL on the arithmetic mean of the data for waste sites closed using a statistical/random sampling design. Statistical calculations were performed in compliance with *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54). This guidance addresses two kinds of data distributions: normal and lognormal. This guidance also implements the substitution method where a proxy value of one-half the detection limit is assigned to nondetected results.<br>For small data sets (n<10) a nonparametric distribution was assumed. When a nonradionuclide was detected in fewer than 50 percent of the samples collected and for focused sampling designs, the maximum detected value was used for comparison purposes. For radionuclides, a 95 percent UCL was always calculated using a nonparametric method based on the "z" statistic. | Representative concentrations pertain to sampled medium, whereas EPCs also include modeled concentrations in other exposure media.<br>In general, the process used in the RCBRA follows EPA guidance as provided in the *ProUCL Version 4.00.05 User Guide (Draft)* (EPA/600/R-07/038). The ProUCL software was not used to calculate representative concentrations. | *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) is the EPA guidance for UCL calculation and ProUCL 4.00.05 serves as the companion software package for this guidance.<br>ProUCL 4.00.05 contains rigorous parametric and nonparametric (including bootstrap methods) statistical methods that can be used on full data sets without nondetects and on data sets with below detection or nondetect observations. Both ProUCL and *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) were used to recalculate the UCLs for the 100-F/IU Source OU. | *ProUCL Version 4.00.05 User Guide (Draft)* (EPA/600/R-07/038) draws from guidance documented in *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10).<br>Methodologies for calculating 95 percent UCLs are similar between the RCBRA (DOE/RL-2007-21) and the RI/FS.<br>The methodology used in the closeout documentation address only two data distributions for the 95 percent UCL calculation and implemented the substitution of one-half the detection limit value for nondetected results. |
| **Waste Site Specific Information** | | | | |
| Exclusion of focused sample design data from waste sites 100-F-19:2, 100-F-27:7, and 600-23. | Both focused and statistical sample design data sets were evaluated in the closeout documentation. | Focused sample design data sets were not evaluated. Only statistical sample design data sets were evaluated. | Both focused and statistical sample design data sets were evaluated in the RI/FS. | Exclusion of some data sets has the potential to understate risks. |

Note: Complete reference citations are provided in Chapter 11.

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Table 6-5. Summary of Differences in Exposure Assumptions for the Resident Monument Worker between the RCBRA and RI/FS Risk Assessment

| Parameter | RCBRA Resident Monument Worker | RI/FS Resident Monument Worker |
|---|---|---|
| Soil ingestion rate | A soil ingestion rate of 100 mg/day is assumed for this receptor. The soil ingestion rate is apportioned to the local area and the broad area based on the amount of time he spends at each area.<br>The RCBRA allocated 52.2 mg/day to the residential portion (local area) of this scenario and 25 mg/day to the occupational portion (broad area) of this scenario. | A soil ingestion rate of 100 mg/day is assumed for this receptor.<br>The RI/FS allocated 76.2 mg/day to residential portion (local area) of this scenario and 23.8 mg/day to the occupational portion (broad area) of this scenario for a total of 100 mg/day. |
| Inhalation rate | The RCBRA assumed an inhalation rate of 0.63 $m^3$/hour based on an inhalation rate of 15 $m^3$/day. | The RI/FS assumed an inhalation rate of 0.83 $m^3$/hour based on an inhalation rate of 20 $m^3$/day. |
| Particulate Emission Factor | The RCBRA used a PEF of $1.08 \times 10^8$ $m^3$/kg for the local area and a PEF of $4.3 \times 10^8$ $m^3$/kg for the broad area. | The RI/FS used the EPA default PEF of $7.3 \times 10^{10}$ $m^3$/kg for the local area and a PEF of $2.6 \times 10^{10}$ $m^3$/kg for the broad area. |
| Time spent on the local area and broad area scale | The RCBRA assumed an exposure time of 13 hours/day spent at the residence (local area), 8 hours spent at onsite at work (broad area), and 3 hours offsite (neither local nor broad area) for a total of 24 hours/day. | The RI/FS assumed that an exposure time of 16 hours/day was spent at the residence (local area) and 8 hours/day onsite at work (broad area) for a total of 24 hours per day. |
| Indoor and outdoor exposure time | The RCBRA assumed that the resident spent 13 hours/day indoors, 8 hours/day outdoors, and 3 hours per day offsite. | The RI/FS assumed that the resident spent 13 hours/day indoors and 3 hours/day outdoors (local area) and the worker spent 8 hours/day outdoors (broad area). |
| Gamma shielding factor | The RCBRA used an external gamma shielding factor of 0.7. | The RI/FS used an external gamma shielding factor of 0.4 based on current guidance. |
| Radiological decay factors | Decay of radioisotopes over the exposure duration was not accounted for. | Decay of radioisotopes over the exposure duration was incorporated. |

The casual user scenario was evaluated in the RCBRA (DOE/RL-2007-21) as a recreational scenario and was applied on a broad area scale. In the RCBRA (DOE/RL-2007-21), the casual user spent time enjoying recreational activities (broad area) only in a region as large as an individual interim action ROD OU and potentially as large as the entire River Corridor. Similar to the resident Monument worker, this exposure scenario was used to calculate forward risk estimates. To incorporate the use of this exposure scenario in the RI/FS process, the scenario was modified to develop a PRG assuming that all of the casual user time was spent on the waste site (local area). This assumption is the only modification made to this exposure scenario; no changes were made to the exposure assumptions used to calculate PRG values. This modification allows a conservative numeric value to be developed to confirm that cleanup actions at the waste site are protective.

Some exposure assumptions for the casual recreational user scenario were updated based on recent EPA guidance or modified to conform to recommended EPA methodology for calculation of PRGs. Exposure assumptions that were updated based on recent guidance include the incidental soil ingestion rate, inhalation rate, PEF, time spent on the local area and broad area scale, external gamma shielding factor, and radiological decay. The exposure assumptions that were modified to correlate to standard PRGs equations include soil ingestion rates and use of decay factors. These updates and modifications allow a numeric value to be developed to confirm that cleanup actions at the waste site are protective of HHE. Table 6-6 summarizes the modifications made to the casual recreational user exposure scenario for use as a PRG.

Table 6-6. Summary of Differences in Exposure Assumptions for the Casual Recreational User between the RCBRA and RI/FS Risk Assessment

| Parameter | RCBRA Casual User | RI/FS Casual Recreational User |
|---|---|---|
| Soil ingestion rate | A soil ingestion rate of 100 mg/day for an adult and 200 mg/day for a child were assumed for this receptor. Soil ingestion at the waste site was assumed proportional to the fraction of waking hours spent at the site. | A soil ingestion rate of 100 mg/day for an adult and 200 mg/day for a child were assumed for this receptor. All soil ingestion was assumed to occur at the waste site. |
| Inhalation rate | The RCBRA assumed an inhalation rate of 1 $m^3$/hour for an adult and 1 $m^3$/hour for a child based on EPA recommended short-term exposure values for light activity. | The RI/FS assumed an inhalation rate of 0.83 $m^3$/hour for an adult, based on an inhalation rate of 20 $m^3$/day, and 0.417 $m^3$/hour for a child, based on an inhalation rate of 10 $m^3$/day (*Risk Assessment Guidance for Superfund: Volume I—Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals): Interim* [EPA/540/R-92/003]). |
| Particulate Emission Factor | The RCBRA used a PEF of $4.3 \times 10^8$ $m^3$/kg for the broad area. | The RI/FS used the EPA default PEF of $7.3 \times 10^{10}$ $m^3$/kg (*Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* [OSWER 9355.4-24]). |
| Time spent on the local area and the broad area scale | The RCBRA assumed an exposure time of 6 hours/day is spent onsite, all in the broad area. | The RI/FS assumed an exposure time of 6 hours/day is spent onsite, all in the local area. |
| Gamma shielding factor | The RCBRA did not apply a gamma-shielding factor (all exposure is assumed to occur outdoors). | The RI/FS did not apply a gamma-shielding factor (all exposure is assumed to be occurring outdoors). |
| Radiological decay factors | Decay of radioisotopes over the exposure duration was not accounted for. | Decay of radioisotopes over the exposure duration was incorporated. |

### 6.1.4 Other Residential Land Use Scenarios in RCBRA

The RCBRA (DOE/RL-2007-21) also evaluated three residential scenarios that describe exposures related to a rural land-use pattern that involves home-produced foods. The subsistence farmer scenario envisions a substantial quantity of home-produced foods, but not a diet composed solely of such foods. The two Native American Resident scenarios, however, envision a complete subsistence lifestyle where all foods are grown at the home or (in the case of fish) caught in the Columbia River. Residential receptors are

assumed to spend effectively all of their time in the area around a residence located on a remediated waste site in order to protectively assign all soil-related exposures to that site.

PRGs were not calculated in the RCBRA (DOE/RL-2007-21) for these additional residential scenarios. Direct contact and food chain exposure associated with radiological contaminants for unrestricted land use are represented by the residential scenario described in Section 6.1.2.

DOE, through discussions with the Tribes ("Contract No. DE-AC06-96RL13200-Native American Scenarios in Remedial Investigation and Feasibility Study Risk Assessments and Assuming Responsibility and Configuration Control of the Soil Inventory Model" [0702827]), has agreed to include quantitative analysis of Native American scenarios in risk assessments supporting RI/FS documents. The two scenarios considered are provided by the Confederated Tribes of the Umatilla Indian Reservation (CTUIR) and the Yakama Nation. The RCBRA (DOE/RL-2007-21) presents the risks and hazards calculated for both Native American exposure scenarios from direct contact, external gamma exposure, inhalation, and food chain pathways from remediated waste sites. The groundwater risk assessment presented in Section 6.3 presents the results of both Native American scenarios for potentially complete exposure pathways associated with groundwater. The groundwater risk assessment presents the risks and hazards calculated for groundwater used as a source of drinking water and as a source of steam for sweat lodge (see Section 6.3.8.5.1). The results from the RCBRA (DOE/RL-2007-21) for remediated waste sites and the results from the groundwater risk assessment can be summed to obtain a cumulative estimate of risk for all exposure pathways included in the CTUIR and Yakama Nation exposure scenarios. These tribal scenarios have been evaluated and presented in Hanford Site risk assessments to assist interested parties in providing input on remedial alternatives (*Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit* [DOE/RL-2007-28]), and have not been used for development of PRGs as part of alternatives analyses in FS.

The results of the local area risk assessment for the Residential scenarios indicate that present-day RME cancer risk is frequently greater than $1 \times 10^{-4}$ (25 of 44 remediated sites for the Subsistence Farmer scenario) and that RME chemical HI frequently exceeds the threshold of 1.0 (25 of 44 remediated sites for the Subsistence Farmer scenario). A summary of risks and noncancer hazards associated with the Subsistence Farmer is provided in Table 6-7. Present-day RME cancer risks greater than $1 \times 10^{-4}$ for the Subsistence Farmer exposure scenario are almost entirely related to one of three factors:

- External irradiation from short-lived radionuclides including europium-152, cesium-137, and cobalt-60
- Exposure to arsenic from ingestion of garden produce
- Exposure to the short-lived radionuclide strontium-90 from ingestion of produce and livestock products

By the year 2075, the RCBRA (DOE/RL-2007-21, Volume II) calculated the Subsistence Farmer RME cancer risks above $1 \times 10^{-4}$ are related overwhelmingly to arsenic exposure from produce ingestion. Because the CTUIR Resident and Yakama Resident scenarios use very high (subsistence level) site-raised food ingestion rates, strontium-90 still plays a significant role in food-related exposures at year 2075 for these scenarios. By year 2150, however, CTUIR Resident and Yakama Resident cancer risks above $1 \times 10^{-4}$ are dominated by arsenic exposure from ingestion of garden produce.

The RCBRA Subsistence Farmer cancer risk and chemical HI results were frequently above threshold criteria. The Subsistence Farmer reported cancer risk and chemical HI results above threshold criteria whereas the closeout documentation reported that residual chemical concentrations met or were below

threshold criteria. The two major differences were identified between the risk assessment methods used in the RCBRA (DOE/RL-2007-21) and the basis of the interim remedial action goals. These differences were as follows:

- Residential interim action RAGs for chemicals are the MTCA Method B levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]), which is an RME scenario based on incidental soil ingestion and does not address the food exposure pathways historically evaluated for radionuclides.
- The interim action RAG for arsenic is 20 mg/kg, which is an "adjusted" value established by the State of Washington to address a range of natural background levels MTCA ("Tables" [WAC 173-340-900]).

These differences largely explain why some waste sites remediated to meet the interim action RAGs still appear to present high levels of residual risk under the Subsistence Farmer scenario.

One of the primary uncertainties for site-specific results relates to modeled exposure concentrations in foods, particularly garden produce. Further discussion of the potential biases in modeled food chain exposures is provided in the RCBRA (DOE/RL-2007-21, Volume II). As discussed in Section 5.9.4.2 of the RCBRA (DOE/RL-2007-21, Volume II), in the case of the noncancer HI results for produce ingestion of mercury, uranium, and copper, a large conservative bias is anticipated because a linear plant uptake model was applied to soil concentrations that are far above naturally occurring levels. In the case of arsenic, produce ingestion provides the largest contribution to total cancer risk, even though the range of site soil concentrations is relatively small. Uncertainty in produce concentrations is attributable to intrinsic variability related to soil conditions, plant species and tissue type, harvest time, and other variables. A review of recommended plant-soil ratios from a number of sources, as described in Section 5.9.2.4 of the RCBRA (DOE/RL-2007-21, Volume II), shows that the range of soil to plant transfer ratios for arsenic (from 0.006 to 1.125) is approximately a factor of 200. The value of 0.53 used in the HHRA, from the RESidual RADioactivity (RESRAD) computer code that has been used to perform dose assessment at the Hanford Site and other DOE facilities, is near the upper end of this range. The high-end values for plant-soil concentrations, many of which were used in the RCBRA (DOE/RL-2007-21, Volume II) to assess exposure through food pathways, may result in a scenario that provides exposures to nonradionuclide contaminants higher than an RME. PRGs identified in this document for nonradiological analytes are based on MTCA procedures which do not include food chain pathways.

## 6.2 Soil Risk Assessment

Section 6.1.1 summarizes the evaluation of residual risks performed in the RCBRA (DOE/RL-2007-21) for waste sites cleaned up under the Interim Action ROD. Section 6.1.2 describes how elements of the RCBRA (DOE/RL-2007-21) were updated to reflect current guidance, risk assessment methodologies, and toxicity information to support the FS. Section 6.2 provides the updated soil risk assessment, which implements the updates described in Section 6.1.2.

Table 6-7. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

| Waste Site Name | Present Day Total Cancer Risk | COPC | Pathway | Present Day Hazard Index | COPC | Pathway |
|---|---|---|---|---|---|---|
| 100-F-37 | $3 \times 10^{-3}$ | Arsenic | Produce Ingestion | 16 | Arsenic | Produce Ingestion |
| 116-F-1 | $1 \times 10^{-3}$ | Arsenic | Produce Ingestion | 5.4 | Arsenic | Produce Ingestion |
| 116-F-14 | $1 \times 10^{-3}$ | Europium-152 | External Radiation | 2.3 | -- | -- |
| | | Arsenic | Produce Ingestion | | | |
| 600-235 | $7 \times 10^{-4}$ | Arsenic | Produce Ingestion | 4.6 | Arsenic | Produce Ingestion |
| | | | | | Cadmium | Produce Ingestion |
| 100-F-26:1 | $5 \times 10^{-4}$ | Arsenic | Produce Ingestion | 3.3 | Arsenic | Produce Ingestion |
| 600-131 | $5 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.8 | -- | -- |
| 600-181 | $5 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.7 | -- | -- |
| 600-23 | $5 \times 10^{-4}$ | Arsenic | Produce Ingestion | 5 | Arsenic | Produce Ingestion |
| | | | | | Aroclor-1254 | Soil Ingestion |
| | | | | | Aroclor-1254 | Milk Ingestion |
| 628-1 | $5 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.5 | -- | -- |
| 100-F-12 | $4 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.2 | -- | -- |
| 100-F-26:7 | $4 \times 10^{-4}$ | Arsenic | Produce Ingestion | 3 | Arsenic | Produce Ingestion |
| | | | | | Mercury | Beef Ingestion |
| 100-F-38 | $4 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.6 | -- | -- |
| 100-F-7 | $4 \times 10^{-4}$ | Arsenic | Produce Ingestion | 3.9 | Arsenic | Produce Ingestion |
| | | | | | Mercury | Beef Ingestion |
| | | | | | Mercury | Produce Ingestion |

Table 6-7. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

| Waste Site Name | Present Day Total Cancer Risk | COPC | Pathway | Present Day Hazard Index | COPC | Pathway |
|---|---|---|---|---|---|---|
| 100-F-9 | $4 \times 10^{-4}$ | Arsenic | Produce Ingestion | 7 | Mercury | Beef Ingestion |
| | | | | | Arsenic | Produce Ingestion |
| | | | | | Mercury | Produce Ingestion |
| 116-F-9 | $4 \times 10^{-4}$ | Strontium-90 | Milk Ingestion | -- | -- | -- |
| | | Strontium-90 | Produce Ingestion | | | |
| | | Strontium-90 | Beef Ingestion | | | |
| | | Carbon-14 | Produce Ingestion | | | |
| 600-132 | $4 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.9 | -- | -- |
| 600-190 | $4 \times 10^{-4}$ | Arsenic | Produce Ingestion | 4.3 | Arsenic | Produce Ingestion |
| | | | | | Aroclor-1254 | Soil Ingestion |
| | | | | | Aroclor-1254 | Milk Ingestion |
| 600-204 | $4 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.4 | -- | -- |
| 100-F-14 | $3 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.7 | -- | -- |
| 100-F-18 | $3 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.6 | -- | -- |
| 100-F-26:2 | $3 \times 10^{-4}$ | Arsenic | Produce Ingestion | 1.8 | -- | -- |
| 100-F-26:5 | $3 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2.1 | -- | -- |
| 116-F-5 | $3 \times 10^{-4}$ | Arsenic | Produce Ingestion | 1.5 | -- | -- |

Table 6-7. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

| Waste Site Name | Present Day Total Cancer Risk | COPC | Pathway | Present Day Hazard Index | COPC | Pathway |
|---|---|---|---|---|---|---|
| 116-F-6 | $3 \times 10^{-4}$ | Strontium-90 | Milk Ingestion | 0.015 | -- | -- |
| | | Strontium-90 | Produce Ingestion | | | |
| | | Strontium-90 | Beef Ingestion | | | |
| | | Cesium-137 | External Irradiation | | | |
| 600-128 | $3 \times 10^{-4}$ | Arsenic | Produce Ingestion | 2 | -- | -- |
| 116-F-10 | $2 \times 10^{-4}$ | Cesium-137 | External Irradiation | 0.2 | -- | -- |
| | | Europium-152 | External Irradiation | | | |
| UPR-100-F-2 | $2 \times 10^{-4}$ | Europium-152 | External Irradiation | -- | -- | -- |
| 100-F-19:2 | $1 \times 10^{-4}$ | -- | -- | 0.25 | -- | -- |
| 116-F-2 | $1 \times 10^{-4}$ | -- | -- | 0.045 | -- | -- |
| 118-F-8:1 | $1 \times 10^{-4}$ | -- | -- | 1.3 | -- | -- |
| 100-F-19:1 | $9 \times 10^{-5}$ | -- | -- | 0.019 | -- | -- |
| 100-F-35 | $9 \times 10^{-5}$ | -- | -- | -- | -- | -- |
| 1607-F2 | $7 \times 10^{-5}$ | -- | -- | -- | -- | -- |
| 100-F-23 | $5 \times 10^{-5}$ | -- | -- | -- | -- | -- |
| 1607-F6 | $5 \times 10^{-5}$ | -- | -- | 0.96 | -- | -- |
| 100-F-24 | $4 \times 10^{-5}$ | -- | -- | -- | -- | -- |
| 116-F-4 | $4 \times 10^{-5}$ | -- | -- | 0.2 | -- | -- |
| 100-F-2 | $3 \times 10^{-5}$ | -- | -- | -- | -- | -- |
| 100-F-25 | $2 \times 10^{-5}$ | -- | -- | 1.8 | -- | -- |

Table 6-7. Summary of Excess Lifetime Cancer Risks and Noncancer Hazards for the Subsistence Farmer Scenario Reported in the RCBRA

| Waste Site Name | Present Day Total Cancer Risk | COPC | Pathway | Present Day Hazard Index | COPC | Pathway |
|---|---|---|---|---|---|---|
| 600-107 | $6 \times 10^{-6}$ | -- | -- | -- | -- | -- |
| 100-F-15 | $2 \times 10^{-8}$ | -- | -- | 0.014 | -- | -- |
| 100-F-16 | $2 \times 10^{-8}$ | -- | -- | 0.015 | -- | -- |
| 116-F-3 | $2 \times 10^{-8}$ | -- | -- | 0.021 | -- | -- |
| 100-F-11 | -- | -- | -- | 0.0011 | -- | -- |

The 100-F/IU Source OU risk assessment followed the following approach:

- Identify all waste sites with a "no action" or "interim closed out" reclassification status.
- Obtain verification sampling and analysis data for all "no action" and "interim closed out" waste sites that have been remediated through March 2012.[4]
- Compute EPCs for each detected analyte measured at a waste site using the ProUCL software (*ProUCL Version 4.00.05 User Guide (Draft)* [EPA/600/R-07/038]).
- Compare EPCs to direct contact RBSLs selected to represent baseline conditions and reasonably anticipated future site use.
- Calculate cancer risk and noncancer hazards for each detected analyte.
- Compare cancer risks and noncancer hazards to acceptable state and federal target risk and noncancer thresholds.
- Determine if the "no action" or "interim closed out" waste site should be carried forward into the FS to select remedial alternatives.

This soil risk assessment follows the guidance in the risk assessment guide (EPA/540/1-89/002). The following subsections describe the four-step process. Because this evaluation is intended to complement the analysis performed in the RCBRA (DOE/RL-2007-21, Volume II), where applicable, a brief description is provided to describe the similarities in approach.

### 6.2.1 Data Analysis

This section describes the sources of data used in the risk assessment (Section 6.2.1.1), describes the data quality assessment (DQA) and data validation process (Section 6.2.1.2), and identifies COPCs in vadose zone material that are accessible for human exposures (Section 6.2.1.3). During the course of this risk assessment, analytes were evaluated to identify COPCs and prioritize those estimated to pose an unacceptable risk and warrant evaluation in the FS.

#### *6.2.1.1 Sources of Analytical Data Used in Risk Assessment*

This evaluation includes vadose zone material samples for remediated waste sites with a "no action" or "interim closed out" reclassification status collected within the 100-F/IU Source OUs. Waste sites where remediation and verification sampling and analysis were assessed by the end of March 2012 are included in the soil risk assessment.

All samples were collected and analyzed in accordance with the requirements stated in *100 Area Remedial Action Sampling and Analysis Plan* (hereinafter called 100 Area SAP [DOE/RL-96-22]). Data collected under 100 Area SAP (DOE/RL-96-22) are used to meet the purpose and objectives of the 100 Area RDR/RAWP (DOE/RL-96-17), which describes the design and the implementation of the remedial action processes required by the following:

- EPA/541/R-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6 and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)*

[4] These are waste sites for which interim action cleanups had been completed under Interim Action RODS and for which the CVPs were completed through March 2012.

- EPA/AMD/R10-97/044, *Amendment to the Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington*
- EPA/ROD/R10-99/039, *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington*
- EPA/541/R-00/121, *Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington*

Remediation of waste sites in the 100-F/IU Source OU began in 1999. The constituents are identified for each waste site based on process knowledge, site history, and site-specific discussions with the lead regulatory agency. Constituents analyzed include the COPCs for the waste site; as a result different constituents are analyzed at each waste site. Therefore, only constituents reported at each waste site are included in risk calculations. Analytical results for each waste site are included in the associated closeout documentation, which are listed in Appendix B, Table B-1, of the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4). The 100-F/IU RI/FS Work Plan and the 100 Area RDR/RAWP (DOE/RL-96-17) were reviewed and approved by the Tri-Parties.

In total, 144 waste sites in the 100-F/IU Source OUs have verification sampling and analysis data and are included in this risk assessment. An additional nine sites in the 100-F/IU Source OUs have been remediated, but are included in another waste site's sampling and closeout documentation. A summary of the waste sites, associated decision unit(s), and reclassification status for the 100-FR-1 and 100-FR-2 Source OUs is provided in Table G-1 and 100-IU-2 and 100-IU-6 Source OUs are provided in Table G-2. Waste site decision units are defined in Section 6.2.2.2. The waste sites listed in Tables G-1 and G-2 are a subset of the waste sites that were listed in Appendix B, Table B-1, of the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4). A summary of the remediated waste sites and consolidated waste sites for the 100-FR-1 and 100-FR-2 Source OUs and 100-IU-2 and 100-IU-6 Source OUs are provided in Table 6-8 and Table 6-9, respectively.

Table 6-8. Summary of Remediated Waste Sites and Associated Waste Sites in the 100-F Source OU

| **Remediated Waste Sites**[a] | | |
|---|---|---|
| **100-FR-1** | | |
| 100-F-11 | 100-F-38 | 116-F-14 |
| 100-F-12 | 100-F-4 | 116-F-15 |
| 100-F-16 | 100-F-44:2 | 116-F-16 |
| 100-F-18 | 100-F-44:5 | 116-F-2 |
| 100-F-19:1[b] | 100-F-44:8 | 116-F-3 |
| 100-F-19:2[c] | 100-F-44:9 | 116-F-4 |
| 100-F-23 | 100-F-45 | 116-F-5 |
| 100-F-24 | 100-F-46 | 116-F-6 |
| 100-F-25[d] | 100-F-47 | 116-F-7 |

Table 6-8. Summary of Remediated Waste Sites and Associated Waste Sites in the 100-F Source OU

| **Remediated Waste Sites[a]** | | |
|---|---|---|
| 100-F-26:1[e] | 100-F-48 | 116-F-8 |
| 100-F-26:10 | 100-F-49 | 116-F-9 |
| 100-F-26:11 | 100-F-51[g] | 118-F-8:1 |
| 100-F-26:12 | 100-F-52 | 118-F-8:3 |
| 100-F-26:13 | 100-F-53 | 118-F-8:4 |
| 100-F-26:14 | 100-F-54 | 126-F-2 |
| 100-F-26:15 | 100-F-55[h] | 128-F-2 |
| 100-F-26:2 | 100-F-56:1 | 132-F-1 |
| 100-F-26:4 | 100-F-60 | 141-C |
| 100-F-26:5 | 100-F-61 | 1607-F2 |
| 100-F-26:7 | 100-F-62[h] | 1607-F3 |
| 100-F-26:8[f] | 100-F-63[g] | 1607-F4 |
| 100-F-26:9 | 100-F-7 | 1607-F5 |
| 100-F-31 | 100-F-9 | 1607-F6 |
| 100-F-33 | 116-F-1 | 1607-F7 |
| 100-F-36 | 116-F-10 | 182-F |
| 100-F-37 | 116-F-11 | UPR-100-F-2 |
| **100-FR-1 Source OU Totals** | **78** | |
| **100-FR-2** | | |
| 100-F-14 | 118-F-1 | 118-F-7 |
| 100-F-15 | 118-F-2 | 120-F-1 |
| 100-F-2 | 118-F-3 | 126-F-1 |
| 100-F-20 | 118-F-4 | 128-F-1 |
| 100-F-35 | 118-F-5 | 128-F-3 |
| 100-F-50 | 118-F-6 | 600-351 |
| **100-FR-2 Source OU Totals** | **18** | |
| **100-F Area Total** | **96** | |

Table 6-8. Summary of Remediated Waste Sites and Associated Waste Sites in the 100-F Source OU

| Remediated Waste Sites[a] |
|---|

a. Represents the remediated waste sites with closeout verification data. An additional nine remediated waste sites are associated with some of these sites (see following footnotes).

b. 100-F-19:3, 116-F-12, and 100-F-34 are associated with the 100-F-19:1 remediation and closeout documentation.

c. 100-F-10, 100-F-29, and UPR-100-F-1are associated with the 100-F-19:2 remediation and closeout documentation.

d. UPR-100-F-3 is associated with the 100-F-25 remediation and closeout documentation.

e. 100-F-44:1 is associated with the 100-F-26:1 remediation and closeout documentation.

f. 1607-F1 (100-FR-2) is associated with 100-F-26:8 (100-FR-1) remediation and closeout documentation.

Sample results are combined for the 100-F-51 and 100-F-63 waste sites.

Sample results are combined for the 100-F-55 and 100-F-62 waste sites.

1

Table 6-9. Summary of Remediated Waste Sites Waste Sites in the 100-IU-2 and the 100-IU-6 Source OUs

| Remediated Waste Sites | | |
|---|---|---|
| **100-IU-2** | | |
| 600-100 | 600-176 | 600-341:1 |
| 600-120[a] | 600-181 | 600-341:2 |
| 600-124 | 600-182 | 600-343 |
| 600-125 | 600-188 | 600-344 |
| 600-127 | 600-190 | 600-345 |
| 600-128 | 600-295 | 600-346 |
| 600-131 | 600-296 | 600-5 |
| 600-132 | 600-297[a] | 628-1 |
| 600-139 | 600-302 | -- |
| **100-IU-2 Source OU Totals** | **26** | |
| **100-IU-6** | | |
| 600-107 | 600-202 | 600-315 |
| 600-108[b] | 600-204 | 600-322 |
| 600-109 | 600-205 | 600-323 |
| 600-111 | 600-23 | 600-327 |
| 600-146 | 600-257[b] | 600-334:1 |
| 600-149:2 | 600-280 | 600-350 |
| 600-178 | 600-3 | JA JONES 1 |
| 600-186 | -- | -- |
| **100-IU-6 Source OU Totals** | **22** | |

a. Sample results are combined for the 600-120 and 600-297 waste sites.

b. Sample results are combined for the 600-108 and 600-257 waste sites.

The following sources of analytical data were used in the soil risk assessment:

- All verification sampling and analysis data reside in the HEIS database.
- All closeout verification data used in this soil risk assessment are included in Appendix D of this report.

#### 6.2.1.2 Data Quality Assessment and Data Validation

A DQA is performed and reported in each closeout documentation report. The DQA compares the verification sampling approach and resulting analytical data with the sampling and data quality requirements specified by the project objectives and performance specifications. The DQA determines if the data are of the right type, quality, and quantity to support site cleanup verification decisions within specified error tolerances. The DQA also determines if the analytical data are found acceptable for decision-making purposes and if the sample design was sufficient for the purpose of cleanup site verification. The cleanup verification sample analytical data and detailed DQA are summarized in the appendices associated with the cleanup verification packages. The results of each DQA are incorporated by reference, and no further DQA was performed as part of this risk assessment.

All analytical data are evaluated and a portion validated, for compliance with QA project plan requirements as documented in the 100 Area RDR/RAWP (DOE/RL-96-17). Data evaluation is performed to determine if the laboratory carried out all steps required by the SAP and the laboratory contract governing the conduct of analysis and reporting of the data. This evaluation also examines the available laboratory data to determine if an analyte is present or absent in a sample and the degree of overall uncertainty associated with that determination. Data validation was done in accordance with validation procedures as part of data evaluation.

#### 6.2.1.3 Identification of COPCs

For the purposes of this evaluation, a "COPC" is defined as an analyte suspected of being associated with site-related activities, that represent a potential threat to HHE, and whose data are of sufficient quality for use in a quantitative baseline risk assessment.

All analytes detected at least once in a waste site decision unit for the 91 waste sites included in the risk assessment are identified as COPCs. As described in Section 6.2.2.2, the floor and sidewalls of an excavated waste site are divided into one or more decision units (e.g., shallow zone, deep zone, overburden, or staging pile area footprint). Verification sampling and analysis data are collected according to sample design requirements for the type of decision unit. For the purpose of this risk assessment, an "exposure area" and a "decision unit" are operationally defined as being the same. Verification sampling and analysis data are subsequently grouped to calculate EPCs.

The contribution from naturally occurring metals and anthropogenic radioisotopes are discussed in the risk characterization section in accordance with *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003). The risk characterization will discuss elevated background concentrations and their contribution to site risks, as well as naturally occurring elements that are not CERCLA hazardous substances, pollutants, and contaminants, but exceed the risk based screening levels (RBSLs).

The RCBRA (DOE/RL-2007-21) identifies a subset of analytes that are excluded from consideration as COPCs by agreement among the Tri-Parties based on relevant Hanford Site data. The following exclusion lists employed in the RCBRA (DOE/RL-2007-21) were also applied to the waste site verification data during the data reduction steps described in Section 6.2.2.2 and listed in Appendix G, Tables G-5 and G-6:

- **Radionuclides with a half-life of less than 3 years:** Radionuclides with half-lives less than 3 years would not be present due to historical Hanford Site operations because of radioactive decay that would have occurred since operations ceased.

- **Essential nutrients:** Essential nutrients that are present at relatively low concentrations and are toxic only at high concentrations need not be considered in a quantitative risk assessment.

- **Water quality or soil physical property measurements:** These analytes were measured to obtain information on water quality or soil properties to understand potential confounding factors for bioassays conducted for soil, sediment, or water or to interpret their influence on the toxicity of COPCs (e.g., grain size for soils, water hardness for metal effects).

- **Background radionuclides (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232):** These background radionuclides were identified by consensus of Tri-Party managers as not directly related to Hanford Site operations or processes.

The RCBRA includes two additional steps to identify COPCs that the soil risk assessment did not apply:

- Evaluate analytes that are commonly reported in waste site cleanup verification reports based on frequency of detection. Inclusion list analytes were not consistently reported in the CVP and RSVP data; therefore, this step was not implemented.

- Evaluate remaining analytes as candidate COPCs, based on comparisons to Hanford Site background, reference areas, and an "analyte-specific" evaluation.

As a result of not applying these last two steps used in the RCBRA to identify COPCs, more analytes are identified as COPCs in this evaluation than were identified in the RCBRA. Identifying all detected analytes (except those on the exclusion list) as COPCs is a more streamlined approach that is consistent with *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003).

### 6.2.2 Exposure Point Concentrations

*Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (hereinafter called Calculating UCL for EPCs [OSWER 9285.6-10]) states that, "an exposure point concentration (EPC) is a conservative estimate of the average chemical concentration in an exposure medium." *Supplemental Guidance to RAGS: Calculating the Concentration Term* (hereinafter called RAGS Supplemental Guidance [OSWER Publication 9285.7-081]) states that, "because of the uncertainty associated with estimating the true average concentration at a site, the 95 percent UCL of the arithmetic mean should be used for this variable." Use of the 95 percent UCL of the arithmetic mean yields risk estimates that correspond to an RME. Instances where a value different from a UCL is used as the EPC are clearly stated in this risk assessment. Reasons and/or justifications are also provided.

Calculating UCL for EPCs (OSWER 9285.6-10) further states that, "The EPC is determined for each individual exposure unit within a site. An exposure unit is the area throughout which a receptor moves and encounters an environmental medium for the duration of the exposure. Unless there is site-specific evidence to the contrary, an individual receptor is assumed to be equally exposed to media within all portions of the exposure unit over the time frame of the risk assessment." For this evaluation, the "exposure unit" and the "decision unit" are operationally defined as being the same. As previously described, one or more decision units are included within a waste site, including shallow vadose zone material (0 to 4.6 m [0 to 15 ft] bgs), deep vadose zone material (greater than 4.6 m [15 ft] bgs), overburden material, and staging area footprint material.

*Statistical Guidance for Ecology Site Managers*, (Ecology Publication 92-54) has been used to calculate EPCs for all closeout documentation to date. *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54) was published in 1992 and this guidance has been superseded by Calculating UCL for EPCs (OSWER 9285.6-10), which was published in 2002. For this soil risk assessment, UCLs were recalculated for all waste sites and decision units to incorporate the updated guidance in Calculating UCL for EPCs (OSWER 9285.6-10). UCLs that incorporate updated guidance use more rigorous statistical methods to estimate exposure concentrations and eliminate the use of the simple substitution method for nondetects where a proxy value of one-half the detection limit is assigned to all nondetected results. Calculating UCL for EPCs (OSWER 9285.6-10) notes that because of the complicated formulas used to compute UCLs, there is no general rule about which substitution rule will yield an appropriate UCL. The uncertainty associated with the substitution method increases and its appropriateness decreases as the detection limit becomes larger and as the number of nondetects in the data set increases.

The following sections describe the statistical methodology used for closeout documentation (Section 6.2.2.1) and the statistical methodology used for this soil risk assessment (Section 6.2.2.2). While both evaluations used the same dataset, the differences in statistical methodologies may result in differences in the EPC values between the closeout documentation and this risk assessment for the same COPCs in a waste site decision unit.

#### 6.2.2.1 Statistical Evaluation Methodology Used for Closeout Documentation

For waste sites closed using a statistical/random sampling design, the primary statistical calculation to support cleanup verification was the 95 percent UCL on the arithmetic mean of the data. Statistical calculations were performed in compliance with *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54). This guidance addresses two kinds of data distributions: normal and lognormal. For normal data, the guidance recommends a UCL on the mean, based on the Student's t-statistic. For lognormal data, the guidance recommends the Land method using the H-statistic. This guidance also implements the substitution method where a proxy value of one-half the detection limit is assigned to nondetected results.

Small data sets ($n<10$) were evaluated in accordance with Section 5.2.1.4 of *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54) and a nonparametric distribution was assumed. When a nonradionuclide was detected in fewer than 50 percent of the samples collected and for focused sampling designs, the maximum detected value was used for comparison purposes.

#### 6.2.2.2 Statistical Evaluation Methodology Used for the Soil Risk Assessment

Calculating UCL for EPCs (OSWER 9285.6-10) is the EPA guidance for UCL calculation and ProUCL 4.00.05 serves as the companion software package for this guidance. ProUCL 4.00.05 contains rigorous parametric and nonparametric (including bootstrap methods) statistical methods that can be used on full data sets without nondetects and on data sets with nondetect observations. Both ProUCL and Calculating UCL for EPCs (OSWER 9285.6-10) were used to recalculate the UCLs for the 100-F/IU Source OUs.

To ensure that waste sites and decision units are grouped correctly and UCLs are accurately recalculated, all waste sites, decision unit groupings, and sample numbers were individually verified against the original closeout documentation. *Waste Site Evaluation Process for the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Source Operable Units* (ECF-100FR1-11-0019), provided in Appendix G, documents the process used to confirm a complete list of waste sites with a reclassification status of "interim closed out" or "no action" through March 2012. Verification of sample numbers associated with each waste site was confirmed along with the decision unit grouping with which the sample is associated. This list of samples is used to verify the sampling results are complete. The analytical data that have undergone this review

process become the final data set used to calculate the UCLs and associated summary statistics used in this soil risk assessment. Tables G-3 and G-4 list the sample numbers associated with each waste site decision unit, along with the date the sample was collected, the type of sample design used, and the Washington state plane coordinates of the sample location for the 100-FR-1 and 100-FR-2 Source OUs and the 100-IU-2 and 100-IU-6 Source OUs, respectively.

#### *6.2.2.2.1 Waste Site Decision Units*

Verification sampling and analysis data that are associated with the samples listed in Table G-3 for the 100-FR-1 and 100-FR-2 Source OUs and Table G-4 for the 100-IU-2 and 100-IU-6 Source OUs (Appendix G) are from several different decision units within a waste site, including shallow vadose zone material, deep vadose zone material, overburden material, and staging pile area footprint material. The following describes the basis of each decision unit and briefly describes the sample designs used.

The floor and sidewalls of an excavated waste site are divided into one or more decision units and a sample design is developed for the decision unit. Sample design requirements for each decision unit are described in the 100 Area SAP (DOE/RL-96-22). In practice, the shallow zone decision unit is typically represented by material from the excavation floor if at or above 4.6 m (15 ft) and any sidewalls from grade level (0 m to a depth of 4.6 m (0 to 15 ft). The deep zone decision unit is represented by material from the excavation floor (if below 4.6 m [15 ft]) and by any sidewall materials below 4.6 m (15 ft). As needed, decision subunits and an associated sampling design are also established for suspect clean overburden stockpiles (i.e., to verify suitability for backfill material) and the footprint of the staging pile area. The layout and orientation of the sampling designs are based on the size, shape, and depth of the site. Sampling of a waste site decision unit to confirm attainment of remedial action objectives was performed according to one of three types of sampling designs: focused sampling design, random or statistical sampling, or a combination of both. The decision unit naming convention is summarized in Table 6-10.

The process used to calculate EPCs for each waste site and decision unit is documented in *Computation of Exposure Point Concentrations for the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Source Operable Units* (ECF-100 FR1-11-0020), which is provided in Appendix G. The purpose of *Computation of Exposure Point Concentrations for the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Source Operable Units* (ECF-100FR1-11-0020) is to document the data processing and reduction steps, methodology, decision logic, assumptions, input files, and output files used to determine the EPCs.

Table 6-10. Summary and Definition of Decision Unit Types

| Decision Unit Name | Depth | Sampling Design Description |
|---|---|---|
| Shallow | 0 to 4.6 m (15 ft) bgs | Samples collected using a statistical sampling design |
| Deep | Greater than 4.6 m (15 ft) bgs | |
| Overburden | Not applicable | |
| Staging pile area | Not applicable | |
| Shallow_Focused | 0 to 4.6 m (15 ft) bgs | Samples collected using a focused sampling design |
| Deep_Focused | Greater than 4.6 m (15 ft) bgs | |
| Overburden_Focused | Not applicable | |
| Staging pile area_Focused | Not applicable | |

#### 6.2.2.2.2 *Data Processing and Reduction*

This section describes the data processing and reduction steps that are taken before the calculation of UCLs. Figure 6-1 shows each of the data processing and data reduction steps, and the number of records associated with each step for the 100-F/IU Source OU.

#### 6.2.2.2.3 *Laboratory and Data Validation Flags*

Analytical data are received from the laboratory with data qualification flags; validation qualifiers are assigned during the data validation process. The following rules are applied to determine how the sample results can be used for calculating UCLs.

- All sample results flagged with a "U" data qualifier or combination of qualifiers that include a "U," such as a "UJ," are considered nondetected concentrations.
- All sample results without a "U" data qualifier are considered detected concentrations, including results without a qualifier or with an "E" or a "J" data qualifier.
- Sample results that are rejected and flagged with an "R" validation qualifier are not used for calculating UCLs.
- where:
  - U = Analyzed for but not detected above limiting criteria.
  - J = Estimated value.
  - E = Reported value is estimated because of interference (inorganics).
  - R = Do not use. Further review indicates the result is not valid.

#### 6.2.2.2.4 *Analytes Reported by Multiple Analytical Methods*

Often, a sample is analyzed for an analyte using more than one analytical method, resulting in multiple results for the analyte from the same location and sample date. When analytes are reported by more than one analytical method for a sample, the results are processed to select the method that provides the most reliable results. Considerations for determining data to be retained include method-associated sample size, detection frequency, and detection limits. The most conservative (i.e., health-protective) use of these types of data is the goal. Larger sample size, higher detection frequencies, and lower detection limits are given higher priority for method selection.

For example, lead may be analyzed using EPA Method 200.8 with an EQL of 0.5 mg/kg or EPA Method 6010 with an EQL of 5.0 mg/kg. For a sample with lead concentrations reported by both methods, the results reported by EPA Method 200.8 are chosen over EPA Method 6010 because of the more sensitive detection limit.

#### 6.2.2.2.5 *Field Duplicate Results*

Field QC samples (field duplicates) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and field QC samples are collected from the same location (i.e., sample node) and same date, resulting in more than one sample per location and date. Because multiple sets of analytical results cannot be used to quantify risk (i.e., this would result in multiple-counting of a chemical), the results for the same location and date are reduced to a single result for each reported analyte. The most conservative (i.e., health-protective) result is the goal. The following criteria are used to reduce multiple sample results for one location and date to a single result:

- If two or more detections are reported, the maximum concentration is used.
- If one detection and one or more nondetections are reported, the detected concentration is used.
- If two or more nondetections are reported, the lowest detection limit is used.

#### *6.2.2.2.6 Identify Analytes for 95 Percent UCL Calculation*

After extracting and processing the data set, it is further reduced to identify a subset of analytes that require computation of a UCL. Analytes that meet any of the exclusion criteria or were not detected in any of the samples analyzed with the 100-F/IU Source OUs are not carried forward into the statistical calculations and EPC calculation. The analyte identification steps and the number of records associated with each of the steps are presented in Figure 6-2 for the 100-F Source OU and in Figure 6-3 for the 100-IU-2/IU-6 Source OUs.

#### 6.2.2.2.7 Apply Exclusion Criteria

The first step used to identify analytes that require a 95 percent UCL calculation is to apply exclusion criteria. Analytes that do not meet the exclusion criteria are carried forward into the next step of the process. Analytes that meet exclusion criteria are eliminated from further consideration. The following were excluded:

- Radionuclides that have half-lives of less than 3 years and that are not significant daughter products
- Background radionuclides that are not directly related to Hanford Site operations or processes (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232)
- Essential nutrients (minerals) (calcium, magnesium, potassium, and sodium)
- Analytes without known toxicity information (for example delta-BHC, endrin ketone, and sulfate)[5]

In total, 48 analytes for the 100-FR-1 and 100-FR-2 Source OUs and 37 analytes for the 100-IU-2/IU-6 Source OUs meet the exclusion criteria (Tables G-5 and G-6 in Appendix G). Sampling dates, minimum and maximum detected concentrations, minimum and maximum method detection limits, and the basis for their exclusion are provided in these tables.

#### *6.2.2.2.8 Identify Nondetected Analytes*

The next step used to identify analytes that require a 95 percent UCL calculation is to identify nondetected analytes. Analytes that are measured at appropriate sampling locations, have adequate detection limits, and that have not been detected in any of the samples are eliminated from further consideration. Any analyte that is detected at least once in the 100-F/IU Source OU is carried forward to the next step of the process.

A total of 72 analytes were not detected in the 100-FR-1 and 100-FR-2 Source OUs samples and are listed in Table G-7 (Appendix G). A total of 83 analytes were not detected in the 100-IU-2/IU-6 Source OUs samples and are listed in Table G-8 (Appendix G). These tables also provide sampling dates, total number of samples, and minimum and maximum MDLs.

#### *6.2.2.2.9 95 Percent UCL Calculation Methodology*

A discussion of waste site decision units was provided earlier in this section. It should be noted that calculated UCLs and EPCs selected for shallow zone and deep zone decision units represent verification data collected from the floor and the sidewall of the excavated waste site. As a result, risks are overstated because the UCL and the EPC do not take credit for the existing clean backfill that covers the remediated waste site.

[5] Note that this exclusion criterion includes the water quality or soil physical property measurements described in Section 6.2.1.3 of this chapter.

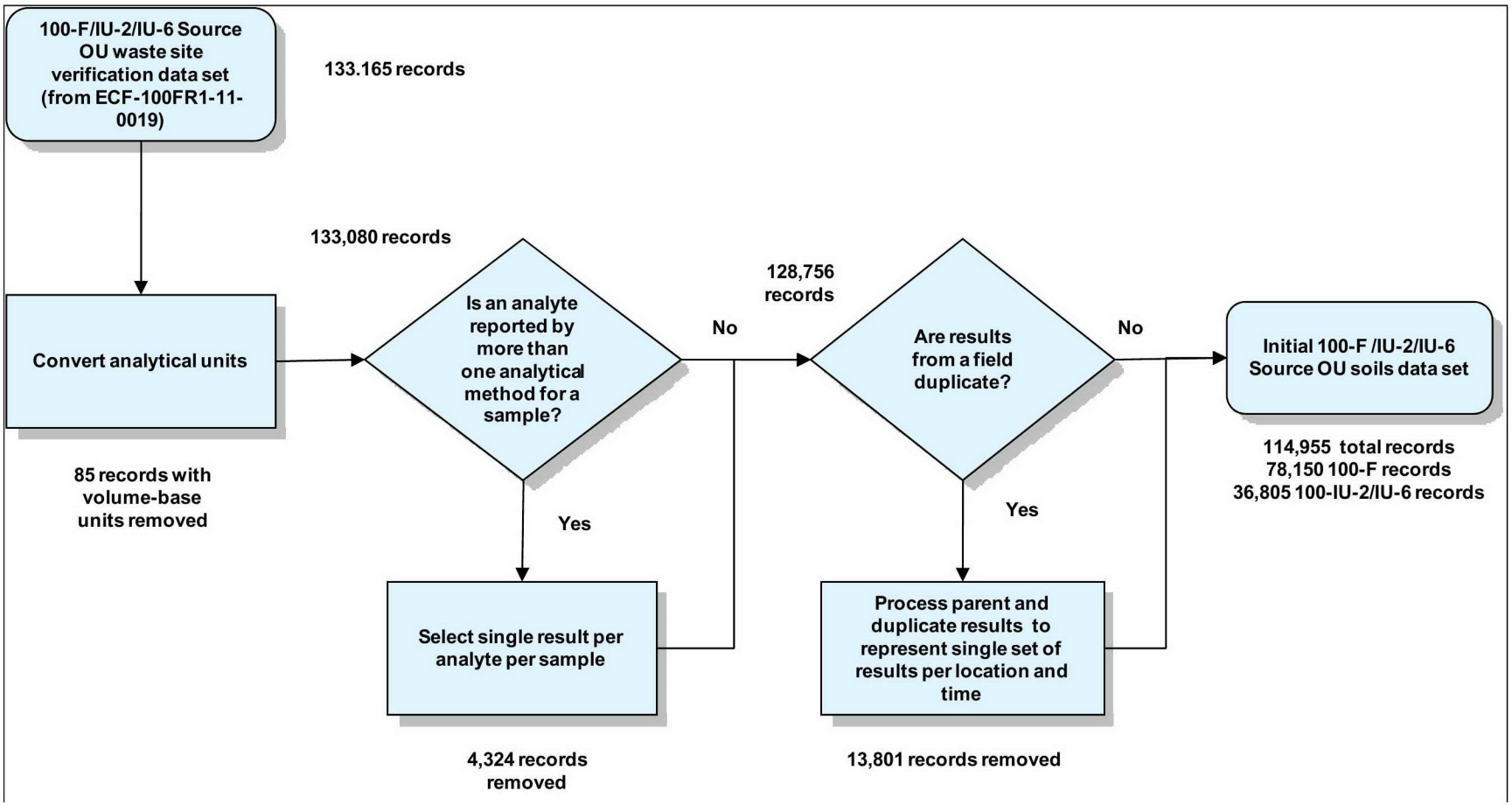


Figure 6-1. Data Processing and Reduction Steps for the 100-F/IU Source OUs

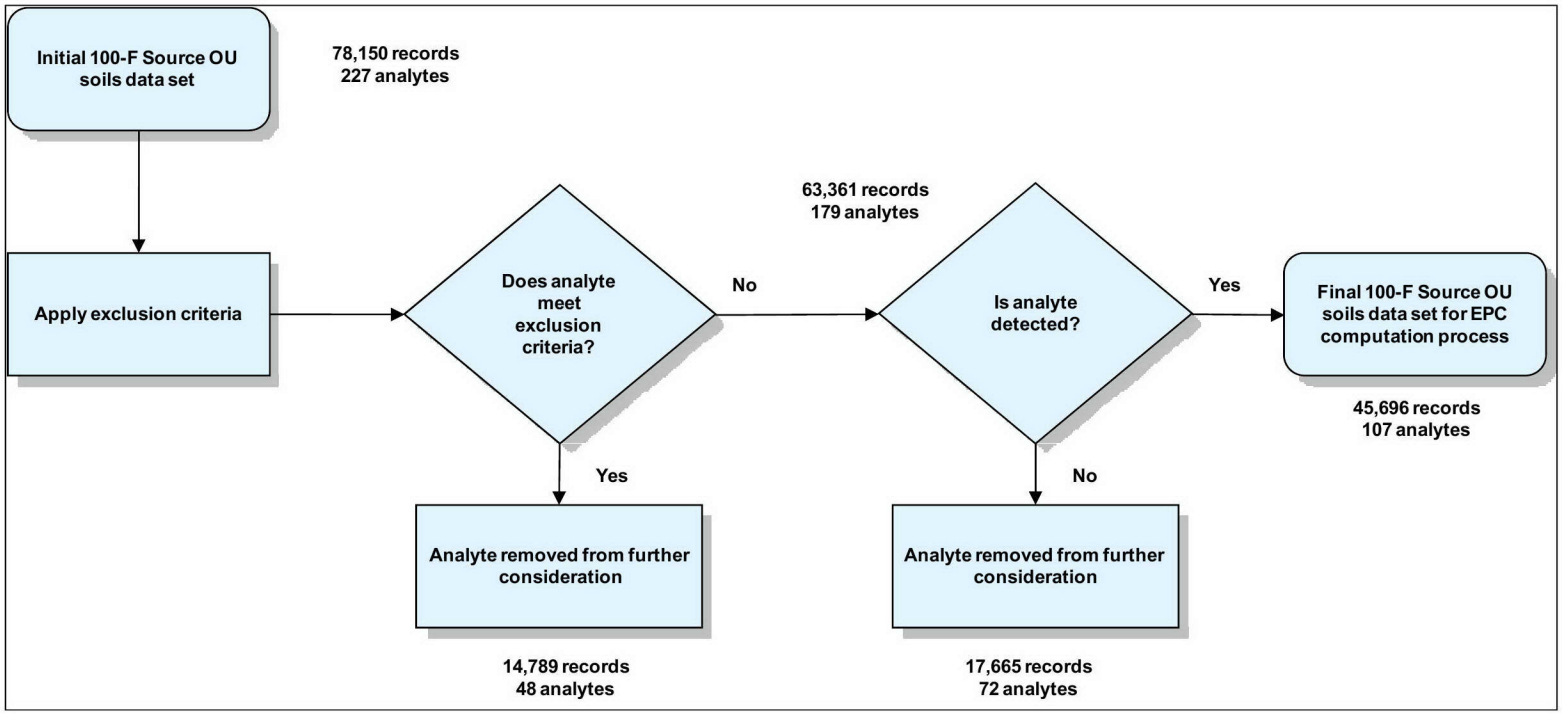


Figure 6-2. Analyte Identification Steps for the 100-F Source OU Data Set

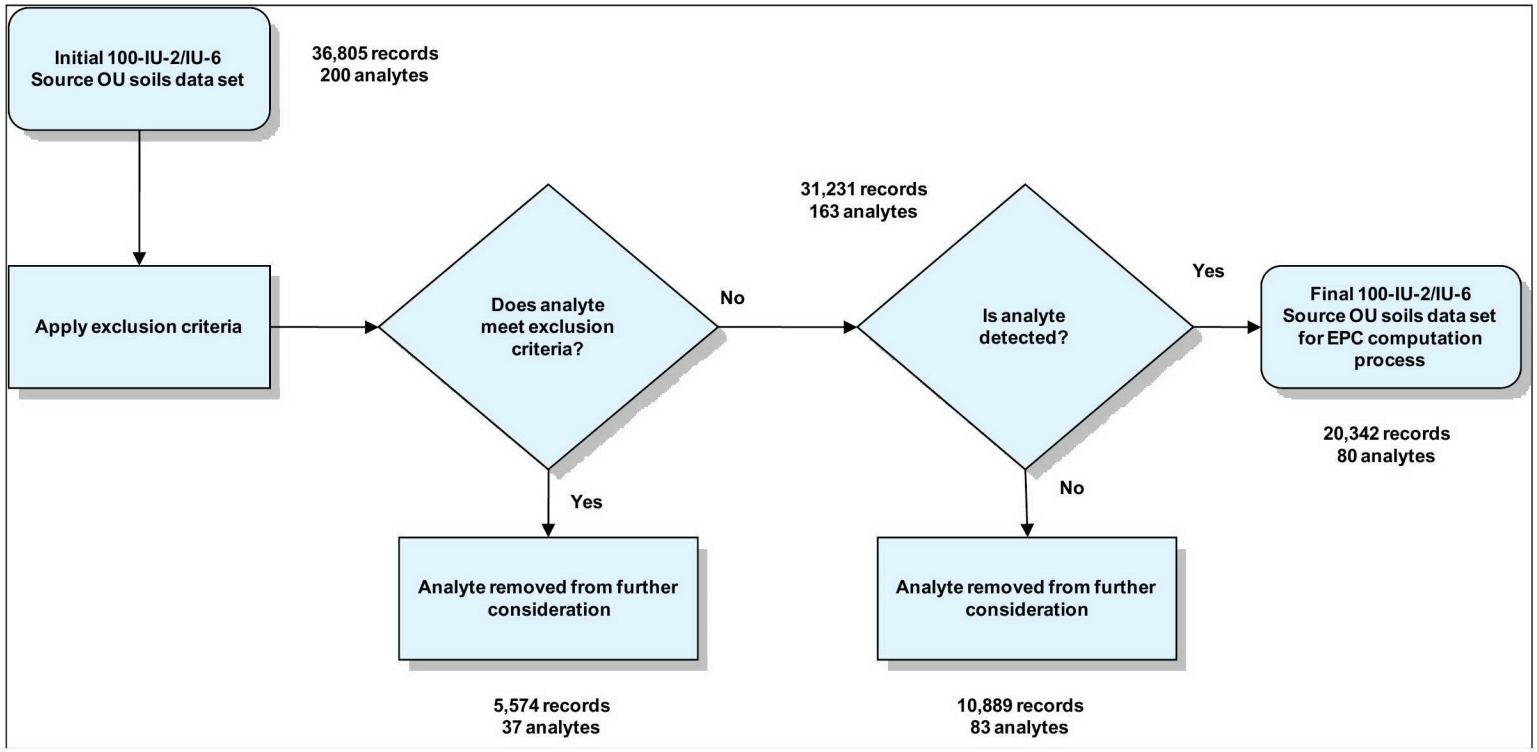


Figure 6-3. Analyte Identification Steps for the 100-IU-2 and 100-IU-6 Source OU Data Set

Analytical data for all analytes that have been detected at least once in each waste site decision unit are extracted from the data set and subsequently formatted so they can be directly imported into ProUCL where 95 percent UCL calculations and summary statistics are performed. The following information is obtained from the UCL calculations and summary statistics generated for each waste site decision unit.

- Waste site decision unit name
- Analyte name and Chemical Abstract Service (CAS) Registry number
- Total number of sample results, total number of detects, and total number of nondetects
- Minimum and maximum detection limits for each detected analyte (when available)[6]
- Minimum and maximum detected concentrations for each analyte
- Coefficient of variation for each analyte
- The UCL value, the UCL basis, and comments and/or warning statements for each analyte

For most data sets, ProUCL recommends a single UCL as the decision statistic. When a single decision statistic is recommended, this UCL is selected. However, ProUCL will recommend more than one decision statistic for some data sets. The most conservative (i.e., health-protective) result, that is not greater than the maximum observed concentration, is the goal when selecting the UCL to represent the EPC. When more than one decision statistic is given, the following logic is used to select the UCL:

- If more than one UCL is recommended as a decision statistic and the UCLs are less than or equal to the maximum observed concentration, then the highest recommended UCL is selected as the decision statistic.
- If more than one UCL is recommended as a decision statistic and the UCLs are greater than the maximum observed concentration, then the maximum observed concentration is selected as the decision statistic.
- If more than one UCL is recommended as a decision statistic, at least one is less than the maximum observed concentration, and at least one is greater than the maximum observed concentration, then the maximum observed concentration is selected as the decision statistic.

There were 27 analytes in the 100-FR-1 and 100-FR-2 Source OUs, one analyte in 100-IU-2 Source OU, and seven analytes in the 100-IU-6 Source OU where more than one UCL was recommended and at least one of the UCLs was greater than the maximum observed concentration.

#### *6.2.2.2.10 Selection of EPCs*

The following logic was used to select the EPC for each detected analyte in a waste site decision unit:

- For samples collected in accordance with a focused sampling design, the maximum detected concentration is selected as the EPC for every detected analyte.
- For samples collected in accordance with a statistical sampling design, the following logic is applied.
  - If a valid 95 percent UCL can be calculated, then the highest potential 95 percent UCL value (if more than one potential UCL value is recommended) is selected.
  - If the recommended 95 percent UCL is greater than the maximum detected concentration, then the maximum detected concentration is selected.

[6] Minimum and maximum detection limits are summarized in the ProUCL output only when a valid UCL can be calculated.

- If a valid 95 percent UCL cannot be calculated, then the maximum detected concentration is selected.

Selection of the EPC value using the above decision logic is presented in Figure 6-4. A summary of the EPCs for each detected analyte in a given waste site decision unit is provided in Table G-9 for the 100-FR-1 and 100-FR-2 Source OUs, Table G-10 for the 100-IU-2 Source OU and Table G-11 for the 100-IU-6 Source OU (Appendix G).

*6.2.2.2.11 Use of Maximum Detected Concentrations to Estimate the EPC*

The EPC defaults to the maximum detected concentration when any of the following conditions are met:

- Samples are collected using a focused sampling design
- A valid 95 percent UCL cannot be calculated because of a limited number of detections (less than 5)
- A valid 95 percent UCL is greater than the maximum detected concentration

The sampling plan for a focused decision unit was designed to sample the areas of suspected contamination. The results from this type of sampling design can introduce bias into statistical analyses to estimate means, such as calculations of UCLs. RAGS Supplemental Guidance (OSWER Publication 9285.7-081) states "a value other than the 95 percent UCL can be used, provided the risk assessor can document that high coverage of the true population mean occurs (i.e., the value equals or exceeds the true population mean with high probability)." Because the sampling design for these decision units focused on areas of suspected contamination, the conclusion that maximum detected concentration exceeds the true population mean in a focused decision unit can be made with certainty. Additionally, the closeout documentation for the focused decision units used the maximum detected concentration to determine if the remedial action goal has been attained (Section 3.6.3 of the 100 Area RDR/RAWP [DOE/RL-96-17]). Because of the potential for statistical bias and to maintain consistency with the 100 Area RDR/RAWP, the maximum detected concentration is selected as a conservative estimate of the EPC for the focused decision units.

ProUCL has minimum size requirements to compute UCLs. For data sets of at least five results, a UCL is not calculated when there is only one detected result in the data set. ProUCL notes that in cases where the number of available detected samples is small (<5), the estimation of the EPC term is decided upon on a site-specific basis. ProUCL generates warning messages regarding the potential deficiencies associated with a small data set. For small data sets with very few detected values (fewer than 5), a valid UCL cannot be calculated. For risk assessment purposes, the maximum concentration is used as a conservative representation of the EPC.

Some of the distributional methods employed by ProUCL can produce very high estimates of the UCL (particularly the Land method). Calculating UCL for EPCs (OSWER 9285.6-10) acknowledges that the Land method can produce extremely high values for the UCL when data exhibit high variance and the sample size is small. RAGS Supplemental Guidance (OSWER Publication 9285.7-081) recognizes the problem of extremely high UCLs, and recommends the maximum detected concentration become the default when the calculated UCL exceeds this value. When the recommended UCL exceeds the maximum detected concentration, ProUCL, however, advises that an alternative UCL (i.e., Chebyshev inequality) be selected instead of the maximum detected concentration for an EPC. When the recommended UCL is greater than the maximum detected result, the maximum detected value is selected as the EPC for the 100-F/IU Source OUs. ProUCL displays a warning message when the recommended 95 percent UCL of the mean exceeds the observed maximum concentration.

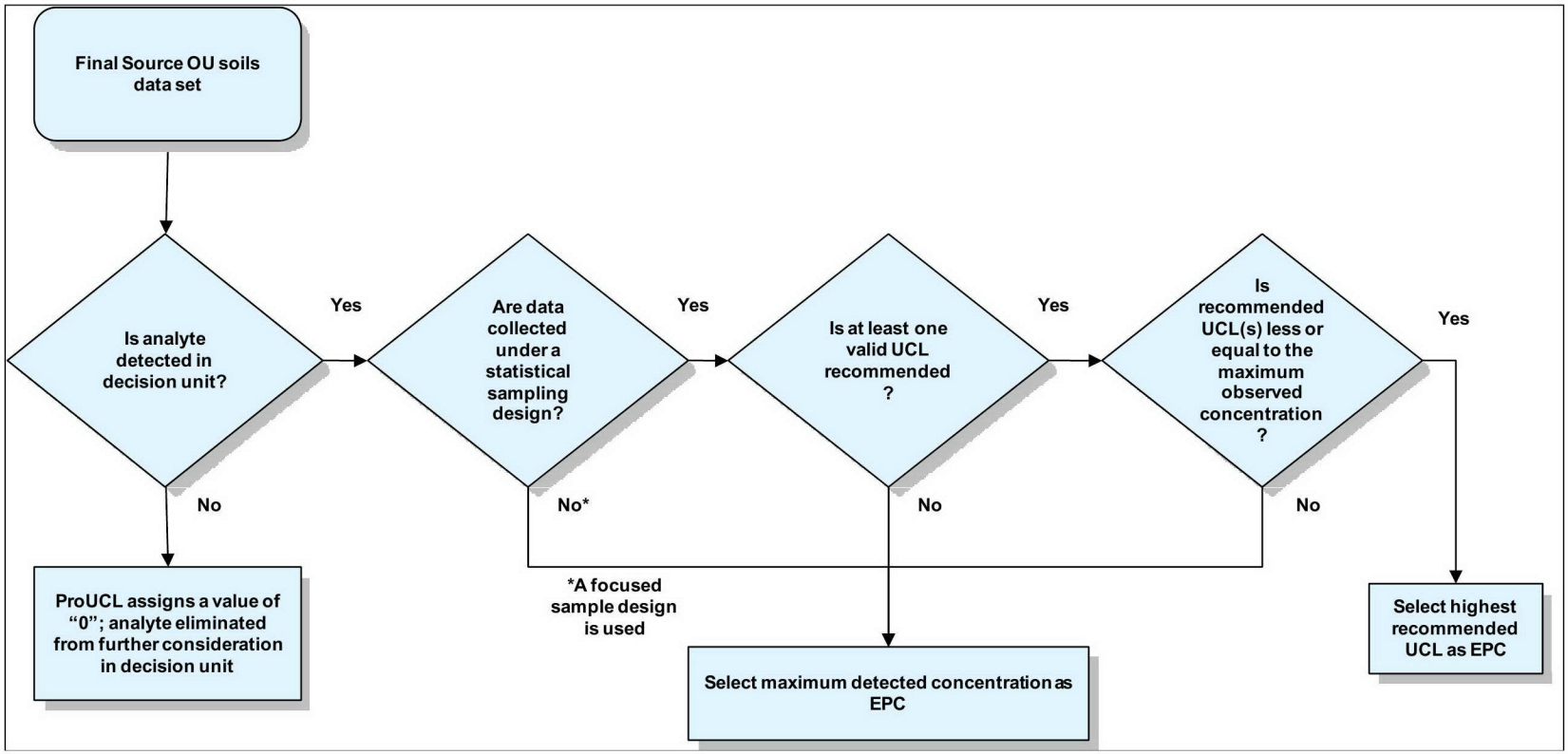


Figure 6-4. Decision Logic for Selection of the EPC Value

#### 6.2.2.3 *Methodology Used to Calculate Total Uranium Concentrations from Isotopic Uranium Concentrations*

Uranium analytical data are reported for most of the 100-F/IU Area Source OU waste site decision units as isotopic uranium (reported in units of pCi/g) and not as total uranium (reported in units of µg/kg). Because total uranium (µg/kg) is needed to support the 100-F/IU Area Source OU FS, an additional step is performed to calculate a mass-based total uranium concentration (µg/kg) from the activity-based isotopic uranium concentrations (pCi/g) reported for each waste site decision unit. This step entails obtaining the uranium isotope analytical data for each sample, converting the data from activity- to mass-based concentrations, and then summing the converted values for detected concentrations to produce a mass-based total uranium value. For sample results where all uranium isotope results are reported as non-detects, the individual values are not summed, but the maximum non-detect value is retained and put in the ProUCL file, flagged as a non-detect.

If both converted isotopic and analytical total uranium EPCs are available for a decision unit, then the EPC based on analytical total uranium concentrations is carried through as the final EPC for that decision unit.

The pCi/g to µg/kg conversions and subsequent summations are performed using specific activities for the uranium isotopes and appropriate conversion factors, as shown in the calculation example provided in Table 6-11. As mentioned previously, only detected concentrations are included in the summations. In the Table 6-11 example, uranium-235 is a nondetect and thus not included in the summation. The calculated total uranium values are assigned an analyte name of Total_U_Isotopes in the data sets and then a ProUCL input file (as described in Section 6.2.2.2) containing the Total_U_Isotopes data is produced for each waste site decision unit.

Table 6-11. Example Conversion from Activity- to Mass-Based Concentration (pCi/g to µg/kg) for Uranium Isotopes and Summation to Produce a Mass-Based Total Uranium Concentration (µg/kg)

| Uranium Isotope | Measured Activity (pCi isotope/ g soil)[a] (ND or D) | Specific Activity (Bq isotope/ g isotope)[b] | Specific Activity (pCi isotope/ g isotope)[c] | Conversion Factor (µg isotope/ g isotope) | Conversion Factor (g soil/ kg soil) | Calculated Concentration (µg isotope/ kg soil)[d] |
|---|---|---|---|---|---|---|
| U-233/234[e] | 0.649 (D) | 2.302E+08 | 6.222E+09 | 1,000,000 | 1,000 | 0.10 |
| U-235 | 0.031 (ND) | 7.995E+04 | 2.161E+06 | 1,000,000 | 1,000 | 14 (not summed) |
| U-238 | 0.338 (D) | 1.243E+04 | 3.359E+05 | 1,000,000 | 1,000 | 1,006 |
| **Total Uranium Concentration (Total_U_Isotopes) (µg total uranium/kg soil) =** | | | | | | **1,006** |

a. Example analytical data shown for illustration purposes only.

b. *Table of Isotopes* (Firestone and Shirley, 1998).

c. Formula = specific activity (Bq/g) / 3.7E+10 Bq/Ci × 1.0E+12 pCi/Ci

d. Formula = measured activity (pCi/g) / specific activity (pCi/g) × conversion factor (µg/g) × conversion factor (g/kg)

e. Values presented are for uranium-234; uranium-234 is assumed to be the dominant isotope in undifferentiated uranium-233/234

ND = nondetect

D = detect

### 6.2.3 Exposure Assessment

This section defines the exposure scenarios used for various land use and receptor activities, describes the potential exposure pathways resulting from site contaminants, and provides the methodology for calculating the RBSLs for direct contact, based on currently available site information. The conceptual exposure model is formulated according to EPA guidance, taking into consideration information on contaminant sources, release mechanisms, routes of migration, potential exposure points, potential routes of exposure, and potential receptor groups associated with the 100-F/IU Source OUs. This results in a set of exposure pathways that reflect an RME.

An exposure pathway can be described as the physical course that a COPC takes from the point of release to a receptor. The route of exposure is the means by which a COPC enters a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A source
- A mechanism of chemical release and transport
- An environmental transport medium
- An exposure point
- An exposure route
- A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete; therefore, it creates no risk or hazard.[7]

#### *6.2.3.1 Contaminant Sources*

The primary sources of contamination in the 100-F Area were the structures and processes associated with the operation of F Reactor.

The effect of Hanford Site-specific past practices in the l00-IU-2 and l00-IU-6 OUs is limited in nature. Most identified waste sites in this area can be traced to pre-Hanford Site activities (agricultural, domestic) or nonproduction-related activities such as temporary worker housing or security. A complete discussion of primary and secondary contaminant sources is provided in Section 5.2 of this report.

#### *6.2.3.2 Release Mechanisms and Environmental Transport Media*

The primary COPC release mechanisms and transport pathways at the 100-F/IU are discussed in Sections 5.3 and 5.4, and include the following:

- Migration of contaminated liquids through the vadose zone column through infiltration, percolation, or leaching
- Direct contact and external radiation from vadose zone material containing COPCs (receptor contact with shallow vadose zone material replaces release and transport)
- Emission of dusts and vapors during former plant operations

[7] With the exception of external irradiation from radionuclides, environmental contaminants must cross a cellular barrier and enter the body of a receptor for exposure to occur.

- Generation of dust emanating from shallow vadose zone material to ambient air from wind, or during maintenance or excavation activities occurring at the 100-F/IU Source OUs
- Volatilization of COPCs emanating from shallow vadose zone material to ambient air at the 100-F/IU Source OUs

#### 6.2.3.3 Potentially Complete Human Exposure Pathways and Receptors

Based on the current understanding of land use conditions near the 100-F/IU Source OUs, the most plausible exposure pathways for calculating PRGs and characterizing the human health risks have been identified (represented in Figures G-1 and G-2 for the 100-F Source OUs and in Figures G-3 and G-4 for the 100-IU-2/IU-6 Source OUs in Appendix G). The groundwater risk assessment is provided in Section 6.3.

For the purpose of this soil risk assessment, shallow vadose zone material is represented by samples collected from 0 to 4.6 m (0 to 15 ft) bgs and deep vadose zone material is represented by samples collected from depths greater than 4.6 m (15 ft) bgs (Section 6.2.1.2, Table 6-10). Groundwater is represented by samples collected from the unconfined aquifer and discussed in Section 6.3.

##### 6.2.3.3.1 Residential Scenario

PRGs (also used as RBSLs) developed for the residential scenario are the numeric values that represent the RAOs presented in Chapter 8. The results of comparing EPCs to the RBSLs in this soil risk assessment will be used to help determine whether additional remedial action is necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as demonstrated by verification sampling and analysis.

The residential scenario for radiological and nonradiological analytes is based on two different conceptual exposure models. The exposure pathways for radionuclides include direct contact in addition to dust inhalation, consumption of homegrown foodstuffs (e.g., produce, beef, and milk), and the leaching pathway (includes drinking water ingestion and fish ingestion). The exposure pathways for nonradiological analytes in vadose zone material include direct contact from incidental ingestion and inhalation of vapors and dust in ambient air.

The residential scenarios described below are consistent with the exposure scenario and ARARs used to develop the interim action ROD RAGs for soil presented in the 100 Area RDR/RAWP (DOE/RL-96-17). This exposure scenario is also evaluated in the RCBRA to determine if cleanup actions completed under the interim action RODs are protective of human health relative to the range of exposure scenarios evaluated in this risk assessment.

*Radiological.* Consistent with the 100 Area RDR/RAWP (DOE/RL-96-17), the RESRAD code is used to evaluate exposure to radiological contaminants in vadose zone material. Revisions to this exposure scenario reflect updates in guidance since the 100 Area RDR/RAWP (DOE/RL-96-17) were originally published in 1996. With the exception of changes resulting from updates in guidance, the residential scenario is the same as that published in the 100 Area RDR/RAWP. Exposure assumptions that were updated to reflect current EPA guidance include a decrease in the external gamma-shielding factor (increased shielding) and a decrease in the outdoor time fraction. Health protective levels were also updated from a target annual dose rate of 15 mrem/yr to a target risk of $1 \times 10^{-4}$ to be consistent with guidance recommended in *Radiation Risk Assessment At CERCLA Sites: Q & A* (EPA/540/R/99/006). A detailed description of this exposure scenario is provided in *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Reports* (ECF-HANFORD-10-0429).

For radiological PRG development, a subsistence farming setting is used. This assumes that each interim remediated waste site decision unit has 1) the potential to be developed into a residence with a basement, 2) vegetable and fruit crops grown in a backyard garden, and 3) a pasture that is used to raise livestock sufficient for meat and milk production. A downgradient well is installed where exposure could potentially occur from contaminants leaching from the vadose zone material to groundwater beneath the residence (i.e., the leaching pathway). The resident could potentially come into direct contact with soil from the remediated waste site and potentially inhale dust in ambient air. The resident could potentially consume crops raised in a backyard garden and consume meat (beef and poultry) and milk raised on the pasture. Based on the established land uses and the proclamation of "Establishment of the Hanford Reach National Monument" (65 FR 37253), it is unlikely that land within the l00-F/IU-2/IU-6 OUs will be used for residential purposes.

The Residential scenario evaluates residential pathways that include exposure to shallow vadose zone material from residential yards or groundwater from domestic wells. Potential routes of exposure to shallow vadose zone material evaluated in the RESRAD code include direct external exposure, incidental material ingestion, and inhalation of dust generated from wind or from yard maintenance activities. This scenario also evaluates residential exposure to radiological contaminants through food chain pathways (uptake of contamination from vadose zone material to plants and animals). Food chain pathways include the consumption of fruits and vegetables grown in a backyard garden, and consumption of meat and milk from livestock raised on the pasture. From the leaching pathway, this scenario evaluates residential consumption of drinking water from a downgradient well, use of the well for irrigation of crops and watering livestock, and residential consumption of fish raised in a pond supplemented with water from the downgradient well.

*Nonradiological.* The residential scenario for nonradiological analytes measured in soil is also consistent with the exposure scenario used for the interim action RAGs for soil presented in the 100 Area RDR/RAWP (DOE/RL-96-17). The exposure scenario for protection of human health is based on the MTCA Standard "Unrestricted Land Use Soil Cleanup Standards," "Method B Soil Cleanup Levels for Unrestricted Land Use" (WAC 173-340-740(3)) and Standard "Cleanup Standards to Protect Air Quality," "Method B Air Cleanup Levels" (WAC 173-340-750(3)). The MTCA (WAC 173-340) Standard Method B soil cleanup levels are based on exposure to a child receptor that includes incidental ingestion, and use residential exposure frequency and duration assumptions. The MTCA (WAC 173-340) Standard Method B air cleanup levels are based on exposure to a child and adult receptor, includes inhalation of vapors and dust in ambient air, and assumes residential exposure frequency and duration assumptions. For arsenic and lead, Table 740-1 Method A ("Tables" [WAC 173-340-900]) soil cleanup levels for unrestricted land use of 20 and 250 mg/kg were used. For total petroleum hydrocarbons (TPH), Table 747-5 ("Tables" [WAC 173-340-900]) residual saturation screening levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil) were used.

*Groundwater.* Groundwater within the 100-FR-3 Groundwater OU and the 100-IU-2 and 100-IU-6 Groundwater Area is currently contaminated and withdrawal is prohibited because of ICs placed on it by (DOE) through the interim action ROD; however, ICs will be evaluated as part of the final remedy. Under current site use conditions, no complete human exposure pathways to groundwater are assumed to exist. In addition, groundwater currently discharges to the Columbia River through upwelling and seeps. Groundwater within this OU is not anticipated to become a future source of drinking water until cleanup criteria are met and groundwater is restored to its highest beneficial use. However, groundwater in this risk analysis is evaluated for drinking water use and undiluted groundwater concentrations are compared to DWSs and aquatic criteria to support the determination of the basis for action and to support the development of PRGs for evaluating remedial alternatives in the FS. It is noted,

that aquatic water quality criteria are only directly applicable where groundwater discharges to surface water.

The residential scenario for radiological and nonradiological analytes measured in groundwater is also consistent with the RAGs documented in the interim action RODs and in the 100 Area RDR/RAWP (DOE/RL-96-17). Groundwater concentrations are compared to current MCLs for radionuclides, which are set at 4 mrem/yr for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity (including radium-226, but excluding uranium and radon), and 5 pCi/L combined for radium-226 and radium-228. A mass based concentration MCL has been established for uranium as 30 µg/L. The exposure scenario for protection of human health is based on the MTCA Standard Method B, "Groundwater Cleanup Standards," "Standard Method B Potable Groundwater Cleanup Levels" (WAC 173-340-720 (4)(b)). The MTCA (WAC 173-340) Standard Method B groundwater cleanup levels are based on exposure to child and adult receptors, include drinking water ingestion and inhalation of vapors, and assume residential exposure frequency and duration assumptions.

#### *6.2.3.3.2 Resident Monument Worker Scenario*

Land use within the River Corridor's 100 and 600 Areas is predominantly conservation/preservation. In 2000, Presidential Proclamation 7319 (*Establishment of the Hanford Reach National Monument*) was signed, creating the Hanford Reach National Monument to be managed by U.S. Fish and Wildlife Service (USFWS) and DOE ("Establishment of the Hanford Reach National Monument" [65 FR 37253]). The Monument was established for protecting the biological, historic, and scientific objects contained within. To support continued protection of natural and cultural resources, the proclamation stated that the Monument would not be developed for residential or commercial use in the future ("Establishment of the Hanford Reach National Monument" [65 FR 37253]).

This exposure scenario was included in the subset of occupational scenarios presented in the RCBRA (DOE/RL-2007-21). The resident Monument worker scenario is a site-specific scenario that envisions a resident employee of the Hanford Reach National Monument. These receptors are assumed to be exposed primarily in an outdoor environment as they lead tours, conduct ecological education, or perform similar activities. When not working, these receptors are envisioned to live in an onsite residence associated with the Monument. By use of a domestic well at their residence, these receptors may also be exposed to groundwater contaminants through domestic water use. Exposure to groundwater as a domestic source of water by the resident Monument worker is not included in the soil PRG value that is calculated for this exposure scenario. The risks from exposure to 100-FR-3 groundwater or the 100-IU-2 and 100-IU-6 Groundwater Area from use as a domestic source of water can be separately added to provide a total risk from exposure to soil and groundwater.

The resident Monument worker scenario for radiological and nonradiological analytes in vadose zone material is based on the same conceptual exposure model. The exposure pathways include direct contact and inhalation of vapors and dust in ambient air. Adults could potentially be exposed to site contaminants in shallow vadose zone material at their residence through direct external exposure, incidental ingestion, dermal absorption, and inhalation. During working activities, these adults may also be potentially exposed to contaminants in shallow vadose zone material by direct external exposure, incidental soil ingestion, dermal absorption, and inhalation. No food chain pathways are included in this exposure scenario.

When the total risk for a waste site is less than $1 \times 10^{-4}$ for radionuclides based on the Residential scenario or $1 \times 10^{-5}$ for chemicals based on the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold, then protection of the resident Monument worker is achieved. The results of these comparisons can be used in risk management decisions (presented in Section 6.2.5.5) and show that the total risk calculated for the Resident and the Resident Monument

Worker scenarios are essentially identical. The Residential PRGs are slightly lower than the Resident Monument Worker PRGs because the Residential exposure scenario includes the food chain pathways.

#### 6.2.3.3.3 *Casual Recreational User Scenario*

As discussed previously, the reasonably anticipated future land use within the River Corridor's 100 and 600 Areas is predominantly conservation/preservation. The casual recreational user is selected as a receptor to represent potential exposures from recreational use along the River Corridor. This exposure scenario was included in the subset of recreational use scenarios presented in the RCBRA (DOE/RL-2007-21). The casual recreational user scenario is a site-specific scenario representing occasional recreational use that focuses on activities such as walking and picnicking in areas along the Columbia River where paths and benches may exist in the future. These receptors are assumed to be exposed entirely in an outdoor environment. This scenario also assumes that drinking water is obtained from an offsite source.

PRGs are presented in this section for the casual recreational user that represents reasonably anticipated future land use Casual recreational user PRG values are developed for radiological and nonradiological contaminants. When the total risk for a waste site is less than $1 \times 10^{-4}$ based on the residential scenario or $1 \times 10^{-5}$ for chemicals based on the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold, then protection of the casual recreational user is achieved. The results of these comparisons (presented in Section 6.2.5.5) can be used in risk management decisions.

The casual recreational user scenario for radiological and nonradiological analytes in vadose zone material is based on the same conceptual exposure model. The exposure pathways include direct contact and inhalation of vapors and dust in ambient air. Adults and children could potentially be exposed to site contaminants in shallow vadose zone material along the river through direct external exposure, incidental ingestion, dermal absorption, and inhalation of vapors and dust in ambient air.

### 6.2.3.4 *Quantification of Potential Exposures*

Quantification of potential exposures in this risk assessment is evaluated through the comparison of EPCs to PRGs (which are also used as RBSLs). *Risk Assessment Guidance for Superfund Volume I – Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals): Interim* (hereinafter called Risk Assessment Guidance Volume I, Part B [EPA/540/R-92/003]) provides guidance on using EPA toxicity values and exposure information to calculate PRGs. Once the BRA has been performed, PRGs can be derived using site-specific risks; PRGs developed in the FS will usually be based on site-specific risks and ARARs and not on screening levels. PRGs are obtained from two general sources: concentrations based on ARARs (for example DWS) and concentrations based on the risk assessment. It should be recognized that the PRGs that are ARAR-based are also considered risk-based. Exposure assumptions published by the state and EPA and toxicity values published by EPA are used to derive risk-based PRGs.

PRGs based on risk assessment equations include the residential, resident Monument worker and the casual recreational user scenarios. PRGs for these scenarios are calculated using methodologies published in Risk Assessment Guidance Volume I, Part B (EPA/540/R-92/003) and EPA's Superfund Radionuclide Preliminary Remediation Goal (PRG) download and calculation web site (*Preliminary Remediation Goals for Radionuclides: User's Guide* [EPA, 2010]). Toxicity values and exposure values published by EPA are used to derive risk-based PRGs.

The residential scenario for chemicals is based on the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) and MTCA Method B Air Cleanup Levels ("Method B Air Cleanup Levels" [WAC 173-340-750]). PRGs for soil ingestion are

calculated using the equations provided in "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(3)). PRGs for the inhalation pathway are calculated using the equations provided in MTCA ("Cleanup Standards to Protect Air Quality," "Method B Air Cleanup Levels" [WAC 173-340-750(3)]). Air cleanup levels are converted to soil concentrations using EPA published volatilization factors for analytes that meet the operational definition of a volatile and a particulate emission factor for analytes that are not volatile. MTCA Method A soil cleanup levels for unrestricted land use, obtained from Table 740-1 ("Tables" [WAC 173-340-900]) are used as PRGs for arsenic and lead.

In addition to the guidance listed previously, radionuclide PRGs for the resident are calculated using the RESRAD code. The RESRAD code was used to calculate PRGs for the residential scenario because of unique exposure pathways. The RESRAD code was used for the residential scenario because this scenario includes the food chain pathway and the leaching to groundwater pathway. According to *User's Manual for RESRAD, Version 6* (ANL/EAD-4), the RESRAD model and computer code were developed as a multifunctional tool to assist in developing cleanup criteria and assessing the dose or risk associated with residual radioactive material. Table 6-12 summarizes the PRG values for each exposure scenario.

#### *6.2.3.4.1 Calculation of Residential PRGs using RESRAD*

The radionuclide PRGs for the residential scenario are calculated using RESRAD Version 6.5 (ANL, 2009a) model and code according to the guidance specified in *User's Manual for RESRAD Version 6* (ANL/EAD-4). The RESRAD model was used to calculate single radionuclide concentrations that correspond to a target cancer risk level of $1 \times 10^{-4}$ for the residential scenario. For the purpose of this risk assessment, the single radionuclide concentrations described in this section are used as PRGs for the residential scenario.

The RESRAD model allows for the use of site-specific chemical and physical parameters to estimate single radionuclide concentrations. The potentially complete exposure pathways considered are direct contact, inhalation pathway, the food chain pathway, and leaching of contaminants in the vadose zone through the vadose zone column to the groundwater table. Exposure routes associated with the direct contact and inhalation pathways include external gamma exposure, incidental ingestion, and inhalation of dust. Exposure routes associated with the food chain exposure pathway include consumption of homegrown produce, meat, and milk. Exposure routes associated with the leaching pathway include crop irrigation, aquatic food consumption, and drinking water ingestion. A detailed description of methodology, inputs, assumptions, and results of the calculations is presented in *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Reports* (ECF-HANFORD-10-0429).

#### *6.2.3.4.2 Calculation of Unrestricted Land Use PRGs Using MTCA Equations*

The direct contact nonradiological PRGs for unrestricted land use (i.e., the resident) are calculated using equations and input parameters described in the MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740(3)]). The Standard Method B soil cleanup levels for unrestricted land use are based on ingestion and were calculated for noncarcinogens and carcinogens using equation 740-1 and equation 740-2, respectively. Standard Method B soil cleanup levels for unrestricted land use are based on an acceptable cancer risk level of $1 \times 10^{-6}$ for nonradiological carcinogens or a hazard quotient (HQ) of 1 for noncarcinogens.

Reference dose and carcinogenic potency factors are determined using the recommended reference hierarchy as described in "Human Health Toxicity Values in Superfund Risk Assessments" (Cook, 2003), hereinafter called Superfund HHT Risk Assessment Values. A detailed description of methodology,

inputs, assumptions and the results of the calculations are presented in *Documentation of Standard Method B Direct Contact Soil Cleanup Levels for Unrestricted Land Use* (ECF-HANFORD-10-0444).

The inhalation nonradiological PRGs for unrestricted land use (i.e., the resident) are calculated using equations and input parameters described in the MTCA ("Cleanup Standards to Protect Air Quality," [WAC 173-340-750(3)]), Method B air cleanup levels. The Method B air PRGs are were calculated for noncarcinogens and carcinogens using equation 750-1 and equation 750-2, respectively.

Air PRGs are converted to soil concentrations using EPA published volatilization factors for analytes that meet the operational definition of a volatile and a PEF for analytes that are not volatile. Method B soil PRGs for the inhalation pathway are based on an acceptable cancer risk level of $1 \times 10^{-6}$ for carcinogens or an HQ of 1 for noncarcinogens. Inhalation reference dose (RfD) and inhalation carcinogenic potency factors are determined using the recommended reference hierarchy, as described in Superfund HHT Risk Assessment Values (Cook, 2003). A detailed description of methodology, inputs and assumptions, and the results of the calculations are presented in *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports* (ECF-HANFORD-11-0033).

Table 6-12. Summary of Preliminary Remediation Goals for the 100-F/IU Source Operable Unit

| Analyte | 90th Percentile Background | Method A Soil Cleanup Level | Residential PRG | Method B Direct Contact Soil Cleanup Level (carcinogen) | Method B Direct Contact Soil Cleanup Level (noncarcinogen) | Method B Inhalation Soil Cleanup Level (carcinogen) | Method B Inhalation Soil Cleanup Level (noncarcinogen) | Casual Recreational User PRG (carcinogen) | Casual Recreational User PRG (noncarcinogen) | Resident National Monument Worker PRG (carcinogen) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Radionuclides (pCi/g)** | | | | | | | | | | |
| Americium-241 | -- | -- | 155 | -- | -- | -- | -- | 2,570 | -- | 275 |
| Carbon-14 | -- | -- | 81 | -- | -- | -- | -- | 327,610 | -- | 52,000 |
| Cesium-137 | 1.1 | -- | 4.4 | -- | -- | -- | -- | 100 | -- | 6.2 |
| Cobalt-60 | 0.0084 | -- | 3.1 | -- | -- | -- | -- | 63 | -- | 3.3 |
| Curium-244 | -- | -- | 551 | -- | -- | -- | -- | 8,590 | -- | 1,280 |
| Europium-152 | -- | -- | 3.7 | -- | -- | -- | -- | 66 | -- | 3.8 |
| Europium-154 | 0.033 | -- | 4.4 | -- | -- | -- | -- | 78 | -- | 4.8 |
| Europium-155 | 0.054 | -- | 327 | -- | -- | -- | -- | 5,869 | -- | 354 |
| Nickel-63 | -- | -- | 608 | -- | -- | -- | -- | 575,308 | -- | 91,600 |
| Plutonium-238 | 0.0038 | -- | 236 | -- | -- | -- | -- | 3,818 | -- | 605 |
| Plutonium-239/240 | 0.025 | -- | 203 | -- | -- | -- | -- | 3,342 | -- | 539 |
| Plutonium-241 | -- | -- | 5,080 | -- | -- | -- | -- | -- | -- | 77,200 |
| Strontium-90 | 0.18 | -- | 2.3 | -- | -- | -- | -- | 5,064 | -- | 518 |
| Technetium-99 | -- | -- | 1.5 | -- | -- | -- | -- | 114,449 | -- | 17,300 |
| Total beta radiostrontium | 0.18 | -- | 2.3 | -- | -- | -- | -- | 5,064 | -- | 518 |
| Tritium | -- | -- | 623 | -- | -- | -- | -- | 15,376 | -- | 1,270,000 |
| Uranium-233/234 | 1.1 | -- | 133 | -- | -- | -- | -- | 5,808 | -- | 931 |
| Uranium-234 | 1.1 | -- | 133 | -- | -- | -- | -- | 5,808 | -- | 931 |
| Uranium-235 | 0.11 | -- | 16 | -- | -- | -- | -- | 295 | -- | 22 |
| Uranium-238 | 1.1 | -- | 54 | -- | -- | -- | -- | 1,093 | -- | 93 |
| **Anions (mg/kg)** | | | | | | | | | | |
| Fluoride | 2.8 | -- | -- | -- | 4,800 | -- | >1,000,000 | -- | 54,750 | -- |
| Nitrate | 52 | -- | -- | -- | 568,000 | -- | -- | -- | >1,000,000 | -- |
| Nitrogen in Nitrate | -- | -- | -- | -- | 128,000 | -- | -- | -- | >1,000,000 | -- |
| Nitrogen in Nitrite and Nitrate | -- | -- | -- | -- | 128,000 | -- | -- | -- | >1,000,000 | -- |
| **Metals (mg/kg)** | | | | | | | | | | |
| Aluminum | 11,800 | -- | -- | -- | 80,000 | -- | >1,000,000 | -- | 912,453 | -- |

Table 6-12. Summary of Preliminary Remediation Goals for the 100-F/IU Source Operable Unit

| Analyte | 90th Percentile Background | Method A Soil Cleanup Level | Residential PRG | Method B Direct Contact Soil Cleanup Level (carcinogen) | Method B Direct Contact Soil Cleanup Level (noncarcinogen) | Method B Inhalation Soil Cleanup Level (carcinogen) | Method B Inhalation Soil Cleanup Level (noncarcinogen) | Casual Recreational User PRG (carcinogen) | Casual Recreational User PRG (noncarcinogen) | Resident National Monument Worker PRG (carcinogen) |
|---|---|---|---|---|---|---|---|---|---|---|
| Antimony | 0.13 | -- | -- | -- | 32 | -- | -- | -- | 365 | -- |
| Arsenic | 6.5 | 20 | -- | 0.67 | 24 | 42,414 | 500,240 | 4.5 | 253 | -- |
| Barium | 132 | -- | -- | -- | 16,000 | -- | >1,000,000 | -- | 182,481 | -- |
| Beryllium | 1.5 | -- | -- | -- | 160 | 75,991 | 666,986 | >1,000,000 | 1,825 | -- |
| Boron | 3.9 | -- | -- | -- | 16,000 | -- | >1,000,000 | -- | 182,500 | -- |
| Cadmium | 0.56 | -- | -- | -- | 40 | 101,322 | 333,493 | >1,000,000 | 821 | -- |
| Chromium | 19 | -- | -- | -- | 120,000 | -- | -- | -- | >1,000,000 | -- |
| Cobalt | 16 | -- | -- | -- | 24 | 20,264 | 200,096 | 920,451 | 274 | -- |
| Copper | 22 | -- | -- | -- | 3,200 | -- | -- | -- | 36,500 | -- |
| Hexavalent Chromium | -- | -- | -- | -- | 240 | 2,171 | >1,000,000 | 98,620 | 2,737 | -- |
| Iron | 32,600 | -- | -- | -- | 56,000 | -- | -- | -- | 638,750 | -- |
| Lead | 10 | 250 | -- | -- | -- | -- | -- | -- | -- | -- |
| Manganese | 512 | -- | -- | -- | 11,200 | -- | >1,000,000 | -- | 127,658 | -- |
| Mercury | 0.013 | -- | -- | -- | 24 | -- | >1,000,000 | -- | 274 | -- |
| Molybdenum | 0.47 | -- | -- | -- | 400 | -- | -- | -- | 4,563 | -- |
| Nickel | 19 | -- | -- | -- | 1,600 | 701,458 | >1,000,000 | >1,000,000 | 18,249 | -- |
| Selenium | 0.78 | -- | -- | -- | 400 | -- | >1,000,000 | -- | 4,562 | -- |
| Silver | 0.17 | -- | -- | -- | 400 | -- | -- | -- | 4,563 | -- |
| Tin | -- | -- | -- | -- | 48,000 | -- | -- | -- | 547,500 | -- |
| Total_U_Isotopes | 3.2 | -- | -- | -- | 240 | -- | >1,000,000 | -- | 2,737 | -- |
| Uranium | 3.2 | -- | -- | -- | 240 | -- | >1,000,000 | -- | 2,737 | -- |
| Vanadium | 85 | -- | -- | -- | 400 | -- | -- | -- | 4,563 | -- |
| Zinc | 68 | -- | -- | -- | 24,000 | -- | -- | -- | 273,750 | -- |
| **Other Organics (mg/kg)** | | | | | | | | | | |
| 1,1-Dichloroethene | -- | -- | -- | -- | 4,000 | -- | 102 | -- | 8,773 | -- |
| 1,2-Dichloroethene (Total) | -- | -- | -- | -- | 720 | -- | -- | -- | 8,213 | -- |
| 1,4-Dichlorobenzene | -- | -- | -- | 185 | 5,600 | 1.5 | 2,375 | 64 | 50,992 | -- |
| 2-(2-methyl-4-chlorophenoxy) propionic acid | -- | -- | -- | -- | 80 | -- | -- | -- | 713 | -- |

Table 6-12. Summary of Preliminary Remediation Goals for the 100-F/IU Source Operable Unit

| Analyte | 90th Percentile Background | Method A Soil Cleanup Level | Residential PRG | Method B Direct Contact Soil Cleanup Level (carcinogen) | Method B Direct Contact Soil Cleanup Level (noncarcinogen) | Method B Inhalation Soil Cleanup Level (carcinogen) | Method B Inhalation Soil Cleanup Level (noncarcinogen) | Casual Recreational User PRG (carcinogen) | Casual Recreational User PRG (noncarcinogen) | Resident National Monument Worker PRG (carcinogen) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2,4,5-T(2,4,5-Trichlorophenoxyacetic acid) | -- | -- | -- | -- | 800 | -- | -- | -- | 7,129 | -- |
| 2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid) | -- | -- | -- | -- | 640 | -- | -- | -- | 5,703 | -- |
| 2,4-Dimethylphenol | -- | -- | -- | -- | 1,600 | -- | -- | -- | 14,258 | -- |
| 2,4-Dinitrotoluene | -- | -- | -- | 3.2 | 160 | >1,000,000 | -- | 18 | 1,420 | -- |
| 2-Butanone | -- | -- | -- | -- | 48,000 | -- | 28,673 | -- | 464,234 | -- |
| 2-Hexanone | -- | -- | -- | -- | 400 | -- | 160 | -- | 3,599 | -- |
| 2-Methylnaphthalene | -- | -- | -- | -- | 320 | -- | -- | -- | 2,676 | -- |
| 4,4'-DDD (Dichlorodiphenyldichloroethane) | -- | -- | -- | 4.2 | -- | >1,000,000 | -- | 24 | -- | -- |
| 4,4'-DDE (Dichlorodiphenyldichloroethylene) | -- | -- | -- | 2.9 | -- | >1,000,000 | -- | 17 | -- | -- |
| 4,4'-DDT (Dichlorodiphenyltrichloroethane) | -- | -- | -- | 2.9 | 40 | >1,000,000 | -- | 20 | 421 | -- |
| 4-Methyl-2-Pentanone | -- | -- | -- | -- | 6,400 | -- | 13,103 | -- | 69,370 | -- |
| 4-Nitroaniline | -- | -- | -- | 50 | 320 | -- | >1,000,000 | 283 | 2,852 | -- |
| Acenaphthene | -- | -- | -- | -- | 4,800 | -- | -- | -- | 40,139 | -- |
| Acetone | -- | -- | -- | -- | 72,000 | -- | 189,926 | -- | 789,195 | -- |
| Aldrin | -- | -- | -- | 0.059 | 2.4 | 37,220 | -- | 0.33 | 21 | -- |
| Alpha-BHC | -- | -- | -- | 0.16 | 640 | 101,322 | -- | 0.90 | 5,703 | -- |
| Alpha-Chlordane | -- | -- | -- | 2.9 | 40 | >1,000,000 | >1,000,000 | 19 | 410 | -- |
| Anthracene | -- | -- | -- | -- | 24,000 | -- | -- | -- | 200,696 | -- |
| Benzene | -- | -- | -- | 18 | 320 | 0.57 | 24 | 22 | 1,513 | -- |
| Benzo(a)anthracene | -- | -- | -- | 1.4 | -- | >1,000,000 | -- | 1.7 | -- | -- |
| beta-1,2,3,4,5,6-Hexachlorocyclohexane (beta-BHC) | -- | -- | -- | 0.56 | -- | 344,111 | -- | 3.1 | -- | -- |
| Bis(2-ethylhexyl) phthalate | -- | -- | -- | 71 | 1,600 | >1,000,000 | -- | 405 | 14,258 | -- |
| Butylbenzylphthalate | -- | -- | -- | 526 | 16,000 | -- | -- | 2,981 | 142,578 | -- |
| Carbazole | -- | -- | -- | 50 | -- | -- | -- | 283 | -- | -- |
| Chlordane | -- | -- | -- | 2.9 | 40 | >1,000,000 | >1,000,000 | 19 | 410 | -- |
| Chlorobenzene | -- | -- | -- | -- | 1,600 | -- | 73 | -- | 5,447 | -- |
| Chloroform | -- | -- | -- | 32 | 800 | 0.24 | 100 | 11 | 4,908 | -- |
| Dibenz[a,h]anthracene | -- | -- | -- | 1.4 | -- | >1,000,000 | -- | 1.7 | -- | -- |
| Dibenzofuran | -- | -- | -- | -- | 80 | -- | -- | -- | 913 | -- |
| Dieldrin | -- | -- | -- | 0.063 | 4.0 | 39,648 | -- | 0.35 | 36 | -- |

Table 6-12. Summary of Preliminary Remediation Goals for the 100-F/IU Source Operable Unit

| Analyte | 90th Percentile Background | Method A Soil Cleanup Level | Residential PRG | Method B Direct Contact Soil Cleanup Level (carcinogen) | Method B Direct Contact Soil Cleanup Level (noncarcinogen) | Method B Inhalation Soil Cleanup Level (carcinogen) | Method B Inhalation Soil Cleanup Level (noncarcinogen) | Casual Recreational User PRG (carcinogen) | Casual Recreational User PRG (noncarcinogen) | Resident National Monument Worker PRG (carcinogen) |
|---|---|---|---|---|---|---|---|---|---|---|
| Diethylphthalate | -- | -- | -- | -- | 64,000 | -- | -- | -- | 570,313 | -- |
| Di-n-butylphthalate | -- | -- | -- | -- | 8,000 | -- | -- | -- | 71,289 | -- |
| Endosulfan I | -- | -- | -- | -- | 480 | -- | -- | -- | 4,277 | -- |
| Endosulfan II | -- | -- | -- | -- | 480 | -- | -- | -- | 4,277 | -- |
| Endrin | -- | -- | -- | -- | 24 | -- | -- | -- | 214 | -- |
| Ethylbenzene | -- | -- | -- | 91 | 8,000 | 2.3 | 1,045 | 90 | 50,140 | -- |
| Fluoranthene | -- | -- | -- | -- | 3,200 | -- | -- | -- | 26,760 | -- |
| Fluorene | -- | -- | -- | -- | 3,200 | -- | -- | -- | 26,760 | -- |
| Gamma-BHC (Lindane) | -- | -- | -- | 0.91 | 24 | 588,319 | -- | 6.0 | 246 | -- |
| Heptachlor | -- | -- | -- | 0.22 | 40 | 140,292 | -- | 1.3 | 356 | -- |
| Heptachlor epoxide | -- | -- | -- | 0.11 | 1.0 | 70,146 | -- | 0.62 | 9.3 | -- |
| Isophorone | -- | -- | -- | 1,053 | 16,000 | -- | 50,482 | 5,962 | 142,578 | -- |
| Methoxychlor | -- | -- | -- | -- | 400 | -- | -- | -- | 3,564 | -- |
| Methylene chloride | -- | -- | -- | 133 | 4,800 | 11 | 965 | 337 | 35,713 | -- |
| m-Xylene | -- | -- | -- | -- | 16,000 | -- | 750 | -- | 55,524 | -- |
| Naphthalene | -- | -- | -- | -- | 1,600 | 1.4 | 25 | 62 | 2,241 | -- |
| o-Xylene | -- | -- | -- | -- | 16,000 | -- | 921 | -- | 63,781 | -- |
| Phenol | -- | -- | -- | -- | 24,000 | -- | 11,614 | -- | 213,867 | -- |
| Styrene | -- | -- | -- | -- | 16,000 | -- | 2,950 | -- | 115,430 | -- |
| Tetrachloroethene | -- | -- | -- | 1.9 | 800 | 0.88 | 256 | 10 | 6,838 | -- |
| Toluene | -- | -- | -- | -- | 6,400 | -- | 4,774 | -- | 63,832 | -- |
| Total petroleum hydrocarbons | -- | 1,000 | -- | -- | -- | -- | -- | -- | -- | -- |
| Total petroleum hydrocarbons - diesel range | -- | 2,000 | -- | -- | -- | -- | -- | -- | -- | -- |
| Total petroleum hydrocarbons - diesel range extended to C36 | -- | 2,000 | -- | -- | -- | -- | -- | -- | -- | -- |
| Total petroleum hydrocarbons - motor oil (high boiling) | -- | 2,000 | -- | -- | -- | -- | -- | -- | -- | -- |
| Xylenes (total) | -- | -- | -- | -- | 16,000 | -- | 103 | -- | 10,346 | -- |
| **Polyaromatic Hydrocarbons (mg/kg)** | | | | | | | | | | |
| Benzo(a)pyrene | -- | -- | -- | 0.14 | -- | 165,799 | -- | 0.17 | -- | -- |
| Benzo(b)fluoranthene | -- | -- | -- | 1.4 | -- | >1,000,000 | -- | 1.7 | -- | -- |

Table 6-12. Summary of Preliminary Remediation Goals for the 100-F/IU Source Operable Unit

| Analyte | 90th Percentile Background | Method A Soil Cleanup Level | Residential PRG | Method B Direct Contact Soil Cleanup Level (carcinogen) | Method B Direct Contact Soil Cleanup Level (noncarcinogen) | Method B Inhalation Soil Cleanup Level (carcinogen) | Method B Inhalation Soil Cleanup Level (noncarcinogen) | Casual Recreational User PRG (carcinogen) | Casual Recreational User PRG (noncarcinogen) | Resident National Monument Worker PRG (carcinogen) |
|---|---|---|---|---|---|---|---|---|---|---|
| Benzo(k)fluoranthene | -- | -- | -- | 1.4 | -- | >1,000,000 | -- | 1.7 | -- | -- |
| Chrysene | -- | -- | -- | 14 | -- | >1,000,000 | -- | 17 | -- | -- |
| Indeno(1,2,3-cd)pyrene | -- | -- | -- | 1.4 | -- | >1,000,000 | -- | 1.7 | -- | -- |
| Pyrene | -- | -- | -- | -- | 2,400 | -- | -- | -- | 20,070 | -- |
| **Polychlorinated Hydrocarbons (mg/kg)** | | | | | | | | | | |
| Aroclor-1016 | -- | -- | -- | 14 | 5.6 | >1,000,000 | -- | 74 | 46 | -- |
| Aroclor-1248 | -- | -- | -- | 0.50 | -- | 319,963 | -- | 2.6 | -- | -- |
| Aroclor-1254 | -- | -- | -- | 0.50 | 1.6 | 319,963 | -- | 2.6 | 13 | -- |
| Aroclor-1260 | -- | -- | -- | 0.50 | -- | 319,963 | -- | 2.6 | -- | -- |

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#### 6.2.3.4.3 Calculation of Resident Monument Worker PRGs for Radiological Analytes using EPA Equations

The radiological PRGs for the resident Monument worker are calculated using equations consistent with those published on the Preliminary Remediation Goals for Radionuclides tables (EPA, 2007). Resident Monument worker PRGs are based on an acceptable cancer risk level of $1 \times 10^{-4}$ for carcinogens. A detailed description of methodology, inputs, and assumptions and the results of the calculations are presented in *Documentation of Radiological Preliminary Remediation Goals in Soil for a Resident Monument Worker Exposure Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Reports* (ECF-HANFORD-11-0142).

As described in Section 6.2.3.3, the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker.

#### 6.2.3.4.4 Calculation of Casual Recreational User PRGs for Radiological Analytes using EPA Equations

The radiological PRGs for the casual recreational user are calculated using equations consistent with those published on "Preliminary Remediation Goals for Radionuclides" (EPA, 2007b). Casual recreational user radiological PRGs are based on an acceptable cancer risk level of $1 \times 10^{-4}$ for carcinogens. A detailed description of methodology, inputs, assumptions, and the results of the calculations are presented in *Calculation of Radiological Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Reports* (ECF-HANFORD-10-0446).

#### 6.2.3.4.5 Calculation of Casual Recreational User PRGs for Nonradiological Analytes using EPA Equations

The nonradiological PRGs for the casual recreational user are calculated using equations consistent with those published on "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (hereinafter called Regional Screening Levels [EPA, 2009b]). Casual recreational user nonradiological PRGs are based on an acceptable cancer risk level of $1 \times 10^{-6}$ for carcinogens or an HQ of 1 for noncarcinogens. Reference dose and carcinogenic potency factors are determined using the recommended reference hierarchy as described in Superfund HHT Risk Assessment Values (Cook, 2003). A detailed description of methodology, inputs, and assumptions and the results of the calculations are presented in *Calculation of Nonradiological Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Reports* (ECF-HANFORD-10-0445).

### 6.2.4 Toxicity Assessment

This toxicity assessment evaluates the relationship between the magnitude of exposure to a contaminant at the 100-F/IU Source OUs and the likelihood of adverse health effects to potentially exposed populations. This assessment provides, where possible, a numerical estimate of the increased likelihood of adverse effects associated with contaminant exposure. The toxicity assessment contains two steps: hazard characterization and dose-response evaluation as discussed in the following subsections.

#### 6.2.4.1 Hazard Characterization

Hazard characterization identifies the types of toxic effects that a chemical can exert. For the toxicity assessment, chemicals can be divided into two broad groups—noncarcinogens and carcinogens—based on their effects on human health.

Carcinogens are those contaminants that are known or suspected causes of cancer following exposure; noncarcinogenic compounds are associated with a wide variety of systemic effects, such as liver toxicity or developmental effects. Some contaminants are capable of eliciting both carcinogenic and noncarcinogenic responses; therefore, these contaminants are evaluated for both effects.

For cancer effects, EPA has developed a carcinogen classification system (*Risk Assessment for Carcinogens* [EPA/630/P-03/001F]) that uses a weight of evidence approach for classifying the likelihood that a chemical is a human carcinogen. Information considered in developing the classification includes human studies of the association between cancer incidence and exposure, as well as long-term animal studies under controlled laboratory conditions. Other supporting evidence considered includes short-term tests for genotoxicity, metabolic and pharmacokinetic properties, toxicological effects other than cancer, structure-activity relationships, and physical and chemical properties of the chemical.

For noncancer effects, toxicity values are derived based on the critical toxic endpoint (i.e., the most sensitive adverse effect following exposure). Table G-12 (Appendix G) lists the COPCs detected at the 100-F/IU Source OUs that have been identified as having documented systemic effects.

#### 6.2.4.1.1 Dose Response Evaluation

The magnitude of toxicity of a contaminant depends on the dose to a receptor. Dose refers to exposure to a contaminant concentration over a specified period. Human exposures are generally classified as acute (typically less than 2 weeks), subchronic (about 2 weeks to 7 years), or chronic (7 years to a lifetime). This HHRA specifically addresses chronic exposure. Acute exposures and risks are evaluated only when chronic exposure estimates pose a high risk. A dose response curve describes the relationship between the degree of exposure (i.e., dose) and the incidence of the adverse effects (i.e., response) in the exposed population. EPA uses this dose response information to establish toxicity values for particular chemicals, as described in the following sections.

*Reference Doses for Noncancer Effects.* The toxicity value describing the dose-response relationship for noncancer effects is the reference dose (RfD) value. For noncarcinogenic effects, the body's protective mechanisms must be overcome before an adverse effect is manifested. If exposure is high enough and these protective mechanisms (or thresholds) are exceeded, adverse health effects can occur. EPA attempts to identify the upper bound of this tolerance range in the development of noncancer toxicity values. EPA uses the apparent toxic threshold value, in conjunction with uncertainty factors based on the strength of the toxicological evidence, to derive an RfD value. EPA defines an RfD value as follows:

> *In general, the RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime. The RfD is generally expressed in units of mg/kg-day.*

Available chronic RfD values for the oral and inhalation exposure routes are used to calculate PRGs. Because EPA has not derived toxicity values specific to skin contact, dermal slope factors and RfD values were derived from oral toxicity factors in accordance with EPA guidance. The RfD values for the contaminants evaluated in the 100-F/IU Source OU are summarized in Table G-12 (Appendix G).

#### 6.2.4.1.2 Slope Factors for Cancer Effects

The dose-response relationship for cancer effects is expressed as a cancer slope factor that converts estimated intake directly to excess lifetime cancer risk (ELCR). Slope factors are expressed in units of risk per level of exposure (or intake). The data used for estimating the dose-response relationship are taken from lifetime animal studies or human occupational or epidemiological studies where excess cancer risk has been associated with exposure to the chemical. However, because risk at low intake levels cannot be directly measured in animal or human epidemiological studies, a number of mathematical models and procedures have been developed to extrapolate from the high doses used in the studies to the low doses typically associated with environmental exposures. The model choice leads to uncertainty associated with the carcinogenic response at very low levels of exposure. EPA assumes linearity at low doses when

uncertainty exists about the mechanism of action of a carcinogen and when information suggesting nonlinearity is absent.

It is assumed, therefore, that if a cancer response occurs at the dose levels used in the study, then there is some probability that a response will also occur at all lower exposure levels (i.e., a dose response relationship with no threshold is assumed). Moreover, the dose-response slope chosen is usually the 95 percent UCL on the mean on the actual dose-response curve observed in the laboratory studies. As a result, uncertainty and conservatism are built into the EPA risk extrapolation approach. EPA has stated that cancer risks estimated by this method produce estimates that "provide a rough but plausible upper limit of risk." The cancer slope factors used in this assessment are summarized in Table G-12 (Appendix G).

#### *6.2.4.2 Toxicity Values*

The analyte-specific toxicity values presented Table G-12 (Appendix G) are determined using the recommended reference hierarchy as described in Superfund HHT Risk Assessment Values (Cook, 2003). The hierarchy is summarized below.

- Tier 1—The EPA Integrated Risk Information System (IRIS) database
- Tier 2—The EPA Provisional Peer Reviewed Toxicity Values (PPRTVs)
- Tier 3—Other Toxicity Values

##### *6.2.4.2.1 Tier 1—IRIS*

The preferred source of toxicity data is EPA's IRIS database. Expert toxicologists at EPA have derived the values in this database and the values have undergone a thorough review and validation both within and outside EPA. If a toxicity value is available in IRIS, that value is used in preference to any other value.

##### *6.2.4.2.2 Tier 2—PPRTVs*

If a toxicity value is not available in IRIS, the next source is EPA's PPRTVs. This source includes toxicity values that have been developed by the Office of Research and Development/National Center for Environmental Assessment/Superfund Health Risk Technical Support Center (STSC). This database is not available to the public, but is accessible to EPA risk assessors via EPA's intranet. These values are also published at Regional Screening Levels (EPA, 2009a).

##### *6.2.4.2.3 Tier 3—Other Toxicity Values*

Tier 3 includes additional EPA and non-EPA sources of toxicity information, including the following:

- The California EPA (CalEPA) Toxicity Criteria Database contains toxicity values that are peer reviewed and address both cancer and noncancer effects.
- The Agency for Toxic Substances and Disease Registry (ATSDR) database Minimal Risk Levels for Hazardous Substances are peer-reviewed estimates of the daily human exposure to hazardous substances that is likely to be without appreciable risk of adverse noncancer health effects over a specified duration of exposure.
- Toxicity values in *Health Effects Assessment Summary Tables: FY 1997 Update* (EPA 540-R-97-036), hereinafter called HEAST.

When Tier 1, Tier 2, or Tier 3 toxicity values are not available for a COPC, the toxicity values from the National Center for Environmental Assessment are used. These values can be found in the Risk Assessment Information System (RAIS) (ORNL, 2010).

A derived RfD for nitrate was calculated from the RfD reported in IRIS (1.6 mg/kg-day) for nitrate as nitrogen (NO3-N) using the mass fraction of nitrogen in nitrate. The mass fraction of nitrogen in nitrate = mol wt N/mol wt NO3- = (14 g/mol)/(62 g/mol) = 0.226. The derived RfD for nitrate = (1.6 mg NO3-N/kg-day) × (1 mg NO3-/0.226 mg NO3-N) = 7.1 mg NO3-/kg-day.

A derived RfD for nitrite was calculated from the RfD reported in IRIS (0.1 mg/kg-day) for nitrite as nitrogen (NO2--N) using the mass fraction of nitrogen in nitrite. The mass fraction of nitrogen in nitrite = mol wt N/mol wt NO2- = (14 g/mol)/(46 g/mol) = 0.304. The derived RfD for nitrite = (0.1 mg NO2-N/kg-day) × (1 mg NO2-/0.304 mg NO2-N) = 0.3 mg NO2-/kg-day.

Toxic equivalence factors were used to calculate toxicity values for dioxins, furans, and carcinogenic polycyclic aromatic hydrocarbons (PAHs) as described in MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(8)(D)(iii)(A)], hereinafter called HHRA Procedures).

For several nonradionuclide analytes, the toxicity value used was obtained from a different source than recommended by the EPA Superfund hierarchy (Superfund HHT Risk Assessment Values [Cook, 2003]). The differences in toxicity values are summarized as follows:

- For consistency with previous Hanford analyses of trichloroethene, the oral cancer slope factor of 0.089 $(mg/kg\text{-}day)^{-1}$ and inhalation unit risk of 2.5E-05 $(\mu g/m^3)^{-1}$ published in HEAST (EPA 540-R-97-036) are used for this assessment. HEAST (EPA 540-R-97-036) has not been updated since 1997 and does not reflect the most current source of information. The oral cancer slope factor and inhalation unit risk currently implemented by EPA in the "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2009a) are established by the CalEPA Office of Health Hazard Assessment (OEHHA). The oral slope factor of 0.0059 $(mg/kg\text{-}day)^{-1}$ and the Inhalation Unit Risk of 2.0E-06 $(\mu g/m^3)^{-1}$ derived by OEHHA are presented in *Public Health Goal for Chemicals in Drinking Water – Trichloroethylene* (OEHHA, 2009). If the revised EPA value were used to calculate the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) level, the soil concentration would increase from 11 to 169 mg/kg. If the revised EPA value were used to calculate the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) soil cleanup level, the soil concentration would increase from 0.17 to 2.2 mg/kg. Use of the HEAST (EPA 540-R-97-036) values in this assessment has the potential to over-estimate cancer risk.

- For fluoride, the oral reference dose of 0.06 mg/kg day published on IRIS is used for this assessment. The value reported on IRIS has not been updated since 1989 and does not reflect the most current source of information. The oral reference dose currently implemented by EPA in the "Regional Screening Levels" (EPA, 2009a) is established by the CalEPA OEHHA. The oral reference dose derived by OEHHA is 0.04 mg/kg day as documented in *Chronic Toxicity Summary: Fluorides Including Hydrogen Fluoride* (OEHHA, 2003). If the revised CalEPA value were used to calculate the "Unrestricted land use soil cleanup standards" (WAC 173-340-740) soil cleanup level, the soil concentration would decrease from 4,800 to 3,200 mg/kg. Use of the IRIS value in this assessment has the potential to under-estimate noncancer hazards.

- For Cr(VI), the current assessment considers cancer effects only for inhalation exposures. Note that an oral reference dose and a reference concentration is available for assessment of noncancer effects. An oral cancer slope factor has recently been published by the New Jersey Department of Environmental Protection (NJDEP). The oral cancer slope factor derived by NJDEP is 0.5 $(mg/kg\text{-}day)^{-1}$, as presented in *Derivation of an Ingestion-Based Soil Remediation Criterion for* $Cr^{+6}$ *Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate* (NJDEP, 2009). If the NJDEP value were used to calculate the "Unrestricted land use soil cleanup standards"

(WAC 173-340-740) soil cleanup level, the soil concentration would decrease from 240 to 2.0 mg/kg. Assessing only inhalation cancer effects from Cr(VI) has the potential to underestimate cancer risk.

- When evaluating toxicity, 1,1-dichloroethane is not considered a carcinogen by Ecology. Therefore, the oral slope factor of 5.7E-03 $(mg/kg\text{-}day)^{-1}$ and inhalation unit risk of 1.5E-06 $(\mu g/m^3)^{-1}$ presented in "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2009a) are not used to evaluate toxicity. This is consistent with the Washington State Department of Ecology's "Cleanup Levels and Risk Calculations" (CLARC) database (Ecology, 2009). In addition, the reference concentration of 0.7 $(mg/m^3)$ published by HEAST (EPA 540-R-97-036) is used to evaluate noncarcinogenic inhalation risk. If the revised EPA value were used to calculate the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) level, the soil concentration would decrease from 16,000 to 175 mg/kg. If the revised EPA value were used to calculate the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) soil cleanup level, the soil concentration would decrease from 573 to 2.8 mg/kg. This is also consistent with the CLARC database (Ecology, 2009).

The analyte-specific toxicity values, decay constants, and half-life presented Table G-12 (Appendix G) are determined using the recommended values from HEAST (EPA 540-R-97-036) Radionuclides Table.

### 6.2.5 Risk Characterization

The risk characterization step is completed through the comparison of the EPC to the preliminary remediation goal. This comparison step is used to determine whether the post-remediation soil concentrations are protective of human health. It is also used to determine if current material concentrations have the potential to exceed an HI greater than 1 or the upper end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use.

Although this risk assessment produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision-making. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them.

For the purpose of this risk characterization step, the potential for unacceptable human health risk is identified using the following risk thresholds:

- ELCR values are compared to the "target range" of $10^{-4}$ to $10^{-6}$ that is generally used by regulatory agencies. MTCA (WAC 173-340) states that cancer risks resulting from multiple hazardous substances should not exceed $1 \times 10^{-5}$ for unrestricted land use. ELCR values within or exceeding this target range require a risk management decision that includes evaluating site-specific characteristics and exposure scenario factors to assess whether remedial action is warranted.

- An HI (the sum of the ratios of the chemical intake to the RfDs for all COPCs) greater than 1 indicates that some potential exists for adverse noncancer health effects associated with exposure to the COPCs.

#### *6.2.5.1 Cancer Risk Estimation Method*

To estimate the cancer risks from exposure to an individual nonradiological carcinogen from all exposure routes considered, the following equation is used:

$$Risk_I = \frac{EPC_{soil}}{PRG_{carcinogen}} \times TR$$

where:

$Risk_I$ = ELCR for individual chemical or radioisotope (unitless)

$EPC_{soil}$ = EPC in soil (µg/kg or pCi/g)

$PRG_{carcinogen}$ = Soil PRG based on $10^{-6}$ carcinogenic effect for chemical (µg/kg) or $10^{-4}$ carcinogenic effect for radioisotope (pCi/g)

$TR$ = Target ELCR of $10^{-6}$ for individual hazardous substance or $10^{-4}$ for individual radioisotope

To estimate the cancer risks from exposure to multiple carcinogens from all exposure routes considered, the following equation is used. The equation presented below is consistent with that published in "Regional Screening Levels" (Ecology, 2009b).

$$Risk_T = \sum_i \frac{EPC_{soil}}{PRG_{carcinogen}} \times TR$$

where:

$Risk_T$ = Total ELCR for all chemicals and radioisotopes

$EPC_{soil}$ = EPC in soil (µg/kg or pCi/g)

$PRG_{carcinogen}$ = Soil PRG based on $10^{-6}$ carcinogenic effect for chemical (µg/kg) or $10^{-4}$ carcinogenic effect for radioisotope (pCi/g)

$TR$ = Target ELCR of $10^{-6}$ for individual hazardous substance or $10^{-4}$ for individual radioisotope

$i$ = The sum of the ratios for the $i^{th}$ chemical

#### 6.2.5.2 *Noncancer Risk Estimation Method*

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (i.e., its RfD). The ratio of the chronic daily intake divided by RfD is termed the HQ.

To estimate the HQ from all exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{EPC_{soil}}{PRG_{noncarcinogen}}$$

where:

$HQ$ = HQ for individual chemical

$EPC_{soil}$ = EPC in soil (µg/kg)

$PRG_{noncarcinogen}$ = Preliminary remediation goal based on HQ=1 noncarcinogenic effects (µg/kg)

To estimate the HI from all exposure routes considered for multiple hazardous substances, the following equation is used. The equation presented below is consistent with that published in "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2009b).

$$HI_T = \sum_i \frac{EPC_{soil}}{PRG_{noncarcinogen}}$$

where:

$HI_T$ = Total HI for all chemicals

$EPC_{soil}$ = EPC in soil (µg/kg)

$PRG_{noncarcinogen}$ = Preliminary remediation goal based on HQ=1 noncarcinogenic effects (µg/kg)

$i$ = The sum of the ratios for the $i^{th}$ chemical

#### 6.2.5.3 Comparisons of Lead, Arsenic, and Total Petroleum Hydrocarbons to MTCA A Soil Cleanup Levels

Potential risks from lead concentrations were evaluated using a different method than what is conventionally used for other carcinogens and noncarcinogens. For direct contact pathways, the EPCs for lead were compared to the Table 740-1 ("Tables" [WAC 173-340-900]) Method A, soil cleanup level for Unrestricted Land Use of 250 mg/kg.

The Method A cleanup level is based on the Integrated Exposure Uptake Biokinetic (IEUBK) model, which is available on the EPA website. The IEUBK model is designed to calculate the probability of blood-lead concentrations for children between 6 months and 84 months (i.e., up to 7 years) of age who have been exposed to lead through various sources (e.g., air, water, soil, dust, and in utero contributions from the mother) to exceed a specific blood lead concentration.

Arsenic EPCs were compared to the Table 740-1 ("Tables" [WAC 173-340-900]) Method A soil cleanup level for Unrestricted Land Use of 20 mg/kg.

Total petroleum hydrocarbon EPCs were compared to the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil).

#### 6.2.5.4 Consideration of Background in Risk Assessment

*Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003) provides national policy considerations for application of background data in risk assessment and remedy selection. This policy recommends an approach that addresses site-specific background issues in the risk characterization. *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003) indicates the following:

> *COPCs that have both release-related and background-related sources should be included in the risk assessment. When concentrations of naturally occurring elements at a site exceed risk-based screening levels, that information should be discussed qualitatively in the risk characterization.*

*Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003) defines background constituents as the following:

- Anthropogenic—natural and artificial substances present in the environment as a result of human activities (not specifically related to the CERCLA release in question)
- Naturally occurring—substances present in the environment in forms that have not been influenced by human activity

#### *6.2.5.4.1 Sources of Background Concentrations*

The 90$^{th}$ percentile and maximum background concentrations for the Hanford Site have been developed for both inorganic chemicals and radionuclides and are considered representative of both naturally occurring and anthropogenic substances. The maximum inorganic background concentrations used in this evaluation are identified as the "overall maximum concentrations" in the Non-Rad Soil Background document (DOE/RL-92-24), Summary Table 1, and the 90$^{th}$ percentile inorganic background concentrations are identified as the "lognormal distribution 90$^{th}$ percentiles" in the Non-Rad Soil Background document (DOE/RL-92-24), Summary Table 2. The exceptions to this are described in the following paragraph. Two types of sampling were conducted to determine the inorganic background values: systematic random sampling and judgment sampling. The overall maximum concentrations were determined by considering the analytical results from both systematic random samples and judgmental samples. The 90$^{th}$ percentile values were calculated using the analytical results from the systematic random samples only.

The Hanford Site background values for antimony, boron, cadmium, lithium, mercury, molybdenum, selenium, silver, and thallium are documented in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038). Boron was not analyzed for in the Non-Rad Soil Background document and the analytical data associated with the remaining analytes in the Non-Rad Soil Background document (DOE/RL-92-24) are considered unusable for statistical analyses because of elevated MDLs. The background concentration values documented in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038), reference *A Review of Metal Concentrations Measured in Surface Soil Samples Collected on and Around the Hanford Site* hereinafter called Review of Metal Concentrations [PNNL-18577]). The ECF documents a review of the data sets from the Non-Rad Soil Background document and Review of Metal Concentrations (PNNL-18577) which indicates the data are comparable and issues associated with elevated detection limits were eliminated because of improvements in analytical methods used for Review of Metal Concentrations (PNNL-18577). It is noted that *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038) recalculates the percentile values based using a nonparametric (Kaplan-Meier) method, consistent with the methodology used in the Non-Rad Soil Background document. Review of Metal Concentrations (PNNL-18577) calculated the 90$^{th}$ percentile values based on an assumption of normally distributed data.

The background concentration values documented in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038) for selenium reference *Natural Background Soil Metals Concentrations in Washington State* (Ecology Publication 94-115) because neither the Non-Rad Soil Background document (DOE/RL-92-24) nor Review of Metal Concentrations (PNNL-18577) had adequate analytical results.

Radionuclide background values (lognormal 90$^{th}$ percentile and maximum) are identified in the Rad Soil Background document (DOE/RL-96-12), Table 5-1. The background values for naturally occurring radionuclides were determined primarily by analyzing a subset of the inorganic systematic random samples from the vadose zone (upper 30 cm [76 in] of the soil column). The background values for the anthropogenic radionuclides were determined from analytical results from surface sampling (upper 2.5 cm [1 in] of the soil column).

The composition of background samples described in the Non-Rad Soil Background document (DOE/RL-92-24), Rad Soil Background document (DOE/RL-96-12), and Review of Metal Concentrations (PNNL-18577) is representative of the sedimentary unit in the vadose zone at the 100-F/IU Source OUs. These background data are recommended for use in environmental-restoration activities on the Hanford Site to maintain consistency between projects, and they have been peer reviewed for technical credibility. Table G-13 (Appendix G) lists the maximum and 90$^{th}$ percentile background concentration values for inorganic chemicals and radionuclides.

#### *6.2.5.4.2 Comparison of Site and Background Risk Contributions*

Understanding the contribution to risk from naturally occurring elements is important because cleanup levels are not set at concentrations below natural background levels under CERCLA. Similarly, "Overview of Cleanup Standards," "Natural Background and Analytical Considerations" (WAC 173-340-700(6)(d)) states:

> *In some cases, cleanup levels calculated using the methods specified in this chapter are less than natural background levels or levels that can be reliably measured. In those situations, the cleanup level shall be established at a concentration equal to the practical quantitation limit or natural background concentration, whichever is higher.*

*Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003) states:

> *When background concentrations are high relative to the concentrations of released hazardous substances, pollutants, and contaminants, a comparison of site and background concentrations may help risk managers make decisions concerning appropriate remedial actions. The contribution of background concentrations to risks associated with CERCLA releases may be important for refining specific RAGs for contaminants of concern that warrant remedial action.*

The 90$^{th}$ percentile value is used as a fixed benchmark concentration for determining which contaminants should be evaluated for purposes of background risk. To assist in risk management decisions concerning appropriate remedial actions, a comparison of background risks to risks from CERCLA releases is provided using the approach.

EPCs from each decision unit at 100-F/IU Source OU are compared to the background value for metals and radionuclides listed in Table G-13 (Appendix G). A comparison of EPCs to the lognormal 90th percentile value for each decision unit is provided in Table G-14 (Appendix G) for the 100-F Source OU, Table G-15 (Appendix G) for the 100-IU-2 Source OU, and Table G-16 (Appendix G) for the 100-IU-6 Source OU. Risk estimates are calculated as follows:

- If the EPC is less than or equal to the background value, then a risk estimate or an HQ is not calculated.
- If the EPC is greater than the background value, then a risk estimate or an HQ is calculated.
- If a background value is not available for an analyte, then a risk estimate or an HQ is calculated.
- The total ELCR is summed for all analytes with EPCs greater than their background value.
- The HI is summed for all analytes with EPCs greater than their respective background value.

### 6.2.5.5 Summary of Risk Estimates by Exposure Scenario

This section summarizes the risk estimates for each of the exposure scenarios considered for the 100-F/IU Source OUs.

#### 6.2.5.5.1 Residential Scenario

PRGs developed for the residential scenario are the numeric values that represent the RAOs presented in Chapter 8. PRGs are established to help determine the need for remedial action at unremediated waste sites. The PRGs are also used to compare EPCs to the RBSLs in this soil risk assessment and are used to help determine whether additional remedial action is necessary for waste sites where remediation has been completed, and whether the goals and objectives of the interim action RODs have been met, as demonstrated by verification sampling and analysis. A complete description of the residential exposure scenario is provided in Section 6.2.3.3.1.

For completeness in analysis, all risk estimates for each waste site decision unit are provided in Appendix G. The risk estimates for the 100-F Source OU, which include all COPCs regardless of their EPCs relative to the background concentrations, are presented in Tables G-17 through G-25 (Appendix G). The risk estimates for the 100-IU-2 and 100-IU-6 Source OUs, which include all COPCs regardless of their EPCs relative to the background concentrations, are presented in Tables G-36 through G-44 and Tables G-55 through G-62, respectively (Appendix G).

Appendix G also includes risk estimates for each waste site decision unit, which includes only those COPCs with EPCs greater than background values or do not have a background value. The 100-F Source OU risk estimates are presented in Tables G-26 through G-35 (Appendix G). The 100-IU-2 Source OU and 100-IU-6 Source OU risk estimates are presented in Tables G-45 through G-54 and Tables G-63 through G-71, respectively. Only the risk estimates without background contributions are discussed in the risk characterization because this information is used for decisions concerning appropriate remedial actions.

**100-F Source OU.** Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone material, overburden material, staging pile area material, and deep vadose zone material. The results without background contribution for the residential scenario are summarized in Tables G-26 through G-35 (Appendix G) for the 100-F Source OU.

An overall summary of the cumulative risk estimates for each of the remediated waste sites evaluated is provided in Table 6-13 and Table 6-14 for the shallow vadose zone material, Table 6-15 and Table 6-16 for overburden material, Table 6-17 and Table 6-18 for staging pile footprint material, and Table 6-19 for the deep vadose zone material. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR and the risk driver and percent contribution (if applicable), and the hazard index and the noncancer hazard driver and percent contribution (if applicable).

*Shallow Zone.* A total of 93 waste sites are reported with CVP/RSVP data associated with the shallow zone in the 100-F Source OU. The following sample designs were applied to the 93 waste sites evaluated:

- Twenty-seven waste sites were sampled using a focused sampling design.
- Forty-seven waste sites were sampled using a statistical sampling design (including two sites each with two statistically distinct decision units).
- Nineteen waste sites were sampled using both a statistical and a focused sampling design (including two sites each with three statistically distinct decision units).

**Radionuclide Results.** As presented in Table 6-13, the potential total ELCR for radiological analytes is greater than or equal to the upper risk threshold of $1 \times 10^{-4}$ at four remediated waste sites, is within the target risk range of $10^{-4}$ to $10^{-6}$ at 30 remediated waste sites, and is less than the lower risk threshold of $1 \times 10^{-6}$ at five remediated waste sites. Risks were not reported at 17 remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at 37 remediated waste sites.

Four remediated waste sites in 100-F Source OU report concentrations of Hanford site-related COPCs that are equal to or exceed the upper threshold of the target risk range. As described below, only one waste site exceeds the upper threshold of the target risk range after decay of radionuclides has been accounted for. The cancer risk levels for the Residential scenario are as follows:

- The 118-F-6 waste site (shallow decision unit) reports a total ELCR of $1.8 \times 10^{-4}$. The primary contributor to risk is strontium-90 ($1.8 \times 10^{-4}$; 100 percent contribution). The EPC of strontium-90 is 4.1 pCi/g, which is greater than the residential RBSL of 2.3 pCi/g. However, the EPC is less than the current direct exposure RAG of 4.5 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17).

- The EPC for strontium-90 is based on the maximum detected concentration. Five soil samples (including a field duplicate) were collected from the shallow decision unit and analyzed for strontium-90. Strontium-90 was detected in all five samples, measured concentrations range between 0.52 and 4.1 pCi/g (two of five results greater than the RBSL). The parent sample (J163H8) and the duplicate sample (J163H9) both report concentrations greater than the residential RBSL of 2.3 pCi/g which were both collected from location A2. Strontium-90 will decay to a total ELCR of less than $1.0 \times 10^{-4}$ by year 2033.

- The 100-F-26:13 waste site (shallow decision unit) reports a total ELCR of $1.1 \times 10^{-4}$. The primary contributors to risk are strontium-90 ($8.9 \times 10^{-5}$, 85 percent contribution) and carbon-14 ($1.6 \times 10^{-5}$; 15 percent contribution). The EPC of strontium-90 is 2.0 pCi/g, which is less than the residential RBSL of 2.3 pCi/g and is also less than the current direct exposure RAG of 4.5 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of carbon-14 is 13.1 pCi/g, which is less than the residential RBSL of 81 pCi/g but is greater than the current direct exposure RAG of 8.7 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The Waste Site Reclassification Form for 100-F-26:13 indicates that the final excavation has a maximum depth of approximately 5.2 m (17 ft) bgs. Activities of all radionuclides have decayed to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ in year 2010.

- The 116-F-14 waste site (shallow decision unit) reports a total ELCR of $1.1 \times 10^{-4}$. The primary contributors to risk include europium-152 ($8.5 \times 10^{-5}$; 77 percent contribution) and strontium-90 ($1.4 \times 10^{-5}$; 13 percent contribution). The EPC of europium-152 is 3.1 pCi/g, which is less than the residential RBSL of 3.7 pCi/g and is also less than the current direct exposure RAG of 3.3 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of strontium-90 is 0.32 pCi/g, which is less than the residential RBSL of 2.3 pCi/g and is also less than the current direct exposure RAG of 4.5 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). *Cleanup Verification Package for the 116-F-14 Retention Basin* (CVP-2001-00009) indicates that the total excavation depth is greater than 4.6 m (15 ft) bgs. Activities of all radionuclides have decayed to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ in year 2005.

Table 6-13. Summary of Total Risks from Radionuclides for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-FR-1 Source OU** | | | | | |
| Interim Closed Out | 100-F-26:13 | -- | Shallow | $1.1 \times 10^{-4}$<br>$<1 \times 10^{-4}$ (2010) | Carbon-14 ($1.6 \times 10^{-5}$ – 15%)<br>Strontium-90 ($8.9 \times 10^{-5}$ – 85%) |
| | 116-F-14 | -- | Shallow | $1.1 \times 10^{-4}$<br>$<1 \times 10^{-4}$ (2005) | Europium-152 ($8.5 \times 10^{-5}$ – 77%)<br>Strontium-90 ($1.4 \times 10^{-5}$ – 13%) |
| | 100-F-19:1 | 100-F-19:3<br>116-F-12<br>100-F-34 | None | $1 \times 10^{-4}$ to $1 \times 10^{-6}$ | None |
| | 100-F-19:2 | 100-F-10<br>100-F-29<br>UPR-100-F-1 | | | |
| | 100-F-25 | UPR-100-F-3 | | | |
| | 100-F-26:14<br>100-F-26:15<br>100-F-26:4<br>100-F-33<br>100-F-44:9<br>100-F-45<br>116-F-1<br>116-F-10<br>116-F-11<br>116-F-15<br>116-F-2<br>116-F-3<br>116-F-6<br>116-F-9<br>118-F-8:1<br>118-F-8:4<br>141-C<br>1607-F2<br>1607-F6<br>UPR-100-F-2 | -- | | | |

Table 6-13. Summary of Total Risks from Radionuclides for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| | 100-F-16<br>100-F-4<br>100-F-51 and 100-F-63 | -- | None | $< 1 \times 10^{-6}$ | None |
| | 100-F-24<br>100-F-26:8<br>100-F-26:9<br>100-F-48<br>100-F-55 and 100-F-62<br>116-F-4<br>116-F-5<br>128-F-2<br>1607-F3<br>1607-F4 | -- | None | No COPCs reported above background | None |
| | 100-F-11<br>100-F-23<br>100-F-26:10<br>100-F-26:12<br>100-F-26:7<br>100-F-31<br>100-F-38<br>100-F-44:8<br>100-F-47<br>100-F-49<br>100-F-56:1<br>100-F-61<br>116-F-16<br>116-F-8<br>132-F-1<br>1607-F5<br>1607-F7<br>182-F | -- | None | No COPCs reported | None |

Table 6-13. Summary of Total Risks from Radionuclides for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| No Action | 100-F-46<br>100-F-54 | -- | None | $1 \times 10^{-4}$ to $1 \times 10^{-6}$ | None |
| | 100-F-36<br>100-F-52<br>100-F-53 | -- | None | No COPCs reported above background | None |
| | 100-F-12<br>100-F-18<br>100-F-26:11<br>100-F-26:2<br>100-F-26:5 | -- | None | No COPCs reported | None |
| | 100-F-26:1 | 100-F-44:1 | | | |
| | 100-F-37<br>100-F-44:2<br>100-F-44:5<br>100-F-60<br>100-F-7<br>100-F-9 | -- | | | |
| **100-FR-2 Source OU** | | | | | |
| Interim Closed Out | 118-F-6 | -- | Shallow | 1.8 × 10-4<br><1 × 10-4 (2033) | Strontium-90 (1.8 × 10-4 – 100%) |
| | 126-F-1 | -- | Shallow | 1.1 × 10-4<br><1 × 10-4 (2004) | Europium-152 (9.1 × 10-5 – 83%)<br>Europium-154 (1.0 × 10-5 – 9.5%) |
| | 100-F-35<br>118-F-1<br>118-F-2<br>118-F-3<br>118-F-7 | -- | None | 1 × 10-4 to 1 × 10-6 | None |
| | 118-F-5 | -- | None | < 1 × 10-6 | None |
| | 100-F-2 | -- | None | No COPCs reported above background | None |
| | -- | 1607-F1c | | | |

Table 6-13. Summary of Total Risks from Radionuclides for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| | 100-F-15<br>100-F-20<br>120-F-1<br>128-F-3<br>600-351 | -- | None | No COPCs reported | None |
| No Action | 100-F-14<br>100-F-50 | -- | None | No COPCs reported above background | None |
| | 118-F-4<br>128-F-1 | -- | None | No COPCs reported | None |

Results summarized from Table G-26, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-F Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ECLR represents risk contributions from radiological COPCs.

c. 1607-F1 is associated with the 100-F-26:8 waste site (100-FR-1)

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-FR-1 Source OU** | | | | | | | |
| Interim Closed Out | 100-F-26:10 | -- | Shallow Focused | $1.3 \times 10^{-5}$ | Arsenic ($1.3 \times 10^{-5}$ – >99%) | <1 | None |
| | 100-F-26:9 | -- | Shallow | $1.2 \times 10^{-6}$ | Benzo(a)pyrene ($8.8 \times 10^{-7}$ – 71%) | | |
| | 100-F-55 and 100-F-62 | -- | Shallow 2 | $1.2 \times 10^{-6}$ | Aroclor-1248 ($4.8 \times 10^{-7}$ – 42%) Benzo(a)pyrene ($4.7 \times 10^{-7}$ – 41%) | | |
| | 100-F-61 | -- | Shallow | $2.2 \times 10^{-6}$ | Benzo(a)pyrene ($1.4 \times 10^{-6}$ – 64%) | | |
| | 116-F-5 | -- | Shallow | $2.6 \times 10^{-5}$ | Arsenic ($2.6 \times 10^{-5}$ – 100%) | | |
| | 128-F-2 | -- | Shallow | $2.8 \times 10^{-6}$ | Benzo(a)pyrene ($1.9 \times 10^{-6}$ – 68%) | | |
| | 1607-F3 | -- | Shallow | $1.2 \times 10^{-5}$ | Arsenic ($1.1 \times 10^{-5}$ – 98%) | | |

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| | 100-F-26:13<br>100-F-26:4<br>100-F-26:8<br>100-F-31<br>100-F-33<br>100-F-38<br>100-F-44:8<br>100-F-44:9<br>100-F-47<br>100-F-48<br>100-F-49<br>100-F-51 and<br>100-F-63<br>100-F-56:1<br>116-F-15<br>118-F-8:1<br>132-F-1<br>141-C<br>1607-F4<br>1607-F5<br>1607-F6<br>1607-F7<br>182-F | -- | None | $< 1 \times 10^{-6}$ | None | <1 | None |
| | 100-F-26:12<br>100-F-26:14<br>100-F-26:15<br>100-F-26:7<br>100-F-45<br>116-F-1<br>116-F-14<br>118-F-8:4 | -- | None | No COPCs reported above background | None | <1 | None |

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| | 100-F-11 | -- | None | No COPCs reported | None | No COPCs reported above background | None |
| | 100-F-16 | | | | | <1 | |
| | 100-F-24 | | | | | No COPCs reported | |
| | 116-F-10 | | | | | No COPCs reported above background | |
| | 116-F-11 | | | | | No COPCs reported | |
| | 116-F-16<br>116-F-2<br>116-F-3<br>116-F-4<br>116-F-6<br>116-F-8 | | | | | <1 | |
| | 116-F-9<br>1607-F2<br>UPR-100-F-2<br>100-F-23 | | | | | No COPCs reported | |
| | 100-F-19:1 | 100-F-19:3<br>116-F-12<br>100-F-34 | | | | <1 | |
| | 100-F-19:2 | 100-F-10<br>100-F-29<br>UPR-100-F-1 | | | | | |

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| | 100-F-25 | UPR-100-F-3 | | | | | |
| | 100-F-4 | -- | | | | | |
| No Action | 100-F-37 | -- | Shallow Focused | $2.6 \times 10^{-5}$ | Arsenic ($2.6 \times 10^{-5}$ – >99%) | <1 | None |
| | 100-F-12<br>100-F-18 | -- | None | $< 1 \times 10^{-6}$ | None | <1 | None |
| | 100-F-26:1 | 100-F-44:1 | | | | | |
| | 100-F-26:11<br>100-F-26:2<br>100-F-46<br>100-F-52<br>100-F-53<br>100-F-7 | -- | | | | | |
| | 100-F-26:5<br>100-F-36<br>100-F-44:2 | -- | None | No COPCs reported above background | None | <1 | None |
| | 100-F-44:5<br>100-F-60 | | | | | No COPCs reported above background | |
| | 100-F-9 | | | | | <1 | |
| | 100-F-54 | -- | None | No COPCs reported | None | No COPCs reported | |
| **100-FR-2 Source OU** | | | | | | | |
| Interim Closed Out | 600-351 | -- | Shallow Focused | $3.8 \times 10^{-4}$ | Arsenic ($3.8 \times 10^{-4}$ – 100%) | 10.5 | Arsenic (10.4 – >99%) |
| | 118-F-7 | -- | Shallow Focused | $1.5 \times 10^{-5}$ | Arsenic ($1.5 \times 10^{-5}$ – 100%) | <1 | None |

Table 6-14. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| | 118-F-2 | -- | None | $< 1\times10^{-6}$ | None | <1 | None |
| | 118-F-6<br>120-F-1<br>128-F-3 | | | | | | |
| | 118-F-1<br>118-F-3 | -- | None | No COPCs reported above background | None | <1 | -- |
| | -- | 1607-F1[c] | | | | | |
| | 100-F-15 | -- | None | No COPCs reported | None | <1 | -- |
| | 100-F-2<br>100-F-20 | | | | | No COPCs reported | |
| | 100-F-35 | | | | | <1 | |
| | 118-F-5 | | | | | No COPCs reported | |
| | 126-F-1 | | | | | No COPCs reported above background | |
| No Action | 100-F-14<br>100-F-50<br>128-F-1 | -- | None | $< 1\times10^{-6}$ | None | <1 | -- |
| | 118-F-4 | -- | None | No COPCs reported | None | No COPCs reported | -- |

Results summarized from Table G-26, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-F Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ECLR represents risk contributions from nonradiological carcinogenic COPCs.

c. 1607-F1 is associated with the 100-F-26:8 waste site (100-FR-1)

Table 6-15. Summary of Total Risks from Radionuclides for the 100-FR-1 OU and 100-FR-2 OU Overburden Material for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-FR-1 Source OU** | | | | | |
| Interim Closed Out | 116-F-4 | -- | Overburden Focused | 2.5 × 10-4<br><1 × 10-4 (2358) | Cesium-137 (8.0 × 10-5 – 32%)<br>Strontium-90 (7.1 × 10-5 – 28%)<br>Technetium-99 (1.0 × 10-4 – 40%) |
| | 100-F-26:14 | -- | Overburden | 1.1 × 10-4<br><1 × 10-4 (2009) | Cesium-137 (4.5 × 10-5 – 41%)<br>Europium-152 (3.7 × 10-5 – 34%)<br>Strontium-90 (1.6 × 10-5 – 15%) |
| | 100-F-19:1 | 100-F-19:3<br>116-F-12<br>100-F-34 | None | 1 × 10-4 to 1 × 10-6 | None |
| | 100-F-19:2 | 100-F-10<br>100-F-29<br>UPR-100-F-1 | | | |
| | 100-F-26:12<br>100-F-26:15<br>100-F-44:9<br>118-F-8:4 | -- | | | |
| | 100-F-51 and 100-F-63 | -- | None | < 1 × 10-6 | None |
| | 100-F-26:13<br>100-F-26:4<br>100-F-26:9<br>100-F-45<br>116-F-2<br>1607-F6<br>182-F | -- | None | No COPCs reported above background | None |

Table 6-15. Summary of Total Risks from Radionuclides for the 100-FR-1 OU and 100-FR-2 OU Overburden Material for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| | 100-F-26:10<br>100-F-26:7<br>100-F-26:8<br>100-F-48<br>116-F-1<br>116-F-16<br>116-F-8<br>1607-F4 | -- | None | No COPCs reported | None |
| **100-FR-2 Source OU** | | | | | |
| Interim Closed Out | 118-F-5<br>118-F-6<br>126-F-1 | -- | None | 1 × 10-4 to 1 × 10-6 | None |
| | 118-F-1 | -- | None | < 1 × 10-6 | None |
| | 118-F-2 | -- | None | No COPCs reported above background | None |
| | 100-F-15<br>118-F-3<br>118-F-7 | -- | None | No COPCs reported | None |

Results summarized from Table G-26, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-F Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ECLR represents risk contributions from radiological COPCs.

Table 6-16. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Overburden Material for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-FR-1 Source OU** | | | | | | | |
| Interim Closed Out | 100-F-26:13 | -- | Overburden Focused | $1.5 \times 10^{-5}$ | Arsenic ($1.4 \times 10^{-5}$ – 99%) | <1 | None |
| | 100-F-26:4 | -- | Overburden Focused 3 | $9.8 \times 10^{-6}$ | Arsenic ($9.8 \times 10^{-6}$ – 100%) | | |
| | 100-F-26:9 | -- | Overburden | $1.5 \times 10^{-6}$ | Aroclor ($3.6 \times 10^{-7}$ – 25%) Benzo(a)pyrene ($8.0 \times 10^{-7}$ – 55%) | | |
| | 116-F-1 | -- | Overburden | $1.7 \times 10^{-5}$ | Arsenic ($1.7 \times 10^{-5}$ – 100%) | | |
| | 100-F-26:10 100-F-26:8 100-F-44:9 100-F-48 100-F-51 and 100-F-63 118-F-8:4 1607-F4 1607-F6 182-F | -- | None | $< 1 \times 10^{-6}$ | None | <1 | None |
| | 100-F-26:12 100-F-26:14 100-F-26:7 100-F-45 | -- | None | No COPCs reported above background | None | <1 | None |
| | 100-F-26:15 | | | | | No COPCs reported above background | |

Table 6-16. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Overburden Material for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| | 100-F-19:1 | 100-F-19:3<br>116-F-12<br>100-F-34 | None | No COPCs reported | None | <1 | None |
| | 100-F-19:2 | 100-F-10<br>100-F-29<br>UPR-100-F-1 | | | | <1 | None |
| | 116-F-16<br>116-F-2<br>116-F-4<br>116-F-8 | -- | | | | <1 | None |
| **100-FR-2 Source OU** | | | | | | | |
| Interim Closed Out | 118-F-1<br>118-F-2 | -- | None | No COPCs reported above background | None | <1 | None |
| | 118-F-3<br>118-F-7 | | | | | No COPCs reported above background | |
| | 100-F-15 | -- | None | No COPCs reported | None | <1 | None |
| | 118-F-5<br>118-F-6<br>126-F-1 | | | | | No COPCs reported | |

Results summarized from Table G-26, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-F Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ECLR represents risk contributions from nonradiological carcinogenic COPCs.

Table 6-17. Summary of Total Risks from Radionuclides for the 100-FR-1 OU and 100-FR-2 OU Staging Pile Areas for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-FR-1 Source OU** | | | | | |
| Interim Closed Out | 100-F-26:12<br>100-F-44:9 | -- | None | 1 × 10-4 to 1 × 10-6 | None |
| | 100-F-45<br>100-F-55 and 100-F-62<br>141-C | -- | None | No COPCs reported above background | None |
| | 100-F-26:7<br>100-F-26:9<br>100-F-33<br>100-F-44:8<br>100-F-49<br>128-F-2<br>132-F-1<br>1607-F3<br>1607-F5<br>1607-F7 | -- | None | No COPCs reported | None |
| **100-FR-2 Source OU** | | | | | |
| Interim Closed Out | 118-F-1<br>118-F-3<br>118-F-7 | -- | None | 1 × 10-4 to 1 × 10-6 | None |
| | 118-F-2 | -- | None | <1 × 10-6 | None |
| | 100-F-20<br>126-F-2 | -- | None | No COPCs reported above background | None |
| | 128-F-3 | -- | None | No COPCs reported | None |

Results summarized from Table G-26, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-F Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ECLR represents risk contributions from radiological COPCs.

Table 6-18. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Staging Piles for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-FR-1 Source OU** | | | | | | | |
| Interim Closed Out | 100-F-26:9 | -- | Staging Pile Area | $1.8 \times 10^{-5}$ | Arsenic ($1.7 \times 10^{-5}$ – 92%) Benzo(a)pyrene ($1.0 \times 10^{-6}$ – 5.7%) | <1 | None |
| | 100-F-55 and 100-F-62 | -- | Staging Pile Area Focused | $1.0 \times 10^{-6}$ | None | | |
| | 128-F-2 | -- | Staging Pile Area Focused | $2.9 \times 10^{-6}$ | Benzo(a)pyrene ($2.0 \times 10^{-6}$ – 71%) | | |
| | 132-F-1 | -- | Staging Pile Area Focused | $1.1 \times 10^{-5}$ | Benzo(a)pyrene ($8.1 \times 10^{-6}$ – 77%) | | |
| | 1607-F3 | -- | Staging Pile Area Focused | $1.8 \times 10^{-5}$ | Arsenic ($1.8 \times 10^{-5}$ – >99%) | | |
| | 1607-F7 | -- | Staging Pile Area Focused | $1.0 \times 10^{-6}$ | None | | |
| | 100-F-33 100-F-44:8 100-F-44:9 100-F-49 141-C 1607-F5 | -- | None | $< 1 \times 10^{-6}$ | None | <1 | None |

Table 6-18. Summary of Total Carcinogenic Risks and Noncancer Hazards from Direct Contact for the 100-FR-1 OU and 100-FR-2 OU Staging Piles for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| | 100-F-26:12<br>100-F-26:7<br>100-F-45 | -- | None | No COPCs reported above background | None | <1 | None |
| **100-FR-2 Source OU** | | | | | | | |
| Interim Closed Out | 118-F-1 | -- | Staging Pile Area | 1.7 ×10-5 | Arsenic (1.7 ×10-5 – 100%) | <1 | None |
| | 118-F-7 | | Staging Pile Area | 1.3 × 10-5 | Arsenic (1.3 × 10-5 – 100%) | | |
| | 126-F-2 | | Staging Pile Area Focused | 7.2 × 10-6 | Benzo(a)pyrene (5.1 ×10-6 – 71%) | | |
| | 128-F-3 | -- | None | < 1 × 10-6 | None | <1 | None |
| | 100-F-20<br>118-F-2<br>118-F-3 | -- | None | No COPCs reported above background | None | <1 | None |

Results summarized from Table G-26, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-F Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ECLR represents risk contributions from nonradiological carcinogenic COPCs.

Table 6-19. Summary of Total Risks for Radionuclides from the 100-FR-1 OU and 100-FR-2 OU Deep Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Consolidated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-FR-1** | | | | | |
| Interim Closed Out | 118-F-8:3 | -- | Deep | $1.8 \times 10^{-2}$<br>$<1 \times 10^{-4}$ (2235) | Cesium-137 ($7.3 \times 10^{-3}$ – 41%)<br>Cobalt-60 ($5.9 \times 10^{-4}$ – 3.3%)<br>Europium-152 ($5.0 \times 10^{-3}$ – 28%)<br>Europium-154 ($1.8 \times 10^{-4}$ – 1.0%)<br>Nickel-63 ($1.0 \times 10^{-4}$ – 0.57%)<br>Strontium-90 ($4.6 \times 10^{-3}$ – 26%) |
| | 100-F-19:1 | 100-F-19:3<br>116-F-12<br>100-F-34 | Deep | $1.1 \times 10^{-2}$<br>$<1 \times 10^{-4}$ (2113) | Cesium-137 ($4.7 \times 10^{-4}$ – 4.4%)<br>Cobalt-60 ($4.0 \times 10^{-4}$ – 3.8%)<br>Europium-152 ($8.9 \times 10^{-3}$ – 85%)<br>Europium-154 ($5.6 \times 10^{-4}$ – 5.3%)<br>Strontium-90 ($1.4 \times 10^{-4}$ – 1.3%) |
| | 116-F-14 | -- | Deep | $6.4 \times 10^{-3}$<br>$<1 \times 10^{-4}$ (2110) | Cesium-137 ($1.8 \times 10^{-4}$ – 2.8%)<br>Cobalt-60 ($4.0 \times 10^{-4}$ – 6.3%)<br>Europium-152 ($5.1 \times 10^{-3}$ – 80%)<br>Europium-154 ($5.3 \times 10^{-4}$ – 8.4%)<br>Nickel-63 ($1.1 \times 10^{-4}$ – 1.8%) |
| | 116-F-2 | -- | Deep | $2.7 \times 10^{-3}$<br>$<1 \times 10^{-4}$ (2108) | Cesium-137 ($9.9 \times 10^{-4}$ – 37%)<br>Europium-152 ($1.5 \times 10^{-3}$ – 55%)<br>Europium-154 ($1.3 \times 10^{-4}$ – 4.8%) |
| | 116-F-6 | -- | Deep | $2.1 \times 10^{-3}$<br>$<1 \times 10^{-4}$ (2122) | Cesium-137 ($2.8 \times 10^{-4}$ – 13%)<br>Europium-152 ($3.5 \times 10^{-4}$ – 17%)<br>Strontium-90 ($1.4 \times 10^{-3}$ – 68%) |
| | 116-F-9 | -- | Deep | $7.6 \times 10^{-4}$<br>$<1 \times 10^{-4}$ (2074) | Europium-152 ($1.8 \times 10^{-4}$ – 23%)<br>Strontium-90 ($4.2 \times 10^{-4}$ – 56%) |
| | 100-F-19:2 | 100-F-10<br>100-F-29<br>UPR-100-F-1 | Deep | $6.1 \times 10^{-4}$<br>$<1 \times 10^{-4}$ (2059) | Europium-152 ($3.4 \times 10^{-4}$ – 56%) |

Table 6-19. Summary of Total Risks for Radionuclides from the 100-FR-1 OU and 100-FR-2 OU Deep Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Consolidated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| | 118-F-8:4 | -- | Deep | $4.3 \times 10^{-4}$<br>$<1 \times 10^{-4}$ (2059) | Cesium-137 ($1.5 \times 10^{-4}$ – 35%)<br>Europium-152 ($1.2 \times 10^{-4}$ – 28%)<br>Strontium-90 ($1.4 \times 10^{-4}$ – 33%) |
| | 116-F-4<br>116-F-8 | -- | None | $1 \times 10^{-4}$ to $1 \times 10^{-6}$ | None |
| | 118-F-8:1 | -- | None | No COPCs reported | None |
| No Action | 116-F-7 | -- | None | No COPCs reported above background | None |
| | 100-F-26:1 | 100-F-44:1 | None | No COPCs reported | None |
| | 100-F-26:5 | -- | | | |
| **100-FR-2** | | | | | |
| No deep zone decision units for waste sites located in the 100-FR-2 OU. | | | | | |

Results summarized from Table G-26, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-F Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs only.

- The 126-F-1 waste site (shallow decision unit) reports a total ELCR of $1.1 \times 10^{-4}$. The primary contributors to risk include europium-152 ($9.1 \times 10^{-5}$; 83 percent contribution) and europium-154 ($1.0 \times 10^{-5}$; 9.5 percent contribution). The EPC of europium-152 is 3.3 pCi/g, which is less than the residential RBSL of 3.7 pCi/g and is equal to the current direct exposure RAG of 3.3 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of europium-154 is 0.5 pCi/g, which is less than the residential RBSL of 4.4 pCi/g is also less than the current direct exposure RAG of 3.0 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). Activities of all radionuclides have decayed to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ in year 2004.

**Nonradiological Results (Direct Contact).** As presented in Table 6-14, the potential cumulative ELCR is less than $1 \times 10^{-6}$ for 39 remediated waste sites and risks are greater than $1 \times 10^{-6}$ at 11 remediated waste sites. Risks were not reported in 16 remediated waste sites because COPC concentrations were less than background. Nonradiological carcinogenic COPCs were not reported at 27 remediated waste sites.

As presented in Table 6-14, 11 remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of $1 \times 10^{-6}$, six of these 11 remediated waste sites report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$. The cancer risk levels for the residential scenario are as follows:

- The 100-F-26:10 waste site (shallow focused decision unit) reports a total ELCR of $1.3 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.3 \times 10^{-5}$; greater than 99 percent contribution).
- The 100-F-37 waste site (shallow focused decision unit) reports a total ELCR of $2.6 \times 10^{-5}$. The primary contributor to risk is arsenic ($2.6 \times 10^{-5}$; greater than 99 percent contribution).
- The 116-F-5 waste site (shallow decision unit) reports a total ELCR of $2.6 \times 10^{-5}$. The primary contributor to risk is arsenic ($2.6 \times 10^{-5}$; 100 percent contribution).
- The 118-F-7 waste site (shallow focused decision unit) reports a total ELCR of $1.5 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.5 \times 10^{-5}$; 100 percent contribution).
- The 1607-F3 waste site (shallow decision unit) reports a total ELCR of $1.2 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.1 \times 10^{-5}$; 98 percent contribution).
- The 600-351 waste site (shallow focused decision unit) reports a total ELCR of $3.8 \times 10^{-4}$. The primary contributor to risk is arsenic ($3.8 \times 10^{-5}$; 100 percent contribution).

Arsenic is the only contributor to risk at the six remediated waste sites. With the exception of arsenic concentrations at 600-351, the EPCs for arsenic at these waste sites range between 7.6 mg/kg and 17.3 mg/kg. Although the EPCs are greater than the lognormal 90$^{th}$ percentile of 6.5 mg/kg, they are consistent with naturally occurring levels at the Hanford Site (Table G-14), and are not the result of a site release. Additionally, arsenic EPCs for these five remediated waste sites are less than the direct exposure RAG of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17).

At waste site 600-351 (shallow focused decision unit), the EPC for arsenic is 250 mg/kg and the EPC for lead is 805 mg/kg which are greater than the Method A soil cleanup levels of 20 mg/kg and 250 mg/kg, respectively.). A summary of the arsenic and lead results follows:

- The EPC for arsenic is based on the maximum detected concentration. Four soil samples were collected from the shallow focused decision unit and analyzed for arsenic. Arsenic was detected in all

four samples with measured concentrations ranging between 49 and 250 mg/kg (all results are greater than the Method A soil cleanup levels of 20 mg/kg).

- The EPC for lead is based on the maximum detected concentration. Four soil samples were collected from the shallow focused decision unit and analyzed for lead. Lead was measured in all four samples with concentrations ranging between 72.2 and 805 mg/kg (two results are greater than the Method A soil cleanup levels of 250 mg/kg).

As shown in Table 6-14, the potential HI for noncancer effects is greater than the target HI of 1 at one remediated waste site and is less than the target HI of 1 at 76 remediated waste sites. An HI was not reported for five remediated waste sites because COPC concentrations were less than background. Nonradiological COPCs were not reported at 11 remediated waste sites.

One remediated waste site reports a HI greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1. The HI for the residential scenario is as follows:

- The 600-351 Waste Site (shallow focused decision unit) reports an HI of 10.5. The primary contributor to the HI is arsenic (HQ = 10.4; 99 percent contribution).

As shown in Table G-28 (Appendix G), with the exception of remediated waste site 600-351, all arsenic and lead EPCs are less than their respective Method A soil cleanup levels of 20 mg/kg and 250 mg/kg, respectively, for unrestricted land use. All TPH EPCs were less than the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil).

**Nonradiological Results (Inhalation).** As presented in Table G-30 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $4.0 \times 10^{-16}$ to $1.8 \times 10^{-7}$. The potential cumulative ELCR is less than the MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) risk value of $1 \times 10^{-6}$ for individual carcinogens for 72 remediated waste sites. Risks were not reported at five remediated waste sites because COPC concentrations were less than background. Nonradiological carcinogenic COPCs were not reported at 16 remediated waste sites.

As presented in Table G-30 (Appendix G), the potential HI is less than the EPA target HI of 1 and the MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750]) target HI of 1 for 68 of 93 remediated waste sites. An HI was not reported at 12 remediated waste sites because COPC concentrations were less than background. Nonradiological noncarcinogenic COPCs were not reported at 13 remediated waste sites.

*Overburden.* A total of 33 remediated waste sites are reported with CVP/RSVP data associated with overburden material in the 100-F Source OU. The following sample designs were applied to the 33 waste sites evaluated:

- Thirteen waste sites were sampled using a focused sampling design (one waste site with two statistically distinct decision units).
- Eighteen waste sites were sampled using a statistical sampling design.
- Two waste sites were sampled using both a statistical and a focused sampling design.

**Radiological Results.** As presented in Table 6-15, the potential total ELCR is greater than the upper risk threshold value of $1 \times 10^{-4}$ for overburden material associated with two remediated waste sites; is within the target risk range of $10^{-4}$ to $10^{-6}$ for overburden material associated with nine remediated waste sites;

and is less than the lower risk threshold value of $1 \times 10^{-6}$ for overburden material associated with three remediated waste sites. Risks were not reported for overburden material associated with eight remediated waste sites because COPC concentrations were less than background. Radiological COPCs were not reported at 11 remediated waste sites.

Overburden material associated with two remediated waste sites report concentrations of site-related radiological COPCs that exceed the upper threshold of the target risk range. The cancer risk levels for the residential scenario are as follows:

- The 116-F-4 waste site (overburden focused decision unit) reports a cumulative ELCR of $2.5 \times 10^{-4}$. The primary contributors to risk are technetium-99 ($1.0 \times 10^{-4}$, 40 percent contribution); cesium-137 ($8.0 \times 10^{-5}$; 32 percent contribution); and strontium-90 ($7.1 \times 10^{-5}$, 28 percent contribution). The EPC of technetium-99 is 1.5 pCi/g, which is equal to the residential RBSL of 1.5 pCi/g and is less than the current direct exposure RAG of 5.8 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of cesium-137 is 3.5 pCi/g, which is less than the residential RBSL of 4.4 pCi/g and is also less than the current direct exposure RAG of 6.2 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of strontium-90 is 1.6 pCi/g, which is less than the residential RBSL of 2.3 pCi/g and is also less than the current direct exposure RAG of 4.5 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC for technetium-99 is based on the maximum detected concentration. Eight soil samples (including a field duplicate) were collected from the overburden decision unit and analyzed for technetium-99. Technetium-99 was detected in a single sample (B097B0) which is the basis of the EPC. Technetium-99 was analyzed for but not detected in the associated shallow decision unit (two samples) and deep decision unit (four samples). Additionally, technetium-99 was not identified as a contaminant of concern for this waste site. As a result, the presence of technetium-99 in overburden is considered an anomalous result and the EPC is an overestimation of the concentration present in the decision unit. Activities of all radionuclides except technetium-99 have decayed to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ in 2011.

- The 100-F-26:14 waste site (overburden decision unit) reports a cumulative ELCR of $1.1 \times 10^{-4}$. The primary risk driver is cesium-137 ($4.5 \times 10^{-5}$; 41 percent contribution); europium-152 ($3.7 \times 10^{-5}$; 34 percent contribution); and strontium-90 ($1.6 \times 10^{-5}$; 15 percent contribution). The EPC of cesium-137 is 2.0 pCi/g, which is less than the residential RBSL of 4.4 pCi/g and is also less than the current direct exposure RAG of 6.2 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of europium-152 is 1.4 pCi/g, which is less than the residential RBSL of 3.7 pCi/g and is also less than the current direct exposure RAG of 3.3 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). The EPC of strontium-90 is 0.37 pCi/g, which is less than the residential RBSL of 2.3 pCi/g and less than the current direct exposure RAG of 4.5 pCi/g published in the 100 Area RDR/RAWP (DOE/RL-96-17). Activities of all radionuclides have decayed to a total ELCR of less than $1.0 \times 10^{-4}$ in year 2009.

**Nonradiological Results (Direct Contact).** As presented in Table 6-16, the potential cumulative ELCR is less than $1 \times 10^{-6}$ for overburden material from 10 remediated waste sites and risks are greater than $1 \times 10^{-6}$ for overburden material from four remediated waste sites. Risks were not reported in overburden material from nine remediated waste sites because COPC concentrations were less than background. Nonradiological carcinogenic COPCs were not reported at 10 remediated waste sites.

As presented in Table 6-16, four remediated waste sites report individual carcinogens greater than the target risk level of $1 \times 10^{-6}$; two of these four remediated waste sites report a total ELCR greater than the

MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$. The cancer risks levels for the residential scenario are as follows:

- The 100-F-26:13 waste site (overburden focused decision unit) reports a total ELCR of $1.5 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.4 \times 10^{-5}$; greater than 99 percent contribution).
- The 116-F-1 (overburden decision unit) reports a total ELCR of 1.7 × 10-5. The primary contributor to risk is arsenic (1.7 × 10-5; 100 percent contribution).

Arsenic is the only contributor to risk in overburden material from both remediated waste sites where the EPCs range from 9.6 mg/kg to 11.1 mg/kg. Although the EPCs are greater than the lognormal 90$^{th}$ percentile of 6.5 mg/kg, they are consistent with naturally occurring levels at the Hanford Site (Table G-14), and are not the result of a site release. Additionally, arsenic EPCs for overburden material from these two remediated waste sites are less than the direct exposure RAG of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17).

As presented in Table 6-16, the potential HI for noncancer effects is less than the target HI of 1 in overburden material from 27 remediated waste sites. An HI was not reported in overburden material from three remediated waste sites because COPC concentrations were less than background. Nonradiological noncarcinogenic COPCs were not reported in overburden material from three remediated waste sites.

As shown in Table G-28 (Appendix G), all arsenic and lead EPCs are less than their respective Method A soil cleanup levels of 20 mg/kg and 250 mg/kg, respectively, for unrestricted land use. All TPH EPCs are less than the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil).

**Nonradiological Results (Inhalation).** As presented in Table G-32 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $1.2 \times 10^{-15}$ to $2.2 \times 10^{-8}$. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk value of $1 \times 10^{-6}$ for individual carcinogens for overburden material from 21 remediated waste sites. Risks were not reported for overburden material from seven remediated waste sites because COPC concentrations were less than background. Nonradiological carcinogenic COPCs were not reported at five remediated waste sites.

As presented in Table G-32 (Appendix G), the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 for overburden material from 26 remediated waste sites. An HI was not reported at four waste sites because COPC concentrations were less than background. Nonradiological noncarcinogenic COPCs were not reported at three remediated waste sites.

*Staging Pile Area.* A total of 23 remediated waste sites are reported with CVP/RSVP data associated with staging pile area material in the 100-F Source OU. The following sample designs were applied to the 23 waste sites evaluated:

- Twelve waste sites were sampled using a focused sampling design.
- Eleven waste sites were sampled using a statistical sampling design.

**Radiological Results.** As presented in Table 6-17, the potential total ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for staging pile material from five remediated waste sites and is less than the lower risk threshold value of $1 \times 10^{-6}$ for staging pile material from one remediated waste site. Risks were not

reported for staging pile material from six remediated waste sites because COPC concentrations were less than background. Radiological COPCs were not reported at 11 remediated waste sites.

**Nonradiological Results (Direct Contact).** As presented in Table 6-18, the potential cumulative ELCR for direct contact from all nonradiological carcinogenic COPCs without background is less than $1 \times 10^{-6}$ for staging pile material from seven remediated waste sites and risks are greater or equal to $1 \times 10^{-6}$ for staging pile material from 10 remediated waste sites. Risks were not reported in staging pile material from six remediated waste sites because COPC concentrations were less than background.

As presented in Table 6-18, 10 remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of $1 \times 10^{-6}$; five of these 10 staging pile material from remediated waste sites report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$. The cancer risk levels for the residential scenario are as follows:

- The 100-F-26:9 waste site (staging pile area decision unit) reports a total ELCR of $1.8 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.7 \times 10^{-5}$; 92 percent contribution) and benzo(a)pyrene ($1.0 \times 10^{-6}$; 5.7 percent contribution).
- The 118-F-1 waste site (staging pile area decision unit) reports a total ELCR of $1.7 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.7 \times 10^{-5}$; 100 percent contribution).
- The 118-F-7 waste site (staging pile area decision unit) reports a total ELCR of $1.3 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.3 \times 10^{-5}$; 100 percent contribution).
- The 132-F-1 waste site (staging pile area focused decision unit) reports a total ELCR of $1.1 \times 10^{-5}$. The primary contributor to risk is benzo(a)pyrene ($8.1 \times 10^{-6}$; 77 percent contribution).
- The 1607-F3 (staging pile area decision unit) reports a total ELCR of $1.8 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.8 \times 10^{-5}$; greater than 99 percent contribution).

Arsenic is the only contributor to risks greater than $1 \times 10^{-5}$ in staging pile material from four of the five remediated waste sites where the EPCs range from 8.6 mg/kg to 12.1 mg/kg. Although the EPCs are greater than the lognormal 90$^{th}$ percentile of 6.5 mg/kg, they are consistent with naturally occurring levels at the Hanford Site (Table-G-14), and are not the result of a site release. Additionally, arsenic EPCs for these four remediated waste sites are less than the direct exposure RAG of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17).

Benzo(a)pyrene is the primary contributor to risks greater than $1 \times 10^{-5}$ in staging pile material from 132-F-1 remediated waste site. A summary of the benzo(a)pyrene results follows:

The EPC for benzo(a)pyrene is 1.11 mg/kg and is based on the maximum detected concentration. Only one sample was collected from this staging area. In addition to benzo(a)pyrene, seven additional PAHs were detected in the same soil sample. Benzo(a)pyrene was also detected in the shallow vadose material associated with this waste site; however, detected concentrations ranged between less than 0.022 and 0.105 mg/kg. PAH concentrations in the staging pile soil data suggest the presence of asphalt rather than what was observed in the shallow zone vadose material.

As shown in Table 6-18 (Appendix G), the potential HI for noncancer effects is less than the target HI of 1 in staging pile material from all 23 remediated waste sites.

As shown in Table G-28 (Appendix G), all arsenic and lead EPCs are less than their respective Method A soil cleanup levels of 20 mg/kg and 250 mg/kg, respectively, for unrestricted land use. Except for TPH

reported at the 126-F-2 staging pile area focused decision unit, all TPH EPCs are less than Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil). A summary of the TPH results from the 126-F-2 staging pile focused decision unit follows:

The EPC for TPH is 1,650 mg/kg and is based on the maximum detected concentration. Only one sample was collected from this staging area. The staging area for this waste site was on the surface of a paved area; as a result the soil sample contained pieces of asphalt from the staging area. The TPH results from this soil sample do not reflect a release of TPH but are attributed to the asphalt from the staging area.

**Nonradiological Results (Inhalation).** As presented in Table G-34 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $2.5 \times 10^{-14}$ to $9.0 \times 10^{-8}$. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk value of $1 \times 10^{-6}$ for individual carcinogens for staging pile material from 19 remediated waste sites. Risks were not reported for staging pile material from four remediated waste sites because COPC concentrations were less than background.

As presented in Table G-34 (Appendix G), the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 for staging pile material from 20 remediated waste sites. An HI was not reported at two remediated waste sites because COPC concentrations were less than background. Nonradiological noncarcinogenic COPCs were not reported in staging pile material from one remediated waste site.

*Deep Zone.* Deep vadose zone samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience as screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

A total of 14 remediated waste sites were reported with CVP/RSVP from deep zone decision units in the 100-F Source OU. The remaining 82 remediated waste sites were not excavated deeper than 4.6 m (15 ft) bgs and are not discussed in this section. The following sample designs were applied to the 14 remediated waste sites evaluated:

- Four remediated waste sites were sampled using a focused sampling design.
- Nine remediated waste sites were sampled using a statistical sampling design.
- One remediated waste site was sampled using both a statistical and a focused sampling design.

The overall risk summary for the residential scenario from all deep zone waste sites evaluated is provided in Table 6-19. Table 6-19 lists the OU that each waste site resides in, the reclassification status, the remediated waste site, the consolidated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR, and the risk driver and percent contribution (if applicable).

**Radiological Results.** As presented in Table 6-19, the total ELCR is greater than the upper risk threshold of $1 \times 10^{-4}$ at eight remediated waste sites and is within the target risk range of $10^{-4}$ to $10^{-6}$ at two remediated waste sites. Risks were not reported at one remediated waste site because COPC concentrations were less than background. Radiological COPCs were not reported at three remediated waste sites.

*100-IU-2 Source OU.* Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone material, overburden material, staging pile area material, and deep vadose zone material. The results without background contribution for the residential scenario are summarized in Tables G-45 through G-54 (Appendix G) for the 100-IU-2 Source OU.

An overall summary of the total risk estimates and noncancer hazards (if applicable) for the residential scenario from each of the remediated waste sites is provided in Table 6-20 and Table 6-21 for shallow zone material, Table 6-22 and Table 6-23 for overburden material, Table 6-24 and Table 6-25 for staging piles, and Table 6-26 for the deep zone. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR and the risk driver and percent contribution (if applicable), and the HI and the noncancer hazard driver and percent contribution (if applicable).

*Shallow Zone.* A total of 26 waste sites are reported with CVP/RSVP data associated with the shallow zone in the 100-IU-2 Source OUs. The following sample designs were applied to the 26 waste sites evaluated:

- Eighteen waste sites were sampled using a focused sampling design (two waste sites with two statistically distinct decision units).
- Six waste sites were sampled using a statistical sampling design.
- Two waste sites were sampled using both a statistical and a focused sampling design.

**Radiological Results**. As presented in Table 6-20, risks were not reported at all 26 remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact).** As presented in Table 6-21, the potential cumulative ELCR is greater than $1 \times 10^{-6}$ for one remediated waste site and is less than $1 \times 10^{-6}$ for 22 remediated waste sites. Risks were not reported at three remediated waste sites because nonradiological carcinogenic COPC concentrations were less than background.

As presented in Table 6-21, one remediated waste site reports an individual carcinogen greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$; however, the risk associated with this remediated waste site is less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$.

As shown in Table 6-21, the potential HI for direct contact from noncancer effects without background contributions is less than the target HI at all 26 remediated waste sites.

As shown in Table G-47 (Appendix G), all arsenic and lead EPCs are less than their respective Method A soil cleanup levels of 20 mg/kg and 250 mg/kg for unrestricted land use. All TPH EPCs were less than the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil).

**Nonradiological Results (Inhalation).** As presented in Table G-49 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $6.2 \times 10^{-16}$ to $8.3 \times 10^{-8}$. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) risk value of $1 \times 10^{-6}$ for individual carcinogens for 23 of the remediated waste sites. Risks were not reported at three remediated waste sites because COPC concentrations were less than background.

Table 6-20. Summary of Total Risks from Radionuclides for the 100-IU-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-IU-2 Source OU** | | | | | |
| Interim Closed Out | 600-100<br>600-120 and 600-297<br>600-124<br>600-125<br>600-127<br>600-128<br>600-131<br>600-132<br>600-139<br>600-176<br>600-181<br>600-182<br>600-188<br>600-190<br>600-295<br>600-341:1<br>600-341:2<br>600-343<br>600-344<br>600-345<br>600-346<br>600-5<br>628-1 | -- | None | No COPCs reported | None |
| No Action | 600-296<br>600-302 | -- | None | No COPCs reported | None |

Results summarized from Table G-45, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-2 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

Table 6-21. Summary of Total Cancer Risks and Noncancer Hazards from Direct Contact for the 100-IU-2 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-IU-2 Source OU** | | | | | | | |
| Interim Closed Out | 600-190 | -- | Shallow Focused | 3.1 × 10-6 | Aroclor-1254 (2.2 × 10-6 – 72%) | <1 | None |
| | 600-100<br>600-120 and 600-297<br>600-124<br>600-127<br>600-128<br>600-131<br>600-132<br>600-139<br>600-176<br>600-181<br>600-188<br>600-295<br>600-341:1<br>600-341:2<br>600-343<br>600-344<br>600-345<br>600-346<br>628-1 | -- | None | < 1×10-6 | None | <1 | None |
| | 600-125<br>600-182<br>600-5 | -- | None | No COPCs reported above background | None | <1 | None |
| No Action | 600-296<br>600-302 | -- | None | < 1×10-6 | None | <1 | None |

Results summarized from Table G-45, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-2 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

Table 6-22. Summary of Total Risks from Radionuclides for the 100-IU-2 OU Overburden Material for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-IU-2 Source OU** | | | | | |
| Interim Closed Out | 600-120 and 600-297<br>600-125<br>600-127<br>600-182<br>600-188 | -- | None | No COPCs reported | None |

Results summarized from Table G-45, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-2 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

Table 6-23. Summary of Total Cancer Risks and Noncancer Hazards from Direct Contact for the 100-IU-2 OU Overburden Material for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-IU-2 Source OU** | | | | | | | |
| Interim Closed Out | 600-120 and 600-297 600-127 600-188 | -- | None | < 1 × 10-6 | None | <1 | None |
| | 600-125 | -- | None | No COPCs reported above background | None | <1 | None |
| | 600-182 | | | | | No COPCs reported above background | None |

Results summarized from Table G-45, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-2 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

Table 6-24. Summary of Total Risks from Radionuclides for the 100-IU-2 OU Staging Piles for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-IU-2 Source OU** | | | | | |
| Interim Closed Out | 600-120 and 600-297<br>600-124<br>600-125<br>600-127<br>600-176<br>600-182<br>600-188<br>600-5 | -- | None | No COPCs reported | None |

Results summarized from Table G-45, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-2 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

Table 6-25. Summary of Total Cancer Risks and Noncancer Hazards from Direct Contact for the 100-IU-2 OU Staging Piles for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-IU-2 Source OU** | | | | | | | |
| Interim Closed Out | 600-120 and 600-297 600-124 600-127 600-176 600-188 | -- | None | < 1 × 10-6 | None | <1 | None |
| | 600-125 600-182 600-5 | -- | None | No COPCs reported above background | None | <1 | None |

Results summarized from Table G-45, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-2 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

Table 6-26. Summary of Total Risks from Radionuclides for the 100-IU-2 OU Deep Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-IU-2 Source OU** | | | | | |
| Interim Closed Out | 600-127 | -- | None | No COPCs reported | None |

Results summarized from Table G-45, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-2 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

As presented in Table G-49 (Appendix G), the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 for 15 remediated waste sites. An HI was not reported at 11 remediated waste sites because COPC concentrations were less than background.

*Overburden.* A total of six remediated waste sites are reported with CVP/RSVP data associated with overburden material in the 100-IU-2 Source OU. The following sample designs were applied to the six waste sites evaluated:

- Six waste sites were sampled using a focused sampling design.

**Radiological Results.** As presented in Table 6-22, risks were not reported for overburden material associated with six remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact).** As presented in Table 6-23, the potential cumulative ELCR is less than $1 \times 10^{-6}$ for overburden material from four remediated waste sites. Risks were not reported in overburden material from two remediated waste sites because COPC concentrations were less than background.

As presented in Table 6-23, the HI is less than EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 in overburden material from five remediated waste sites. An HI was not reported in overburden material from one remediated waste site because COPC concentrations were less than background.

As shown in Table G-47 (Appendix G), all arsenic and lead EPCs are less than their respective Method A soil cleanup levels of 20 mg/kg and 250 mg/kg, respectively. All TPH EPCs were less than the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil).

**Nonradiological Results (Inhalation)**. As presented in Table G-51 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $6.0 \times 10^{-10}$ to $6.6 \times 10^{-8}$. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk value of $1 \times 10^{-6}$ for individual carcinogens in overburden material from four of the remediated waste sites. Risks were not reported in overburden material from two remediated waste sites because COPC concentrations were less than background.

As presented in Table G-51 (Appendix G), the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 in overburden material from four remediated waste sites. An HI was not reported in overburden material from two remediated waste sites because COPC concentrations were less than background.

*Staging Pile Area.* A total of nine waste sites are reported with CVP/RSVP data associated with staging pile area material in the 100-IU-2 Source OU. The following sample designs were applied to the nine waste sites evaluated:

- Four waste sites were sampled using a focused sampling design.
- Five waste sites were sampled using a statistical sampling design (two waste sites with two statistically distinct decision units).

**Radiological Results**. As presented in Table 6-24, risks were not reported for staging pile material associated with all nine remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact).** As presented in Table 6-25, potential cumulative ELCR is less than $1 \times 10^{-6}$ for staging pile material from six remediated waste sites. Risks were not reported in staging pile material from three remediated waste sites because COPC concentrations were less than background.

As presented in Table 6-25, the potential HI is less than EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 for staging pile material from all nine remediated waste sites.

As shown in Table G-47 (Appendix G), all arsenic EPCs are less than the Method A soil cleanup level of 20 mg/kg for unrestricted land use. Except for the lead EPC in staging pile material from one remediated waste site (600-176), all lead EPCs are less than the Method A soil cleanup level of 250 mg/kg for unrestricted land use. A summary of the lead results is provided below.

For staging pile material_2 decision unit at the 600-176 remediated waste site, the EPC for lead is 457 mg/kg and is based on the 99 percent Chebyshev UCL. Twelve soil samples were collected from the staging pile material and analyzed for lead. Lead concentrations range between 2.5 and 498 mg/kg (one result greater than the Method A soil cleanup level of 250 mg/kg). With the exception of single detection of lead above 250 mg/kg in sample J1C039, all lead concentrations range between 2.5 and 65 mg/kg. Use of the 99 percent Chebyshev UCL overestimates the lead concentration for the entire decision unit. The EPC value is likely to be less than the Method A value of 250 mg/kg.

All TPH EPCs were less than the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil).

**Nonradiological Results (Inhalation).** As presented in Table G-53 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $3.4 \times 10^{-14}$ to $3.8 \times 10^{-8}$. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk value of $1 \times 10^{-6}$ for individual carcinogens for staging pile material from six remediated waste sites. Risks were not reported for staging pile material from three remediated waste sites because COPC concentrations were less than background.

As presented in Table G-53 (Appendix G), the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 in staging pile material from five remediated waste sites. An HI was not reported in staging pile material from four remediated waste sites because COPC concentrations were less than background.

*Deep Zone.* Deep vadose zone samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience as screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

One remediated waste site was reported with CVP/RSVP with the deep zone in the 100-IU-2 Source OU. This waste site was sampled using both a statistical and a focused sampling design. The remaining 25 remediated waste sites were not excavated deeper than 4.6 m (15 ft) bgs and are not discussed in this section.

**Radiological Results**. As presented in Table 6-26, risks were not reported at this remediated waste site because radiological COPCs were not reported.

**100-IU-6 Source OU.** Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone material, overburden material, and staging pile area material. There are no deep vadose zone material decision units associated with the 100-IU-6 Source OU. The results without background contribution for the residential scenario are summarized in Tables G-63 through G-71 (Appendix G) for the 100-IU-6 Source OU.

An overall summary of the total risk estimates and noncancer hazards (if applicable) for the residential scenario from each of the remediated waste sites is provided in Table 6-27 and Table 6-28 for shallow zone material, Table 6-29 and Table 6-30 for overburden material, and Table 6-31 and Table 6-32 for staging piles. These tables list the OU that each remediated waste site resides in, the reclassification status, the remediated waste site, the associated waste site (if applicable), the decision unit reported with an exceedance (if applicable), the total ELCR and the risk driver and percent contribution (if applicable), and the hazard index and the noncancer hazard driver and percent contribution (if applicable).

*Shallow Zone.* A total of 22 waste sites are reported with CVP/RSVP data associated with the shallow zone in the 100-IU-6 Source OU. The following sample designs were applied to the 22 waste sites evaluated:

- Fifteen waste sites were sampled using a focused sampling design.
- Seven waste sites were sampled using both a statistical and a focused sampling design (two waste sites with three statistically distinct decision units).

**Radiological Results.** As presented in Table 6-27, the potential cumulative total ELCR is less than the lower risk threshold of $1 \times 10^{-6}$ at one remediated waste site. Risks were not reported at three remediated waste sites because COPC concentrations were less than background. Risks were not reported at 18 remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact).** As presented in Table 6-28, the potential cumulative ELCR is greater than $1 \times 10^{-6}$ for five remediated waste sites and is less than $1 \times 10^{-6}$ for 11 remediated waste sites. Risks were not reported at four remediated waste sites because nonradiological carcinogenic COPC concentrations were less than background. Risks were not reported at two remediated waste sites because radiological COPCs were not reported.

As presented in Table 6-28, five remediated waste sites report individual carcinogens greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$; however, three remediated waste sites report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$. The cancer risks levels for the Residential scenario are as follows:

- The 600-109 waste site (shallow decision unit) reports a total ELCR of $1.2 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.2 \times 10^{-5}$; 99 percent contribution).
- The 600-111 waste site (shallow focused decision unit) reports a total ELCR of $1.3 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.3 \times 10^{-5}$; 100 percent contribution).
- The 600-202 (shallow focused decision unit) reports a total ELCR of $1.5 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.5 \times 10^{-5}$; 99 percent contribution).

Table 6-27. Summary of Total Risks from Radionuclides for the 100-IU-6 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-IU-6 Source OU** | | | | | |
| Interim Closed Out | 600-111 | -- | None | < 1×10-6 | None |
| | 600-23<br>600-3 | -- | None | No COPCs reported above background | None |
| | 600-108 and 600-257<br>600-109<br>600-146<br>600-149:2<br>600-178<br>600-202<br>600-204<br>600-205<br>600-280<br>600-350<br>JA JONES 1 | -- | None | No COPCs reported | None |
| No Action | 600-107 | -- | None | No COPCs reported above background | None |
| | 600-186<br>600-315<br>600-322<br>600-323<br>600-327<br>600-334:1 | -- | None | No COPCs reported | None |

Results summarized from Table G-63, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-6 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

Table 6-28. Summary of Total Cancer Risks and Noncancer Hazards from Direct Contact for the 100-IU-6 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-IU-6 Source OU** | | | | | | | |
| Interim Closed Out | 600-109 | -- | Shallow | $1.2 \times 10^{-5}$ | Arsenic ($1.2 \times 10^{-5}$ – 99%) | <1 | None |
| | 600-111 | | Shallow Focused | $1.3 \times 10^{-5}$ | Arsenic ($1.3 \times 10^{-5}$ – 100%) | | |
| | 600-202 | | Shallow Focused | $1.5 \times 10^{-5}$ | Arsenic ($1.5 \times 10^{-5}$ – 99%) | | |
| | 600-23 | | Shallow Focused | $2.6 \times 10^{-6}$ | Aroclor-1254 ($2.6 \times 10^{-6}$ – >99%) | | |
| | 600-3 | | Shallow Focused | $1.2 \times 10^{-6}$ | None | | |
| | 600-108 and 600-257 600-146 | -- | None | $< 1 \times 10^{-6}$ | None | <1 | None |
| | 600-178 | | | | | No COPCs reported above background | None |
| | 600-204 600-205 600-350 | | | | | <1 | None |
| | 600-149:2 600-280 | -- | None | No COPCs reported above background | None | <1 | None |

Table 6-28. Summary of Total Cancer Risks and Noncancer Hazards from Direct Contact for the 100-IU-6 OU Shallow Zone Waste Sites for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| | JA JONES 1 | -- | None | No COPCs reported | None | No COPCs reported above background | None |
| No Action | 600-186 | -- | Shallow Focused | $< 1\times10^{-6}$ | None | 2.5 | Iron (HQ = 1.8 – 73%) |
| | 600-322 | | Shallow Focused | | | 1.8 | Iron (HQ = 1.7 – 92%) |
| | 600-323 600-334:1 | | None | | | <1 | None |
| | 600-315 600-327 | -- | None | No COPCs reported above background | None | <1 | None |
| | 600-107 | -- | None | No COPCs reported | None | No COPCs reported | None |

Results summarized from Table G-63, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-6 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

Table 6-29. Summary of Total Risks from Radionuclides for the 100-IU-6 OU Overburden Material for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sitesa | Decision Unit with Exceedance | Total ELCRb | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-IU-6 Source OU** | | | | | |
| Interim Closed Out | 600-109<br>600-178<br>600-23<br>JA JONES 1 | -- | None | No COPCs reported | None |

Results summarized from Table G-63, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-6 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

Table 6-30. Summary of Total Cancer Risks and Noncancer Hazards from Direct Contact for the 100-IU-6 OU Overburden Material for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-IU-6 Source OU** | | | | | | | |
| Interim Closed Out | 600-109 | -- | Overburden Focused | 2.3 × 10-5 | Arsenic (2.3 × 10-5 – >99%) | <1 | None |
| | 600-178 | -- | None | < 1 × 10-6 | None | <1 | None |
| | 600-23 | -- | None | No COPCs reported above background | None | No COPCs reported above background | None |
| | JA JONES 1 | -- | None | No COPCs reported | None | No COPCs reported above background | None |

Results summarized from Table G-63, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-6 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

Table 6-31. Summary of Total Risks from Radionuclides for the 100-IU-6 OU Staging Piles for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sitesa | Decision Unit with Exceedance | Total ELCRb | Risk Driver and % Contribution |
|---|---|---|---|---|---|
| **100-IU-6 Source OU** | | | | | |
| Interim Closed Out | 600-3 | -- | None | No COPCs reported above background | None |
| | 600-108 and 600-257<br>600-109<br>600-178<br>600-202<br>600-205 | -- | None | No COPCs reported | None |

Results summarized from Table G-63, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-6 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from radiological COPCs.

Table 6-32. Summary of Total Cancer Risks and Noncancer Hazards from Direct Contact for the 100-IU-6 OU Staging Piles for the Residential Scenario

| Classification Status | Remediated Waste Site | Associated Waste Sites[a] | Decision Unit with Exceedance | Total ELCR[b] | Risk Driver and % Contribution | HI | Hazard Driver and % Contribution |
|---|---|---|---|---|---|---|---|
| **100-IU-6 Source OU** | | | | | | | |
| Interim Closed Out | 600-109 | -- | Staging Pile Area | 3.6 × 10-5 | Arsenic (3.6 × 10-5 – >99%) | 1.0 | Arsenic (1.0 – 97%) |
| | 600-3 | | Staging Pile Area | 1.4 × 10-5 | Arsenic (1.3 × 10-5 – 97%) | <1 | None |
| | 600-108 and 600-257 600-178 600-202 600-205 | -- | None | < 1×10-6 | None | <1 | None |

Results summarized from Table G-63, Residential Scenario Risk Estimates and Noncancer Hazards for the 100-IU-6 Source OU Waste Site Decision Units Without Background Contribution.

a. Associated waste sites are those sites for which remediation and closeout documentation were consolidated with another remediated waste site.

b. Total ELCR represents risk contributions from nonradiological carcinogenic COPCs.

Arsenic is the only contributor to risk at the above three remediated waste sites. The EPCs for arsenic at these waste sites range between 7.7 mg/kg and 10.2mg/kg. Although the EPCs are greater than the lognormal 90$^{th}$ percentile of 6.5 mg/kg, they are consistent with naturally occurring levels at the Hanford Site (Table G-16), and are not the result of a site release. Additionally, arsenic EPCs for these three remediated waste sites are less than the direct exposure RAG of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17).

As presented in Table 6-28, the potential HI is less than EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 for 17 remediated waste sites and greater than the target HI of 1 for two remediated waste sites. An HI was not reported for two remediated waste sites because there were COPC concentrations were less than background. An HI was not reported at one remediated waste site because nonradiological noncarcinogenic COPCs were not reported. The HIs for the Residential scenario are as follows:

- The 600-186 waste site (shallow focused decision unit) reports a HI of 2.5. The primary contributor to the HI is iron (HQ = 1.8; 73 percent contribution).
- The 600-322 waste site (shallow focused decision unit) reports a HI of 1.8. The primary contributor to the HI is iron (HQ = 1.7; 92 percent contribution).

For the 600-186 remediated waste site, the EPC for iron is 101,000 mg/kg and is based on the maximum detected concentration. Thirteen samples (including three field duplicates) were collected from this decision unit and analyzed for iron. Iron was detected in all samples with concentrations ranging between 15,600 and 101,000 mg/kg (one result greater than the residential RBSL of 56,000). Use of the maximum detected concentration as the EPC for iron is considered an overestimation of the overall iron concentration for the entire decision unit. The EPC is likely to be less than the Residential RBSL of 56,000 mg/kg.

For the 600-322 remediated waste site, the EPC for iron is 94,600 mg/kg and is based on the maximum detected concentration. Two soil samples were sample was collected from this focused decision unit and analyzed for iron. Iron was detected in both samples with concentrations ranging between 20,800 and 94,600 (one sample greater than the residential RBSL of 56,000). Soil sample (J1C2K2) that was reported with an iron concentration of 94,600 mg/kg was collected from the soil inside the lateral pipe where the vertical pipe feeds in. As a result, the elevated iron concentration reported from this location is likely from the pipe and not the result of a Site release. As shown in Table G-65 (Appendix G), all arsenic EPCs are less than the Method A soil cleanup level of 20 mg/kg. Except for two remediated waste sites, the lead EPCs are less than the Method A soil lead cleanup level of 250 mg/kg. Except for one remediated waste site, all TPH EPCs are less than the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil). The lead and TPH results are summarized below.

At the 600-202 remediated waste site (Shallow Focused Decision Unit), the EPC for lead is 278 mg/kg and is based on the maximum detected concentration. Four soil samples were collected from this decision unit and analyzed for lead. Lead concentrations range between 5.3 and 278 mg/kg (one result greater than the Method A soil cleanup levels of 250 mg/kg). Lead concentrations less than the Method A cleanup level range between 5.3 and 6.8 mg/kg (less than the 90$^{th}$ percentile Hanford Site background value of 10.2 mg/kg). Use of the maximum detected concentration as the EPC for lead is considered an overestimation of the lead concentration for entire decision unit. The EPC value is likely to be less than the Method A value of 250 mg/kg.

At the 600-3 remediated waste site (Shallow Focused Decision Unit), the EPC for lead is 1,640 mg/kg. However, it was identified that the location with the elevated lead concentration (sample ID J1FFR5) was remediated and the sample was replaced by a lower concentration (sample ID J1HNN4). As a result, the EPC was recalculated and determined to be 259 mg/kg based on the maximum detected concentration. With the exception of the maximum detected result of 259 mg/kg, lead concentrations in the remaining 18 samples (including field duplicates) ranged between 3.3 and 110 mg/kg. Use of the maximum detected concentration as the EPC for lead is considered an overestimation of the lead concentration for entire decision unit. The EPC value is likely to be less than the Method A value of 250 mg/kg.

At the 600-205 remediated waste site (shallow focused decision unit), the EPC for TPH is 1,900 mg/kg which is based on the maximum detected concentration. Ten soil samples were collected from this decision unit and analyzed for TPH. There was a single detection of TPH (1,900 mg/kg) and all remaining results were nondetected concentrations. Use of the maximum detected concentration as the EPC for TPH is considered an overestimation of the overall TPH concentration for the entire decision unit. The EPC is likely to be less than the Method A value of 1,000 mg/kg.

**Nonradiological Results (Inhalation).** As presented in Table G-67 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $4.9 \times 10^{-16}$ to $8.9 \times 10^{-8}$. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk value of $1 \times 10^{-6}$ for individual carcinogens for 17 remediated waste sites. Risks were not reported for four remediated waste sites because COPC concentrations were less than background. Risks were not reported at one remediated waste site because nonradiological carcinogens were not reported.

As presented in Table G-67 (Appendix G), the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 for 14 remediated waste sites. An HI was not reported in for four remediated waste sites because COPCs concentrations were less than background. Hazards were not reported at four remediated waste sites because nonradiological noncarcinogens were not reported.

*Overburden.* Four remediated waste sites are reported with CVP/RSVP data associated with overburden material in the 100-IU-6 Source OU. The following sample designs were applied to the four waste sites evaluated:

- Two waste sites were sampled using a focused sampling design.
- Two waste sites were sampled using a statistical sampling design.

**Radiological Results**. As presented in Table 6-29, risks were not reported in overburden material from all four remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact).** As presented in Table 6-30, the potential cumulative ELCR is less than $1 \times 10^{-6}$ in overburden material from one remediated waste site and risks are greater than $1 \times 10^{-6}$ in overburden material from one remediated waste site. Risks were not reported in overburden material from one remediated waste site because COPC concentrations were less than background. Risks were not reported at one remediated waste site because nonradiological carcinogens were not reported.

As presented in Table 6-30, overburden material from one remediated waste site reports an individual carcinogen greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$, and this remediated waste site is also greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$. The cancer risk level for the Residential scenario is as follows:

- The 600-109 (overburden focused decision unit) reports a total ELCR of $2.3 \times 10^{-5}$. The primary contributor to risk is arsenic ($2.3 \times 10^{-5}$; greater than 99 percent contribution).

Arsenic is the only contributor to risk in overburden material from one remediated waste site 600-109. The EPC for arsenic in overburden material is 15.3 mg/kg. Although this EPC is greater than the lognormal 90$^{th}$ percentile of 6.5 mg/kg, it is consistent with naturally occurring levels at the Hanford Site (Table G-16), and is not the result of a site release. Additionally, the arsenic EPC for overburden material from this remediated waste site is less than the direct exposure RAG of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17).

As presented in Table 6-30, the potential HI is less than EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 in overburden material from two remediated waste sites. An HI was not reported in overburden material from two remediated waste sites because COPC concentrations were less than background.

As shown in Table G-65 (Appendix G), all arsenic and lead EPCs are less than their respective Method A soil cleanup levels of 20 mg/kg and 250 mg/kg, respectively. All TPH EPCs are less than the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil).

**Nonradiological Results (Inhalation).** As presented in Table G-69 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $5.0 \times 10^{-15}$ to $3.6 \times 10^{-10}$. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk value of $1 \times 10^{-6}$ for individual carcinogens in overburden material from two remediated waste sites. Risks were not reported in overburden material from two remediated waste sites because COPC concentrations were less than background.

As presented in Table G-69 (Appendix G), the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 in overburden material from one remediated waste site. An HI was not reported in overburden material from three remediated waste sites because COPC concentrations were less than background.

*Staging Pile Area.* A total of seven waste sites are reported with CVP/RSVP data associated with staging pile area material in the 100-IU-6 Source OU. The following sample designs were applied to the seven waste sites evaluated:

- Four waste sites were sampled using a focused sampling design.
- Two waste sites were sampled using a statistical sampling design (two waste sites with two statistically distinct decision units).
- One waste site was sampled using both a statistical and a focused sampling design.

**Radiological Results.** As presented in Table 6-31, risks were not reported for staging pile material from six remediated waste sites because radiological COPCs were not reported. Risks were not reported for staging pile material from one remediated waste site because radiological COPC concentrations were less than background.

**Nonradiological Results (Direct Contact).** As presented in Table 6-32, the potential cumulative ELCR is greater than $1 \times 10^{-6}$ for staging pile material associated with two remediated waste sites and is less than $1 \times 10^{-6}$ for five remediated waste sites.

As presented in Table 6-32, staging pile material from two previously remediated waste sites report individual carcinogens greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$, and both remediated waste sites also report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$. The cancer risks levels for the residential scenario are as follows:

- The 600-109 (staging pile decision unit) reports a total ELCR of $3.6 \times 10^{-5}$. The primary contributor to risk is arsenic ($3.6 \times 10^{-5}$; greater than 99 percent contribution).
- The 600-3 (staging pile decision unit) reports a total ELCR of $1.4 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.3 \times 10^{-5}$; 97 percent contribution).

Arsenic is the only contributor to risk in staging pile material associated with the two remediated waste sites. The EPCs for arsenic at these waste sites range between 8.9 and 24.0 mg/kg. The EPC for the staging pile material for waste site 600-3 is greater than the lognormal 90$^{th}$ percentile of 6.5 mg/kg, it is consistent with naturally occurring levels at the Hanford Site (Table G-16) and is not the result of a site release. Additionally, the arsenic EPC for staging material from this remediated waste site is less than the direct exposure RAG of 20 mg/kg published in the 100 Area RDR/RAWP (DOE/RL-96-17).

For staging pile material at the 600-109 Remediated Waste Site, the EPC for arsenic is 24 mg/kg and is based on the 95 percent Student's t UCL. Thirteen soil samples (including one field duplicate) were collected from the staging pile material and analyzed for arsenic. Arsenic concentrations range between 5.5 and 41 mg/kg (five results greater than the Method A soil cleanup level of 20 mg/kg). Arsenic concentrations greater than the Method A cleanup level range between 23 and 41 mg/kg.

As presented in Table 6-32, the potential HI is less than or equal to the EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 in staging pile material from all seven remediated waste sites.

As shown in Table G-65 (Appendix G), all lead EPCs are less than the Method A soil cleanup level of 250 mg/kg. All TPH EPCs are less than the Table 747-5 ("Tables" [WAC 173-340-900]) Residual Saturation Screening Levels for TPH of 1,000 mg/kg for unknown composition or type and 2,000 mg/kg for middle distillates (e.g. Diesel No. 2 fuel oil). As discussed above, the arsenic EPC of 24 mg/kg at 600-109 (staging pile area decision unit) is greater than the Method A soil cleanup levels of 20 mg/kg.

**Nonradiological Results (Inhalation).** As presented in Table G-71 (Appendix G), the potential cumulative ELCR for the inhalation pathway from all nonradiological carcinogenic COPCs without background contribution ranges from $5.5 \times 10^{-16}$ to $8.6 \times 10^{-9}$. The potential cumulative ELCR is less than the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) Method B risk value of $1 \times 10^{-6}$ for individual carcinogens for staging pile material from all seven remediated waste sites.

As presented in Table G-71 (Appendix G), the potential HI is less than the EPA target HI of 1 and the "Cleanup Standards to Protect Air Quality" (WAC 173-340-750) target HI of 1 in staging pile material from three remediated waste sites. An HI was not reported in staging pile material from two remediated waste sites because COPC concentrations were less than background. Risks were not reported for staging pile material from two remediated waste sites because nonradiological noncarcinogenic COPCs were not reported.

*Deep Zone.* There are no waste sites excavated deeper than 4.6 m (15 ft) bgs within the 100-IU-6 Source OU and results are not discussed in this section.

#### *6.2.5.5.2 Resident Monument Worker Scenario*

PRGs developed for the resident Monument worker scenario represents a reasonably anticipated future land use. The results of this comparison are used to confirm that cleanup actions are protective of the reasonably anticipated future land uses that DOE and the USFWS anticipate for the river corridor. The resident Monument worker scenario is described in Section 6.2.3.3.

For completeness in analysis, all risk estimates for each waste site decision unit are provided in Appendix G. The risk estimates, which include all radiological COPCs regardless of their EPCs relative to the background concentration are presented in Tables G-72 through Table G-75 for the 100-F Source OU and Tables G-80 through G-82 for the 100-IU-6 Source OU.

Appendix G also includes risk estimates for each waste site decision unit, which includes only those radiological COPCs with EPCs greater than background values or that do not have a background value. The risk estimates are presented in Tables G-76 through Table G-79 for the 100-F Source OU and Tables G-83 through G-85 for the IU-6 Source OU (Appendix G). Only the risk estimates without background contributions are discussed in the risk characterization because this information is used for decisions concerning appropriate remedial actions.

Radiological analytes were not analyzed in samples collected from the 100-IU-2 Source OU; therefore, the resident Monument worker scenario is not evaluated in this section.

**100-F Source OU.** Risk estimates were calculated for the shallow vadose material, overburden material, and staging pile area material decision units within a waste site. Risk estimates were not calculated for the deep zone decision units because the direct contact exposure pathway is incomplete. The results without background contribution for the resident Monument worker scenario are presented in Table G-76 through Table G-79 (Appendix G).

*Shallow Zone.*

**Radionuclide Results.** As presented in Table G-77, the total ELCR for radionuclides is equal to the upper risk threshold value of $1 \times 10^{-4}$ at one remediated waste site, is within the target risk range of $10^{-4}$ to $10^{-6}$ at 26 remediated waste sites and is less than the lower risk threshold value of $1 \times 10^{-6}$ at 12 remediated waste sites. Risks were not reported at 17 remediated waste sites because COPC concentrations were less than background. Radiological COPCs were not reported at 37 remediated waste sites. The results of the Resident Monument Worker scenario are compared to the Residential scenario below.

Four remediated waste sites report concentrations of Hanford Site-related COPCs that are equal to or exceed the upper range of the target threshold for the Residential scenario (see Table 6-13). Whereas only one remediated waste site reports concentrations of site-related COPCs that is equal to the upper threshold of the target risk range for the resident Monument worker scenario. The cancer risk levels for the resident Monument worker scenario are as follows:

- The 126-F-1 waste site (shallow decision unit) reports a total ELCR of $1.0 \times 10^{-4}$. The primary contributor to risk is europium-152 ($8.7 \times 10^{-5}$; 84 percent contribution) and europium-154 ($9.5 \times 10^{-6}$; 9.2 percent contribution).

**Nonradiological Results (Direct Contact and Inhalation).** As described in Section 6.2.3.3, the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740])

are the PRG values used to achieve protection of the resident Monument worker. Table 6-14 provides the results for the residential scenario.

*Overburden.*

**Radiological Results.** As presented in Table G-78, the total ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for overburden material from eight remediated waste sites and is less than the lower risk threshold value of $1 \times 10^{-6}$ for overburden material from six remediated waste sites. Risks were not reported for overburden material associated with eight remediated waste sites because COPC concentrations were less than background. Radiological COPCs were not reported at 11 remediated waste sites. The results of the Resident Monument Worker scenario are compared to the Residential scenario below.

Overburden material associated with two remediated waste sites report concentrations of site-related radiological COPCs that exceed the upper threshold of the target risk range for the Residential scenario (see Table 6-15). Whereas overburden material from remediated waste sites did not report concentrations of site-related COPCs greater than the upper threshold of the target risk range for the resident Monument worker scenario.

**Nonradiological Results (Direct Contact and Inhalation).** As described in Section 6.2.3.3, the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-16 provides the results for the residential scenario.

*Staging Pile Area.*

**Radiological Results** As presented in Table G-79 (Appendix G), the total ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for staging pile material from four remediated waste sites and is less than the lower risk threshold value of $1 \times 10^{-6}$ for staging pile material from two remediated waste sites. Risks were not reported for staging pile material from six remediated waste sites because COPC concentrations were less than background. Radiological COPCs were not reported in staging pile material from 11 remediated waste sites.

Results for the Residential scenario are similar to the Resident Monument Worker scenario, as staging piles associated with remediated waste sites did not exceed the upper risk threshold of $1 \times 10^{-4}$.

**Nonradiological Results (Direct Contact and Inhalation).** As described in Section 6.2.3.3, the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-18 provides the results for the residential scenario.

**100-IU-6 Source OU**. Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone material and staging pile area material. Risk estimates were not calculated for the deep zone decision units because the direct contact exposure pathway is incomplete (i.e., samples are collected from depths greater than 4.6 m [15 ft] bgs). The results without background contribution for the resident Monument worker scenario are summarized in Tables G-83 through G-85 for the 100-IU-6 Source OU (Appendix G).

*Shallow Zone.*

**Radiological Results**. As presented in Table G-81, the potential cumulative total ELCR is less than the lower risk threshold of $1 \times 10^{-6}$ at one remediated waste site. Risks were not reported at three remediated waste sites because COPC concentrations were less than background. Risks were not reported at 18 remediated waste sites because radiological COPCs were not reported.

Results for the Residential scenario are similar to the Resident Monument Worker scenario, as remediated waste sites did not exceed the upper risk threshold of $1 \times 10^{-4}$.

**Nonradiological Results (Direct Contact and Inhalation).** As described in Section 6.2.3.3, the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-28 provides the results for the residential scenario.

*Overburden.*

**Radiological Results**. Results for the Residential scenario are similar to the Resident Monument Worker scenario because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact and Inhalation).** As described in Section 6.2.3.3, the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-30 provides the results for the residential scenario.

*Staging Pile Area.*

**Radiological Results.** Results for the Residential scenario are similar to the Resident Monument Worker scenario because COPC concentrations in staging pile material associated with remediated waste sites were less than background.

**Nonradiological Results (Direct Contact and Inhalation).** As described in Section 6.2.3.3, the MTCA Method B Soil Cleanup Levels ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) are the PRG values used to achieve protection of the resident Monument worker. Table 6-32 provides the results for the residential scenario.

#### *6.2.5.5.3 Casual Recreational User Scenario*

PRG developed for the casual recreational user scenario represents a reasonably anticipated future land use. The results of this comparison are used to confirm that cleanup actions are protective of the reasonably anticipated future land uses that DOE and USFWS anticipate for the River Corridor. The casual recreational user scenario is described in Section 6.2.3.3.

For completeness in analysis, risk estimates for each waste site decision unit are provided in Appendix G. The risk estimates for the 100-F Source OU, which include all COPCs regardless of their EPCs relative to the background concentrations, are presented in Tables G-86 through G-89 (Appendix G). The risk estimates for the 100-IU-2 and 100-IU-6 Source OUs, which include all COPCs regardless of their EPCs relative to the background concentrations, are presented in Tables G-94 through G-97 and Tables G-102 through G-105, respectively (Appendix G).

Appendix G also includes risk estimates for each waste site decision unit, which include only those COPCs with EPCs greater than background values or that do not have a background value. The 100-F Source OU risk estimates are presented in Tables G-90 through G-93 (Appendix G). The 100-IU-2 Source OU and 100-IU-6 Source OU risk estimates are presented in Tables G-98 through G-101 and Tables G-106 through G-109, respectively. Only the risk estimates without background contributions are discussed in the risk characterization because this information is used for decisions concerning appropriate remedial actions.

**100-F Source OU.** Risk estimates were calculated for the shallow vadose zone material, overburden material and staging pile area material decision units within a waste site. Risk estimates were not calculated for the deep zone decision units because the direct contact exposure pathway is incomplete.

The results without background contribution for the casual recreational user scenario are presented in Table G-90 (Appendix G).

*Shallow Zone.*

**Radionuclide Results**. As presented in Table G-91 (Appendix G), the total ELCR for radionuclides is within the target risk range of $10^{-4}$ to $10^{-6}$ at nine remediated waste sites and is less than the lower risk threshold of $1 \times 10^{-6}$ at 30 remediated waste sites. Risks were not reported at 17 remediated waste sites because radiological COPC concentrations were less than background. Radiological COPCs were not reported at 37 remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

One remediated waste site (118-F-6) in 100-F Source OU reports concentrations of Hanford site-related COPCs that exceed the upper threshold of the target risk range for the Residential scenario (see Table 6-13). Whereas shallow zone remediated waste sites did not exceed the upper range of the target threshold for the Casual Recreational User scenario.

**Nonradiological Results (Direct Contact and Inhalation).** As presented in Table G-91 (Appendix G), the potential cumulative ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ at eight remediated waste sites and is less than $1 \times 10^{-6}$ at 42 remediated waste sites. Risks were not reported in 27 remediated waste sites because COPC concentrations were less than background. Nonradiological carcinogenic COPCs were not reported at 16 remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, 11 remediated waste sites report individual carcinogens greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$, six of these 11 remediated waste sites report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ (see Table 6-14). Arsenic was the only contributor to risk at five of the six remediated waste sites and these concentrations were less than the Method A soil cleanup level of 20 mg/kg. Remediated waste site 600-351 reported arsenic and lead concentrations greater than the Method A soil cleanup levels of 20 mg/kg and 250 mg/kg, respectively. For the Casual Recreational User scenario, one remediated waste site (600-351) is greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of $1 \times 10^{-5}$. The cancer risk levels for the Casual Recreational User scenario are as follows:

The 600-351 waste site (shallow focused decision unit) reports a total ELCR of $1.2 \times 10^{-5}$. The primary contributor to risk is arsenic ($1.2 \times 10^{-5}$; 100 percent contribution).

As shown in Table G-91 (Appendix G), the potential HI for noncancer effects is less than the target HI of 1 at 77 remediated waste sites. An HI was not reported for five remediated waste sites because COPC concentrations were less than background. Nonradiological COPC were not reported at 11 remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, one remediated waste site (600-351) reports a HI greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1 (see Table 6-14). For the Casual Recreational User scenario, all remediated waste sites that report a HI less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) target HI of 1.

*Overburden.*

**Radiological Results.** As presented in Table G-92 (Appendix G), the potential cumulative ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for overburden material associated with two remediated waste sites and is less than the lower risk threshold value of $1 \times 10^{-6}$ for overburden material associated with 12 remediated waste sites. Risks were not reported for overburden material associated with eight remediated waste sites because COPC concentrations were less than background. Radiological COPCs were not reported at 11 remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, overburden material associated with one remediated waste sites report concentrations of site-related radiological COPCs that exceed the upper threshold of the target risk range (see Table 6-15). Overburden material associated with the 116-F-4 remediated waste site reported an anomalous technetium-99 result and risks are overstated for this decision unit because of this result. For the Casual Recreational User scenario, overburden material associated with remediated waste sites did not exceed the upper range of the target threshold.

**Nonradiological Results (Direct Contact and Inhalation).** As presented in Table G-92 (Appendix G), the potential cumulative ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for overburden material associated with three remediated waste sites and is less than $1 \times 10^{-6}$ for overburden material associated with 18 remediated waste sites. Risks were not reported in overburden material from seven remediated waste sites because COPC concentrations were less than background. Nonradiological carcinogenic COPCs were not reported at five remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, four remediated waste sites report individual carcinogens greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$; two of these four remediated waste sites report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ (Table 6-16). Arsenic is the only contributor to risk at both remediated waste sites and arsenic concentrations are less than the Method A soil cleanup level of 20 mg/kg. For the Casual Recreational User scenario, all overburden material associated with remediated waste sites were less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of $1 \times 10^{-5}$.

As shown in Table G-92 (Appendix G), the potential HI for noncancer effects is less than the target HI of 1 in overburden material from 27 remediated waste sites. An HI was not reported in overburden material from three remediated waste sites because COPC concentrations were less than background. Nonradiological noncarcinogenic COPCs were not reported in overburden material from three remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario because overburden material associated with remediated waste sites were less than the EPA target HI of 1 and the MTCA "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1.

*Staging Pile Area.*

**Radiological Results.** As presented in Table G-93 (Appendix G), the potential cumulative ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for staging pile material from one remediated waste sites and is less than the lower risk threshold value of $1 \times 10^{-6}$ for staging pile material from five remediated waste sites. Risks were not reported for staging pile material from six remediated waste sites because COPC

concentrations were less than background. Radiological COPCs were not reported at 11 remediated waste sites.

Results for the Residential scenario are similar to the Casual Recreational User scenario for radionuclides, because staging piles associated with remediated waste sites did not exceed the upper risk threshold of $1 \times 10^{-4}$.

**Nonradiological Results (Direct Contact and Inhalation).** As presented in Table G-93 (Appendix G), the potential cumulative ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for staging pile material associated with seven remediated waste sites and is less than $1 \times 10^{-6}$ for staging pile material associated with 12 remediated waste sites. Risks were not reported in staging pile material from four remediated waste sites because COPC concentrations were less than background. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, 10 remediated waste sites report individual carcinogens greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$; 5 of these 10 remediated waste sites report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ (Table 6-16). Arsenic is the only contributor to risk at four of the five remediated waste sites and arsenic concentrations are less than the Method A soil cleanup level of 20 mg/kg. Benzo(a)pyrene concentrations is the primary contributor to risks greater than $1 \times 10^{-5}$ in staging pile material from 132-F-1 remediated waste site. However, the presence of benzo(a)pyrene is associated with asphalt and is not the result of a Site release. For the Casual Recreational User scenario, all overburden material associated with remediated waste sites were less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of $1 \times 10^{-5}$.

As shown in Table G-93 (Appendix G), the potential HI for noncancer effects is less than the target HI of 1 in staging pile material from all 23 remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario as staging pile material associated with remediated waste sites were less than the EPA target HI of 1 and the MTCA "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1.

**100-IU-2 Source OU.** Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone material, overburden material, and staging pile area material. The results without background contribution for the casual recreational user scenario are summarized in Tables G-98 through G-101 (Appendix G) for the 100-IU-2 Source OU.

*Shallow Zone.*

**Radiological Results.** Radiological risks were not reported for the Residential scenario or the Casual recreational User scenario at all 26 remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact and Inhalation).** As presented in Table G-99 (Appendix G) for the 100-IU-2 Source OU, the potential cumulative ELCR is less than $1 \times 10^{-6}$ for 23 remediated waste sites. Risks were not reported for three remediated waste sites because COPC concentrations were less than background. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, one remediated waste site reports an individual carcinogen greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times$

$10^{-6}$; however, the risk associated with this remediated waste site is less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ (see Table 6-21). For the Casual Recreational User scenario, no remediated waste sites report individual carcinogens greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$, and all remediated waste sites are less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of $1 \times 10^{-5}$.

As shown in Table G-99 (Appendix G), the potential HI for noncancer effects is less than the target HI of 1 at all 26 remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario because all shallow zone remediated waste sites were less than the EPA target HI of 1 and the MTCA "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1.

*Overburden.*

**Radiological Results**. Radiological risks were not reported for the Residential scenario or the Casual recreational User scenario in overburden material associated with six remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact and Inhalation)**. As presented in Table G-100, the potential cumulative ELCR is less than $1 \times 10^{-6}$ for overburden material from four remediated waste sites. Risks were not reported in overburden material from two remediated waste sites because COPC concentrations were less than background. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Cancer risks for the Residential scenario and the Casual Recreational User scenario are similar because all remediated waste sites report individual carcinogens less than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$, and all remediated waste sites are less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of $1 \times 10^{-5}$.

As presented in Table G-100 (Appendix G), the potential HI is less than EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 in overburden material from five remediated waste sites. An HI was not reported in overburden material from one remediated waste site because COPC concentrations were less than background. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario because all overburden material associated with remediated waste sites were less than the EPA target HI of 1 and the MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

*Staging Pile Area.*

**Radiological Results**. Radiological risks were not reported for the Residential scenario or the Casual recreational User scenario in staging pile material associated with nine remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact and Inhalation).** As presented in Table G-101, the potential cumulative ELCR is less than $1 \times 10^{-6}$ for staging pile material from six remediated waste sites. Risks were not reported in staging pile material from three remediated waste sites because COPC concentrations

were less than background. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Cancer risks for the Residential scenario and the Casual Recreational User scenario are similar because all staging pile material associated with remediated waste sites report individual carcinogens less than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$, and all staging pile material associated with remediated waste sites are less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) cumulative risk threshold of $1 \times 10^{-5}$.

As presented in Table G-101 (Appendix G), the potential HI is less than EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 for staging pile material from all nine remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario because all staging pile material associated with remediated waste sites were less than the EPA target HI of 1 and the MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

**100-IU-6 Source OU**. Risk estimates were calculated for each decision unit within a waste site including shallow vadose zone material, overburden material, and staging pile area material. The results without background contribution for the casual recreational user scenario are summarized in Tables G-106 through G-109 (Appendix G) for the 100-IU-6 Source OU.

*Shallow Zone.*

**Radiological Results.** As presented in Table G-107 (Appendix G), the potential cumulative total ELCR is less than the lower risk threshold of $1 \times 10^{-6}$ at one remediated waste site. Risks were not reported at 18 remediated waste sites because COPC concentrations were less than background. Risks were not reported at three remediated waste sites because radiological COPCs were not reported.

Results for the Residential scenario are similar to the Casual Recreational User scenario because shallow zone material remediated waste sites did not exceed the upper risk threshold of $1 \times 10^{-4}$.

**Nonradiological Results (Direct Contact and Inhalation).** As presented in Table G-107 (Appendix G) for the 100-IU-6 Source OU, the potential cumulative ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for three remediated waste sites and less than $1 \times 10^{-6}$ for 14 remediated waste sites. Risks were not reported in four remediated waste sites because COPC concentrations were less than background. Risks were not reported at one remediated waste site because radiological COPCs were not reported. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, five remediated waste sites report individual carcinogens greater than the WAC 173-340-740 acceptable cancer risk level of $1 \times 10^{-6}$, three of the five remediated waste sites report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ (see Table 6-28). Arsenic is the only contributor to risk at these three remediated waste sites and all concentrations are less than the Method A soil cleanup level of 20 mg/kg. For the Casual Recreational User scenario, four remediated waste sites report individual carcinogens greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$; however, three remediated waste sites report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$.

As presented in Table G-107 (Appendix G), the potential HI is less than EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 for 19 remediated waste sites. An HI was not reported for two remediated waste sites because there were COPC concentrations were less than background. Hazards were not reported at one remediated waste sites because nonradiological COPCs were not reported. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario because all remediated waste sites were less than the EPA target HI of 1 and the MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

*Overburden.*

**Radiological Results.** Radiological risks were not reported for the Residential scenario or the Casual recreational User scenario in overburden material associated with four remediated waste sites because radiological COPCs were not reported.

**Nonradiological Results (Direct Contact and Inhalation).** As presented in Table G-108, the potential cumulative ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for overburden material from one remediated waste site and is less than $1 \times 10^{-6}$ for overburden material from one remediated waste site. Risks were not reported in overburden material from two remediated waste sites because COPC concentrations were less than background. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, overburden material associated with one remediated waste site reports an individual carcinogen greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$, and this remediated waste site is also greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ (see Table 6-30). Arsenic is the only contributor to risk at this remediated waste site and the concentration is less than the Method A soil cleanup level of 20 mg/kg. For the Casual Recreational User scenario, overburden material associated with one remediated waste site reports an individual carcinogen greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$; however, this remediated waste site is less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$.

As presented in Table G-108 (Appendix G), the potential HI is less than EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 in overburden material from two remediated waste sites. An HI was not reported in overburden material from two remediated waste sites because COPC concentrations were less than background. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario because all overburden material associated with remediated waste sites were less than the EPA target HI of 1 and the MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

*Staging Pile Area.*

**Radiological Results**. Radiological risks were not reported for the Residential scenario or the Casual Recreational User scenario for staging pile material associated with six remediated waste sites because

radiological COPCs were not reported. Risks were not reported for staging pile material associated with one remediated waste site because radiological COPCs were less than background.

**Nonradiological Results (Direct Contact and Inhalation).** As presented in Table G-109, the potential cumulative ELCR is within the target risk range of $10^{-4}$ to $10^{-6}$ for staging pile material from two remediated waste sites and is less than $1 \times 10^{-6}$ for staging pile material from five remediated waste site. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

For the Residential scenario, staging pile material from two previously remediated waste sites report individual carcinogens greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$ and both remediated waste sites also report a total ELCR greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ (see Table 6-32). Arsenic is the only contributor to risk at both remediated waste sites and both concentrations are less than the Method A soil cleanup level of 20 mg/kg. For the Casual Recreational User scenario, staging pile material associated with two remediated waste sites report individual carcinogen greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) acceptable cancer risk level of $1 \times 10^{-6}$; however, both remediated waste sites are less than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$.

As presented in Table G-109 (Appendix G), the potential HI is less than or equal to the EPA target HI of 1 and the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1 in staging pile material from all seven remediated waste sites. The results of the Casual Recreational User scenario are compared to the Residential scenario below.

Noncancer hazards for the Residential scenario are similar to the Casual Recreational User scenario because all overburden material associated with remediated waste sites were less than the EPA target HI of 1 and the MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) target HI of 1.

### 6.2.6 Uncertainties in the Soil Risk Assessment

The purpose of this soil risk assessment is to determine whether a further remedial action is warranted under CERCLA. Estimating and evaluating health risk from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions must be made to quantify health risks.

In this assessment, uncertainties are associated with sampling and analysis data, sampling design, the EPCs, radiological decay, exposure, toxicity assumptions, and risk characterization.

#### *6.2.6.1 Uncertainties Associated with Sampling and Analysis Data*

Sampling and analysis data used in this soil risk assessment represent post-remediation conditions of waste sites with a "no action" or an "interim closed out" remediation status. All soil samples were collected in accordance with the requirements stated in 100 Area SAP (DOE/RL-96-22). These data were collected specifically to determine if the remedial action processes implemented met the remedial action objectives and remedial action goals stated in the interim action records of decision listed in Section 6.2.1.1.

Some uncertainties may be associated with the changing requirements associated with the analysis of COCs identified in each record of decision. When remediation initially began in 1996 in the 100 Area, only those analytes identified as COCs were analyzed and reported by the laboratory. However, as remediation continued, analytical methods improved, guidance was superseded, and reporting

requirements changed. Currently, analytes identified as COCs are analyzed using a methods based approach, which requires each laboratory to report the concentration of the COC and all associated target analytes included in the analytical method.

Waste sites associated with the earliest interim action RODs are generally the radioactive high-volume liquid effluent sites. In general, verification samples collected to determine if remedial action objectives had been met report fewer analytes than those that have been remediated more recently. The majority of waste sites typically include verification samples analyzed using a method-based approach. These generally include burial grounds and waste sites identified during discovery process. If a method-based approach were used, risks may be slightly higher but would remain protective of human health. This conclusion is supported by results of the method-based approach used for RI samples collected for this report.

#### *6.2.6.2 Uncertainties Associated with Sampling Design and Exposure Point Concentrations*

Calculating UCL for EPCs (OSWER 9285.6-10) recommends using a 95 percent UCL on the mean for estimating EPCs. Section 6.2.2.2 describes the methodology for calculating the EPCs for detected analytes.

When the following conditions were met, the maximum concentration rather than the 95 percent UCL was selected as the EPC:

- When samples are collected using a focused sampling design
- When a valid 95 percent UCL cannot be calculated because of a limited number of detections (<5)
- When a valid 95 percent UCL is greater than the maximum detected concentration

When these conditions are met, statistical bias is introduced resulting in the potential to overstate risk.

In addition, EPCs selected for shallow zone and deep zone decision units represent verification data collected from the floor and the sidewall of the excavated waste site. As a result, risks are likely overstated because the EPC does not take credit for the existing clean backfill that covers the remediated waste site.

#### *6.2.6.3 Uncertainties Associated with Sample Design and Depth of Collection*

Soil samples collected from 100-F-26:13 and 116-F-14 are assigned to a shallow zone decision unit for both of these waste sites for interim closure purposes. "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(6)(d) indicates that the point of compliance for human exposure via direct contact be established in the soils throughout the site from the ground surface to 4.6 m (15 ft) bgs. Closeout documentation for each of these waste sites indicate that the excavation depth was greater than 4.6 m (15 ft) bgs and, therefore, verification samples are actually collected from depths greater than 4.6 m (15 ft) bgs. For both waste sites, the direct contact exposure pathway is considered incomplete because samples are collected at depths greater than 4.6 m (15 ft) bgs. Comparison of EPCs to residential RBSLs overstates risk for direct contact exposure because sample collection depths are greater than 4.5 m (15 ft) bgs. Remedial action for both sites should be similar to those that are considered for deep zone decision units. The time required for radioisotope concentrations to decay to the residential RBSLs is provided in Section 6.2.6.4. It should be noted that activities of all radionuclides have decayed to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ in year 2010 and year 2005, respectively.

#### *6.2.6.4 Adjustments in EPCs Associated with Decay of Radioisotopes*

Section 6.2.5.5 provides a summary of the risk estimates by exposure scenario evaluated. The results of the soil risk assessment for the residential scenario identify a group of waste sites with concentrations of

site-related COPCs that result in individual risks greater than the upper risk threshold value of $1 \times 10^{-4}$. Table G-110 (Appendix G) lists the 100-F/IU waste sites and the applicable decision unit, each radioisotope reported for the waste site decision unit, the year the samples were collected, the EPCs, the half-life for each radioisotope, and the year that each radioisotope decays to an activity level equal to the residential RBSL. The tables also present the number of years required for radioisotope decay to reach a total risk estimate (based on all radionuclides reported) less than the upper risk threshold value of $1 \times 10^{-4}$. Deep zone soil samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

The elapsed time at which the activity level would decay below the residential RBSL is based on the radioactive decay law using the following equation:

$$\tau = \frac{\log \frac{A_E}{A_O}}{\log 0.5} \times \tau \frac{1}{2}$$

where:

$A_E$ = The remaining amount of substance (the PRG) (pCi/g)

$A_O$ = The original amount of substance (the EPC) (pCi/g)

$\tau_{1/2}$ = The half-life of the substance (years)

$\tau$ = The elapsed amount of time (years) since the sample was collected

The number of years required for total risk to be less than $1 \times 10^{-4}$ (represented by "t") was back-calculated using the following inequality for a waste site with "n" radionuclides reported:

$$\left( \frac{EPC_1 \times 10^{\left[ \frac{t}{\frac{t_1}{2}} \times log\left(\frac{1}{2}\right) \right]}}{PRG_1} \right) + \cdots + \left( \frac{EPC_n \times 10^{\left[ \frac{t}{\frac{t_1}{2}} \times log\left(\frac{1}{2}\right) \right]}}{PRG_n} \right) < 1 \times 10^{-4}$$

Concentrations of radioisotopes currently measured in shallow decision units where the final excavation depth is less than 4.6 m (15 ft) bgs decay to activity levels less than residential RBSLs as follows:

- Strontium-90 concentrations at 118-F-6 (shallow decision unit) decayed to a level less than the residential RBSL in year 2032. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2033.

Concentrations of radioisotopes currently measured at depths greater than 4.6 m (15 ft) bgs or deep decision units decay to activity levels less than residential RBSLs as follows:

- Cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 concentrations at 100-F-19:1 (deep decision unit) decay to levels less than the residential RBSL by year 2088. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2113.

- Europium-152 concentrations at 100-F-19:2 (deep decision unit) decay to levels less than residential RBSLs by year 2027. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2059.

- Cesium-137, cobalt-60, europium-152, europium-154, and nickel-63 concentrations at 116-F-14 (deep decision unit) decay to levels less than the residential RBSL by year 2076. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2110.

- Cesium-137, europium-152, and europium-154 concentrations at 116-F-2 (deep decision unit) decay to levels less than residential RBSLs by year 2101. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2108.

- Cesium-137, europium-152, and strontium-90 concentrations at 116-F-6 (deep decision unit) decay to a levels less than the residential RBSL by year 2113. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2122.

- Europium-152 and strontium-90 concentrations at 116-F-9 (deep decision unit) decay to levels less than residential RBSLs by year 2062. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2074.

- Cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 concentrations at 118-F-8:3 (deep decision unit) decay to levels less than the residential RBSL by year 2187. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2235.

- Cesium-137 and strontium-90 concentrations at 116-F-2 (deep decision unit) decay to levels less than residential RBSLs by year 2102. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2108.

- Cesium-137, europium-152, and strontium-90 concentrations at 118-F-8:4 (deep decision unit) decay to levels less than residential RBSLs by year 2025. Activities of all radionuclides will decay to a total cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2059.

#### 6.2.6.5 *Uncertainties Associated with Exposure Assumptions*

The exposure assumptions used to develop the RBSLs for each exposure scenario represent an RME. For estimating the RME, 95 percentile values (or upper-bound estimates of national averages) are generally used for exposure assumptions, and exposed populations and exposure scenarios are selected to represent upper-bound exposures. The intent of the RME, as discussed by the EPA Deputy Administrator and the Risk Assessment Council "Guidance on Risk Characterization for Risk Managers and Risk Assessors" (Habicht, 1992) is to present risks as a range from central tendency to high-end risk (above the $90^{th}$ percentile of the population distribution). This descriptor is intended to estimate the risks that are expected to occur in small but definable "high-end" segments of the subject population ("Guidance on Risk Characterization for Risk Managers and Risk Assessors" [Habicht, 1992]). EPA distinguishes between those scenarios that are possible but highly improbable and those that are conservative but more likely to occur within a population, with the latter being favored in risk assessment. In general, these assumptions are intended to be conservative and yield an upper bound of the risk or hazard.

#### 6.2.6.6 *Uncertainties Associated with Toxicity Assessment*

The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of uncertainty as defined in the risk assessment guide (EPA/540/1-89/002) and in Superfund HHT Risk Assessment Values (Cook, 2003). These sources may include or result from the extrapolation from high to low doses and from animals to humans. This is contingent on the species, gender, age, and strain

differences in the uptake, metabolism, organ distribution, and target site susceptibility of a toxin. The human population's variability with respect to diet, environment, activity patterns, and cultural factors are also sources of uncertainty.

Traditionally, EPA has developed toxicity criteria for carcinogens by assuming that all carcinogens are nonthreshold contaminants. However, EPA has recently published revised cancer guidelines (*Guidelines for Carcinogen Risk Assessment* [EPA/630/P-03/001F]) where they have modified their former position of assuming nonthreshold action for all carcinogens. This new guidance emphasizes establishing the specific toxicokinetic mode of action that leads to development of cancer. In the future, toxicity criteria for carcinogens in the United States will be developed assuming no threshold for contaminants that exhibit genotoxic modes of action, or where the mode of action is not known. However, currently available EPA toxicity criteria for carcinogens were all derived assuming a nonthreshold model.

In most of the world, nonthreshold toxicity criteria are developed only for those carcinogens that appear to cause cancer through a genotoxic mechanism (International Toxicity Estimates for Risk database [TERA, 2011]). Specifically, for genotoxic contaminants, the cancer dose-response model is based on high-dose to low-dose extrapolation and assumes there is no lower threshold for the initiation of toxic effects. Cancer effects observed at high doses are found in laboratory animals or are extrapolated from occupational or epidemiological studies. Cancer effects observed at low doses are commonly found in environmental exposures. These models are essentially linear at low doses, so no dose is without some risk of cancer. Although this assumes there is no dose without some risk of cancer, there may be a threshold level at low doses.

*Slope Factors for Cr(VI).* The oral reference dose of 0.003 mg/kg day published by IRIS is used to develop the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) direct contact soil cleanup level for Cr(VI). NJDEP has recently published an oral carcinogenic potency factor of 0.5 $(mg/kg\text{-}day)^{-1}$ (*Derivation of an Ingestion-Based Soil Remediation Criterion for* $Cr^{+6}$ *Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate* [NJDEP, 2009]). If the NJDEP value were used to calculate the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) direct contact soil cleanup level, the cleanup level would decrease from 240 mg/kg to 2.0 mg/kg. The use of the oral reference dose published by IRIS may result in underestimating risk.

### 6.2.6.7 Uncertainties Associated with Risk Characterization

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of noncancer adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that constituents act synergistically or antagonistically, resulting in an overestimation or underestimation of risk.

#### 6.2.6.7.1 Uncertainties in Risk Estimates Associated with Remedial Investigation and Limited Field Investigation Soil Data

In addition to the waste site closeout remediation data (CVP/RSVP), two additional sources of data were considered for use in the RI/FS and the soil risk assessment. These sources of data include: 1) vadose zone data collected for the RI to fill data gaps associated with the nature and extent of contamination or associated with understanding the fate and transport of contaminants, and 2) LFI data collected in 1993 from the 100-F OU. Note that RI and LFI data were not collected for the 100-IU-2/IU-6 OUs because data gaps were not identified for these OUs. These data were collected for purposes other than fulfilling needs of the risk assessment; as such, they were not used for quantitative evaluation of risks. However, these data were evaluated qualitatively by comparing concentrations of analytes to risk-based

screening levels to determine if the results could be useful for risk management decisions. The results of this comparison are provided in Appendix G, Attachment G-1.

Soil data identified as useful for informing risk management decisions include those collected to fill Data Gaps 2, 3, and 7. Chapter 2, Table 2-1 lists the data gaps and the work conducted per the 100-F Work Plan (DOE/RL-2008-46-ADD4). Three boreholes and three monitoring wells were drilled for the RI. In general, the comparison of soil concentrations from RI data to RBSLs are consistent with those risk results reported for closeout documentation data (CVP/RSVP), because most boreholes and test pits were collected through waste sites that were previously remediated.

In the early 1990s, an LFI was performed in the 100-FR-1 OU and the 100-FR-3 OU. Results of the qualitative risk evaluation show elevated risk results at some waste sites. However, use of the LFI data over state risks because these waste sites have been subsequently remediated under the interim action ROD.

## 6.3 Groundwater Risk Assessment

EPA guidance provided in "Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration" (Woolford and Reeder, 2009) clarifies EPA's policies for determining whether a groundwater remedial action is warranted under CERCLA. In discussing the role of the BRA, "Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration" (Woolford and Reeder, 2009) quotes the preamble to the NCP (40 CFR 300):

> *The results of the baseline risk assessment are used to determine whether remediation is necessary, to help provide justification for performing remedial action, and to assist in determining what exposure pathways need to be remediated.*

"Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration" (Woolford and Reeder, 2009) clarifies when a CERCLA remedial action is appropriate (page 5):

> *A CERCLA remedial action generally is appropriate*[8] *in various circumstances, including a regulatory standard that helps define protectiveness (e.g., a federal or state MCL or nonzero MCLG for current or potential drinking water aquifers) is exceeded; when the estimated risk calculated in a risk assessment exceeds a noncarcinogenic level for an adverse health effect or the upper end of the NCP risk range for cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use;*[9] *the noncarcinogenic hazard index is greater than one (using reasonable maximum exposure assumptions for either the current or reasonably anticipated future land use); or the site contaminants cause adverse environmental effects.*[10] *It is important to note that all conditions do not need to be present for action and the conditions may be independent of each other.*

EPA guidance provided in "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (Clay, 1991) describes how to use the BRA to make risk management decisions such as determining whether remedial action under CERCLA Section 104 or Section 106 is necessary. "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (Clay, 1991) describes the following conditions when a CERCLA action is generally warranted:

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[8] See *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013).

[9] See "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (Clay, 1991).

[10] See *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013).

- The BRA indicates that a cumulative site risk to an individual using RME assumptions for either current or future land use exceeds the $10^{-4}$ ELCR end of the risk range.
- For groundwater actions, MCLs and nonzero maximum contaminant limit goals (MCLGs) will generally be used to gauge whether remedial action is warranted.
- Chemical-specific standards that define acceptable risk levels also may be used to determine whether an exposure is associated with an unacceptable risk to HHE and whether remedial action is warranted.

Protectiveness of human health is evaluated by comparing groundwater concentrations within the groundwater OU to existing federal or state MCLs or nonzero MCLGs. Protectiveness of aquatic receptors is determined by the comparison of groundwater concentrations at the point of discharge to surface water to water quality criteria established under Section 304 or Section 303 of the *Clean Water Act of 1977* as well as Washington State water quality standards. The point of compliance for surface water cleanup levels is defined in the MTCA ("Surface Water Cleanup Standards" [WAC 173-340-730(7)(a)]) as the point or points at which hazardous substances are released to surface waters of the state. MTCA, "Surface Water Cleanup Standards" (WAC 173-340-730(7)(b)) indicates that no mixing zone shall be allowed to demonstrate compliance with surface water cleanup levels.

Groundwater concentrations are compared to "Groundwater Cleanup Standards" (WAC 173-340-720) and "Surface Water Cleanup Standards" (WAC 173-340-730) to determine whether EPCs result in an HI greater than one. The EPCs also are used to calculate ELCRs that are compared to the upper end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use.

EPA guidance provided in "Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA" (Fields, 1997) clarifies the relationship between two statutory mandates of CERCLA: protect HHE and attain or waive, if justified, based on site-specific circumstances, ARARs. It remains EPA's policy that ARARs will generally be considered protective, absent multiple contaminants or pathways of exposure. However, the guidance clarifies that, in rare situations, even absent multiple pathways or contaminants, PRGs should be set at levels more protective than required by a given ARAR, where application of the ARAR would not be protective of HHE.

The RCBRA (DOE/RL-2007-21) evaluated groundwater data collected from 1998 to 2008. During the development of the integrated work plan (DOE/RL-2008-46) approximately one year of additional groundwater data were collected and evaluated. The integrated work plan (DOE/RL-2008-46) identified the need to collect representative spatial and temporal samples from a subset of wells. These data were collected over an 8-month period between October 22, 2009 and June 30, 2010. In this RI/FS, three analyses of groundwater data are presented. Section 4.3.1 uses all available information to describe the nature and extent of contamination in groundwater. Section 4.3.2 provides summary statistics for groundwater data collected over the last 5 years and were used for COPC identification. Finally, Section 6.3 provides the groundwater risk assessment based on the representative spatial and temporal data set.

A groundwater risk assessment was performed for the 100-FR-3 Groundwater OU. The 100-FR-3 Groundwater OU risk assessment followed the strategy outlined as follows:

- Evaluate current groundwater data to identify contaminants present in groundwater in the OU. Analytical measurement data collected to resolve spatial, chemical, and temporal uncertainties described in the Integrated Work Plan (DOE/RL-2008-46) were used.

- Identify action levels for detected contaminants, using ARARs or risk-based concentrations to establish a basis for screening analytes.

- Compare the detected contaminant concentrations to action levels in order to identify COPCs within the entire 100-FR-3 Groundwater OU. These analytes are also used to provide a comprehensive evaluation of contribution to cumulative risk and total hazard.

- Conduct the risk characterization step on the set of COPCs, including a determination that action levels have been exceeded.

Results of this groundwater risk assessment indicate that concentrations of contaminants in the 100-FR-3 Groundwater OU exceed action levels, and warrant investigation in an FS to address groundwater contamination within the OU. The COPCs represent contaminants that will be evaluated in the FS to define the COCs and develop and select remedial alternatives.

Results of the nature and extent evaluation presented in Section 4.3.2 of this report indicate that concentrations of contaminants in groundwater beneath the 100-IU-2 and 100-IU-6 Source OUs exceed action levels in some areas; however, groundwater contaminants originate from the 100-FR-3 Groundwater OU as well as the 200 Areas rather than 100-IU-2 and 100-IU-6 waste sites. Groundwater beneath the 100-IU-2 and 100-IU-6 Source OUs is generally attributed to groundwater contaminants that originate from the 200 East Area that have dispersed from the 200-BP-5 Groundwater OU or 200-PO-1 Groundwater OU, respectively. It has also been influenced by groundwater contaminants that originate from the 200 West Area that have dispersed from the 200-ZP-1 Groundwater OU. Additionally, the "eastern" portion of the IU-2 and IU-6 Groundwater Area contains groundwater contaminants that originate from the 100-FR-3 groundwater OU. A groundwater risk assessment is not provided in this section for groundwater within the 100-IU-2 and 100-IU-6 Groundwater Area. This is because groundwater contaminants within the 100-IU-2 and 100-IU-6 Groundwater Area are addressed by other OUs including the 200 Area and 100-FR-3 groundwater OUs.

The groundwater risk assessment identifies multiple contaminants within the 100-FR-3 Groundwater OU that exceed chemical-specific ARARs or risk-based concentrations. MTCA "Human Health Risk Assessment Procedures" (WAC 173-340-708(5)(a) and WAC 173-340-708(6)(b)) require that cleanup levels be adjusted downward to take into account exposure to multiple hazardous substances or multiple pathways of exposure. This adjustment needs to be made only if, without this adjustment, the HI would exceed 1, or the total ELCR would exceed 1 in 100,000 ($1 \times 10^{-5}$).

Additionally, several local and regional Tribes have ancestral ties to the Hanford Reach of the Columbia River and surrounding lands. DOE has requested that each Tribe provide an exposure scenario that reflects their traditional activities. At this time, the CTUIR (*Exposure Scenario for CTUIR Traditional Subsistence Lifeways* [Harris and Harper, 2004]) and the Yakama Nation (*Yakama Nation Exposure Scenario for Hanford Site Risk Assessment* [Ridolfi, 2007]) have provided scenarios. A quantitative risk assessment is included for both Tribal use scenarios to evaluate each of the potentially complete groundwater exposure pathways. The results for the Native American Risk Assessment are provided in *Native American Risk Assessment for the 100-FR-3 Groundwater Operable Unit* (ECF-100FR3-11-0025) in Appendix G. Attachment G1 in Appendix G provides a summary of this evaluation. A quantitative evaluation of human health risk to a resident from exposure to tap water is included for comparison to the Native American Risk Assessment. This comparison is provided because the Native American scenarios and the EPA tap water scenario include the same exposure pathways and exposure routes but have different exposure assumptions. The EPA tap water scenario includes RME assumptions whereas the Native American scenarios include high-end exposure assumptions. The Native American scenarios are discussed in more detail in the uncertainty section (Section 6.3.8.5.1). The results of the comparison show

the similarities and differences that result in the use of RME and high-end assumptions. The results of the Tap Water Risk Assessment are provided in *Tap Water Risk Assessment for the 100-FR-3 Groundwater Operable Unit* (ECF-100FR3-11-0026) in Appendix G.

### 6.3.1 Findings of the River Corridor Baseline Risk Assessment

The RCBRA (DOE/RL-2007-21) provides a screening level groundwater risk assessment for the 100-FR-3/100-IU-2/100-IU-6 Groundwater OU to evaluate potential risks associated with groundwater exposure. The results of the groundwater screening-level risk assessment indicate potential risk above EPA thresholds within the 100-FR-3/100-IU-2/100-IU-6 Groundwater OU. Noncancer chemical hazard results were also above the EPA's threshold value of 1.

Uncertainties associated with the groundwater data set were identified in the RCBRA (DOE/RL-2007-21). These uncertainties relate to the ability of the groundwater data set collected from 1998 to 2008 to represent current baseline conditions and potential exposure within each groundwater OU. Analytical data used for the screening level assessment were collected to fulfill a variety of state and federal regulations, including RCRA, CERCLA, the *Atomic Energy Act of 1954*, and Section 173 of the *Washington Administrative Code*. While the monitoring data can be used for risk assessment purposes, there are uncertainties associated with its use. Specifically, target analytes, sampling frequencies, and method detection limits (or reporting limits) are different between programs because the information is used to meet different requirements.

As a result of the uncertainties identified in the RCBRA (DOE/RL-2007-21), the Integrated Work Plan (DOE/RL-2008-46) added activities that would help reduce uncertainties, verify conclusions of the HHRA presented in the RCBRA (DOE/RL-2007-21), and ensure that no contaminants were inadvertently overlooked based on the use of the existing data set. Section 3.6.5.1 of the Integrated Work Plan (DOE/RL-2008-46) identifies the following activities to reduce uncertainties:

- Identify existing and/or install new monitoring wells that are spatially representative of the groundwater. This set of wells will represent locations where a receptor potentially could contact groundwater.
- Conduct multiple rounds of sampling to obtain temporal representation of the unconfined aquifer from influence of river stage. Additional rounds of sampling at spatially representative monitoring wells will represent current groundwater conditions and capture the influence of river fluctuations on COPC concentrations.
- Analyze all spatially representative monitoring wells for a focused list of groundwater COPCs identified for each round of sampling. Analyzing each of the monitoring wells for COPCs will provide a data set that is representative of potential releases to the groundwater.
- Evaluate sample results from characterization activities to support final remedial action decisions for groundwater.

The RCBRA (DOE/RL-2007-21) evaluated exposure to groundwater for three residential scenarios (Subsistence Farmer, CTUIR Resident, and Yakama Resident scenarios) and the residential component of the Resident Monument Worker Exposure scenario. Direct exposure to contaminants in groundwater was evaluated for household uses of groundwater in each of these scenarios, such as drinking and cooking (ingestion) and bathing (dermal absorption). If VOCs were measured in groundwater, indirect exposure by inhalation of VOCs in air may occur while bathing or when using groundwater in the home for other purposes. The inhalation pathway for VOCs associated with household use of groundwater is evaluated for VOCs that are identified as COPCs in groundwater. Additionally, ingestion, inhalation, and dermal

exposures to COPCs in groundwater used in a sweat lodge were evaluated in the CTUIR Resident and Yakama Resident scenarios.

Nitrate, strontium-90, trichloroethene, chromium, tritium, and uranium are identified as key contaminants in *Hanford Site Groundwater Monitoring for Fiscal Year 2006* (PNNL-16346). The results of the screening level groundwater risk assessment provided in the RCBRA (DOE/RL-2007-21) identified strontium-90 and tritium in the 100-FR-3/100-IU-2/100-IU-6 Groundwater OU as the primary contributors to risk through ingestion of groundwater. Uranium, Cr(VI), and nitrate are identified as primary contributors to noncancer hazards through ingestion of groundwater.

### 6.3.2 Identification of Contaminants of Potential Concern

The first step of this groundwater risk assessment is data evaluation to select the COPCs for protection of HHE. A preliminary COPC evaluation was conducted in 2008 to support the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4) and the 100-F/IU SAP (DOE/RL-2009-43). The work plan effort evaluated groundwater analytical data collected over a 16-year period (1992 to 2008) and resulted in the identification of 37 COPCs, which are listed in Table 6-33.

Table 6-33. List of Historical Contaminants of Potential Concern in the 100-FR-3 Groundwater OU

| **100-FR-3 Groundwater OU** | | | |
|---|---|---|---|
| **Metals** | | | |
| Antimony | Arsenic | Beryllium | Cadmium |
| Chromium | Cobalt | Copper | Cr(VI) |
| Lead | Manganese | Mercury | Nickel |
| Selenium | Thallium | Zinc | |
| **Volatile Organic Compounds** | | | |
| 1,1-Dichloroethene | Carbon tetrachloride | Chloroform | Styrene |
| Tetrachloroethene | Trichloroethene | Vinyl chloride | |
| **Radiological** | | | |
| Americium-241 | Carbon-14 | Cesium-137 | Cobalt-60 |
| Europium-154 | Iodine-129 | Plutonium-238 | Plutonium-239/240 |
| Strontium-90 | Technetium-99 | Thorium-230 | Tritium |
| **Anions** | | | |
| Fluoride | Nitrate (as N) | Sulfate | |

* DOE/RL-2009-43, *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*, Table 1-3 and Table 1-4.

The COPCs identified during the work plan phase were validated by using groundwater samples analyzed using the analytical methods documented in the 100-F/IU SAP (DOE/RL-2009-43), Tables 2-7 and 2-8, respectively. The groundwater data set used for COPC identification consists of sampling and analysis data collected from 19 monitoring wells within the 100-FR-3 Groundwater OU. The monitoring well

network represents locations where human or ecological receptors could potentially encounter groundwater within the OU. The primary exposure pathway for humans is through groundwater obtained from a residential or community water well.

Identification of groundwater COPCs for the 100-FR-3 Groundwater OU is a two-step process. The first step of the process establishes a set of analytes that will be carried forward to identify COPCs for the entire Groundwater OU. These COPCs are then evaluated in the risk characterization step of the groundwater risk assessment where a set of COPCs is identified for evaluation in the FS. Figure 6-5 presents a summary of the COPC identification process. The left side of Figure 6-5 illustrates the two steps used to identify COPCs. The right side of Figure 6-5 illustrates how the results of the tap water scenario analysis are used to confirm that COPCs are the major risk and hazard drivers.

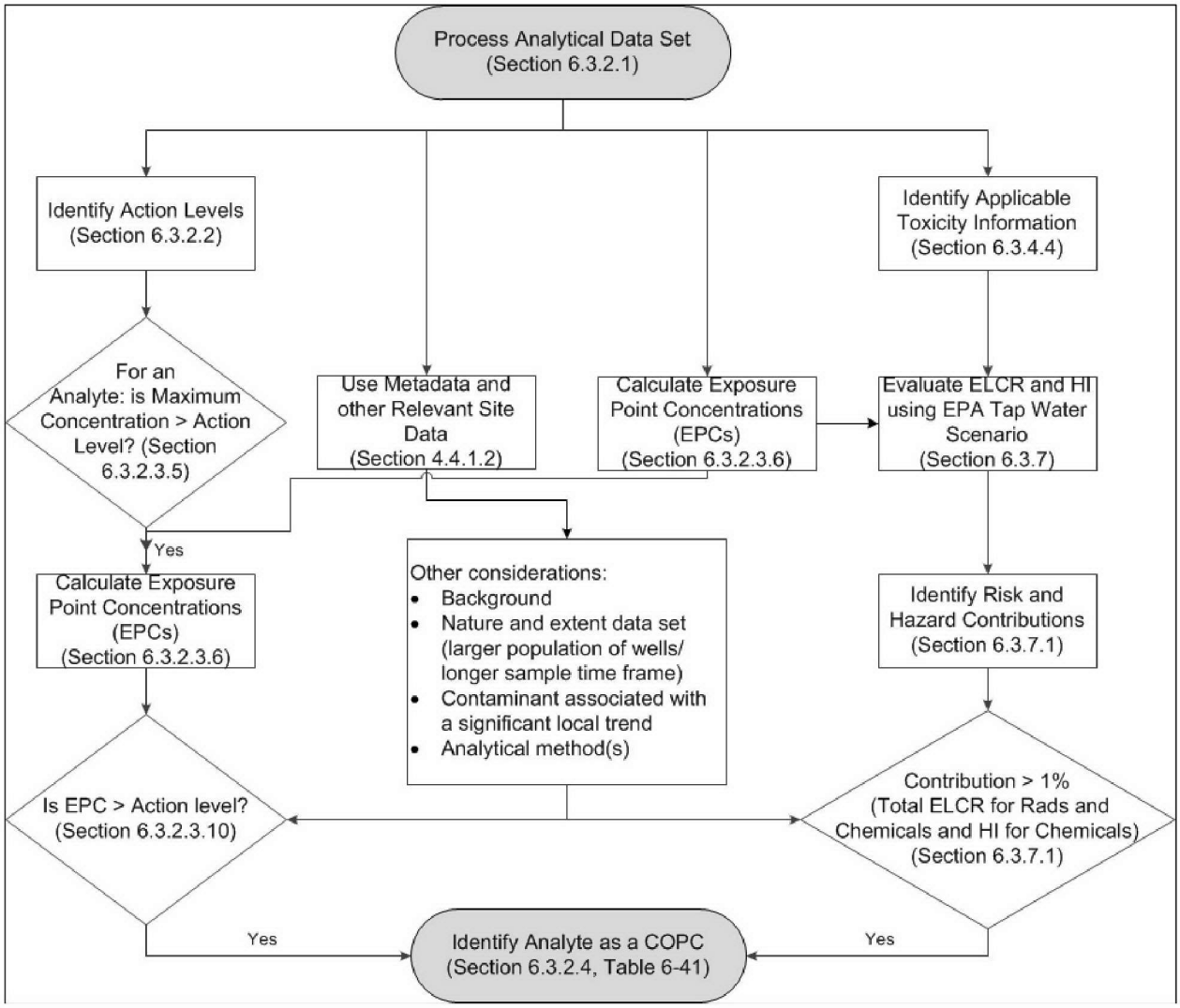


Figure 6-5. Overview of COPC Identification Process

The process used to identify data for COPC selection and the selection of action levels for this groundwater risk assessment are described in Section 6.3.2.1 and 6.3.2.2. The process used to identify the COPCs and the methodology used to calculate EPCs is described in Section 6.3.2.3. The exposure assessment and toxicity assessment are presented in Sections 6.3.3 and 6.3.4, respectively. Finally, the risk characterization step is described in Section 6.3.5, and the EPA tap water scenario is described in

Section 6.3.7. The primary objective of this groundwater risk assessment is to provide information necessary to identify what remedial actions will be necessary in the remedy selected for the 100-FR-3 Groundwater OU.

#### 6.3.2.1 Data Used to Identify Contaminants of Potential Concern

The sampling and analysis data used to identify COPCs for the 100-FR-3 Groundwater OU were collected over a 7-month period between May 5, 2010, and November 29, 2010. Three sampling events were used to capture the effects of temporal fluctuations of river stage on groundwater conditions. Samples collected in May 2010 represent the aquifer when the river stage is at its highest elevation. Samples collected from late-September to late-November 2010 represent the aquifer when the river is at its lowest elevation. Samples collected in July 2010 represent the aquifer when the river is transitioning from high to low river stage.

All monitoring wells used in this monitoring network were screened in the unconfined aquifer. All the wells in the network were existing monitoring or compliance wells. Table 6-34 lists the wells used in the groundwater risk assessment for the 100-FR-3 Groundwater OU and Figure 6-6 shows their locations.

Table 6-34. Monitoring Well s Used in the Groundwater Risk Assessment from the 100-FR-3 Groundwater OU

| 100-FR-3 Groundwater OU | | |
|---|---|---|
| **Well Name** | | |
| 199-F1-2 | 199-F5-1 | 199-F5-4 |
| 199-F5-42 | 199-F5-43A | 199-F5-44 |
| 199-F5-45 | 199-F5-46 | 199-F5-48 |
| 199-F5-6 | 199-F6-1 | 199-F7-1 |
| 199-F7-2 | 199-F7-3 | 199-F8-2 |
| 199-F8-3 | 199-F8-4 | 199-F8-7 |
| 699-77-36 | | |

The analytical data set for the 100-FR-3 Groundwater OU risk assessment are extracted from the HEIS database. After extraction, the analytical data are processed to obtain a single set of results per sampling location and time of collection. A total of 10,870 records were obtained from HEIS, and 119 analytes were included in the data set before analytical data processing. After analytical data processing (as described in the next section), the final data set used for the COPC identification process contained a total of 6,782 records, with 119 analytes included in the data set.

##### 6.3.2.1.1 Analytical Data Processing

The data set obtained from HEIS included the following types of information:

- Analytical results from both unfiltered and filtered samples
- Data qualification and data validation flags, including rejected results
- Results for a given analyte reported by more than one analytical method
- Parent, field duplicate, and field split sample results

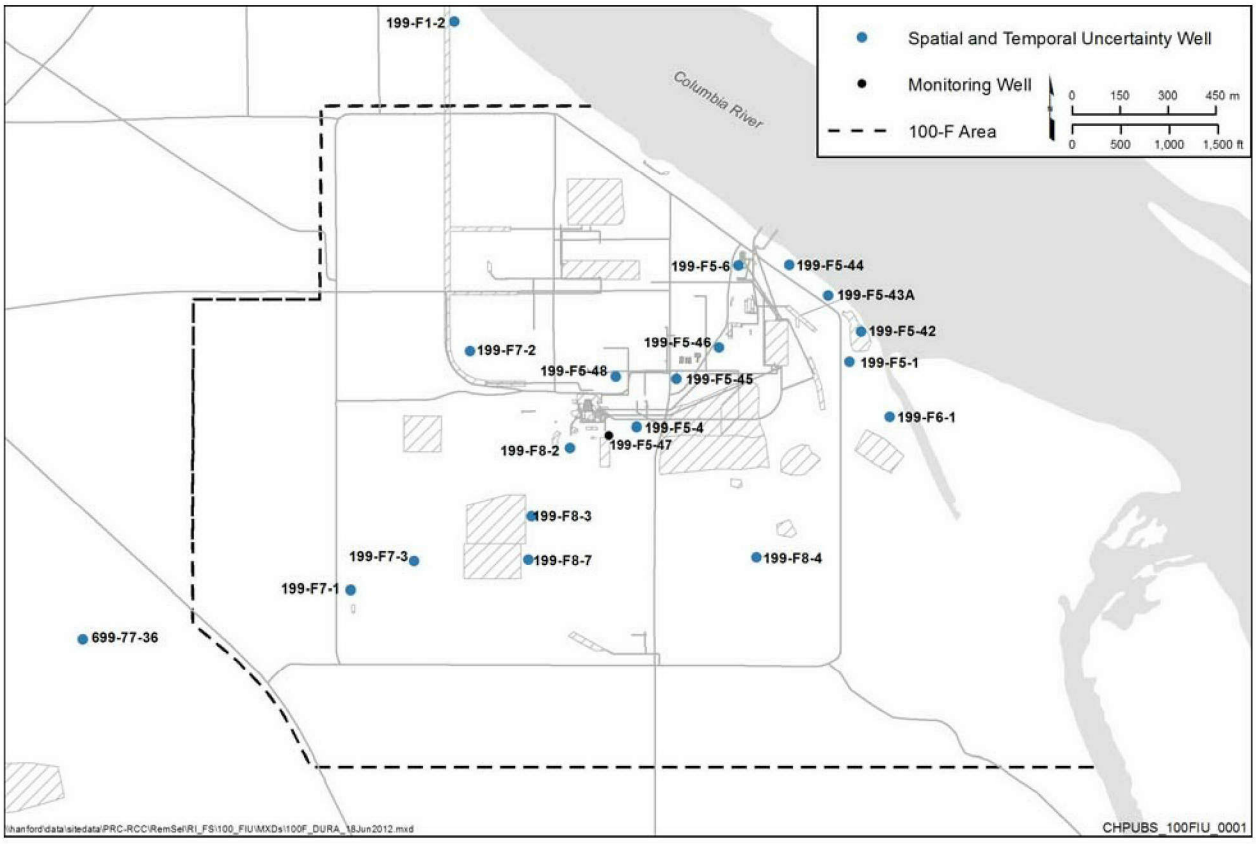


Figure 6-6. Monitoring Well Locations within the 100-FR-3 Groundwater OU

The analytical data were processed using the steps described below and thus identify one set of results per sampling location and date of sample collection. The data processing steps and the numbers of records associated with each step are presented in Figure 6-7. Descriptions of the data processing steps follow.

*Sample Results.* Only analytical results from unfiltered samples are used in identifying COPCs; results from filtered samples that may have been collected in support of other monitoring or compliance programs are excluded. Unfiltered sample results represent total concentrations of the analytes, while filtered sample results represent only dissolved concentrations. Use of filtered sampling results might lead to underestimation of chemical and radiological concentrations (e.g., in water from an unfiltered tap).

The risk assessment guide (EPA/540/1-89/002) addresses this issue in providing guidance on estimating exposure concentrations in groundwater:

> *While filtration of ground-water samples provides useful information for understanding chemical transport within an aquifer, the use of filtered samples for estimating exposure is very controversial, because these data may underestimate chemical concentrations in water from an unfiltered tap. Therefore, data from unfiltered samples should be used to estimate exposure concentrations.*

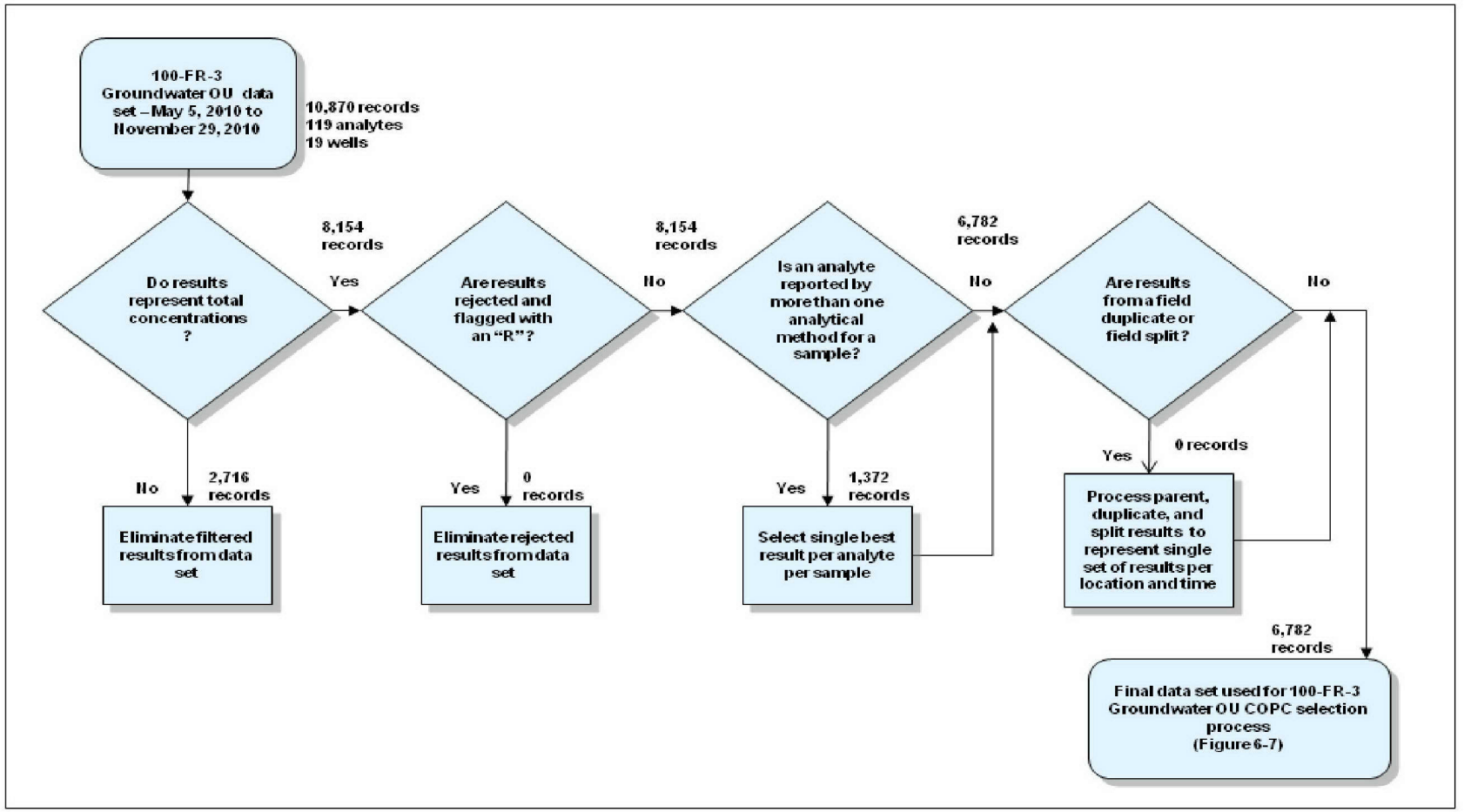


Figure 6-7. Data Processing and Reduction Steps for the 100-FR-3 Groundwater OU Data Set

*Laboratory and Data Validation Flags.* Analytical data are received from the laboratory with data qualification flags. Validation qualifiers are assigned during the data validation process. The following rules determine how flagged and/or qualified sample results are used in identifying COPCs.

- Sample results flagged with a "U" data qualifier or combinations of qualifiers that include a "U," such as a "UJ," are considered nondetected results.
- Sample results without a "U" data qualifier are considered detected concentrations, including results with no data qualifier or with a "J" data qualifier.
- Sample results that are rejected and flagged with an "R" validation qualifier are not used in identifying COPCs.

where:

| | | |
|---|---|---|
| *U* | = | Analyzed for but not detected above limiting criteria. |
| *J* | = | Estimated value. |
| *R* | = | Do not use. Further review indicates the result is not valid. |

*Analytes Reported by Numerous Analytical Methods.* Often analytes are reported by more than one analytical method. Therefore, multiple results for an analyte at the same location and sample date are possible. Because multiple sets of analytical results cannot be used to quantify risk (i.e., this would result in multiple counting of a chemical), the set of data that best represents the actual concentration will be retained. The results are processed to select the method that provides the most reliable results. Considerations for determining data to be retained include method-associated sample size, detection frequency, and detection limits. The most conservative (i.e., health protective) use of these types of data will be the goal. Larger sample size, higher detection frequencies, and lower detection limits are given higher priority for method selection.

For example, lead may be analyzed using EPA Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]), with an EQL of 2 µg/L, or EPA Method 6010 in SW 846 [SW-846], with an EQL of 50 µg/L. For a sample with lead concentrations reported using both methods, the result reported by EPA Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]) is selected over EPA Method 6010 (SW 846 [SW-846]) because of the more sensitive detection limit.

*Field Duplicate and Field Split Results.* Field QC samples (field duplicates and field splits) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and QC samples are collected from the same location (i.e., monitoring well) on the same date, resulting in more than one sample per location and date. The following criteria are used to reduce multiple sample results for an individual location and date to a single result:

- If two or more detections exist, the maximum concentration is used.
- If at least one detection and one or more nondetected results exist, the detected concentration is used.
- If only (two or more) nondetected results exist, the lowest detection limit is used.

#### 6.3.2.2 Identify Action Levels

For the purpose of risk assessment and identification of COPCs, action levels are screening levels derived from chemical-specific ARARs and/or risk-based concentrations using default exposure assumptions. All sources of action levels for each of the 119 analytes reported in the HEIS database for the 100-FR-3 OU are identified in Table 6-35.

Although the term "action level" is used for screening purposes, the term "action level" is not used to determine remediation levels nor does it imply that a groundwater action should be taken. Cleanup levels for groundwater contaminants are developed in the ROD.

The sources of action levels from federal regulations are:

- "National Primary Drinking Water Regulations" (40 CFR 141), MCLs, secondary MCLs, and nonzero MCLGs established under the *Safe Drinking Water Act of 1974* (SDWA)
- *National Recommended Water Quality Criteria* (EPA, 2009a), Ambient Water Quality Criteria (AWQC) established under Section 304 of the *Clean Water Act of 1977*
- "Water Quality Standards" (40 CFR 131) for states not complying with Section 303 of the *Clean Water Act of 1977*

The sources of action levels from Washington State regulations are:

- "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)
- "Groundwater Cleanup Standards" (WAC 173-340-720)
- "Surface Water Cleanup Standards" (WAC 173-340-730)
- "Group A Public Water Supplies" "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)" (WAC 246-290-310)

While surface water and AWQC standards are considered for the identification of action levels, it must be noted that these standards only apply for groundwater where it enters the Columbia River. For the upland parts of groundwater, only drinking water standards are applicable.

Derivation of State of Washington groundwater cleanup levels is provided in a separate calculation brief (*Environmental Calculation of WAC 173-340-720 Method B Groundwater Cleanup Levels for Potable Groundwater in the 100 Areas and 300 Area* [ECF-100NPL-10-0462]). Derivation of State of Washington surface water cleanup levels is provided in a separate calculation brief (*Environmental Calculation of WAC 173-340-730 Method B Surface Water Cleanup Levels for Potable Groundwater in the 100 Areas and 300 Area* [ECF-100NPL-10-0463]).

#### 6.3.2.3 COPC Identification Process

Section 6.3.2.1 defined the analytical data set and described the analytical data processing steps used in this section for identifying groundwater COPCs. Section 6.3.2.2 identified the action levels used in this section for identifying groundwater COPCs. The COPC identification process described in this section is used to identify a subset of analytes to be carried forward into the risk characterization step provided in Section 6.3.5. This step of the process uses sampling and analysis data collected from the 19 monitoring wells within the 100-FR-3 Groundwater OU. The purpose of grouping all sampling and analysis data together is to identify those analytes with detected concentrations above the lowest available action level before an EPC is calculated in Appendix G. The COPC identification steps, number of records, and number of analytes associated with each step are depicted in Figure 6-8 and 6-9 for the 100-FR-3 Groundwater OU and are listed as follows:

- Apply exclusion criteria.
- Identify nondetected analytes.

Table 6-35. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-FR-3 Groundwater OU

| | | | | Groundwater | | | | | Surface Water | | | | | | | | Action Level Value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 40 CFR 141 | | WAC 246-290-310 | WAC 173-340-720 | | Clean Water Act National Recommended Water Quality Criteria | | | WAC 173-201A | 40 CFR 131 | | | WAC 173-340-730 | | |
| CAS# | Analyte Name | Alternate Analyte Name | Units | Federal MCL | Federal MCLG | State MCL | Groundwater Method A Cleanup Levels | Groundwater Method B Unrestricted Land Use | Acute Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Freshwater CCC | Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Surface Water Method B Unrestricted Land Use | Action Level | Action Level Basis |
| 630-20-6 | 1,1,1,2-Tetrachloroethane | -- | µg/L | -- | -- | -- | -- | 1.7 | -- | -- | -- | -- | -- | -- | -- | 6.2 | 1.7 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 71-55-6 | 1,1,1-Trichloroethane | -- | µg/L | 200 | 200 | -- | -- | 16,000 | -- | -- | -- | -- | -- | -- | -- | 925,926 | 200 | 40 CFR 141—Federal MCL |
| 79-34-5 | 1,1,2,2-Tetrachloroethane | -- | µg/L | -- | -- | -- | -- | 0.22 | -- | -- | 0.17 | -- | -- | -- | 0.17 | 6.5 | 0.17 | Clean Water Act--Human Health Water + Organism |
| 79-00-5 | 1,1,2-Trichloroethane | -- | µg/L | 5.0 | 3.0 | -- | -- | 0.77 | -- | -- | 0.59 | -- | -- | -- | 0.60 | 25 | 0.59 | Clean Water Act—Human Health Water + Organism |
| 75-34-3 | 1,1-Dichloroethane | -- | µg/L | -- | -- | -- | -- | 1,600 | -- | -- | -- | -- | -- | -- | -- | 73,549 | 1,600 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 75-35-4 | 1,1-Dichloroethene | 1,1-Dichloroethylene | µg/L | 7.0 | 7.0 | -- | -- | 400 | -- | -- | 330 | -- | -- | -- | 0.057 | 23,148 | 0.057 | 40 CFR 131—Human Health Water + Organism |
| 96-18-4 | 1,2,3-Trichloropropane | -- | µg/L | -- | -- | -- | -- | 0.0015 | -- | -- | -- | -- | -- | -- | -- | 0.017 | 0.0015 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 96-12-8 | 1,2-Dibromo-3-chloropropane | -- | µg/L | 0.20 | -- | -- | -- | 0.055 | -- | -- | -- | -- | -- | -- | -- | 0.70 | 0.055 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 106-93-4 | 1,2-Dibromoethane | -- | µg/L | 0.050 | -- | -- | -- | 0.022 | -- | -- | -- | -- | -- | -- | -- | 0.22 | 0.022 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 107-06-2 | 1,2-Dichloroethane | -- | µg/L | 5.0 | -- | -- | -- | 0.48 | -- | -- | 0.38 | -- | -- | -- | 0.38 | 59 | 0.38 | Clean Water Act—Human Health Water + Organism |
| 540-59-0 | 1,2-Dichloroethene (Total) | 1,2-Dichloroethylene Mixed Isomers | µg/L | -- | -- | -- | -- | 72 | -- | -- | -- | -- | -- | -- | -- | 2,102 | 72 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 78-87-5 | 1,2-Dichloropropane | -- | µg/L | 5.0 | -- | -- | -- | 1.2 | -- | -- | 0.50 | -- | -- | -- | -- | 44 | 0.50 | Clean Water Act—Human Health Water + Organism |
| 106-46-7 | 1,4-Dichlorobenzene | -- | µg/L | 75 | 75 | -- | -- | 8.1 | -- | -- | 63 | -- | -- | -- | 400 | 22 | 8.1 | WAC 173-340-720(4)(b)(iii)(A) and (B) |

Table 6-35. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-FR-3 Groundwater OU

| | | | | Groundwater | | | | | Surface Water | | | | | | | | Action Level Value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 40 CFR 141 | | WAC 246-290-310 | WAC 173-340-720 | | Clean Water Act National Recommended Water Quality Criteria | | | WAC 173-201A | 40 CFR 131 | | | WAC 173-340-730 | | |
| CAS# | Analyte Name | Alternate Analyte Name | Units | Federal MCL | Federal MCLG | State MCL | Groundwater Method A Cleanup Levels | Groundwater Method B Unrestricted Land Use | Acute Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Freshwater CCC | Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Surface Water Method B Unrestricted Land Use | Action Level | Action Level Basis |
| 123-91-1 | 1,4-Dioxane | -- | µg/L | -- | -- | -- | -- | 4.0 | -- | -- | -- | -- | -- | -- | -- | -- | 4.0 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 71-36-3 | 1-Butanol | N-Butanol | µg/L | -- | -- | -- | -- | 800 | -- | -- | -- | -- | -- | -- | -- | 82,044 | 800 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 78-93-3 | 2-Butanone | Methyl Ethyl Ketone | µg/L | -- | -- | -- | -- | 4,800 | -- | -- | -- | -- | -- | -- | -- | 492,264 | 4,800 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 591-78-6 | 2-Hexanone | -- | µg/L | -- | -- | -- | -- | 80 | -- | -- | -- | -- | -- | -- | -- | 3,429 | 80 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 108-10-1 | 4-Methyl-2-pentanone | 4-Methyl-2-Penatone | µg/L | -- | -- | -- | -- | 640 | -- | -- | -- | -- | -- | -- | -- | 61,002 | 640 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 67-64-1 | Acetone | -- | µg/L | -- | -- | -- | -- | 7,200 | -- | -- | -- | -- | -- | -- | -- | 738,397 | 7,200 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 75-05-8 | Acetonitrile | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 107-02-8 | Acrolein | -- | µg/L | -- | -- | -- | -- | 4.0 | -- | 3.0 | 6.0 | -- | -- | -- | 320 | -- | 3.0 | Clean Water Act—Freshwater CCC |
| 107-05-1 | Allyl chloride | -- | µg/L | -- | -- | -- | -- | 2.1 | -- | -- | -- | -- | -- | -- | -- | 62 | 2.1 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 7429-90-5 | Aluminum | -- | µg/L | 50 | -- | -- | -- | 16,000 | 750 | 87 | -- | -- | -- | -- | -- | 5,185 | 87 | Clean Water Act—Freshwater CCC |
| 14596-10-2 | Americium-241 | -- | pCi/L | 15 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 15 | 40 CFR 141 - Federal MCL |
| 7440-36-0 | Antimony | Antimony (metallic) | µg/L | 6.0 | 6.0 | 6.0 | -- | 6.4 | -- | -- | 5.6 | -- | -- | -- | 14 | 1,037 | 5.6 | Clean Water Act—Human Health Water + Organism |
| 7440-38-2 | Arsenic | Arsenic, Inorganic | µg/L | 10 | -- | 10 | -- | 0.058 | 340 | 150 | 0.018 | 190 | 360 | 190 | 0.018 | 0.098 | 0.018 | Clean Water Act—Human Health Water + Organism |
| 7440-39-3 | Barium | -- | µg/L | 2,000 | 2,000 | 2,000 | -- | 3,200 | -- | -- | 1,000 | -- | -- | -- | -- | 129,630 | 1,000 | Clean Water Act—Human Health Water + Organism |

Table 6-35. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-FR-3 Groundwater OU

| | | | | Groundwater | | | | | Surface Water | | | | | | | | Action Level Value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 40 CFR 141 | | WAC 246-290-310 | WAC 173-340-720 | | Clean Water Act National Recommended Water Quality Criteria | | | WAC 173-201A | 40 CFR 131 | | | WAC 173-340-730 | | |
| CAS# | Analyte Name | Alternate Analyte Name | Units | Federal MCL | Federal MCLG | State MCL | Groundwater Method A Cleanup Levels | Groundwater Method B Unrestricted Land Use | Acute Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Freshwater CCC | Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Surface Water Method B Unrestricted Land Use | Action Level | Action Level Basis |
| 71-43-2 | Benzene | -- | µg/L | 5.0 | -- | -- | -- | 0.80 | -- | -- | 2.2 | -- | -- | -- | 1.2 | 23 | 0.80 | WAC 173-340-720(4)(b)(iii)(A(B) |
| 7440-41-7 | Beryllium | Beryllium and Compounds | µg/L | 4.0 | 4.0 | 4.0 | -- | 32 | -- | -- | -- | -- | -- | -- | -- | 273 | 4.0 | 40 CFR 141—Federal MCL |
| 7440-69-9 | Bismuth | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7440-42-8 | Boron | Boron And Borates Only | µg/L | -- | -- | -- | -- | 3,200 | -- | -- | -- | -- | -- | -- | -- | -- | 3,200 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 24959-67-9 | Bromide | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 75-27-4 | Bromodichloromethane | -- | µg/L | -- | -- | -- | -- | 0.71 | -- | -- | 0.55 | -- | -- | -- | 0.27 | 28 | 0.27 | 40 CFR 131—Human Health Water + Organism |
| 75-25-2 | Bromoform | -- | µg/L | -- | 80 | -- | -- | 5.5 | -- | -- | 4.3 | -- | -- | -- | 4.3 | 219 | 4.3 | Clean Water Act—Human Health Water + Organism |
| 74-83-9 | Bromomethane | -- | µg/L | -- | -- | -- | -- | 11 | -- | -- | 47 | -- | -- | -- | 48 | 968 | 11 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 7440-43-9 | Cadmium | Cadmium (Water) | µg/L | 5.0 | 5.0 | 5.0 | -- | 8.0 | 2.0 | 0.25 | -- | 0.91 | 3.9 | 1.0 | -- | 20 | 0.25 | Clean Water Act—Freshwater CCC |
| 7440-70-2 | Calcium | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 75-15-0 | Carbon disulfide | -- | µg/L | -- | -- | -- | -- | 800 | -- | -- | -- | -- | -- | -- | -- | 13,295 | 800 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 56-23-5 | Carbon tetrachloride | -- | µg/L | 5.0 | -- | -- | -- | 0.34 | -- | -- | 0.23 | -- | -- | -- | 0.25 | 2.7 | 0.23 | Clean Water Act—Human Health Water + Organism |
| 14762-75-5 | Carbon-14 | -- | pCi/L | 2,000 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2,000 | 40 CFR 141 - Federal MCL |
| 10045-97-3 | Cesium-137 | -- | pCi/L | 200 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 200 | 40 CFR 141 - Federal MCL |
| 16887-00-6 | Chloride | -- | µg/L | 250,000 | -- | 250,000 | -- | -- | 860,000 | 230,000 | -- | 230,000 | -- | -- | -- | -- | 230,000 | Clean Water Act—Freshwater CCC |
| 108-90-7 | Chlorobenzene | -- | µg/L | 100 | 100 | -- | -- | 160 | -- | -- | 130 | -- | -- | -- | 680 | 5,034 | 100 | 40 CFR 141—Federal MCL |
| 75-00-3 | Chloroethane | Ethylchloride | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

Table 6-35. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-FR-3 Groundwater OU

| | | | | Groundwater | | | | | Surface Water | | | | | | | | Action Level Value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 40 CFR 141 | | WAC 246-290-310 | WAC 173-340-720 | | Clean Water Act National Recommended Water Quality Criteria | | | WAC 173-201A | 40 CFR 131 | | | WAC 173-340-730 | | |
| CAS# | Analyte Name | Alternate Analyte Name | Units | Federal MCL | Federal MCLG | State MCL | Groundwater Method A Cleanup Levels | Groundwater Method B Unrestricted Land Use | Acute Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Freshwater CCC | Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Surface Water Method B Unrestricted Land Use | Action Level | Action Level Basis |
| 67-66-3 | Chloroform | -- | µg/L | 80 | -- | 80 | -- | 1.4 | -- | -- | 5.7 | -- | -- | -- | 5.7 | 56 | 1.4 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 74-87-3 | Chloromethane | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 126-99-8 | Chloroprene | 2-Chloro-1,3-butadiene | µg/L | -- | -- | -- | -- | 160 | -- | -- | -- | -- | -- | -- | -- | 2,412 | 160 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 7440-47-3 | Chromium | -- | µg/L | 100 | 100 | 100 | -- | 24,000 | 570 | 65 | -- | 156 | 550 | 180 | -- | 19,444 | 65 | Clean Water Act—Freshwater CCC |
| 156-59-2 | cis-1,2-Dichloroethylene | -- | µg/L | 70 | 70 | -- | -- | 80 | -- | -- | -- | -- | -- | -- | -- | 2,336 | 70 | 40 CFR 141—Federal MCL |
| 10061-01-5 | cis-1,3-Dichloropropene | -- | µg/L | -- | -- | -- | -- | 0.44 | -- | -- | 0.34 | -- | -- | -- | -- | 34 | 0.34 | Clean Water Act—Human Health Water + Organism |
| 7440-48-4 | Cobalt | -- | µg/L | -- | -- | -- | -- | 4.8 | -- | -- | -- | -- | -- | -- | -- | 2.6 | 2.6 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 10198-40-0 | Cobalt-60 | -- | pCi/L | 100 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 100 | 40 CFR 141 - Federal MCL |
| 7440-50-8 | Copper | -- | µg/L | 1,300 | 1,300 | -- | -- | 640 | 13 | 9.0 | 1,300 | -- | 17 | 11 | -- | 2,881 | 9.0 | Clean Water Act—Freshwater CCC |
| 124-48-1 | Dibromochloromethane | -- | µg/L | 60 | 60 | -- | -- | 0.52 | -- | -- | 0.40 | -- | -- | -- | 0.41 | 21 | 0.40 | Clean Water Act—Human Health Water + Organism |
| 74-95-3 | Dibromomethane | Methylene Bromide | µg/L | -- | -- | -- | -- | 80 | -- | -- | -- | -- | -- | -- | -- | 4,216 | 80 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 75-71-8 | Dichlorodifluoromethane | -- | µg/L | -- | -- | -- | -- | 1,600 | -- | -- | -- | -- | -- | -- | -- | 84,312 | 1,600 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 107-12-0 | Ethyl cyanide | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 97-63-2 | Ethyl methacrylate | -- | µg/L | -- | -- | -- | -- | 720 | -- | -- | -- | -- | -- | -- | -- | 26,365 | 720 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 100-41-4 | Ethylbenzene | -- | µg/L | 700 | 700 | -- | -- | 4.0 | -- | -- | 530 | -- | -- | -- | 3,100 | 16 | 4.0 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 14683-23-9 | Europium-152 | -- | pCi/L | 200 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 200 | 40 CFR 141 - Federal MCL |

Table 6-35. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-FR-3 Groundwater OU

| | | | | Groundwater | | | | | Surface Water | | | | | | | | Action Level Value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 40 CFR 141 | | WAC 246-290-310 | WAC 173-340-720 | | Clean Water Act National Recommended Water Quality Criteria | | | WAC 173-201A | 40 CFR 131 | | | WAC 173-340-730 | | |
| CAS# | Analyte Name | Alternate Analyte Name | Units | Federal MCL | Federal MCLG | State MCL | Groundwater Method A Cleanup Levels | Groundwater Method B Unrestricted Land Use | Acute Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Freshwater CCC | Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Surface Water Method B Unrestricted Land Use | Action Level | Action Level Basis |
| 15585-10-1 | Europium-154 | -- | pCi/L | 60 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 60 | 40 CFR 141 - Federal MCL |
| 14391-16-3 | Europium-155 | -- | pCi/L | 600 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 600 | 40 CFR 141 - Federal MCL |
| 16984-48-8 | Fluoride | -- | µg/L | 4,000 | 4,000 | 4,000 | -- | 960 | -- | -- | -- | -- | -- | -- | -- | -- | 960 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 12587-46-1 | Gross alpha | -- | pCi/L | 15 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 15 | 40 CFR 141 - Federal MCL |
| 12587-47-2 | Gross beta | -- | mrem/yr | 4.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4.0 | 40 CFR 141 - Federal MCL |
| 18540-29-9 | Cr(VI) | Chromium (VI) | µg/L | -- | -- | -- | -- | 48 | 16 | 11 | -- | 10 | 15 | 10 | -- | 486 | 10 | 40 CFR 131—Freshwater CCC |
| 15046-84-1 | Iodine-129 | -- | pCi/L | 1.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.0 | 40 CFR 141 - Federal MCL |
| 74-88-4 | Iodomethane | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7439-89-6 | Iron | -- | µg/L | 300 | -- | 300 | -- | 11,200 | -- | 1,000 | 300 | -- | -- | -- | -- | 9,074 | 1,000 | Clean Water Act—Freshwater CCC |
| 78-83-1 | Isobutyl alcohol | -- | µg/L | -- | -- | -- | -- | 2,400 | -- | -- | -- | -- | -- | -- | -- | 246,132 | 2,400 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 7439-92-1 | Lead | Lead and Compounds | µg/L | 15 | -- | -- | 15 | -- | 65 | 2.5 | -- | 2.1 | 65 | 2.5 | -- | -- | 2.1 | WAC 173-201A |
| 7439-93-2 | Lithium | -- | µg/L | -- | -- | -- | -- | 32 | -- | -- | -- | -- | -- | -- | -- | -- | 32 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 7439-95-4 | Magnesium | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7439-96-5 | Manganese | Manganese (Water) | µg/L | 50 | -- | 50 | -- | 2,240 | -- | -- | 50 | -- | -- | -- | -- | 907 | 907 | WAC 173-340-730(3)(b)(iii)(A)(B) |
| 7487-94-7 | Mercury | Mercuric chloride | µg/L | 2.0 | 2.0 | 2.0 | -- | 4.8 | 1.4 | 0.77 | -- | 0.012 | 2.1 | 0.012 | 0.14 | 0.78 | 0.012 | 40 CFR 131—Freshwater CCC |
| 126-98-7 | Methacrylonitrile | -- | µg/L | -- | -- | -- | -- | 0.80 | -- | -- | -- | -- | -- | -- | -- | 82 | 0.80 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 80-62-6 | Methyl methacrylate | -- | µg/L | -- | -- | -- | -- | 11,200 | -- | -- | -- | -- | -- | -- | -- | 960,219 | 11,200 | WAC 173-340-720(4)(b)(iii)(A)(B) |

Table 6-35. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-FR-3 Groundwater OU

| | | | | Groundwater | | | | | Surface Water | | | | | | | | Action Level Value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 40 CFR 141 | | WAC 246-290-310 | WAC 173-340-720 | | Clean Water Act National Recommended Water Quality Criteria | | | WAC 173-201A | 40 CFR 131 | | | WAC 173-340-730 | | |
| CAS# | Analyte Name | Alternate Analyte Name | Units | Federal MCL | Federal MCLG | State MCL | Groundwater Method A Cleanup Levels | Groundwater Method B Unrestricted Land Use | Acute Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Freshwater CCC | Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Surface Water Method B Unrestricted Land Use | Action Level | Action Level Basis |
| 75-09-2 | Methylene chloride | -- | µg/L | 5.0 | -- | -- | -- | 5.8 | -- | -- | 4.6 | -- | -- | -- | 4.7 | 960 | 4.6 | Clean Water Act—Human Health Water + Organism |
| 7439-98-7 | Molybdenum | -- | µg/L | -- | -- | -- | -- | 80 | -- | -- | -- | -- | -- | -- | -- | 1,296 | 80 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 7440-02-0 | Nickel | Nickel Soluble Salts | µg/L | -- | 100 | 100 | -- | 320 | 470 | 52 | 610 | 137 | 1,400 | 160 | 610 | 1,103 | 52 | Clean Water Act—Freshwater CCC |
| 14681-63-1 | Niobium-94 | -- | pCi/L | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 40 CFR 141 - Federal MCL |
| 14797-55-8 | Nitrate | -- | µg/L | 45,000 | 45,000 | 45,000 | -- | 113,600 | -- | -- | 45,000 | -- | -- | -- | -- | -- | 45,000 | 40 CFR 141—Federal MCL |
| 14797-65-0 | Nitrite | -- | µg/L | 3,300 | 3,300 | 3,300 | -- | 4,800 | -- | -- | -- | -- | -- | -- | -- | -- | 3,300 | 40 CFR 141—Federal MCL |
| 14265-44-2 | Phosphate | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 13981-16-3 | Plutonium-238 | -- | pCi/L | 15 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 15 | 40 CFR 141 - Federal MCL |
| PU-239/240 | Plutonium-239/240 | -- | pCi/L | 15 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 15 | 40 CFR 141 - Federal MCL |
| 7440-09-7 | Potassium | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Radium-228 | -- | pCi/L | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 5.0 | 40 CFR 141 - Federal MCL |
| 7782-49-2 | Selenium | -- | µg/L | 50 | 50 | 50 | -- | 80 | -- | 5.0 | 170 | 5.0 | 20 | 5.0 | -- | 2,701 | 5.0 | Clean Water Act—Freshwater CCC |
| 7440-21-3 | Silicon | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7440-22-4 | Silver | -- | µg/L | 100 | -- | 100 | -- | 80 | 3.2 | -- | -- | 2.6 | 3.4 | -- | -- | 25,926 | 2.6 | WAC 173-201A |
| 7440-23-5 | Sodium | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7440-24-6 | Strontium | Strontium, Stable | µg/L | -- | -- | -- | -- | 9,600 | -- | -- | -- | -- | -- | -- | -- | 25,926 | 9,600 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 10098-97-2 | Strontium-90 | -- | pCi/L | 8.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8.0 | 40 CFR 141—Federal MCL |
| 100-42-5 | Styrene | -- | µg/L | 100 | 100 | -- | -- | 1,600 | -- | -- | -- | -- | -- | -- | -- | 38,409 | 100 | 40 CFR 141—Federal MCL |

Table 6-35. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-FR-3 Groundwater OU

| | | | | Groundwater | | | | | Surface Water | | | | | | | | Action Level Value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 40 CFR 141 | | WAC 246-290-310 | WAC 173-340-720 | | Clean Water Act National Recommended Water Quality Criteria | | | WAC 173-201A | 40 CFR 131 | | | WAC 173-340-730 | | |
| CAS# | Analyte Name | Alternate Analyte Name | Units | Federal MCL | Federal MCLG | State MCL | Groundwater Method A Cleanup Levels | Groundwater Method B Unrestricted Land Use | Acute Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Freshwater CCC | Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Surface Water Method B Unrestricted Land Use | Action Level | Action Level Basis |
| 14808-79-8 | Sulfate* | -- | µg/L | 250,000 | -- | 250,000 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 250,000 | 40 CFR 141—Secondary Federal MCL |
| 14133-76-7 | Technetium-99 | -- | pCi/L | 900 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 900 | 40 CFR 141 - Federal MCL |
| 127-18-4 | Tetrachloroethene | Perchloroethylene (PCE) | µg/L | 5.0 | -- | -- | -- | 0.081 | -- | -- | 0.69 | -- | -- | -- | 0.80 | 0.39 | 0.081 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 109-99-9 | Tetrahydrofuran | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 7440-28-0 | Thallium | Thallium (Soluble Salts) | µg/L | 2.0 | 0.50 | 2.0 | -- | -- | -- | -- | 0.24 | -- | -- | -- | 1.7 | -- | 0.24 | Clean Water Act—Human Health Water + Organism |
| 14269-63-7 | Thorium-230 | -- | pCi/L | 15 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 15 | 40 CFR 141 - Federal MCL |
| 7440-31-5 | Tin | -- | µg/L | -- | -- | -- | -- | 9,600 | -- | -- | -- | -- | -- | -- | -- | 519 | 519 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 108-88-3 | Toluene | -- | µg/L | 1,000 | 1,000 | -- | -- | 640 | -- | -- | 1,300 | -- | -- | -- | 6,800 | 19,384 | 640 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| TPHDIESEL | Total petroleum hydrocarbons – diesel range | -- | µg/L | -- | -- | -- | 500 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 500 | WAC 173-340-900, Table 720-1 |
| 156-60-5 | trans-1,2-Dichloroethylene | -- | µg/L | 100 | 100 | -- | -- | 160 | -- | -- | 140 | -- | -- | -- | -- | 32,818 | 100 | 40 CFR 141—Federal MCL |
| 10061-02-6 | trans-1,3-Dichloropropene | -- | µg/L | -- | -- | -- | -- | 0.44 | -- | -- | 0.34 | -- | -- | -- | -- | 34 | 0.34 | Clean Water Act—Human Health Water + Organism |
| 110-57-6 | trans-1,4-Dichloro-2-butene | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 79-01-6 | Trichloroethene | Trichloroethylene (TCE) | µg/L | 5.0 | -- | -- | -- | 0.49 | -- | -- | 2.5 | -- | -- | -- | 2.7 | 6.6 | 0.49 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 75-69-4 | Trichloromono-fluoromethane | Trichlorofluoromethane | µg/L | -- | -- | -- | -- | 2,400 | -- | -- | -- | -- | -- | -- | -- | -- | 2,400 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 10028-17-8 | Tritium | -- | pCi/L | 20,000 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 20,000 | 40 CFR 141—Federal MCL |
| 7440-61-1 | Uranium | Uranium (Soluble Salts) | µg/L | 30 | -- | -- | -- | 48 | -- | -- | -- | -- | -- | -- | -- | 778 | 30 | 40 CFR 141—Federal MCL |

Table 6-35. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-FR-3 Groundwater OU

| | | | | Groundwater | | | | | Surface Water | | | | | | | | Action Level Value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 40 CFR 141 | | WAC 246-290-310 | WAC 173-340-720 | | Clean Water Act National Recommended Water Quality Criteria | | | WAC 173-201A | 40 CFR 131 | | | WAC 173-340-730 | | |
| CAS# | Analyte Name | Alternate Analyte Name | Units | Federal MCL | Federal MCLG | State MCL | Groundwater Method A Cleanup Levels | Groundwater Method B Unrestricted Land Use | Acute Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Freshwater CCC | Freshwater CMC | Freshwater CCC | Human Health Water + Organism | Surface Water Method B Unrestricted Land Use | Action Level | Action Level Basis |
| 7440-62-2 | Vanadium | Vanadium and Compounds | µg/L | -- | -- | -- | -- | 80 | -- | -- | -- | -- | -- | -- | -- | -- | 80 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 108-05-4 | Vinyl acetate | -- | µg/L | -- | -- | -- | -- | 8,000 | -- | -- | -- | -- | -- | -- | -- | 820,441 | 8,000 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 75-01-4 | Vinyl chloride | -- | µg/L | 2.0 | -- | -- | -- | 0.061 | -- | -- | 0.025 | -- | -- | -- | 2.0 | 7.7 | 0.025 | Clean Water Act—Human Health Water + Organism |
| 1330-20-7 | Xylenes (total) | Xylenes (mixture) | µg/L | 10,000 | 10,000 | -- | -- | 1,600 | -- | -- | -- | -- | -- | -- | -- | -- | 1,600 | WAC 173-340-720(4)(b)(iii)(A)(B) |
| 7440-66-6 | Zinc | Zinc (Metallic) | µg/L | 5,000 | -- | 5,000 | -- | 4,800 | 120 | 120 | 7,400 | 91 | 110 | 100 | -- | 16,548 | 91 | WAC 173-201A |

Sources: 40 CFR 131, "Water Quality Standards."

40 CFR 141, "National Primary Drinking Water Regulations."

*Clean Water Act of 1977*.

EPA, 2009a, *National Recommended Water Quality Criteria*.

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

WAC 173-340-720(4), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."

WAC 173-340-730(3), "Surface Water Cleanup Standards," "Noncarcinogens and Carcinogens."

WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)."Note that 40 CFR 131, "Water Quality Standards," National Recommended Water Quality Criteria, and WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington" only apply in locations where groundwater has the potential to the Columbia River.

* Sulfate secondary MCL value is included in this table because it was identified as a historical COPC.

1

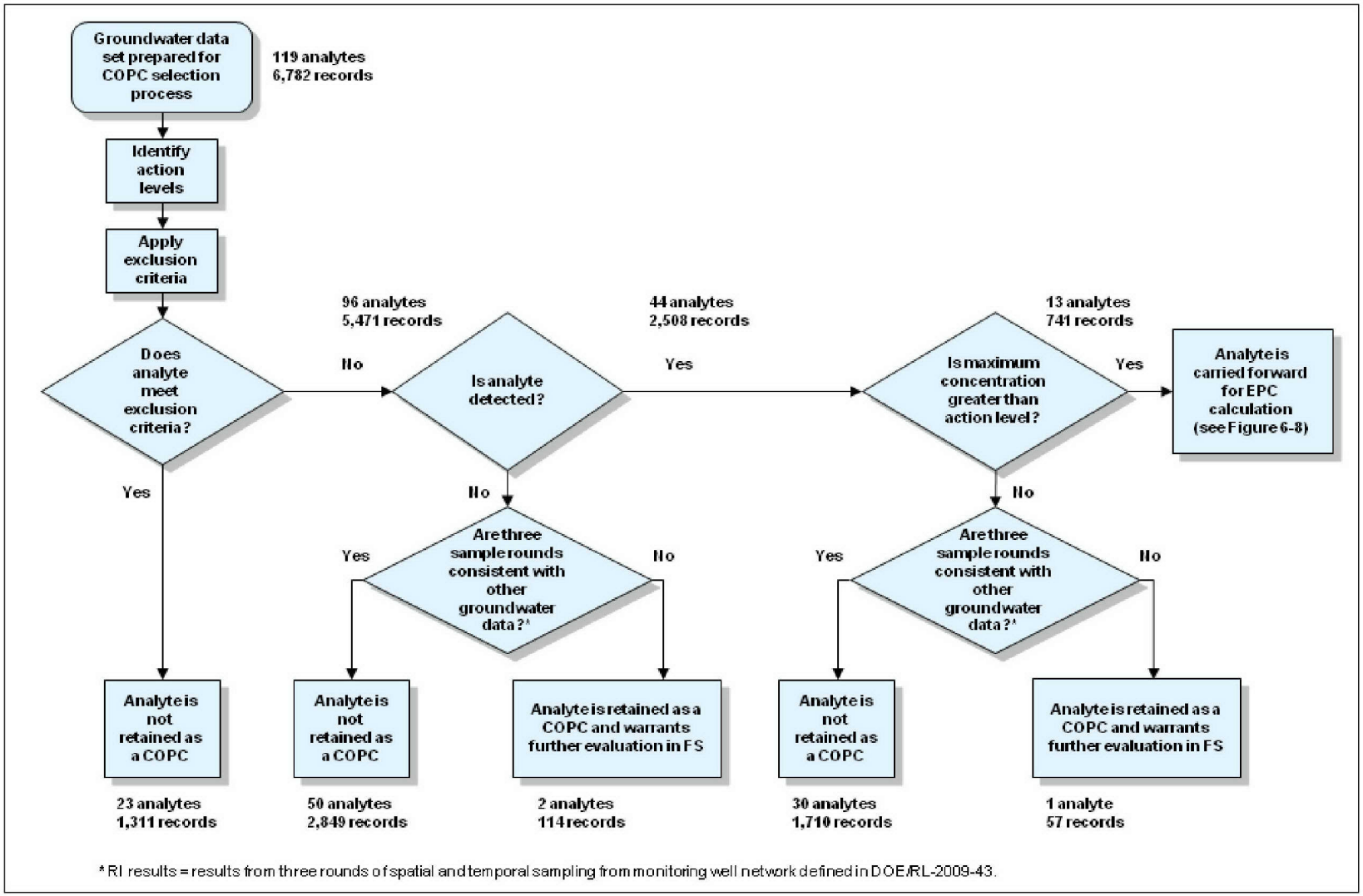


Figure 6-8. COPC Identification Process for the 100-FR-3 Groundwater OU: Part 1

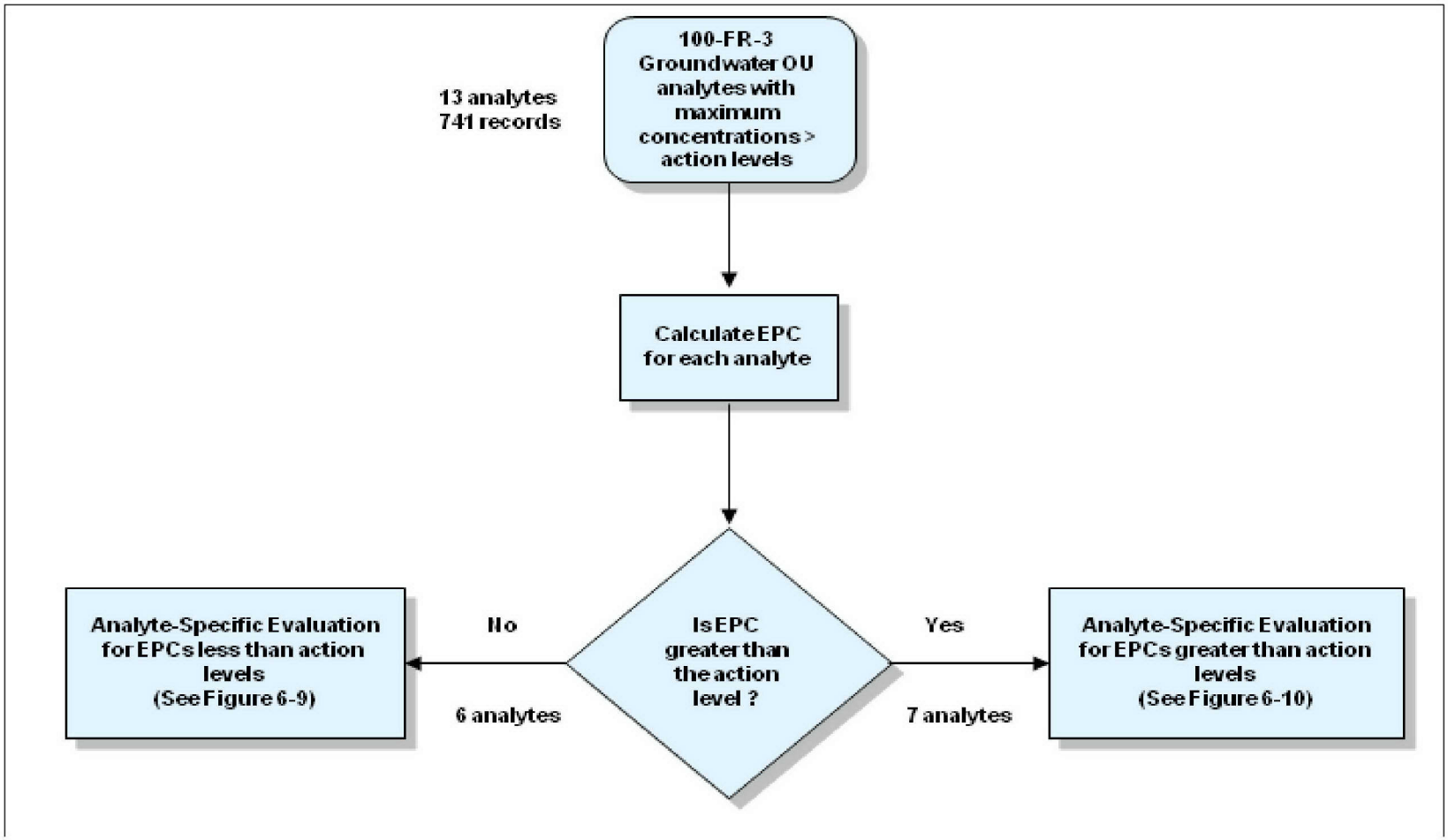


Figure 6-9. COPC Identification Process for the 100-FR-3 Groundwater OU: Part 2

- Identify analytes with maximum detected concentrations less than action levels.
- Identify analytes with maximum detected concentrations greater than action levels.
- Calculate EPCs for analytes with maximum detected concentrations greater than action levels.
- Identify analytes with EPCs less than action level.
- Identify analytes with EPCs greater than action level.

#### *6.3.2.3.1 Summary of Nature and Extent Evaluation*

Section 4.3.2 presents the nature and extent of contamination in groundwater based on the last 5 years of data (i.e., samples collected between January 2006 and December 2010). All monitoring wells within the 100-FR-3 Groundwater OU that are screened in the unconfined aquifer were included in the nature and extent evaluation (see Figure 6-6). The nature and extent evaluation reviewed all analytes identified as historical COPCs. As described previously, historical COPCs were identified in the work plan using data collected over a 16-year period (1992 to 2008) (see Table 6-33 for a list of historical COPCs). The nature and extent evaluation also includes the review of analytes that were not identified in Table 6-33 but reported concentrations greater than an action level using the current RI data. The data set used for the nature and extent evaluation is considered to be representative of current groundwater conditions based on the overall spatial coverage of monitoring wells across the OU and based on the inclusion of RI data that were collected to resolve uncertainties identified in the RCBRA (DOE/RL-2007-21) and the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4). This analysis is included to confirm that analytes that are identified as COPCs using RI data are consistent with the observations and characteristics of the data from a larger population of wells and analytical results collected over a longer period.

#### *6.3.2.3.2 Apply Exclusion Criteria*

The first step in the groundwater COPC identification process is to apply certain exclusion criteria. Analytes that met one or more of the exclusion criteria were eliminated as COPCs. The eliminated analytes are listed in Table 6-36. Analytes that did not meet any of the exclusion criteria were carried forward into the next step. The exclusion criteria are:

- Naturally occurring radionuclides associated with background radiation
- Radionuclides that have half-lives of less than three years and are not significant daughter products
- Essential nutrients (minerals)
- Analytes without known toxicity information

Two naturally occurring radionuclides associated with background radiation (potassium-40 and thorium-232) were measured in groundwater from the 100-FR-3 Groundwater OU and were eliminated as COPCs (Table 6-36).

Radioisotopes with half-lives less than or equal to 3 years are eliminated from further consideration, because only a small fraction of their original activity remains after 30 years of decay since the reactors ceased operation. A total of five radioisotopes met this exclusion criterion (antimony-125, beryllium-7, cesium-134, ruthenium-106, and thorium-228) and were eliminated from further consideration as COPCs for the 100-FR-3 Groundwater OU. All of these radioisotopes were reported with non-detectable concentrations. Additionally, these isotopes are not significant daughter products associated with a decay chain.

Essential nutrients are those analytes considered essential for human nutrition. The essential nutrients calcium, magnesium, potassium, and sodium were detected in the groundwater in the 100-FR-3 OU, but are excluded from further consideration as COPCs.

The federal MCL for gross beta is based on the four mrem/yr annual dose and was used to indicate the presence of a general group of "beta-emitters". This standard is available, but it requires a conversion from an activity based level (pCi/L) to an annual dose based rate (mrem/yr). So, beta-emitting radioisotopes such as strontium-90, technetium-99, and tritium were compared to their isotope specific standard, which is based on a four mrem/yr annual dose and is considered more protective than the overall standard for gross beta. It should be noted the gross beta standard provides a measure for the daughter products of uranium, which are also beta emitters. Although the four mrem/yr standard for gross beta exists, gross beta is not carried forward.

Analytes without an action level were identified in Table 6-35. Because of the lack of action levels (Table 6-35), these analytes were not evaluated herein as this section focuses on comparing detected concentrations against action levels. However, the overall contribution of these analytes (and all other detections) were evaluated in the EPA tap water scenario (Section 6.3.7), using all available toxicity information. For example, chloromethane does not have a promulgated standard, but toxicity information is published and was used to evaluate the risk for this contaminant. Note that toxicity information is also available for acetonitrile; however, it was not detected in groundwater and was not evaluated in the EPA tap water scenario. For some analytes without an action level, toxicological information that could be considered in assessing any risks they may present is not available. Eight analytes from the 100-FR-3 Groundwater OU were eliminated from further consideration as COPCs because they do not have an action level nor do they have available toxicological information.

#### *6.3.2.3.3 Identify Nondetected Analytes*

The next step in the groundwater COPC identification process was to identify nondetected analytes. Chemicals and radionuclides that have been analyzed for, but not detected in any sample (collected from appropriate locations with adequate detection limits), were eliminated as COPCs. All analytes detected at least once were carried forward to the next step.

A total of 52 analytes were not detected in any of the samples collected during the RI from the 100-FR-3 Groundwater OU. These analytes are listed in Table 6-37, each with sampling dates, minimum and maximum MDLs, the action level, the basis of the action level.

**100-FR-3 Groundwater OU.** 1,1-Dichloroethene, antimony, beryllium, cadmium, carbon tetrachloride cesium-137, cobalt-60, europium-154, iodine-129, mercury, thallium, thorium-230, and vinyl chloride were identified as historic COPCs in the work plan, but are not detected in the samples collected for this RI. Antimony, cadmium, and carbon tetrachloride are discussed below. The other ten analytes (1,1-dichloroethene, beryllium, cesium-137, cobalt-60, europium-154, iodine-129, mercury, thallium, thorium-230, and vinyl chloride) were not detected in samples collected specifically for this RI analytical results were not available for the larger population of monitoring wells described in Sections 4.3.2 and 6.3.2.3.1. All MDLs associated with these ten analytes were less than the action level or the EQL (as applicable) listed in the 100-F/IU SAP (DOE/RL-2009-43). Therefore, these ten analytes are not retained as COPCs and will not be carried forward into the FS.

Table 6-36. Summary of Groundwater Analytes that Meet Exclusion Criteria in the 100-FR-3 Groundwater OU

| Analyte Name | Analyte Class | Begin Sample Date | End Sample Date | Total Samples | Total Detects | Frequency of Detection | Units | Minimum Detection Limit | Maximum Detection Limit | Minimum Detected Result | Maximum Detected Result | Basis for Exclusion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Bromide | ANION | 5/5/2010 | 11/29/2010 | 57 | 39 | 68.42% | µg/L | 90 | 110 | 140 | 618 | No Action Level/No Toxicity Values |
| Phosphate | ANION | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 166 | 429 | -- | -- | No Action Level/No Toxicity Values |
| Bismuth | METAL | 5/5/2010 | 11/29/2010 | 57 | 2 | 3.51% | µg/L | 23 | 37 | 23 | 29 | No Action Level/No Toxicity Values |
| Calcium | METAL | 5/5/2010 | 11/29/2010 | 57 | 56 | 98.25% | µg/L | 39 | 39 | 20,400 | 146,000 | Essential Nutrient |
| Magnesium | METAL | 5/5/2010 | 11/29/2010 | 57 | 56 | 98.25% | µg/L | 16 | 16 | 3,910 | 37,700 | Essential Nutrient |
| Potassium | METAL | 5/5/2010 | 11/29/2010 | 57 | 57 | 100% | µg/L | -- | -- | 246 | 8,120 | Essential Nutrient |
| Silicon | METAL | 5/5/2010 | 11/29/2010 | 57 | 56 | 98.25% | µg/L | 61 | 61 | 5,920 | 21,300 | No Action Level/No Toxicity Values |
| Sodium | METAL | 5/5/2010 | 11/29/2010 | 57 | 57 | 100% | µg/L | -- | -- | 65 | 69,300 | Essential Nutrient |
| Antimony-125 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -6.63 | 19 | -- | -- | Half-Life less than 3 years |
| Beryllium-7 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -26.5 | 85 | -- | -- | Half-Life less than 3 years |
| Cesium-134 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -2.0 | 12 | -- | -- | Half-Life less than 3 years |
| Gross beta | RAD | 5/5/2010 | 11/29/2010 | 57 | 49 | 85.96% | pCi/L | 1.8 | 8.0 | 2.4 | 44 | No Action Level/No Toxicity Values |
| Potassium-40 | RAD | 5/5/2010 | 11/29/2010 | 57 | 1 | 1.75% | pCi/L | -101 | 97 | 388 | 388 | Background Radiation |
| Ruthenium-106 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -18.7 | 86 | -- | -- | Half-Life less than 3 years |
| Thorium-228 | RAD | 5/5/2010 | 11/29/2010 | 57 | 5 | 8.77% | pCi/L | -0.0201 | 0.35 | 0.22 | 0.45 | Half-Life less than 3 years |
| Thorium-232 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -0.0178 | 0.058 | -- | -- | Background Radiation |
| Acetonitrile | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 2.0 | 2.0 | -- | -- | No Action Level/Toxicity Values Available |
| Chloroethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.099 | 0.099 | -- | -- | No Action Level/No Toxicity Values |
| Chloromethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 4 | 7.02% | µg/L | 0.077 | 0.077 | 0.11 | 0.57 | No Action Level/Toxicity Values Available |
| Ethyl cyanide | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 1.4 | 1.4 | -- | -- | No Action Level/No Toxicity Values |
| Iodomethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 3 | 5.26% | µg/L | 0.092 | 0.092 | 0.50 | 0.73 | No Action Level/No Toxicity Values |
| Tetrahydrofuran | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 1.1 | 1.1 | -- | -- | No Action Level/No Toxicity Values |
| trans-1,4-Dichloro-2-butene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.29 | 0.29 | -- | -- | No Action Level/No Toxicity Values |

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Table 6-37. Summary of Analytes that Were Not Detected in the 100-FR-3 Groundwater OU

| Analyte Name | Analyte Class | Begin Sample Date | End Sample Date | Total Samples | Total Detects | Frequency of Detection | Units | Minimum Detection Limit | Maximum Detection Limit | Action Level | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrite | ANION | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 9.9 | 118 | 3,300 | 40 CFR 141 - Federal MCL |
| Antimony | METAL | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.30 | 1.1 | 5.6 | Clean Water Act -- Human Health Water + Organism |
| Beryllium | METAL | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.050 | 0.11 | 4.0 | 40 CFR 141 - Federal MCL |
| Cadmium | METAL | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.055 | 0.20 | 0.25 | Clean Water Act -- Freshwater CCC |
| Mercury | METAL | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.050 | 0.10 | 0.012 | 40 CFR 131 -- Freshwater CCC |
| Silver | METAL | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.040 | 0.20 | 2.6 | WAC 173-201A |
| Thallium | METAL | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.050 | 0.55 | 0.24 | Clean Water Act -- Human Health Water + Organism |
| Cesium-137 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -1.30E+00 | 7.8 | 200 | 40 CFR 141 - Federal MCL |
| Cobalt-60 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -2.50E+00 | 13 | 100 | 40 CFR 141 - Federal MCL |
| Europium-152 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -5.42E+00 | 20 | 200 | 40 CFR 141 - Federal MCL |
| Europium-154 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -5.78E+00 | 25 | 60 | 40 CFR 141 - Federal MCL |
| Europium-155 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | pCi/L | -4.70E+00 | 20 | 600 | 40 CFR 141 - Federal MCL |
| Iodine-129 | RAD | 5/5/2010 | 11/29/2010 | 56 | 0 | 0.00% | µg/L | -2.04E+00 | 0.16 | 1.0 | 40 CFR 141.66 |
| Thorium-230 | RAD | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | -1.28E-01 | 0.23 | 15 | 40 CFR 141.66 |
| 1,1,1,2-Tetrachloroethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.090 | 0.090 | 1.7 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 1,1,1-Trichloroethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.069 | 0.069 | 200 | 40 CFR 141 - Federal MCL |
| 1,1,2,2-Tetrachloroethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.098 | 0.098 | 0.17 | Clean Water Act -- Human Health Water + Organism |
| 1,1,2-Trichloroethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.15 | 0.15 | 0.59 | Clean Water Act -- Human Health Water + Organism |
| 1,1-Dichloroethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.068 | 0.068 | 1,600 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 1,1-Dichloroethene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.083 | 0.083 | 0.057 | 40 CFR 131 -- Human Health Water + Organism |
| 1,2,3-Trichloropropane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.15 | 0.15 | 0.0015 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 1,2-Dibromo-3-chloropropane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.41 | 0.41 | 0.055 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 1,2-Dibromoethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.13 | 0.13 | 0.022 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 1,2-Dichloroethene (Total) | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.15 | 0.15 | 72 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 1,2-Dichloropropane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.097 | 0.097 | 0.50 | Clean Water Act -- Human Health Water + Organism |
| 1-Butanol | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 12 | 12 | 800 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 2-Butanone | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.52 | 0.52 | 4,800 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 2-Hexanone | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.22 | 0.22 | 80 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| 4-Methyl-2-pentanone | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.12 | 0.12 | 640 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Acrolein | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 2.8 | 2.8 | 3.0 | Clean Water Act -- Freshwater CCC |

Table 6-37. Summary of Analytes that Were Not Detected in the 100-FR-3 Groundwater OU

| Analyte Name | Analyte Class | Begin Sample Date | End Sample Date | Total Samples | Total Detects | Frequency of Detection | Units | Minimum Detection Limit | Maximum Detection Limit | Action Level | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Allyl chloride | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.11 | 0.11 | 2.1 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Benzene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.064 | 0.064 | 0.80 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Bromodichloromethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.088 | 0.088 | 0.27 | 40 CFR 131 -- Human Health Water + Organism |
| Bromoform | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.17 | 0.17 | 4.3 | Clean Water Act -- Human Health Water + Organism |
| Carbon disulfide | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.051 | 0.051 | 800 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Carbon tetrachloride | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.12 | 0.12 | 0.23 | Clean Water Act -- Human Health Water + Organism |
| Chloroprene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.097 | 0.097 | 160 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| cis-1,2-Dichloroethylene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.087 | 0.087 | 70 | 40 CFR 141 - Federal MCL |
| cis-1,3-Dichloropropene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.073 | 0.073 | 0.34 | Clean Water Act -- Human Health Water + Organism |
| Dibromochloromethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.13 | 0.13 | 0.40 | Clean Water Act -- Human Health Water + Organism |
| Dibromomethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.21 | 0.21 | 80 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Dichlorodifluoromethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.084 | 0.084 | 1,600 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Ethyl methacrylate | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.11 | 0.11 | 720 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Ethylbenzene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.086 | 0.086 | 4.0 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Isobutyl alcohol | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 8.7 | 8.7 | 2,400 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Methacrylonitrile | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.50 | 0.50 | 0.80 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Methyl methacrylate | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.26 | 0.26 | 11,200 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Methylene chloride | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.11 | 0.11 | 4.6 | Clean Water Act -- Human Health Water + Organism |
| trans-1,2-Dichloroethylene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.083 | 0.083 | 100 | 40 CFR 141 - Federal MCL |
| trans-1,3-Dichloropropene | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.083 | 0.083 | 0.34 | Clean Water Act -- Human Health Water + Organism |
| Vinyl acetate | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.18 | 0.18 | 8,000 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Vinyl chloride | VOC | 5/5/2010 | 11/29/2010 | 57 | 0 | 0.00% | µg/L | 0.084 | 0.084 | 0.025 | Clean Water Act -- Human Health Water + Organism |

Note: Shading indicates that a constituent is identified in the proposed list of contaminants of potential concern in DOE/RL-2009-43, *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*.
Sources: 40 CFR 131, "Water Quality Standards."
40 CFR 141, "National Primary Drinking Water Regulations."
*Clean Water Act of 1977*.
WAC 173-340-720(4), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."

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Antimony was not detected in any of the groundwater samples collected for the RI; however, it was detected at a low frequency in the larger population of wells sampled over the past 5 years as discussed in Sections 4.3.2 and 6.3.2.3.1. Antimony concentrations and MDLs greater than the action level were from a larger population of wells sampled in the past 5 years and reported by Method 6010 (SW 846 [SW-846]). Antimony concentrations reported by Method 6010 (SW 846 [SW-846]) are considered uncertain because this method cannot accurately report trace concentrations. Groundwater samples analyzed by Method 6010 (SW 846 [SW-846]) generally report MDLs greater than the action level resulting in nondetected concentrations greater than the action level. Similarly, detected concentrations are reported as estimates (flagged with a "B" qualifier) at concentrations greater than the action level and are below the contract-required calibration range of the instrument. Additionally, antimony concentrations above the action level are not associated with a specific location or with a trend. Although antimony was not detected in the samples analyzed for the RI by Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]), its historical presence with infrequent detections above the action level result in an uncertain status. Therefore, antimony is retained as a COPC and it warrants further evaluation in the FS.

Cadmium was not detected in any of the unfiltered groundwater samples collected for the RI nor was it detected in the unfiltered samples from the larger population of wells sampled over the past 5 years as discussed in Sections 4.3.2 and 6.3.2.3.1. Cadmium was detected once in a filtered sample collected during the RI at a concentration less than the action level. Cadmium MDLs greater than the action level were from a larger population of wells sampled in the past 5 years and reported by Method 6010 (SW 846 [SW-846]). Groundwater samples analyzed by Method 6010 (SW 846 [SW-846]) generally report MDLs greater than the action level resulting in nondetected concentrations greater than the action level. Although cadmium was not detected in the samples analyzed for the RI by Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]), MDLs above the action level result in an uncertain status. Therefore, cadmium is retained as a COPC and it warrants further evaluation in the FS.

Carbon tetrachloride was not detected in any of the groundwater samples collected for the RI; however, it was detected at a low frequency in the larger population of wells sample over the past 5 years as discussed in Sections 4.3.2 and 6.3.2.3.1. The action level for carbon tetrachloride is 0.23 µg/L based on the *National Recommended Water Quality Criteria* (EPA, 2009a), "Human Health Water + Organism" value; however, it defaults to the EQL of 1 µg/L reported in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. Detections of carbon tetrachloride from the larger population of wells sampled over the past 5 years were less than the EQL. The results of this evaluation indicate that carbon tetrachloride was not detected in samples collected specifically for the RI and detections of carbon tetrachloride in the larger population of wells are less than the EQL. Therefore, carbon tetrachloride is not retained as a COPC and will not be carried forward into the FS.

#### *6.3.2.3.4 Identify Analytes with Maximum Detected Concentrations Less than Action Levels*[11]

This step identifies analytes with maximum concentrations less than action levels. In this screening, the maximum concentration of each analyte detected in groundwater was compared to its action level, to identify analytes not likely to contribute significantly to overall risk. If the maximum detected concentration of an analyte was less than its action level, the analyte was eliminated as a COPC, unless the nature and extent evaluation described below indicates otherwise.

Thirty-one analytes were detected at least once and had maximum detected concentrations less than their respective action levels in samples during the RI from the 100-FR-3 Groundwater OU. These analytes are

[11] See Section 6.3.2.2 for the definition of an action level.

listed in Table 6-38, each with sampling dates, minimum and maximum MDLs, minimum and maximum detected concentrations, the action levels, and the basis for each action level.

**100-FR-3 Groundwater OU.** Americium-241, carbon-14, cobalt, copper, fluoride, lead, manganese, nickel, plutonium-238, plutonium-239/240, styrene, sulfate, technetium-99, tritium, and zinc were identified as historical COPCs in the work plan. Americium-241, carbon-14, copper, fluoride, nickel, plutonium-238, plutonium-239/240, styrene, sulfate, technetium-99, tritium, and zinc were detected in groundwater at concentrations below their respective action level in samples collected for the RI and in the larger population of monitoring wells described in Sections 4.3.2 and 6.3.2.3.1. Lead was detected in groundwater at concentrations below the DWS in samples collected for the RI and it was not analyzed in the larger population of monitoring wells described in Sections 4.3.2 and 6.3.2.3.1. Therefore, americium-241, carbon-14, copper, fluoride, lead, nickel, plutonium-238, plutonium-239/240, styrene, sulfate, technetium-99, tritium, and zinc are not retained as COPCs and will not be carried forward into the risk characterization section or into the FS.

Cobalt and manganese were detected in groundwater samples collected for the RI at concentrations below their respective action level. However, these analytes were detected at concentrations above their respective action level in the larger population of monitoring wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. The results for these two analytes are discussed below.

Detections of cobalt above the action level were from the larger population of wells sampled in the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. All cobalt results (detected concentrations and MDLs) reported by Method 6010 (SW 846 [SW-846]) were greater than the action level. Cobalt concentrations reported by Method 6010 (SW 846 [SW-846]) are considered uncertain because this method cannot accurately report trace concentrations. Groundwater samples analyzed by Method 6010 (SW 846 [SW-846]) generally report MDLs greater than the action level, resulting in nondetected concentrations greater than the action level. Similarly, detected concentrations are reported as estimates (flagged with a "B" qualifier) at concentrations greater than the action level and are below the contract-required calibration range of the instrument. Additionally, cobalt concentrations above the action level are not associated with a specific location or with a trend. Although cobalt was detected at concentrations less than the action level in RI samples analyzed by Method 200.8 (*Methods for the Determination of Metals in Environmental Samples, Supplement I* [EPA-600/R-94/111]), its historical presence with infrequent detections above the action level result in an uncertain status. Therefore, cobalt is retained as a COPC and it warrants further evaluation in the FS.

Detections of manganese above the action level were measured in the larger population of wells sampled in the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. Manganese affects aesthetic qualities relating to public acceptance of drinking water. Manganese concentrations in groundwater are compared to the "Surface Water Cleanup Standards" (WAC 173-340-730) level of 907 µg/L. All manganese concentrations are less the action level of 907 µg/L. Therefore, manganese is not retained as a COPC and will not be carried forward into the risk characterization section or into the FS.

#### *6.3.2.3.5 Identify Analytes with Maximum Detected Concentrations Greater than Action Levels*

This step identifies analytes with maximum concentrations greater than their respective action levels. Such analytes have the potential to contribute to overall risk. If the maximum detected concentration of an analyte is greater than its action level, the analyte is carried forward into the next step of the analysis for calculation of EPCs.

Table 6-38. Summary of Groundwater Analytes that Do Not Exceed an Action Level in the 100-FR-3 Groundwater OU

| Analyte Name | Analyte Class | Begin Sample Date | End Sample Date | Total Samples | Total Detects | Frequency of Detection | Units | Minimum Detection Limit | Maximum Detection Limit | Minimum Detected Result | Maximum Detected Result | Action Level | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chloride | ANION | 5/5/2010 | 11/29/2010 | 57 | 57 | 100.00% | µg/L | -- | -- | 378 | 62,100 | 230,000 | Clean Water Act -- Freshwater CCC |
| Fluoride | ANION | 5/5/2010 | 11/29/2010 | 57 | 36 | 63.16% | µg/L | 60 | 88 | 90 | 610 | 960 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Sulfate | ANION | 5/5/2010 | 11/29/2010 | 57 | 56 | 98.25% | µg/L | 130 | 130 | 8,830 | 136,000 | 250,000 | 40 CFR 141 – Secondary Federal MCL |
| Barium | METAL | 5/5/2010 | 11/29/2010 | 57 | 56 | 98.25% | µg/L | 0.40 | 0.40 | 13 | 153 | 1,000 | Clean Water Act -- Human Health Water + Organism |
| Boron | METAL | 5/5/2010 | 11/29/2010 | 57 | 37 | 64.91% | µg/L | 19 | 41 | 21 | 307 | 3,200 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Cobalt | METAL | 5/5/2010 | 11/29/2010 | 57 | 13 | 22.81% | µg/L | 0.050 | 0.22 | 0.099 | 0.31 | 2.6 | WAC 173-340-730(3)(b)(iii)(A) and (B) |
| Copper | METAL | 5/5/2010 | 11/29/2010 | 57 | 38 | 66.67% | µg/L | 0.10 | 0.20 | 0.23 | 3.0 | 9.0 | Clean Water Act -- Freshwater CCC |
| Iron | METAL | 5/5/2010 | 11/29/2010 | 57 | 38 | 66.67% | µg/L | 18 | 38 | 18 | 138 | 1,000 | Clean Water Act—Freshwater CCC |
| Lead | METAL | 5/5/2010 | 11/29/2010 | 57 | 1 | 1.75% | µg/L | 0.10 | 0.20 | 0.21 | 0.21 | 2.1 | WAC 173-201A |
| Manganese | METAL | 5/5/2010 | 11/29/2010 | 57 | 4 | 7.02% | µg/L | 3.3 | 6.0 | 6.0 | 11 | 907 | WAC 173-340-730(3)(b)(iii)(A)(B) |
| Molybdenum | METAL | 5/5/2010 | 11/29/2010 | 57 | 57 | 100.00% | µg/L | -- | -- | 0.11 | 8.5 | 80 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Nickel | METAL | 5/5/2010 | 11/29/2010 | 57 | 8 | 14.04% | µg/L | 4.0 | 4.0 | 4.0 | 36 | 52 | Clean Water Act -- Freshwater CCC |
| Strontium | METAL | 5/5/2010 | 11/29/2010 | 57 | 56 | 98.25% | µg/L | 4.0 | 4.0 | 82 | 1,240 | 9,600 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Tin | METAL | 5/5/2010 | 11/29/2010 | 57 | 4 | 7.02% | µg/L | 0.050 | 0.10 | 0.10 | 0.36 | 519 | WAC 173-340-730(3)(b)(iii)(A) and (B) |
| Vanadium | METAL | 5/5/2010 | 11/29/2010 | 57 | 10 | 17.54% | µg/L | 12 | 17 | 4.1 | 27 | 80 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Zinc | METAL | 5/5/2010 | 11/29/2010 | 57 | 7 | 12.28% | µg/L | 4.0 | 6.0 | 4.0 | 12 | 91 | WAC 173-201A |
| Americium-241 | RAD | 5/5/2010 | 11/29/2010 | 57 | 4 | 7.02% | µg/L | -0.18 | 0.19 | 0.06 | 0.08 | 15 | 40 CFR 141.66 |
| Carbon-14 | RAD | 5/5/2010 | 11/29/2010 | 57 | 9 | 15.79% | µg/L | -11.9 | 7.84 | 8.98 | 70.7 | 2,000 | 40 CFR 141.66 |
| Gross alpha | RAD | 5/5/2010 | 11/29/2010 | 57 | 17 | 29.82% | pCi/L | -3.10E+00 | 5.5 | 2.1 | 10 | 15 | 40 CFR 141 - Federal MCL |
| Plutonium-238 | RAD | 5/5/2010 | 11/29/2010 | 57 | 4 | 7.02% | µg/L | -1.70E+00 | 0.28 | 0.12 | 0.30 | 15 | 40 CFR 141.66 |
| Plutonium-239/240 | RAD | 5/5/2010 | 11/29/2010 | 57 | 17 | 29.82% | µg/L | -4.40E-02 | 0.54 | 0.061 | 1.1 | 15 | 40 CFR 141.66 |
| Technetium-99 | RAD | 5/5/2010 | 11/29/2010 | 57 | 5 | 8.77% | pCi/L | -1.10E+01 | 3.2 | 9.0 | 40 | 900 | 40 CFR 141 - Federal MCL |
| Tritium | RAD | 5/5/2010 | 11/29/2010 | 57 | 30 | 52.63% | pCi/L | -5.00E+01 | 170 | 200 | 3,800 | 20,000 | 40 CFR 141 - Federal MCL |
| 1,4-Dichlorobenzene | VOC | 5/5/2010 | 11/29/2010 | 57 | 12 | 21.05% | µg/L | 0.12 | 0.12 | 0.17 | 0.78 | 8.1 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Acetone | VOC | 5/5/2010 | 11/29/2010 | 57 | 6 | 10.53% | µg/L | 0.34 | 0.34 | 0.77 | 5.5 | 7,200 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Bromomethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 19 | 33.33% | µg/L | 0.13 | 0.25 | 0.17 | 0.85 | 11 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Chlorobenzene | VOC | 5/5/2010 | 11/29/2010 | 57 | 1 | 1.75% | µg/L | 0.15 | 0.15 | 0.24 | 0.24 | 100 | 40 CFR 141 - Federal MCL |
| Styrene | VOC | 5/5/2010 | 11/29/2010 | 57 | 9 | 15.79% | µg/L | 0.074 | 0.074 | 0.10 | 0.52 | 100 | 40 CFR 141 - Federal MCL |

Table 6-38. Summary of Groundwater Analytes that Do Not Exceed an Action Level in the 100-FR-3 Groundwater OU

| Analyte Name | Analyte Class | Begin Sample Date | End Sample Date | Total Samples | Total Detects | Frequency of Detection | Units | Minimum Detection Limit | Maximum Detection Limit | Minimum Detected Result | Maximum Detected Result | Action Level | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Toluene | VOC | 5/5/2010 | 11/29/2010 | 57 | 1 | 1.75% | µg/L | 0.072 | 0.072 | 0.17 | 0.17 | 640 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Trichloromonofluoromethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 2 | 3.51% | µg/L | 0.11 | 0.11 | 0.22 | 0.25 | 2,400 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Xylenes (total) | VOC | 5/5/2010 | 11/29/2010 | 57 | 3 | 5.26% | µg/L | 0.2 | 0.2 | 0.21 | 0.49 | 1,600 | WAC 173-340-720(4)(b)(iii)(A) and (B) |

Note: Shading indicates that a constituent is identified in the proposed list of contaminants of potential concern in DOE/RL-2009-43, *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*.

Sources: 40 CFR 131, "Water Quality Standards."

40 CFR 141, "National Primary Drinking Water Regulations."

*Clean Water Act of 1977*.

WAC 173-340-720(4), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."

WAC 173-340-730(3), "Surface Water Cleanup Standards," "Noncarcinogens and Carcinogens."

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Thirteen analytes were detected at least once and had maximum detected concentrations greater than their respective action levels in samples during the RI from the 100-FR-3 Groundwater OU. These analytes are listed in Table 6-39, each with sampling dates, minimum and maximum MDLs, minimum and maximum detected concentrations, the action levels, and the basis for each action level.

#### *6.3.2.3.6 Calculate EPCs for Each Analyte with Maximum Detected Concentrations Greater than Action Levels* [12]

COPCs are identified by comparing statistical EPC estimates to action levels for each analyte and exposure area. EPCs are calculated as the 90$^{th}$ percentile value for each analyte with a maximum detected concentration greater than the action level from the groundwater data set collected specifically for the RI. The MDL is used as the concentration for nondetect results in the percentile calculations.
The 90$^{th}$ percentile exposure is identified in *Guidelines for Exposure Assessment* (EPA/600/Z-92/001) for describing and characterizing health risks and producing risk estimates corresponding to an RME.
A description of the methodology used to calculate the 90$^{th}$ percentile values is provided in *Tap Water Risk Assessment for the 100-FR-3 Groundwater Operable Unit* (ECF-100FR3-11-0026) in Appendix G.

In general, Calculating UCL for EPCs (OSWER 9285.6-10) recommends using a 95 percent UCL on the average for estimating EPCs. However, experience at the Hanford Site indicates that averages and UCLs cannot be reliably calculated for groundwater data sets. The 100-FR-3 Groundwater OU exhibits an aquifer setting where multiple groundwater contaminants are present in overlapping plumes, and the highest concentrations of the various COPCs have different locations within the plumes.

Use of the 90$^{th}$ percentile value from a distribution of groundwater concentration data as an estimate of the EPC is a different approach for estimating EPCs than that provided in Calculating UCL for EPCs (OSWER 9285.6-10). However, as described in the following text, the 90$^{th}$ percentile exposure concentration is identified in other EPA risk assessment guidance as appropriate for describing and characterizing health risks; its use yields risk estimates that correspond to an RME.

According to *An Examination of EPA Risk Assessment Principles and Practices* (EPA/100/B-04/001), the RME is an appropriate exposure scenario for risk calculations, within the realistic range of exposure, since the goal of the Superfund program is to protect against high-end, not worst-case, exposures.
The "high end" is defined as that part of the exposure distribution that is above the 90$^{th}$ percentile, but below the 99.9$^{th}$ percentile. The approach is consistent with the peer-reviewed *Guidelines for Exposure Assessment* (EPA/600/Z-92/001). Groundwater concentrations directly reflect potential exposures and risks, so a 90$^{th}$ percentile concentration reflects an RME scenario.

Groundwater data sets at the Hanford Site are highly skewed, with a large proportion of below detection limit (BDL) values. *Data Quality Assessment: Statistical Methods for Practitioners* (EPA/240/B-06/003), provides guidance for estimating statistical parameters (whether means or upper percentiles) depending on the variability in the data set. The variability of the data set is assessed in terms of the coefficient of variation (CV) and the proportion of observations that are BDL. For data sets with CVs greater than 0.5 and 50 percent or more observations that are BDL, EPA recommends using upper percentiles as opposed to means to develop summary statistics.

Therefore, the rationale for using a 90$^{th}$ percentile value as an estimate of the EPC is consistent with the definition of an RME scenario, and is an appropriate statistic for groundwater data sets in this groundwater OU. Additional statistical evaluation of the 100-FR-3 Groundwater OU data sets that support the selection of the 90$^{th}$ percentile value as the EPC is provided in *Calculation of Exposure Point Concentrations for the 100-FR-3 Groundwater Operable Unit* (ECF-100FR3-11-0024) in Appendix G.

[12] See Section 6.3.2.2 for the definition of an action level.

This evaluation includes an estimation of the 95 percent UCL value for each detected analyte, along with the analysis of variability, to assess the reliability of the 95 percent UCL estimates. Results of the evaluation indicate that, for the majority of analytes, a reliable and meaningful 95 percent UCL estimate cannot be calculated because of an insufficient number of samples, an insufficient number of detections, or a high variance of the data. Therefore, the 90$^{th}$ percentile is adopted as the estimated EPC for all analytes. A comparison of the 90$^{th}$ percentile and 95 percent UCL values is provided in the uncertainty analysis (Section 6.3.8.2).

A flowchart depicting the COPC identification process and the number of analytes associated with each process step is provided on Figure 6-10. The steps in the sequence are described in the following sections.

#### *6.3.2.3.7 Identify Analytes with 90th Percentile Values Less than Action Levels*

The 90$^{th}$ percentile values are compared to the lowest available action level for protection of human health and aquatic receptors (i.e., action levels). A comparison of EPCs to action levels for the 100-FR-3 Groundwater OU is provided in Table 6-40. A flow chart depicting this comparison is provided in Figure 6-11.

**100-FR-3 Groundwater OU.** Six of the 13 analytes have been detected at least once in groundwater and have 90$^{th}$ percentile values less than their respective action levels (Table 6-40). Four of the six analytes (chromium, selenium, strontium-90, and chloroform) were identified as historical COPCs in the work plan. A discussion of all analytes with EPCs less than the action level is provided in the following paragraphs.

1,2-Dichloroethane was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of 1,2-dichloroethane above the action level were reported in groundwater samples collected for the RI and were less than the action level in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. The action level for 1,2-dichloroethane is 0.38 µg/L based on the "Water Quality Standards" (40 CFR 131) Health Water + Organism value; however, it defaults to the EQL of 5 µg/L listed in the 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All 1,2-dichloroethane results (detections and MDLs) are less than the EQL. Therefore, 1,2-dichloroethane is not retained as a COPC and will not be carried into the risk characterization section.

Aluminum was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of aluminum above the action level were reported in groundwater samples collected for the RI and were less than the action level in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. Aluminum affects aesthetic qualities relating to public acceptance of drinking water. Aluminum concentrations in groundwater are compared to the AWQC of 87 µg/L. Aluminum concentrations are greater than the AWQC of 87 µg/L in one of three unfiltered samples collected from 199-F8-7 (where concentrations range less than 10 and 90 µg/L). All aluminum results from filtered samples were less than the AWQC of 87 µg/L at 199-F8-7. Aluminum results above the AWQC were not measured in filtered samples and are not associated with a specific trend or location. Based on these results, aluminum is not retained as a COPC and will not be carried forward into the risk characterization section.

Table 6-39. Summary of Analytes that Exceed an Action Level in the 100-FR-3 Groundwater OU

| Analyte Name | Analyte Class | Begin Sample Date | End Sample Date | Total Samples | Total Detects | Frequency of Detection | Units | Minimum Detection Limit | Maximum Detection Limit | Minimum Detected Result | Maximum Detected Result | Action Level | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrate | ANION | 5/5/2010 | 11/29/2010 | 57 | 56 | 98.25% | µg/L | 274 | 274 | 912 | 139,000 | 45,000 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Aluminum | METAL | 5/5/2010 | 11/29/2010 | 57 | 19 | 33.33% | µg/L | 10 | 10 | 6.1 | 90 | 87 | Clean Water Act -- Freshwater CCC |
| Arsenic | METAL | 5/5/2010 | 11/29/2010 | 57 | 48 | 84.21% | µg/L | 0.80 | 0.80 | 0.68 | 12 | 0.018 | Clean Water Act -- Human Health Water + Organism |
| Chromium | METAL | 5/5/2010 | 11/29/2010 | 57 | 55 | 96.49% | µg/L | 1.0 | 1.0 | 1.3 | 98 | 65 | Clean Water Act -- Freshwater CCC |
| Hexavalent Chromium | METAL | 5/5/2010 | 11/29/2010 | 57 | 23 | 40.35% | µg/L | 2.0 | 2.0 | 2.5 | 92 | 10 | 40 CFR 131 -- Freshwater CCC |
| Lithium | METAL | 5/5/2010 | 11/29/2010 | 57 | 38 | 66.67% | µg/L | 4.0 | 4.0 | 4.0 | 53 | 32 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Selenium | METAL | 5/5/2010 | 11/29/2010 | 57 | 39 | 68.42% | µg/L | 0.30 | 0.60 | 0.64 | 5.4 | 5.0 | Clean Water Act -- Freshwater CCC |
| Strontium-90 | RAD | 5/5/2010 | 11/29/2010 | 57 | 8 | 14.04% | pCi/L | -8.40E+00 | 0.99 | 2.0 | 19 | 8.0 | 40 CFR 141 - Federal MCL |
| 1,2-Dichloroethane | VOC | 5/5/2010 | 11/29/2010 | 57 | 2 | 3.51% | µg/L | 0.10 | 0.10 | 0.33 | 0.82 | 0.38 | Clean Water Act -- Human Health Water + Organism |
| 1,4-Dioxane | VOC | 5/5/2010 | 11/29/2010 | 57 | 1 | 1.75% | µg/L | 7.6 | 7.6 | 20 | 20 | 4.0 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Chloroform | VOC | 5/5/2010 | 11/29/2010 | 57 | 28 | 49.12% | µg/L | 0.10 | 0.10 | 0.11 | 1.9 | 1.4 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Tetrachloroethene | VOC | 5/5/2010 | 11/29/2010 | 57 | 3 | 5.26% | µg/L | 0.18 | 0.18 | 0.44 | 1.1 | 0.081 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Trichloroethene | VOC | 5/5/2010 | 11/29/2010 | 57 | 27 | 47.37% | µg/L | 0.21 | 0.25 | 0.25 | 20 | 0.49 | WAC 173-340-720(4)(b)(iii)(A) and (B) |

Note: Shading indicates that a constituent is identified in the proposed list of contaminants of potential concern in DOE/RL-2009-43, *Sampling and Analysis Plan for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units Remedial Investigation/Feasibility Study*.

Sources: 40 CFR 131, "Water Quality Standards."

40 CFR 141, "National Primary Drinking Water Regulations."

40 CFR 141.66, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels for Radionuclides."

*Clean Water Act of 1977*.

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

WAC 173-340-720(4), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."

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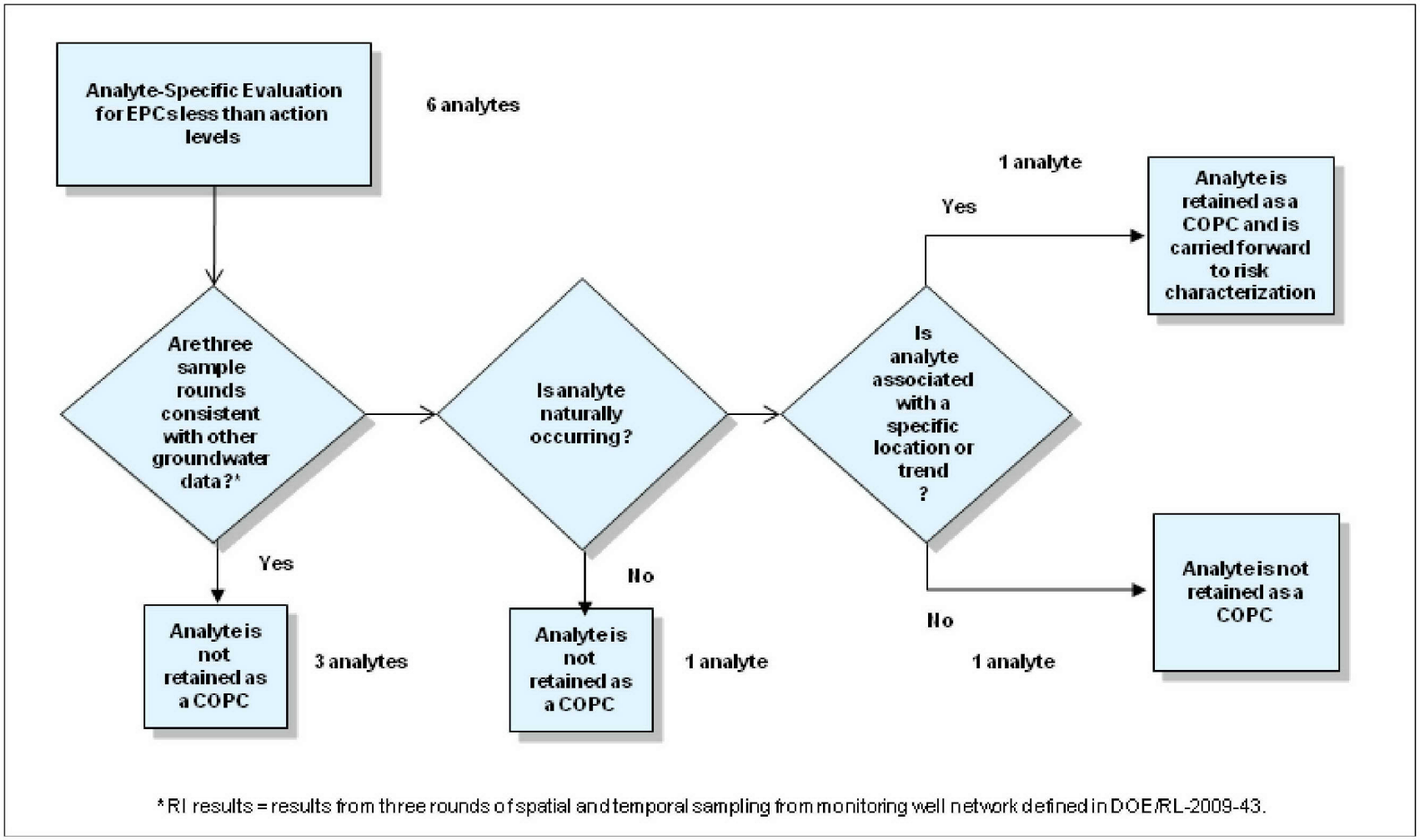


Figure 6-10. Analyte-Specific Evaluation of COPCs with EPCs Less than Action Levels

Chloroform was detected in groundwater samples collected for the RI and the EPC is less than the action level. Detections of chloroform above the action level were reported in groundwater samples collected for the RI and in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. The action level for chloroform is 1.4 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; however, it defaults to the EQL of 5 µg/L reported in 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All chloroform results (detections and MDLs) are less than the EQL. Therefore, chloroform is not retained as a COPC and will not be carried forward into the risk characterization section.

Chromium was detected in groundwater samples collected for the RI and the EPC is less than the AWQC. Detections of chromium above the AWQC were reported in groundwater samples collected for the RI and in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. Except for chromium detected at 199-F5-46 during one sampling round, all chromium concentrations were less than the AWQC of 65 µg/L. Chromium concentrations above the AWQC were reported in the unfiltered sample (98 µg/L) and the filtered sample (93 µg/L) during the same sampling round at well 199-F5-46. Chromium results from two previous and three subsequent sample rounds were less than the AWQC at well 199-F5-46. Chromium concentrations above the AWQC reported at 199-F5-46 do not appear to be associated with a trend. Based on these results, chromium is not retained as a COPC and will not be carried forward into the risk characterization section.

Selenium was detected in groundwater samples collected for the RI and the EPC is less than the action level. Selenium concentrations above the action level of 5 µg/L were measured in three RI wells and were less than the action level in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. However, all selenium concentrations in filtered and unfiltered groundwater samples are less than or equal to the 90$^{th}$ percentile Hanford Site background level of 11 µg/L. Therefore, selenium is not retained as a COPC and will not be carried forward into the risk characterization section or the FS.

Strontium-90 was detected in groundwater samples collected for the RI and the EPC is less than the DWS. Detections of strontium-90 above the DWS were reported in groundwater samples collected for the RI and detections were less than the DWS in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. Except for strontium-90 detected at 199-F5-1 and 199-F5-46, all strontium-90 concentrations were less than the DWS of 8 pCi/L. All five strontium-90 results (12 to 26 pCi/L) from 199-F5-1 were greater than the DWS. One sample round (8.25 pCi/L) was greater than the DWS and five subsequent samples rounds were less than the DWS at 199-F5-46. Strontium-90 concentrations reported at 199-F5-1 appear to be associated with a trend. Based on these results, strontium-90 is retained as a COPC and will be carried forward into the risk characterization section.

#### *6.3.2.3.8 Identify COPCs with 90th Percentile Values Greater than Action Levels*

The 90$^{th}$ percentile values are compared to the lowest available action level for protection of human health and aquatic receptors. A comparison of EPCs to action levels for the 100-FR-3 Groundwater OU is provided in Table 6-40. A flow chart depicting this comparison is provided in Figure 6-11.

**100-FR-3 Groundwater OU.** Of the 13 analytes, 7 have been detected at least once in groundwater and have 90$^{th}$ percentile values greater than their respective action levels (Table 6-40). Four of the seven analytes (Cr(VI), nitrate, tetrachloroethene, and trichloroethene) were identified as historical COPCs in the work plan. A discussion of all analytes with EPCs greater than the action level is provided in the following paragraphs.

Table 6-40. Exposure Point Concentration Summary for the 100-FR-3 OU

| Analyte Name | Analyte Class | Total Number of Samples | Number of Detects | Frequency of Detection | Units | Minimum Detection Limit | Maximum Detection Limit | Minimum Detected Result | Maximum Detected Result | 90th Percentile of RI Data* | Action Level | Action Level Basis | 90th Percentile > Action Level? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Nitrate | Anion | 57 | 56 | 98.25% | µg/L | 274 | 274 | 912 | 139,000 | 109,500 | 45,000 | WAC 173-340-720(4)(b)(iii)(A) and (B) | Yes |
| Aluminum | METAL | 57 | 19 | 33.33% | µg/L | 10 | 10 | 6.1 | 90 | 22 | 50 | 40 CFR 141 - Federal MCL | No |
| Arsenic | METAL | 57 | 48 | 84.21% | µg/L | 0.80 | 0.80 | 0.68 | 12 | 9.0 | 0.018 | Clean Water Act -- Human Health Water + Organism | Yes |
| Chromium | METAL | 57 | 55 | 96.49% | µg/L | 1.0 | 1.0 | 1.3 | 98 | 26 | 65 | Clean Water Act -- Freshwater CCC | No |
| Hexavalent Chromium | METAL | 57 | 23 | 40.35% | µg/L | 2.0 | 2.0 | 2.5 | 92 | 20 | 10 | 40 CFR 131 -- Freshwater CCC | Yes |
| Lithium | METAL | 57 | 38 | 66.67% | µg/L | 4.0 | 4.0 | 4.0 | 53 | 35 | 32 | WAC 173-340-720(4)(b)(iii)(A) and (B) | Yes |
| Selenium | METAL | 57 | 39 | 68.42% | µg/L | 0.30 | 0.60 | 0.64 | 5.4 | 4.2 | 5.0 | Clean Water Act -- Freshwater CCC | No |
| Strontium-90 | RAD | 57 | 8 | 14.04% | pCi/L | -8.40 | 0.99 | 2.0 | 19 | 3.3 | 8.0 | 40 CFR 141 - Federal MCL | No |
| 1,2-Dichloroethane | VOC | 57 | 2 | 3.51% | µg/L | 0.10 | 0.10 | 0.33 | 0.82 | 0.10 | 0.38 | Clean Water Act -- Human Health Water + Organism | No |
| 1,4-Dioxane | VOC | 57 | 1 | 1.75% | µg/L | 7.6 | 7.6 | 20 | 20 | 7.6 | 4.0 | WAC 173-340-720(4)(b)(iii)(A) and (B) | Yes |
| Chloroform | VOC | 57 | 28 | 49.12% | µg/L | 0.10 | 0.10 | 0.11 | 1.9 | 0.46 | 1.4 | WAC 173-340-720(4)(b)(iii)(A) and (B) | No |
| Tetrachloroethene | VOC | 57 | 3 | 5.26% | µg/L | 0.18 | 0.18 | 0.44 | 1.1 | 0.18 | 0.081 | WAC 173-340-720(4)(b)(iii)(A) and (B) | Yes |
| Trichloroethene | VOC | 57 | 27 | 47.37% | µg/L | 0.21 | 0.25 | 0.25 | 20 | 11 | 0.49 | WAC 173-340-720(4)(b)(iii)(A) and (B) | Yes |

Sources: 40 CFR 131, "Water Quality Standards."
40 CFR 141, "National Primary Drinking Water Regulations."
40 CFR 141.66, "National Primary Drinking Water Regulations," "Maximum Contaminant Levels for Radionuclides."
*Clean Water Act of 1977*.
WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."
WAC 173-340-720(4), "Groundwater Cleanup Standards," "Noncarcinogens and Carcinogens."
* This value represents the $90^{th}$ percentile concentration of groundwater data collected under the integrated remedial investigation work plan (DOE/RL-2008-46).

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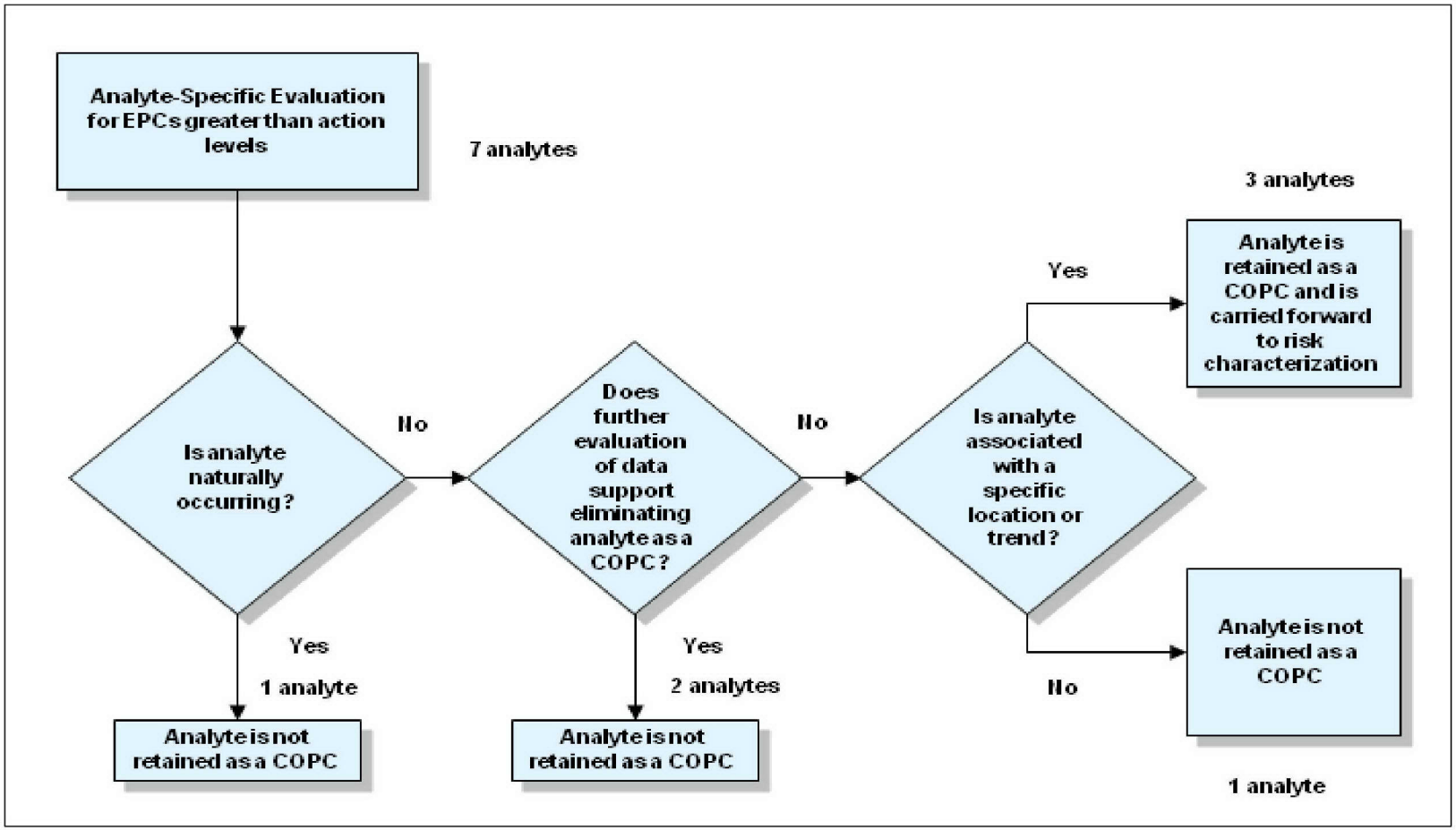



Figure 6-11. Analyte-Specific Evaluation of COPCs with EPCs Greater than Action Levels

1,4-Dioxane was detected in one groundwater sample collected for the RI and the EPC is greater than the action level. 1,4-Dioxane was not analyzed in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. The action level for 1,4-dioxane is 4.0 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; an EQL was not reported 100-F SAP (DOE/RL-2009-43). However, the reporting limit for 1,4-dioxane is 7.6 µg/L and the required detection limit is 20 µg/L. 1,4-Dioxane was detected at a concentration of 20 µg/L at 199-F8-7, and it was reported as nondetected concentrations in two subsequent rounds. 1,4-Dioxane was not detected in any other sample collected for the RI and it does not appear to be associated with a trend at well 199-F8-7. Therefore, 1,4-dioxane is not retained as a COPC and will not be carried into the risk characterization section.

Arsenic is detected in groundwater samples collected for the RI and the EPC is above the action level. Detections of arsenic above the action level have been measured in RI sample and in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. Minimum, maximum, and 90th percentile values for Hanford Site (filtered) background concentrations of arsenic are 0.5, 8.8, and 7.9 µg/L, respectively. Hanford site background values are based on filtered sample results, background values would likely be higher for samples that are not filtered. Arsenic concentrations in unfiltered samples range between 0.68 and 12 µg/L and concentrations range between 0.82 and 11 µg/L in filtered samples. At 199-F1-2, unfiltered results range from 3.6 to 9.7 µg/L and filtered results range from 9.1 to 9.2 µg/L. At 199-F7-1, unfiltered results range from 9.9 to 11.2 µg/L and filtered results range from 9.4 to 10.9 µg/L. At 199-F5-48, one of three unfiltered results was greater than background (2.2 to 9.9 µg/L) and all filtered results were less than background (0.8 to 2.6 µg/L). Based on these results, the presence of arsenic at wells 199-F1-2, 199-F7-1, and 199-F5-48 is slightly greater than background range and likely to be naturally occurring. Therefore, arsenic is a not retained as a COPC and will not be carried forward into the risk characterization section.

Cr(VI) was detected in groundwater samples collected for the RI and the EPC is above the AWQC. Detections of Cr(VI) above the AWQC have also been measured in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. Cr(VI) is associated with a trend at 199-F5-44 (less than 2 to 12 µg/L), 199-F5-46 (20 to 93 µg/L), 199-F5-48 (11 to 16 µg/L), and 199-F5-6 (less than 2 to 61 µg/L) with concentrations of Cr(VI) consistently greater than the AWQC. Cr(VI) has also been infrequently detected at concentrations greater than the AWQC at 199-F5-45 (7.6 to 21 µg/L) and 199-F5-47 (11 µg/L). Therefore, Cr(VI) is retained as a COPC and will be carried forward into the risk characterization section.

Lithium is detected in groundwater samples collected for the RI and the EPC is above the action level. Detections of lithium above the action level have also been measured in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. Lithium concentrations in unfiltered samples ranged between 4 and 53 µg/L and between 4 and 54 µg/L in filtered samples. Unfiltered and filtered results from one of three rounds were reported above the action level at 199-F5-4 (less than 4 to 39 µg/L), 199-F5-45 (less than 4 to 38 µg/L), 199-F5-48 (less than 4 to 36 µg/L), 199-F8-3 (less than 4 to 54 µg/L), 199-F8-4 (7 to 35 µg/L), and 199-F8-7 (9 to 43 µg/L). However, the unfiltered and filtered results from two subsequent rounds at the same wells were less than the action level. Therefore, lithium concentrations above the action level do not appear to be associated with a trend. Based on these results, lithium is a not retained as a COPC and will not be carried forward into the risk characterization section.

Nitrate was detected in groundwater samples collected for the RI and the EPC is above the DWS. Detections of nitrate above the DWS have also been measured in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. Nitrate is associated with a trend at

199-F5-4 (88,100 to 133,000 µg/L), 199-F5-45 (88,500 to 99,200 µg/L), 199-F5-46 (34,000 to 64,200 µg/L), 199-F5-47 (93,000 to 134,000 µg/L), 199-F5-48 (75,300 to 111,000 µg/L), 199-F7-1 (52,700 to 59,800 µg/L), 199-F7-2 (56,700 to 65,100 µg/L), 199-F7-3 (78,800 to 114,000 µg/L), 199-F8-2 (68,200 to 84,100 µg/L), 199-F8-3 (77,900 to 139,000 µg/L), 199-F8-4 (58,900 to 79,700 µg/L), and 199-F8-7 (91,600 to 122,000 µg/L) with concentrations of nitrate consistently greater than the DWS. Therefore, nitrate is a retained as COPC and will be carried forward into the risk characterization section.

Tetrachloroethene was detected in groundwater samples collected for the RI and the EPC is above than the action level. Detections of tetrachloroethene above the action level have also been measured in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. The action level for tetrachloroethene is 0.081 µg/L based on the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level; however, it defaults to the EQL of 5 µg/L reported in 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. All tetrachloroethene results (detected concentrations and MDLs) are less than the EQL. Therefore, tetrachloroethene is not retained as a COPC and will not be carried forward into the risk characterization section.

Trichloroethene was detected in groundwater samples collected for the RI and the EPC is above than the action level. Detections of trichloroethene above the action level have also been measured in the larger population of wells sampled over the past 5 years as described in Sections 4.3.2 and 6.3.2.3.1. The action level for trichloroethene is 0.49 µg/L based on the MTCA, "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level; however, it defaults to the EQL of 1 µg/L reported in 100-F/IU SAP (DOE/RL-2009-43) when the analytical method cannot achieve the action level. Trichloroethene is associated with a trend at 199-F5-47 (0.21 to 4.3 µg/L), 199-F5-48 (1.0 to 2.2 µg/L), 199-F7-1 (9.7 to 20 µg/L), 199-F7-2 (2.6 to 5.5 µg/L), 199-F7-3 (5 to 10 µg/L), 199-F8-4 (0.68 to 1.3 µg/L), and 699-77-36 (8.5 to 13 µg/L) with concentrations consistently greater than the EQL. Therefore, trichloroethene is retained as a COPC and will be carried forward into the risk characterization section.

### *6.3.2.4 Summary of COPCs*

Table 6-41 presents a summary of the COPCs identified for the 100-FR-3 Groundwater OU. This list of COPCs represents the analytes most likely to contribute to overall risk within the 100-FR-3 Groundwater OU. These analytes are evaluated in the risk characterization section.

#### *6.3.2.4.1 100-FR-3 Groundwater Area*

Cr(VI), nitrate and trichloroethene were retained as COPCs because the 90$^{th}$ percentile concentration exceeded the action level. As described in Section 6.3.2.3, strontium-90 is retained as COPC because it is associated with a long-term trend and with a continuing local source of contamination.

Table 6-41. Summary of Groundwater COPCs Identified for the 100-FR-3 Groundwater OU

| 100-FR-3 Groundwater OU | | |
|---|---|---|
| **Metals** | **VOCs** | **Radionuclides** |
| Antimony[b] | Trichloroethene | Strontium-90[a] |
| Cadmium[b] | | |
| Cobalt[b] | | |

Table 6-41. Summary of Groundwater COPCs Identified for the 100-FR-3 Groundwater OU

| 100-FR-3 Groundwater OU |
|---|
| Cr(VI) |
| **Nonradioactive Anions** |
| Nitrate |

a. EPC did not exceed action level, but was retained as a COPC because of localized contamination.

b. EPC did not exceed action level, but infrequent detections above action level result in uncertain status and warrant further evaluation in the FS.

The COPC identification process identified three analytes for the 100-FR-3 Groundwater OU that are considered COPCs and warrant further evaluation in the FS. The occurrence of antimony, cadmium, and cobalt in groundwater is uncertain because these analytes historically have been detected in groundwater at concentrations above their respective action level; however, their presence was not associated with a specific location or a trend and the analytical methods used were not of sufficient accuracy for risk characterization purposes. In addition, the EPCs for these analytes are less than their respective action level. Therefore, antimony, cadmium, and cobalt are considered COPCs where they warrant further evaluation in the FS; however, they will not move forward into the risk characterization section.

### 6.3.3 Exposure Assessment

The exposure assessment component of the risk assessment typically identifies the populations that may be exposed, the routes by which these receptors may become exposed, and the magnitude, frequency, and duration of potential exposures.

#### *6.3.3.1 Contaminant Sources*

The primary sources of contamination in the 100-F Source OU is the water-cooled nuclear reactor (105-F) and the structures (e.g., fuel storage basins) and processes (e.g., sodium dichromate process) associated with reactor operations and the experimental animal farm. The effect of Hanford site-specific past practices in the 100-IU-2 and 100-IU-6 OUs is limited in nature. A complete discussion of primary and secondary contaminant sources is provided in Section 5.2.

#### *6.3.3.2 Release Mechanisms and Environmental Transport Media*

The primary COPC release mechanisms and transport pathways evaluated at 100-F Source OU and the100-IU-2 and 100-IU-6 OUs are discussed in Sections 5.3 and 5.4, and include the following:

- Direct contact with groundwater containing COPCs
- Volatilization of COPCs in groundwater from showering or household activities
- Discharge of groundwater to the Columbia River through upwelling and seeps

#### *6.3.3.3 100-FR-3 Groundwater OU*

The 100-FR-3 Groundwater OU is generally distinguished by the presence of Cr(VI), nitrate, strontium-90, and trichloroethene plumes. The nitrate plume has the highest concentrations in the central portion of the 100-F Area and extends southward. A strontium-90 plume with concentrations above the federal MCL is present in the eastern portion of the 100-F Area. Trichloroethene concentrations in the southwestern 100-F Area exceed the federal MCL. Cr(VI) concentrations above the ambient water quality criteria have been observed near the 116-F-4 Retention Basins and the 116-F-9 Trench. The

100-FR-3 Groundwater OU represents all the plume sources in 100-F and is evaluated as a single exposure area.

The 100-IU-2 and 100-IU-6 Groundwater Area does not have any groundwater plumes specifically associated with releases within the 100-IU-2 and 100-IU-6 waste sites. Rather, the presence of groundwater contaminants in this area is the result of contaminants that have dispersed from Groundwater OUs that originate in the 200 West and 200 East Areas. In addition, nitrate that originates from the 100-FR-3 Groundwater OU extends into the eastern portion of the 100-IU-2 and 100-IU-6 Groundwater Area.

The primary objective for evaluating the 100-FR-3 Groundwater OU as a single exposure area is to provide information necessary to determine the need for remedial action and to use the information to select the best remedy. Evaluating the 100-FR-3 Groundwater OU as a single exposure area captures the highest contaminant concentrations from the primary sources of contamination.

#### *6.3.3.4 Potentially Complete Human Exposure Pathways and Receptors*

This section describes the potentially complete exposure pathways and receptors that specifically addressed in the action levels (see Section 6.3.2.2) evaluated in this groundwater risk assessment.

##### *6.3.3.4.1 Action Levels Used to Evaluate Protection of Human Health*

All the action levels for use as a drinking water source consider ingestion as a complete and significant pathway for exposure. Washington State regulations assume that inhalation of vapors for VOCs is also a complete and significant exposure pathway. Washington State regulations do not include the dermal contact exposure route in the equations for calculation of potable groundwater cleanup levels, whereas federal regulations consider dermal contact exposure a complete but insignificant groundwater contaminant exposure pathway. Elimination of the dermal contact exposure route from action levels may result in an overestimation of the cleanup level; uncertainties associated with exclusion of this exposure route are addressed in Section 6.3.6.4.

For groundwater with the potential to affect surface water, federal water quality standards assume that exposure to humans occurs through ingestion of water and consumption of fish tissue. These federal standards are developed for protection of human health where groundwater discharges to surface water that is used as a drinking water source and used for fishing. Washington State regulations as defined in MTCA ("Surface Water Cleanup Standards" [WAC 173-340-730(3)(b)]) developed surface water standards that assume that exposure occurs through consumption of fish tissue.

##### *6.3.3.4.2 Action Levels Used to Evaluate Protection of Aquatic Receptors*

The objectives and methodology for deriving the numerical AWQC are described in *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (PB85-227049). The AWQC are intended to provide a reasonable level of protection of all except a small fraction (0.05) of the taxa, unless a commercially or recreationally important species is very sensitive. Protection of the following aquatic organisms and their uses are defined in *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (PB85-227049) as prevention of unacceptable long-term and short-term effects:

- Commercially, recreationally, and other important species
- Fish and benthic invertebrate assemblages in rivers and streams
- Fish, benthic invertebrate, and zooplankton assemblages in lakes, reservoirs, estuaries, and oceans

Numeric values are expressed as two numbers, the criteria maximum concentration (CMC) and criteria continuous concentration (CCC), which provide an appropriate degree of protection of aquatic organisms

and their uses from acute and chronic toxicity to animals, toxicity to plants, and bioaccumulation by aquatic organisms. The CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. EPA derives acute criteria from 48- to 96-hour tests of lethality or immobilization. The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect. EPA derives chronic criteria from longer-term (often greater than 28 days) tests that measure survival, growth, reproduction or, in some cases, bioconcentration. The CMC and the CCC are two of the six parts of the aquatic life criterion. The other four parts are the acute averaging period, chronic averaging period, acute frequency of allowed exceedance, and chronic frequency of allowed exceedance. The lower of the CMC or the CCC is the numeric water quality criteria used as the action level for protection of freshwater species.

### 6.3.4 Toxicity Assessment

The toxicity assessment component evaluates the relationship between the magnitude of exposure to an analyte and the likelihood of adverse health effects to potentially exposed populations. Similar to the exposure assessment, the comparison to action levels takes into consideration the likelihood of an adverse health effect to occur to the potentially exposed population. The risk-based concentrations, such as the "Groundwater Cleanup Standards" (WAC 173-340-720), are developed using toxicological information published at EPA's IRIS database and EPA's hierarchy of toxicity values described in Section 6.2.4.2. The assignment of action levels to COPCs is described in Section 6.3.2.2.

#### *6.3.4.1 State and Federal Maximum Contaminant Levels for Nonradionuclides*

The MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse health effects occur, allowing for an adequate margin of safety. MCLGs are non-enforceable health goals. EPA establishes the MCL, an enforceable standard, based on the MCLG. The MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. Before the *Safe Drinking Water Act of 1974* (SDWA) amendments in 1996, the MCL was set as close to the MCLG as was feasible. The 1996 Amendments to the SDWA permit consideration of costs and benefits in establishing an MCL. Primary MCLs are legally enforceable standards and protect public health by limiting the levels of contaminants in drinking water. Secondary MCLs are non-enforceable guidelines regulating those contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

*Six-Year Review Chemical Contaminants Health Effects Technical Support Document* (EPA 822-R-03-008) describes how MCLGs are derived. MCLGs are developed using an oral RfD for contaminants that exhibit a threshold toxic effect. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious noncancer effects during a lifetime. EPA generally assumes that the relative source contribution from drinking water is 20 percent of the RfD, unless other exposure data for the chemical are available. This allows 80 percent of the total exposure to come from sources other than drinking water, such as exposure from food, inhalation, or dermal contact.

#### *6.3.4.2 Maximum Contaminant Levels for Radionuclides in Drinking Water*

Current MCLs for radionuclides are set at 4 mrem/yr for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity (including radium-226, but excluding uranium and radon), and 5 pCi/L combined for radium-226 and radium-228. A mass-based concentration MCL of 30 μg/L has been established for uranium. The current regulations for beta emitters specify that MCLs are to be calculated based upon an annual dose equivalent of 4 mrem to the total body or any internal organ.

It is further specified that the calculation be performed based on a 2 L (0.5 gal)/day drinking water intake using the 168-hour data listed in *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure* (NBS Handbook 69).

#### 6.3.4.3 Washington State Regulations

Toxicological parameter values are obtained from the CLARC database (Ecology, 2009) compendium of technical information related to the calculation of cleanup levels under MTCA (WAC 173-340). The sources for the oral cancer potency values and RfDs are provided in the CLARC database (Ecology, 2009). The sources for identifying reference doses and carcinogenic potency factors are defined in MTCA (HHRA Procedures [WAC 173-340-708(7) and WAC 173-340-708(8)]).

#### 6.3.4.4 Toxicity Values

The sources of toxicity values for human health are the same as those described in Section 6.2.4.2 of this report.

As discussed in Section 6.3.3.4.2, the lower of the CMC or the CCC is the numeric water quality criteria used as the action level for protection of freshwater species. *Technical Support Document for Water Quality-based Toxics Control* (EPA/505/2-90-001) explains that development of national numerical water quality criteria for the protection of aquatic organisms is a complex process that uses information from many areas of aquatic toxicology. After a decision is made that a national criterion is needed for a particular material, all available information concerning toxicity to and bioaccumulation by aquatic organisms is collected and reviewed for acceptability. If enough acceptable data for 48- to 96-hour toxicity tests on aquatic animals are available, they are used to derive the acute criterion. If sufficient data on the ratio of acute to chronic toxicity concentrations are available, they are used to derive the chronic or long-term exposure criteria. The chronic criteria can also be calculated directly if sufficient data are available. If justified, one or both of the criteria may be related to another water quality characteristic (e.g., pH, temperature, or hardness). Separate criteria are developed for fresh water and salt water.

### 6.3.5 Risk Characterization

Risk characterization is the final step of the HHRA process. In this step, the toxicity values are combined with the estimated chemical intakes for the receptor populations in order to quantitatively estimate both carcinogenic risks and risks from noncarcinogens. The risk characterization step is completed through the comparison of the EPC to the action level using the equations presented in Section 6.3.5.1. As described earlier in this section, the comparison to action levels determines whether existing groundwater concentrations are protective of HHE. It is also used to determine if current groundwater concentrations have the potential to exceed an HI greater than 1 or the upper end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use.

#### 6.3.5.1 Protectiveness Evaluation

Protectiveness of human health is determined by the comparison of 90$^{th}$ percentile groundwater concentrations to existing federal or state MCLs. Similarly, protectiveness of human and aquatic receptors is determined by the comparison of 90$^{th}$ percentile groundwater concentrations to water quality criteria established under Section 304 or 303 of the *Clean Water Act of 1977* and Washington State water quality standards.

This risk characterization step is included to address the presence of multiple exposure pathways or the potential for exposure to multiple nonradiological contaminants. This step is included to address the requirements of MTCA (HHRA Procedures [WAC 173-340-708(5)(a) and WAC 173-340-708(6)(b)]). These regulations require that cleanup levels be adjusted downward to take into account exposure to

multiple hazardous substances or multiple pathways of exposure. This adjustment needs to be made only if without this adjustment, the HI would exceed 1 or the total ELCR would exceed 1 in 100,000 ($1 \times 10^{-5}$).

To determine the potential to exceed an HI greater than 1 or the upper end of the NCP (40 CFR 300) risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use, the following standards are used:

- "Groundwater Cleanup Standards" (WAC 173-340-720)
- "Surface Water Cleanup Standards" (WAC 173-340-730)
- *National Recommended Water Quality Criteria* (EPA, 2009a)

For the purposes of this risk assessment, the potential for unacceptable human health risk is identified using the following risk thresholds:

- ELCR values are compared to the "target range" of $10^{-4}$ to $10^{-6}$ that is generally used by EPA. The MTCA (WAC 173-340) states that cancer risks resulting from multiple hazardous substances should not exceed $1 \times 10^{-5}$ for unrestricted land use. ELCR values within or exceeding the target range require a risk management decision that includes evaluating site-specific characteristics and exposure scenario factors to assess whether remedial action is warranted.

- An HI (the sum of the ratios of the chemical intake to the RfDs for all COPCs) greater than 1 indicates that some potential exists for adverse noncancer health effects associated with exposure to the COPCs.

Although this groundwater risk assessment produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision making. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them.

Protectiveness of humans from exposure to beta/photon emitters is determined by an annual dose equivalent to the body or any internal organ and determined by comparison to activity concentrations in drinking water for alpha emitters; therefore, the sum of fractions is used determine the annual dose from exposure to beta/photon emitters.

#### *6.3.5.1.1 Cancer Risk Estimation Method*

The potential for cancer effects is evaluated by estimating the ELCRs. This risk is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to site chemicals occurs). To estimate the cancer risks from exposure to an individual carcinogen from all exposure routes considered, the following equation is used:

$$Risk_I = \frac{EPC_{water}}{CUL_{carcinogen}} \times TR$$

where:

$Risk_I$ = ELCR for individual chemical

$EPC_{water}$ = 90th percentile concentration in groundwater (µg/L)

$CUL_{carcinogen}$ = Groundwater cleanup level based on $10^{-6}$ carcinogenic effect (µg/L)

$TR$ = Target ELCR for individual hazardous substance for unrestricted land use ($10^{-6}$)

To estimate the cancer risks from exposure to multiple carcinogens from all exposure routes considered, the following equation is used:

$$Risk_T = \sum_i \frac{EPC_{water}}{CUL_{carcinogen}} \times TR$$

where:

$Risk_T$ = Total ELCR for all chemicals

$EPC_{water}$ = 90th percentile concentration in groundwater (µg/L)

$CUL_{carcinogen}$ = Groundwater cleanup level based on $10^{-6}$ carcinogenic effect (µg/L)

$TR$ = Target ELCR for individual hazardous substance for unrestricted land use ($10^{-6}$)

$i$ = The sum of the ratios for the $i^{th}$ chemical

#### *6.3.5.1.2 Noncancer Risk Estimation Method*

For noncancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (i.e., its RfD). The ratio of the chronic daily intake divided by RfD is termed the HQ.

When the HQ for a chemical exceeds 1 (i.e., exposure exceeds RfD), a concern exists for potential noncancer health effects. To estimate the HQ from all exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{EPC_{water}}{CUL_{noncarcinogen}}$$

where:

$HQ$ = HQ for individual chemical

$EPC_{water}$ = 90th percentile concentration in groundwater (µg/L)

$CUL_{noncarcinogen}$ = Groundwater cleanup level based on HQ = 1 noncarcinogenic effects (µg/L)

To estimate the HI from all exposure routes considered for multiple hazardous substances, the following equation is used:

$$HI_T = \sum_i \frac{EPC_{water}}{CUL_{noncarcinogen}}$$

where:

$HI_T$ = Total HI for all chemicals

$EPC_{water}$ = 90th percentile concentration in groundwater (µg/L)

$CUL_{noncarcinogen}$ = Groundwater cleanup level based on HQ=1 noncarcinogenic effects (µg/L)

$i$ = The sum of the ratios for the $i^{th}$ chemical

#### 6.3.5.1.3 *Estimating the Sum of Fractions and 4 mrem/yr Dose Equivalent*

An annual cumulative dose equivalent of 4 mrem to the total body or any internal organ from beta and photon emitters is considered protective of human health. The sum-of-fractions (SOF) is used to determine whether the contribution of each radioisotope is greater than the cumulative annual dose equivalent of 4 mrem. The following equation is used to determine if the 4 mrem standard is exceeded when a mixture of radioisotopes is present:

$$Sum\ of\ Fractions = \left( \frac{A\left(\frac{pCi}{L}\right)}{MCL_A\left(\frac{pCi}{L}\right)} + \frac{B\left(\frac{pCi}{L}\right)}{MCL_B\left(\frac{pCi}{L}\right)} + \bullet\bullet\bullet \right)$$

where:

$A$ = The EPC activity concentration of specific beta/photon emitting nuclide A

$B$ = The EPC activity concentration of specific beta/photon emitting nuclide B

$MCL_A$ = The derived single-nuclide beta/photon emitting MCL-equivalent activity concentration for nuclide A

$MCL_B$ = The derived single-nuclide beta/photon emitting MCL-equivalent activity concentration for nuclide B

The 4 mrem standard is not exceeded if the SOF is less than 1. Each fraction is converted to a dose equivalent of 4 mrem/yr by multiplying the fraction by 4.

### 6.3.6 Risk Characterization Results Using Action Levels

Action levels that are considered protective of HHE were used to identify COPCs that warrant further evaluation in the FS. The lowest of the available action levels was selected for comparison if more than one action level exists for a certain analyte. The analytes listed in Table 6-42, Table 6-43, Table 6-38, and Table 6-41 are considered COPCs because the 90$^{th}$ percentile groundwater concentration is greater than the lowest available action level or the analyte is measured at concentrations above the lowest action level in a localized area.

#### 6.3.6.1 *100-FR-3 Groundwater Operable Unit*

Groundwater in the 100-FR-3 Groundwater OU is evaluated as a potential drinking water source and near-shore groundwater has the potential to discharge to the Columbia River. Table 6-42 provides a summary of the COPCs, the 90th percentile groundwater concentration, federal and state MCLs, and the MTCA "Groundwater Cleanup Standards" (WAC 173-340-720) for carcinogenic and noncarcinogenic effects. Table 6-43 provides a summary of the COPCs, the 90th percentile groundwater concentration, and federal and state surface water quality standards. These standards (listed in Tables 6-42 and 6-43) represent the action levels that were exceeded by at least one COPC.

Table 6-42. Summary of Current Conditions 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173-340-720 Groundwater Cleanup Levels for the 100-FR-3 Groundwater OU (Human Health Action Levels)

| COPCs | Units | 90th Percentile Value | Federal MCL | State MCL | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|
| | | | | | Noncarcinogens | Carcinogens at 10-6 Risk Level | Carcinogens at 10-5 Risk Level |
| Cr(VI) | µg/L | 20 | -- | -- | 48 | -- | -- |
| Nitrate | µg/L | 109,500 | 45,000 | 45,000 | 113,600 | -- | -- |
| Strontium-90* | pCi/L | 3.3 | 8.0 | -- | -- | -- | -- |
| Trichloroethene | µg/L | 11 | 5.0 | 5.0 | -- | 0.49 | 4.9 |

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

* EPC did not exceed action level, but was retained as a COPC because of localized contamination.

Table 6-43. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State Water Quality Standards for the 100-FR-3 Groundwater OU (Aquatic Action Levels)

| COPCs | Units | 90th Percentile Value | AWQC | | WAC 173-201A | 40 CFR 131 Water Quality Standards | |
|---|---|---|---|---|---|---|---|
| | | | Freshwater CMC (acute) | Freshwater CCC (chronic) | Freshwater CCC (chronic) | Freshwater CMC (acute) | Freshwater CCC (chronic) |
| Cr(VI) | µg/L | 20 | 16 | 11 | 10 | 15 | 10 |
| Nitrate | µg/L | 109,500 | -- | -- | -- | -- | -- |
| Strontium-90 | pCi/L | 3.3 | -- | -- | -- | -- | -- |
| Trichloroethene | µg/L | 11 | -- | -- | -- | -- | -- |

Sources: 40 CFR 131, "Water Quality Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

#### *6.3.6.1.1 Protectiveness Evaluation for Human Health*

The protectiveness evaluation for human health is performed to help determine if a CERCLA remedial action is appropriate. *Rules of Thumb for Superfund Remedy Selection* (EPA 540-R-97-013) states that a remedial action is generally appropriate when a regulatory standard that helps define protectiveness (a federal or state MCL or nonzero MCLG for current or potential drinking water aquifers) is exceeded.

The 90th percentile groundwater concentration for strontium-90 is less than the DWS developed for the protection of human health and is a minimal contributor to overall dose (1.7 mrem/yr [see Table 6-44]). Of the 19 wells, 2 monitoring wells (199-F5-1 and 199-F5-46) were reported with strontium-90 concentrations greater than the DWS of 8 pCi/L. Strontium-90 has been detected in well 199-F5-1 at concentrations above the MCL, indicating its presence is localized downgradient of the 116-F-2 Liquid Waste Disposal Trench, the 116-F-14 Retention Basin, and the 116-F-9 Animal Waste

Leaching Trench. A single detection above the DWS was measured at 199-F5-46. Strontium-90 is identified as a COPC, indicating the need to evaluate potential remedial technologies for strontium-90 in the FS. A detailed discussion of the strontium-90 plume is provided in Section 4.3.2.

Table 6-44. Summary of 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions for the 100-FR-3 Groundwater OU

| COPC | Units | 90th Percentile Value | Federal MCL | Individual Fraction |
|---|---|---|---|---|
| Strontium-90* | pCi/L | 3.3 | 8 | 0.41 |
| **Sum of Fractions** | | | | **0.41** |
| **Cumulative Annual Dose (mrem)** | | | | **1.7** |

Note: MCL; derived single-nuclide MCL-equivalent activity concentration.

* EPC did not exceed action level, but was retained as a COPC because of localized contamination.

A federal MCL is not available for Cr(VI); therefore, the protectiveness evaluation for human health was not performed. Cr(VI) is discussed in the protectiveness evaluation for aquatic organisms and the risk evaluation.

The 90th percentile groundwater concentration for nitrate is greater than the federal and state DWS of 45,000 µg/L developed for the protection of human health. Of the 19 monitoring wells, 11 monitoring wells (199-F5-4, 199-F5-45, 199-F5-46, 199-F5-48, 199-F7-1, 199-F7-2, 199-F7-3, 199-F8-2, 199-F8-3, 199-F8-4, and 199-F8-7) were reported with concentrations of nitrate above the DWS of 45,000 µg/L. Nitrate concentrations above the DWS were also measured at 199-F5-47, based on results from the larger population of wells and longer sampling timeframe. Nitrate is identified as a COPC indicating the need to evaluate potential remedial technologies for nitrate in the FS. A detailed discussion of the nitrate plume is provided in Section 4.3.2.

The 90th percentile groundwater concentration of trichloroethene is greater than the federal and state DWS of 5 µg/L developed for the protection of human health. Of the 19 wells, 4 monitoring wells (199-F7-1, 199-F7-2, 199-F7-3, and 699-77-36) were reported with concentrations of trichloroethene above the DWS of 5 µg/L. Trichloroethene is identified as a COPC indicating the need to evaluate potential remedial technologies for trichloroethene in the FS. A detailed discussion of the trichloroethene plume is provided in Section 4.3.2.

#### *6.3.6.1.2 Protectiveness Evaluation for Aquatic Receptors*

As described in the exposure assessment, groundwater discharges to the Columbia River through upwelling and seeps. The point of compliance is defined in MTCA ("Surface Water Cleanup Standards" [WAC 173-340-730(7)(a)]) as the point or points at which hazardous substances are released to surface waters of the state. "Surface Water Cleanup Standards" (WAC 173-340-730(7)(b)) indicate that no mixing zone shall be allowed to demonstrate compliance with surface water cleanup levels. Groundwater EPCs from the entire 100-FR-3 Groundwater OU are compared to the ambient water quality standards to determine if groundwater concentrations discharging to the Columbia River are in compliance with federal and state standards.

Action levels for strontium-90 are not included because the federal MCL for protection of human health is considered protective of aquatic organisms. A need to evaluate potential remedial technologies for strontium-90 in the FS was established based on the results of the protectiveness evaluation for human health.

Federal and state water quality standards for the protection of freshwater organisms are not published for trichloroethene or nitrate; therefore, a protectiveness evaluation for aquatic receptors is not included. Trichloroethene and nitrate are evaluated in the protectiveness evaluation for human health in Section 6.3.6.1 and the risk evaluation is presented in Section 6.3.6.3.

The 90$^{th}$ percentile groundwater concentration for Cr(VI) is greater than the "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A) freshwater AWQC value of 10 µg/L. The 90$^{th}$ percentile groundwater concentration is not considered protective of aquatic organisms and Cr(VI) is identified as a COPC. The results of this evaluation indicate the need to evaluate potential remedial technologies for Cr(VI) in the FS. Of the 19 monitoring wells, five monitoring wells (199-F5-44, 199-F5-45, 199-F5-46, 199-F5-48, and 199-F5-6) were reported with concentrations of Cr(VI) above the "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A) freshwater AWQS value of 10 µg/L. Cr(VI) concentrations above the AWQC were also measured at 199-F5-47, based on results from the larger population of wells and longer sampling timeframe. The following lists the approximate distance from the Columbia River for those wells reporting concentrations greater than 10 µg/L:

- 199-F5-44 (35.5 m [116 ft])
- 199- F5-45 (32.2 m [1,509 ft])
- 199- F5-46 (376 m [1,234 ft])
- 199 F5-47 (790 m [2,591 ft])
- 199- F5-48 (641 m [2,103 ft])
- 199- F5-6 (134 m [440 ft])

Although all monitoring wells within the plume area were compared to the AWQC concentration, only near-river wells would need to meet this criterion. A detailed discussion of Cr(VI) plume is presented in Section 4.3.2.

#### *6.3.6.1.3 Risk Evaluation*

The potential cumulative ELCR from all nonradiological carcinogenic COPCs is $2.2 \times 10^{-5}$, which is greater than the HHRA Procedures (WAC 173-340-708) risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and less than the upper NCP (40 CFR 300) threshold of $1 \times 10^{-4}$. Table 6-45 shows the only contributor to risk is trichloroethene ($2.2 \times 10^{-5}$, 100 percent contribution). Trichloroethene is identified as a COPC based on the results of this evaluation.

The HI for the 100-FR-3 Groundwater OU is 1.4, which is greater than the EPA and MTCA (WAC 173-340) target HI of 1. The primary contributor to the noncancer HI is nitrate (HQ = 0.96, 69 percent contribution). The individual HQs for Cr(VI) and nitrate are each less than one. The primary noncancer health effects associated with exposure to nitrate is methemoglobinemia. Nitrate and Cr(VI) are not identified as COPCs based on the results of this evaluation.

### 6.3.7 Risk Characterization Results of the EPA Tap Water Scenario

This section summarizes the results for each of the exposure pathways associated with use of groundwater as a drinking water (tap water) source. As described at Regional Screening Levels (EPA, 2009b), the tap water scenario reflects an RME scenario and is consistent with a residential exposure scenario as it incorporates default residential exposure assumptions. The results of the tap water risk assessment are provided in *Tap Water Risk Assessment for the 100-FR-3 Groundwater Operable Unit* (ECF-100FR3-11-0026) in Appendix G.

Table 6-45. Summary of 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Noncancer Hazard Index for the 100-FR-3 Groundwater OU

| COPC | Units | 90th Percentile Value | WAC 173-340-720 Cleanup Levels | | | |
|---|---|---|---|---|---|---|
| | | | Noncarcinogens | HQ | Carcinogens at $10^{-6}$ Risk Level | ELCR |
| Trichloroethene | µg/L | 11 | -- | -- | 0.49 | **$2.2 \times 10^{-5}$** |
| **Total ELCR** | | | | | | **$2.2 \times 10^{-5}$** |
| Cr(VI) | µg/L | 20 | 48 | 0.42 | -- | -- |
| Nitrate | µg/L | 109,500 | 113,600 | 0.96 | -- | -- |
| **Hazard Index** | | | | **1.4** | | |

Source: WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

Potentially complete exposure routes for the EPA tap water scenario include exposure of adult and children residents to groundwater used as a drinking water source and include the following:

- Ingestion of drinking water
- Inhalation of volatiles when showering and other domestic purposes
- Dermal contact with skin while showering and using groundwater for other domestic purposes (such as washing dishes)

It should be noted that EPA considers external radiation to be a significant exposure route only for radionuclides in soil (risk assessment guide [EPA/540/1-89/002]). External radiation from radionuclides in water is considered insignificant because of its shielding effects. EPA does not publish radionuclide cancer slope factors to quantify cancer risk from external or dermal exposure to radioactive analytes in groundwater. Radionuclide cancer risk is therefore calculated in this evaluation only for ingestion and inhalation exposure routes.

### *6.3.7.1 Use of Groundwater as a Potential Tap Water Source*

In order to provide a comprehensive evaluation of current risks associated with the 100-FR-3 Groundwater OU, potential exposure to groundwater as a tap water source is evaluated under this scenario. Potential routes of exposure to groundwater include ingestion, dermal contact, and inhalation of volatiles during household activities.

#### *6.3.7.1.1 100-FR-3 Groundwater Operable Unit*

As shown in Table 6-46, the total ELCR is $2.2 \times 10^{-4}$ for nonradiological analytes and $9.8 \times 10^{-6}$ for radiological analytes. The total ELCR for nonradiological analytes is greater than the EPA upper target risk threshold of $1 \times 10^{-4}$ and is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ for radiological analytes.

Table 6-46. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations for the 100-FR-3 Groundwater OU

| Exposure Route | ELCR | HI |
|---|---|---|
| **Nonradionuclide COPCs** | | |

Table 6-46. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations for the 100-FR-3 Groundwater OU

| Exposure Route | ELCR | HI |
|---|---|---|
| Ingestion | 2.2 × 10-4 | 2.4 |
| Dermal | 4.4 × 10-6 | 0.09 |
| Inhalation | 1.5 × 10-6 | <0.01 |
| **Total** | **2.2 × 10-4** | **2.5** |
| **Radionuclide COPCs** | | |
| Ingestion | 9.4 × 10-6 | -- |
| Inhalation | 4.0 × 10-7 | -- |
| **Total** | **9.8 × 10-6** | **--** |
| **Total Cumulative ELCR*** | **2.3 × 10-4** | **--** |

* Total cumulative ELCR represents the sum of the total nonradionuclide ELCR and the total radionuclide ELCR.
-- = HI is not applicable

As shown in Table 6-47, the major contributors to the total cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) are trichloroethene ($1.8 \times 10^{-5}$; 7.9 percent contribution), strontium-90 ($3.5 \times 10^{-6}$; 1.5 percent contribution), and tritium ($3.0 \times 10^{-6}$; 1.3 percent contribution). Contribution to the ELCR is elevated for arsenic ($2.0 \times 10^{-4}$; 86 percent contribution), where measured concentrations are within natural background values.

As shown in Table 6-48, the HI is 2.5, which is greater than the EPA target HI of 1.0. All individual analytes (arsenic, fluoride, Cr(VI), lithium, molybdenum, nitrate, strontium, and vanadium) that contribute greater than one percent of the HI also report an HQ less than 1. The mechanisms of action (critical effect) for each of the analytes are as follows:

- Arsenic – hyperpigmentation, keratosis and possible vascular complications
- Fluoride – objectionable dental fluorosis, a cosmetic effect
- Hexavalent chromium – nasal septum atrophy
- Lithium – none reported
- Molybdenum – increased uric acid levels
- Nitrate – early clinical signs of methemoglobinemia
- Strontium – rachitic bone
- Vanadium – decreased hair cystine

Exposure to each of the analytes that contribute to the HI of 2.5 results in a different critical effect, as such it is appropriate to segregate the contributions of each analyte.

Table 6-47. Summary of EPA Tap Water Scenario Total Cumulative Risk Results for Nonradiological and Radiological Analytes in Groundwater for the 100-FR-3 Groundwater OU

| Analyte Name | 90th Percentile Concentration in Groundwater (mg/L or pCi/L) | Volatile[a] | Risk (Ingestion) | Risk (Dermal) | Risk (Inhalation) | Total Risk | % Contribution |
|---|---|---|---|---|---|---|---|
| 1,2-Dichloroethane | 0.00010 | Yes | 1.35E-07 | 6.41E-09 | 1.29E-08 | 1.55E-07 | 0.066 |
| 1,4-Dichlorobenzene | 0.00024 | Yes | 1.93E-08 | 1.25E-08 | 1.31E-08 | 4.49E-08 | 0.019 |
| 1,4-Dioxane | 0.0076 | -- | 1.24E-06 | 4.31E-09 | --[b] | 1.25E-06 | 0.54 |
| Acetone | 0.0013 | Yes | -- | -- | -- | -- | -- |
| Aluminum | 0.022 | -- | -- | -- | --[b] | -- | -- |
| Arsenic | 0.0090 | -- | 2.00E-04 | 1.08E-06 | --[b] | 2.01E-04 | 86 |
| Barium | 0.11 | -- | -- | -- | --[b] | -- | -- |
| Boron | 0.14 | -- | -- | -- | --[b] | -- | -- |
| Bromomethane | 0.00051 | Yes | -- | -- | -- | -- | -- |
| Chlorobenzene | 0.00015 | Yes | -- | -- | -- | -- | -- |
| Chloroform | 0.00046 | Yes | 2.10E-07 | 1.84E-08 | 5.20E-08 | 2.80E-07 | 0.12 |
| Chloromethane | 0.000077 | Yes | -- | -- | -- | -- | -- |
| Chromium | 0.026 | -- | -- | -- | --[b] | -- | -- |
| Cobalt | 0.00017 | -- | -- | -- | --[b] | -- | -- |
| Copper | 0.0023 | -- | -- | -- | --[b] | -- | -- |
| Fluoride | 0.52 | -- | -- | -- | --[b] | -- | -- |
| Hexavalent Chromium | 0.020 | -- | -- | -- | --[b] | -- | -- |
| Iron | 0.083 | -- | -- | -- | --[b] | -- | -- |

Table 6-47. Summary of EPA Tap Water Scenario Total Cumulative Risk Results for Nonradiological and Radiological Analytes in Groundwater for the 100-FR-3 Groundwater OU

| Analyte Name | 90th Percentile Concentration in Groundwater (mg/L or pCi/L) | Volatile[a] | Risk (Ingestion) | Risk (Dermal) | Risk (Inhalation) | Total Risk | % Contribution |
|---|---|---|---|---|---|---|---|
| Lithium | 0.035 | -- | -- | -- | --[b] | -- | -- |
| Manganese | 0.0060 | -- | -- | -- | --[b] | -- | -- |
| Molybdenum | 0.0079 | -- | -- | -- | --[b] | -- | -- |
| Nickel | 0.0050 | -- | -- | -- | --[b] | -- | -- |
| Nitrate | 110 | -- | -- | -- | --[b] | -- | -- |
| Selenium | 0.0042 | -- | -- | -- | --[b] | -- | -- |
| Strontium | 0.93 | -- | -- | -- | --[b] | -- | -- |
| Styrene | 0.00014 | Yes | -- | -- | -- | -- | -- |
| Tetrachloroethene | 0.00018 | Yes | 1.45E-06 | 8.32E-07 | 5.27E-09 | 2.28E-06 | 0.98 |
| Tin | 0.00010 | -- | -- | -- | --[b] | -- | -- |
| Toluene | 0.000072 | Yes | -- | -- | -- | -- | -- |
| Trichloroethene | 0.011 | Yes | 1.46E-05 | 2.43E-06 | 1.37E-06 | 1.84E-05 | 7.9 |
| Trichloromonofluoromethane | 0.00011 | Yes | -- | -- | -- | -- | -- |
| Vanadium | 0.017 | -- | -- | -- | --[b] | -- | -- |
| Xylenes (total) | 0.00020 | Yes | -- | -- | -- | -- | -- |
| Zinc | 0.0060 | -- | -- | -- | --[b] | -- | -- |
| Americium-241 | 0.13 | -- | 2.56E-07 | -- | --[b] | 2.56E-07 | 0.11 |
| Carbon-14 | 12 | -- | 3.47E-07 | -- | --[b] | 3.47E-07 | 0.15 |

Table 6-47. Summary of EPA Tap Water Scenario Total Cumulative Risk Results for Nonradiological and Radiological Analytes in Groundwater for the 100-FR-3 Groundwater OU

| Analyte Name | 90th Percentile Concentration in Groundwater (mg/L or pCi/L) | Volatile[a] | Risk (Ingestion) | Risk (Dermal) | Risk (Inhalation) | Total Risk | % Contribution |
|---|---|---|---|---|---|---|---|
| Gross alpha | 6.2 | -- | -- | -- | --[b] | -- | -- |
| Plutonium-238 | 0.24 | -- | 5.82E-07 | -- | --[b] | 5.82E-07 | 0.25 |
| Plutonium-239/240 | 0.70 | -- | 1.78E-06 | -- | --[b] | 1.78E-06 | 0.76 |
| Strontium-90 | 3.3 | -- | 3.49E-06 | -- | --[b] | 3.49E-06 | 1.5 |
| Technetium-99 | 6.1 | -- | 3.17E-07 | -- | --[b] | 3.17E-07 | 0.14 |
| Tritium | 2,700 | Yes | 2.59E-06 | -- | 3.97E-07 | 2.98E-06 | 1.3 |
| Total Cumulative ELCR | | | 2.27E-04 | 4.38E-06 | 1.85E-06 | 2.33E-04 | 100 |

Note: Shading identifies analytes with a risk contribution greater than 1 percent.

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2009b) or as defined by EPA 540-R-97-036, *Health Effects Assessment Summary Tables: FY 1997 Update*, "April 16, 2001 Update: Radionuclide Toxicity" ("Radionuclide Table: Radionuclide Carcinogenicity – Slope Factors").

b. Nonvolatile constituents are not considered in the inhalation exposure route.

-- = Indicates toxicity criteria not available to quantify contaminant's cancer risk via this exposure route.

ELCR = excess lifetime cancer risk.

Table 6-48. Summary of EPA Tap Scenario Noncancer Hazard Results for Nonradiological Analytes in Groundwater for the 100-FR-3 Groundwater OU

| Analyte Name | 90th Percentile Concentration in Groundwater Cw (mg/L) | Volatile[a] | HQ (Ingestion) | HQ (Dermal) | HQ (Inhalation) | Total HQ | % Contribution |
|---|---|---|---|---|---|---|---|
| 1,2-Dichloroethane | 0.00010 | Yes | 1.37E-04 | 6.72E-06 | 4.83E-07 | <0.01 | 0.0057 |
| 1,4-Dichlorobenzene | 0.00024 | Yes | 9.39E-05 | 6.30E-05 | 3.48E-06 | <0.01 | 0.0064 |
| 1,4-Dioxane | 0.0076 | -- | 2.08E-03 | 7.48E-06 | --[b] | <0.01 | 0.083 |
| Acetone | 0.0013 | Yes | 3.91E-05 | -- | 4.80E-07 | <0.01 | 0.0016 |
| Aluminum | 0.022 | -- | 6.10E-04 | 3.18E-06 | --[b] | <0.01 | 0.024 |
| Arsenic | 0.0090 | -- | 8.18E-01 | 4.27E-03 | --[b] | 0.82 | 33 |
| Barium | 0.11 | -- | 1.51E-02 | 1.12E-03 | --[b] | 0.016 | 0.64 |
| Boron | 0.14 | -- | 1.86E-02 | 9.72E-05 | --[b] | 0.019 | 0.74 |
| Bromomethane | 0.00051 | Yes | 9.88E-03 | 3.15E-04 | 1.17E-03 | 0.11 | 0.45 |
| Chlorobenzene | 0.00015 | Yes | 2.05E-04 | 7.39E-05 | 3.48E-05 | <0.01 | 0.012 |
| Chloroform | 0.00046 | Yes | 1.25E-03 | 1.14E-04 | 5.38E-05 | <0.01 | 0.056 |
| Chloromethane | 0.000077 | Yes | -- | -- | 9.91E-06 | <0.01 | 0.00039 |
| Chromium | 0.026 | -- | 4.79E-04 | 1.93E-04 | --[b] | <0.01 | 0.027 |
| Cobalt | 0.00017 | -- | 1.58E-02 | 3.30E-05 | --[b] | 0.016 | 0.63 |
| Copper | 0.0023 | -- | 1.61E-03 | 8.38E-06 | --[b] | <0.01 | 0.064 |
| Fluoride | 0.52 | -- | 2.37E-01 | 1.24E-03 | --[b] | 0.24 | 9.5 |
| Hexavalent Chromium | 0.020 | -- | 1.83E-01 | 7.65E-02 | --[b] | 0.26 | 10 |
| Iron | 0.083 | -- | 3.23E-03 | 1.69E-05 | --[b] | <0.01 | 0.13 |
| Lithium | 0.035 | -- | 4.79E-01 | 2.50E-03 | --[b] | 0.48 | 19 |
| Manganese | 0.0060 | -- | 6.85E-03 | 8.94E-04 | --[b] | <0.01 | 0.31 |

Table 6-48. Summary of EPA Tap Scenario Noncancer Hazard Results for Nonradiological Analytes in Groundwater for the 100-FR-3 Groundwater OU

| Analyte Name | 90th Percentile Concentration in Groundwater Cw (mg/L) | Volatile[a] | HQ (Ingestion) | HQ (Dermal) | HQ (Inhalation) | Total HQ | % Contribution |
|---|---|---|---|---|---|---|---|
| Molybdenum | 0.0079 | -- | 4.35E-02 | 2.27E-04 | --[b] | 0.044 | 1.7 |
| Nickel | 0.0050 | -- | 6.85E-03 | 1.79E-04 | --[b] | <0.01 | 0.28 |
| Nitrate | 110 | -- | 4.23E-01 | 2.21E-03 | --[b] | 0.43 | 17 |
| Selenium | 0.0042 | -- | 2.30E-02 | 1.20E-04 | --[b] | 0.023 | 0.92 |
| Strontium | 0.93 | -- | 4.24E-02 | 2.22E-04 | --[b] | 0.043 | 1.7 |
| Styrene | 0.00014 | Yes | 1.85E-05 | 8.30E-06 | 1.56E-06 | <0.01 | 0.0011 |
| Tetrachloroethene | 0.00018 | Yes | 4.93E-04 | 2.94E-04 | 7.72E-06 | <0.01 | 0.032 |
| Tin | 0.00010 | -- | 4.57E-06 | 2.38E-08 | --[b] | <0.01 | 0.00018 |
| Toluene | 0.000072 | Yes | 2.47E-05 | 8.57E-06 | 1.67E-07 | <0.01 | 0.0013 |
| Trichloroethene | 0.011 | Yes | -- | -- | 3.64E-03 | <0.01 | 0.14 |
| Trichloromonofluoromethane | 0.00011 | Yes | 1.00E-05 | 1.96E-06 | 1.82E-06 | <0.01 | 0.00055 |
| Vanadium | 0.017 | -- | 9.32E-02 | 4.86E-04 | --[b] | 0.094 | 3.7 |
| Xylenes (total) | 0.00020 | Yes | 2.74E-05 | 1.78E-05 | 2.32E-05 | <0.01 | 0.0027 |
| Zinc | 0.0060 | -- | 5.48E-04 | 1.72E-06 | --[b] | <0.01 | 0.022 |
| **Total HI** | | | **2.43E+00** | **9.12E-02** | **4.95E-03** | **2.52** | **100** |

Note: Shading identifies analytes with a HQ contribution greater than 1 percent.

a. Volatile contaminants as defined by "Regional Screening Levels for Chemical Contaminants at Superfund Sites" (EPA, 2009b).

b. Nonvolatile constituents are not considered in the inhalation exposure route.

-- = Indicates toxicity criteria not available to quantify contaminant's hazard via this exposure route.

HI = Hazard Index

HQ = Hazard Quotient

### 6.3.8 Uncertainties in the Groundwater Risk Assessment

The purpose of this groundwater risk assessment is to determine whether a groundwater remedial action is warranted under CERCLA. Estimating and evaluating health risk from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions must be made to quantify health risks.

In this assessment, uncertainties relate to the selection of COPCs and the development of media concentrations to which receptors may be exposed, the assumptions about exposure and toxicity, and the characterization of health risks. Uncertainties exist regarding the quantification of health risks in terms of several assumptions about exposure and toxicity, including site-specific and general uncertainties. Based on the anticipation of uncertainty when quantifying exposure and toxicity, the health risks and hazards presented in this risk assessment are more likely to provide an upper bound on risk.

#### *6.3.8.1 Uncertainties Associated with Sampling and Analysis Data*

Sampling and analysis data used in this groundwater risk assessment were collected specifically to address the uncertainties identified in the RCBRA (DOE/RL-2007-21) and the 100-F/IU RI/FS Work Plan (DOE/RL-2008-46-ADD4). These uncertainties were generally associated with the chemical, spatial, and temporal representativeness of the data set used to evaluate current baseline conditions in the RCBRA (DOE/RL-2007-21). Uncertainties with chemical representativeness were related to the analysis of varying analytical methods between monitoring wells within the OU. Uncertainties with spatial and temporal representativeness were associated with varying sampling frequencies between monitoring wells because of differing monitoring programs.

For the 100-FR-3 Groundwater OU, current baseline conditions are presented by groundwater data collected over a 7-month period between May 5, 2010 and November 29, 2010. Three sampling events were used to capture the effects that temporal fluctuations of river stage have on groundwater conditions. The COPCs identified during the work plan phase were validated by using groundwater samples analyzed for the analytical methods documented in the 100-F/IU SAP (DOE/RL-2009-43). The groundwater data set used for COPC identification consists of sampling and analysis data collected from 19 monitoring wells within the 100-FR-3 Groundwater OU. The monitoring well network represents locations where human or ecological receptors could potentially encounter groundwater within the OU. The primary exposure pathway for humans is through groundwater obtained from a residential or community water well, assuming development of the land for future human habitation.

All samples were analyzed using methods that could accurately measure analytes to concentrations equal or less than the lowest action level. When analytical methods could not achieve the lowest action level, the action level defaulted to the method detection limit that could reasonably be achieved. These detection limits are documented in Table 2-7 and Table 2-8 of the 100-F/IU SAP (DOE/RL-2009-43).

#### *6.3.8.2 Uncertainties Associated with Exposure Point Concentrations*

The protectiveness and risk assessment methodology uses an RME concentration for each COPC for the entire OU rather than performing the evaluation on a specific well or location. In general, EPA Superfund guidance recommends using a 95 percent UCL on the arithmetic mean for estimating EPCs that reflect an RME. However, experience at the site indicates that averages and UCLs cannot be reliably calculated for groundwater data sets.

Groundwater data sets at the Hanford Site are highly skewed, with a large proportion of BDL values. Guidance from *Data Quality Assessment: Statistical Methods for Practitioners* (EPA/240/B-06/003) is for estimating statistical parameters (whether means or upper percentiles) depending on the variability in the data set, as expressed as the CV and the proportion of observations that are BDL. For data sets with CVs

greater than 0.5 and 50 percent or more observations that are BDL, EPA recommends using upper percentiles as opposed to means to develop summary statistics.

EPA's ProUCL software is used to estimate EPCs and statistics for comparison with standards and background levels, in accordance with EPA Superfund risk assessment guidance. ProUCL contains computational methods for parametric and nonparametric UCL, upper prediction limits (UPLs), and upper tolerance limits (UTLs) for use with data sets without non-detects as well as data sets with below detection limit (BDL) observations. These computational methods can address skewed data sets with and without BDL observations. However, in practice, ProUCL will provide warning flags for 95 percent UCLs from data sets that are both highly skewed and that contain a large proportion (50 percent or greater) BDL observations.

Use of the 90$^{th}$ percentile value from a distribution of groundwater concentration data as an estimate of the EPC is an alternative approach for estimating EPCs in cases where ProUCL does not provide reliable UCL values. However, use of the 90$^{th}$ percentile exposure concentration to develop an EPC is consistent with other EPA risk assessment guidance for describing and characterizing health risks. *Guidance for Risk Characterization* (EPA, 1995) states that risk assessments should provide an evaluation of risks at the high end of the distribution of exposure. Conceptually, the high end of the distribution means above the 90$^{th}$ percentile of the population distribution, but not higher than the individual in the population with the highest exposure (*Guidelines for Exposure Assessment* [EPA/600/Z-92/001]), which is comparable to the definition of RME as defined in the risk assessment guide (EPA/540/1-89/002). Therefore, use of the 90$^{th}$ percentile as the basis for a groundwater EPC yields risk estimates that correspond to an RME.

To illustrate the problem with using the 95 percent UCL for the groundwater data sets described in this report, Table 6-49 presents a few statistics for each contaminant, including the frequency of detection, 90$^{th}$ percentile, mean, and 95 percent UCL. The mean in Table 6-49 is calculated (by the ProUCL software) using only the detected concentration values; nondetect results are not used. For the 95 percent UCL recommended by ProUCL for censored data sets (i.e., some concentrations were below the detection limit), the nondetect results were used (by the same software, ProUCL) in the calculation of the 95 percent UCL using a Kaplan-Meier statistical method (a nonparametric method). For highly skewed and/or highly censored datasets (i.e., those when the frequency of detection is low), these differing statistical approaches with respect to the dataset can lead to large differences between the two calculated values. This is especially true when the frequency of nondetects exceeds 40 percent. For example, the calculated mean concentration value for aluminum is 22 µg/L. This mean value is based on only the 19 detected values. When ProUCL used its algorithms to calculate the 95 percent UCL, the recommended calculated value was 15 µg/L, which is significantly smaller than the mean value calculated by the software. This is due to the consideration of the 38 nondetect values in calculating the 95 percent UCL for which the method detection limit is used as the observed concentration for these measurements. This situation occurs for many of the contaminants in the 100-F area. A similar situation exists for the other areas in Table 6-49.

Other situations exist for which the recommended 95 percent UCL value is either not calculated (because the frequency of detection is too small) or where the UCL value is higher than the mean but only nominally higher and within less than a single significant digit.

Table 6-49. Percentile Concentrations and Summary Statistics

| Analyte | Units | Number of Detections | Number of Nondetects | Frequency of Nondetects | Coefficient of Variation | 90th Percentile of RI Data | Max | Mean of Detected Values | 95 Percent UCL | Is 95 Percent UCL > 90th Percentile? | Action Level |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **100-FR-3 Groundwater OU** | | | | | | | | | | | |
| 1,2-Dichloroethane | µg/L | 2 | 55 | 96% | 0.60 | 0.10 | 0.82 | 0.58 | 0.36 | Yes | 0.38 |
| 1,4-Dichlorobenzene | µg/L | 12 | 45 | 79% | 0.62 | 0.24 | 0.78 | 0.30 | 0.23 | No | 8.1 |
| 1,4-Dioxane | µg/L | 1 | 56 | 98% | N/A | 7.6 | 20 | 20 | Not Calculated | N/A | 4.0 |
| Acetone | µg/L | 6 | 51 | 89% | 0.69 | 1.3 | 5.5 | 2.4 | 1.1 | No | 7,200 |
| Aluminum | µg/L | 19 | 38 | 67% | 1.1 | 22 | 90 | 22 | 15 | No | 50 |
| Americium-241 | pCi/L | 4 | 53 | 93% | 0.12 | 0.13 | 0.080 | 0.070 | 0.071 | No | 15 |
| Arsenic | µg/L | 48 | 9 | 16% | 0.63 | 9.0 | 12 | 4.6 | 4.6 | No | 0.018 (4.0) |
| Barium | µg/L | 56 | 1 | 2% | 0.65 | 110 | 153 | 47 | 64 | No | 1,000 |
| Boron | µg/L | 37 | 20 | 35% | 0.65 | 136 | 307 | 94 | 84 | No | 3,200 |
| Bromomethane | µg/L | 19 | 38 | 67% | 0.36 | 0.51 | 0.85 | 0.44 | 0.35 | No | 11.2 |
| Carbon-14 | pCi/L | 9 | 48 | 84% | 0.91 | 12 | 71 | 26 | 27 | Yes | 2,000 |
| Chloride | µg/L | 57 | 0 | 0% | 0.79 | 36,600 | 62,100 | 18,198 | 26,544 | No | 230,000 |
| Chlorobenzene | µg/L | 1 | 56 | 98% | N/A | 0.15 | 0.24 | 0.24 | Not Calculated | N/A | 100 |
| Chloroform | µg/L | 28 | 29 | 51% | 1.1 | 0.46 | 1.9 | 0.36 | 0.31 | No | 1.4 (5.0) |
| Chloromethane | µg/L | 4 | 53 | 93% | 0.61 | 0.077 | 0.57 | 0.31 | 0.31 | Yes | N/A |
| Chromium | µg/L | 55 | 2 | 4% | 1.3 | 26 | 98 | 11 | 20 | No | 65 |

Table 6-49. Percentile Concentrations and Summary Statistics

| Analyte | Units | Number of Detections | Number of Nondetects | Frequency of Nondetects | Coefficient of Variation | 90th Percentile of RI Data | Max | Mean of Detected Values | 95 Percent UCL | Is 95 Percent UCL > 90th Percentile? | Action Level |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Cobalt | µg/L | 13 | 44 | 77% | 0.45 | 0.17 | 0.31 | 0.16 | 0.13 | No | 2.6 |
| Copper | µg/L | 38 | 19 | 33% | 0.87 | 2.3 | 3.0 | 0.99 | 0.93 | No | 9 |
| Fluoride | µg/L | 36 | 21 | 37% | 0.60 | 520 | 610 | 282 | 249 | No | 960 |
| Gross alpha | µg/L | 17 | 40 | 70% | 0.41 | 6.2 | 10 | 5.5 | 4.2 | No | 15 |
| Hexavalent Chromium | µg/L | 23 | 34 | 60% | 1.3 | 20 | 92 | 16 | 11 | No | 10 |
| Iron | µg/L | 38 | 19 | 33% | 0.63 | 83 | 138 | 50 | 48 | No | 300 |
| Lead | µg/L | 1 | 56 | 98% | N/A | 0.20 | 0.21 | 0.21 | Not Calculated | N/A | 2.1 |
| Lithium | µg/L | 38 | 19 | 33% | 0.67 | 35 | 53 | 19 | 16 | No | 32 |
| Manganese | µg/L | 4 | 53 | 93% | 0.35 | 6.0 | 11 | 7.3 | 6.4 | Yes | 50 |
| Molybdenum | µg/L | 57 | 0 | 0% | 0.77 | 7.9 | 8.5 | 3.5 | 5.3 | No | 80 |
| Nickel | µg/L | 8 | 49 | 86% | 1.1 | 5.0 | 36 | 9.7 | 6.2 | Yes | 52 |
| Nitrate | µg/L | 56 | 1 | 2% | 0.75 | 109,500 | 139,000 | 54,439 | 77,355 | No | 45,000 |
| Plutonium-238 | pCi/L | 4 | 53 | 93% | 0.34 | 0.24 | 0.30 | 0.24 | 0.30 | Yes | 15 |
| Plutonium-239/240 | pCi/L | 17 | 40 | 70% | 0.52 | 0.70 | 1.1 | 0.53 | 0.37 | No | 15 |
| Selenium | µg/L | 39 | 18 | 32% | 0.54 | 4.2 | 5.4 | 2.6 | 2.3 | No | 5 |
| Strontium | µg/L | 56 | 1 | 2% | 0.61 | 930 | 1,240 | 512 | 686 | No | 9,600 |
| Strontium-90 | pCi/L | 8 | 49 | 86% | 0.93 | 3.3 | 19 | 6.9 | 3.4 | Yes | 8 |
| Styrene | µg/L | 9 | 48 | 84% | 0.70 | 0.14 | 0.52 | 0.20 | 0.14 | No | 100 |
| Sulfate | µg/L | 56 | 1 | 2% | 0.64 | 127,000 | 136,000 | 61,850 | 83,994 | No | 250,000 |
| Technetium-99 | pCi/L | 5 | 52 | 91% | 0.64 | 6.1 | 40 | 19 | 17 | Yes | 900 |

Table 6-49. Percentile Concentrations and Summary Statistics

| Analyte | Units | Number of Detections | Number of Nondetects | Frequency of Nondetects | Coefficient of Variation | 90th Percentile of RI Data | Max | Mean of Detected Values | 95 Percent UCL | Is 95 Percent UCL > 90th Percentile? | Action Level |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tetrachloroethene | µg/L | 3 | 54 | 95% | 0.44 | 0.18 | 1.1 | 0.76 | 1.1 | Yes | 0.081 (5.0) |
| Tin | µg/L | 4 | 53 | 93% | 0.73 | 0.10 | 0.36 | 0.17 | 0.14 | Yes | 519 |
| Toluene | µg/L | 1 | 56 | 98% | N/A | 0.072 | 0.17 | 0.17 | Not Calculated | N/A | 640 |
| Trichloroethene | µg/L | 27 | 30 | 53% | 0.91 | 11 | 20 | 6.0 | 4.1 | No | 0.49 (1.0) |
| Trichloromonofluoromethane | µg/L | 2 | 55 | 96% | 0.090 | 0.11 | 0.25 | 0.24 | 0.22 | Yes | 2,400 |
| Tritium | pCi/L | 30 | 27 | 47% | 0.73 | 2,700 | 3,800 | 1,432 | 1,066 | No | 20,000 |
| Vanadium | µg/L | 10 | 47 | 82% | 0.37 | 17 | 27 | 17 | 16 | No | 80 |
| Xylenes (total) | µg/L | 3 | 54 | 95% | 0.46 | 0.20 | 0.49 | 0.32 | 0.49 | Yes | 1,600 |
| Zinc | µg/L | 7 | 50 | 88% | 0.41 | 6.0 | 12 | 7.3 | 6.4 | Yes | 91 |

Note: Value in parentheses () represents the estimated quantitation limit reported in *Sampling and Analysis Plan for the 100-F/IU-2/IU-6 Decision Unit Remedial Investigation/Feasibility Study* (DOE/RL-2009-43).

Sufficient percentage of detections is considered to be 50% or greater.

Coefficient of Variation = Standard Deviation/Mean. Data is considered variable if greater than 0.5.

This discussion only highlights the limits of the 95 percent UCL calculations and the need to use judgment in the establishment of the final EPCs. One advantage of using the 90$^{th}$ percentile is that fewer assumptions are used in the calculation and it can be consistently used for data sets regardless of skewness, frequency of detection issues, multiple detection limits, and other similar factors that can influence the 95 percent UCL calculation. Finally, future monitoring efforts should facilitate the calculation of the 95 percent UCL value to allow future compliance monitoring to provide the requisite data. A comparison of the 90$^{th}$ percentile values used for the protectiveness and risk evaluations and the 95 percent UCLs is presented Table 6-49. In addition, Table 6-49 shows the frequency of detection and CVs for the COPCs in groundwater. As shown in Table 6-49, the data sets for most of the COPCs are characterized by a high proportion of BDL values, high CVs, or both; for those COPCs, the 90$^{th}$ percentile is the most appropriate statistic for an EPC. In addition, the 90$^{th}$ percentile concentrations are greater than the 95 percent UCL values for COPCs that are risk drivers in groundwater, such as Cr(VI), trichloroethene, and nitrate.

#### *6.3.8.2.1 100-FR-3 Groundwater Operable Unit*

The 90$^{th}$ percentile concentrations of RI data are greater than the 95 percent UCL for 28 of 45 analytes reported on Table 6-49. The 95 percent UCL concentration is greater than the 90$^{th}$ percentile concentration for 13 analytes. Although the 90$^{th}$ percentile concentrations are less than the 95 percent UCL concentrations for 1,2-dichloroethane, bromomethane, manganese, nickel, plutonium-238, strontium-90, technetium-99, tetrachloroethene, tin, trichloromonofluoromethane, xylenes (total) and zinc, both concentrations are less than the action level or EQL (as applicable) and use of the 95 percent UCL would not result in a different conclusion. Although the 90$^{th}$ percentile concentration is less than the 95 percent UCL for trichloroethene, both concentrations are greater than the EQL (as applicable) and use of the 95 percent UCL would not result in a different conclusion. For chloromethane, an action level is not available for comparison purposes. A 95 percent UCL was not calculated for four analytes because there was only one detected result.

### *6.3.8.3 Uncertainties Associated with Exposure Assessment*

The exposure assumptions used to develop the action levels represent an RME. For estimating the RME, 95 percent UCL values (or upper-bound estimates of national averages) under residential exposure scenarios are generally used for exposure assumptions, and exposed populations and exposure scenarios are selected to represent upper-bound exposures. The intent of the RME, as discussed by the EPA Deputy Administrator and the Risk Assessment Council "Guidance on Risk Characterization for Risk Managers and Risk Assessors" (Habicht, 1992), is to present risks as a range from central tendency to high-end risk (above the 90$^{th}$ percentile of the population distribution). This descriptor is intended to estimate the risks that are expected to occur in small but definable "high-end" segments of the subject population ("Guidance on Risk Characterization for Risk Managers and Risk Assessors" [Habicht, 1992]). EPA distinguishes between those scenarios that are possible but highly improbable and those that are conservative but more likely to occur within a population, with the latter being favored in risk assessment. In general, these assumptions are intended to be conservative and yield an upper bound of the true risk or hazard.

#### *6.3.8.3.1 Uncertainties Associated with Dermal Contact Exposure*

The action levels for use as a drinking water source consider ingestion and inhalation of vapors as complete and significant pathways for exposure. For the action levels, the dermal contact pathway is considered a complete but insignificant pathway of exposure for the contaminants detected in groundwater. The exclusion of the dermal contact exposure route from the action levels may have the potential to underestimate the actual cleanup level.

EPA considers the dermal contact route to be significant if it contributes at least 10 percent of the exposure derived from the oral pathway. These results are based on comparing two main household daily uses of water: as a source for drinking and for showering or bathing (*Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment): Final* [EPA/540/R/99/005]). Exhibit B-3 and Exhibit B-4 of *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment): Final* (EPA/540/R/99/005) provide a screening tool to focus the dermal risk assessment on those chemicals that are more likely to contribute to the overall risk. Exhibit B-3 indicates that dermal exposure exceeds 10 percent of drinking water for chromium, Cr(VI), and trichloroethene. The ratio of the dermal absorbed dose (DAD) from dermal to oral is 40 percent for chromium, 42 percent for Cr(VI), and 17 percent for trichloroethene. Based on this comparison, the action levels concentrations may have the potential to underestimate exposure to these COPCs.

#### 6.3.8.3.2 Uncertainties Associated with Action Levels that include the Fish Consumption Exposure Pathway

Water quality standards used as action levels to identify COPCs have been developed to include exposure to groundwater contaminants through direct contact (groundwater ingestion and fish consumption). These specific action levels are:

- "Water Quality Standards" (40 CFR 131) for states not complying with Section 303 of the *Clean Water Act of 1977*, Human Health Water + organism
- *National Recommended Water Quality Criteria* (Ecology, 2009a), Ambient Water Quality Criteria (AWQC) established under Section 304 of the *Clean Water Act of 1977*, Human Health Water + organism

These water quality standards were used to identify COPCs in groundwater based on the potential for effects to surface water. While groundwater adjacent to the Columbia River can discharge to the river through the hyporheic zone, contaminants potentially in groundwater undergo dilution in the river flows to concentrations indistinguishable from levels upstream. Correspondingly, this limits potential accumulation of groundwater contaminants into fish to levels indistinguishable from levels upstream. Based on these factors, potential exposure pathways from groundwater through fish consumption along the Hanford Site are considered incomplete.

### 6.3.8.4 Uncertainties Associated with Toxicity Assessment

The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of uncertainty as defined in the risk assessment guide (EPA/540/1-89/002) and in Superfund HHT Risk Assessment Values (Cook, 2003). These sources may include or result from the extrapolation from high to low doses and from animals to humans. This is contingent on the species, gender, age, and strain differences in the uptake, metabolism, organ distribution, and target site susceptibility of a toxin. The human population's variability with respect to diet, environment, activity patterns, and cultural factors are also sources of uncertainty.

Traditionally, EPA has developed toxicity criteria for carcinogens by assuming that all carcinogens are nonthreshold contaminants. However, EPA has recently published revised cancer guidelines (*Guidelines for Carcinogen Risk Assessment* [EPA/630/P-03/001F]) modifying its former position of assuming nonthreshold action for all carcinogens. This new guidance emphasizes establishing the specific toxicokinetic mode of action that leads to development of cancer. In the future, toxicity criteria for carcinogens in the United States will be developed assuming no threshold for contaminants that exhibit genotoxic modes of action, or where the mode of action is not known. This is because there currently are

no criteria for classification of chemicals that demonstrate non-genotoxic or unknown mechanisms of action. However, currently available EPA toxicity criteria for carcinogens were all derived assuming a nonthreshold model.

In most of the world, nonthreshold toxicity criteria are developed only for those carcinogens that appear to cause cancer through a genotoxic mechanism (International Toxicity Estimates for Risk database [TERA, 2011]). Specifically, for genotoxic contaminants, the cancer dose-response model is based on high-dose to low-dose extrapolation and assumes there is no lower threshold for the initiation of toxic effects. Cancer effects observed at high doses are found in laboratory animals or are extrapolated from occupational or epidemiological studies. Cancer effects observed at low doses are commonly found in environmental exposures. These models are essentially linear at low doses, so no dose is without some risk of cancer. This is a health protective assumption, because a threshold may exist for some chemicals present at low concentrations.

#### *6.3.8.4.1 Slope Factors for Trichloroethene*

The oral cancer potency factor of 0.089 $(mg/kg\text{-}day)^{-1}$ is used to develop the "Groundwater Cleanup Standards" (WAC 173-340-720) level obtained from the CLARC database (Ecology, 2009). The factor is obtained from a draft EPA risk assessment prepared in 2001, which has since been updated; therefore, in this case, the oral cancer potency factor does not reflect the most current source of information.

The oral slope factor currently recommended by EPA for trichloroethene was published in IRIS in September 2011. The source of this toxicity value is consistent with the hierarchy of toxicity values recommended in Superfund HHT Risk Assessment Values (Cook, 2003). The oral slope factor is 0.046 $(mg/kg\text{-}day)^{-1}$ (IRIS). Trichloroethene is considered an "early-life exposure" carcinogen for kidney cancer, because it acts through a mutagenic mode-of-action. Accounting for kidney cancer risks from early-life exposure would result in slightly more conservative value (by a factor of 2) for the oral slope factor.

The newly reviewed EPA value is lower than the value of 0.089 $(mg/kg\text{-}day)^{-1}$ for oral exposures published in the CLARC database (Ecology, 2009). However, the EPA value accounting for early life exposure is slightly greater than the value published in the CLARC database (Ecology, 2009).

If the revised EPA value were used to calculate the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) groundwater cleanup level, the groundwater concentration would increase from 0.49 to 0.95 µg/L. The groundwater risks at the 90$^{th}$ percentile would decrease from $7.8 \times 10^{-6}$ to $4.0 \times 10^{-6}$ in groundwater. However, the cumulative risk would remain below $1 \times 10^{-5}$. Use of the oral cancer potency factor from HEAST (EPA 540-R-97-036) results in an overestimation of risks when compared to the oral slope factor developed by EPA.

#### *6.3.8.4.2 Slope Factors for Cr(VI)*

The oral reference dose of 0.003 mg/kg-day published by IRIS is used to develop the "Groundwater Cleanup Standards" (WAC 173-340-720) groundwater cleanup level for Cr(VI). An oral carcinogenic potency factor has recently been published by NJDEP (*Derivation of an Ingestion-Based Soil Remediation Criterion for $Cr^{+6}$ Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate* [NJDEP, 2009]). The oral carcinogenic potency factor derived by NJDEP is 0.5 $(mg/kg\text{-}day)^{-1}$ (*Derivation of an Ingestion-Based Soil Remediation Criterion for $Cr^{+6}$ Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate* [NJDEP, 2009]). If the NJDEP value was used to calculate the MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) level, the groundwater concentration would decrease from 48 to 0.18 µg/L.

#### 6.3.8.5 Uncertainties Associated with Risk Characterization

As discussed in Section 6.3.4.2, MCLs for radionuclides are set at 4 mrem/yr for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity (including Ra-226, but excluding uranium and radon), and 5 pCi/L combined for Ra-226 and Ra-228. A mass concentration MCL has been established for uranium as 30 µg/L. At this time, no additional federal or state standards are associated with evaluating the effects of exposure to radionuclides. Risks were estimated for radioisotopes identified as COPCs using inputs and equation 720-2 from MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720(4)(iii)(B)]) and radionuclide slope factors from HEAST (EPA 540-R-97-036). Exposure inputs and equation 720-2 were selected to calculate risks to be consistent with the risk evaluation section that is presented in Section 6.3.6.1.3. Cancer risks for strontium-90 in the 100-FR-3 Groundwater OU were also calculated using the tap water scenario and presented in Table 6-47. The MCL concentrations reported for each of the radionuclide COPCs do not individually exceed the $10^{-4}$ ELCR end of the NCP (40 CFR 300) risk range (Table 6-50). Although the 90$^{th}$ percentile value for strontium-90 does not exceed the upper end of the risk range, strontium-90 was retained as a COPC for further evaluation in the FS because it was present in localized areas at concentrations greater than the DWS.

Table 6-50. Summary of 90$^{th}$ Percentile Current Groundwater Concentrations for the 100-FR-3 Groundwater OU, Associated Cancer Risk and Associated Sum of Fractions for Radioactive COPCs

| COPC | 90$^{th}$ Percentile Value (pCi/L) | Federal or State MCL (pCi/L) | ELCR at Federal MCL | Individual Fraction | Individual ELCR |
|---|---|---|---|---|---|
| Strontium-90 | 3.3 | 8 | 8.5 × 10-6 | 0.41 | 3.5 × 10-6 |
| **Sum of Fractions** | | | | **0.41** | **-** |
| **Cumulative Annual Dose (mrem)** | | | | **1.7** | **-** |
| **Cumulative ELCR for Radioactive COPCs** | | | | **-** | **6.2 × 10-6** |

##### 6.3.8.5.1 Uncertainties Associated with the Native American Risk Assessments

As discussed in Section 6.1.3, the RCBRA (DOE/RL-2007-21) evaluated three residential scenarios that describe exposure related to rural land-use patterns that involved exposure assumptions, which represented subsistence use. Of the three residential scenarios, two Native America scenarios were evaluated including the CTUIR and the Yakama Nation. Although groundwater within the 100-FR-3 Groundwater is not anticipated to become a source of drinking water, risks from contaminants in groundwater were assessed using the two Native American scenarios (as provided by the CTUIR and the Yakama Nation) to provide estimates of human health risks that are based on future full-time occupancy. In addition, the risks calculated using the Native American scenarios were compared with risks estimated using EPA's standard default assumptions for residential tap water use (the tap water scenario). As described at Regional Screening Levels (EPA, 2009b), the residential tap water scenario reflects an RME scenario.

The groundwater risk assessment provided in this RI/FS provides an update to address the uncertainties associated with the assessment of groundwater risks presented in the RCBRA (DOE/RL-2007-21); see Section 6.3.2. The uncertainties in the RCBRA (DOE/RL-2007-21) were associated with the ability of the groundwater data set collected from 1998 to 2008 to represent current baseline conditions and potential

exposure within each groundwater OU. The following paragraphs discuss the uncertainties with risks associated with groundwater contaminants based on current baseline conditions.

The Native American and tap water scenarios addressed direct exposure to contaminants in groundwater associated with household uses of groundwater, such as drinking and cooking (ingestion) and bathing (dermal absorption). If VOCs were measured in groundwater and identified as COPCs, indirect exposure by inhalation of VOCs in air while bathing or when using groundwater in the home for other purposes was addressed. The CTUIR and Yakama Nation scenarios incorporated ingestion, inhalation, and dermal exposures to COPCs in groundwater used in a sweat lodge.

Exposure parameters for drinking water ingestion, VOC inhalation, and dermal absorption differ between the Native American exposure scenarios and the EPA tap water scenario. Examples of these differences include the following:

- Exposure frequency: Native American 365 days/yr and EPA tap water 350 days/yr
- Exposure duration: Native American 70 years and EPA tap water 30 years
- Drinking water ingestion rate: Native American 4 L/day (1 gal/day) and EPA tap water 2 L/day (0.5 gal/day)
- Inhalation rate: CTUIR 25 $m^3$/day (883 $ft^3$/day), Yakama Nation 26 $m^3$/day (918 $ft^3$/day), and EPA tap water 20 $m^3$/day (706 $ft^3$/day)

As a result, the Native American exposure scenarios both produce higher total ELCR and HI that the EPA tap water scenario; depending on the contaminants and pathways involved. As described below, ELCR and HI for the Native American scenarios may be four- to five-times greater than for the tap water scenario, drinking water ingestion, VOC inhalation, and dermal absorption exposure pathways. COPCs are the same between each of the exposure scenarios; the percent contribution for each COPC is higher for the Native American scenarios than the EPA tap water scenario.

The largest uncertainties associated with the Native American scenarios are with the use of groundwater in a sweat lodge. EPCs for air in a sweat lodge were calculated for the CTUIR Resident and Yakama Resident scenarios. Appendix 4 of *Exposure Scenario for CTUIR Traditional Subsistence Lifeways* (Harris and Harper, 2004) provides equations for estimating air-phase contaminant concentrations for volatile and semivolatile COPCs in the water used to create steam in the lodge, as well as separate equations for nonvolatile COPCs. Inhalation exposure to nonvolatile COPCs in the sweat lodge was evaluated in the CTUIR and Yakama Nation resident scenarios in spite of concerns with the model for calculating these air-phase EPCs. The *Exposure Scenario for CTUIR Traditional Subsistence Lifeways* (Harris and Harper, 2004) equation for calculating air-phase EPCs for nonvolatile analytes (Equation 3-2) calculates the concentration of a nonvolatile COPC in air as a function of the concentration of water vapor produced by the volatilization of water poured over hot rocks in a sweat lodge. Because nonvolatile contaminants have no vapor pressure, Equation 3-2 does not have a common physical basis with volatile chemicals. It is possible that inhalation of nonvolatile COPCs might occur by an alternative physical model, such as respiration of breathable-size aerosols, if such aerosols were formed when water is poured over the hot rocks in a lodge. However, a model of resuspension of nonvolatile impurities in aerosol form is inconsistent with other mechanical processes involving steam. For example, EPA does not address this pathway in shower volatilization models (*Volatilization Rates from Water to Indoor Air Phase II* [EPA 600/R-00/096]). It is also inconsistent with the widespread use of steam distillation for commercial water purification.

As described in Section 6.1.4, the RCBRA (DOE/RL-2007-21) presents the risks and hazards calculated for both Native American exposure scenarios from direct contact, external gamma exposure, inhalation, and food chain pathways at remediated waste sites. The groundwater risk assessment presents the risks and hazards calculated for groundwater used as a source of drinking water and as a source of steam for sweat lodge use. The results from the RCBRA for remediated waste sites and the results from the groundwater risk assessment are presented in Table 6-51. The risks and hazards can be summed to obtain a cumulative estimate of risk and hazard for all exposure pathways included in the CTUIR and Yakama Nation exposure scenarios.

These results for evaluating groundwater as a drinking water source are partially consistent with the screening level groundwater risk assessment provided in the RCBRA (DOE/RL-2007-21), which identified tritium and uranium in the 100-FR-3/100-IU-2/100-IU-6 Groundwater OUs as the primary contributor to risk through ingestion of groundwater. As discussed above, the uncertainties associated with the sweat lodge scenario would considerably overstate the contribution of Cr(VI) to total risks and noncancer hazards from contaminants in groundwater.

Groundwater within the 100-FR-3 OU is currently contaminated, and withdrawal is prohibited because of ICs placed on it by DOE through the interim action ROD. Under current site use conditions, no complete human exposure pathways to groundwater are assumed to exist. Groundwater within this OU is not anticipated to become a future source of drinking water until cleanup criteria are met and groundwater is restored to its highest beneficial use.

## 6.4 Risk Assessment Conclusions of the Riparian and Near-Shore Environment from RCBRA and the Columbia River Component

Human health risks were assessed in areas outside the footprints of waste sites as part of the RCBRA (DOE/RL-2007-21, Volume II) and the CRC (DOE/RL-2010-117, Volume II). The following sections summarize the conclusions obtained from these two risk assessments.

Table 6-52 presents a summary of the total risks and noncancer hazards associated with the riparian and near-shore area and the Columbia River within the 100-F/IU OUs.

### 6.4.1 Conclusions from the River Corridor Baseline Risk Assessment

The assessment of human health risks was based on "broad-area" environmental data that characterized concentrations of COPCs in upland and riparian surface soils, river water and sediment in near-shore areas, and fish tissue.

The exposure scenarios considered for riparian and near-shore areas were avid angler, casual user, and Tribal scenarios, including nonresident Tribal scenario, and ingestion of fish in the CTUIR and Yakama residential scenarios. The casual user scenario addresses occasional recreational use. The scenario is focused on activities such as walking and picnicking in riparian areas near the river. The avid angler is focused on individuals who are not engaged in a subsistence lifestyle. The avid angler application is associated with exposure in the near-shore region of the River Corridor, and takes into consideration potential exposures to sediments and fish. The nonresident Tribal scenario is focused on individuals engaged in a subsistence lifestyle who reside offsite but use the River Corridor for various activities such as hunting, gathering plants, and fishing.

Table 6-51. Summary of Cancer Risks and Noncancer Hazards for Soil and Groundwater Exposure Pathways Associated with the CTUIR and the Yakama Nation Exposure Scenarios

| Environmental Medium/ Exposure Pathway | CTUIR Total ELCR | CTUIR Risk Drivers (Contributes > 1 × 10-6) | CTUIR Hazard Index | CTUIR Hazard Drivers | Yakama Nation Total ELCR | Yakama Nation Risk Drivers (Contributes > 1 × 10-6) | Yakama Nation Hazard Index | Yakama Nation Hazard Drivers |
|---|---|---|---|---|---|---|---|---|
| **100-FR-3 Groundwater OU** | | | | | | | | |
| Remediated Waste Sites (Direct Contact and Food Chain Pathways) | $4.0 \times 10^{-2}$ to $7 \times 10^{-8}$ | Arsenic, carbon-14, cesium-137, europium-152, strontium-90 | 0.0011 to 180 | Arsenic, cadmium, mercury | $4.0 \times 10^{-2}$ to $6 \times 10^{-8}$ | Arsenic, carbon-14, cesium-137, europium-152, strontium-90 | 0.0024 to 110 | Arsenic, cadmium mercury |
| Groundwater as a Potential Drinking Water Source | $9.1 \times 10^{-4}$ | Trichloroethene, strontium-90. tritium | 5.2 | Lithium | $9.8 \times 10^{-4}$ | Trichloroethene, strontium-90. tritium | 5.2 | Cr(VI) |
| Groundwater as a Potential Source of Steam from Sweat Lodge Use (Includes Vaporized Nonvolatiles) | $1.4 \times 10^{-2}$ | Cr(VI) | 11 | Cr(VI) | $1.0 \times 10^{-1}$ | Cr(VI) | 80 | Cr(VI), manganese, nickel, fluoride, cobalt |
| Groundwater as a Potential Source of Steam from Sweat Lodge Use (Excludes Vaporized Nonvolatiles) | -- | -- | -- | -- | $1.8 \times 10^{-4}$ | Trichloroethene, tritium, 1,4-dioxane, chloroform | 1.3 | None |

Table 6-52. Summary of Total Risks and Noncancer Hazards for the Riparian and Near-Shore in the 100-F/IU OUs

| Environment/Exposure Media | Excess Lifetime Cancer Risk | Primary Risk Drivers | Non-cancer Hazard Index | Primary Non-cancer Hazards | Comment | Source |
|---|---|---|---|---|---|---|
| **Casual User Scenario** | | | | | | |
| Riparian Soil | 8.0 × 10-6 | Cs-137, Eu-152 | 0.024 | None | -- | RCBRA (DOE/RL-2007-21) Tables 4-14 and 4-16 |
| **Avid Angler Scenario** | | | | | | |
| Near-Shore – sediment, river water, dust | 6.0 × 10-7 | None | 0.015 | None | -- | RCBRA (DOE/RL-2007-21) Tables 4-17 and 4-19 |
| Fish ingestion - Sculpin | NA | None | 2.9 | Metals | Screening-level result employing near-shore COPC concentrations in sculpin, a small fish with a limited home range. | |
| **Nonresident Tribal Scenario** | | | | | | |
| Soil, sediment, water | 1.0 × 10-4 | | 0.94 | | -- | RCBRA (DOE/RL-2007-21) Tables 4-24 and 4-26 |
| Plants and game | 1.0 × 10-2 | Arsenic | 94 | Arsenic | Ingestion of contaminants in plants and game were modeled using high-end bio-transfer factors, which overstated concentrations, accumulated from soil. Uncertainties associated with the large range of published bio-transfer factors. | |

Table 6-52. Summary of Total Risks and Noncancer Hazards for the Riparian and Near-Shore in the 100-F/IU OUs

| Environment/Exposure Media | Excess Lifetime Cancer Risk | Primary Risk Drivers | Non-cancer Hazard Index | Primary Non-cancer Hazards | Comment | Source |
|---|---|---|---|---|---|---|
| Fish Ingestion - Sculpin | NA | None | 17 | Metals | Screening-level result employing near-shore COPC concentrations in sculpin, a small fish with a limited home range. | |
| **Casual User Scenario (Child - Columbia River)** | | | | | | |
| 100-A Study Area COPCs in Surface Water | 0 | None | 0.005 | None | Risks in each media summed across chemical carcinogens and radionuclides. | CRC (DOE/RL-2010-117) Tables 6-1 and 6-2. |
| 100-A Study Area COPCs in Sediment | $4.0\ 10^{-7}$ | None | 0.02 | None | | |
| 100-B Study Area COPCs in Surface Water | 0 | None | 0.003 | None | | |
| 100-B Study Area COPCs in Sediment | $4.0\ 10^{-7}$ | None | 0.02 | None | | |
| 100-B Study Area COPCs in Island Soil | $8 \times 10^{-7}$ | None | 0.02 | None | | |
| **Casual User Scenario (Adult - Columbia River)** | | | | | | |
| 100-A Study Area COPCs in Surface Water | 0 | None | 0.001 | None | Risks in each media summed across chemical carcinogens and radionuclides. | CRC (DOE/RL-2010-117) Tables 6-13 and 6-14. |
| 100-A Study Area COPCs in Sediment | $3.0 \times 10^{-6}$ | None | 0.003 | None | | |
| 100-B Study Area COPCs in Surface Water | 0 | None | 0.0009 | None | | |
| 100-B Study Area COPCs in Sediment | $2 \times 10^{-6}$ | None | 0.002 | None | | |
| 100-B Study Area COPCs in Island Soil | $5 \times 10^{-7}$ | None | 0.003 | None | | |

Table 6-52. Summary of Total Risks and Noncancer Hazards for the Riparian and Near-Shore in the 100-F/IU OUs

| Environment/Exposure Media | Excess Lifetime Cancer Risk | Primary Risk Drivers | Non-cancer Hazard Index | Primary Non-cancer Hazards | Comment | Source |
|---|---|---|---|---|---|---|
| **Avid Angler Scenario (Child - Columbia River)** | | | | | | |
| 100 Area, Fish Ingestion | $1 \times 10^{-6}$ | None | 7 | PCBs (dioxin and non-dioxin like) | -- | CRC (DOE/RL-2010-117) Table 6-25 |
| **Avid Angler Scenario (Youth - Columbia River)** | | | | | | |
| 100-A Study Area COPCs in Surface Water | 0 | None | 0.001 | None | Risks in each media summed across chemical carcinogens and radionuclides. | CRC (DOE/RL-2010-117) Tables 6-28 and 6-29. |
| 100-A Study Area COPCs in Sediment | $7.0 \times 10^{-7}$ | None | 0.005 | None | | |
| 100-A Study Area COPCs in Fish | $4 \times 10^{-6}$ | None | 7 | PCBs (dioxin and non-dioxin like) | | |
| 100-B Study Area COPCs in Surface Water | 0 | None | 0 | None | | |
| 100-B Study Area COPCs in Sediment | $5.0 \times 10^{-7}$ | None | 0.003 | None | | |
| 100-B Study Area COPCs in Island Soil | $4.0 \times 10^{-9}$ | None | 0.006 | None | | |
| 100-B Study Area COPCs in Fish | $4 \times 10^{-6}$ | None | 7 | PCBs (dioxin and non-dioxin like) | | |
| **Avid Angler Scenario (Adult- Columbia River)** | | | | | | |
| 100-A Study Area COPCs in Surface Water | 0 | None | 0.0007 | None | Risks in each media summed across chemical carcinogens and radionuclides. | CRC (DOE/RL-2010-117) Tables 6-34 and 6-35. |
| 100-A Study Area COPCs in Sediment | $3.0 \times 10^{-6}$ | None | 0.003 | None | | |
| 100-A Study Area COPCs in Fish | $3.0 \times 10^{-5}$ | None | 7 | PCBs (dioxin and non-dioxin like) | | |

Table 6-52. Summary of Total Risks and Noncancer Hazards for the Riparian and Near-Shore in the 100-F/IU OUs

| Environment/Exposure Media | Excess Lifetime Cancer Risk | Primary Risk Drivers | Non-cancer Hazard Index | Primary Non-cancer Hazards | Comment | Source |
|---|---|---|---|---|---|---|
| 100-B Study Area COPCs in Surface Water | 0 | None | 0.0005 | None | | |
| 100-B Study Area COPCs in Sediment | $2.0 \times 10^{-6}$ | None | 0.002 | None | | |
| 100-B Study Area COPCs in Island Soil | $5.0 \times 10^{-7}$ | None | 0.003 | None | | |
| 100-B Study Area COPCs in Fish | $3.0 \times 10^{-5}$ | None | 7 | PCBs (dioxin and non-dioxin like) | | |

Notes: Zero values indicate that there were no COPCs for that medium; therefore, no risks or noncancer hazards were calculated.

Carbon-14 in the 100-K area is the only COPC in sculpin.

Risks presented in this table are for COPCs identified in the Study Area (i.e. along the River Corridor Sites. COPCs for Reference Areas are presented in the CRC report. Note that risks associated with Reference Area COPCs typically are greater than risks associated with Study Area COPCs.

Risk estimates for the CTUIR and Yakama Nation scenarios are provided in the RCBRA (*River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessment* [DOE/RL-2007-21]) and CRC (*Columbia River Component Risk Assessment, Volume II: Baseline Human Health Risk Assessment* [DOE/RL-2010-117]).

Carbon-14 was not detected in near-shore groundwater, seeps, or sediment but was detected in one soil sample collected from the riparian area.

NA = not available

EPCs in soil in the riparian environment were calculated using MULTI-INCREMENT® sampling from riparian locations in the 100-F Area (RCBRA SAP [DOE/RL-2005-42]). Discrete sediment samples used to calculate EPCs were obtained from sites in the River Corridor selected from locations of known groundwater plumes, areas of groundwater discharge to the river, results of past biota sampling locations, or areas of fine-grained sediment deposits. Data from sculpin, clams, and benthic macroinvertebrates (primarily crayfish and clams) were used to estimate fish ingestion risks to avid angler and nonresident Tribal receptors.

The results of the broad area risk assessment in the 100-F Area showed that lifetime cancer risks for the casual user were $8 \times 10^{-6}$. Lifetime cancer risks for the avid angler scenarios were $6 \times 10^{-7}$. Non-cancer HI values for both scenarios were below one for direct exposures to soil, sediment, and surface water.

Risks for riparian soils were higher than $1 \times 10^{-4}$ cancer risk and above a noncancer HI of one for the nonresident Tribal scenario. Modeled concentrations of arsenic from riparian soil into native revegetation provided the largest contribution to cancer risks and noncancer hazard indices. However, as discussed in the RCBRA (DOE/RL-2007-21, Volume II), uncertainties in the food chain modeling methods considerably overstate risks from plant ingestion exposure pathways, particularly for arsenic. No carcinogenic COPCs were identified in fish, based on data in sculpin, clams, crayfish, and juvenile suckers. The noncancer HIs associated with fish ingestion, based on these biota data in sculpin, clams, crayfish and juvenile suckers was higher than one for the Tribal scenarios. The COPC providing the major contribution to noncancer hazard was copper detected in clams and crayfish. As discussed in the RCBRA (DOE/RL-2007-21), it is likely that the calculated HI values for copper considerably overstate the risks from ingestion of this metal. Copper is present in hemocyanin for carrying oxygen in the blood, both in crayfish and clams. In addition, HI values for ingestion of crayfish from reference areas are similar to the 100-F Area. In addition, human health risks from copper are associated with gastrointestinal irritation by free copper ions in drinking water, which is an effect that may not be relevant to ingestion of copper in food.

### 6.4.2 Risk Assessment Conclusions from the Columbia River Component

The CRC HHRA (DOE/RL-2010-117, Volume II) provides a comprehensive assessment of human health risks for the Hanford Reach. The intent of the CRC HHRA (DOE/RL-2010-117, Volume II) was to complete the assessment of the "bank-to-bank" Hanford Reach and downstream areas (i.e., Lake Wallula) of the Columbia River, characterizing risk in areas not previously addressed under the RCBRA. Human exposure scenarios addressed in the CRC HHRA (DOE/RL-2010-117, Volume II) were an avid angler, casual user, hypothetical future resident, and a Native American (Yakama Nation) subsistence fisher. As discussed in the CRC HHRA (DOE/RL-2010-117, Volume II), fish ingestion exposure provided the largest contribution to overall human health risks. A fish sampling program was specifically created to support the CRC HHRA (DOE/RL-2010-117, Volume II) and provided a consistent sampling and analysis approach among species, tissue types, and analytes (Columbia River RI Work Plan [DOE/RL-2008-11]). The fish species targeted in the sampling program were intended to be the most representative of the exposure scenarios identified in the CRC HHRA (DOE/RL-2010-117, Volume II) and included the following:

- Common carp (*Cyprinus carpio*)
- Mountain whitefish (*Prosopium williamsoni*)
- Walleye (*Sander vitreus*)
- Smallmouth bass (*Micropterus dolomieui*)
- Bridgelip sucker (*Catostomus columbianus*)
- White sturgeon (*Acipenser transmontanus*)

Separate fillets, carcass (including the head and skeleton), and combined livers and kidneys were analyzed. Fillet samples for all species except sturgeon were prepared with the skin on, as skin for these types of fish is often left on during preparation and consumption.

As described previously, the fish consumption pathway provided the largest contribution (99 percent contribution) to human health risks (evaluated for the avid angler and Native American scenarios). The fish consumption pathway was evaluated using two separate approaches. In the first approach, risk was quantified assuming a receptor consumed a varied diet consisting of all six species evaluated. In a second approach, risk was quantified for each individual fish species. Although the concentrations of COPCs, and hence, estimated hazard/risk, varied among the different species, the relative magnitude of risk remained similar among all six fish species. Relative magnitude of risk for the avid angler scenario was generally in the range of $2 \times 10^{-3}$ to $8 \times 10^{-3}$, with bass and carp having the overall lowest and highest associated cancer risk, respectively. PCBs, chlorinated pesticides (notably dieldrin), cobalt, lithium, and mercury were the primary risk drivers through fish ingestion. Along the 100 Area portion of the Columbia River, including the 100-F Area, all of the risk drivers also were identified as COPCs in upstream reference areas. Carbon-14 was the only radionuclide consistently detected among fish tissue samples although at a very low (1 percent) frequency of detection. Carbon-14 was also only sporadically detected in abiotic media.

PCBs, mercury, and chlorinated pesticides in fish tissue, which are primary risk drivers, are prevalent in fish tissue in many water bodies, because of their widespread historical use, atmospheric deposition and, consequently, high prevalence in abiotic media. The results from Chapter 4 and Riparian and Near-Shore CSM in Appendix L show that there are unlikely to be sources or transport pathways from Hanford Site soils or groundwater that would have resulted in transport of PCBs, mercury, or chlorinated pesticides to Columbia River media (sediment or surface water) where they could have been accumulated into fish tissue. Based on the absence of transport pathways from 300 Area sites or groundwater, coupled with comparable risks associated with fish caught in reference areas, it is unlikely that Hanford Site activities in the 300 Area are associated with the fish ingestion risks projected in the CRC HHRA (DOE/RL-2010-117, Volume II).

Results from the risk characterization indicate that risks related to exposure to surface water, sediment, and island soil are very small relative to that from the fish ingestion pathway. For abiotic media, reference COPCs account for the majority of noncancer hazard and, in most cases, chemical cancer risk in all sub-areas. Cancer risks for the casual user scenario from island soils were $2 \times 10^{-6}$ or lower. Cancer risks for the avid angler scenario from sediments were $3 \times 10^{-6}$ or lower. Non-cancer HIs were well below one for all scenarios, for island soils and sediments. Arsenic in sediment within most of the exposure points accounted for over half of the cumulative risk. Of the radionuclides, cobalt-60, europium-152, and cesium-137 constitute the majority of radiation cancer risk. Radionuclide risks from abiotic media (surface water, island soils, and sediments) fell within the target cancer risk range. Cesium-137 is a known constituent of worldwide atmospheric fallout; it was found in reference areas. Risks from island soil exposures were relatively minor compared to risks from other abiotic media.

### 6.4.3 Risk Assessment Conclusions for River Pipelines

During operations, water used in fuel production to cool the reactors was discharged to the Columbia River via effluent pipelines. The release of this cooling water ended when the associated reactors and facilities were shut down. Today, the single inactive 100-F effluent pipeline remains in its original location in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F Areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the

pipelines. The RCBRA (DOE/RL-2007-21, Volume II) provided a summary of the previous characterization efforts and risk assessment for these pipelines in Section 8.2.2.

In 1984, *River Discharge Lines Characterization Report* (UNI-3262) discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the 105-C, 105-DR, and 105-F Reactors. The pipelines were also visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides. The major radionuclides detected included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. The human health risk assessment determined that elevated human radiological exposure could occur if portions of the river pipelines became dislodged and washed ashore (DOE/RL-2007-21, Section 8.2.2).

In 1994, a comprehensive geophysical survey (*Columbia River Effluent Pipeline Survey* [WHC-SD-EN-TI-278]) located and mapped the reactor effluent pipelines. The study relied mainly on remote sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and ground-penetrating radar. The results indicated that the pipelines have neither broken loose nor moved from their original locations. However, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D areas were sampled and physically characterized using a robotic transporter (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (*River Discharge Lines Characterization Report* [UNI-3262]) and were expected to represent "worst case" conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the 105-B and 105-D/DR Reactors.

Evaluations of human health and ecological risk have been performed for the river effluent pipelines, as they are today, located on or beneath the river channel bottom, and for a scenario in which a pipeline Section breaks away from the main pipeline and is washed onto the shore of the river. Both the 1996 risk assessment effort (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]) and the 1998 risk assessment effort (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) relied on data collected from the 1984 and 1995 characterization work. The evaluation of human health and ecological risk performed in 1998 (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) concluded that the concentrations of chromium and mercury in the scale and sediment within the pipelines pose minimal ecological risk, because they have been in contact with river water without dissolving since the reactors were shut down. The 1998 risk evaluation results indicated pipelines present no unacceptable risks and, therefore, no remediation requirements under CERCLA. This is supported by the following:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations because of decay
- Inaccessible location
- Unavailability of significant contaminants to affect HHE

Based on available information, no elevated risk levels are expected to be associated with these pipelines.

## 6.5 Summary and Conclusions

The soil and groundwater risk assessment for the 100-F/IU Source OUs and the 100-FR-3 groundwater OU accomplishes the following objectives:

- Proposes direct contact PRGs in soil for use in the FS consistent with values presented in the RCBRA (DOE/RL-2007-21).
- Evaluates the effectiveness of source interim actions for the 100-F Source OUs and the 100-IU-2 and 100-IU-6 Source OUs.
- Qualitatively evaluates soil data from RI and LFI soil borings and wells to determine if results could be useful for risk management decisions.
- Confirms that waste sites are remediated to the RAOs and RAGs published in the 100 Area RDR/RAWP (DOE/RL-96-17). In addition, confirms that waste sites achieve the direct contact PRGs proposed for the FS. In other words, sites cleaned up under interim action do not need to be revisited in the FS to demonstrate protection of human health.
- Identifies the waste sites and COCs in the vadose zone that require further evaluation in the FS.
- Confirms that waste sites that have not been remediated are carried forward into the FS based on process history and/or sampling results.
- Identifies the COCs in groundwater that require further evaluation in the FS.

The methodology used to assess risks for the RI/FS uses PRGs developed in the RCBRA (DOE/RL-2007-21), and incorporates the most current agency guidance. COPCs in the vadose zone and groundwater were identified in a conservative manner, using exclusions identified in the RCBRA (DOE/RL-2007-21) to identify COPCs. The methods for developing EPCs are based on EPA's ProUCL guidance manual. The residential scenario used to develop PRGs and characterize risks to human health from contaminants in the vadose zone is drawn from the scenario that was used to develop cleanup levels for the 100 Area RDR/RAWP (DOE/RL-96-17), and was brought up to date to be consistent with most recent regulatory guidance. PRGs for the vadose zone were developed to reflect a range of exposure scenarios and include those that represent the RAOs (residential scenario) and the reasonably anticipated future land use (resident-Monument worker and casual-recreational user).

Contaminant concentrations in groundwater were compared with a range of groundwater and surface water standards for protection of human health and aquatic organisms. In addition, risks from contaminants in groundwater were assessed using Tribal scenarios based on assumptions provided by the CTUIR and Yakama Nation. The EPA tap water scenario is also evaluated to provide a similar scenario using exposure assumptions that represent RME.

Cumulative risks were calculated for multiple contaminants and multiple exposure pathways by exposure media (i.e., soil or groundwater). Cumulative risks summed across soil and groundwater were not calculated for the residential scenario because the RME for this scenario does not include combined exposures to both media; therefore, they are presented separately.

RI and LFI data were compared to PRGs developed in the RCBRA (DOE/RL-2007-21). Soil samples collected from depth intervals ranging from 0 to 4.6 m (15 ft) bgs from each individual soil boring or test pit were combined and compared to PRGs including those that represent the RAOs (residential scenario) and reasonably anticipate future land use (resident Monument worker and casual-recreational user). Soil

samples collected from depth intervals greater than 4.6 m (15 ft) bgs from each individual soil boring or test pit were combined and compared to residential PRGs.

The protection of groundwater and surface water from contaminants currently in the vadose zone was discussed in Chapter 5. The ecological risk assessment that evaluates the protection of terrestrial receptors is discussed in Chapter 7.

### 6.5.1 Conclusions for the Soil Risk Assessment

The contaminants that are the largest contributors to calculated risks and hazard indices in the vadose zone are radionuclides and metals. The radionuclides can be categorized as being related to waste disposal, including cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90. A summary of the remediated waste sites that warrant further evaluation in the FS and their associated contaminants of potential concern are provided in Table 6-53.

Table 6-53. Summary of Remediated Waste Sites and COPCs that Warrant Further Evaluation in the FS

| Source OU | Remediated Waste Site | Data Source | COCs warranting further evaluation in FS | Year that cumulative risk is less than 1.0 × 10-4 |
|---|---|---|---|---|
| 100-FR-1 | 118-F-6 | Shallow (CVP/RSVP) | strontium-90 | 2033 |
| 100-FR-2 | 600-351 | Shallow Focused (CVP/RSVP) | arsenic, lead | Not Applicable |
| 100-FR-1 | 100-F-19:1 | Deep(CVP/RSVP) | cesium-137, cobalt-60, europium-152, europium-154, strontium-90 | 2113 |
| 100-FR-1 | 100-F-19:2 | Deep (CVP/RSVP) | europium-152 | 2059 |
| 100-FR-1 | 116-F-14 | Deep (CVP/RSVP) | cesium-137, cobalt-60, europium-152, europium-154, nickel-63 | 2110 |
| | | Deep (RI borehole) | cesium-137, cobalt-60, europium-152, europium-154, strontium-90 | 2176 |
| 100-FR-1 | 116-F-2 | Deep (CVP/RSVP) | cesium-137, europium-152, europium-154 | 2108 |
| | | Deep (LFI borehole) | cesium-137, cobalt-60, europium-152, europium-154, strontium-90 | 2078 |

Table 6-53. Summary of Remediated Waste Sites and COPCs that Warrant Further Evaluation in the FS

| Source OU | Remediated Waste Site | Data Source | COCs warranting further evaluation in FS | Year that cumulative risk is less than 1.0 × 10-4 |
|---|---|---|---|---|
| 100-FR-1 | 116-F-6 | Deep (CVP/RSVP) | cesium-137, europium-152, strontium-90 | 2122 |
| | | Deep (LFI) | strontium | 2025 |
| 100-FR-1 | 116-F-9 | Deep (CVP/RSVP) | europium-152, strontium-90 | 2074 |
| | | Deep (LFI borehole) | strontium-90 | 2037 |
| | | Deep (Test pit) | strontium-90 | 2083 |
| 100-FR-1 | 118-F-8:3 | Deep (CVP/RSVP) | cesium-137, cobalt-60, europium-152, europium-154, strontium-90 | 2235 |
| 100-FR-1 | 118-F-8:4 | Deep (CVP/RSVP) | cesium-137, europium-152, strontium-90 | 2059 |

#### *6.5.1.1 Shallow Zone Results for Closeout Verification Data*

Cancer risks associated with all radionuclides at remediated waste sites within the top 4.6 m (15 ft) of soil are in the $10^{-4}$ range for the 100-FR-1 and 100-FR-2 Source OUs, based on the Residential exposure scenario. Four remediated in the 100-F Source OUs were reported with individual COPCs greater than $1 \times 10^{-4}$. Cancer risks associated with all radionuclides at remediated waste sites within the top 4.6 m (15 ft) of soil for the 100-IU-2 and 100-IU-6 Source OUs were not reported because radionuclides were not identified as COPCs (at 100-IU-2 Source OU) or they were present at concentrations less than background (at 100-IU-6 Source OU). Cancer risks associated with the Resident Monument Worker scenario are similar to the Residential scenario. Risks associated with the resident Monument worker are slightly lower than the Residential scenario because it does not include the food chain pathways. Cancer risks for a casual-recreational user scenario are approximately two orders of magnitude lower than the residential scenarios. This slight exceedance of target risk thresholds is a result of health protective levels being updated from a target annual dose rate of 15 mrem/yr to a target risk of $1 \times 10^{-4}$ to be consistent with *Radiation Risk Assessment At CERCLA Sites: Q & A* (EPA/540/R/99/006). In addition, the residual radionuclides have relatively short half-lives. It is anticipated that concentrations would decay to levels corresponding to EPA's target risk range within 110 years.

Concentrations of strontium-90 in the 100-F-26:13 (shallow decision unit), concentrations of cesium-137 and strontium-90 in the 100-F-26:14 (overburden decision unit), concentrations of europium-152 and strontium-90 in the 116-F-4 (shallow decision unit), and concentrations of europium-152 and europium-154 at 126-F-1 (shallow decision unit) have to decayed to residential RBSLs, activities of all radionuclides have decayed to levels less than $1 \times 10^{-4}$, and do not warrant further evaluation in the FS.

The presence of technetium-99 in the 116-F-4 remediated waste site (overburden focused decision unit) is considered an anomalous result and does not warrant further evaluation in the FS.

The following waste site contains site-related COPCs in the top 4.6 m (15 ft) and warrants further evaluation as a COC in the FS:

- 118-F-6 (shallow decision unit) contained strontium-90 at a concentration of 4.1 pCi/g, resulting in a risk of $1.8 \times 10^{-4}$, when sampled in year 2007. Strontium-90 concentrations decay to levels less than residential PRG by year 2032. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2033.

For nonradiological contaminants, the COPCs that are the largest contributors to calculated risks and hazard indices are arsenic and lead. For all but 10 remediated waste sites that have been remediated under interim action RODs, the cancer risks and noncancer hazard indices for nonradioactive contaminants fell within EPA's target risk ranges for all exposure scenarios. Concentrations of arsenic in vadose zone material are associated with cancer risks higher than MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ under unrestricted exposure assumptions. For most remediated waste sites, the concentrations of arsenic in vadose zone material posing risks greater than MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ are consistent with Sitewide naturally occurring background in vadose zone material. The following waste sites reported analytes that were greater than MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$ or were greater than the a MTCA Method A soil cleanup level.

For remediated waste site 600-109 (staging pile decision unit), the EPC for arsenic is greater than the Method A soil cleanup levels of 20 mg/kg. However, the EPC is based on a maximum detected value which overestimates the concentration within the decision unit. The staging pile area associated with this remediated waste site does not warrant further evaluation in the FS.

Similarly, remediated waste site 600-176 (staging pile material_2 decision unit), remediated waste site 600-202 (shallow focused decision unit), and remediated waste site 600-3 (shallow focused decision unit) report lead concentrations greater than the Method A soil cleanup levels of 250 mg/kg. The EPCs for each of these remediated waste sites are based on maximum detected values which overestimates the concentration within the entire decision unit. These remediated waste sites do not warrant further evaluation in the FS.

Remediated waste site 132-F-1 (staging pile focused decision unit) contains benzo(a)pyrene at a concentrations that results in a risk greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708(5)]) total risk threshold of $1 \times 10^{-5}$. Benzo(a)pyrene is attributed to the presence of asphalt within the staging area and do not reflect a Site release, this is further supported by lower concentrations of benzo(a)pyrene reported in the associated shallow vadose zone material. The staging pile area associated with this remediated waste site does not warrant further evaluation in the FS.

Remediated waste site 600-186 (shallow focused decision unit) contains iron at concentrations that result in a HI greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1. The EPC for iron is based on the maximum detected value which overestimates the concentration within the decision unit. This remediated waste site does not warrant further evaluation in the FS.

Remediated waste site 600-322 (shallow focused decision unit) contains iron at concentrations that result in a HI greater than the "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740) target HI of 1. The EPC for iron is based on the maximum detected value which overestimates the concentration

within the decision unit. The iron concentration measured in this soil sample is associated with the pipe it was collected from. This remediated waste site does not warrant further evaluation in the FS.

For Remediated waste site 600-205 (shallow focused decision unit), the EPC for TPH is greater than the Residual Saturation Screening Level for TPH of 1,000 mg/kg for unknown composition or type. The EPC for TPH is based on the maximum detected value which overestimates the concentration within the decision unit. This remediated waste site does not warrant further evaluation in the FS.

For Remediated waste site 126-F-2 (staging pile area), the EPC for TPH is greater than the Residual Saturation Screening Level for TPH of 1,000 mg/kg for unknown composition or type. TPH is attributed to the presence of asphalt within the staging area and do not reflect a Site release. This staging pile area associated with this remediated waste site does not warrant further evaluation in the FS.

Remediated waste site 600-351 (shallow focused decision unit) contains arsenic and lead at concentrations greater than the Method A soil cleanup level of 20 mg/kg and 250 mg/kg, respectively. Arsenic and lead in remediated waste site 600-351 (shallow focused decision unit) warrant further evaluation as COCs in the FS.

#### *6.5.1.2 Shallow Zone Results for RI and LFI Data*

Soil samples were collected from 0 to 4.6 m (15 ft) bgs from four LFI test pits, five LFI soil borings, and two LFI monitoring wells. The conclusion from the evaluation of the shallow zone RI and LFI data are consistent with the conclusions of the soil risk assessment.

Although the seven waste sites (116-F-14 Retention Basin, 116-F-1 Lewis Canal, 116-F-2 Basin Overflow Trench, 116-F-3 Fuel Storage basin Trench, 116-F-4 Pluto Crib, 116-F-6 Liquid Waste Disposal Trench, and 116-F-9 PNL Animal Waste Leach Trench) report soil concentrations greater than residential RBSLs in the top 4.6 m (15 ft), all of these waste sites have been subsequently remediated under the interim action ROD. The soil risk assessment did not identify risks associated with these sites based on current conditions.

The risk results for the two LFI wells are within acceptable EPA risk thresholds.

RI and LFI data were not available for the 100-IU-2 and 100-IU-6 Source OUs.

#### *6.5.1.3 Deep Zone Results for Closeout Verification Data*

Deep vadose zone samples were evaluated to identify remediated waste sites where exposure to residual contamination could present a potential risk from an inadvertent exposure through deep excavation activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience as screening values to identify such sites in order to allow institutional controls to be established to control access to deep contamination.

Eight waste sites are reported with concentrations of site-related COPCs at depths greater than 4.6 m (15 ft) bgs and warrant further evaluation in Chapter 8. The following eight waste sites report concentrations of cesium-137, cobalt-60, europium-152, europium-154, nickel-63, or strontium-90 at concentrations greater than the residential RBSL.

- 100-F-19:1 deep decision unit contained cesium-137 at a concentration of 20.5 pCi/g, cobalt-60 at a concentration of 12.5 pCi/g, europium-152 at a concentration of 325 pCi/g, europium-154 at a concentration of 24.7 pCi/g, and strontium-90 at a concentration of 3.1 pCi/g when sampled in year 2002. The cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 will decay to a concentration less than the residential RBSL by years 2069, 2013, 2088, 2024, 2004, and

2015, respectively. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2113.

- 100-F-19:2 deep decision unit contained europium-152 at a concentration of 12.5 pCi/g when sampled in year 2003. The europium-152 will decay to a concentration less than the residential RBSL by year 2027. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2059.

- 116-F-14 deep decision unit contained cesium-137 at a concentration of 7.9 pCi/g, cobalt-60 at a concentration of 12.5 pCi/g, europium-152 at a concentration of 185 pCi/g, europium-154 at a concentration of 23.4 pCi/g, and nickel-63 at a concentration of 686 pCi/g when sampled in year 2001. The cesium-137, cobalt-60, europium-152, europium-154, and nickel-63 will decay to a concentration less than the residential RBSL by years 2026, 2012, 2076, 2022, and 2018, respectively. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2110.

- 116-F-2 deep decision unit contained cesium-137 at a concentration of 43.7 pCi/g, europium-152 at a concentration of 53.8 pCi/g, and europium-154 at a concentration of 5.6 pCi/g when sampled in year 2002. The cesium-137, europium-152, and europium-154 will decay to a concentration less than the residential RBSL by years 2101, 2054, and 2005, respectively. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2108.

- 116-F-6 deep decision unit contained cesium-137 at a concentration of 12.2 pCi/g, europium-152 at a concentration of 12.7 pCi/g, and strontium-90 at a concentration of 31.8 pCi/g when sampled in year 2002. The cesium-137, europium-152, and strontium-90 will decay to a concentration less than the residential RBSL by years 2046, 2026, and 2113, respectively. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2122.

- 116-F-9 deep decision unit contained europium-152 at a concentration of 6.4 pCi/g and strontium-90 at a concentration of 9.6 pCi/g when sampled in year 2002. The europium-152 and strontium-90 will decay to a concentration less than the residential RBSL by years 2013 and 2062, respectively. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2074.

- 118-F-8:3 deep decision unit contained cesium-137 at a concentration of 319 pCi/g, cobalt-60 at a concentration of 18 pCi/g, europium-152 at a concentration of 183 pCi/g, europium-154 at a concentration of 7.7 pCi/g, nickel-63 at a concentration of 617 pCi/g, and strontium-90 at a concentration of 103 pCi/g, when sampled in year 2002. The cesium-137, cobalt-60, europium-152, europium-154, nickel-63, and strontium-90 will decay to a concentration less than the residential RBSL by years 2187, 2015, 2077, 2009, 2004, and 2162, respectively. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2235.

- 118-F-8:4 deep decision unit contained cesium-137 at a concentration of 6.6 pCi/g, europium-152 at a concentration of 4.4 pCi/g, and strontium-90 at a concentration of 3.2 pCi/g when sampled in year 2007. The cesium-137, europium-152, and strontium-90 will decay to a concentration less than the residential RBSL by years 2025, 2010, and 2022, respectively. Activities of all radionuclides will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2059.

#### *6.5.1.4 Deep Zone Results for RI and LFI Data*

Soil samples were collected from depths greater than 4.6 m (15 ft) bgs from three RI soil borings, three RI wells, four LFI test pits, five LFI soil borings, and 13 LFI wells.

Radionuclide concentrations from soil borings and test pits that report concentrations greater than residential PRGs were decayed to determine the year that activities would be reduced to levels less than the residential PRG. The following summarizes the results of the comparisons for the above waste sites:

- RI soil boring data, CVP/RSVP closeout data, and LFI data are available for the 116-F-14 Retention Basin. The LFI data for 199-F5-51 borehole through the 116-F-14 retention basin report risks less than $1 \times 10^{-4}$. The RI borehole (199-F5-55) through the 116-F-14 retention basin identifies cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 as contributors to risk. Activities of all radionuclides from the RI data decay to levels less than $1 \times 10^{-4}$ by year 2176 (see Table G1-5). The risk assessment for 116-F-14 (deep decision unit) identifies cesium-137, cobalt-60, europium-152, europium-154, and nickel-63 as contributors to risk. Activities of all radionuclides based on CVP/RSVP data will decay to a cumulative ELCR of less than $1.0 \times 10^{-4}$ by year 2110. Based on the results of the RI data analysis and the risk assessment, radioisotope concentrations decay to levels less than residential PRGs by years 2176 and 2110, respectively.

- RI soil boring data and CVP/RSVP closeout data are available for the 118-F-8:3 Fuel Storage Basin. The RI borehole (199-F5-56) through the 118-F-8:3 Fuel Storage Basin indicate that individual risks from all detected analytes are less than the risk threshold of $1 \times 10^{-4}$. The risk assessment for 118-F-8:3 (deep decision unit) identifies cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 as contributors to risk. Based on the results of the risk assessment, radioisotope concentrations decay to levels less than residential PRGs by year 2187.

- The LFI borehole (199-F4-2) through the 116-F-1 Lewis Canal identified carbon-14 at concentrations greater than the residential RBSL at depths ranging from the surface to 6.9 m (22.5 ft) bgs. However, carbon-14 data collected during closeout verification from the shallow decision unit report carbon-14 at levels two orders of magnitude lower than the LFI data. Although the excavation did not go down to 6.9 m (22.5 ft) bgs, the closeout data suggest that carbon-14 was not present at elevated levels at the 116-F-1 remediated waste site. Additionally, carbon-14 was not detected in the soil samples collected from either of the test pits from the unremediated 116-F-1 Lewis Canal waste site. Therefore, the presence of carbon-14 at the 116-F-1 waste site is likely overstated based on the LFI results. The results of the soil risk assessment for the shallow zone indicate that cumulative ELCR is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

- CVP/RSVP closeout data and LFI data are available for the 116-F-2 Basin Overflow Trench. The risk assessment for 116-F-2 Basin Overflow Trench (deep decision unit) identifies cesium-137, europium-152, and europium-154 as contributors to risk. The LFI borehole (199-F5-49) through the 116-F-2 Basin Overflow Trench indicates that carbon-14, cesium-137, cobalt-60, europium-152, europium-154, and strontium-90 are present at concentrations greater than residential RBSLs. However, carbon-14 data collected during closeout verification from the shallow decision unit was reported at lower concentrations than what was reported during the LFI. Although the excavation did not go down to 9.8 m (32 ft) bgs, the closeout data suggest that carbon-14 was not present at elevated levels at the 116-F-2 remediated waste site. Activities of all radionuclides except carbon-14 in LFI data decay to levels less than $1 \times 10^{-4}$ by year 2078. The soil risk assessment for 116-F-2 Basin Overflow Trench (deep decision unit) identifies cesium-137, europium-152, and europium-154 as contributors to risk. Activities of all radionuclides decay to levels less than $1 \times 10^{-4}$ by year 2108. With the exception of the carbon-14 results, the closeout results and the LFI results are similar. The presence of carbon-14 at the 116-F-2 remediated waste site is likely overstated based on the differences between LFI and CVP results.

- CVP/RSVP closeout data and LFI data are available for the 116-F-4 Pluto Crib. The risk assessment for 116-F-4 (deep decision unit) indicates that the total ELCR is within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The LFI borehole (199-F8-5) through the 116-F-4 Pluto Crib indicate that europium-152 and strontium-90 are present at concentrations greater than residential RBSLs; however, this waste site has been subsequently remediated under the interim action ROD. The risk assessment for 116-F-4 Pluto Crib (shallow and deep decision unit) reports a cumulative total ELCR within the EPA risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

- CVP/RSVP closeout data and LFI data are available for the 116-F-6 Liquid Waste Disposal Trench. The risk assessment for 116-F-6 (deep decision unit) identifies cesium-137, europium-152, and strontium-90 as contributors to risk. The LFI borehole (199-F8-6) through the 116-F-6 Liquid Waste Disposal Trench indicate that strontium-90 is present at concentrations greater than residential RBSLs. Activities of strontium-90 in the LFI soil boring decay to levels less than $1 \times 10^{-4}$ by year 2025. The soil risk assessment for 116-F-6 Liquid Waste Disposal Trench (deep decision unit) identifies cesium-137, europium-152, and strontium-90 as contributors to risk. Activities of all radionuclides from the CVP data decay to levels less than $1 \times 10^{-4}$ by year 2122.

- CVP/RSVP closeout data and LFI data are available for the 116-F-9 Animal Waste Leach Trench. The risk assessment for 116-F-9 (deep decision unit) identifies europium-152 and strontium-90 as contributors to risk. Activities of all radionuclides from the CVP data decay to levels less than $1 \times 10^{-4}$ by year 2074. The LFI borehole (199-F5-50) and the test pit (116-F-9D-TP1) through the 116-F-9 Animal Waste Leach Trench indicate that strontium-90 is present at concentrations greater than residential RBSLs. Activities of strontium-90 in the LFI soil boring and test pit decay to levels less than $1 \times 10^{-4}$ by year 2037 and 2083, respectively.

The results from several of the waste sites are based on small data sets, which create uncertainties in obtaining reliable EPCs in vadose zone material. The uncertainties relating to small data sets could result in risks either being over- or understated. EPCs selected for shallow zone and deep zone decision units represent verification data collected from the floor and the sidewall of the excavated waste site. EPCs developed from the floor and sidewall of the excavated waste site overstate risk because the contaminant is assumed to be uniformly distributed across the entire decision unit. In addition, exposure is assumed to occur at the surface. However, these sample locations are actually at depth and take no credit for the existing clean backfill that covers the remediated waste site. Should the contaminants be disturbed in the future, their distribution within decision unit would be blended with the clean backfill resulting in an overall reduction of the EPC for the decision unit. The approach for identifying COPCs is conservative because it excludes few contaminants and, therefore, probably overstates risks. The exposure factors and toxicity values used to develop the PRGs generally are conservative and tend to provide upper bound estimates of risks in vadose zone material.

Based on the results of the soil risk assessment for the 100-F Source OUs, 100-IU-2 Source OU, and 100-IU-6 Source OU, cleanups in vadose zone material conducted as part of the interim actions appear to have been effective in reducing human health risks to within EPA's target risk range. In some cases, residual risks are higher than the State of Washington's cancer risk threshold; however, in all cases, the contaminant exceeding the State of Washington's cancer risk threshold is arsenic and is present at concentrations consistent with naturally occurring background. Cleanup of shallow vadose zone material (4.6 m [15 ft]) to achieve residential or unrestricted uses is also protective of a range of exposure scenarios, including a casual recreational user and a resident-Monument worker.

Deep vadose zone samples (from remediated waste sites) were used to identify locations where institutional controls should be implemented to prevent inadvertent exposure through deep excavation

activities. While this exposure would be industrial in nature, the RBSLs (developed for the Residential exposure scenario) were used for convenience to identify sites where institutional controls should be established to control access to deep contamination. These sites do not pose significant risks because there is no current exposure pathway for deep contamination. Concentrations in deep vadose material will decay to the residential RBSLs within 135 years. In addition, data and process knowledge indicate that human health PRGs would be exceeded at unremediated waste sites and provide the basis for action. Table 8-3provides the contaminants that are anticipated to exceed human health PRGs for unremediated waste sites.

### 6.5.2 Risk Assessment Conclusions for Allowable Residual Contamination Level Sites

Radiological risks were evaluated for sites that previously had undergone decontamination and decommissioning in accordance with the Allowable Residual Contamination Level (ARCL) method. The risk assessment procedure used for the ARCL sites is documented in *Calculation of Radiological Risks for ARCL Sites in the River Corridor in Support of the 100 and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Reports* (ECF-HANFORD-12-0066) in Appendix G. The ARCL sites are support structures and facilities located in proximity to the reactor buildings. Examples of ARCL sites include filter buildings, gas recirculation buildings, exhaust ventilation stacks, and reactor stacks. After decontamination, these structures were demolished and the rubble was buried under a minimum of 1 m (3 ft) of clean fill. Four ARCL sites from the 100-F Source OU were evaluated and include 132-F-3, 132-F-4, 132-F-5, and 132-F-6.

The estimated risks for each ARCL site were based on the casual recreational user exposure scenario. The exposure assumptions reflect an individual who could spend a portion of time walking on or exploring in proximity to an ARCL Site. The risk estimates for ARCL sites 132-F-3, 132-F-4, and 132-F-5 were less than $1 \times 10^{-6}$. The risk estimate for ARCL site 132-F-6 was within the target risk range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$.

### 6.5.3 Conclusions for the Groundwater Risk Assessment

Results of the nature and extent evaluation of this report indicate that concentrations of contaminants in groundwater beneath the 100-IU-2 and 100-IU-6 Source OUs exceed action levels in some areas; however, groundwater contaminants originate from the 100-FR-3 Groundwater OU as well as the 200 Areas rather than 100-IU-2 and 100-IU-6 waste sites. Groundwater beneath the 100-IU-2 and 100-IU-6 Source OUs is generally attributed to groundwater contaminants that originate from the 200 East Area that have dispersed from the 200-BP-5 Groundwater OU or 200-PO-1 Groundwater OU, respectively. It has also been influenced by groundwater contaminants that originate from the 200 West Area that have dispersed from the 200-ZP-1 Groundwater OU. Additionally, the "eastern" portion of the IU-2 and IU-6 Groundwater Area contains groundwater contaminants that originate from the 100-FR-3 groundwater OU. As a result a groundwater risk assessment was not performed for groundwater within the 100-IU-2 and 100-IU-6 Groundwater Area. This is because groundwater contaminants within the 100-IU-2 and 100-IU-6 Groundwater Area are addressed by other OUs including the 200 Area and 100-FR-3 groundwater OUs.

In addition to comparison to the action levels, risks associated with all analytes with available toxicity information were quantified using EPA's tap water scenario. This scenario was used to quantify risks from ingestion of tap water, inhalation of volatiles, and dermal exposure from showering, bathing, or performing other domestic activities. The risk posed by each analyte was then quantified and compared individually and collectively to the CERCLA ($10^{-4}$ to $10^{-6}$) acceptable risk range. Additionally, the quantified risks were used to confirm that the COPC identification process was reasonable and representative of the starting dataset. The results of this confirmation analysis indicate that the COPCs

identified are representative and appropriate for assessing risk and for making contaminant-specific remedial action decisions. If the contaminant had a quantified risk level that was above EPA's acceptable risk range, the contaminant was defined as a COPC subject to remedial technology review in the FS.

#### 6.5.3.1 100-FR-3 Groundwater OU

The 100-FR-3 Groundwater OU was evaluated as a single exposure area. The contaminants in groundwater that are the largest contributors to calculated risks, dose, and hazard indices are Cr(VI), nitrate, strontium-90, and trichloroethene. The EPCs in groundwater were compared with federal and state surface water standards for protection of human health and aquatic organisms, primary and secondary DWSs, and state groundwater cleanup levels.

The EPC for Cr(VI) is greater than the federal and state water quality criteria. Cr(VI) is identified as a COPC, indicating the need to evaluate potential remedial technologies for this analyte in the FS.

The EPC for nitrate is greater than the federal DWS developed for the protection of human health. Nitrate is identified as a COPC, indicating the need to evaluate potential remedial technologies for nitrate in the FS.

The EPC for trichloroethene is greater than the federal DWS developed for the protection of human health. The EPC for trichloroethene was greater than the MTCA (WAC 173-340) Method B groundwater cleanup level, which is based on a $1 \times 10^{-6}$ target cancer risk level. The cumulative risk for trichloroethene is also greater than the MTCA ("Human Health Risk Assessment Procedures" [WAC 173-340-708]) cumulative risk level of $1 \times 10^{-5}$ for multiple contaminants. Trichloroethene is identified as a COPC, indicating the need to evaluate potential remedial technologies for nitrate in the FS.

The EPC for strontium-90 is less than the federal DWS; however, strontium-90 is present at concentrations above the DWS in localized areas. Strontium-90 is identified as a COPC, indicating the need to evaluate potential remedial technologies in the FS.

The COPC identification process identified three analytes for the 100-FR-3 Groundwater OU that are considered COPCs and warrant further evaluation in the FS. The occurrence of antimony, cadmium, and cobalt in groundwater is uncertain because these analytes historically have been detected in groundwater at concentrations above their respective action level; however, their presence was not associated with a specific location or a trend and the analytical methods used were not of sufficient accuracy for risk characterization purposes. In addition, the EPCs for these analytes are less than their respective action level. Therefore, antimony, cadmium, and cobalt are considered COPCs where they warrant further evaluation in the FS.

Risks associated with all analytes with available toxicity information were quantified using EPA's tap water scenario. This scenario was used to quantify risks from ingestion of tap water, inhalation of volatiles, and dermal exposure from showering, bathing, or performing other domestic activities. The risk posed by each analyte was then quantified and compared individually and collectively to the CERCLA ($10^{-4}$ to $10^{-6}$) acceptable risk range. Additionally the quantified risks were used to confirm that the COPC identification process was reasonable and representative of the starting dataset. The results of this confirmation analysis indicate that the COPCs identified are representative and appropriate for assessing risk and for making contaminant-specific remedial action decisions. If the contaminant had a quantified risk level that was above EPA's acceptable risk range, the contaminant was defined as a COPC subject to remedial technology review in the FS.

In addition to the chemical-specific ARARs analysis, risks were evaluated using the Native American scenarios and the EPA Tap Water scenario. The total cumulative ELCRs for the CTUIR and Yakama

Nation exposure scenarios are $9.1 \times 10^{-4}$ and $9.8 \times 10^{-4}$, respectively, when groundwater was used as a drinking water source. The total cumulative ELCR for the EPA tap water scenario is $2.3 \times 10^{-4}$. All scenarios are greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Major contributors to risk for the Native American scenarios and the EPA tap water scenario are trichloroethene, strontium-90, and tritium. Contribution to the ELCR is elevated for arsenic, where measured concentrations are within natural background values. The total HI is 5.2 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA tap water scenario is 2.5. All individual analytes (fluoride, Cr(VI), lithium, molybdenum, nitrate, strontium, and vanadium) that contribute greater than one percent of the HI also report a HQ less than 1 for the Native American scenarios and the EPA tap water exposure scenario. Trichloroethene and strontium-90 are identified as COPCs to be evaluated in the FS. Tritium was not identified as a COPC to be evaluated in the FS because all concentrations were less than the DWS of 20,000 pCi/g.

The total cumulative ELCR for the CTUIR and Yakama Nation exposure scenarios are $1.4 \times 10^{-2}$ and $3.0 \times 10^{-2}$, respectively, when groundwater is used as a source of steam for a sweat lodge. The total cumulative ELCRs for the Native American scenarios are greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The major contributor to the cumulative ELCR (those analytes that contribute greater than 1 percent of total cumulative ELCR) for both Native American scenarios is Cr(VI). The total HI for the CTUIR and Yakama Nation exposure scenarios are 11 and 23, respectively. The primary contributor to the noncancer HI (those analytes that contribute greater than 1 percent of total HI) for both Native American resident scenarios is Cr(VI). All remaining individual analytes (barium, cobalt, Cr(VI), fluoride, manganese, and nickel) that contribute greater than one percent of the HI also report a HQ less than 1.

The key uncertainties in the assessment of groundwater risks are with the assessment of dermal contact exposure pathways, selection of the toxicity value for trichloroethene, and recent developments with the toxicity value for Cr(VI). The evaluation of potential risks from VOCs is based on ingestion and inhalation exposure pathways. The evaluation does not consider exposure through dermal contact with water. Not including the dermal contact, exposure pathway potentially results in risks from these contaminants being understated. The cancer slope factor used by the State of Washington to develop the Method B groundwater cleanup level for trichloroethene has not yet been updated to reflect current agency guidelines. Use of this toxicity value overstates risks from trichloroethene by approximately a factor of two. Use of a current cancer slope factor would decrease the groundwater risk associated with trichloroethene from $7.8 \times 10^{-6}$ to $4.0 \times 10^{-6}$. Ingestion exposure to Cr(VI) currently is assessed as a noncarcinogen for purposes of developing groundwater cleanup levels for protection of human health and Cr(VI) currently does not have a federal MCL. However, some state agencies, particularly the NJDEP, have developed a cancer slope factor for Cr(VI). Assessing ingestion of Cr(VI) in groundwater as a carcinogen is not yet incorporated into regulatory requirements or guidance at this time; however, groundwater standards for protection of human health for Cr(VI) would be considerably lower if these were based on carcinogenic effects.

The results from the assessment of groundwater risks were based on three additional rounds of groundwater sampling across the 100-FR-3 Groundwater OU, which were intended to provide a more definitive identification of COPCs. The results of this groundwater risk assessment did not identify any COPCs in addition to those identified in the work plan. The results of the groundwater risk assessment identified antimony, cadmium, cobalt, strontium-90, including Cr(VI), trichloroethene, and nitrate as contaminants warranting further evaluation in the FS.

# 7 Ecological Risk Assessment

The integration of past and ongoing ecological risk assessments (ERAs) supports the development of remedial alternatives for waste sites and contaminated groundwater in the 100-F/IU OUs. These risk assessments have been integrated with the cleanup performed under the interim action RODs to identify the need for further remedial action and facilitate development of ecological PRGs.

*Highlights*

- The ecological risk assessment evaluated soil contaminant concentrations at 94, 25, and 21 waste sites at 100-F, 100-IU-2, and 100-IU-6, respectively.
- The ERA relied on ecological PRGs presented in the RCBRA that are protective of populations and communities. The exposure area and the relative size of the waste sites were used in conjunction with the ecological PRGs to determine where ecological protection is required.
- Concentrations of radionuclides in upland soil verification samples did not exceed screening levels.
- Interim remedial actions at 100-F/IU under interim action ROD remedial action goals were protective of ecological receptors at all waste sites.
- An examination of the interrelationships between potential contaminant sources, transport mechanisms, exposure pathways, and receptors in the Columbia River concluded that there are no COPECs in the 100-FR-3 Groundwater OU contributing to potential ecological risks. However, because Cr(VI) has some limited potential to discharge to surface water above AWQS, it is recommended to be monitored at discharge points to surface water.
- Data and process knowledge indicate that ecological PRGs will be exceeded at unremediated waste sites. Those exceedances will be evaluated through the ERA process, including consideration of such factors as waste site size and wildlife home ranges within a scientific management decision point to determine a basis for action.

As described in the previous chapters, the remedial actions completed to date in the River Corridor were implemented under interim action RODs. The RAOs in the 100 Area interim action RODs were developed to achieve protection of human health from direct contact with vadose zone material or to protect groundwater and surface water from contaminants leaching from vadose zone material. Protection of ecological receptors from direct contact with contaminated vadose zone material was not addressed directly in the interim action RODs but indirectly with the assumptions that attainment of standards for protection of human health or that reduced contaminant leaching would also be protective of ecological receptors. Protection of ecological receptors from discharges into the river was considered in the interim action RODs through consideration of state water quality standards and federal AWQC.

CERCLA requires a baseline risk assessment to characterize current and potential threats to HHE before issuance of the ROD. The soil and groundwater component of the RCBRA (DOE/RL-2007-21)[1] was prepared to address the regulatory requirement to perform a baseline risk assessment. The RCBRA (DOE/RL-2007-21) was a comprehensive examination of current and potential risks in areas potentially affected by Hanford Site processes within the 100 and 300 Area OUs. One of the objectives of the RCBRA (DOE/RL-2007-21) was to determine whether the interim actions were protective of ecological receptors (*Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL-2004-37]). The scope of the RCBRA (DOE/RL-2007-21) addressed the following portions of the River Corridor:

- Upland areas, including remediated CERCLA waste sites within 100-K, 100-D/H, 100-F, 100-BC, and 100-F/IU Areas; the White Bluffs and Hanford Townsites; and the 300 Area
- Riparian and near-shore aquatic zones on the southern and western shorelines of the Columbia River on the Hanford Site

[1] All citations to the RCBRA (DOE/RL-2007-21) in this chapter are referring to *Volume I: Ecological Risk Assessment*.

- Groundwater and areas of groundwater emergence on the southern and western shorelines of the Columbia River on the Hanford Site

The RCBRA (DOE/RL-2007-21) used multiple measures of exposure, ecological effect, and ecosystem/receptor characteristics to evaluate risks at 20 study sites across the River Corridor associated with remediated waste sites (10 excavated/backfilled sites and 10 surface removal/native soil sites) and 10 reference areas, as described in the RCBRA SAP (DOE/RL-2005-42). The sites studied were selected from high-priority waste sites that had been remediated when the study was developed. The sites represent the types of waste sites and remedial actions addressed by the interim action RODs. Based on this set of study sites, the results from the RCBRA (DOE/RL-2007-21) identified some contaminants in soil as contaminants of ecological concern (COECs). The principal COECs were metals and pesticides.

The study design of the ERA in the RCBRA (DOE/RL-2007-21) provided risk conclusions that applied across the entire River Corridor. The study design, coupled with results that identified COECs across the River Corridor, required development of an ERA approach for the RI/FS that allowed evaluation of risks on a site-by-site basis and supported development of PRGs. That approach incorporates the use of ecological SSLs and ecological PRGs, which have been developed using the tiered process outlined in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311), respectively, found in Appendix H of *Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR, and 100-KR-4 Operable Units* (DOE/RL-2010-97), hereinafter called the 100-K RI/FS. This tiered process allows the incorporation of more sophisticated ERA methods and increasing levels of ecological site-specific and site-relevant information to provide SSLs and PRGs that are more representative of Hanford Site conditions. Development of the risk-based concentration values (SSLs) and PRGs incorporates the problem formulation, the conceptual ecological exposure models, and selected bioaccumulation datasets developed in the RCBRA (DOE/RL-2007-21). These values were used to screen the waste sites in the 100-F/IU OUs, with verification sampling and analytical information to provide site-specific ecological risk information for each site.

The CRC (DOE/RL-2010-117)[2] used analytical chemistry collected from surface water, sediment, pore water, and island soil to evaluate the potential for risk to ecological receptors, including aquatic life living within the Columbia River and wildlife frequenting or inhabiting the islands within the river. Based on a screening level ERA using refined toxicity and distributional data, the CRC (DOE/RL-2010-117) identified some contaminants in soil as contaminants of potential ecological concern (COPECs). The COPECs were principally metals. The potential for these contaminants to have originated from the 100-F/IU OUs is discussed later in this chapter.

The following approach has been used for addressing ecological risks potentially associated with waste sites in the 100-F/IU OUs:

- **Updating the identification of COPCs (Section 7.1).** The RCBRA went through a process to identify COPCs for ecological receptors based on a Sitewide review of River Corridor data. This identification process has been updated to account for verification sampling data specifically in individual 100-F/IU waste sites.

- **Presenting the problem formulation (Section 7.2).** This section summarizes the problem formulation used in developing the risk-based concentration values used in this evaluation as

[2] All citations to the CRC (DOE/RL-2010-17) in this chapter are referring to *Volume I: Screening-Level Ecological Risk Assessment*.

ecological SSLs. This problem formulation reflects conditions in upland environments across the Hanford Site and incorporates information developed from the RCBRA (DOE/RL-2007-21).

- **Presenting effects and exposure assessments (Section 7.3).** This section summarizes the quantitative assessments used in developing the risk-based concentration values, including the wildlife exposure factors, biotransfer factors, and wildlife toxicity reference values (TRVs) (Appendix H, Tables H-1 and H-2). The data and methods used to develop risk-based concentrations protective of plants and soil invertebrates are discussed in this section. More detailed descriptions of the data and methods used to calculate all of the ecological risk-based concentrations in soil are presented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311). In addition, these values are also incorporated into the RCBRA (DOE/RL-2007-21).

- **Updating the ecological risk characterization for 100-F/IU waste sites (Section 7.4).** Verification sampling and analysis data for the 140 waste sites in 100-F/IU were used to calculate exposure point concentrations (EPCs), which were then compared with the ecological SSLs and, as appropriate, the PRGs. The results from these comparisons were used to identify receptors of interest and COECs for purposes of identifying the need for further action at 100-F/IU waste sites. In addition, the results of this risk characterization were used to determine which of the risk-based concentration values should be recommended for use as PRGs.

- **Analyzing risks in the riparian, near-shore areas, and the Columbia River (Section 7.5).** Final recommended COECs in riparian and island soil and the surface water and sediments of the Columbia River, as identified in the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117), were evaluated as to the potential for attribution to the 100-F/IU near-shore area.

- **Preliminary scientific management decision point (SMDP) (Section 7.6).** Potential risks identified through the direct comparison of verification sampling soil data to SSLs and PRGs were considered in the context of a number of additional factors. Uncertainties in the risk characterization, spatial information, data quality, magnitude and aerial extent of risk, and confidence in risk-based values were included with other factors to make recommendations of which risks should be addressed further in the FS. A discussion of the process for developing final remediation goals was also included along with recommendations for the SMDP for evaluating waste sites:

  - Size of the waste site relative to home range of wildlife receptors (e.g., developing and applying an area use factor [AUF] in the comparison of an EPC to the PRGs)
  - Estimation of exposure using a central tendency estimate such as the 95 percent UCL
  - Size of the waste site relative to area of adjacent uncontaminated habitat
  - Nature and extent of residual contamination following remediation
  - Potential presence of exposure pathways following remediation
  - Number and frequency of exceedances of the risk thresholds (PRGs)
  - Location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances

Section 6.3 evaluates the protection of aquatic receptors from groundwater that has the potential to discharge to the Columbia River. The approach used to identify COPCs that warrant further evaluation in the FS presented in Section 6.3 is based on comparison of groundwater concentrations to the lowest available chemical-specific ARARs published for the protection of human health and aquatic receptors. Thus, risks to aquatic receptors have been considered in the context of evaluating the risks that groundwater may contribute to surface water at the groundwater/surface water interface. Combining the evaluation of human health provides a streamlined approach that addresses the restoration of groundwater and the protection of aquatic receptors.

In addition to the analysis of waste sites, Chapter 7 summarizes an evaluation of ecological risks in riparian and near-shore areas based on the analysis developed in the RCBRA (DOE/RL-2007-21) and risk in the Columbia River developed for the CRC (DOE/RL-2010-117). Appendix L evaluates ecological risks identified within the Columbia River and the relationship between potential sources to the Columbia River in the 100-F/IU OUs, transport pathways, and ecological receptors. The RCBRA (DOE/RL-2007-21) evaluated risks to an array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics at representative near-shore study sites. The study sites were selected to represent locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, and sediment). The assessment conducted in the RCBRA (DOE/RL-2007-21) has been supplemented through the development of a conceptual model depicting the relationships between sources in the 100-F/IU OUs and riparian and near-shore media (soil, sediment, pore water, and surface water). This conceptual model is presented in Appendix L.

## 7.1 Identification of Contaminants of Potential Concern

This section describes the sources of data used in the ERA, the DQA and data validation process, and the process for identifying COPCs in soil. CVP and RSVP data collected within 140 waste sites in the 100-F/IU OUs were used to identify COPCs. This chapter presents the risk assessment for individual waste sites using CVP/RSVP data. During the course of this ERA, COPCs were examined to identify a refined list of COPECs estimated to pose site-related ecological risks to receptor populations.

### 7.1.1 Data Summary

Remediation of waste sites in the 100-F/IU OUs began in 1999. A total of 94 waste sites in the 100-FR-1 and 100-FR-2 Source OUs, 25 waste sites in the 100-IU-2 Source OU, and 21 waste sites in the 100-IU-6 Source OU have verification sampling and analysis data and are included in this risk evaluation. Forty-four waste sites from the 100-F/IU Source OUs were evaluated in the RCBRA (DOE/RL-2007-21). Ninety-three additional waste sites with closeout verification data have been remediated at the 100-F/IU Source OU since 2005, and are not addressed in the RCBRA (DOE/RL-2007-21). An additional eight sites in the 100-F/IU Source OU have been remediated but are included in another waste site's sampling and closeout documentation. The focus was on data characterized as being collected from shallow depths, defined as upper and lower sampling depths from ground surface to no more than 4.6 m (15 ft) bgs. Tables G-1 and G-2 (Appendix G) summarize the remediation sites, associated decision units, and reclassification status for the 100-F OUs and the 100-IU-2/IU-6 OUs, respectively. The waste sites listed in Tables G-1 and G-2 (Appendix G) are a subset of the waste sites that were listed in Appendix B, Table B-1, of the 100-F/IU Work Plan (DOE/RL-2008-46-ADD4).

### 7.1.2 Data Quality Assessment

A DQA is performed and reported in each closeout documentation report. The DQA compares the verification sampling approach and resulting analytical data with the sampling and data quality requirements specified by the project objectives and performance specifications. The DQA determines

whether the data are of the right type, quality, and quantity to support site cleanup verification decisions within specified error tolerances. The DQA also determines whether the analytical data are found acceptable for decision-making purposes and whether the sample design was sufficient for the purpose of clean site verification. The cleanup verification sample analytical data and detailed DQA are summarized in the appendices associated with the CVPs. The results of each DQA are incorporated by reference, and no further DQA was performed as part of this risk assessment.

All analytical data are evaluated, and a portion is validated for compliance with quality assurance project plan requirements as documented in the 100 Area RDR/RAWP (DOE/RL-96-17). Data evaluation is performed to determine whether the laboratory carried out all steps required by the 100-F/IU SAP (DOE/RL-2009-43) and the laboratory contract governing the conduct of analysis and reporting of the data. This evaluation also examines the available laboratory data to determine whether an analyte is present or absent in a sample and the degree of overall uncertainty associated with that determination.

### 7.1.3 Identification of COPCs

All analytes detected at least once in a waste site decision unit for the 94, 25, and 21 waste sites in the 100-F, 100-IU-2, and 100-IU-6 OUs, respectively, included in the risk assessment, are identified as COPCs except those exclusions described below. No detected analytes were identified from two waste sites (100-F-23 and 118-F-4); therefore, no additional consideration was given to these waste sites. Verification sampling and analysis data are collected according to sample design requirements for the type of decision unit. For this ERA, an "exposure area" and a "decision unit" are operationally defined as being the same. Verification sampling and analysis data are subsequently grouped to calculate EPCs.

The contribution from naturally occurring metals and anthropogenic radioisotopes is discussed in the risk characterization section in accordance with *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003). The risk characterization discusses both elevated background concentrations and their contribution to site risks, and naturally occurring elements that are not CERCLA hazardous substances, pollutants, and contaminants but exceed the risk-based screening levels.

The RCBRA (DOE/RL-2007-21) identifies a subset of analytes that are excluded from consideration as COPCs by agreement among the Tri-Parties based on relevant Hanford Site data. The following exclusion lists used in the RCBRA (DOE/RL-2007-21) were also applied to the waste site verification data during the data reduction steps described in Section 6.2.2.2:

- **Radionuclides with a half-life of less than 3 years:** Radionuclides with half-lives of less than 3 years would not result from historical Hanford Site operations because of radioactive decay that would have occurred since operations ceased.
- **Essential nutrients:** Essential nutrients that are present at relatively low concentrations and are toxic only at high concentrations were not considered in the quantitative risk assessment.
- **Water quality or soil physical property measurements:** These analytes were measured only to obtain information on water quality or soil properties to understand potential confounding factors for bioassays conducted for soil, sediment, or water or to interpret their influence on the toxicity of COPCs (e.g., grain size for soil, water hardness for metal effects).
- **Background radionuclides (potassium-40, radium-226, radium-228, thorium-228, thorium-230, and thorium-232):** As identified and implemented in the RCBRA (DOE/RL-2007-21), these background radionuclides were identified by consensus of Tri-Party managers as not directly related to Hanford Site operations or processes.

A list of the analytes that meet the exclusion criteria for the soil risk assessment is described in Section 6.2.2.2 and presented in Appendix G, Table G-3. The RCBRA (DOE/RL-2007-21) includes two additional steps to identify COPCs that the soil risk assessment did not apply:

- Analytes that are commonly reported in waste site cleanup verification reports based on frequency of detection. Inclusion list analytes were not consistently reported in the CVP and RSVP data; therefore, this step was not implemented.

- Evaluate remaining analytes as candidate COPCs, based on comparisons to Hanford Site background, reference areas, and an "analyte-specific" evaluation.

As a result of not applying the last two steps used in the RCBRA (DOE/RL-2007-21) to identify COPCs, more analytes are identified as COPCs in this risk assessment than were identified in the RCBRA (DOE/RL-2007-21). Identifying all detected analytes (except those on the exclusion list) as COPCs is a more streamlined approach that is consistent with *Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* (EPA 540-R-01-003).

In addition to the steps described above, aluminum and iron were excluded as COPCs for all decision units within the 100-F/IU Area OUs. The EcoSSLs for aluminum and iron are based on soil pH (*Ecological Soil Screening Level for Aluminum: Interim Final* [OSWER Directive 9285.7-60] and *Ecological Soil Screening Level for Iron: Interim Final* [OSWER Directive 9285.7-69). The potential for aluminum toxicity is only identified in soils when the pH is 5.5 or less. While iron is essential for plant growth and is generally considered to be a micronutrient (*Soils and Soil Fertility* [Thompson and Troeh, 1973]), the potential for iron bioavailability is only identified when the pH is less than 5 or greater than 8 (*Ecological Soil Screening Level for Iron: Interim Final* [OSWER Directive 9285.7-69]). Oxidized environments (upland or well-aerated soils, such as those at the Hanford Site) promote the precipitation of ferric-oxide compounds, which are not available to plants for uptake. The main concern from an ecological risk perspective for iron is not direct chemical toxicity per se, but the effect of iron as a mediator in the geochemistry of other (potentially toxic) metals and the potential physical hazard of depositing flocculent (*Ecological Soil Screening Level for Iron: Interim Final* [OSWER Directive 9285.7-69]). Section 7.3 presents an evaluation of these other COPECs with the screening levels identified. While some individual measurements of pH indicate potential bioavailability of aluminum and iron, most measurements of soil pH in the River Corridor are within the ranges where these chemicals are not bioavailable. Data collected during the 2011 Hanford Sitewide field study indicated that pH in soils range between 5.8 and 8.7 (*Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals [PRGs] for Nonradionuclides for Use at the Hanford Site* [ECF-HANFORD-11-0158]). Thus, aluminum and iron concentrations are not bioavailable and do not pose a risk to terrestrial ecological receptors.

The COPC list for these OUs was evaluated to develop a COPEC list in this risk assessment. A COPEC is defined as a COPC with concentrations exceeding both the background concentration and ecological screening level (ESL). The process to identify COPECs is discussed in Section 7.4.

## 7.2 Problem Formulation

The problem formulation includes the physical layout of the site, its history and ecology, and the development of an ecological conceptual site exposure model that evaluates potential exposure pathways and identifies the representative species that were used to assess ecological risk to those and other similar species. The problem formulation includes identification of the important aspects of the 100-F/IU OUs waste site decision units to be protected (referred to as "assessment endpoints") and the means by which the assessment endpoints are evaluated (measures of exposure and effects).

### 7.2.1 Site Setting

The 100-F/IU OUs are shown on Figure 1-1 and collectively cover an area of approximately 375 $km^2$ (145 $mi^2$). The Columbia River section along the 100-F/IU OUs defines a portion of the Hanford Reach, an important ecological, cultural, historic, and recreational feature. This upland environment is described in this section, while the riparian and near-shore habitats are described in Appendix L, which focuses on evaluating the potential for exposures in the riparian and near-shore environments to be of concern and to have originated from Hanford Site operations (i.e., from waste sites in the 100-F/IU OUs).

The predominant plant community in the 100 Area is sagebrush/Sandberg's bluegrass/cheatgrass. Currently, no plant species on the Hanford Site are federally listed as threatened or endangered under the *Endangered Species Act of 1973*. Plant species listed as threatened or endangered by the state of Washington include the awned halfchaff sedge (*Lipocarpha aristulata*), grand redstem (*Ammannia robusta*), lowland toothcup (*Rotala ramosior*), and persistent sepal yellowcress (*Rorippa columbiae*). All of these plant species are restricted to wetlands in the riparian zone of the Columbia River (NEPA Characterization Report [PNNL-6415]). Table 3-14 presents the complete list of state-listed flora.

Shrub and grassland habitats dominate the Hanford Site and support a diverse and abundant variety of wildlife species, including in the uplands of the River Corridor. The 100 Areas are mostly undisturbed or fully recovered and thus support these diverse and abundant wildlife communities, while wildlife use of the remaining disturbed and developed areas is expected to be reduced because these areas are less attractive and provide fewer of the needs of wildlife than do natural habitats. However, even these areas can be frequented by wildlife. Common species include large animals like Rocky Mountain elk (*Cervus elaphus*) and mule deer (*Odocoileus hemionus*); predators such as coyote (*Canis latrans*), bobcat (*Lynx rufus*), and badger (*Taxidea taxus*); and herbivores including deer mice (*Peromyscus maniculatus*), harvest mice (*Riethrodontonomys megalotis*), ground squirrels (*Spermophilus* spp.), voles (*Lemmiscus curtatus, Microtus* spp.), and black-tailed jackrabbits (*Lepus californicus*). The most abundant mammal on the Hanford Site is the Great Basin pocket mouse (*Perognathus parvus*). Other nonburrowing animals, including cottontails (*Sylvilagus nutalli*), jackrabbits, snakes, and burrowing owls (*Athene cunicularia*), may use abandoned burrows of other animals.

No species that regularly frequent the Hanford Site are listed currently as threatened or endangered under the *Endangered Species Act of 1973*. Species listed as threatened or endangered by Washington State include the burrowing owl (*Athene cunicularia*), Merriam's shrew (*Sorex merriami*), and Washington ground squirrel (*Urocitellus washingtoni*). Table 3-15 presents the complete list of state listed fauna.

Although the bald eagle has been removed from the list of federally endangered species, it is still protected under the *Bald and Golden Eagle Protection Act of 1940*. In addition, DOE continues to protect nest and roost sites on the Hanford Site under the *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (DOE/RL-94-150), hereinafter called the Bald Eagle Management Plan. Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 to 400 m (2,625 to 1,312 ft).

Bald eagles have generally been observed at the Hanford Site from November to March ("A Congregation of Wintering Bald Eagles" [Fitzner and Hanson, 1979]). During daylight hours, bald eagles perch along the Hanford Reach of the Columbia River and a few kilometers inland (Bald Eagle Management Plan [DOE/RL-94-150]). The primary perching areas occur in trees from the Hanford Townsite to the Vernita Bridge. Several perch sites are east and southeast of 100-F, along the Columbia River. Two roosting sites are in this same area (Bald Eagle Management Plan [DOE/RL-94-150]). One roosting and nesting site is approximately 1.6 km (1 mi) southeast of the 100-F Area in a grove of large trees on the White Bluffs Peninsula (Bald Eagle Management Plan [DOE/RL-94-150]). A second

nesting site is within 1.6 km (1 mi) to the north of the 100-F Area, located on the riverbank. Bald eagles predominantly forage on the banks of the river and the island where waterfowl roost and salmon carcasses can be found. The vicinity of Locke Island through Island 1 and the 100-F slough is also considered an important feeding area. The 100-F/IU is outside of the nesting buffer zones and important foraging areas. Additional consideration of these species is not required for this risk assessment. Additional site setting information is presented in Section 3.10, and site history is described in Section 1.2.

### 7.2.2 Simplified Ecological Exposure Model for Upland Sites

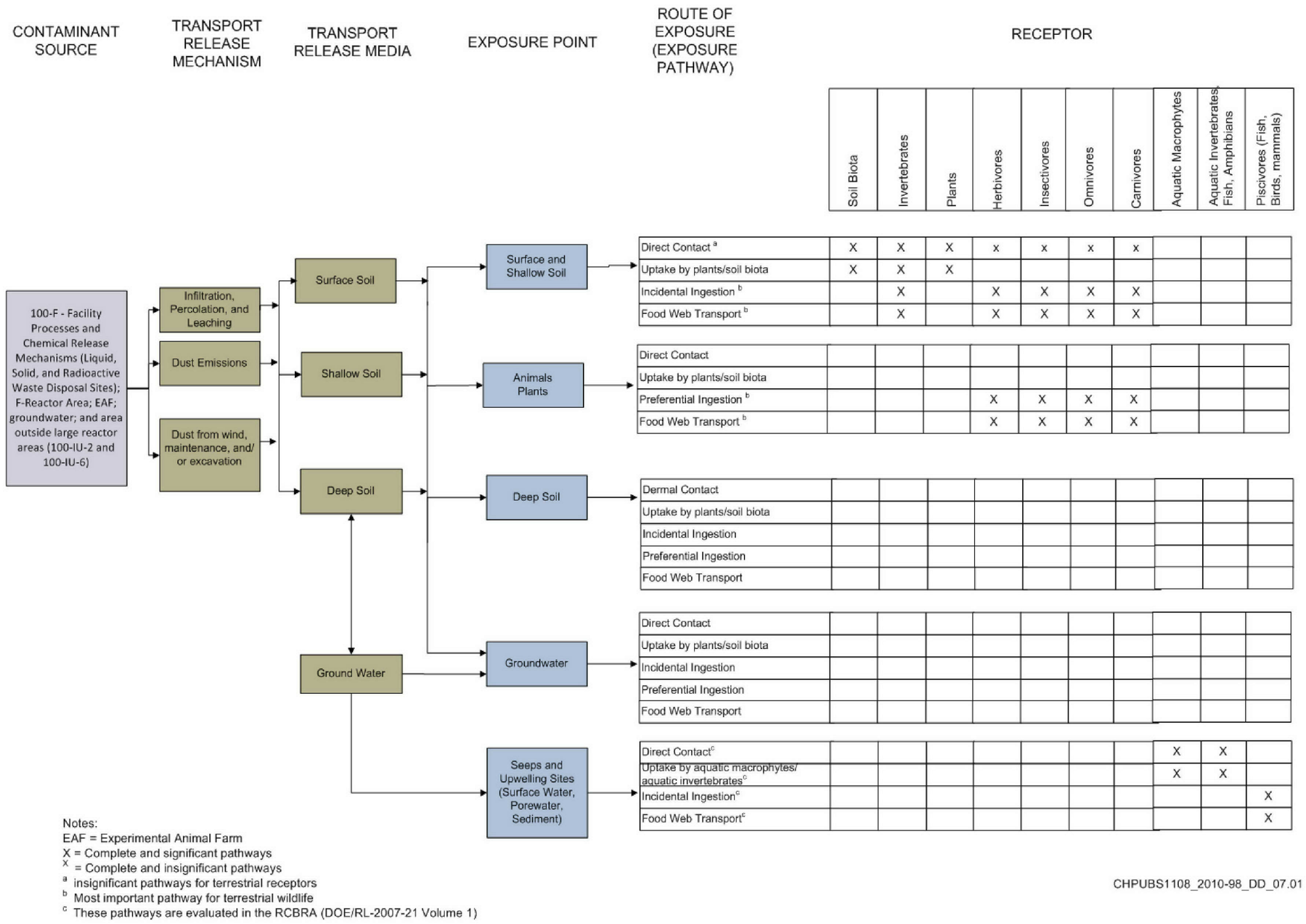
Development of the ecological exposure model for this ERA involved characterizing the exposure pathways and ecological receptors that might be associated with the habitat types in the upland environment of the waste sites within the 100-F/IU OUs. Appropriate exposure pathways and representative endpoint species for the upland environment of the 100-F/IU OUs were developed based on information from the RCBRA (DOE/RL-2007-21) and are discussed below. A full risk evaluation of the riparian area or the islands within the Columbia River are not presented because they were already completed for the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117); however, the same models and receptors were used here as in those documents. The aquatic exposure models are described in Appendix L, Section L.2.4, with the evaluation of the aquatic exposure pathways. Results of those exposure and effects evaluations (i.e., the risk characterization) are discussed in Chapter 4, Appendix L, and Section 7.6 of this chapter with respect to the potential for the 100-F/IU OU to contribute to the final identified risks.

With consideration of the ecological setting, land use, and COPC release mechanisms and transport pathways known at the 100-F/IU OUs upland environments, the ecological exposure pathways considered most plausible are graphically displayed on Figure 7-1 and include the following:

- Direct contact of vegetation with analytes in surface soil
- Direct contact with, or ingestion of, surface soil by terrestrial invertebrates (e.g., beetles and ants)
- Direct contact with, or ingestion of, surface soil by terrestrial avian and mammalian wildlife
- Dietary exposure of terrestrial and mammalian wildlife to COPCs bioaccumulated in food items (e.g., plants or prey)
- Dietary exposure to emissions from radionuclides bioaccumulated and retained within the tissues of plants, terrestrial invertebrates, and terrestrial wildlife
- External exposure of plants, terrestrial invertebrates, and terrestrial wildlife to emissions from radionuclides in soil

Ecological receptors are not likely to have complete exposure pathways to soil below the biologically active zone. Therefore, deep soil was not evaluated in this ERA.

A food web model for the upland environment of the Hanford Site (Figure 7-2) has been developed based upon an understanding of the ecology of the area and documented in the previous ERAs.




Source: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*.

Figure 7-1. Ecological Conceptual Site Model for Terrestrial Habitats in Hanford Site Upland Environment

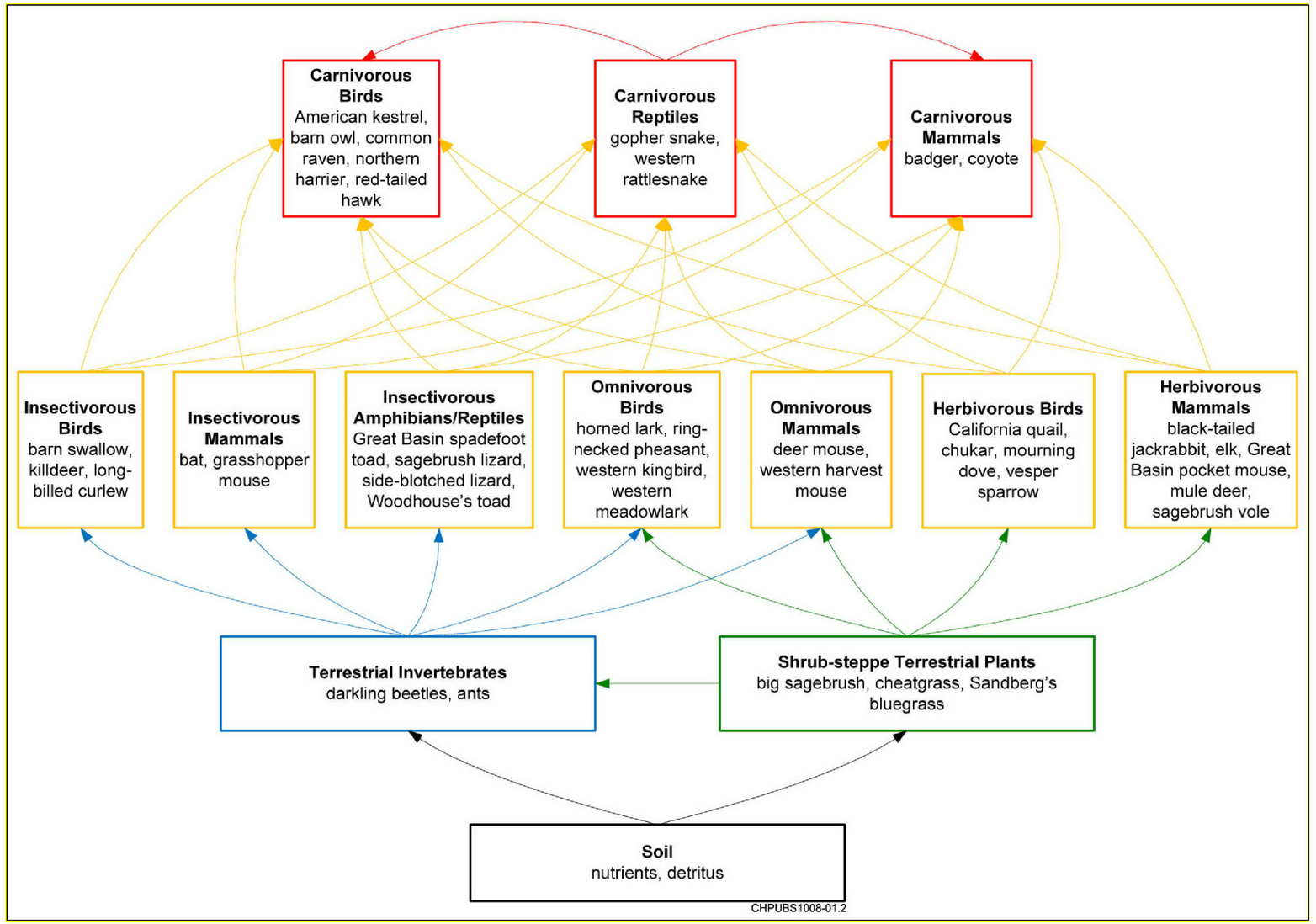



Figure 7-2. Hanford Site Upland Environment Terrestrial Food Web

The following entities (represented by trophic guilds) and their associated organizational level have been identified for evaluation:

- Terrestrial plants—community level
- Terrestrial invertebrates—community level
- Soil micro-organisms and microbial processes—community level
- Herbivorous birds—population level
- Herbivorous mammals—population level
- Insectivorous birds—population level
- Insectivorous mammals—population level
- Omnivorous birds—population level
- Omnivorous mammals—population level
- Carnivorous birds—population level
- Carnivorous mammals—population level
- Reptiles and amphibians[3]

Some endpoint entities are evaluated at the population level and others at the community level. As reported in *Summary Report: Risk Assessment Forum Technical Workshop on Population-level Ecological Risk Assessment* (EPA/100/R-09/006): "Define ecological risk assessment...as estimating the likelihood or probability of adverse effects (e.g., mortality to single species of organisms, reduction in populations of nontarget organisms due to acute, chronic, reproductive effects, or disruption in community and ecosystem level functions." The EPA has developed guidance that can aid in distinguishing the assessment level, including *Framework for Ecological Risk Assessment* (EPA/630/R-92/001), *Ecological Significance and Selection of Candidate Assessment Endpoints* (EPA/540/F-95/037), and *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment* (EPA/630/P-02/004F). These guidelines intentionally do not specify a target level of organization to protect for an entity allowing flexibility in setting the target organizational level that works for the individual project. The organizational levels described above align with the management goals originally defined in *DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* (BHI-01757), which focuses on the protection of individuals for special-status species, preventing adverse effects on Hanford Site biota from contaminants, protecting rare habitats, and minimizing contaminant loading into biota. With the ecosystem present at the Hanford Site, maintaining the health of wildlife populations and the function of a plant community are appropriate, as opposed to focusing on populations of particular plant species within that community.

As noted in Appendix A to *Generic Ecological Assessment Endpoints (GEAEs) for Ecological Risk Assessment* (EPA/630/P-02/004F), EPA's principles for ERA and risk management at Superfund sites state, "Superfund's goal is to reduce ecological risks to levels that will result in the recovery and maintenance of healthy local populations and communities of biota." Should a special-status species of plant (such as an endangered species of native grass or forb) be present at a given waste site at the Hanford Site, then protecting that population would be acceptable. However, the measurement endpoints, which align with the entities listed above, were selected appropriately to protect populations and communities. Although the endpoints identified may be expressed as single species toxicity tests, as these

[3] Although reptiles and amphibians are part of the food web for the upland environment, effects data for them are limited. Therefore, SSLs were not developed for this trophic guild.

guidance documents express, interpretation of the results relative to lowest observed effect concentration (LOEC) or lowest observed adverse effect level (LOAEL) endpoints for the protection of populations and communities is appropriate. Section III of *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (OSWER Directive 9285.7-28 P) states the following: "Levels that are expected to protect local populations and communities can be estimated by extrapolating from effects on individuals and groups of individuals using a lines-of-evidence approach. The performance of multi-year field studies at Superfund sites to try to quantify or predict long-term changes in local populations is not necessary for appropriate risk management decisions to be made. Data from discrete field and laboratory studies, if properly planned and appropriately interpreted, can be used to estimate local population or community-level effects." *Issuance of Final Guidance: Ecological Risk Assessment and Risk Management Principles for Superfund Sites* (OSWER Directive 9285.7-28 P) further states that "Superfund ERAs gather effects data on individuals in order to predict or postulate potential effects on local wildlife, fish, invertebrates, and plant populations and communities that occur in specific habitats at sites." Finally, as noted in *Overview of the Ecological Risk Assessment Process in the Office of Pesticide Programs, U.S. Environmental Protection Agency—Endangered and Threatened Species Effects Determinations* (EPA, 2004), "…if effects on the survival and reproduction of individuals are limited, it is assumed that risks at the population level from such effects will be of minor consequence."

To calculate EcoSSLs, endpoint representative species were selected for each entity identified above (trophic guilds/functional groups) that could use the site. For example, a red-tailed hawk may be considered representative of raptors visiting the site. Consistent with ERAGs (EPA 540-R-97-006), *Guidelines for Ecological Risk Assessment* (EPA/630/R-95/002F) and MTCA ("Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]), endpoint species should preferably be ones that have ecological relevance, are of societal value, are susceptible to chemical stressors at the site, or allow risk managers to meet policy goals. These factors were used to select representative receptor species common to the Hanford Site upland environment that are within the trophic guilds identified above. Selected receptors are conservative indicators of the potential for risk to the trophic guilds identified for evaluation. The representative receptor species selected for each of the trophic guilds are as follows:

- Herbivorous birds—California quail (*Callipepla californica*)
- Herbivorous mammals—Great Basin pocket mouse (*Perognathus parvus*)
- Insectivorous birds—killdeer (*Charadrius vociferus*)
- Insectivorous mammals—northern grasshopper mouse (*Onychomys leucogaster*)
- Omnivorous birds—western meadowlark (*Sturnella neglecta*)
- Omnivorous mammals—deer mouse (*Peromyscus maniculatus*)
- Carnivorous birds (raptors)—red-tailed hawk (*Buteo jamaicensis*)
- Carnivorous mammals—badger (*Taxidea taxus*)

Unlike birds and mammals, methods to differentiate exposure and/or effects among different plant species or among different invertebrate species are unavailable. Therefore, individual species for terrestrial vegetation and invertebrates were not selected to represent the plant or invertebrate populations and communities for evaluation.

### 7.2.3 Assessment Endpoints

Assessment endpoints are an expression of the important ecological values that are to be protected at a site (*Ecological Risk Assessment* [Suter, 1993]; *Guidelines for Ecological Risk Assessment* [EPA/630/R-95/002F]; *Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]). Assessment endpoints are based on known information concerning the analytes present, the study area, the ecological CSM, and risk hypotheses. There are three components to each assessment endpoint: an *entity* (e.g., migratory birds), an *attribute* of that entity (e.g., individual survival), and a *measure* (e.g., a measurable value, such as an effect level). Measures are described following the general description of assessment endpoints (*Guidelines for Ecological Risk Assessment* [EPA/630/R-95/002F]; *Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]).

The assessment endpoint entities for the 100-F/IU OU waste sites were selected based on the following principal criteria:

- Ecological relevance
- Societal relevance
- Susceptibility (or high exposure) to known or potential stressors at the Hanford Site

The attribute selected for each entity was based on the organizational level of the entity and the primary criteria that were used to select it. Entities and attributes were selected for community and population levels of assessment.

### 7.2.4 Measures of Exposure and Effects

Measures (formerly referred to as measurement endpoints) are measurable attributes used to evaluate the risk hypotheses and are predictive of effects on the assessment endpoints (*Guidelines for Ecological Risk Assessment* [EPA/630/R-95/002F]). The three categories of measures are as follows:

- Measures of exposure are used to evaluate intake of a contaminant from contact with environmental media (e.g., soil). Measures of exposure can be an EPC of a COPC in an environmental medium or food item. A measure of exposure also can be a dose occurring through ingestion, inhalation, or dermal contact with a contaminant in an environmental medium. SSLs were estimated by back-calculating from a target dose associated with the selected assessment endpoint to a corresponding concentration in soil (see Section 7.3.1 for further discussion).

  The measure of exposure represents the exposure appropriate for the assessment endpoint (e.g., a wildlife population) throughout its exposure area (e.g., the entire home range of the target species). Thus, the average exposure to multiple individuals (e.g. the population of wildlife or the plant community) in a species is the basis for population or community-level effects.

- Measures of effect are used to evaluate the response of an organism that is exposed to a stressor. Measures of effects used in this evaluation included TRVs for wildlife and the LOECs in soil for plants and soil invertebrates (Section 7.3.1). The maximum acceptable adverse effect levels generally selected for population- and community-level assessment endpoints are lowest LOECs or LOAELs, when available.

- Measures of ecosystem and receptor characteristics are used to evaluate the ecosystem characteristics that influence the assessment endpoints, the distribution of stressors, and the characteristics of the assessment endpoints that may affect exposure or response to the stressor. Measures of ecosystem and receptor characteristics are used to characterize ecological risks as part of a baseline ERA or evaluation. These kinds of ecological information were not used directly in calculating SSLs.

However, measures of ecosystem and receptor characteristics may represent additional lines of evidence that can be used along with SSLs in evaluating remedial alternatives in the RI/FS.

## 7.3 Effects and Exposure Assessment

The effects and exposure assessments were conducted and then integrated to develop two levels of thresholds for evaluating the 100-F/IU data. This follows the tiered process referred to earlier and as described in ERAGS (EPA 540-R-97-006). The initial evaluation versus conservative thresholds (SSLs) helps to focus the evaluation down to those COPEC-receptor-waste-site combinations that might require further evaluation. The additional evaluation completed with a comparison to PRGs helps identify which COPEC-receptor-waste-site combinations should be brought forward to the SMDP in Section 7.6. Comparisons to SSLs were used to identify COPEC receptor waste sites combinations for the SMDP in cases where the second tier of effect level (PRG) was not available or recommended (e.g., organics, radionuclides, and a few inorganics).

For wildlife, the effects assessment presents TRVs that have been derived from available literature-based toxicity information on COPCs and that can be used in determining the potential for adverse effects to ecological receptors. Two types of effects-based values are presented in this ERA: (1) initial conservative values from the published literature (e.g., Ecology, EPA, and DOE guidance or compendiums), and (2) Hanford Site-specific values (values established using data collected at the Hanford Site). These values are then used within food chain exposure dose models from the exposure assessment to establish media benchmarks (thresholds). For plants and invertebrates, the effects data are incorporated more simply because the effects are measured relative to direct exposure. Thus, the concentration associated with an observed effect in the exposure medium (soil, water, sediment) becomes the benchmark (threshold).

The exposure assessment identifies exposure pathways associated with the representative receptor species listed in Section 7.2.2. As with the effects values, the exposure assessment employs two types of exposure evaluations: (1) the avian and mammalian SSLs, and (2) Hanford Site-specific avian and mammalian PRGs. It also describes the models used to calculate SSLs and PRGs.

The TRVs were combined with the exposure information to calculate SSLs and PRGs. This section presents the salient features of the effects and exposure assessments as they were used to calculate the SSLs and PRGs. An overview of the development of the nonradionuclide and radionuclide SSLs and PRGs is described in the exposure assessment for each receptor group (i.e., plants, soil invertebrates, and wildlife). The methodology used to develop the SSLs is detailed in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784). The methodology used to develop the PRGs for wildlife is detailed in *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311). The methodology used to develop the Hanford Site-specific risk thresholds and to select PRGs for plants and invertebrates is detailed in *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158). These documents are presented in Appendix H of the 100-K RI/FS (DOE/RL-2010-97).

The effects and exposure assessment is organized as follows:

- Section 7.3.1 presents the effects assessment with separate sections for radionuclides (Section 7.3.1.1) and nonradionuclides (Section 7.3.1.2) because of the method of their derivation. Within each of these, effects for plants and invertebrates are discussed separately from wildlife. For nonradionuclides, plant and invertebrate effects are described relative to direct exposure, whereas, for

wildlife, the effects are described relative to the ingested dose. For radionuclides, the effects assessment includes values that correspond to effects from a dose of radiation.

- Section 7.3.2 presents the exposure assessment with separate sections for plants and invertebrates (Section 7.3.2.1) and wildlife (Section 7.3.2.2). Exposure to wildlife is further broken out to describe the food chain models that estimate the concentration in ingested prey and to explain how the assumptions of the model differ in the development of SSLs versus PRGs. Section 7.2.3.3 even further describes specific differences in the modeling of wildlife exposure to radionuclides. The SSLs that result from the effects and exposure assessments are presented in these sections.
- Section 7.3.3 provides a description of wildlife exposure through drinking from seeps along the Columbia River.
- Section 7.3.4 describes and presents the PRGs that result from the effects and exposure assessment.
- Section 7.3.5 describes how soil and seep data were used to estimate EPCs for comparisons with the SSLs and PRGs presented.

## 7.3.1 Effects Assessment

The ecological effects assessment consists of an evaluation of available toxicity or other effects information that can be used to interpret the significance of the exposures to COPCs relative to potential adverse effects to ecological receptors. Data that can be used include literature-derived or site-specific single-chemical toxicity data (wildlife), site-specific ambient-media toxicity tests (plants and invertebrates), and site-specific field surveys (*Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]). The effects data used in this ERA are represented by single-chemical toxicity data from literature sources and are summarized below for radionuclides and nonradionuclides (Appendix H, Tables H-1 and H-2). The effects levels presented are used either directly (for plants and invertebrates) or within exposure dose models (for wildlife) to establish concentrations in exposure media (e.g., soil) that are protective of plant and invertebrate communities and wildlife populations.

### *7.3.1.1 Effects Assessment for Radionuclides*

Radionuclide toxicity data for plants and wildlife are represented by DOE's Biota Concentration Guides (BCGs) for radionuclides, presented in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002), hereinafter called Graded Approach for Radiation Doses to Biota. Two radionuclide effect thresholds, as determined by consensus of international radiation regulatory agencies, form the basis for effect thresholds used to develop screening levels of radionuclides in soil for the protection of plants and animals. General guidance from the International Council for Radiological Protection (*Recommendations of the International Commission on Radiological Protection* [ICRP-60]), *Proliferation Resistance Fundamentals for Future Nuclear Energy Systems* (IAEA STR-332), and *Sources and Effects of Ionizing Radiation* (UNSCEAR, 2000) with scientific annexes (Sales Publication No. E.00.IX.4) concluded that radiological doses to terrestrial plants and terrestrial vertebrates should not exceed 1.0 and 0.1 rad/day, respectively. If radiation exposure does not exceed these biota dose levels, the consensus opinion of the international radiological organizations is that ecological populations will be protected. DOE has adopted these effect thresholds and integrated them into Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002).

Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002) includes a screening method and three more detailed levels of analysis for demonstrating compliance with applicable dose limits for protection of biota:

- A general screening that involves comparing maximum radionuclide concentrations in environmental media (i.e., soil) with a set of BCGs to evaluate compliance with the biota dose limits.
- Site-specific screening using more realistic site-representative lumped parameters (e.g., bioaccumulation factors [BAFs]) in place of conservative default parameters, using mean radionuclide concentrations in place of maximum values, and taking into account time dependence and spatial extent of contamination.
- Site-specific analysis employing a kinetic-allometric modeling methodology. Multiple parameters that represent contribution to an organism's internal dose can be modified to represent site- and organism-specific characteristics. These parameters include body mass, consumption rates of food or soil, inhalation rate, lifespan, and biological elimination rates. Development of the organism-specific characteristics involves using allometric equations that relate these parameters to body mass.
- Site-specific biota dose assessment involving the collection and analysis of biota samples.

BCGs can be calculated using dose models, equations, and default parameters that are presented in Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002). The values in soil, calculated using these default methods, are found in Table 6-4 in Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002). These dose models, equations, and default parameters are also incorporated into RESRAD-BIOTA for Windows, Version 1.5 (ANL, 2009b) model (*RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User's Guide, Version 1* [DOE/EH-0676]) to establish values protective of wildlife populations and plant communities. *Effects of Ionizing Radiation on Terrestrial Plants and Animals: A Workshop Report* (ORNL/TM-13141) also discusses populations of wildlife and communities of plants as the basis for the BCGs. RESRAD-BIOTA presents three levels of analysis, which correspond to the following levels in the graded approach:

- Level 1: General screening approach
- Level 2: Site-specific screening with representative parameters
- Level 3: Site-specific analysis using the kinetic/allometric modeling methodology

The BCGs for plants for this ERA were calculated using the Level 1 analysis in RESRAD-BIOTA and are shown in Table 7-1.

For wildlife (animals), more receptor-specific SSLs were developed using RESRAD-BIOTA for Windows, Version 1.5 (ANL, 2009b) with Level 3 assumptions. Values were established for eight different species representing feeding guilds found at the site. However, Hanford Site-specific tissue residue of radionuclides was insufficient for developing models so that values from relevant published literature were used ("Derivation of Transfer Parameters for Use Within the ERICA Tool and the Default Concentration Ratios for Terrestrial Biota" [Beresford et al., 2008]). Final radionuclide SSLs for wildlife are shown in Table 7-2.

Because the dose from radionuclides is additive ("Principles and Issues in Radiological Ecological Risk Assessment" [Jones et al., 2003]), the total contribution of radionuclides known to be associated with Hanford Site processes was also calculated. A total radionuclide exposure estimate was calculated using the SOF method. With the SOF method, the contributions of various radionuclides were reviewed to determine their contribution to dose. Contributions were considered further if the radionuclide EPC was greater than the SSL and detected frequently.

Table 7-1. Soil Screening Levels in Upland Soil for Plants and Soil Invertebrates

| Group | Soil Constituent | Units | EPA EcoSSLs | | | ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2 | | DOE BCGs | | Ecology - MTCA WAC 173-340, Table 749-3 | | Lowest Screening Benchmark by Receptor Type | | | Background Soil Concentrations[a] | SSL for Plants and Soil Invertebrates[b] | Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plants | Invertebrate | Reference | Plants | Invertebrate | Terrestrial Plant | Terrestrial Animal | Plant | Soil Biota | Plant | Inverts | Overall Lowest Screening Benchmark | | | |
| Radionuclides | Americium-241 | pCi/g | --- | --- | --- | --- | --- | 21,500 | 3,890 | --- | --- | 21,500 | --- | 21,500 | --- | 21,500 | Benchmark |
| | Antimony-125 | pCi/g | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Carbon-14 | pCi/g | --- | --- | --- | --- | --- | 60,700 | 4,760 | --- | --- | 60,700 | --- | 60,700 | --- | 60,700 | Benchmark |
| | Cesium-134 | pCi/g | --- | --- | --- | --- | --- | 1,090 | 11.3 | --- | --- | 1,090 | --- | 1,090 | --- | 1,090 | Benchmark |
| | Cesium 137 | pCi/g | --- | --- | --- | --- | --- | 2,210 | 20.8 | --- | --- | 2,210 | --- | 2,210 | 1.05 | 2,210 | Benchmark |
| | Cobalt-60 | pCi/g | --- | --- | --- | --- | --- | 6,130 | 692 | --- | --- | 6,130 | --- | 6,130 | 0.00842 | 6,130 | Benchmark |
| | Curium-244 | pCi/g | --- | --- | --- | --- | --- | 153,000 | 4,060 | --- | --- | 153,000 | --- | 153,000 | --- | 153,000 | Benchmark |
| | Europium-152 | pCi/g | --- | --- | --- | --- | --- | 14,700 | 1,520 | --- | --- | 14,700 | --- | 14,700 | --- | 14,700 | Benchmark |
| | Europium-154 | pCi/g | --- | --- | --- | --- | --- | 12,500 | 1,290 | --- | --- | 12,500 | --- | 12,500 | 0.0334 | 12,500 | Benchmark |
| | Europium-155 | pCi/g | --- | --- | --- | --- | --- | 153,000 | 15,800 | --- | --- | 153,000 | --- | 153,000 | 0.0539 | 153,000 | Benchmark |
| | Hydrogen-3 (tritium) | pCi/g | --- | --- | --- | --- | --- | 1,680,000 | 174,000 | --- | --- | 1,680,000 | --- | 1,680,000 | --- | 1,680,000 | Benchmark |
| | Neptunium-237 | pCi/g | --- | --- | --- | --- | --- | 8,150 | 3,860 | --- | --- | 8,150 | --- | 8,150 | --- | 8,150 | Benchmark |
| | Nickel-63 | pCi/g | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Plutonium-238 | pCi/g | --- | --- | --- | --- | --- | 17,500 | 5,270 | --- | --- | 17500 | --- | 17,500 | 0.00378 | 17,500 | Benchmark |
| | Plutonium-239/240 | pCi/g | --- | --- | --- | --- | --- | 12,700 | 6,110 | --- | --- | 12,700 | --- | 12,700 | 0.0248 | 12,700 | Benchmark |
| | Radium-226 | pCi/g | --- | --- | --- | --- | --- | 288 | 50.6 | --- | --- | 288 | --- | 288 | 0.815 | 288 | Benchmark |
| | Radium-228 | pCi/g | --- | --- | --- | --- | --- | 245 | 43.9 | --- | --- | 245 | --- | 245 | --- | 245 | Benchmark |
| | Strontium-90 | pCi/g | --- | --- | --- | --- | --- | 3,580 | 22.5 | --- | --- | 3,580 | --- | 3,580 | 0.178 | 3,580 | Benchmark |
| | Technetium-99 | pCi/g | --- | --- | --- | --- | --- | 21,900 | 4,490 | --- | --- | 21,900 | --- | 21,900 | --- | 21,900 | Benchmark |
| | Thorium-232 | pCi/g | --- | --- | --- | --- | --- | 23,500 | 1,510 | --- | --- | 23,500 | --- | 23,500 | 1.32 | 23,500 | Benchmark |
| | Uranium-234 | pCi/g | --- | --- | --- | --- | --- | 51,600 | 5,130 | --- | --- | 51,600 | --- | 51,600 | 1.1 | 51,600 | Benchmark |
| | Uranium-235 | pCi/g | --- | --- | --- | --- | --- | 27,400 | 2,770 | --- | --- | 27,400 | --- | 27,400 | 0.109 | 27,400 | Benchmark |
| | Uranium-238 | pCi/g | --- | --- | --- | --- | --- | 15,700 | 1,580 | --- | --- | 15,700 | --- | 15,700 | 1.06 | 15,700 | Benchmark |
| Metals | Aluminum | mg/kg | Narrative Statement | | OSWER Dir. 9285.7-60 | 50 | --- | --- | --- | 50 | --- | 50 | --- | 50 | 11,800 | 11,800 | Background |
| | Antimony | mg/kg | --- | 78 | OSWER Dir. 9285.7-61 | 5 | --- | --- | --- | 5 | --- | 5 | 78 | 5 | 5.2 | 5.2 | Background |
| | Arsenic, total all valence states | mg/kg | 18 | --- | OSWER Dir. 9285.7-62 | 10 | 60 | --- | --- | --- | --- | 10 | 60 | 10 | 6.47 | 10 | Benchmark |
| | Arsenic(III) | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Arsenic(V) | mg/kg | --- | --- | --- | --- | --- | --- | --- | 10 | 60 | 10 | 60 | 10 | --- | 10 | Benchmark |
| | Barium | mg/kg | --- | 330 | OSWER Dir. 9285.7-63 | 500 | --- | --- | --- | 500 | --- | 500 | 330 | 330 | 132 | 330 | Benchmark |
| | Beryllium | mg/kg | --- | 40 | OSWER Dir. 9285.7-64 | 10 | --- | --- | --- | 10 | --- | 10 | 40 | 10 | 1.51 | 10 | Benchmark |
| | Bismuth | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Boron | mg/kg | --- | --- | --- | 0.5 | --- | --- | --- | 0.5 | --- | 0.5 | --- | 0.5 | --- | 0.5 | Benchmark |
| | Cadmium | mg/kg | 32 | 140 | OSWER Dir. 9285.7-65 | 4 | 20 | --- | --- | 4 | 20 | 4 | 20 | 4 | 0.78 | 4 | Benchmark |
| | Chromium (total)[c,d] | mg/kg | --- | --- | OSWER Dir. 9285.7-66 | 1 | 0.4 | --- | --- | 42 | 42 | 1 | 0.4 | 0.4 | 18.5 | 18.5 | Background |
| | Chromium (III) | mg/kg | --- | --- | OSWER Dir. 9285.7-66 | 1 | 0.4 | --- | --- | 42 | 42 | 1 | 0.4 | 0.4 | --- | 0.4 | Benchmark |

Table 7-1. Soil Screening Levels in Upland Soil for Plants and Soil Invertebrates

| Group | Soil Constituent | Units | EPA EcoSSLs | | | ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2 | | DOE BCGs | | Ecology - MTCA WAC 173-340, Table 749-3 | | Lowest Screening Benchmark by Receptor Type | | | Background Soil Concentrations[a] | SSL for Plants and Soil Invertebrates[b] | Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plants | Invertebrate | Reference | Plants | Invertebrate | Terrestrial Plant | Terrestrial Animal | Plant | Soil Biota | Plant | Inverts | Overall Lowest Screening Benchmark | | | |
| | Chromium (VI) | mg/kg | --- | --- | OSWER Dir. 9285.7-66 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Cobalt | mg/kg | 13 | --- | OSWER Dir. 9285.7-67 | 20 | --- | --- | --- | 20 | --- | 13 | --- | 13 | 15.7 | 15.7 | Background |
| | Copper | mg/kg | 70 | 80 | OSWER Dir. 9285.7-68 | 100 | 50 | --- | --- | 100 | 50 | 70 | 50 | 50 | 22 | 50 | Benchmark |
| | Lead | mg/kg | 120 | 1,700 | OSWER Dir. 9285.7-70 | 50 | 500 | --- | --- | 50 | 500 | 50 | 500 | 50 | 10.2 | 50 | Benchmark |
| | Lithium[d] | mg/kg | --- | --- | --- | 2 | --- | --- | --- | 35 | --- | 2 | --- | 2 | 33.5 | 33.5 | Background |
| | Manganese[d] | mg/kg | 220 | 450 | OSWER Dir. 9285.7-71 | 500 | --- | --- | --- | 1,100 | --- | 220 | 450 | 220 | 512 | 512 | Background |
| | Mercury | mg/kg | --- | --- | --- | 0.3 | 0.1 | --- | --- | 0.3 | 0.1 | 0.3 | 0.1 | 0.1 | 0.33 | 0.33 | Background |
| | Molybdenum | mg/kg | --- | --- | --- | 2 | --- | --- | --- | 2 | --- | 2 | --- | 2 | 6 | 6 | Background |
| | Nickel | mg/kg | 38 | 280 | OSWER Dir. 9285.7-76 | 30 | 200 | --- | --- | 30 | 200 | 30 | 200 | 30 | 19.1 | 30 | Benchmark |
| | Selenium | mg/kg | 0.52 | 4.1 | OSWER Dir. 9285.7-72 | 1 | 70 | --- | --- | 1 | 70 | 0.52 | 4.1 | 0.52 | 0.78 | 0.78 | Background |
| | Silver | mg/kg | 560 | --- | OSWER Dir. 9285.7-77 | 2 | --- | --- | --- | 2 | --- | 2 | --- | 2 | 0.73 | 2 | Benchmark |
| | Strontium | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Thallium | mg/kg | --- | --- | --- | 1 | --- | --- | --- | 1 | --- | 1 | --- | 1 | | 1 | Benchmark |
| | Tin | mg/kg | --- | --- | --- | 50 | --- | --- | --- | 50 | --- | 50 | --- | 50 | --- | 50 | Benchmark |
| | Uranium | mg/kg | --- | --- | --- | 5 | --- | --- | --- | 5 | --- | 5 | --- | 5 | 3.21 | 5 | Benchmark |
| | Vanadium | mg/kg | --- | --- | OSWER Dir. 9285.7-75 | 2 | --- | --- | --- | 2 | --- | 2 | --- | 2 | 85.1 | 85.1 | Background |
| | Zinc[d] | mg/kg | 160 | 120 | OSWER Dir. 9285.7-73 | 50 | 200 | --- | --- | 86 | 200 | 50 | 120 | 50 | 67.8 | 67.8 | Background |
| General Inorganics | Ammonia/ammonium | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 9.23 | 9.23 | Background |
| | Chloride | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 100 | 100 | Background |
| | Cyanide | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Fluoride | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 2.81 | 2.81 | Background |
| | Iodine | mg/kg | --- | --- | --- | 4 | --- | --- | --- | 4 | --- | 4 | --- | 4 | --- | 4 | Benchmark |
| | Nitrate/nitrite | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 52 | 52 | Background |
| | Phosphate | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 0.785 | 0.785 | Background |
| | Sulfate/sulfite | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 237 | 237 | Background |
| | Total organic carbon | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Volatile Organics | 1,1-Dichloroethane | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 1,1-Dichloroethene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 1,1,1-Trichloroethane | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 1,1,2-Trichloroethane | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 1,1,2,2-Tetrachloroethane | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 1,2-Dichlorobenzene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 1,2-Dichloroethane (DCA) | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 1,3-dichlorobenzene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 2-Butanone (methyl ethyl ketone/MEK) | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |

Table 7-1. Soil Screening Levels in Upland Soil for Plants and Soil Invertebrates

| Group | Soil Constituent | Units | EPA EcoSSLs | | | ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2 | | DOE BCGs | | Ecology - MTCA WAC 173-340, Table 749-3 | | Lowest Screening Benchmark by Receptor Type | | | Background Soil Concentrations[a] | SSL for Plants and Soil Invertebrates[b] | Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plants | Invertebrate | Reference | Plants | Invertebrate | Terrestrial Plant | Terrestrial Animal | Plant | Soil Biota | Plant | Inverts | Overall Lowest Screening Benchmark | | | |
| | 2-Hexanone | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Benzene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Butanol | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Carbon tetrachloride | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Chlorobenzene | mg/kg | --- | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | 40 | --- | 40 | Benchmark |
| | Chloroform | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | cis-1,2-Dichloroethylene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Dichloromethane (methylene chloride) | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Ethyl benzene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Methyl isobutyl ketone | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | n-butyl Benzene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Tetrachloroethylene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Toluene | mg/kg | --- | --- | --- | 200 | --- | --- | --- | 200 | --- | 200 | --- | 200 | --- | 200 | Benchmark |
| | trans-1,2-Dichloroethylene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Trichloroethene (TCE) | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Xylene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Polycyclic Aromatic Hydrocarbons (PAHs) | Acenaphthene | mg/kg | --- | 29 | OSWER Dir. 9285.7-75 | 20 | --- | --- | --- | 20 | --- | 20 | 29 | 20 | --- | 20 | Benchmark |
| | Acenaphthylene | mg/kg | --- | 29 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 29 | 29 | --- | 29 | Benchmark |
| | Anthracene | mg/kg | --- | 29 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 29 | 29 | --- | 29 | Benchmark |
| | Benzo(a)pyrene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Benzo(a)anthracene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Benzo(b)fluoranthene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Benzo(ghi)perylene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Benzo[k]fluoranthene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Chrysene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Dibenz(ah)anthracene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Fluoranthene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Fluorene | mg/kg | --- | 29 | OSWER Dir. 9285.7-75 | --- | 30 | --- | --- | --- | 30 | --- | 29 | 29 | --- | 29 | Benchmark |
| | Indeno[1,2,3-cd]pyrene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | 2-Methylnaphthalene | mg/kg | --- | 29 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 29 | 29 | --- | 29 | Benchmark |
| | Naphthalene | mg/kg | --- | 29 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 29 | 29 | --- | 29 | Benchmark |
| | Phenanthrene | mg/kg | --- | 29 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 29 | 29 | --- | 29 | Benchmark |
| | Pyrene | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| | Total PAHs | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Low molecular weight PAHs[e] | mg/kg | --- | 29 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 29 | 29 | --- | 29 | Benchmark |

Table 7-1. Soil Screening Levels in Upland Soil for Plants and Soil Invertebrates

| Group | Soil Constituent | Units | EPA EcoSSLs | | | ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2 | | DOE BCGs | | Ecology - MTCA WAC 173-340, Table 749-3 | | Lowest Screening Benchmark by Receptor Type | | | Background Soil Concentrations[a] | SSL for Plants and Soil Invertebrates[b] | Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plants | Invertebrate | Reference | Plants | Invertebrate | Terrestrial Plant | Terrestrial Animal | Plant | Soil Biota | Plant | Inverts | Overall Lowest Screening Benchmark | | | |
| | High molecular weight PAHs[f] | mg/kg | --- | 18 | OSWER Dir. 9285.7-75 | --- | --- | --- | --- | --- | --- | --- | 18 | 18 | --- | 18 | Benchmark |
| Petroleum | Gasoline range organics | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | 100 | --- | 100 | 100 | --- | 100 | Benchmark |
| | TPH-diesel | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | 200 | --- | 200 | 200 | --- | 200 | Benchmark |
| | TPH-kerosene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Semivolatile Organics | Normal paraffin hydrocarbons | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Phenol | mg/kg | --- | --- | --- | 70 | 30 | --- | --- | 70 | 30 | 70 | 30 | 30 | --- | 30 | Benchmark |
| | 2-Methylphenol (o-cresol) | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 4-Methylphenol (p-cresol) | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | 2,4-Dinitrotoluene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Bis[2-ethylhexyl] phthalate[g] | mg/kg | --- | --- | --- | 100 | --- | --- | --- | 100 | --- | 100 | --- | 100 | --- | 100 | Benchmark |
| | Polychlorinated biphenyls (PCB)[h,i] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| | Aroclor-1016[h,i] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| | Aroclor-1221[h,i] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| | Aroclor-1232[h,i] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| | Aroclor-1242[h,i] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| | Aroclor-1248[h,i] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| | Aroclor-1254[h,i] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| | Aroclor-1260[h,i] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| | Aroclor-1262[h,i, j] | mg/kg | --- | --- | --- | 40 | --- | --- | --- | 40 | --- | 40 | --- | 40 | --- | 40 | Benchmark |
| Herbicide | Dichloroprop | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Pesticide | Aldrin | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | beta-1,2,3,4,5,6-Hexachlorocyclohexane | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | alpha-Chlordane[k] | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | 1 | --- | 1 | 1 | --- | 1 | Benchmark |
| | gamma-Chlordane[k] | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | 1 | --- | 1 | 1 | --- | 1 | Benchmark |
| | Dichlorodiphenyldichloroethylene | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Dichlorodiphenyltrichloroethane | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Dieldrin | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Endosulfan I | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Endosulfan II | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Endosulfan sulfate | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Endrin aldehyde | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| | Methoxychlor | mg/kg | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |

Table 7-1. Soil Screening Levels in Upland Soil for Plants and Soil Invertebrates

| Group | Soil Constituent | Units | EPA EcoSSLs | | | ORNL - ES/ER/TM-85/R3, ES/ER/TM-126/R2 | | DOE BCGs | | Ecology - MTCA WAC 173-340, Table 749-3 | | Lowest Screening Benchmark by Receptor Type | | | Background Soil Concentrations[a] | SSL for Plants and Soil Invertebrates[b] | Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plants | Invertebrate | Reference | Plants | Invertebrate | Terrestrial Plant | Terrestrial Animal | Plant | Soil Biota | Plant | Inverts | Overall Lowest Screening Benchmark | | | |

Notes: Complete citations of OSWER Directives are provided in Chapter 11.

Sources: ES/ER/TM-85/R3, *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*.

ES/ER/TM-126/R2, *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*.

WAC 173-340, "Model Toxics Control Act—Cleanup" (MTCA).

a. Background soil concentrations are selected according to the following hierarchy: the 90$^{th}$ percentile of Hanford Site background; Washington State background. See the text for further discussion of sources.

b. The selected PRG is the higher of either the background in soil or the overall lowest screening value between plants and soil invertebrates.

c. When chromium (total) not available, the lower of either Cr(III) or Cr(VI) as available were used as a surrogate.

d. MTCA plant and soil biota benchmarks were replaced by Washington State natural background concentration.

e. Screening values from EPA (OSWER Directive 9285.7-78 [*Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs): Interim Final*]) represent the sum of the low molecular weight PAHs. For this assessment, the benchmark was also applied to the individual low molecular weight PAHs.

f. Screening values from EPA (OSWER Directive 9285.7-78 [*Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs): Interim Final*]) represents the sum of the high molecular weight PAHs. For this assessment, the benchmark was also applied to the individual high molecular weight PAHs.

g. Values for diethyl phthalate were used as a surrogate for bis[2-ethylhexyl] phthalate.

h. Aroclor-1254 value was used as surrogate.

i. MTCA values represent screening value for PCB mixtures.

j. MTCA Aroclor-1260 values used as surrogate for Aroclor-1262.

k. MTCA values based on chlordane.

--- = value not available

BCG = Biota Concentration Guide
DOE = U.S. Department of Energy
Ecology = Washington State Department of Ecology
EcoSSL = ecological soil screening level
EPA = U.S. Environmental Protection Agency
PCB = polychlorinated biphenyl
PRG = preliminary remediation goal
SSL = soil screening level

Table 7-2. Wildlife (Birds and Mammals) SSLs for Radionuclides

| Soil Constituent | Units | NOAEL-Based Site-Specific SSLs | | | | | | | | | LOAEL-Based Site-Specific SSLs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | California Quail | Meadowlark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grasshopper Mouse | Badger | NOAEL Lowest | California Quail | Meadowlark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grasshopper Mouse | Badger | LOAEL Lowest |
| Americium-241 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 28,900 | 25,000 | 11,900 | 17,800 | 72,100 | 48,700 | 41,400 | 4,840 | 4,840 |
| Carbon-14 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 54 | 60 | 56 | 50 | 61 | 60 | 135 | 32 | 32 |
| Curium-244 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 389,000 | 252,000 | 105,000 | 207,000 | 2,300,000 | 722,000 | 499,000 | 50,800 | 50,800 |
| Cobalt-60 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 805 | 805 | 805 | 863 | 805 | 805 | 806 | 1,000 | 805 |
| Cesium-134 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,140 | 1,190 | 1,200 | 854 | 1,160 | 1,180 | 1,270 | 562 | 562 |
| Cesium 137 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2,390 | 2,700 | 2,800 | 1,430 | 2,510 | 2,630 | 3,280 | 924 | 924 |
| Europium-152 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,740 | 1,740 | 1,740 | 1,880 | 1,740 | 1,740 | 1,740 | 2,220 | 1,740 |
| Europium-154 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,610 | 1,610 | 1,610 | 1,740 | 1,610 | 1,610 | 1,610 | 2,060 | 1,610 |
| Europium-155 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 33,400 | 33,400 | 33,400 | 37,300 | 33,400 | 33,400 | 33,400 | 48,600 | 33,400 |
| Hydrogen-3 (tritium) | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1,430 | 1,280 | 936 | 1,130 | 3,270 | 2,290 | 2,830 | 420 | 420 |
| Neptunium-237 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8,190 | 8,140 | 7,880 | 9,150 | 8,250 | 8,170 | 8,180 | 11,200 | 7,880 |
| Nickel-63 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Plutonium-238 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 36,300 | 56,200 | 20,900 | 26,800 | 291,000 | 161,000 | 161,000 | 5,980 | 5,980 |
| Plutonium-239/240 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 38,800 | 60,300 | 22,300 | 28,400 | 324,000 | 175,000 | 176,000 | 6,270 | 6,270 |
| Radium-226 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 168 | 142 | 58 | 377 | 285 | 165 | 199 | 193 | 58 |
| Radium-228 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 169 | 140 | 55 | 418 | 306 | 165 | 203 | 193 | 55 |
| Antimony-125 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 4,580 | 4,580 | 4,580 | 5,040 | 4,580 | 4,580 | 4,580 | 6,130 | 4,580 |
| Strontium-90 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 521 | 302 | 151 | 112 | 706 | 519 | 413 | 91 | 91 |
| Technetium-99 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 5,360 | 11,500 | 137,000 | 280,000 | 8,670 | 12,100 | 412,000 | 128,000 | 5,360 |
| Thorium-232 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 5,070 | 12,900 | 5,340 | 12,400 | 34,400 | 32,500 | 86,200 | 4,560 | 4,560 |
| Uranium-234 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 12,700 | 21,800 | 6,370 | 40,900 | 30,300 | 24,800 | 51,600 | 14,200 | 6,370 |
| Uranium-235 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6,340 | 7810 | 4,360 | 10,200 | 8,600 | 8,130 | 9,630 | 8,060 | 4,360 |
| Uranium-238 | pCi/g | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8,020 | 10,400 | 5,150 | 22,100 | 11,900 | 11,000 | 13,900 | 13,400 | 5,150 |

LOAEL = lowest observed adverse effect level
NOAEL = no observed adverse effect level

#### 7.3.1.2 Effects Assessment for Nonradionuclides

Effects data for the nonradionuclide COPCs are presented below for plants and invertebrates and for wildlife. A description is included of the sources or the information used and an explanation of the selection of effects data. The overarching theme was to employ the most recent of relevant toxicological information available as described within ERAGs (EPA 540-R-97-006) and MTCA ("Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]).

*Plants and Invertebrates*. Single-chemical screening-level toxicity values for terrestrial plants and soil invertebrates were available from the following sources:

- EPA's Ecological Soil Screening Levels (EcoSSLs) (http://www.epa.gov/ecotox/ecossl/)
- Screening benchmark concentrations in soil developed by ORNL; many of the Ecological Indicator Soil Concentrations published by Ecology (see below) were drawn from ORNL screening benchmark concentrations
- Ecology's Ecological Indicator Soil Concentrations, found in MTCA ("Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493(2)(a)(i)]), Table 749-3

The lowest available plant or invertebrate value from these sources was selected as the SSL for each analyte because it represents direct exposure of the receptor to the media. These SSLs are presented in Table 7-1. A brief discussion of each source is provided below.

EPA's EcoSSLs for plants and soil invertebrates were derived using data from tests performed within soil conditions favoring relatively high bioavailability for upland soil. The soil chemistry conditions of relatively high bioavailability were defined by organic matter content and by low soil pH. From the studies reviewed, the measure of toxic effects to either plants or soil invertebrates was grouped into one of four ecologically relevant endpoints: reproduction, population characteristics, growth, or physiological changes. Toxicity parameters used in deriving the EcoSSLs were the EC20 (effective concentration affecting 20 percent of a test population), the maximum acceptable toxicant concentration (MATC), and the EC10 (effect concentration affecting 10 percent of a test population). The MATC was calculated by EPA from studies that reported a no observed adverse effects concentration (NOAEC) and a lowest observed adverse effects concentration (LOAEC). The MATC was calculated as the geometric mean of the NOAEC and LOAEC. Studies that reported only an LOAEC or only an NOAEC (e.g., unbound studies) were not considered to provide a reliable assessment of the dose response and were not used for EcoSSL development. The EcoSSL for plants and soil invertebrates was calculated as the geometric mean of all the toxicity parameters from studies conducted under conditions of high bioavailability. Note that use of the EC20, MATC, and EC10 as toxicity parameters means that EcoSSLs for plants and soil invertebrates are not based on NOAECs. Therefore, the recommended value is at a level where effects have been observed but to a percent of individuals considered acceptable within the ERA practice, as demonstrated by its use within the EcoSSL approach documents (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]).

The ORNL benchmarks for the toxicity to plants from chemical analytes in soil were based on thresholds for effects on growth and reproduction derived from published toxicity studies conducted in soil or solution. The benchmarks are concentrations of chemicals that correspond to the LOEC for the $10^{th}$ percentile of plant species tested. The ORNL benchmarks for toxicity to soil invertebrates and heterotrophic processes from analytes in soil represent thresholds (LOECs) for statistically significant effects on growth, reproduction, or activity. The toxicity benchmarks were derived by rank-ordering the LOEC values and then selecting a value that approximated the $10^{th}$ percentile.

If 10 or fewer values were available for a chemical, the lowest LOEC was used. If the 10$^{th}$ percentile fell between LOEC values, a value was chosen by interpolation. If a chemical concentration in soil represented a 50 percent or higher reduction in survivorship of plants, the concentration was divided by 5 to approximate the more sensitive endpoints of growth or production. Plant toxicity benchmarks for metals are usually lower than those benchmarks for soil invertebrates or microbial processes. The plant toxicity benchmarks for metals are lower than most PRGs calculated for wildlife.

Ecology's ecological indicator soil concentrations, presented in Table 749-3 of MTCA (WAC 173-340), represent soil concentrations that are expected to be protective at any MTCA (WAC 173-340) site and are provided for use in eliminating hazardous substances from further consideration under MTCA ("Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493(2)(a)(i)]). The ecological indicator soil concentrations for plants are based on benchmarks published in *Toxicological Benchmarks for Screening Potential Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision* (ES/ER/TM-85/R3). The ecological indicator soil concentrations for soil biota are based on benchmarks published in *Toxicological Benchmarks for Contaminants of Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision* (ES/ER/TM-126/R2).

*Wildlife (Birds and Mammals).* Bird and mammal TRVs for both the no observed adverse effect levels (NOAELs) and LOAELs were used in the SSL and PRG development. The TRVs were used within models relating the ingested dose of the chemicals (exposure assessment; see Section 7.3.2) with the TRVs to establish SSLs or PRGs that represent adverse effects thresholds. The TRVs were obtained from various sources, and focus was given to the most recent sources and those derived or endorsed by EPA and Ecology (as evidenced by their use in either EcoSSLs or in the MTCA [WAC 173-340]). The primary literature sources used were EcoSSLs. The toxicity studies used were selected initially from the following sources, which have been listed in order of preference:

- Office of Solid Waste and Emergency Response (OSWER) Directives:
  - 9285.7-56, *Ecological Soil Screening Levels for Dieldrin: Interim Final*
  - 9285.7-57, *Ecological Soil Screening Levels for DDT and Metabolites: Interim Final*
  - 9285.7-60, *Ecological Soil Screening Level for Aluminum: Interim Final*
  - 9285.7-61, *Ecological Soil Screening Levels for Antimony: Interim Final*
  - 9285.7-62, *Ecological Soil Screening Levels for Arsenic: Interim Final*
  - 9285.7-63, *Ecological Soil Screening Levels for Barium: Interim Final*
  - 9285.7-64, *Ecological Soil Screening Levels for Beryllium: Interim Final*
  - 9285.7-65, *Ecological Soil Screening Levels for Cadmium: Interim Final*
  - 9285.7-66, *Ecological Soil Screening Levels for Chromium: Interim Final*
  - 9285.7-67, *Ecological Soil Screening Levels for Cobalt: Interim Final*
  - 9285.7-68, *Ecological Soil Screening Levels for Copper: Interim Final*
  - 9285.7-69, *Ecological Soil Screening Level for Iron: Interim Final*
  - 9285.7-70, *Ecological Soil Screening Levels for Lead: Interim Final*
  - 9285.7-71, *Ecological Soil Screening Levels for Manganese: Interim Final*
  - 9285.7-72, *Ecological Soil Screening Levels for Selenium: Interim Final*
  - 9285.7-73, *Ecological Soil Screening Levels for Zinc: Interim Final*
  - 9285.7-75, *Ecological Soil Screening Levels for Vanadium: Interim Final*
  - 9285.7-76, *Ecological Soil Screening Levels for Nickel: Interim Final*

  - 9285.7-77, *Ecological Soil Screening Levels for Silver: Interim Final*
  - 9285.7-78, *Ecological Soil Screening Levels for Polycyclic Aromatic Hydrocarbons (PAHs): Interim Final*
- MTCA (WAC 173-340), Table 749-5
- Other available literature—primarily *Toxicological Benchmarks for Wildlife: 1996 Revision* (ES/ER/TM-86/R3)
- NOAEL and LOAEL values selected for chemicals and reported in Integrated Risk Information System
- NOAEL and LOAEL values presented in Wildlife Toxicity Assessments developed by the U.S. Army Center for Health Promotion and Preventive Medicine

An EPA panel of experts developed a process for reviewing and selecting TRVs for EcoSSL development for wildlife; the process was to select NOAELs to develop EcoSSLs for wildlife. Selected TRVs were either the highest NOAEL for population level effects (e.g., survival, growth, and reproduction endpoints) below the lowest LOAEL for population level effects or the geometric mean of NOAELs, depending on the number and quality of data available. Selection of the TRVs for development of Hanford Site SSLs and PRGs attempted to draw on the work of this expert panel. Thus, the NOAELs for analytes for which EPA has developed EcoSSLs for birds and mammals were used for wildlife SSL and PRG development for the Hanford Site (for a full detailed description, see Appendix H of the 100-K RI/FS [DOE/RL-2010-97], and *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]). In some cases, the NOAEL-based TRV for the EcoSSL was the highest NOAEL below the lowest LOAEL identified for studies evaluating survival, growth, and reproduction endpoints. In these cases, the paired LOAEL from the study was selected as the LOAEL for Hanford Site SSL and PRG development. In other cases, the geometric mean of the NOAELs for growth and reproduction endpoints was selected to derive the EcoSSL. In these cases, the LOAEL for Hanford Site SSL and PRG development was selected as the lowest LOAEL from the EcoSSL dataset above the geometric mean NOAEL.

The only exception to this TRV selection process was for the arsenic TRV for avian receptors, in which case the selected study was not identified and reviewed by the EPA panel. The selected study ("Main and Interactive Effects of Arsenic and Selenium on Mallard Reproduction and Duckling Growth and Survival" [Stanley et al., 1994]) was conducted by USFWS at Patuxent Wildlife Research Center over a period of 92 to 173 days that resulted in both a NOAEL and LOAEL for reproductive effects. The EcoSSL document considered nine studies on the effects of arsenic to have sufficient quality to consider in developing the avian SSL. All of these studies were conducted over 70 days or less. "Arsenic Residues in Eggs from Laying Hens Fed with a Diet Containing Arsenic(III) Oxide" (Holcman and Stibilj, 1997) presented an unbound NOAEL that was selected because it was the lowest value. "Main and Interactive Effects of Arsenic and Selenium on Mallard Reproduction and Duckling Growth and Survival" (Stanley et al., 1994) was conducted by a reliable research group over a much longer time frame and produced bounded results (i.e., the NOAEL was bound by a LOAEL). The intent of the EcoSSLs is to provide a value that can be used to provide a reliable conservative screen, whereas TRV selection for this ERA is for use in PRG development for remedial decisions. Given all of this information, the NOAEL and LOAEL from "Main and Interactive Effects of Arsenic and Selenium on Mallard Reproduction and Duckling Growth and Survival" (Stanley et al., 1994) were selected over the EcoSSL recommendation.

For analytes lacking EcoSSLs, other primary and secondary sources of studies were used. Whenever possible, the primary literature sources were obtained and evaluated. Appropriate toxicity studies were selected from these sources based on several criteria:

- Studies were of chronic exposures or exposures during a critical stage of life (e.g., reproduction).
- Exposure was oral through food ingestion to ensure that data were representative of oral exposures expected for wildlife in the field.
- Emphasis was placed on studies of reproductive effects to ensure relevancy to population level effects.
- Studies presented adequate information to evaluate and determine the magnitude of exposure and effects (or no-effects concentrations).

Specifically, toxicity studies were selected to serve as the TRV if exposure was chronic or was measured during a critical life stage, the dosing regime was sufficient to identify both a NOAEL and a LOAEL, and the study considered ecologically relevant effects (e.g., growth, reproduction, or survival). If multiple studies for a given COPC meet these criteria, the study generating the lowest reliable toxicity value was selected to be the TRV.

The full explanations of the TRVs selected, the method of calculating the SSLs and PRGs, and the resulting SSLs and PRGs are found in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) for SSLs, and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311) for PRGs (100-K RI/FS [DOE/RL-2010-97], Appendix H).

### 7.3.2 Exposure Assessment

A summary of the exposure assessment for plants and invertebrates, wildlife, and radionuclide exposures is provided below. Additionally, a brief description of SSL and PRG development as a relationship between the effects assessment described in Section 7.3.1 and the exposure assessment is provided. For wildlife, this description is provided with distinct sections for nonradionuclide SSLs, radionuclide SSLs, and nonradionuclide PRGs, which all included unique details in the estimation of exposure.

#### *7.3.2.1 Exposure Assessment for Terrestrial Plants and Soil Invertebrates*

Terrestrial plants and soil invertebrates experience exposure primarily through the soil in which they live. This exposure occurs because of living in a contaminated medium (i.e., receptors are directly exposed to COPCs). Although other exposure pathways (e.g., dietary exposure for invertebrates or foliar uptake for plants) may contribute to total exposure for these receptors, exposure through the soil predominates. Consequently, estimates of exposure for terrestrial plants and soil invertebrates are represented by the concentration of COPCs in the soil (mg/kg). As such, the concentrations of chemicals in soil that correspond to adverse effects described in the effects assessment (Section 7.3.1) were also assigned as the SSLs. The assumption is the same for PRG selection for plants and invertebrates but is described separately in Section 7.3.4.

#### *7.3.2.2 Exposure Assessment for Wildlife (Birds and Mammals)*

In contrast to plants and soil invertebrates, birds and mammals experience chemical exposure through multiple pathways, including the ingestion of surface water, sediment/soil, biotic media (food), inhalation, and dermal contact. Modeling is often used to assess exposure via these multiple exposure pathways. The product, or exposure estimate, for birds and mammals is a dose estimate that quantifies the amount of chemical in milligrams per kilogram receptor body weight per day (mg/kg/day).

Following is the general form of the model used to estimate exposure of birds and mammals to chemicals in environmental media (*Ecological Risk Assessment for Contaminated Sites* [Suter et al., 2000]):

$$E_t = E_o + E_d + E_i$$

where:

$E_t$ = total chemical exposure experienced by wildlife

$E_o$ = oral exposure

$E_d$ = dermal exposure

$E_i$ = inhalation exposure

Oral exposure occurs through the consumption of contaminated food, water, or sediment/soil; dermal exposure occurs when contaminants are absorbed directly through the skin; and inhalation exposure occurs when volatile compounds or fine particulates are inhaled into the lungs. Although methods are available for assessing dermal exposure to humans (*Dermal Exposure Assessment: Principles and Applications* [EPA/600/8-91/011B]), data necessary to estimate dermal exposure generally are not available for wildlife (*Wildlife Exposure Factors Handbook* [EPA/600/R-93/187]). Similarly, methods and data necessary to estimate wildlife inhalation exposures are poorly developed (*Wildlife Exposure Factors Handbook* [EPA/600/R-93/187]) or limited. Additionally, a wildlife receptor's exposure to contaminants by inhalation and dermal contact usually contributes little to its overall exposure (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]). Dermal exposure also is likely to be low, even in burrow-dwelling animals because of the presence of protective dermal layers (e.g., feathers, fur, or scales). Therefore, for the purposes of developing the SSL values, both dermal and inhalation exposures were assumed negligible.[4] Therefore, only oral exposure via ingestion of soil and food were included in the development of risk-based concentrations for birds and mammals.

Large mammalian wildlife using the upland 100-F/IU waste site areas move down to the Columbia River riparian area and drink from the freshwater seeps and from the more abundant Columbia River. Bats and birds frequenting or residing in these areas also can use the seeps along the Columbia River to meet their daily needs. A semi-quantitative evaluation of the ingestion of seep water was performed and is discussed with the risk characterization in Section 7.4.4.

Total chemical exposure experienced by wildlife ($E_t$) is assumed to be equal to oral exposure ($E_o$). By replacing $E_o$ with a generalized exposure model modified from *Ecological Risk Assessment for Contaminated Sites* (Suter et al., 2000) to include only soil and food ingestion, the previous equation was rewritten as follows:

$$E_t = \left[\left[\sum_{i=1}^{n} B_{ij} \times P_i \times FIR\right] + \left[Soil_j \times P_s \times FIR\right]\right] x\, AUF$$

where:

$E_t$ = total exposure (mg/kg/day)

$Soil_j$ = chemical concentration in soil (mg/kg dry weight)

[4] If the CSM had indicated that VOCs are a significant COPEC, focused analyses of the inhalation pathway may have been warranted, but VOCs were not significant at 100-F/IU. Risk based concentrations or PRGs for this pathway, however, are beyond the scope of this report.

$P_s$ = soil ingestion rate as proportion of diet (unitless)

FIR = food intake rate (kg food/kg body weight/day, dry weight)

$B_{ij}$ = chemical concentration in biota type (i) (mg/kg, dry weight)

$P_i$ = proportion of biota type (i) in diet (unitless)

AUF = area use factor (area of site/home range [Appendix H, Table H-6] of receptor) (unitless)

The bird and mammal effects data (Section 7.3.1.1) were combined with the wildlife exposure model to calculate avian/mammal SSLs and PRGs for nonradionuclides. These SSLs and PRGs consist of soil concentrations that are associated with estimated dietary exposures equivalent to a selected effect level, and were calculated using the following basic equation:

$$1 = \frac{TRV}{\sum(SSLorPRG \times DFI) \times \left[(Frac_v \times C_v) + (Frac_i \times C_i) + (Frac_m \times C_m) + (C_s \times Frac_s)\right]}$$

where:

TRV = toxicity reference value (mg/kg body weight/day)

SSL = wildlife soil screening level (mg/kg)

PRG = wildlife preliminary remediation goal (mg/kg)

$Frac_v$ = fraction of diet represented by vegetation (unitless)

DFI = daily ingestion rate of all food items (kg/kg body weight/day dry weight)

$C_v$ = concentration in vegetation tissue (mg/kg dry weight)

$Frac_i$ = fraction of diet represented by terrestrial invertebrates (unitless)

$C_i$ = concentration in soil invertebrate tissue (mg/kg dry weight)

$Frac_m$ = fraction of diet represented by small mammals/birds (unitless)

$C_m$ = concentration in small mammal tissue (mg/kg dry weight)

$Frac_s$ = fraction of diet represented by incidentally ingested soil (unitless)

$C_s$ = concentration in soil (mg/kg dry weight)

The TRV denotes the level of toxicity of the chemical, as reported from literature sources. The wildlife SSLs and PRGs use the LOAELs, which is consistent with protecting ecological receptors at the population and community level. The daily ingestion rate and dietary fractions are specific to bird and mammal receptors identified for the upland environment of the Hanford Site. The chemical concentration in the food item (vegetation, soil invertebrate, and small mammal) is estimated by BAFs or bioaccumulation regression models to extrapolate to the food source. This equation is solved for wildlife SSLs or PRGs such that exposure (the denominator) equals the TRV (the numerator).

For the purposes of this risk assessment, the LOAEL-based wildlife SSLs and wildlife PRGs were used to evaluate residual risks at the 100-F/IU OUs remediated waste sites. The SSLs and PRGs were compared to EPCs developed for the 100-F/IU OUs, as described in Section 7.4.1.

*Wildlife Exposure Factors*. Within the exposure models described above, species-specific exposure parameters are required to estimate exposure. These include body weight, food ingestion rate, diet composition represented by dietary fractions, and percent or fraction of diet as incidental soil ingestion.

The following assumptions were part of the calculation of wildlife exposures used to develop the wildlife SSLs and wildlife PRGs:

- For SSL and PRG development, it was conservatively assumed that wildlife forage exclusively within the waste site being evaluated resulting in an AUF of one. In other words, the resulting SSLs and PRGs did not attempt to account for wildlife home range instead assuming that prey tissue concentrations from food obtained outside the waste site boundaries might contain lower concentrations of contaminants. This assumption is discussed in more detail in the risk conclusions SMDP (discussed in Section 7.6), including accounting for home range and development of site-specific AUFs, as warranted.
- Incidental soil ingestion was not included as part of the total dietary composition, but instead was added to the total; for calculation purposes, it was treated as a percentage of total dietary intake.
- All animals were assumed to be year-round residents. Migration away from areas contaminated with COPCs was not assumed to occur.
- Bioavailability of analytes was assumed equivalent to the chemical form used for developing TRVs in the toxicity studies.
- 100 percent of the estimated soil concentrations (EPCs) were assumed bioavailable for uptake into tissues within the exposure models.

The exposure parameters and source references used for each representative receptor species are summarized in Appendix H, Table H-3. All weight-based exposure parameters are listed on a dry-weight basis. Species-specific biological information was unavailable for some parameters. When this occurred, allometric equations that express general biological relationships for broader classes of animals were used to estimate the exposure parameters ("Food Requirements of Wild Animals: Predictive Equations for Free-living Mammals, Reptiles, and Birds" [Nagy, 2001]). These allometric conversions are detailed in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784).

*Estimation of Bioaccumulation into Food Items.* A major component of the desktop food chain model described above is modeling the concentration of contaminates within the prey consumed by wildlife within the waste sites being evaluated. This modeled dose received through ingesting food was considered in the final estimate of the soil concentration that represents a toxic threshold (i.e., the SSL or PRG). Bioaccumulation models and assumptions that were used within the calculation of wildlife SSLs and PRGs are described below. While some of the models and assumptions are the same as those within MTCA guidance ("Site-Specific Terrestrial Ecological Evaluation Procedures [WAC 173-340-7493]) promulgated in 2001, advancements in estimating bioaccumulation into food items were published as part of the initial *Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* (OSWER Directive 92857-55) in 2003 and subsequent updates. These models and assumptions represent the most recent equations used in ERA and are now the standard of practice; thus, they were used for developing SSLs and PRGs for Hanford:

- **Estimating prey tissue concentration for SSLs:** The concentrations of COPCs in each food item were estimated rather than measured. For the purposes of exposure estimation, partitioning of analytes from environmental media to prey was estimated from literature values and models. The models presented in the EPA EcoSSLs methodology (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]) were used preferentially for estimation of bioaccumulation into biota from soil. Consistent with the approach used for the EcoSSLs,

regression-based models (if available) and median BAFs from the source selected by EPA were used. In the absence of applicable bioaccumulation models, a default value of one was assumed. In all cases, it was assumed that tissue uptake occurs under steady-state conditions. Bioaccumulation models used to derive wildlife SSLs are presented in Appendix H, Table H-4. The Tier 1 wildlife SSLs are presented in Table 7-2 for radionuclides and Table 7-3 for nonradionuclides. The methodology used to develop the SSLs is detailed in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784), presented in Appendix H of the 100-K RI/FS (DOE/RL-2010-97).

- **Estimating prey tissue concentration for PRGs:** Development of the PRGs for birds and mammals focused on the integration of available site-specific bioaccumulation data for plants, terrestrial arthropods and small mammals with data from the existing bioaccumulation models (i.e., those from *Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]) that were used to develop the EcoSSLs in order to develop a set of more site-specific and site-relevant bioaccumulation models.[5] The following Hanford Site-specific and literature-based datasets were used to develop these bioaccumulation models presented in Appendix H, Table H-5:

  Hanford Site-specific bioaccumulation data have been collected in support of the RCBRA (DOE/RL-2007-21) and other projects at the site. Data representing tissue from terrestrial plants (foliage, shoots, and other aboveground parts of grasses, shrubs, and trees), small mammals (whole individual mice or composites of multiple whole mice), and terrestrial arthropods (whole individual invertebrates or composites of multiple whole invertebrates), and collocated soil data were extracted from the HEIS database. Only paired samples in which the target analytes were detected in both tissue and soil were retained for the bioaccumulation database; observations that were nondetects in either the soil or tissue of a sample pair were excluded from consideration.

*Literature-Derived Bioaccumulation Data for Plants and Small Mammals.* Data from previously developed and published bioaccumulation models for plants and small mammals were used to augment the Hanford Site-specific data. Specifically, the plant bioaccumulation database from *Empirical Models for the Uptake of Inorganic Chemicals from Soil by Plants* (BJC/OR-133) and "Uptake of Inorganic Chemicals from Soil by Plant Leaves: Regressions of Field Data" (Efroymson et al., 2001) were used. In addition, the small mammal bioaccumulation database from *Development and Validation of Bioaccumulation Models for Small Mammals* (ES/ER/TM-219) was used. These data also represent the primary bioaccumulation data for inorganics integrated into *Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* (OSWER Directive 9285.7-55). Electronic copies of the original databases were obtained from the authors to facilitate integration with Hanford Site-specific data.

The development of the plant bioaccumulation database is described in "Uptake of Inorganic Chemicals from Soil by Plant Leaves: Regressions of Field Data" (Efroymson et al., 2001) as follows:

> *Field and greenhouse studies in which concentrations of arsenic, cadmium, copper, lead, mercury, nickel, selenium, or zinc in both surface soil and collocated, aboveground plant tissue were analyzed were identified. Information regarding soil and plant concentrations, soil parameters, exposure time, chemical form, dry or wet weight, extraction method, plant species, and plant part was compiled in a spreadsheet. The database included the following*

[5] These bioaccumulation models are defined as partially site-specific because they are based on both site-specific data and data from published literature sources. This combining of Hanford Site-specific and literature data was performed to maximize the utility of the Hanford Site-specific data collected over comparatively narrow concentration ranges by expanding the dataset to include literature data collected across a wider concentration range.

*number of observations per growth form: 525, graminoid; 544, forb/herb; 4, forb/herb or vine; 69, forb/herb or shrub; 16, shrub; 18, tree or shrub; 49, tree; and 107, unknown or composited samples. Approximately 30% of the data represented chemical concentrations in plant leaves, excluding stems, fruits and seeds; and the remaining aboveground samples included clippings, unspecified aboveground parts or shoots. Samples of fruits or seeds alone were excluded from the database. Tests in which salts (e.g., cadmium chloride, copper sulfate, sodium selenate) were added in solution to soil were excluded because of preliminary results that suggested that regressions of concentrations in plants on concentrations in soil were different for field and salt chemical forms.*

*Only studies in which concentrations were expressed on an air- or oven-dry weight basis were used. Although most studies reported that plant material was washed, studies were not excluded if the extent of washing was not stated in the paper. Studies were used even if the individual investigators observed no correlation between concentrations of contaminants in soils and plants. Concentrations of chemicals in soil or plants were sometimes estimated from a figure, but only if estimates could be made within about 10%. Data for species that are known to hyperaccumulate metals were excluded. Data for which measured concentrations were below detection thresholds were excluded.*

*Each plant species or variety, soil type, location, and concentration of the test element in soil represented an independent observation in the dataset. Differences in exposure duration or above-ground plant part did not constitute separate observations; concentrations in soils or plants that differed on the basis of one of these two variables were averaged. The number of observations in these means, which ranged between 1 and 6, was not retained in the subsequent statistical analysis.*

*Concentrations of contaminants in soil at the time of plant sampling were used if known. If these concentrations were not measured (as was often the case in pot studies), the initial concentration of the element measured in or added to soil was assumed to be equivalent to the final concentration. In field experiments, the change in soil concentration of an element over time was assumed to be minimal.*

*Observations were included in the database if the total chemical concentration in soil was measured, either by extraction with strong acid or by extraction with moderately strong acid (e.g., 4N sulfuric acid) sometimes accompanied by heat. Studies in which concentrations of contaminants in soil were determined by a partial extraction with DTPA (diethylene triamine pentaacetic acid), weak acids, or water were excluded from analysis.*

*For studies in which contaminant concentrations at multiple depths were measured, the concentration at the 0-10, 0-15, or 0-20 cm depth interval was recorded. Where only a single soil depth was measured, it ranged from 5 to 70 cm.*

*Studies included contamination from the following sources: mine wastes (ores, tailings), smelter deposits, other industrial sources, vehicle and other urban emissions, wastewater effluents, composts, fertilizers, dredged materials, sewage sludges, fly ashes, flue dusts, nuclear waste, and arsenical pesticide residues. Where materials such as fertilizers were added to soil, data were excluded if mixing with soil did not occur. In addition, some measurements were taken from background locations. For example, chemical data for arsenic included the following sources: mine waste (24 observations), smelter operations (23 observations), fly ash disposal (18 observations), pesticide use (19 observations), nuclear waste (4 observations), unidentified urban sources (3 observations), background or*

> *no apparent anthropogenic source (13 observations), and unknown source (18 observations).Field studies in which a current, local atmospheric source of contaminants was present were excluded from the database.*"

Similarly, the development of the small mammal bioaccumulation database was described in *Development and Validation of Bioaccumulation Models for Small Mammals* (ES/ER/TM-219) as follows:

> *A literature search was performed for studies that reported chemical concentrations in co-located small mammal and soil samples. Data were restricted to only studies that reported whole body or carcass (whole body minus selected organs or other tissues) concentrations. To ensure relevancy of UFs and models to field situations, only field studies in which resident small mammals were collected were considered. All small mammal tissue burdens were therefore assumed to be at equilibrium with soil concentrations. To ensure comparability of data, only 'total' chemical analyses of both soil and small mammals (i.e., resulting from extractions of metals using concentrated acids) were included. Data resulting from DTPA, acetic acid, and other mild extraction methods were excluded. The mean (or composite) chemical concentration in soil and small mammal reported for each sampling location evaluated in each study was considered an observation. If data for multiple small mammal species were reported at a site, each was considered a separate observation. Soil and small mammal data in the database were reported as mg/kg dry weight. If studies reported small mammal concentrations in terms of wet weight, dry weight concentrations were estimated assuming a 68% water content (EPA, 1993). Data concerning soil characteristics (e.g., soil pH, % organic matter, cation exchange capacity, soil texture, etc.) were rarely reported and therefore do not appear in the database. Because chemical uptake was expected to vary according to small mammal diet preferences, each species was assigned to one of the three trophic groups: insectivore (diet consisting primarily of insects and other invertebrates), herbivore (diet consisting primarily of plant material), and omnivore (diet consisting of both animal and plant material). A summary of the small mammal species included in the database and the trophic groups to which they were assigned is presented in Table 1. To validate the models developed from the literature-derived data, soil and small mammal data collected as part of Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) remedial investigations at sites in Oklahoma (PTI, 1995) and Montana (LaTier et al., 1995) were acquired as a validation dataset. Small mammal species in this validation dataset, however, represented only the herbivore and omnivore trophic groups. Validation data for insectivores were unavailable.*[6]

*Literature Derived Bioaccumulation Data for Terrestrial Arthropods.* Estimating exposures to insectivorous or omnivorous wildlife involved estimating bioaccumulation into soil invertebrates. Soil invertebrate bioaccumulation models used for SSLs consisted of the earthworm models from *Development and Validation of Bioaccumulation Models for Earthworms* (ES/ER/TM-220) and "Literature-Derived Bioaccumulation Models for Earthworms: Development and Validation" (Sample et al., 1999). Hanford Site-specific observations (as detailed in the RCBRA [DOE/RL-2007-21] and *Central Plateau Ecological Risk Assessment Data Package Report* [DOE/RL-2007-50]) indicate that earthworms are nonexistent in

[6] References in this passage can be found in the original source (*Development and Validation of Bioaccumulation Models for Small Mammals* [ES/ER/TM-219]); complete citation is provided in Chapter 11.

upland soil and have little or no contribution to the invertebrate portion of bird and mammal diets at the Hanford Site. Rather, insects and other arthropods (e.g., beetles, ants, and spiders) are the primary prey of invertebrate-feeding birds and mammals at the site. Consequently, the data collected to address site-specific bioaccumulation into invertebrate prey of birds and mammals focused on arthropods (RCBRA [DOE/RL-2007-21]). Additional bioaccumulation data for terrestrial arthropods were identified and extracted from published literature to supplement the Hanford Site-specific data. This database was largely developed to support bioaccumulation modeling for the U.S. Army Adaptive Risk Assessment Modeling Systems (ARAMS[7]) and was first presented in *Development of Terrestrial Exposure and Bioaccumulation Information for the Army Risk Assessment Modeling System (ARAMS)* (USACHPPM, 2004).

A literature search was performed for studies that reported chemical concentrations in collocated biota and media samples.[8] Literature databases searched included those hosted by the Defense Technical Information Center (*Online Information for the Defense Community* (DTIC, 2012), the EPA (ECOTOX database) and the U.S. National Library of Medicine (TOXLINE: Toxicology Data Network).

From the range of studies reviewed, 22 were identified as containing relevant data (i.e., reported collocated soil and biota concentrations). Terrestrial invertebrate data focused on studies of accumulation in insects or spiders and reported whole body concentrations. To ensure relevancy of the soil to biota factors and models to field situations, only field studies that collected resident terrestrial invertebrates were considered. Therefore, all terrestrial invertebrate residues were assumed to be at equilibrium with soil concentrations.

To ensure comparability of data, only "total" chemical analyses of both soil and biota (e.g., resulting from extractions of metals using concentrated acids) were included. Data resulting from acetic acid, diethylenetriaminepentaacetic acid, and other mild extraction methods were excluded. The mean (or composite) chemical concentration in media and biota reported for each sampling location evaluated in each study was considered an observation. If data for multiple species were reported at a site, each species was considered a separate observation. Soil and biota data in the terrestrial arthropod database were reported as mg/kg DW (drinking water). If a study identified in the literature search reported biota concentrations in wet weight, then drinking water concentrations were either calculated using the water content presented in the study or estimated assuming water content percentages as presented in *Wildlife Exposure Factors Handbook* (EPA/600/R-93/187) when water content was not presented in the study.

Data concerning species, soil pH, percent organic matter (OM), cation exchange capacity (CEC), soil texture, and soil Ca concentration (mg/kg dry weight) were included in the database whenever reported. Additionally, class, order, and family taxonomic data were included for each species in the database. These data was used to develop uptake factors by taxon for terrestrial invertebrates. Because chemical uptake was expected to vary according to terrestrial invertebrate diet preferences, each species was assigned to one of three trophic groups: predator (diet consisting primarily of other insects), herbivore

[7] Note that ARAMS was previously known as the "Army Risk Assessment Modeling System."

[8] Data usability requirements included the following: only paired/collocated samples with detects in both tissue and soil at levels above detection limits; terrestrial invertebrate data focuses on whole body tissue samples; only field studies, not laboratory studies, were included except where noted; only total chemical analyses of both soil and biota – data resulting from mild acid extraction methods were excluded; the mean or composite chemical concentration in media and biota reported per location in each study was considered an observation; data on distinct species were considered separate observations; all wet weight measurements were converted to dry weight using study-specific water content or estimations from *Wildlife Exposure Factors Handbook* (EPA/600/R-93/187). Additional detail on data usability is provided in CHPRC-01311 within Appendix H of the 100-K RI/FS (DOE/RL-2010-97).

(diet consisting primarily of plant material), and detritivore (diet consisting primarily of organic matter in the leaf litter).

To ensure the accuracy of the terrestrial arthropod database, all data were verified by at least one reviewer. The reviewer would first exam the study for data presented and analytical methods used. The reviewer would then check all calculations and conversions necessary to obtain required units (e.g., mg/kg dry weight). Finally, a minimum of 25 percent of all data was checked. If an error was found during this check, then 100 percent of the data was verified. Unit conversion and transposition errors were the most common types of errors found; however these were infrequent. All errors were corrected.

*Development of Integrated Bioaccumulation Models.* The Hanford Site-specific plant, soil invertebrate, and small mammal data were integrated with the literature-derived bioaccumulation data. Bioaccumulation analyses were performed once biota data were converted to standard units (mg/kg-dry weight). Analyses were restricted to observations where the chemical of interest was detected in both soil and the matched tissue sample; all observations in which either soil or tissue concentrations were nondetects, were excluded from the analyses. Analyses consisted of development of BAFs and nonlinear regression analyses. BAFs are simply the ratio between concentrations measured in tissue and that in soil. BAFs for all paired soil-tissue observations and summary statistics (arithmetic mean, standard deviation, minimum, maximum, median, and $90^{th}$ percentile) were calculated.

To evaluate if a log-linear relationship exists between the chemical concentration in soil and that in terrestrial biota, simple log-linear regressions were performed using SAS PROC REG (*SAS/STAT User's Guide, Version 9* [SAS Institute, 1999]). Chemical concentrations in both soil and biota tissues were transformed to natural-log (ln) before regression analyses. Regression analyses were considered significant and suitable for estimation purposes if all three of the following criteria were met: $p > 0.05$, $r2 > 0.2$, and a positive slope. If regression analyses did not meet any one of these criteria, the median BAFs were used to estimate tissue concentrations in exposure models.

The wildlife SSLs for nonradionuclides are presented in Table 7-3, and the wildlife PRGs (metals only) are presented in Table 7-4. In cases where the second tier of effect level (PRG) was not available or recommended (e.g., organics, radionuclides, and a few inorganics), the PRGs defaulted to the SSLs. For the purposes of this ERA, the LOAEL-based SSLs (SSLs that used lowest effect levels from the effects assessment) were used to evaluate residual risks at the remediated 100-F/IU waste sites. To focus the assessment on COPEC-receptor-waste site combinations that might require further evaluation, the SSLs were compared to EPCs developed for 100-F/IU, as described in Section 7.4.1. Then, to identify which COPEC-receptor-waste sites combinations should be brought forward to the SMDP to identify community- or population-level impacts to be addressed in the FS, EPCs were compared to PRGs for COPCs that exceeded SSLs and background, as described in Section 7.4.3.

#### *7.3.2.3 Radionuclide Exposures*

Exposure to radionuclides differs from chemical exposure. Terrestrial biota receives exposure to radionuclides through a combination of both internal and external pathways. Internal exposure is a function of radiation emitted from radionuclides that are retained in tissues. At a terrestrial site such as the 100-F/IU OUs, external exposure is due to radiation from radionuclides in soil with which biota come into contact (or come near). For the purposes of developing SSLs, radionuclide exposure was estimated based on the internal and external radiation exposure models used to develop BCGs as described in Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002).

Table 7-3. Wildlife (Birds and Mammals) Soil Screening Levels for Nonradionuclides

| Group | Soil Constituent | Units | NOAEL-Based Site-Specific SSLs | | | | | | | | | LOAEL-Based Site-Specific SSLs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | NOAEL Lowest | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | LOAEL Lowest |
| Metals | Aluminum | mg/kg | 22,020 | 18,602 | 4,921 | 61,782 | 687 | 271 | 380 | 710 | 271 | -- | -- | -- | -- | 6,872 | 2,708 | 3,799 | 7,101 | 2,708 |
| | Antimony | mg/kg | -- | -- | -- | -- | 8.8 | 0.7 | 0.6 | 16.7 | 0.6 | -- | -- | -- | -- | 97 | 7 | 6 | 167 | 6 |
| | Arsenic, total all valence states | mg/kg | 1,800 | 1,981 | 425 | 10,344 | 265 | 105 | 171 | 549 | 105 | 8,104 | 10,559 | 2,132 | 45,439 | 459 | 190 | 318 | 881 | 190 |
| | Arsenic(III) | mg/kg | 1,800 | 1,981 | 425 | 10,344 | 265 | 105 | 171 | 549 | 105 | 8,104 | 10,559 | 2,132 | 45,439 | 459 | 190 | 318 | 881 | 190 |
| | Arsenic(V) | mg/kg | 1,800 | 1,981 | 425 | 10,344 | 265 | 105 | 171 | 549 | 105 | 8,104 | 10,559 | 2,132 | 45,439 | 459 | 190 | 318 | 881 | 190 |
| | Barium | mg/kg | 1,229 | 1,271 | 660 | 14,442 | 2,082 | 1,889 | 4,605 | 18,843 | 660 | 2,464 | 2,548 | 1,323 | 28,954 | 3,470 | 3,148 | 7,676 | 31,405 | 1,323 |
| | Beryllium | mg/kg | -- | -- | -- | -- | 14 | 18 | 101 | 283 | 14 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Bismuth | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Boron | mg/kg | 63.9 | 86.5 | 139.7 | 796.7 | 40 | 50 | 284 | 767 | 40 | 222 | 300 | 485 | 2,766 | 133 | 167 | 949 | 2,563 | 133 |
| | Cadmium | mg/kg | 151.1 | 2.8 | 0.9 | 1,374.9 | 76 | 1.5 | 1.3 | 455 | 0.9 | 278 | 5 | 2 | 2,335 | 2,065 | 28 | 24 | 5,228 | 2 |
| | Chromium (total) | mg/kg | 334.3 | 96.5 | 36.5 | 1,286.5 | 320 | 75 | 78 | 752 | 37 | 349 | 101 | 38 | 1,355 | 1,284 | 299 | 313 | 3,536 | 38 |
| | Chromium(III) | mg/kg | 334.3 | 96.5 | 36.5 | 1,286.5 | 320 | 75 | 78 | 752 | 37 | 349 | 101 | 38 | 1,355 | 1,284 | 299 | 313 | 3,536 | 38 |
| | Chromium(VI) | mg/kg | -- | -- | -- | -- | 1,233.4 | 287.7 | 300.2 | 3,379.9 | 287.7 | -- | -- | -- | -- | 5,340 | 1,245 | 1,300 | 16,583 | 1,245 |
| | Cobalt | mg/kg | 1,425.3 | 305.3 | 108.8 | 1,601.4 | 2,174.4 | 260.9 | 250.1 | 1,346.1 | 108.8 | 1,461 | 313 | 111 | 1,633 | 3,233 | 388 | 372 | 1,869 | 111 |
| | Copper | mg/kg | 485.2 | 85.3 | 35.8 | 3,727.7 | 872.9 | 99.9 | 109.4 | 2,640.1 | 35.8 | 1,914 | 272 | 107 | 13,021 | 1,894 | 176 | 182 | 4,672 | 107 |
| | Lead | mg/kg | 247 | 49 | 16 | 979 | 1,204 | 151 | 153 | 2,005 | 16 | 537 | 115 | 36 | 2,433 | 2,544 | 332 | 336 | 4,108 | 36 |
| | Lithium | mg/kg | -- | -- | -- | -- | 3,189 | 1,258 | 1,749 | 257 | 257 | -- | -- | -- | -- | 6,379 | 2,517 | 3,498 | 515 | 515 |
| | Manganese | mg/kg | 16,369 | 24,184 | 9,588 | 113,951 | 4,227 | 4,115 | 18,430 | 20,464 | 4,115 | 31,823 | 48,820 | 19,636 | 221,536 | 5,828 | 5,798 | 27,720 | 28,213 | 5,798 |
| | Mercury | mg/kg | 3.1 | 0.4 | 0.04 | 25 | 0.5 | 0.03 | 0.03 | 9 | 0.03 | 36 | 21 | 4 | 134 | 8 | 2 | 3 | 43 | 2 |
| | Molybdenum | mg/kg | 35 | 27 | 18 | 98 | 2 | 1 | 3 | 7 | 1 | 345 | 270 | 179 | 977 | 17 | 14 | 28 | 71 | 14 |
| | Nickel | mg/kg | 1,081 | 79 | 31 | 6,037 | 303 | 18 | 16 | 637 | 16 | 1,912 | 136 | 53 | 11,078 | 676 | 36 | 33 | 1,438 | 33 |
| | Selenium | mg/kg | 5.6 | 3.7 | 1.7 | 158 | 2.1 | 1.2 | 1.8 | 32 | 1.2 | 10 | 8 | 4 | 417 | 3 | 2 | 3 | 60 | 2 |
| | Silver | mg/kg | 345 | 13 | 5 | 2,044 | 1,442 | 35 | 30 | 3,097 | 5 | 3,453 | 128 | 50 | 20,437 | 14,418 | 346 | 300 | 30,969 | 50 |
| | Strontium | mg/kg | -- | -- | -- | -- | 9,442 | 4,849 | 6,476 | 4,228 | 4,228 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Thallium | mg/kg | -- | -- | -- | -- | 5.1 | 1.8 | 2.4 | 2.6 | 1.8 | -- | -- | -- | -- | 25 | 9 | 12 | 13 | 9 |
| | Tin | mg/kg | 82 | 128 | 231 | 1,852 | 187 | 252 | 2,691 | 5,107 | 82 | 204 | 318 | 575 | 4,603 | 279 | 377 | 4,025 | 7,639 | 204 |
| | Uranium | mg/kg | 2,502 | 2,691 | 785 | 18,730 | 610 | 393 | 748 | 1,694 | 393 | -- | -- | -- | -- | 1,217 | 786 | 1,494 | 3,383 | 786 |

Table 7-3. Wildlife (Birds and Mammals) Soil Screening Levels for Nonradionuclides

| Group | Soil Constituent | Units | NOAEL-Based Site-Specific SSLs | | | | | | | | | LOAEL-Based Site-Specific SSLs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | NOAEL Lowest | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | LOAEL Lowest |
| | Vanadium | mg/kg | 67 | 58 | 16 | 268 | 1,363 | 577 | 835 | 1,864 | 16 | 134 | 116 | 31 | 537 | 2,723 | 1,153 | 1,668 | 3,723 | 31 |
| | Zinc | mg/kg | 4,973 | 714 | 67 | 70,825 | 4,612 | 633 | 794 | 38,590 | 67 | 5,015 | 726 | 68 | 71,294 | 4,661 | 644 | 810 | 38,866 | 68 |
| General Inorganics | Ammonia/ammonium | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Chloride | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Cyanide | mg/kg | -- | -- | -- | -- | 27,971 | 20,693 | 78,123 | 38,061 | 20,693 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Fluoride (fluorine) | mg/kg | 1,492 | 2,812 | 556 | 9,206 | 9,825 | 8,216 | 35,673 | 17,379 | 556 | 6,123 | 11,539 | 2,281 | 37,771 | 16,521 | 13,816 | 59,985 | 29,224 | 2,281 |
| | Iodine | mg/kg | -- | -- | -- | -- | 159 | 183 | 1,558 | 759 | 159 | -- | -- | -- | -- | 1,594 | 1,834 | 15,579 | 7,590 | 1,594 |
| | Nitrate/nitrite | mg/kg | -- | -- | -- | -- | 206,422 | 152,711 | 576,537 | 280,885 | 152,711 | -- | -- | -- | -- | 460,073 | 340,361 | 1,284,984 | 626,035 | 340,361 |
| | Phosphate | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Sulfate/sulfite | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Total organic carbon | % | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Volatile Organics | 1,1-Dichloroethane | mg/kg | 3,615 | 217 | 83 | 13,955 | 20,357 | 574 | 502 | 22,894 | 83 | 7,230 | 435 | 165 | 27,909 | -- | -- | -- | -- | 165 |
| | 1,1-Dichloroethene | mg/kg | 3,615 | 217 | 83 | 11,433 | 12,214 | 344 | 301 | 12,238 | 83 | 7,230 | 434 | 165 | 22,866 | -- | -- | -- | -- | 165 |
| | 1,1,1-Trichloroethane | mg/kg | 3,615 | 217 | 82 | 8,936 | 407,144 | 11,444 | 10,016 | 349,074 | 82 | 7,230 | 433 | 165 | 17,871 | -- | -- | -- | -- | 165 |
| | 1,1,2-Trichloroethane | mg/kg | 3,615 | 217 | 83 | 12,031 | 407,144 | 11,472 | 10,041 | 420,572 | 83 | 7,230 | 434 | 165 | 24,063 | -- | -- | -- | -- | 165 |
| | 1,1,2,2-Tetrachloroethane | mg/kg | 3,615 | 217 | 82 | 9,549 | 3,636 | 102 | 89 | 3,255 | 82 | 7,230 | 433 | 165 | 19,098 | 36,358 | 1,022 | 894 | 32,554 | 165 |
| | 1,2-Dichlorobenzene | mg/kg | 88 | 91 | 82 | 4,343 | 282 | 294 | 854 | 17,612 | 82 | 176 | 182 | 164 | 8,687 | -- | -- | -- | -- | 164 |
| | 1,2-Dichloroethane (DCA) | mg/kg | 3,615 | 222 | 84 | 16,084 | 20,357 | 586 | 513 | 24,710 | 84 | 7,230 | 444 | 169 | 32,168 | -- | -- | -- | -- | 169 |
| | 1,3-Dichlorobenzene | mg/kg | 96 | 96 | 82 | 4,051 | 310 | 314 | 854 | 16,652 | 82 | 192 | 192 | 164 | 8,103 | -- | -- | -- | -- | 164 |
| | 2-butanone (methyl ethyl ketone/MEK) | mg/kg | 2,102 | 1,041 | 312 | 11,538 | 721,052 | 159,713 | 176,661 | 970,851 | 312 | 21,017 | 10,406 | 3,123 | 115,382 | >1,000,000 | 412,224 | 455,968 | >1,000,000 | 3,123 |
| | 2-Hexanone | mg/kg | 2,102 | 548 | 186 | 9,653 | 2,036 | 244 | 237 | 2,512 | 186 | 21,017 | 5,483 | 1,856 | 96,532 | 14,698 | 1,759 | 1,708 | 18,135 | 1,708 |
| | Benzene | mg/kg | 8,554 | 513 | 195 | 27,053 | 285 | 8 | 7 | 286 | 7 | -- | -- | -- | -- | 2,850 | 80 | 70 | 2,856 | 70 |
| | Butanol | mg/kg | -- | -- | -- | -- | 50,893 | 2,906 | 2,626 | 67,049 | 2,626 | -- | -- | -- | -- | 203,572 | 11,625 | 10,503 | 268,194 | 10,503 |
| | Carbon tetrachloride | mg/kg | 3,615 | 216 | 82 | 7,382 | 6,514 | 183 | 160 | 4,904 | 82 | 7,230 | 433 | 165 | 14,765 | -- | -- | -- | -- | 165 |
| | Chlorobenzene | mg/kg | 3,615 | 216 | 82 | 6,672 | 7,939 | 223 | 195 | 5,561 | 82 | 7,230 | 433 | 165 | 13,345 | 15,756 | 442 | 387 | 11,036 | 165 |
| | Chloroform | mg/kg | 3,615 | 217 | 83 | 13,003 | 6,107 | 172 | 151 | 6,600 | 83 | 7,230 | 434 | 165 | 26,006 | 16,693 | 470 | 412 | 18,041 | 165 |
| | cis-1,2-Dichloroethylene | mg/kg | 3,615 | 217 | 83 | 13,446 | 18,403 | 518 | 453 | 20,271 | 83 | 7,230 | 434 | 165 | 26,892 | -- | -- | -- | -- | 165 |

Table 7-3. Wildlife (Birds and Mammals) Soil Screening Levels for Nonradionuclides

| Group | Soil Constituent | Units | NOAEL-Based Site-Specific SSLs | | | | | | | | | LOAEL-Based Site-Specific SSLs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | NOAEL Lowest | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | LOAEL Lowest |
| | Dichloromethane (methylene chloride) | mg/kg | 3,615 | 218 | 83 | 17,281 | 2,382 | 67 | 59 | 2,999 | 59 | 7,230 | 436 | 166 | 34,562 | 20,357 | 576 | 504 | 25,632 | 166 |
| | Ethyl benzene | mg/kg | 159 | 183 | 194 | 12,721 | 342 | 384 | 1,357 | 33,025 | 159 | -- | -- | -- | -- | 1,027 | 1,151 | 4,075 | 99,076 | 1,027 |
| | Methyl isobutyl ketone | mg/kg | 2,102 | 573 | 193 | 10,211 | 721,052 | 90,040 | 87,996 | 915,292 | 193 | 21,017 | 5,729 | 1,927 | 102,114 | >1,000,000 | 232,395 | 227,119 | >1,000,000 | 1,927 |
| | n-butyl Benzene | mg/kg | 301 | 263 | 193 | 7,857 | 530 | 485 | 1,092 | 18,135 | 193 | -- | -- | -- | -- | 1,589 | 1,454 | 3,275 | 54,406 | 1,454 |
| | Tetrachloroethylene | mg/kg | 3,615 | 216 | 82 | 7,733 | 570 | 16 | 14 | 443 | 14 | 7,230 | 431 | 164 | 15,467 | 2,850 | 80 | 70 | 2,216 | 70 |
| | Toluene | mg/kg | 8,554 | 512 | 195 | 17,200 | 21,171 | 594 | 520 | 15,763 | 195 | -- | -- | -- | -- | 211,715 | 5,944 | 5,202 | 157,633 | 5,202 |
| | trans-1,2-Dichloroethylene | mg/kg | 3,615 | 217 | 83 | 11,881 | 18,403 | 518 | 453 | 18,869 | 83 | 7,230 | 434 | 165 | 23,763 | -- | -- | -- | -- | 165 |
| | Trichloroethene (TCE) | mg/kg | 3,615 | 217 | 82 | 7,498 | 285 | 8 | 7 | 217 | 7 | 7,230 | 434 | 165 | 14,996 | 2,850 | 80 | 70 | 2,169 | 70 |
| | Xylene | mg/kg | 149 | 175 | 194 | 13,419 | 422 | 481 | 1,787 | 45,266 | 149 | -- | -- | -- | -- | 826 | 940 | 3,494 | 88,509 | 826 |
| Polycyclic Aromatic Hydrocarbons | Acenaphthene | mg/kg | 6,831 | 285 | 110 | 38,362 | 71,250 | 1,396 | 1,211 | 96,952 | 110 | 68,306 | 2,849 | 1,096 | 383,617 | 142,500 | 2,793 | 2,422 | 193,905 | 1,096 |
| | Acenaphthylene | mg/kg | 3,506 | 19 | 7 | 38,362 | 24,321 | 91 | 78 | 96,952 | 7 | 43,766 | 186 | 74 | 383,617 | 54,132 | 183 | 156 | 193,905 | 74 |
| | Anthracene | mg/kg | 3,405 | 170 | 68 | 38,362 | 178,811 | 4,784 | 4,213 | 554,013 | 68 | 43,405 | 1,716 | 678 | 383,617 | -- | -- | -- | -- | 678 |
| | Benzo(a)pyrene | mg/kg | 47 | 6 | 2.4 | 767 | 60 | 8.1 | 7.6 | 554 | 2.4 | -- | -- | -- | -- | 635 | 81 | 76 | 5,540 | 76 |
| | Benzo(a)anthracene | mg/kg | 118 | 5.2 | 2.0 | 767 | 307 | 7.3 | 6.4 | 554 | 2.0 | -- | -- | -- | -- | 3,636 | 73 | 64 | 5,540 | 64 |
| | Benzo(b)fluoranthene | mg/kg | 22 | 3.0 | 1.3 | 767 | 25 | 4.1 | 3.9 | 554 | 1.3 | -- | -- | -- | -- | 247 | 41 | 39 | 5,540 | 39 |
| | Benzo(ghi)perylene | mg/kg | 12 | 2.6 | 1.1 | 767 | 13 | 3.5 | 3.5 | 554 | 1.1 | -- | -- | -- | -- | 89 | 32 | 35 | 5,540 | 32 |
| | Benzo[k]fluoranthene | mg/kg | 136 | 3.2 | 1.3 | 767 | 406 | 4.6 | 3.9 | 554 | 1.3 | -- | -- | -- | -- | 4,069 | 46 | 39 | 5,540 | 39 |
| | Chrysene | mg/kg | 118 | 3.6 | 1.4 | 767 | 307 | 5.1 | 4.5 | 554 | 1.4 | -- | -- | -- | -- | 3,636 | 51 | 45 | 5,540 | 45 |
| | Dibenz(ah)anthracene | mg/kg | 44 | 3.5 | 1.4 | 767 | 54 | 4.9 | 4.4 | 554 | 1.4 | -- | -- | -- | -- | 543 | 49 | 44 | 5,540 | 44 |
| | Fluoranthene | mg/kg | 15 | 2.5 | 1.1 | 767 | 1,957 | 421 | 420 | 69,252 | 1.1 | -- | -- | -- | -- | 3,915 | 841 | 839 | 138,503 | 839 |
| | Fluorene | mg/kg | 6,831 | 45 | 17.5 | 38,362 | 50,893 | 157 | 134 | 69,252 | 17.5 | 68,306 | 446 | 175 | 383,617 | 101,786 | 313 | 267 | 138,503 | 175 |
| | Indeno[1,2,3-cd]pyrene | mg/kg | 49 | 2.9 | 1.2 | 767 | 63 | 3.6 | 3.6 | 554 | 1.2 | -- | -- | -- | -- | 626 | 40 | 36 | 5,540 | 36 |
| | 2-Methylnaphthalene | mg/kg | 5 | 5.7 | 155 | 38,362 | 5 | 5.5 | 500 | 27,867 | 5.0 | 8 | 9 | 1,547 | 383,617 | 6 | 7 | 1,132 | 63,047 | 6 |
| | Naphthalene | mg/kg | 34 | 37 | 416 | 38,362 | 33 | 36 | 116 | 27,701 | 33 | 340 | 369 | 378 | 383,617 | 100 | 109 | 348 | 83,102 | 100 |
| | Phenanthrene | mg/kg | 4,329 | 236 | 94 | 38,362 | 301,134 | 6,731 | 5,919 | 554,013 | 94 | 56,061 | 2,406 | 943 | 383,617 | -- | -- | -- | -- | 943 |
| | Pyrene | mg/kg | 11 | 3.9 | 1.9 | 767 | 825 | 360 | 436 | 41,551 | 1.9 | -- | -- | -- | -- | 1,375 | 600 | 727 | 69,252 | 600 |
| | Total PAHs | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

Table 7-3. Wildlife (Birds and Mammals) Soil Screening Levels for Nonradionuclides

| Group | Soil Constituent | Units | NOAEL-Based Site-Specific SSLs | | | | | | | | | LOAEL-Based Site-Specific SSLs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | NOAEL Lowest | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | LOAEL Lowest |
| | Low molecular weight PAHs | mg/kg | 6,592 | 12,623 | 2,316 | 38,362 | 25,369 | 19,170 | 74,597 | 36,343 | 2,316 | 67,600 | 128,679 | 23,165 | 383,617 | 130,652 | 97,560 | 372,987 | 181,716 | 23,165 |
| | High molecular weight PAHs | mg/kg | 40 | 72 | 46 | 767 | 29 | 39 | 699 | 341 | 29 | -- | -- | -- | -- | 157 | 209 | 3,491 | 1,701 | 157 |
| Petroleum | Gasoline range organics | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Petroleum | TPH-diesel | mg/kg | 105,086 | 199,535 | 35,638 | 590,179 | 407,144 | 301,205 | >1,000,000 | 554,013 | 35,638 | >1,000,000 | >1,000,000 | 356,382 | >1,000,000 | 610,716 | 451,807 | >1,000,000 | 831,020 | 356,382 |
| Petroleum | TPH-kerosene | mg/kg | 105,086 | 199,535 | 35,638 | 590,179 | 407,144 | 301,205 | >1,000,000 | 554,013 | 35,638 | >1,000,000 | >1,000,000 | 356,382 | >1,000,000 | 610,716 | 451,807 | >1,000,000 | 831,020 | 356,382 |
| Semivolatile Organics | Normal paraffin hydrocarbons | mg/kg | 170,870 | 324,445 | 57,948 | 959,632 | 407,144 | 301,205 | >1,000,000 | 554,013 | 57,948 | -- | -- | -- | -- | 610,716 | 451,807 | >1,000,000 | 831,020 | 451,807 |
| Semivolatile Organics | Phenol | mg/kg | -- | -- | -- | -- | 4,886 | 526.1 | 503.7 | 5,919 | 503.7 | -- | -- | -- | -- | 14,657 | 1,578 | 1,511 | 17,756 | 1,511 |
| Semivolatile Organics | 2-Methylphenol (o-cresol) | mg/kg | -- | -- | -- | -- | 127,436 | 10,038 | 9,293 | 134,503 | 9,293 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Semivolatile Organics | 4-Methylphenol (p-cresol) | mg/kg | -- | -- | -- | -- | 127,436 | 10,102 | 9,358 | 136,361 | 9358 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Semivolatile Organics | 2,4-Dinitrotoluene | mg/kg | 0 | 0.3 | 0.2 | 7 | 14 | 13.5 | 35.6 | 286 | 0.2 | 38 | 39 | 26 | 932 | 29 | 28 | 74 | 597 | 26 |
| Semivolatile Organics | Bis[2-ethylhexyl] phthalate[a] | mg/kg | 111 | 0.4 | 0.1 | 263 | 1,733 | 5 | 5 | 3,599 | 0.1 | -- | -- | -- | -- | 17,332 | 54 | 45 | 35,994 | 45 |
| Semivolatile Organics | Polychlorinated biphenyls (PCB)[b] | mg/kg | 10 | 0.65 | 0.33 | 25 | 3 | 0.3 | 0.27 | 8 | 0.27 | 100 | 4 | 2 | 251 | 29 | 2 | 1 | 85 | 1 |
| Semivolatile Organics | Aroclor-1016[b] | mg/kg | 6.4 | 0.64 | 0.33 | 22 | 35 | 2.8 | 2.5 | 150 | 0.33 | 64 | 4 | 2 | 218 | 88 | 5 | 5 | 377 | 2 |
| Semivolatile Organics | Aroclor-1221[b] | mg/kg | 2.7 | 0.61 | 0.33 | 24 | 0.7 | 0.25 | 0.27 | 8.2 | 0.25 | 27 | 3 | 2 | 240 | 7 | 1 | 1 | 82 | 1 |
| Semivolatile Organics | Aroclor-1232[b] | mg/kg | 2.2 | 0.59 | 0.33 | 26 | 0.55 | 0.24 | 0.27 | 8.8 | 0.24 | 22 | 3 | 2 | 262 | 5 | 1 | 1 | 88 | 1 |
| Semivolatile Organics | Aroclor-1242[b] | mg/kg | 10.4 | 0.65 | 0.33 | 26 | 3.1 | 0.3 | 0.27 | 8.7 | 0.27 | 104 | 4 | 2 | 256 | 31 | 2 | 1 | 87 | 1 |
| Semivolatile Organics | Aroclor-1248[b] | mg/kg | 9.4 | 0.65 | 0.33 | 24 | 0.35 | 0.06 | 0.06 | 1.1 | 0.06 | 94 | 4 | 2 | 243 | 3 | 0 | 0 | 11 | 0 |
| Semivolatile Organics | Aroclor-1254 | mg/kg | 11.5 | 0.65 | 0.33 | 27 | 3.5 | 0.3 | 0.27 | 9 | 0.27 | 115 | 4 | 2 | 273 | 35 | 2 | 1 | 91 | 1 |
| Semivolatile Organics | Aroclor-1260[b] | mg/kg | 20 | 0.66 | 033 | 51 | 7.7 | 0.3 | 0.27 | 15 | 0.27 | 204 | 4 | 2 | 515 | 77 | 2 | 1 | 154 | 1 |
| Semivolatile Organics | Aroclor-1262[b] | mg/kg | 38 | 72 | 13 | 212 | 27.7 | 20.5 | 77 | 38 | 13 | 378 | 718 | 128 | 2,125 | 277 | 205 | 773 | 377 | 128 |
| Pesticide | Aldrin | mg/kg | 0.45 | 0.08 | 0.03 | 1.1 | 10.2 | 2.0 | 2.0 | 27 | 0.03 | 2.2 | 0.4 | 0.2 | 5.3 | 51 | 10 | 10 | 134 | 0.2 |
| Pesticide | beta-1,2,3,4,5,6-Hexachlorocyclohexane | mg/kg | 4 | 4 | 2.7 | 112 | 1.9 | 1.7 | 4 | 67 | 1.7 | 6.2 | 5.5 | 4.1 | 168 | 9.4 | 8.7 | 20 | 335 | 4.1 |
| Pesticide | alpha-Chlordane | mg/kg | 122 | 24 | 10 | 302 | 93 | 21 | 21 | 264 | 10 | 608 | 121 | 50 | 1,508 | 925 | 205 | 207 | 2,641 | 50 |
| Pesticide | gamma-Chlordane | mg/kg | 122 | 24 | 10 | 302 | 93 | 20 | 21 | 264 | 10 | 608 | 121 | 50 | 1,508 | 925 | 204 | 206 | 2,641 | 50 |
| Pesticide | Dichlorodiphenyl-dichloroethane (DDD)[c] | mg/kg | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

Table 7-3. Wildlife (Birds and Mammals) Soil Screening Levels for Nonradionuclides

| Group | Soil Constituent | Units | NOAEL-Based Site-Specific SSLs | | | | | | | | | LOAEL-Based Site-Specific SSLs | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | NOAEL Lowest | California Quail | Meadow-lark | Killdeer | Red-tailed Hawk | Great Basin Pocket Mouse | Deer Mouse | Grass-hopper Mouse | Badger | LOAEL Lowest |
| | Dichlorodiphenyl-dichloroethylene (DDE)[c] | mg/kg | 30.4 | 0.21 | 0.07 | 0.06 | 20.5 | 0.11 | 0.09 | 0.03 | 0.03 | 300 | 2.3 | 0.8 | 1.7 | 136 | 0.7 | 0.6 | 0.4 | 0.4 |
| | Dichlorodiphenyl-trichloroethane | mg/kg | 30.4 | 0.3 | 0.10 | 2.5 | 20.5 | 0.16 | 0.14 | 1.4 | 0.10 | 300 | 3.5 | 1.2 | 46 | 136 | 1.0 | 0.9 | 12.7 | 0.9 |
| | Dieldrin | mg/kg | 1.9 | 0.06 | 0.02 | 1.6 | 0.28 | 0.01 | 0.01 | 0.35 | 0.01 | 6 | 0.2 | 0.08 | 5.2 | 0.57 | 0.02 | 0.02 | 0.69 | 0.02 |
| | Endosulfan I | mg/kg | 93.4 | 66.3 | 41.4 | 1,671 | 0.92 | 0.71 | 1.29 | 21.9 | 0.71 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Endosulfan II | mg/kg | 93.4 | 66.3 | 41.4 | 1,671 | 0.92 | 0.71 | 1.29 | 21.9 | 0.71 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Endosulfan sulfate | mg/kg | 62.9 | 55.4 | 41.4 | 2,160 | 0.61 | 0.56 | 1.29 | 27.2 | 0.56 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| | Endrin aldehyde | mg/kg | 2.6 | 0.52 | 0.23 | 52.9 | 0.51 | 0.14 | 0.14 | 14.0 | 0.14 | -- | -- | -- | -- | 5 | 1.4 | 1.4 | 140 | 1.4 |
| | Methoxychlor | mg/kg | -- | -- | -- | -- | 59.8 | 11.2 | 10.9 | 441 | 10.9 | -- | -- | -- | -- | 120 | 22.4 | 21.8 | 882 | 21.8 |

a. Values for diethyl phthalate and di-n-butyl phthalate were used as a surrogate for bis(2)ethylhexyl phthalate

b. Aroclor-1254 value was used as surrogate.

LOAEL = lowest observed adverse effect level

NOAEL = no observed adverse effect level

1

Table 7-4. Preliminary Remediation Goals for Wildlife (Birds and Mammals)

| Analyte Group | Analyte | Units | California Quail | Western Meadowlark | Killdeer | Red-Tailed Hawk | Lowest Avian PRG | Great Basin Pocket Mouse | Deer Mouse | Grasshopper Mouse | Badger | Lowest Mammal PRG | Lowest Wildlife PRG |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Metal | Silver | mg/kg | 4,238 | 3,973 | **983** | 20,186 | 983 | 24,465 | 9,806 | 14,362 | 30,778 | 9,806 | 983 |
| Metal | Aluminum | mg/kg | 19,217 | 31,220 | 7,214 | 74,599 | 7,214 | 4,883 | **3,988** | 13,059 | 7,811 | 3,988 | 3,988 |
| Metal | Arsenic | mg/kg | 4,776 | 7,403 | 2,284 | 40,102 | 2,284 | 201 | **127** | 302 | 847 | 127 | 127 |
| Metal | Boron | mg/kg | **54** | 68 | 91 | 2,714 | 54 | **32** | 39 | 170 | 2,516 | 32 | 32 |
| Metal | Barium | mg/kg | 1,721 | 2,335 | **1,687** | 8,101 | 1,687 | 2,265 | 2,617 | 11,873 | 12,430 | 2,265 | 1,687 |
| Metal | Beryllium | mg/kg | NTD | NTD | NTD | NTD | NTD | **14** | 20 | 181 | 289 | 14 | 14 |
| Metal | Cadmium | mg/kg | 294 | 103 | **29** | 1,711 | 29 | 2,203 | 624 | 858 | 4,704 | 624 | 29 |
| Metal | Cobalt | mg/kg | 1,397 | 2,050 | **484** | 4,798 | 484 | 2,901 | 2,136 | 5,610 | 4,234 | 2,136 | 484 |
| Metal | Chromium | mg/kg | 193 | 221 | **109** | 610 | 109 | 544 | 517 | 1,424 | 1,765 | 517 | 109 |
| Metal | Copper | mg/kg | 423 | 461 | 213 | 12,881 | 213 | 233 | **193** | 1,217 | 4,631 | 193 | 193 |
| Metal | Mercury | mg/kg | 36 | 4.7 | 2 | 92 | 2 | 7.9 | **1.6** | 1.8 | 33 | 1.6 | 1.6 |
| Metal | Lithium | mg/kg | -- | -- | -- | -- | -- | **1,664** | 1,797 | 8,347 | 6,522 | 1,664 | 1,664 |
| Metal | Manganese | mg/kg | 20,746 | 26,026 | 14,407 | 150,899 | 14,407 | **3,322** | 3,467 | 11,780 | 21,916 | 3,322 | 3,322 |
| Metal | Molybdenum | mg/kg | 125 | 117 | 95 | 515 | 95 | 5.9 | **5.7** | 14 | 38 | 5.7 | 5.7 |
| Metal | Nickel | mg/kg | 2,051 | 1,127 | 361 | 11,625 | 361 | 711 | **247** | 342 | 1,520 | 247 | 247 |
| Metal | Lead | mg/kg | 559 | 664 | **156** | 2,300 | 156 | 2,672 | 1,578 | 3,807 | 3,966 | 1,578 | 156 |
| Metal | Antimony | mg/kg | NTD | NTD | NTD | NTD | NTD | 97 | **92** | 366 | 325 | 92 | 92 |
| Metal | Selenium | mg/kg | 10 | 4.9 | 2.4 | 24 | 2 | 2.7 | **1.4** | 1.9 | 8.8 | 1.4 | 1.4 |
| Metal | Strontium (elemental) | mg/kg | -- | -- | -- | -- | -- | **1,214** | 1,449 | 6,540 | 8,256 | 1,214 | 1,214 |
| Metal | Thallium | mg/kg | -- | -- | -- | -- | -- | 8.7 | **6.2** | 12 | 25 | 6.2 | 6.2 |
| Metal | Uranium (calculated total) | mg/kg | 2,002 | 339 | 139 | 82 | 82 | 812 | 123 | 119 | **40** | 40 | 40 |
| Metal | Vanadium | mg/kg | 81 | 107 | **43** | 505 | 43 | 260 | 297 | 4,531 | 3,596 | 260 | 43 |
| Metal | Zinc | mg/kg | 6,289 | 4,662 | **856** | 906 | 856 | 6,711 | 3,331 | 12,666 | 1,037 | 1,037 | 856 |

Notes: **Bold values** represent lowest PRG for that analyte.
Shaded values are based on NOAELs because of the lack of LOAELs.
LOAEL = lowest observed adverse effect level
NTD = no toxicity data (for selected analyte)
NOAEL = no observed adverse effect level
PRG = preliminary remediation goal

The BCGs for terrestrial plants and animals represent SSLs for radionuclides in soil for assessing ecological risks at the 100-F/IU OU waste sites (Tables 7-1). The BCGs for radionuclides use conservative assumptions for internal and external exposure. While existing effects data support the application of these dose limits to representative individuals within populations of plants and animals, the assumptions and parameters applied in the derivation of the BCGs are based on a maximally exposed individual, representing a conservative approach for screening purposes. The following assumptions are used for estimating doses from external exposure for purposes of developing BCGs:

- The source medium is infinite in extent and contains uniform concentrations of radionuclides (i.e., there are no "hot spots").
- One hundred percent of the radionuclide energies are absorbed (despite the small size of some of the receptors).
- Organisms exposed to soil are uniformly surrounded by the source medium.

The following assumptions are used in estimating doses from internal exposure for purposes of developing BCGs:

- All radionuclide decay energies are retained in tissue (100 percent of energies absorbed).
- Exposure for a given radionuclide includes all decay chain progeny.
- All radionuclides are uniformly distributed such that all target tissues may be affected.

### 7.3.3 Drinking Water Exposure

The estimates of exposure from drinking water ingestion by wildlife include the use of a simplified model whereby the rate of ingestion is standardized to the body weight of the receptor on a per kilogram basis. The simplified allometric scaling equations presented in "Scaling of Osmotic Regulation in Mammals and Birds" (Calder and Braun, 1983) were used to estimate water ingestion as the number of liters consumed per kilogram body weight per day. These rates of ingestion were then multiplied by the concentration of COPECs to calculate the total dose from the drinking water pathway as shown below:

$$\text{Dose} = [\text{Water X DWIR}] \text{ X AUF}$$

where:

Dose = drinking water exposure (mg/kg body weight/day)

Water = chemical concentration in seep water (mg/L)

DWIR = drinking water ingestion rate (L/kg body weight/day)

AUF = area use factor (area of site/home range of receptor) (unitless)

Drinking water ingestion was estimated for several species of birds and mammals expected to occur in the 100-F/IU riparian area along the Columbia River. This estimate was with the initial assumption that they reside at the site and fulfill their drinking water requirements exclusively from the seeps, but only for 9 months of the year because the river stage is elevated from mid-April through mid-July, making the seeps inaccessible. Therefore, an AUF of 0.75 was used for all species except bats. For bats, an AUF of 0.5 was used since bats use a combination of hibernating and seeking alternative sources of emergent insects during the winter months (*Living with Wildlife: Bats* [WDFW, 2004]).

Estimates are not included for small mammals because they maintain water balance through excreting concentrated urine, obtaining water from food and water generated during metabolism ("Perognathus parvus" [Verts and Kirkland, 1988]). Estimating drinking water exposure can be complicated because the

presence of seeps and observed concentrations depend on river stage and, for several species of birds, migration patterns are also a factor. Assuming that wildlife meet their daily drinking water requirements from the seeps, instead of a more available source (e.g., the river), is a conservative approach meant to evaluate a worst-case scenario. Therefore, though it represents an overestimate, the 95 percent UCL of the arithmetic mean concentration of the analyzed constituent was used as the EPC for simplicity. While filtered water data are used in evaluations of the effects on aquatic receptors because those concentrations are bioavailable, unfiltered concentrations are more appropriate for drinking water, as bioavailability may change within the digestive tract. Both were included to be comprehensive, as in rare cases filtered measurements can be higher than unfiltered. Results were not pooled to not bias any one sampling event at which both measurements occurred.

### 7.3.4 Primary Remediation Goals

The PRGs presented in this chapter represent Hanford Site-specific values as presented in *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311). Much of the modeling used to develop PRGs for wildlife is presented in this chapter because the PRGs build on the SSLs (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]), using the same receptors, exposure models, life history parameters, and TRVs. The only deviations from the SSL development were the use of bioaccumulation models that included exclusively arthropods as the invertebrate portion of receptors' diets[9] and integration of Hanford Site-specific data. The SSLs included prey tissue estimation models that were generic and included a wide variety of species, only some of which are likely to occur within the semiarid environment at the Hanford Site. Most invertebrate data included in the food web models for SSL development for invertivores and omnivores relied on bioaccumulation data from earthworms and other soil invertebrates. Soil invertebrates such as earthworms are rarely encountered in the semiarid upland soil found at Hanford. Thus, modeling for PRG development (*Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-01311]) incorporated additional Hanford Site-specific tissue data, data from other closely related ecosystems, as well as more recent data specific to insects found at the Hanford Site that had not been available when either the MTCA guidance ("Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]) or EPA EcoSSLs were developed.

The development of PRGs corresponds to an exposure and effects assessment, conducted as part of a baseline ERA within ERAGS (EPA 540-R-97-006), and reflects *Issuance of Final Guidance: Ecological Risk Assessment and Management Principles for Superfund Sites* (OSWER Directive 9385.7-28 P), which encourages the use of site-specific ecological risk data to support cleanup decisions whenever practicable. The process for developing of PRGs is also consistent with MTCA ("Site-specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]). None of the differences were recalculations of the original datasets and models used to derive the WAC values. Rather, all of the changes from WAC 173-340, Table 749-3 are based on updated exposure models (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55]) and toxicological literature reviews that were not available at the time MTCA (WAC 173-340), Table 749-3 was developed. These PRGs are intended to be applied to all upland environments across the Hanford Site. Though additional receptors may also be present in riparian areas, the wildlife PRGs, the supporting bioaccumulation and exposure models, and TRVs are applicable for riparian areas and can be used in conjunction with values for those additional receptors.

[9] Further detail on the estimation of invertebrate tissue concentrations is found in Section 7.3.2.2.

Hanford Site-specific wildlife PRGs are presented in Table 7-4. Hanford Site-specific PRGs were researched for inorganic and organic constituents, but not radionuclides. Ultimately, Hanford Site-specific PRGs were only recommended for inorganics, as Hanford Site-specific data were limited for organics.[10] Confidence in these PRGs as a whole is greater than for the SSLs, as they were developed specifically for use at the Hanford Site using site-specific data. Relative to each other, confidence in some PRGs is greater than in others. The additional confidence is due to a combination of the total number of Hanford Site-specific paired soil and tissue samples and the strength of the relationship between tissue and soil concentration (correlation). Details regarding the confidence in specific PRGs were included in the SMDP in Section 7.6 as needed.

PRGs for inorganic chemicals protective of plants and invertebrates are presented in Table 7-5. When Hanford Site-specific toxicological data on the effects of plants and soil invertebrates were available, these data were considered for PRG selection. These data are summarized in the following three documents:

- *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158), found in Appendix H of the 100-K RI/FS
- RCBRA (DOE/RL-2007-21)
- *Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Ecology* (Ecology Publication 11-03-006)

All of the site-specific toxicological thresholds presented in these documents are NOECs. Thus, for each chemical studied in one or more of these documents, the greatest NOEC among these documents was selected as the PRG for that chemical. When Hanford Site-specific thresholds for plants and invertebrates were not presented in these three documents, the EcoSSL was selected as the PRG because it included more recent information than what was available when MTCA (WAC 173-340), Table 749-3 was developed. When an EcoSSL was not available, the value from MTCA (WAC 173-340) was selected. The two exceptions were as follows:

- The Hanford Site-specific background value for cobalt was selected as the PRG for both plants and invertebrates. There is no *Washington Administrative Code* or EcoSSL value for invertebrates. The background value of 15.7 mg/kg is greater than the plant EcoSSL of 13 mg/kg. While the *Washington Administrative Code* plant value of 20 mg/kg is greater than the background value, it is based upon the value from ORNL, and the original authors gave the value low confidence. Site-specific plant and invertebrate NOEC values of 11.2 mg/kg and 12.2 mg/kg were also available from the RCBRA (DOE/RL-2007-21), but these values were the highest concentration tested and were lower than background.
- The cadmium value for invertebrates of 20 mg/kg from the *Washington Administrative Code* was selected as the PRG over the EcoSSL of 140 mg/kg. The *Washington Administrative Code* value was based upon an ORNL recommendation, where the authors gave a moderate to high confidence in the recommendation. This was considered of equal weight with the EcoSSLs, so the lower of values of equal confidence was selected.

[10] Within this chapter, if a second tier effect threshold (e.g., PRG) was not available or recommended, chemical waste site combinations were retained for further evaluation in the SMDP (Section 7.6) if the EPC exceeded the SSL.

The final recommended PRG represented the most appropriate value, leaning toward the most recent data available that met the criteria set forth in ERAGS (EPA 540-R-97-006) and MTCA ("Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]) guidelines for selecting site-specific criteria. In the selection of values that differ from MTCA (WAC 173-340), Table 749-3, when multiple recent toxicological data sources were available, the value of the highest confidence or the lower of two values with equally high confidence was chosen. The site-specific values are preferred over those from published literature because they are more recent data that were not available at the time MTCA (WAC 173-340) guidance or EcoSSLs were developed. They reflect the potential for toxicity under conditions found specifically at the Site. However, with some COPECs, more recent site-specific sampling efforts were unable to obtain concentration ranges above those from published literature. With all of the site-specific studies conducted for the RCBRA (DOE/RL-2007-21), by Ecology, and recently by CHPRC, no clear significant toxicity to plants and invertebrates attributable to site soil contaminants was observed; thus, recommended toxicological values are unbound NOECs. Hence, in some cases, published literature values above these unbound NOECs were selected as PRGs over site-specific values. Final selection of PRGS for plants and invertebrates is discussed in detail in *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158). As with the wildlife PRGs, details regarding the confidence in specific PRGs were included in the SMDP in Section 7.6 as needed.

Table 7-5. Final Recommended Soil PRGs for Plants and Invertebrates

| Chemical | Plant NOEC (mg/kg) | Invertebrate NOEC (mg/kg) |
|---|---|---|
| Antimony | 842 | 842 |
| Arsenic | 128 | 128 |
| Barium | 500 | 358 |
| Beryllium | 10 | 40 |
| Boron | 29.6 | 28.6 |
| Cadmium | 9.84 | 20 |
| Chromium | 259 | 149 |
| Cobalt | 15.7 | 15.7 |
| Copper | 70 | 58 |
| Lead | 9,090 | 1,700 |
| Manganese | 1,260 | 1,260 |
| Mercury | 0.3 | 12.5 |
| Molybdenum | 2 | 28 |
| Nickel | 38 | 280 |
| Selenium | 2.02 | 4.1 |
| Silver | 560 | 2.99 |
| Thallium | 1 | 0.459 |
| Tin | 838 | 838 |

Table 7-5. Final Recommended Soil PRGs for Plants and Invertebrates

| Chemical | Plant NOEC (mg/kg) | Invertebrate NOEC (mg/kg) |
|---|---|---|
| Uranium | 250 | 100 |
| Vanadium | 89.4 | 116 |
| Zinc | 621 | 8,980 |

### 7.3.5 Estimation of EPCs in Waste Sites

As mentioned earlier, assuming that wildlife forage exclusively within the boundaries of a waste site or that the data collected from within a waste site represents the central tendency of exposure to wildlife is a highly conservative assumption. In reality, the concentration of contaminants to which a wildlife population is exposed includes points both within and outside of the waste site being investigated unless there are physical barriers preventing exposure. Thus, a true exposure estimate would include data points both within and outside of the site boundary, and in some investigations for other sites, the points outside have been generated by either measured data or have been assumed to be at background. However, methods for this type of estimate of exposure are not defined in guidance and are not commonplace. What is common in ERA practice, and what was done for this ERA, is to initially characterize risks assuming an area use factor of 1 (all exposure is within the site) and then refining that assumption, should the highly conservative exposure estimate and risk characterization suggest an unacceptable risk warranting further evaluation. Hence, this section describes the method that EPCs were derived within the waste sites that assumed an AUF of 1. The SMDP in Section 7.6 describes in detail how AUFs should be used for evaluating waste sites.

A total of 92, 25, and 21 remediated waste sites in the 100-F, 100-IU-2, and 100-IU-6 OUs, respectively, were verification sampled and included in this ERA. Chapter 6 details the computation of the EPCs for the waste sites at the 100-F/IU OU. Briefly, the 95 percent UCL of the arithmetic mean was calculated as the EPC for each decision unit (shallow, shallow focused, staging pile area, staging pile area footprint, staging pile area focused, staging pile footprint focused, overburden, and overburden focused) within each waste site. Two separate statistical evaluations were performed: one used for the closeout documentation, and one used for human health and ERAs, as follows:

- **Statistical evaluation used for closeout documentation:** For the closeout documentation, the primary statistical calculation to support cleanup verification was the 95 percent UCL on the arithmetic mean of the data. As in *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54), a 95 percent UCL on the mean based on the Student's t-test statistic was used for normally distributed data, and the Land method using the H-statistic was used for lognormal data. This guidance also employs the use of proxy values of one-half the detection limits for nondetect values. For small datasets (*n* less than10), typically the maximum detected concentration was used as the EPC.

- **Statistical evaluation used for soil risk evaluation:** Both *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10), which is the most recent EPA guidance for UCL calculation, and "Statistical Software ProUCL 4.1.00 for Environmental Applications for Data Sets with and without Nondetect Observations" [ProUCL Software, 2011]) were used to recalculate EPCs for the HHRA and ERA of the 100-F/IU waste site decision units. Although *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54)

has been used to calculate EPCs for all closeout documentation to date, EPCs were recalculated according to *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites* (OSWER 9285.6-10) to allow for the use of more rigorous statistical methods to estimate exposure concentration. In addition, this guidance eliminates the use of the one-half the detection limit used in *Statistical Guidance for Ecology Site Managers* (Ecology Publication 92-54), which has the potential to underestimate exposure concentrations.

The process used to calculate EPCs for each waste site and decision unit is documented in *Computation of Exposure Point Concentrations for the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Source Operable Units* (ECF-100FR1-11-0020) is to document the data processing and reduction steps, methodology, decision logic, assumptions, input files, and output files used to determine the EPCs. EPCs generated for use in this evaluation for each waste site, decision unit, and detected analyte at the 100-F/IU OUs are provided in Appendix H, Tables H-6, H-7, and H-8.

For the drinking water evaluation included in Section 7.4.4, limited data are available; therefore estimating exposure can be complicated, as the presence of seeps and observed concentrations are dependent on river stage. For several species of birds, migration patterns are also a factor. EPCs of the seep concentrations in the 100-F/IU OUs were used for simplicity, calculated using ProUCL software in the same way as were soil EPCs.

## 7.4 Risk Characterization

The outcome of this step is a list of COPECs for each medium-pathway-receptor combination evaluated. Risks at the 100-F/IU OUs waste sites were estimated using the HQ method as follows:

$$HQ = EPC/SSL \text{ or } PRG$$

where:

HQ = ecological hazard quotient (unitless)

EPC = soil concentration (µg/kg for nonradionuclides and pCi/g for radionuclides)

SSL = plant/invertebrate or wildlife soil screening level (µg/kg for nonradionuclides and pCi/g for radionuclides)

PRG = plant/invertebrate or wildlife preliminary remediation goal (µg/kg for nonradionuclides)

HQ values less than 1.0 indicate that adverse effects associated with exposure to a given analyte are unlikely (ERAGS [EPA 540-R-97-006]). These analytes were not considered to present a significant risk and were excluded from further evaluation. An HQ greater than or equal to 1.0 indicates that data are insufficient to exclude the potential for risk, but does not indicate that risks are actually present; therefore, these COPCs were carried forward for further evaluation.

In the screening evaluation, the soil EPC for each waste site and decision unit (as applicable) was compared to the plant/invertebrate SSL and the wildlife SSL for all COPCs, including metals, pesticides, PCBs (as Aroclors), and PAHs. The HQs for these comparisons are provided in Appendix H, Tables H-6, H-7, and H-8. COPCs with HQs equal to or greater than 1.0 were carried forward for further evaluation. COPCs for which appropriate toxicity data were unavailable were not evaluated further but were retained as uncertainties.

The plant/invertebrate and/or wildlife SSL values for 10 COPCs (arsenic, boron, lithium, mercury, manganese, molybdenum, selenium, strontium, thallium, and uranium) were higher than the corresponding PRG values. Since the PRG values are considered more site-relevant, SSLs for these

10 chemicals cannot be used exclusively as a screening tool without understanding whether concentrations are also below PRGs. EPCs for these chemicals were compared to both SSLs and PRGs to confirm that the EPCs were below both the SSL and PRG. Only if the EPC was below both values was the chemical dismissed from further consideration. For these 10 chemicals, if an EPC was greater than either the SSL or the PRG, the chemical was carried into the background evaluation for that specific waste site decision unit, the next phase in the risk characterization.

### 7.4.1 Risk Characterization for Radionuclides and Aroclors

Because the dose from radionuclides and Aroclors are additive, the total contributions of radionuclides and Aroclors were calculated using sum of fractions (SOF) and hazard index (HI), respectively. With the SOF and HI methods, contributions were considered significant if the EPC was greater than the SSL. The SOF method and HI equation is as follows:

$$\text{HI or SOF} = \sum_{j=1}^{n} \text{Exposure}_j / \text{SSL}_j$$

where:

- HI = hazard index
- SOF = sum-of-fractions
- $\text{Exposure}_j$ = exposure concentration for radionuclides
- $\text{SSL}_j$ = soil screening level for radionuclides

For the purposes of this evaluation, the HQs for each radionuclide were summed within each decision unit to equal an SOF. If the SOF was greater than 1, then individual detected radionuclide isotope COPCs were carried forward to the background evaluation. For those COPCs that exceeded one or more SSLs, the EPC was then compared to the background value and summarized in the subsequent table (Appendix H, Table H-6 in Section 7.4.2.

Similarly, for Aroclors, HIs were calculated to evaluate additive effects. If the HI for Aroclors was greater than 1, then the detected Aroclors were identified for further evaluation. This approach is conservative because the measurement of Aroclors as mixtures of PCB congeners does produce some overlap of congeners in multiple Aroclor mixtures. However, a total Aroclor HI is not an uncommon practice. While potential duplication could occur depending on which mixtures are detected, at most sites only one or two Aroclor mixtures are detected and tend to dominate. Also, by carrying the HI greater than 1 forward when a conclusion of no risk or no unacceptable risk is reached, there is less uncertainty with the conclusion because of the additional conservatism in the approach.

### 7.4.2 Characterization Relative to Background

Background concentrations for inorganic analytes in soil at the Hanford Site are described in the Non-Rad Soil Background document (DOE/RL-92-24). That document provides the 90$^{th}$ percentile background concentrations for several inorganic analytes. For selected inorganic analytes not included in the Non-Rad Soil Background document (DOE/RL-92-24), the 90$^{th}$ percentile concentration has been obtained from PNNL, as summarized in *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038), and from the 100 Area RDR/RAWP (DOE/RL-96-17) for uranium. Background concentrations for radiological analytes in soil at the Hanford Site are described in Rad Soil Background document (DOE/RL-96-12), which provides the 90$^{th}$ percentile concentration of background concentrations for several radiological analytes. Background concentrations were not identified for organic chemicals; therefore, all organic chemicals, with HQs greater than or equal to 1.0 were carried

forward. COPC EPCs that were less than the 90$^{th}$ percentile background concentration were excluded from further evaluation. COPCs with EPCs that were not within the range of site background were carried forward for comparison to the PRGs.

### 7.4.3 Further (Refined) Characterization Relative to PRGs

In the PRG evaluation, the soil EPC for each waste site and decision unit (as applicable) was compared to the plant/invertebrate PRG and the wildlife PRG for all remaining COPCs. COPCs with HQs equal to or greater than 1.0 were retained as COPECs. COPECs were then given further consideration under the SMDP. The methodology used in this step of the risk characterization is provided in Appendix H (*Ecological Risk Evaluation for the 100-FR-1, 100-FR-2, and 100-IU-6 Source Operable Units* [ECF-100FR1-11-0022]). For any chemical-waste site EPC that exceeded both the SSL and background, if no PRG is presented in Table 7-4 or 7-5, then the chemical-waste site combination was automatically retained for additional evaluation in the SMDP presented in Section 7.6.

### 7.4.4 Characterization of Risk through Ingestion of Drinking Water

Freshwater seep drinking ingestion HQs for inorganic chemicals were estimated as the ratio of estimated ingestion doses to TRVs. The TRVs used were the same as those used to develop the wildlife PRGs used to evaluate soil as presented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311).

$$HQ = Dose/TRV$$

where:

HQ = ecological hazard quotient (unitless)

Dose = drinking water exposure (mg/kg body weight/day)

TRV = toxicological reference value (mg/kg-body weight-day)

For radionuclides, the HQs for evaluating freshwater seep drinking water ingestion were simply a ratio of the measured concentrations in water multiplied by the AUF to the BCGs for wildlife. The lowest water BCG of terrestrial or riparian animal receptors were taken from Graded Approach for Radiation Doses to Biota (DOE-STD-1153-2002) or were calculated using the RESRAD BIOTA tool (*RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User's Guide, Version 1* [DOE/EH-0676]) when not available. SOFs were calculated as described above. In addition, as with the soil evaluation, the EPC represents the 95 percent UCL of the arithmetic mean concentration of the analyzed constituent.

$$HQ = (EPC*AUF)/BCG$$

where:

HQ = ecological hazard quotient (unitless)
EPC = radionuclide concentration in seep (pCi/L)
AUF = area use factor
BCG = biota concentration guides (pCi/L)

### 7.4.5 Screening Evaluation Results

The comparisons to plant/invertebrate and wildlife SSLs are provided in Appendix H, Tables H-6 through H-8 for 100-F, 100-F/IU-2, and 100-F/IU-6, respectively. A detailed description of the results of the

screening evaluation (i.e., comparison of EPCs with SSLs) of metals, PAH, PCB (as Aroclors), and other organics detected in soil is provided by waste site as follows (in Tables 7-6 through 7-8).

### 7.4.5.1 100-F

100-F has 94 waste sites evaluated in this ERA. Samples collected greater than 4.6 m (15 ft) bgs. (deep and deep focused) were not included in the risk assessment, so 2 of the 94 sites were eliminated from the risk assessment (116-F-7, and 118-F-8:3). Only waste sites where detected concentrations were present were included in the risk assessment, so 2 of the 92 sites with shallow soil data were eliminated from the evaluation (100-F-23 and 118-F-4) (Section 7.1.3). Therefore, plant/invertebrate and avian/mammalian SSL HQs for all 90 of the remaining waste sites are provided in Appendix H, Table H-6. The SSL-based HQs were less than 1.0 for all COPCs in all of the decision units evaluated at 19 of the 90 waste sites.

The waste sites that did not require further evaluation of ecological risk are as follows:

- 100-F Area sites: 100-F-19:1, 100-F-2, 100-F-24, 100-F-35, and 100-F-54
- 116-F Area sites: 116-F-11, 116-F-16, 116-F-2, 116-F-3, 116-F-4, 116-F-6, 116-F-8, and 116-F-9
- 118-F Area sites: 118-F-5 and 118-F-6
- 126-F-1
- 132-F-1
- 1607-F2
- UPR-100-F-2

Within the remaining 71 waste sites, EPCs exceeded the plant/invertebrate SSLs at each waste site, while fewer analytes exceeded the wildlife SSLs. The EPCs for arsenic, barium, boron, chromium, copper, lead, manganese, mercury, molybdenum, selenium, silver, vanadium, zinc, and dieldrin exceeded one or both of the SSLs in 132 waste site/decision unit combinations, as presented in Appendix H, Table H-6. These waste site/decision units were carried forward into the background evaluation.

The SSLs, background, and PRGs were not available for nickel-63, 1,4-dichlorobenzene, 2-(2-methyl-4-chlorophenoxy) propionic acid, 2,4-db(4-(2,4-dichlorophenoxy)butanoic acid), 4-nitroaniline, acetone, alpha-BHC, butylbenzylphthalate, carbazole, dibenzofuran, di-n-butylphthalate, endrin, gamma-BHC (lindane), heptachlor, heptachlor epoxide, m-xylene, nitrogen in nitrite and nitrate, o-xylene, styrene, TPH, and TPH-diesel range extended to c36. These COPCs were retained as an uncertainty and are further discussed in Section 7.4.5. The Aroclor HIs and radionuclide SOFs were less than 1 for all waste sites. All Aroclors and radionuclides were eliminated from further evaluation.

### 7.4.5.2 100-IU-2

This ERA evaluates 25 waste sites in 100-IU-2. Samples collected greater than 4.6 m (15 ft) bgs (deep and deep focused) were not included in the risk assessment and were eliminated from the risk assessment. Plant/invertebrate and avian/mammalian SSL HQs for all 25 waste sites are provided in Appendix H, Table H-7. The SSL-based HQs were greater than 1.0 for at least one COPC in all of the decision units evaluated at all the waste sites.

The EPCs for barium, boron, cadmium, chromium, lead, manganese, mercury, selenium, vanadium, and zinc exceeded one or both of the SSLs in 44 waste site/decision units, as presented in Appendix H, Table H-7. Within the 25 waste sites, EPCs of analytes exceeded the plant/invertebrate SSLs at each waste site, while fewer analytes exceeded the wildlife SSLs. These waste site decision units were carried forward into the background evaluation.

The SSLs, background, and PRGs were not available for 1,2-dichloroethene (total), 2,4-DB (4-(2,4-dichlorophenoxy)butanoic acid), 2,4,5-T(2,4,5-trichlorophenoxyacetic acid), acetone, di-n-butylphthalate, endrin, heptachlor, nitrogen in nitrate, nitrogen in nitrite and nitrate, TPH, TPH–diesel range extended to c36, and TPH–motor oil (high boiling). These COPCs was retained as uncertainties and are further discussed in Section 7.4.5. The Aroclor HIs were less than 1 for all waste sites. All Aroclors were eliminated from further evaluation.

#### *7.4.5.3 100-IU-6*

This ERA has 21 waste sites evaluated in 100-IU-6. Samples collected greater than 4.6 m (15 ft) bgs (deep and deep focused) were not included in the risk assessment. Plant/invertebrate and avian/mammalian SSL HQs for all 21 waste sites are provided in Appendix H, Table H-8. The SSL-based HQs were less than 1.0 for all COPCs in all of the decision units evaluated at 3 of the 21 waste sites. The 600 Area waste sites (600-107, 600-108, 600-257, and 600-350) did not require further evaluation of ecological risk.

The EPCs for the inorganic analytes antimony, arsenic, barium, boron, chromium, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, vanadium, and zinc exceeded one or both of the SSLs in 37 waste site/decision units, as presented in Appendix H, Table H-8. Within the remaining 18 waste sites, EPCs of analytes exceeded the plant/invertebrate SSLs at each waste site, while fewer analytes exceeded the wildlife SSLs. These waste site decision units were carried forward into the background evaluation.

The SSLs, background, and PRGs were not available for 2,4-dimethylphenol, alpha-BHC, butylbenzylphthalate, di-n-butylphthalate, endrin, isophorone, nitrogen in nitrate, nitrogen in nitrite and nitrate, styrene, TPH, TPH–diesel range extended to c36, TPH–motor oil (high boiling). These COPCs were retained as uncertainties and are further discussed in Section 7.4.5. The Aroclor HIs and radionuclide SOFs were less than 1 for all waste sites. All Aroclors and radionuclides were eliminated from further evaluation.

### 7.4.6 Results of Background Characterization

Although an exceedance of an SSL, EPCs for many of the COPCs within the waste sites were below the 90$^{th}$ percentile background concentrations so were eliminated from further evaluation. The comparisons of EPCs to the 90$^{th}$ percentile background for all COPCs carried forward from the screening evaluation are provided in Appendix H, Tables H-9 through H-11.

#### *7.4.6.1 100-F*

Although in exceedance of an SSL, EPCs for many of the COPCs within the remaining waste sites were below the 90$^{th}$ percentile background concentrations so were eliminated from further evaluation. The comparisons of COPC EPCs to the 90$^{th}$ percentile background for the remaining waste sites are provided in Appendix H, Table H-9. COPCs did not exceed the 90$^{th}$ percentile background concentrations in all of the decision units evaluated at 23 of the remaining 71 waste sites. The following 23 waste sites did not require further evaluation of ecological risks:

- 100-F Area sites: 100-F-11, 100-F-12, 100-F-14, 100-F-15, 100-F-16, 100-F-18, 100-F-26-1, 100-F-26-11, 100-F-26-12, 100-F-26-2, 100-F-26-5, 100-F-36, 100-F-4, 100-F-44-5, 100-F-50, 100-F-51 and 100-F-63, 100-F-52, 100-F-53, and 100-F-60
- 116-F-10
- 128-F-1

- 1607 Area sites: 1607-F-5 and 1607-F-6

Within the remaining 48 waste sites, 77 decision units had COPC EPCs in exceedance of both an SSL and background. The COPC EPCs detected in exceedance of background were carried forward to the PRG evaluation. The inorganic analytes arsenic, barium, boron, chromium, copper, lead, mercury, molybdenum, selenium, silver, and zinc were detected outside of the range of background. Because a background value was not available for dieldrin, it was carried forward to the PRG evaluation. A summary of SSL and background evaluation results for the 48 waste sites is provided in Table 7-6.

Table 7-6. Summary of 100-F Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 0.3 m [1 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 100-F-19:2_Overburden | Mercury (4.1) | — |
| 100-F-20_Staging pile area | Zinc (1.8) | Zinc (1.3) |
| 100-F-25_Shallow | Mercury (1.4) | — |
| 100-F-26:10_Overburden_Focused | Boron (11.6)<br>Selenium (3.5) | — |
| 100-F-26:10_Shallow | Selenium (2.6) | — |
| 100-F-26:13_Overburden_Focused | Boron (12.2) | — |
| 100-F-26:14_Overburden | Boron (27.0) | — |
| 100-F-26:14_Shallow | Boron (63.2) | — |
| 100-F-26:15_Shallow | Boron (8.3)<br>Mercury (1.3) | — |
| 100-F-26:4_Overburden_Focused | Boron (64.6)<br>Mercury (1.5) | — |
| 100-F-26:4_Overburden_Focused_3 | Boron (10.2) | — |
| 100-F-26:4_Shallow_1 | Boron (11.5)<br>Selenium (5.2) | Selenium (1.4) |
| 100-F-26:4_Shallow_2 | Boron (9.8)<br>Selenium (1.8) | — |
| 100-F-26:4_Shallow_Focused | Mercury (1.5)<br>Zinc (1.7) | Zinc (1.3) |
| 100-F-26:7_Overburden_Focused | Boron (21.2) | — |
| 100-F-26:7_Shallow | Boron (17.9) | — |
| 100-F-26:7_Staging Pile Area Footprint | Boron (11.5)<br>Selenium (1.8) | — |

Table 7-6. Summary of 100-F Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 0.3 m [1 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 100-F-26:8_Shallow | Mercury (1.6)<br>Selenium (2.6) | — |
| 100-F-26:9_Overburden | Boron (31.3) | — |
| 100-F-26:9_Overburden_Focused | Barium (2.0)<br>Boron (123.4)<br>Copper (3.7)<br>Lead (1.6)<br>Zinc (1.7) | Copper (1.7)<br>Lead (2.3)<br>Zinc (1.3) |
| 100-F-26:9_Shallow | Boron (28.7)<br>Mercury (2.8) | — |
| 100-F-26:9_Shallow_Focused | Boron (57.2)<br>Mercury (8.1)<br>Selenium (2.5)<br>Zinc (2.4) | Zinc (1.8) |
| 100-F-26:9_Staging Pile Area | Arsenic (1.1)<br>Mercury (1.2) | — |
| 100-F-31_Shallow | Mercury (12.0) | — |
| 100-F-33_Shallow | Zinc (1.4) | Zinc (1.1) |
| 100-F-33_Staging pile area_Focused | Mercury (3.8) | — |
| 100-F-37_Shallow_Focused | Arsenic (1.7)<br>Barium (1.5)<br>Lead (4.3) | Lead (6.0) |
| 100-F-38_Shallow_Focused | Barium (1.2)<br>Boron (47.0) | Lead (1.1) |
| 100-F-44:2_Shallow_Focused | Zinc (1.8) | Zinc (1.3) |
| 100-F-44:8_Shallow | Boron (23.5)<br>Mercury (1.1) | — |
| 100-F-44:9_Overburden_Focused | Selenium (2.1) | — |
| 100-F-44:9_Staging Pile Area Footprint | Selenium (1.8) | — |
| 100-F-45_Overburden_Focused | Chromium (51.8) | — |
| 100-F-45_Shallow | Chromium (85.8)<br>Mercury (10.3) | — |
| 100-F-46_Shallow_Focused | Boron (7.8) | — |

Table 7-6. Summary of 100-F Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 0.3 m [1 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 100-F-47_Shallow | Mercury (9.1) | — |
| 100-F-48_Shallow_1 | Boron (8.7)<br>Mercury (1.5) | — |
| 100-F-49_Shallow | Selenium (2.3) | — |
| 100-F-49_Staging Pile Area Footprint_Focused | Boron (8.2)<br>Chromium (55.3) | — |
| 100-F-55 and 100-F-62_Shallow_1 | Lead (1.3) | Lead (1.8) |
| 100-F-55 and 100-F-62_Shallow_2 | Boron (8.3)<br>Mercury (67.9) | Mercury (3.6) |
| 100-F-55 and 100-F-62_Staging Pile Area Footprint_Focused | Boron (16.6)<br>Mercury (6.9)<br>Zinc (1.5) | Zinc (1.1) |
| 100-F-56:1_Shallow | Mercury (17.7) | — |
| 100-F-56:1_Shallow_Focused | Chromium (146.5) | Chromium (1.5) |
| 100-F-61_Shallow | Mercury (6.4) | — |
| 100-F-7_Shallow_Focused | Mercury (1.3) | — |
| 100-F-9_Shallow_Focused | Mercury (4.1) | — |
| 116-F-1_Overburden | Arsenic (1.1) | — |
| 116-F-14_Shallow | Chromium (60.4) | — |
| 116-F-15_Shallow | Boron (23.1)<br>Mercury (1.8) | — |
| 116-F-5_Shallow | Arsenic (1.7) | — |
| 118-F-1_Overburden | Selenium (2.7)<br>Silver (2.2) | — |
| 118-F-1_Staging Pile Area | Arsenic (1.2) | — |
| 118-F-2_Overburden | Selenium (2.7) | — |
| 118-F-2_Staging Pile Area | Selenium (2.7) | — |
| 118-F-3_Shallow | Boron (25.4) | — |
| 118-F-3_Staging Pile Area | Boron (13.2) | — |

Table 7-6. Summary of 100-F Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 0.3 m [1 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 118-F-7_Shallow | Boron (9.6)<br>Molybdenum (1.2) | — |
| 118-F-7_Shallow_Focused | Arsenic (1.0)<br>Lead (1.3) | Lead (1.8) |
| 118-F-7_Staging Pile Area | Boron (7.8)<br>Copper (11.0) | Copper (5.2) |
| 118-F-8:1_Shallow | Chromium (96.9) | Chromium (1.0) |
| 118-F-8:4_Overburden | Mercury (1.3) | — |
| 118-F-8:4_Shallow | Mercury (5.3)<br>Selenium (2.9) | — |
| 120-F-1_Shallow | Mercury (1.0)<br>Selenium (3.5) | — |
| 126-F-2_Staging pile area_Focused | Boron (11.2)<br>Zinc (1.5) | Zinc (1.1) |
| 128-F-2_Shallow | Chromium (53.9) | — |
| 128-F-2_Staging pile area_Focused | Chromium (80.5)<br>Selenium (1.8)<br>Zinc (2.5) | Zinc (1.8) |
| 128-F-3_Shallow | Boron (34.0)<br>Chromium (105.2) | Chromium (1.1) |
| 128-F-3_Staging pile area_Focused | Boron (11.0) | — |
| 141-C_Shallow | Boron (10.7) | — |
| 1607-F3_Shallow | Selenium (8.1) | Selenium (2.2) |
| 1607-F3_Staging pile area_Focused | Arsenic (1.2)<br>Lead (1.1) | Lead (1.5) |
| 1607-F4_Overburden_Focused | Boron (11.6) | — |
| 1607-F4_Shallow | Mercury (12.0)<br>Selenium (3.1) | — |
| 1607-F7_Staging pile area_Focused | Boron (15.4)<br>Zinc (1.4) | Dieldrin (1.1)<br>Zinc (1.1) |
| 182-F_Overburden_Focused | Chromium (56.5)<br>Lead (1.2)<br>Zinc (2.8) | Lead (1.6)<br>Zinc (2.1) |

Table 7-6. Summary of 100-F Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 0.3 m [1 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 600-351_Shallow_Focused | Arsenic (25.0)<br>Lead (16.1)<br>Selenium (1.8) | Arsenic (1.3)<br>Lead (22.6) |

* Exceedances of both the SSL and 90th percentile of Hanford Site background concentration, when background value is available.

HQ = hazard quotient

SSL = soil screening level

### 7.4.6.2 100-IU-2

Although in exceedance of an SSL, EPCs for many of the COPCs within the waste sites were below the 90th percentile background concentrations so were eliminated from further evaluation. The comparisons of COPC EPCs to the 90th percentile background for the waste sites are provided in Appendix H, Table H-10. COPCs did not exceed the 90th percentile background concentrations in all of the decision units evaluated at 18 of the 25 waste sites. The following 18 waste sites did not require further evaluation of ecological risks:

- 600 Area sites: 600-5, 600-100, 600-124, 600-125, 600-128, 600-131, 600-132, 600-139, 600-181, 600-182, 600-188, 600-190, 600-295, 600-343, 600-344, 600-345, and 600-346
- 628-1

Within the remaining 7 waste sites, 11 decision units had COPC EPCs in exceedance of both an SSL and background. The COPC EPCs detected in exceedance of background were carried forward to the PRG evaluation. The inorganic analytes barium, boron, cadmium, chromium, lead, manganese, mercury, selenium, and zinc were detected outside of the range of background. A summary of SSL and background evaluation results for the 25 waste sites is provided in Table 7-7.

Table 7-7. Summary of 100-IU-2 Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 4.6 m [15 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 600-120 and 600-297_Shallow | Boron (8.1) | — |
| 600-127_Shallow | Selenium (1.8) | — |
| 600-127_Staging Pile Area_3 | Boron (10.7) | — |
| 600-127_Staging Pile Area_4 | Boron (15.8) | — |

Table 7-7. Summary of 100-IU-2 Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 4.6 m [15 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 600-176_Staging Pile Area Footprint_2 | Chromium (151.6)<br>Lead (9.1) | Chromium (1.6)<br>Lead (12.8) |
| 600-176_Staging Pile Area Footprint_3 | — | Lead (1.2) |
| 600-296_Shallow_Focused | Barium (2.2)<br>Lead (1.2)<br>Mercury (6.5)<br>Zinc (2.5) | Lead (1.7)<br>Zinc (1.8) |
| 600-302_Shallow_Focused | Zinc (2.4) | Zinc (1.8) |
| 600-341:1_Shallow_1_Focused | Manganese (2.6)<br>Mercury (1.8)<br>Zinc (6.3) | Cadmium (1.1)<br>Zinc (4.7) |
| 600-341:1_Shallow_2_Focused | Zinc (2.1) | Zinc (1.6) |
| 600-341:2_Shallow_Focused | Zinc (2.4) | Zinc (1.8) |

* Exceedances of both the SSL and 90$^{th}$ percentile of Hanford Site background concentration, when background value is available.

HQ = hazard quotient

SSL = soil screening level

#### *7.4.6.3 100-IU-6*

The comparisons of COPC EPCs to the 90$^{th}$ percentile background for the remaining 18 waste sites are provided in Appendix H, Table H-11. COPCs did not exceed the 90$^{th}$ percentile background concentrations in all of the decision units evaluated at 5 of the remaining 18 waste sites. The five 600 Area waste sites (600-23, 600-178, 600-204, 600-280, and 600-327) did not require further evaluation of ecological risks.

Within the remaining 13 waste sites, 19 decision units had COPC EPCs in exceedance of both an SSL and background. The COPC EPCs detected in exceedance of background were carried forward to the PRG evaluation. The inorganic analytes antimony, arsenic, barium, boron, chromium, copper, lead, manganese, mercury, molybdenum, nickel, selenium, silver, vanadium, and zinc were detected outside of the range of background. A summary of SSL and background evaluation results for the 18 waste sites is provided in Table 7-8.

Table 7-8. Summary of 100-IU-6 Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 4.6 m [15 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 600-109_Overburden_Focused | Arsenic (1.5)<br>Lead (1.4) | Lead (2.0) |
| 600-109_Staging Pile Area | Arsenic (2.4)<br>Lead (2.5)<br>Zinc (1.4) | Lead (3.5)<br>Zinc (1.0) |
| 600-111_Shallow | Manganese (2.3) | — |
| 600-146_Shallow_Focused | Copper (9.5)<br>Nickel (1.3)<br>Zinc (3.1) | Copper (4.4)<br>Nickel (1.2)<br>Zinc (2.3) |
| 600-149:2_Shallow | Selenium (1.7) | — |
| 600-149:2_Shallow_Focused | Lead (3.1)<br>Selenium (2.1) | Lead (4.3) |
| 600-186_Shallow_Focused | Chromium (245.0)<br>Lead (1.9)<br>Mercury (8.5)<br>Silver (11.0)<br>Vanadium (70.5)<br>Zinc (2.7) | Chromium (2.6)<br>Lead (2.6)<br>Vanadium (4.5)<br>Zinc (2.0) |
| 600-202_Shallow_2 | Chromium (56.0) | — |
| 600-202_Shallow_Focused | Arsenic (1.0)<br>Boron (26.0)<br>Chromium (54.8)<br>Copper (1.8)<br>Lead (5.6)<br>Zinc (8.1) | Lead (7.8)<br>Zinc (5.9) |
| 600-202_Staging Pile Area Footprint | Boron (19.9)<br>Lead (1.3)<br>Zinc (3.5) | Lead (1.8)<br>Zinc (2.6) |
| 600-205_Shallow_Focused | Vanadium (43.1) | Lead (1.1)<br>Vanadium (2.8) |
| 600-3_Shallow_2 | Lead (1.3) | Lead (1.8) |
| 600-3_Shallow_Focused | Antimony (2.3)<br>Barium (2.5)<br>Chromium (48.5)<br>Copper (3.0)<br>Lead (32.8)<br>Zinc (7.7) | Antimony (2.0)<br>Copper (1.4)<br>Lead (46.1)<br>Zinc (5.7) |

Table 7-8. Summary of 100-IU-6 Waste Sites Ecological Evaluation Based on SSLs and Background for Surface Soils (0 to 4.6 m [15 ft])

| Waste Site/Decision Unit | Exceedances Based on Comparisons to SSLs and Background* | |
|---|---|---|
| | Plant/Invertebrate SSL-Based HQ | Wildlife SSL-Based HQ |
| 600-3_Staging Pile Area Footprint_Focused | Lead (4.7) | Lead (6.6) |
| 600-315_Shallow_Focused | Boron (26.6)<br>Selenium (2.7) | — |
| 600-322_Shallow_Focused | Chromium (82.0)<br>Copper (1.1)<br>Lead (1.4)<br>Manganese (2.5)<br>Molybdenum (2.2)<br>Nickel (1.2) | Lead (2.0)<br>Nickel (1.1) |
| 600-323_Shallow_Focused | Barium (1.7)<br>Boron (68.0)<br>Selenium (4.2) | Selenium (1.2) |
| 600-334:1_Shallow_Focused | Mercury (19.0)<br>Zinc (1.5) | Mercury (1.0)<br>Zinc (1.1) |
| JA JONES 1_Shallow | Lead (1.1) | Lead (1.5) |

* Exceedances of both the SSL and 90$^{th}$ percentile of Hanford Site background concentration, when background value is available.

HQ = hazard quotient

SSL = soil screening level

### 7.4.7 Results of PRG Characterization

Further evaluation was conducted on those waste sites that were not eliminated in the SSL and background evaluations. Risks were evaluated based on the resulting PRG HQs and are provided in Appendix H, Tables H-12 through H-14 and summarized below. The PRG exceedances presented in this section are further evaluated in Appendix H, and risk conclusions are provided in Section 7.6.

#### *7.4.7.1 100-F*

The following 25 waste sites did not exceed the plant/invertebrate PRGs or the wildlife PRGs (HQs were less than 1) and were eliminated from further evaluation (Appendix H, Table H-12):

- 100-F Area sites: 100-F-7, 100-F-20, 100-F-25, 100-F-26-7, 100-F-26-8, 100-F-26-13, 100-F-26-15, 100-F-44-2, 100-F-44-8, 100-F-44-9, 100-F-46, 100-F-48, and 100-F-49
- 116-F Area sites: 116-F-1, 116-F-5, 116-F-14, and 116-F-15
- 118-F Area site: 118-F-2, 118-F-3, and 118-F-8-1
- 126-F-2

- 128-F Area site: 128-F-2 and 128-F-3
- 141-C
- 182-F

The EPCs for the inorganic analytes arsenic, barium, boron, copper, lead, mercury, molybdenum, selenium, and silver exceeded one or both groups of PRGs (plants/invertebrates and wildlife). Because PRGs are not available for dieldrin, the concentrations of dieldrin detected at concentrations exceeding wildlife SSLs were carried forward. These COPCs will be retained as COPECs in one or more of the remaining 27 waste site decision units as follows (Table H-12 in Appendix H and Table 7-9):

- 100-F-9_Shallow_Focused: Mercury
- 100-F-19-2_Overburden: Mercury
- 100-F-26-4_Overburden_Focused: Boron
- 100-F-26-4_Shallow_1: Selenium
- 100-F-26-9_Overburden_Focused: Barium, Boron, Copper
- 100-F-26-9_Shallow_Focused: Mercury
- 100-F-26-10_Overburden_Focused: Selenium
- 100-F-26-14_Shallow: Boron
- 100-F-31_Shallow: Mercury
- 100-F-33_Staging Pile Area_Focused: Mercury
- 100-F-37_Shallow_Focused: Barium, lead
- 100-F-38_Shallow_Focused: Barium
- 100-F-45_Shallow: Mercury
- 100-F-47_Shallow: Mercury
- 100-F-55 and 100-F-62_Shallow_2: Mercury
- 100-F-55 and 100-F-62_Staging Pile Area Footprint_Focused: Mercury
- 100-F-56:1_Shallow: Mercury
- 100-F-61_Shallow: Mercury
- 118-F-1_Overburden: Silver
- 118-F-7_Shallow: Molybdenum
- 118-F-7_Staging Pile Area: Copper
- 118-F-8-4_Shallow: Mercury, Selenium
- 120-F-1_Shallow: Selenium
- 1607-F3_Shallow: Selenium
- 1607-F4_Shallow: Mercury, Selenium
- 1607-F7_Staging Pile Area_Focused: Dieldrin
- 600-351_Shallow_Focused: Arsenic, Lead

Table 7-9. Summary of 100-F Source OU Waste Sites Ecological Evaluation Based on PRGs for Surface Soils (0 to 4.6 m [15 ft])

| Waste Site/Decision Unit | Plant/Invertebrate HQ | Wildlife HQ |
|---|---|---|
| 100-F-19:2_Overburden | Mercury (1.4) | — |
| 100-F-26:10_Overburden_Focused | — | Selenium (1.3) |
| 100-F-26:14_Shallow | Boron (1.1) | — |
| 100-F-26:4_Overburden_Focused | Boron (1.1) | Boron (1.0) |
| 100-F-26:4_Shallow_1 | Selenium (1.3) | Selenium (1.9) |
| 100-F-26:9_Overburden_Focused | Barium (1.8)<br>Boron (2.1)<br>Copper (3.2) | Boron (1.9) |
| 100-F-26:9_Shallow_Focused | Mercury (2.7) | — |
| 100-F-31_Shallow | Mercury (4.0) | — |
| 100-F-33_Staging pile area_Focused | Mercury (1.3) | — |
| 100-F-37_Shallow_Focused | Barium (1.4) | Lead (1.4) |
| 100-F-38_Shallow_Focused | Barium (1.1) | — |
| 100-F-45_Shallow | Mercury (3.4) | — |
| 100-F-47_Shallow | Mercury (3.0) | — |
| 100-F-55 and 100-F-62_Shallow_2 | Mercury (22.6) | Mercury (4.4) |
| 100-F-55 and 100-F-62_Staging Pile Area Footprint_Focused | Mercury (2.3) | — |
| 100-F-56:1_Shallow | Mercury (5.9) | Mercury (1.1) |
| 100-F-61_Shallow | Mercury (2.1) | — |
| 100-F-9_Shallow_Focused | Mercury (1.4) | — |
| 118-F-1_Overburden | Silver (1.4) | — |
| 118-F-7_Shallow | Molybdenum (1.2) | — |
| 118-F-7_Stagging pile area | Copper (9.5) | Copper (2.6) |
| 118-F-8:4_Shallow | Mercury (1.8) | Selenium (1.0) |
| 120-F-1_Shallow | — | Selenium (1.3) |
| 1607-F3_Shallow | Selenium (2.1) | Selenium (2.9) |
| 1607-F4_Shallow | Mercury (4.0) | Selenium (1.1) |
| 1607-F7_Staging pile area_Focused | — | Dieldrin (1.1) |

Table 7-9. Summary of 100-F Source OU Waste Sites Ecological Evaluation Based on PRGs for Surface Soils (0 to 4.6 m [15 ft])

| Waste Site/Decision Unit | Plant/Invertebrate HQ | Wildlife HQ |
|---|---|---|
| 600-351_Shallow_Focused | Arsenic (2.0) | Arsenic (2.0)<br>Lead (5.2) |

Note: These PRG exceedances are further evaluated in Appendix H, and risk conclusions are discussed in Section 7.6.

HQ = hazard quotient

PRG = preliminary remediation goal

#### *7.4.7.2 100-IU-2*

The 600 Area waste sites (600-120 and 600-297, 600-127, 600-302, 600-341-1, and 600-341-2) did not exceed the plant/invertebrate PRGs or the wildlife PRGs (HQs were less than 1). These sites were eliminated from further evaluation (Appendix H, Table H-13).

The EPCs for the inorganic analytes barium, lead, and mercury exceeded one group of PRGs (plants/invertebrates, wildlife). These COPCs will be retained as COPECs in the remaining two waste site decision units as follows (Table H-13 in Appendix H, and Table 7-10):

- 600-176_Staging Pile Area Footprint_2: Lead
- 600-296_Shallow_Focused: Barium, Mercury

Table 7-10. Summary of 100-IU-2 OU Waste Sites Ecological Evaluation Based on PRGs for Surface Soil (0 to 4.6 m [15 ft])

| Waste Site/Decision Unit | Plant/Invertebrate HQ | Wildlife HQ |
|---|---|---|
| 600-176_Staging Pile Area Footprint_2 | — | Lead (2.9) |
| 600-296_Shallow_Focused | Barium (2.1)<br>Mercury (2.2) | — |

Note: These PRG exceedances are further evaluated in Appendix H, and risk conclusions are provided in Section 7.6.

HQ = hazard quotient

PRG = preliminary remediation goal

#### *7.4.7.3 100-IU-6*

The following five waste sites did not exceed the plant/invertebrate PRGs or the wildlife PRGs (HQs were less than 1) and were eliminated from further evaluation (Appendix H, Table H-14):

- 600 Area sites: 600-109, 600-111, 600-149-2, and 600-315
- JA JONES 1

The EPCs for the inorganic barium, boron, copper, lead, mercury, molybdenum, nickel, selenium, silver, and vanadium exceeded one group of PRGs (plants/invertebrates, wildlife). These COPCs will be retained

as COPECs in the remaining nine waste site decision units as follows (Table H-14 in Appendix H, and Table 7-11):

- 600-146_Shallow_Focused: Copper, Nickel
- 600-186_Shallow_Focused: Mercury, Silver, Vanadium
- 600-202_Shallow_Focused: Copper, Lead
- 600-205_Shallow_Focused: Vanadium
- 600-3_Shallow_Focused: Barium, Copper, Lead
- 600-3_Staging Pile Area Footprint_Focused: Lead
- 600-322_Shallow_Focused: Molybdenum
- 600-323_Shallow_Focused: Barium, Boron, Selenium
- 600-334:1_Shallow_Focused: Mercury

Table 7-11. Summary of 100-IU-6 Source OU Waste Sites Ecological Evaluation Based on PRGs for Surface Soils (0 to 4.6 m [15 ft])

| Waste Site/Decision Unit | Plant/Invertebrate HQ | Wildlife HQ |
|---|---|---|
| 600-146_Shallow_Focused | Copper (8.2)<br>Nickel (1.0) | Copper (2.2) |
| 600-186_Shallow_Focused | Mercury (2.8)<br>Silver (7.3)<br>Vanadium (1.6) | Vanadium (3.3) |
| 600-202_Shallow_Focused | Copper (1.5) | Lead (1.8) |
| 600-205_Shallow_Focused | — | Vanadium (2.0) |
| 600-3_Shallow_Focused | Barium (2.3)<br>Copper (2.6) | Lead (10.5) |
| 600-3_Staging Pile Area Footprint_Focused | — | Lead (1.5) |
| 600-322_Shallow_Focused | Molybdenum (2.2) | — |
| 600-323_Shallow_Focused | Barium (1.5)<br>Boron (1.1)<br>Selenium (1.1) | Selenium (1.5)<br>Boron (1.1) |
| 600-334:1_Shallow_Focused | Mercury (6.3) | Mercury (1.2) |

Note: These PRG exceedances are further evaluated in Appendix H, and risk conclusions are provided in Section 7.6.

HQ = hazard quotient

PRG = preliminary remediation goal

### 7.4.8 Characterization of Drinking Water Ingestion

The EPCs from seep water along the 100-F/IU Area of the Columbia River were evaluated for drinking water intake by birds and mammals representing feeding guilds in the upland and riparian areas of the Columbia River Corridor. The results of these comparisons for nonradionuclide chemicals are provided in Appendix H, Table H-15. Under this scenario, modeled exposure from ingestion of nitrogen (as nitrate

and nitrite) and vanadium were more than negligible (e.g., resulted in drinking water ingestion HQs of 0.01 or greater), while exposure from all other chemicals to all receptors produced HQs of less than 0.01. Thus, other than for nitrogen and vanadium, potential adverse effects to wildlife due to exposure through drinking ingestion was not significant. Further, the results of the evaluation presented in Tables 7-6 through 7-11 should be considered acceptable for all of the chemical-source OU combinations as inclusion of drinking ingestion to the exposure models presented in this chapter (Sections 7.4.1 through 7.4.3) would not have altered the outcomes. Because there are no HQs from the ingestion of prey and soil for nitrogen whether in nitrate or nitrite, the drinking ingestion HQs represent the primary contribution to the total dose and yielded a maximum HQ of 0.33 for all wildlife evaluated (Appendix H, Table H-15) under the worst-case scenario. Therefore, risks from wildlife ingesting nitrogen in seep water are not a concern. The drinking ingestion dose of vanadium resulted in an HQ of 0.01. While vanadium concentrations in several upland waste sites approach or exceed 1.0 suggesting potential ecological risks, only two waste sites (600-186_Shallow_Focused and 600-205_Shallow_Focused) had EPCs above background. In neither case would a potential drinking ingestion hazard quotient of 0.01 substantially influence risk estimates. Thus, potential drinking water risks from vanadium are insignificant. The potential risks do not warrant further evaluation.

Evaluation of radionuclide doses from wildlife drinking the seep water is included in Appendix H, Table H-16. EPCs for seeps were compared to the lower of BCGs for terrestrial, aquatic, and riparian animals. The total SOF for wildlife drinking seep water from 100-IU-2/IU-6 was 0.08. The maximum (worst-case) dietary SOFs from any waste site within the 100-F OUs is 0.44 (100-F-26:13_Shallow, as shown in Appendix H, Table H-6); 0.003 (600-3_Staging Pile Area Footprint, as shown in Appendix H, Table H-8) within the 100-IU-6 OUs; and no SOFs for 100-IU-2. These provide no additional risk for wildlife exposure to radionuclides from drinking seeps at 100-F/IU.

Given the results provided in Appendix H (Tables H-15 and H-16), there is no significant risk to wildlife in the 100-F/IU OUs from drinking freshwater seeps along the Columbia River in the 100-F/IU riparian area. Further, the results of the evaluation presented in Appendix H should be considered acceptable for all of the chemical-source OU combinations because the inclusion of drinking ingestion in the exposure models presented in this chapter (Sections 7.4.1 through 7.4.3) would not have altered the risk outcomes or conclusions. Inclusion of drinking ingestion in the development of SSLs and PRGs is therefore not warranted.

### 7.4.9 Uncertainties Assessment

Uncertainties are present in all risk assessments because of the limitations of available data and the need to make certain assumptions and extrapolations based on incomplete information. In addition, the use of various models (e.g., uptake and food web exposures) carries with it some associated uncertainty as to how well the model reflects actual conditions. Since conservative assumptions were generally used in the exposure and effects assessments, these uncertainties are more likely to result in an overestimation rather than an underestimation of the likelihood and magnitude of risks to ecological receptor. The following uncertainties and limitations are associated with the proposed methodology and available data for the ERA:

- **Data use:** The quantitative evaluation of chemical concentrations in soil included surface soil from the 0 to 4.6 m (15 ft) depth range. Ecology uses a standard point of compliance in soil of 4.6 m (15 ft) for demonstrating protection of ecological receptors (MTCA, "Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7490(4)(b)]). This depth range overestimates the depth to which many terrestrial receptors would be exposed. MTCA (WAC 173-340) identifies the biologically active zone as 0 to 1.8 m (6 ft) (MTCA [WAC 173-340]). Evaluation of data that extends beyond the biologically active zone could either over or under estimate risk. For this ERA, the depth from 1.8 to 4.6 m

(6 to 15 ft) is also included because human activities could bring materials from that depth to the surface, creating a complete exposure pathway.

No toxicological data or background values were available for the following COPCs:

- Nickel-63
- 1,2-Dichloroethene (total)
- 1,4-Dichlorobenzene
- 2-(2-Methyl-4-chlorophenoxy) propionic acid
- Acetone
- Alpha-BHC
- Butylbenzylphthalate
- Carbazole
- Dibenzofuran
- di-n-Butylphthalate
- Endrin
- Gamma-BHC (lindane)
- Heptachlor
- Heptachlor epoxide
- 4-(2,4-Dichlorophenoxy)butanoic acid
- 2,4-Dimethylphenol
- 2,4,5-Trichlorophenoxyacetic acid
- 4-Nitroaniline
- Isophorone
- m-xylene
- Nitrogen in nitrate
- Nitrogen in nitrite and nitrate
- o-xylene
- Styrene
- TPH
- TPH–diesel range extended to c36
- TPH–motor oil (high boiling)

In addition, toxicological data or background values were limited for some COPC/receptor combinations. Therefore, SSLs could not be calculated for all receptors or COPCs. Exclusion of COPCs from SSL development may not adequately address aggregate risk at a site, although it should be noted that remedial alternatives that are protective of receptors with SSLs may also be protective of receptors lacking sufficient toxicity data. In addition, the absence of SSLs for plants and soil invertebrates can be addressed through performing site-specific bioassays, which are a component of Tier 2.

With respect to TPH, though no SSL or PRG was previously developed for soil at the Hanford Site, published literature is available to provide some prospective. In "Ecotoxicity Test Data for Total Petroleum Hydrocarbons in Soil: Plants and Soil-Dwelling Invertebrates" (Efroymson et al., 2004), the authors compiled a literature review on toxicological effects to plant and invertebrates, with the results suggesting that invertebrates are more sensitive to some petroleum hydrocarbons than plants. Using lube oil to represent motor oil, no effect thresholds ranged from 15 to 1,490 mg/kg in soil and EC20 were found as low as 15 to 149 mg/kg. Conversely, lube oil NOAECs for plants ranged from 969 mg/kg to 12,000 mg/kg. MTCA (WAC 173-340, Table 749-3) lists ecological indicator soil concentrations for soil biota for diesel- and gasoline-range organics at 200 mg/kg and 100 mg/kg, respectively, based on original work published at ORNL (*Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision* [ES/ER/TM-126/R2]). Although TPH–motor oil (high boiling) specifically was not measured in any of these studies, with concentrations as high as 602 mg/kg and 115 mg/kg measured at waste sites decision units within the 100-IU-2 OUs and 100-IU-6 OUs, respectively, should be considered in the SMDP. For waste site decision units within 100-IU-2, these include the following sites:

- 600-100_Shallow
- 600-120 and 600-297_Overburden_Focused
- 600-120 and 600-297_Staging Pile Area
- 600-124_Staging Pile Area
- 600-125_Overburden_Focused
- 600-176_Staging Pile Area Footprint_3
- 600-182_Shallow_2_Focused
- 600-188_Overburden_Focused
- 600-188_Shallow
- 600-188_Staging Pile Area_Focused
- 600-341:1_Shallow_1_Focused
- 600-341:1_Shallow_2_Focused
- 600-341:2_Shallow_Focused
- 600-343_Shallow_Focused
- 600-344_Shallow_Focused
- 600-345_Shallow_Focused
- 600-346_Shallow
- 600-5_Shallow_Focused
- 600-5_Staging Pile Area_Focused

For waste site decision units within 100-IU-6, these include the following sites:

- 600-109_Overburden_Focused
- 600-109_Staging Pile Area
- 600-186_Shallow_Focused
- 600-202_Shallow_Focused
- 600-202_Staging Pile Area Footprint
- 600-205_Staging Pile Area Footprint_Focused
- 600-280_Shallow_Focused
- 600-3_Shallow_2
- 600-3_Shallow_Focused
- 600-3_Staging Pile Area Footprint

Bioavailability and toxicity of metals are functions of many factors including soil pH, with metals (e.g., aluminum, lead, and mercury) generally being more bioavailable and toxic at low pHs (*Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs)* [OSWER Directive 9285.7-55])). The pH levels for soil used to develop plant toxicity values range from 3 to 8 (mean = 6.3) (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]). The pH range for soil used to develop invertebrate toxicity values was between 3.8 and 8.1 (mean = 5.6) (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]). The minimum soil pH reported in the RCBRA (DOE/RL-2007-21) in riparian and upland soil was 6.6. Because the range of pH values in soil associated with plant and soil invertebrate toxicity values within the published literature include values that are substantially lower than those present throughout most of the Hanford Site, it is likely that the resulting SSLs for plants and soil invertebrates do not accurately represent toxicity. Since metals are more bioavailable at lower pH, the SSLs may overestimate concentrations in Hanford soil that would be toxic to plants and soil invertebrates; therefore, risk estimates may be overly conservative. Evaluating this potential overestimation of bioavailability was one of the goals of a 2011 Hanford Site field effort to collect soil with a pH range more reflective of Hanford soil. With the exception of four samples collected from within the River Corridor, the range of pH values from samples collected for the 2011 study was between 5.8 and 8.7, with all but 5 of 67 samples above the minimum pH of 6.6 identified in previous RCBRA (DOE/RL-2007-21) soil samples. Further, oxidized environments (upland or well-aerated soils like those at the Hanford Site) promote the precipitation of ferric-oxide compounds, which are not available to plants for uptake. Thus, the PRGs more accurately reflect the actual bioavailability of potential contaminants within

Hanford Site soil than they do the SSLs developed using published data from laboratory studies and other sites.

- **Wildlife TRVs:** Data on the toxicity of many chemicals to the receptor species were sparse or lacking, requiring the extrapolation of data from other wildlife species or from laboratory studies with non-wildlife species. This is a typical limitation and extrapolation for ERAs because so few wildlife species have been tested directly for most chemicals. The uncertainties associated with toxicity extrapolation were minimized through the selection of the most appropriate test species for which suitable toxicity data were available. The factors considered in selecting a test species to represent a receptor species included taxonomic relatedness, trophic level, foraging method, and similarity of diet.

  A second uncertainty related to the derivation of TRVs applies to metals. Most of the toxicological studies on which the TRVs for metals were based used forms of the metal (e.g., salts) that have high water solubility and high bioavailability to receptors. Since the analytical samples on which site-specific exposure estimates were based measured total metal (regardless of form), and these highly bioavailable forms are expected to compose only a fraction of the total metal concentration, this is likely to result in an overestimation of potential risks for these chemicals. A recent study was conducted comparing the toxicity of laboratory-spiked soil versus aged field-collected soil and the predictive ability of the European Union's predicted no effect concentrations for five metals. The study concluded that total metals concentrations in field-collected soil are poor indicators of toxicity ("Toxicity of Trace Metals in Soil as Affected by Soil Type and Aging After Contamination: Using Calibrated Bioavailability Models to Set Ecological Soil Standards" [Smolders et al., 2009]).

- **Chemical mixtures:** The SSLs used in this assessment are based on exposure to individual analytes. Information on the ecotoxicological effects of chemical interactions is generally lacking, which required (as is standard for evaluations of ecological risk) that the chemicals be evaluated on a compound-by-compound basis during the comparison to SSLs. This could result in an underestimation of risk (if there are additive or synergistic effects among chemicals) or an overestimation of risks (if there are antagonistic effects among chemicals). Assessment of data in this report resulted in a description of potential exposure risks because of metals, which are typically known to be additive. In this case, effects may be underestimated.

- **Receptor species selection:** Several receptors were identified as being part of the food web present at the Hanford Site. While mammalian and avian receptors are documented quantitatively, reptiles were not evaluated quantitatively even when exposure pathways were complete due to limited effects data, as noted in Section 7.2.2. A qualitative assessment of potential risk to these taxa can be made by using the results of quantitative evaluation for other fauna with similar diets and assumed similarity in metabolizing COPECs to make inferences. Considering the results of quantitative evaluation of avian receptors can provide some indication regarding the potential for risks to these taxa.

  The uncertainty associated with the lack of toxicological data for reptiles and inferring risk from other fauna either could overestimate or underestimate risks.

  It was also assumed that reptiles neither were exposed to significantly higher concentrations of chemicals nor were more sensitive to chemicals than the other receptor species evaluated in the food web model. This assumption was a source of uncertainty in the ERA. In addition, there is some uncertainty associated with the use of specific receptor species to represent larger groups of organisms (e.g., guilds).

- **Food web exposure modeling:** While much life history data are available for many of the wildlife species found at the Hanford Site, Hanford Site-specific data were unavailable for several specific parameters included in the desktop food web models used to estimate exposure to wildlife. These factors included food ingestion rate, incidental soil ingestion (as a percent or as a rate), home range, and dietary composition established as the percent of stomach contents. Because of this lack of Hanford Site-specific data, exposure parameters were modeled based on allometric relationships (e.g., food intake rates) or on data from the same species in other portions of its range. Because diet composition, as well as food and soil ingestion rates, can differ among individuals and locations, published parameter values may not accurately reflect individuals present at the Hanford Site. Consequently, SSLs may be either over conservative or under conservative. For example, the wildlife EcoSSLs were derived with a model that incorporates prey tissue items that comprise 100 percent of the receptor's diet coming from the site, not accounting for any food obtained in adjacent uncontaminated areas, whereas MTCA (WAC 173-340) values do account for some offsite prey consumption. Therefore, the assumed contributions of ingestion of analytes in prey tissues for the wildlife Eco-SSLs are greater than those used to develop the MTCA (WAC 173-340) values. The Eco-SSLs would be expected to overestimate risk.

  Ultimately, there is some uncertainty with both the MTCA (WAC 173-340) and EPA values used as SSLs with respect to site specificity. The wildlife PRGs used in this ERA are more site-specific than the SSLs because prey concentrations were estimated with Hanford Site data. However, there is also some uncertainty in those values associated with the percentage of diet obtained from the site. In applying the PRGs, the assumption was that 100 percent of the food ingestion was from the site, which in many cases is an overestimate. This assumption was evaluated on a case-by-case basis to aid the SMDP presented in Section 7.6.

- **Central tendency versus maximum exposure concentration estimates:** As is typical in an ERA, a finite number of samples of environmental media is used to develop the exposure estimates. The maximum measured concentration provides a conservative estimate for sessile biota or those with a limited home range. The most realistic exposure estimates for mobile species with relatively large home ranges and for species populations (even those that are sessile or have limited home ranges) are those based upon an estimate of central tendency of chemical concentrations in each medium to which these receptors are exposed. This is reflected in the wildlife dietary exposure models contained in *Wildlife Exposure Factors Handbook* (EPA/600/R-93/187). It is possible, however, that receptors could spend additional time foraging at a nearby waste site and thus be exposed to analytes from more than one site. Thus, EPC estimates of contaminants in individual waste site media and food sources may not accurately represent contaminant exposure to a receptor ranging into other sites. It is likely, however, that assuming an AUF of 1 will result in a conservative estimate of exposure because it is likely that offsite foraging would be conducted in uncontaminated areas than at other waste sites. Given the mobility of the upper trophic level receptor species used in the ERA, the use of maximum chemical concentrations as EPCs when UCLs were not calculated by ProUCL to estimate the exposure via food webs is very conservative. This conservatism was reduced to levels that are more realistic when the number of samples collected in a site was adequate in sample size to develop a UCL on the mean.

- **Comparisons to background concentrations:** Background concentrations were used to judge whether measured concentrations within waste sites are reflective of site-related activities, background, or a combination of both. If site chemical concentrations were consistent with these background levels, it was assumed that the concentrations were not site-related. Comparisons to background in this evaluation include the use of the $90^{th}$ percentile of the background dataset as

compared to the EPC. Thus, 10 percent of the background dataset is even higher than the 90$^{th}$ percentile. Concentrations measured above background may be within the distribution of background variability and could represent a false positive risk. The possibility also exists that concentrations below background were indeed site-related, rendering the assumption false. However, the impact of this possibility is minimal because metals and radioisotopes at concentrations consistent with background conditions should exhibit no different ecological effects than those commonly occurring in areas not affected by releases, regardless of their source.

- **Risk estimates associated with remedial investigation and limited field investigation soil data:** In addition to the waste site remediation data (CVP/RSVP), two additional sources of data were considered for use in the ERA:
  - Vadose zone data collected for the RI to fill data gaps associated with the nature and extent of contamination or associated with understanding the fate and transport of contaminants
  - LFI data collected in 1993 from the 100-F OU (Note that RI and LFI data were not available for the 100-IU-2/IU-6 OUs)

These data were collected for purposes other than fulfilling needs of the risk assessment; as such, they were not used to quantitatively evaluate risks. However, these data were evaluated qualitatively by comparing concentrations of analytes to risk-based screening levels to determine whether the results could be useful for risk management decisions.

The RI and LFI data are summarized in more detail in Appendix G. All RI and LFI soil data from the soil borings and wells described in Appendix G were compared to the PRGs or SSLs used in the ERA. Detailed datasets and vertical profiles are provided in Section 4.2, and a summary of the soil borings/wells and associated depth intervals for data in the ERA is provided in Appendix H, Table H-17.

Similar to the CVP/RSVP data, soil data from each soil boring, well, or test pit were grouped by depth. Soil data were processed and reduced using the same methods as those described in Section 7.1. Soil samples collected from depth intervals ranging from 0 to 4.6 m (15 ft) bgs were combined and the maximum detected concentration was compared to the Hanford Site background concentration and the lowest available ecological PRG value (or SSL in the absence of a PRG). Soil samples collected from depth intervals greater than 4.6 m (15 ft) bgs were not evaluated because they extend beyond the standard point of compliance for ecological receptors defined by MTCA ("Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7490(4)(b)]).

A comparison of the range of detected concentrations to Ecological PRGs or SSLs from each of these sample locations is provided in Appendix H, Table H-18. A summary of the wells and test pits that report any detected concentration greater than the ecological SSLs and PRG is provided in Table 7-12. Six LFI boreholes (199-F5-51, 199-F4-2, 199-F5-49, 199-F8-5, 199-F5-50, and 199-F7-3) and four LFI test pits (116-F-1B-TP1, 116-F-1C-TP-1, 116-F-3-TP-1, and 116-F-9D-TP1) report soil concentrations greater than ecological SSLs. For all the LFI sample locations (both boreholes and test pits) associated with a waste site, these waste sites have been remediated under the interim action ROD. Analytical results at the remediated waste sites (from samples collected before remedial actions were implemented) show detections of aluminum, barium, bis(2-ethylhexyl)phthalate, carbon-14, chromium, cesium-137, lead, mercury, silver, and strontium-90 above ecological PRGs. Interim remedial actions (RTD) have mitigated any potential ecological impacts associated with these waste sites.

Table 7-12. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

| Waste Site | RI Data | Shallow Zone Ecological Risks? | CVP/RSVP Data | Shallow Zone Ecological Risks? | LFI Data | Shallow Zone Ecological Risks? |
|---|---|---|---|---|---|---|
| **Soil Borings Installed to Characterize Nature and Vertical Extent of Contamination Beneath Select Waste Site** | | | | | | |
| 116-F-14 Retention Basin | 199-F5-55 (C7970) | No samples collected from this depth range | CVP-2001-00009 | No individual risks > thresholds | 199-F5-51 (A5682) | Aluminum (0.91 to 1.5 m [3 to 5 ft])<br>BEHP (3.2 to 4.0 m [10.5 to 13 ft])<br>Chromium (1.5 to 2.1 m [5 to 7 ft]) |
| 118-F-1 Burial Ground | C7971 | No samples collected from this depth range | CVP-2007-00001 | No individual risks > thresholds | — | — |
| 118-F-8:3 Reactor (Fuel Storage Basin) | 199-F5-56 (C7972) | No samples collected from this depth range | CVP-2003-00017 | No individual risks > thresholds | — | — |
| **Monitoring Wells Installed to Characterize Fate and Transport Across Vadose Zone and Beneath the Unconfined Aquifer(not waste site-specific)** | | | | | | |
| — | 199-F5-52 (C7790) | No samples collected from this depth range | — | — | — | — |
| — | 199-F5-53 (C7791) | No samples collected from this depth range | — | — | — | — |
| — | 199-F5-54 (C7792) | No samples collected from this depth range | — | — | — | — |
| **Soil Borings and Test Pits Installed During LFI to Characterize Priority Waste Sites in 100-FR-1** | | | | | | |
| 116-F-1 Lewis Canal | — | — | CVP-2002-00009 | No individual risks > thresholds | 199-F4-2 | Lead (0 to 0.61 m [2 ft])<br>Carbon-14 (0 to 3.4 m [11 ft]) |
| | | | | | 116-F-1B-TP1 | Mercury (1.5 m [5 ft])<br>Mercury (4.6 m [15 ft]) |

Table 7-12. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

| Waste Site | RI Data | Shallow Zone Ecological Risks? | CVP/RSVP Data | Shallow Zone Ecological Risks? | LFI Data | Shallow Zone Ecological Risks? |
|---|---|---|---|---|---|---|
| | | | | | 116-F-1C-TP1 | Mercury (0 to 0.3 m [1 ft])<br>BEHP (0 to 0.3 m [1 ft]) |
| 116-F-2 Basin Overflow Trench | — | — | CVP-2001-00005 | No individual risks > thresholds | 199-F5-49 | Mercury (3.0 to 3.7 m [10 to 12 ft])<br>Carbon-14 (0 to 3.7 m [12 ft]) |
| 116-F-3 Fuel Storage Basin Trench | — | — | CVP-2002-00008 | No individual risks > thresholds | 116-F-3-TP1 | Barium (0 to 0.3 m [1 ft])<br>Mercury (2.1 m [7 ft]) |
| 116-F-4 Pluto Crib | — | — | CVP-2001-00006 | No individual risks > thresholds | 199-F8-5 | Cesium-137 (2.4 to 3.5 m [8 to 11.4 ft])<br>Strontium-90 (1.5 to 4.6 m [5 to 15 ft]) |
| 116-F-6 Liquid Waste Disposal Trench | — | — | CVP-2002-00010 | No individual risks > thresholds | 199-F8-6 | No individual risks > thresholds |
| 116-F-9 PNL Animal Waste Leach Trench | — | — | CVP-2001-00008 | No individual risks > thresholds | 116-F-9D-TP1 | Silver (2.7 to 3.0 m [9 to 10 ft]) |
| | | | | | 199-F5-50 | Carbon-14 (0 to 3.4 m [12 ft]) |
| **Monitoring Wells Installed for 100-FR-3 OU LFI** | | | | | | |
| — | — | — | — | — | 199-F1-2 | No samples collected from this depth range |
| — | — | — | — | — | 199-F5-42 | No samples collected from this depth range |
| — | — | — | — | — | 199-F5-43A | No individual risks > thresholds |

Table 7-12. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data

| Waste Site | RI Data | Shallow Zone Ecological Risks? | CVP/RSVP Data | Shallow Zone Ecological Risks? | LFI Data | Shallow Zone Ecological Risks? |
|---|---|---|---|---|---|---|
| — | — | — | — | — | 199-F5-43B | No samples collected from this depth range |
| — | — | — | — | — | 199-F5-44 | No samples collected from this depth range |
| — | — | — | — | — | 199-F5-45 | No samples collected from this depth range |
| — | — | — | — | — | 199-F5-46 | No samples collected from this depth range |
| — | — | — | — | — | 199-F5-47 | No samples collected from this depth range |
| — | — | — | — | — | 199-F5-48 | No samples collected from this depth range |
| — | — | — | — | — | 199-F6-1 | No samples collected from this depth range |
| — | — | — | — | — | 199-F7-3 | Mercury (1.5 to 2.0 m [5 to 6.5 ft]) |
| — | — | — | — | — | 199-F8-3 | No samples collected from this depth range |
| — | — | — | — | — | 199-F8-4 | No samples collected from this depth range |

Note: Complete reference citations for CVPs are provided in Chapter 11.

CVP = cleanup verification package
LFI = limited field investigation
RI = remedial investigation
RSVP = remaining site verification package

At 199-F5-43A, a single mercury result (0.5 mg/kg) from the 1.5 to 2.3 m (5.0 to 6.5 ft) bgs depth interval was greater than the ecological SSLs value of 0.30 mg/kg. Out of three mercury measurements at this well, two nondetects were reported at depths between 3.0 and 7.3 m (10 and 24 ft) bgs. No ecological impact is expected associated with mercury at this location.

## 7.5 Assessment of Risks in Riparian, Near-Shore Media, and Columbia River

The RCBRA (DOE/RL-2007-21) evaluated soil, sediment, and water located in riparian and near-shore areas. The RAGs used in the interim actions addressed risks to human health from direct contact with soil and threats to groundwater and surface water because of leaching from soil; however, the RAGs did not directly address risks to ecological receptors, except those protected through compliance with AWQC and state water quality standards at the groundwater/surface water interface. The ERA conducted as part of the RCBRA (DOE/RL-2007-21) addresses residual contaminant concentrations at remediated waste sites in the upland zones and the transport of contaminants from waste sites to the Columbia River riparian and near-shore zones (Integrated Work Plan [DOE/RL-2008-46]). The CRC (DOE/RL-2010-117) evaluated island soil, sediment, water, and fish tissue located in the Columbia River beyond the near-shore environment. Several investigations conducted on effluent pipelines that discharged to the Columbia River are also summarized in the following subsections.

### 7.5.1 Summary of Results and Conclusions of RCBRA

The RCBRA (DOE/RL-2007-21) evaluated ecological risks at 48 near-shore study sites potentially affected by contamination from Hanford Site sources in comparison to reference sites. Study sites were selected in areas where known contaminated groundwater plumes enter the Columbia River and in areas between the plumes. For the near-shore environment, 22 COPECs were identified and 16 of these (all inorganics) were further identified as COECs. The RCBRA (DOE/RL-2007-21) concluded that across the Hanford Reach of the Columbia River (i.e., corridor-wide), five COECs (cadmium, chromium, Cr[VI], manganese, and uranium) in the near-shore environment may present an unacceptable level of risk for one or more of the assessment endpoint entities (aquatic plants, aquatic invertebrates, amphibians, fish, and riparian/near-shore wildlife). These results are based primarily upon the comparisons of COPEC concentrations to toxicity benchmarks, measures of exposure and effects in biota, or the results of wildlife exposure analyses (RCBRA [DOE/RL-2007-21]). A summary of the evaluation of these sediment COECs is provided below:

- **Cadmium:** Detected in three of six sediment samples in the 100-F near-shore environment and all five samples in the 100-IU-2/IU-6 near-shore environment, with all concentrations below the upper threshold ESL of 5.4 mg/kg from *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* (Ecology Publication 11-09-054); thus, cadmium was not carried forward to the FS.

- **Total chromium:** Detected above the upper threshold ESL (88 mg/kg) in 1 of 11 samples from the 100-F/IU near-shore sediments collected for the RCBRA (DOE/RL-2007-21). Verification sampling[11] at the 100-F-59 waste site, conducted after completion of the RCBRA (DOE/RL-2007-21) sampling, also included nearly 60 samples, 19 of which exceeded the sediment ESL. However, as noted briefly in Section L3.4 and in greater detail in Section L4.7 (Appendix L), these samples are reflective of a terrestrial environment more than half of the year (12 of these samples exceed the terrestrial invertebrate ESL as well) but are not expected to result in community-level impacts to

[11] Verification sampling from four sub-areas (Area C, Near Waste Site, Slough Area, and North Shore Area) are depicted in Figures L-12 and L-13 of Appendix L.

benthic or terrestrial organisms. The RCBRA (DOE/RL-2007-21) samples for 100-F are described in Appendix L, Section L2 and are identified in Figures L-8 through L-11. As shown more clearly in Figure L-12, one of the RCBRA (DOE/RL-2007-21) samples (the maximum soil/sediment sample of 286 mg/kg) was collected at the southwest corner of the 100-F-59 waste site. This area is only inundated above 210 kcfs (April to August) and while identified as sediment, actually represents a soil sample from a riparian area. All five sediment samples of chromium in the 100-IU Area, all samples collected in the "100-F Slough" (much further downstream than 100-F-59) and the other five near-shore sediment samples at 100-F were detected below the lower threshold ESL. There was no correlation between chromium concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*) in the samples collected in the near-shore samples that are more regularly inundated,[12] and environmental conditions support the establishment of benthic communities. Exposure of benthic organisms where the chromium was measured above the ESL is not reflective of a high-quality habitat. From September to the end of March, this area represents a terrestrial environment, not an aquatic habitat. While some smaller and free-floating benthic species may wash into the area when river flow exceeds 210 kcfs, these aquatic species are not expected to survive once the area dries out. A resident benthic community is not present and a community cannot be supported under the current conditions. Detailed maps in Appendix L demonstrate that concentrations closest to the Columbia River were all below the ESL (88 mg/kg), suggesting that source material is not reaching the river. With source material not reaching the river, no correlation between chromium and bioassay results on sensitive species in near-shore sediment samples, and no resident community present in the only area exceeding the ESL (which is in a riparian soil environment), coupled with a unique environment that does not support establishment of a resident community, the conclusion was that no further evaluation was warranted for effects to benthic organisms. Analysis of risk to wildlife is also included in Appendix L, with a conclusion that there are no unacceptable risks based on chromium concentrations in the riparian or near-shore environment.

- **Manganese:** Detected in all 11 sediment samples in the 100-F/IU near-shore environment, with all concentrations below the screening level of 460 mg/kg published in *NOAA Screening Quick Reference Tables* (Buchman, 2008); thus, manganese was not carried forward to the FS.

Aquifer tubes were used for the RCBRA (DOE/RL-2007-21) and are still included as part of annual monitoring along with groundwater wells, although not necessarily at the same frequency. Seeps have previously been sampled by PNNL. Porewater and surface water were sampled for the RCBRA (DOE/RL-2007-21), although not specifically adjacent to the 100-FR-1 and 100-FR-2 OUs.[13] The pooled data from these events are presented in Appendix L and were used to evaluate the potential for the 100-F/IU OUs to have contributed to, or to be the likely primary sources of, porewater COECs identified in the RCBRA (DOE/RL-2007-21). The evaluation of these pore water COECs is summarized below:

- **Cr(VI):** Detected in two of three RCBRA (DOE/RL-2007-21) pore water samples in 100-IU-2/IU-6 near-shore area. Within 100-IU-2/IU-6, aquifer tube samples (1 of 12 filtered, and 2 of 25 unfiltered) exceeded the ESL (Appendix L, Table L-43). Samples collected within all of the other the 100-IU-2/IU-6 riparian and near-shore aqueous media (pore water, seep, and near-shore well samples) were below the ESL. Within the vicinity of 100-F, Cr(VI) samples were detected above the

[12] Soil form the sample detected at 286 mg/kg was not included in the benthic invertebrate bioassay testing.

[13] For the RCBRA, no porewater was collected directly adjacent to F Reactor, but one sample was collected upstream near 100-IU-2 and two samples were collected downstream in backwater sloughs at RCBRA (DOE/RL-2007-21) stations 2l and 2m.

ESL in aquifer tubes (1 of 50 filtered samples, and 4 of 50 unfiltered samples), seeps (1 of 1 sample), and near-shore groundwater wells (5 of 18 filtered samples, and 4 of 19 unfiltered samples). Concentrations appeared to be decreasing (Appendix L, Table L-37) as they approach the hyporheic zone (i.e., decreasing at the point of exposure where groundwater meets pore water). Cr(VI) within the 100-FR-3 Groundwater OU was not contributing to concentrations in the Hanford Reach of the Columbia River adjacent to or downstream from the 100-FR-3 Groundwater OU near-shore area. However, while Cr(VI) has not been determined to be an ongoing risk for aquatic communities within the area of discharge of the 100-F/IU OUs, there is some potential for groundwater discharge above AWQS at discharge points to surface water. Therefore, monitoring is recommended to ensure that ARARs are met.

- **Manganese:** Was not sampled in the pore water directly adjacent to the 100-F near-shore area for the RCBRA (DOE/RL-2007-21) but was detected in three of three pore water samples in the 100-IU-2/IU-6 near-shore area. Within the vicinity of 100-IU, only aquifer tubes (1 of 20 filtered samples, and 1 of 16 unfiltered samples) exceeded the ESL (Appendix L, Table L-43). Samples collected within all other 100-IU-2/IU-6 riparian and near-shore aqueous media (pore water, seeps, and near-shore well samples) were below the ESL. Further, within the 100-F Area, all aqueous media (groundwater, aquifer tubes, and filtered seeps) were detected below the ESL, except one of three unfiltered seeps sample. No clear patterns of manganese affecting the aquatic environment were evident, thus manganese was not carried forward into the risk characterization section or into the FS.

- **Uranium:** Was not sampled from the 100-F near-shore area pore water and was not detected in the pore water from the 100-IU-2/IU-6 near-shore area. While concentrations of uranium were elevated in one near-shore groundwater well unfiltered sample (Appendix L, Table L-37) within 100-F, all other aqueous media samples collected within the vicinity of the 100-F or 100-IU-2/IU-6 OUs were below the ESL, thus uranium was not carried forward into the FS.

The RCBRA (DOE/RL-2007-21) identified 9 of the identified 22 COPECs (arsenic, chromium, copper, lead, mercury, selenium, TPH-diesel, vanadium, and zinc) as possibly presenting some level of risk for one or more of the assessment endpoint entities (terrestrial plants and invertebrates, and riparian wildlife). This is based on soil bioassays, comparison of COPEC concentrations to plant or terrestrial invertebrate benchmarks, or the results of wildlife exposure analyses. However, conclusions were that on a River Corridor-wide basis, only six of these COPECs should be considered further (arsenic, chromium, lead, mercury, TPH-diesel, and zinc). A summary of the evaluation of these COECs is provided below.

As shown in Appendix L, Tables L-56 (plants and invertebrates) through L-58 (wildlife), concentrations of arsenic, chromium, lead, mercury, TPH-diesel, and zinc in the 100-F/IU riparian soil were all below the PRGs presented in Tables 7-3 and 7-4, except for 1 of 11 samples of chromium within 100-F. Thus, none of these soil COECs was carried forward to the FS.

The final COECs identified within the RCBRA (DOE/RL-2007-21) are included in Table 7-13. These COECs were determined for the River Corridor as a whole. The potential or likelihood for the 100-F/IU OUs to have contributed to the potential ecological risks identified for these COECs is discussed in Appendix L and summarized in the remainder of this section.

Table 7-13. Riparian, Near-Shore, and Riverine COECs from the RCBRA and CRC

| COEC | Receptors | Media | Is 100-FR-1, 100-FR-2, 100-IU-2, or 100-IU-6 a Potential Source?[c] | Is 100-FR-3 a Potential Source?[c] |
|---|---|---|---|---|
| Arsenic[a] | Terrestrial plants | Riparian soil | No | No |
| Cadmium[a] | Aquatic plants and invertebrates | Sediment | No | No |
| Chromium[a,b] | Aquatic plants and invertebrates | Sediment | No | No |
| Chromium[a] | Wildlife | Sediment | No | No |
| Chromium[a] | Terrestrial plants and invertebrates | Riparian soil | No | No |
| Cr(VI)[a,b] | Fish, aquatic invertebrates, and aquatic plants | Pore water | No | Yes |
| Cr(VI)[b] | Aquatic plants and invertebrates | Sediment | No | No |
| Lead[a] | Terrestrial plants | Riparian soil | No | No |
| Manganese[a] | Aquatic plants and invertebrates | Sediment | No | No |
| Manganese[a,b] | Aquatic plants and invertebrates | Pore water | No | No |
| Mercury[a] | Terrestrial invertebrates | Riparian soil | No | No |
| TPH–diesel[a] | Terrestrial invertebrates | Riparian soil | No | No |
| Uranium[a] | Aquatic plants and invertebrates | Groundwater/ pore water | No | No |
| Zinc[a] | Terrestrial plants, invertebrates, and kingbirds | Riparian soil | No | No |

Sources: DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment.*
DOE/RL-2010-117, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*.
a. COECs presented in Sections 8.4 and 8.5 of the RCBRA (DOE/RL-2007-21).
b. COECs presented in the executive summary of the CRC (DOE/Rl-2010-117).
c. Evaluation completed in Appendix L, Section L4.

### 7.5.2 Summary of Results and Conclusions of CRC

The CRC (DOE/RL-2010-117) included an ERA that combines both screening and baseline elements. Abiotic media were compared to screening benchmarks for surface water, sediment, and pore water to identify COECs. Soil concentrations were compared to plant and invertebrate benchmarks, while desktop food web models were used to evaluate risks to wildlife. A baseline assessment was conducted to assess risk to fish using tissue residue data. The CRC (DOE/RL-2010-117) concluded that there were nine

COECs within sediment, pore water, island soil, and shoreline sediment (aluminum, chromium, Cr[VI], lead, manganese, nickel, nitrate, selenium, and uranium) of the 100 and 300 Areas. Additional evaluation of aquatic risks in the Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C are presented in detail in Appendix L and summarized in Section 7.5.6 of this chapter. The CRC (DOE/RL-2010-117) evaluation included distinct conclusions for the reach adjacent to the 100 Area versus those for the reach adjacent to the 100-F/IU OUs. Cr(VI) and manganese were identified for pore water within the 100-F/IU OUs and chromium and Cr(VI) were identified for sediment within the 100 Areas as a whole, as presented in Table 7-13 (CRC [DOE/RL-2010-117]). The potential or likelihood for the 100-F/IU OUs to have contributed to the potential ecological risks identified for these COECs is discussed in Appendix L and summarized in the remainder of this section. The evaluation of these COECs is summarized as follows:

- **Total chromium:** Detected above the upper threshold ESL (88 mg/kg) in 3 of 123 sediment samples collected for the CRC (DOE/RL-2010-117). The CRC (DOE/RL-2010-117) samples were collected in the mid-channel area and are not marked on Figures L-8 through L-11 of Appendix L but can be found in Figures A-16 and A-17 of the CRC (DOE/RL-2010-117). Within the reach of the Columbia River to which the 100-FR-3 discharges, approximately 27 locations were sampled for shallow or shoreline sediment. As reported in the CRC (DOE/RL-2010-117), one sample that exceeded the ESL was located upstream of 100-F across from N Reactor at 122 mg/kg, a second was identified across from the White Bluffs townsite (100-IU-2) at 275 mg/kg, and one across from F Reactor at 151 mg/kg. Details of chromium in RCBRA (DOE/RL-2007-21) sediment samples are discussed in Section 7.5.1. There was no correlation between chromium concentrations in RCBRA (DOE/RL-2007-21) bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*) in the samples collected in the near-shore samples that are more regularly inundated, and environmental conditions support the establishment of benthic communities. Detailed maps in Appendix L demonstrate that concentrations closest to the Columbia River in the 100-F-59 site were all below the ESL (88 mg/kg), suggesting that source material is not reaching the river. As discussed in Section 7.5.1, the conclusion was that no further evaluation was warranted for effects of chromium in sediment to benthic organisms.

- **Cr(VI):** Detected in 31 of 117 sediment samples in the 100 Areas reach of the Columbia River as part of the CRC (DOE/RL-2010-117), with a maximum of 7.38 mg/kg. It was also detected in one of two near-shore sediment samples collected in the 100-F near-shore for the RCBRA (DOE/RL-2007-21). With no substantial toxicological data available with which to evaluate the bulk sediment measurements, this contaminant was identified as a COEC in both the RCBRA (DOE/RL-2007-21) and the CRC (DOE/RL-2010-117). Within 100-IU, aquifer tube samples (1 of 12 filtered, and 2 of 25 unfiltered) exceeded the ESL (Appendix L, Table L-43). Samples collected within all other 100-IU-2/IU-6 riparian and near-shore aqueous media (pore water, seep, and near-shore well samples) were below the ESL. As shown in Table L-37 of Appendix L, within the vicinity of 100-F, Cr(VI) samples were detected above the ESL in aquifer tubes (1 of 50 filtered samples, and 4 of 50 unfiltered samples), seeps (1 of 1 sample), and groundwater wells (5 of 18 filtered samples, and 4 of 19 unfiltered samples). Since concentrations appear to be decreasing as they approach the hyporheic zone (i.e., decreasing at the point of exposure where groundwater meets pore water), Cr(VI) was not carried forward to the FS. However, while Cr(VI) has not been determined to be an ongoing risk for aquatic communities within the area of discharge of the 100-F/IU OUs, there is some potential for groundwater discharge above AWQS at discharge points to surface water. Therefore, monitoring is recommended to ensure that ARARs are met.

- **Manganese** was identified as COEC in the CRC (DOE/RL-2010-117) based on 1 of 3 detections exceeding the LOEC ESL of 1.31 mg/L. Within the vicinity of 100-IU-2/IU-6, only aquifer tubes (1

of 20 filtered samples, and 1 of 16 unfiltered samples) exceeded the ESL (Appendix L, Table L-43). Samples collected within all other 100-IU-2/IU-6 riparian and near-shore aqueous media (pore water, seeps, and near-shore well samples) were below the ESL. Further, within the reach of the Columbia River to which the 100-FR-3 discharges, all aqueous media (groundwater, aquifer tubes, and filtered seeps) were detected below the ESL, except one of three unfiltered seep samples. Therefore, manganese was not carried forward into the risk characterization section or into the FS.

### 7.5.3 100-F/IU River Effluent Pipeline Investigations

During operations, water used in fuel production to cool the reactors was discharged to the Columbia River via effluent pipelines. The release of this cooling water ended when the associated reactors and facilities were shut down. Today, one inactive 100-F effluent pipeline remains in its original location in the Columbia River channel. Past characterization efforts obtained samples of the river effluent pipelines from the 100-BC, 100-D, and 100-F Areas. Characterization data collected during the river pipeline evaluations were used to evaluate potential risks from contaminants within the pipelines. The RCBRA (DOE/RL-2007-21) provided a summary of the previous characterization efforts and risk assessment for these pipelines in Section 8.2.2.

In 1984, *River Discharge Lines Characterization Report* (UNI-3262) discussed samples of scale (flakes of mostly rust) from the interior surfaces and enclosed sediment of the effluent pipelines from the C, DR, and F Reactors. The pipelines were also visually inspected underwater by a diver, and their positions and physical conditions were assessed. Samples of scale and sediment were analyzed for radionuclides, and the major radionuclides detected included cobalt-60, cesium-137, europium-152, europium-154, and europium-155. Radionuclide concentrations were greater in the scale than in the sediment. Direct beta-gamma radiation measurements were also obtained for interior and exterior pipe surfaces. The dose rates measured for direct contact with the interior of the pipe surfaces were less than 1 mrem/hr, and readings on the exterior were below the instrument's detection capability. Because the half-lives of all of these radionuclides are less than 30 years, the activity levels have declined by a factor of two to five. These radionuclides are no longer expected to be ecological risk drivers.

In 1994, a comprehensive geophysical survey (*Columbia River Effluent Pipeline Survey* [WHC-SD-EN-TI-278]) located and mapped the reactor effluent pipelines. The study relied mainly on remote-sensing geophysical techniques, including navigation and echo sounding, side-scanning radar, sub-bottom profiling, seismic reflection profiling, and ground-penetrating radar. The results indicated that the pipelines have neither broken loose nor moved from their original locations. However, portions of some pipelines are no longer buried.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D Areas were sampled and physically characterized using a robotic transporter (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (*River Discharge Lines Characterization Report* [UNI-3262]) and were expected to represent worst-case conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the B and D/DR Reactors.

The analytical results from the 1984 and 1995 effluent pipeline characterization studies at the B, C, D/DR, and F Reactors may reasonably be applied to effluent pipelines in 100-F/IU, because operations among these reactors were similar. Evaluations of human health and ecological risk have been performed for the river effluent pipelines (as they are today) located on or beneath the river channel bottom, and for a scenario in which a pipeline section breaks away from the main pipeline and is washed onto the shore of the river. Both the 1996 risk assessment effort (*100 Area River Effluent Pipelines Characterization*

*Report* [BHI-00538]) and the 1998 risk assessment effort (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) relied on data collected from the 1984 and 1995 characterization work. The evaluation of human health and ecological risk performed in 1998 (BHI-01141) concluded that the concentrations of chromium and mercury in the scale and sediment within the pipelines pose minimal ecological risk, because they have been in contact with river water without dissolving since the reactors were shut down. *100 Area River Effluent Pipelines Risk Assessment* (BHI-01141) results indicated that pipelines present no unacceptable risks and, therefore, no remediation requirements under CERCLA. This is supported by the following:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations due to decay
- Inaccessible location
- Unavailability of significant contaminants to affect HHE

Accordingly, no further action is considered for below river effluent pipeline waste sites 100-F-39 in this RI/FS.

### 7.5.4 Summary of the Evaluation of Riparian Soil

The RCBRA (DOE/RL-2007-21) evaluated ecological risks at representative riparian study sites located adjacent to, or where they may be directly affected by, known contaminated media (groundwater, seeps, soil, or sediment). The RCBRA (DOE/RL-2007-21) concluded that six COECs identified for the riparian environment (arsenic, chromium, lead, mercury, zinc, and TPH-diesel) may present an unacceptable level of risk to one or more of the assessment endpoint entities based on soil bioassays, comparison of COPEC concentrations to plant or terrestrial invertebrate toxicity benchmarks, or the results of wildlife exposure analyses. The CRC (DOE/RL-2010-117) did not identify any risks to terrestrial plants, invertebrates, or wildlife from exposure to island and riparian soil.

Most concentrations detected in riparian soil within the 100-F/IU OUs fell below ESLs (in this case, specifically the SSLs) described previously. Except for aluminum, chromium, and copper, all other detections were below PRGs within the 100-F/IU Areas (Appendix L, Tables L-56 through L-58). Those chemicals below PRGs do not warrant further evaluation in the FS. Aluminum, chromium, and copper are discussed in Section 7.5.4.3.

Unremediated waste sites in the riparian area were not evaluated in this analysis. Because those sites (listed in Table 8-6) have similar histories to the sites currently evaluated, the predicted outcomes are anticipated to be similar as well. Some unremediated waste sites may have exceedances of PRGs, which would provide the basis for remedial action or further evaluation. Additional discussion is provided in Section 7.6.2.

#### *7.5.4.1 Risks to Terrestrial Plants in the Riparian Area*

Measurements of all chemicals within the riparian soil of the 100-F/IU OUs were below plant ESLs, except one occurrence of copper in the 100-F riparian area (Appendix L, Tables L-52, L-53, and L-56). One exceedance of the ESL out of 11 samples, at an HQ of 1.07, does not constitute a risk warranting remedial action. Likewise, the CRC (DOE/RL-2010-117) did not identify any risks to terrestrial plants from exposure to island and riparian soil. Therefore, no COPECs in 100-F riparian soil warrant further evaluation in the FS based on risks to terrestrial plants. This finding is also supported by the results of several biological measures collected as part of the RCBRA (DOE/RL-2007-21), including plant bioassays on Sandberg's bluegrass (*Poa secunda*) and plant tissue testing. Though these lines of evidence carry less weight given their more limited datasets and temporal variability (i.e., they were conducted just

once), the results do support the same conclusion. There were no significant correlations with chemicals and bioassay measures, and there were no significant correlations between soil chemistry and plant tissue measurements.

#### 7.5.4.2 Risks to Terrestrial Invertebrates in the Riparian Area

Concentrations of chromium, copper, mercury, and zinc exceeded RCBRA benchmarks protective of terrestrial invertebrates in the 100-F/IU riparian soil study area (2j, 2l, 3b, 4a, and Rip7) (RCBRA [DOE/RL-2007-21], Table 5-70). Chromium and copper each had 1 of 11 samples that exceeded Hanford Site-specific PRGs protective of terrestrial invertebrates (Appendix L, Table L-56). An additional 12 of 60 verification samples collected in and around the 100-F-59 waste site also exceeded the chromium PRG but are not expected to result in community-level impacts (details are found in Section L4.7 of Appendix L). Even with an exceedance in one or two samples, ample unimpacted habitat for terrestrial invertebrates is available in the adjacent area and along the River Corridor. The CRC (DOE/RL-2010-117) did not identify any risks to terrestrial invertebrates from exposure to island and riparian soil. Based on this analysis, no COPECs in riparian soil for terrestrial invertebrates warrant further evaluation in the FS based on risks to terrestrial invertebrates.

Terrestrial invertebrate tissue concentrations, which provide an indication of contaminant uptake and bioavailability, were measured at riparian study sites and reference locations and some, but not all, chemicals were detected in terrestrial invertebrates. Statistical differences were found between terrestrial invertebrate tissue concentrations for certain chemicals between riparian study sites and reference sites. However, this line of evidence was ranked low because of the lack of detections in invertebrate tissue for certain riparian chemicals and the possibility of bias due to sample collection methods. Statistical differences in tissue concentrations of mercury and zinc in terrestrial invertebrates were noted between River Corridor and reference study sites; this relationship is based on data across the entire River Corridor and should not be inferred as a relationship that is specific for the 100-F/IU Areas. However, there is insufficient evidence of a correlation for chemicals between tissue concentrations in terrestrial invertebrates and concentrations in soil (RCBRA [DOE/RL-2007-21]).

#### 7.5.4.3 Risk to Wildlife in the Riparian Area

Risk to wildlife in the riparian area was evaluated in the RCBRA (DOE/RL-2007-21) using both field measures and desktop food web modeling, employing similar models to those described in this ERA for SSLs. A separate desktop food web evaluation was included in this ERA using the SSLs and PRGs presented in Tables 7-2 and 7-3. Results of all three of these analyses are described below. The results all suggest that there is no risk to wildlife in the riparian soil of the 100-F/IU OUs.

For riparian soil, field ecological measures of the small mammal community were developed as qualitative information on the status of these populations. Estimated dietary contaminant exposures and chemical concentrations in bird or small mammal tissues were compared to ecological effect levels established for dietary ingestion or related to tissue residues. For selected chemicals (cadmium, chromium, lead, selenium, and PCBs), measured tissue concentrations in small mammals trapped in study sites were not greater than reference areas (RCBRA [DOE/RL-2007-21], Table 5-48), and were less than available tissue effect levels (RCBRA [DOE/RL-2007-21], page 5-91).

Dietary exposure to terrestrial birds and mammals estimated using wildlife exposure models and riparian soil concentrations across the River Corridor indicated potential exposure higher than LOAEL-based SSL values for copper, selenium, vanadium, and zinc (RCBRA [DOE/RL-2007-21], Section 8.4.1.3). Only zinc was identified as a final COEC for riparian soil exposure to birds and mammals. However, with the exception of zinc, concentrations of these four metals in soil in 100-F/IU fall within Hanford Sitewide background and, therefore, should not warrant further evaluation in the FS. Zinc concentrations in

100-F/IU riparian soil were compared to the Hanford Site PRGs, as shown in Appendix L, Tables L-54 and L-55. The results from this comparison show that all zinc concentrations fell below the PRG. Therefore, zinc concentrations in riparian soil do not warrant further evaluation in the FS based on risks to wildlife.

Most concentrations detected in riparian soil within the 100-F/IU areas fell below SSLs and PRGs. ESL results showed that only aluminum within riparian soil had concentrations above wildlife ESLs within the 100-F/IU OUs (Appendix L, Section L.4.5 and Tables L-57 and L-58). However, aluminum was not identified as a COEC in the RCBRA (DOE/RL-2007-21). Aluminum does not warrant further evaluation in the FS. Aluminum was detected below background and is not bioavailable or considered toxic to wildlife at pH levels above 5.5 like those found in the 100-F/IU riparian areas; therefore, aluminum concentrations is soil do not warrant further evaluation in the FS based on risk to wildlife.

A separate discussion of potential risks to wildlife feeding in the area of the 100-F-59 waste site, including bufflehead, is provided in Appendix L, Section L.4.7. The same conclusions were drawn, and no unacceptable risks were identified.

### 7.5.5 Summary of Evaluation of Near-Shore and Columbia River

The results from the evaluation in Appendix L showed that inorganic, organic, and radiological contaminants detected in near-river groundwater samples collected from the 100-FR-3 OU are not affecting the aquatic life exposed to pore water, surface water, or sediment in the Columbia River near the 100-F/IU OUs.[14] Numerous lines of evidence were considered as part of the evaluation. The evidence included, but was not limited to, the comparison of aquatic media (aquifer tube, pore water, spring/seep, and surface water) in the riparian and near-shore areas to ESLs, data quality, temporal significance, correlations (or the lack thereof) with chemistry, and observed responses in the bioassays and reference data. In general, data quality issues such as presence of contamination in blank samples, elevated detection limits relative to the criteria in wells not nearest to the river, and the use of unfiltered data (potentially overestimating exposure) indicate that data may overestimate risks initially identified through aquatic criteria comparisons.

Although the biological measures collected do not represent all seasonal conditions and river-stage fluctuations, the results of pore water bioassays on aquatic invertebrates and amphibians also suggest little or no correlation between COPEC concentrations and observed responses in the bioassays. At many stations, the responses were no different from, or were better than, those of upstream references. Benthic invertebrate community structure data also suggest no differences between reference sites and locations adjacent to the Hanford Site. The results from this analysis confirm the results from the evaluation presented in Appendix L; no COECs are affecting aquatic life exposed to pore water or surface water in the Columbia River near the 100-F/IU OUs.

#### *7.5.5.1 Risk to Fish*

No COECs in the RCBRA (DOE/RL-2007-21) or CRC (DOE/RL-2010-117) were identified for surface water exposures to fish.

Pore water concentrations at study sites were greater than the water standards or criteria for Cr(VI) (RCBRA [DOE/RL-2007-21], Section 8.5.1.4). The CRC (DOE/RL-2010-117) also indicated

[14] Both filtered and unfiltered water sample results were evaluated in the RCBRA (DOE/RL-2007-21). In some cases, the toxicity information or standards/criteria are based on dissolved metals concentrations (filtered samples). Therefore, exposure and the potential for risk from metals may be overestimated by using the unfiltered (or total metals) concentrations.

exceedances of the water quality criteria for Cr(VI) and the risk-based Tier 2 chronic value[15] for manganese in 100-F/IU pore water samples. These values are not necessarily indicative of risks to fish, because these screening values are based on water quality or plant or invertebrate risk. Most other lines of evidence suggest that there is no unacceptable risk to fish in the Columbia River. As described in Section 7.5.1 and in Appendix L (Section L.4), with the exception of Cr(VI), these chemicals are not found in near-shore groundwater. Therefore, there is no source for these COECs from the 100-FR-3 OU.

In general, across the River Corridor, fish were smaller (in length and mass) at study sites relative to reference sites. However, many factors either confound or contribute to the size of fish captured, such as fishing pressure or ease of capture of the target-size range. Correlation with capture size, chemical concentration, or any other factor (e.g., habitat and nutrient availability) was not possible since it was not considered as part of the original study design. There were no strong trends in fish histopathological observations between those collected at study sites and those from reference site locations. No tissue COPECs were correlated with histopathological endpoints associated with adverse effects at study sites. No exceedances of tissue effects levels for near-shore aquatic COPECs were measured in fish tissue. In addition, evidence of greater contaminant uptake in fish from study sites was not apparent for most COPECs and tissues.

For the 100-FR-3 OU, COPECs detected in pore water above AWQC do not appear to be issues in groundwater or aquifer tubes, suggesting that the 100-FR-3 Groundwater OU is not the source of observed elevated concentrations. More detailed discussion of the exceedances for additional chemicals is provided in Appendix L. In general, exceedances of AWQC for chemicals within various aquatic media (pore water, seeps, aquifer tubes, groundwater, surface water) were either anomalous (i.e., very low frequency) or due to various laboratory reporting issues.

#### *7.5.5.2 Risks to Aquatic Plants*

Potential effects on aquatic plants were evaluated through results of a bioassay in sediment and comparison of sediment and pore water concentrations to SSLs (RCBRA [DOE/RL-2007-21], Tables 6-88 through 6-91). Based on the combined pore water and sediment concentrations, the RCBRA identified cadmium, chromium, Cr(VI), manganese, and uranium as COECs warranting further evaluation for potential effects on aquatic plants (DOE/RL-2007-21, Section 8.5.1.1). The CRC (DOE/RL-2010-117) identified the final COECs for pore water and sediment within the 100-FR-3 OU and 100 Areas as Cr(VI), chromium, and manganese. For the 100-F/IU Area near-shore sampling sites, antimony and chromium were detected at concentrations greater than the upper threshold sediment biota ESL (Appendix L, Tables L-66 and L-68) and aluminum pore water concentrations were greater than the chronic AWQC (Appendix L, Table L-22). Sediment COPECs/COECs are discussed in more detail below regarding risks to aquatic invertebrates and in more detail in Appendix L, with the conclusion that, with the exception of total chromium within 100-F, observed sediment concentrations are below upper thresholds ESLs and do not warrant further evaluation. Pore water COPECs from the 100-F/IU near-shore sampling sites are discussed in more detail in Appendix L, Section L.4.2, which concluded that, with the exception of Cr(VI), concentrations in the pore water were not at levels warranting additional evaluation in the FS. While Cr(VI) has not been determined to be an ongoing risk for aquatic communities in the 100-F/IU OUs, there is some potential for groundwater discharge above AWQS at discharge points to surface water. Therefore, monitoring is recommended to ensure that ARARs are met.

[15] This refers to an aquatic toxicity value and matches that used in the CRC (DOE/RL-2010-117) and RCBRA (DOE/RL-2007-21), and is presented in Appendix L, Table L-3. The source is *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota* (ES/ER/TM-96/R2).

Laboratory bioassays (i.e., toxicity tests) were conducted with field-collected sediments. Some significant relationships were determined with observed responses within aquatic plant toxicity tests in association with confounding factors and some chemicals. Additionally, clear measures of exposure (i.e. accumulation into plants), primarily for inorganic chemicals, were detected in pore water and sediment. However, of the significant relationships determined, none was with chemicals for which pore water concentrations were greater than aquatic plant benchmarks. Further, no risks to aquatic plants were noted based on toxicity testing.

#### 7.5.5.3 Risks to Aquatic Invertebrates

The primary lines of evidence used to evaluate risks to aquatic invertebrates are field surveys, the results of bioassays, and comparison of sediment and water concentrations to ESLs.

*Abiotic Media Concentrations Compared to Literature Values.* The final COECs for pore water in the CRC (DOE/RL-2010-117) within the 100-F/IU OUs were identified as Cr(VI) and manganese. Pore water concentrations at study sites across the Hanford Reach were greater than chronic water standards or criteria for three COECs (Cr[VI], manganese, and uranium; RCBRA [DOE/RL-2007-21], Section 8.5.1.1). However, there are significant uncertainties relative to many of the conclusions based on pore water sampling. Further, all of these abiotic measurements represent a single-point measurement within a dynamic river system with daily and seasonal fluctuations, and flow volumes that can shift the composition of the substrates that were sampled. Exceedances should not be ignored, as they can be indicative of exposure an levels presenting a risk. However, because of the uncertainty in the representativeness of the measurements due to the dynamic environment, the exceedances should be considered along with other data that identifies whether there is, in fact, an ongoing source of the measurements. This analysis is presented in Appendix L. The interpretation of pore water results as an indication of adverse effects to aquatic invertebrates is the same as that for aquatic plants. Given that the ESLs are protective of both plants and aquatic invertebrates, no COPECs represent a potential source for pore water, and no further evaluation is required.

For the River Corridor as a whole, sediment COECs (cadmium, chromium, and manganese) suggest a potential for adverse effects (RCBRA [DOE/RL-2007-21], Section 8.5.1.2). Chromium and Cr(VI) sediment COECs were also identified for the 100 Areas as a whole in the CRC (DOE/RL-2010-117). For sediment samples collected within the 100-F/IU near-shore (Appendix L, Tables L-66 and L-68), concentrations were greater than the upper threshold ESL for antimony and chromium.

Given the uncertainty with representativeness mentioned above, a more detailed discussion of each of these five COECs in 100-F/IU Area near-shore sediment is presented in Appendix L. The conclusions were that there is no clear source of antimony, cadmium, or manganese from the 100-F/IU OUs or the 100-FR-3 Groundwater OU. Concentrations of most Hanford Reach sediment COECs are either below ESLs or below reference in the 100-F/IU area near-shore environment (explanations for the exceptions are described in Appendix L). This suggests that sediments upstream from the Hanford Site potentially contribute to concentrations observed in the 100-F/IU Area near-shore sediments. Further, riparian soil for most of the COECs are lower than upstream sediment and Hanford Site reference soil concentrations, suggesting that the riparian soil in the 100-F/IU Area is not a source of the observed sediment concentrations for the COECs identified.

Concentrations of chromium are elevated in one waste site within the riparian area (100-F-59, formerly Area C of 128-F-2). However, as described above in Sections 7.5.1 and 7.5.2 and in more detail in Section L.4 of Appendix L, the concentrations do not represent an unacceptable risk. The area where concentrations exceed sediment benchmarks is a unique environment that is dry 7 months of the year and only seasonally inundated when river stage exceeds 210 kcfs. A significant benthic community is not

present and cannot survive under the existing conditions. Detailed maps in Appendix L demonstrate that concentrations closest to the river are all below the ESL (88 mg/kg) suggesting that source material is not reaching the river.

Biological measures such as amphipod bioassays, clam tubes, and community surveys from rock baskets show no clear indication of toxicity or correlation of response with COEC concentrations observed in the near-shore environment found at the 100-F, 100-IU-2, and 100-IU-6 areas. Although they do represent only a snapshot in time and do not represent all seasonal conditions and river-stage fluctuations, these measures do support the analysis that Hanford Site operations at 100-F/IU Area are not adversely affecting aquatic receptors exposed to sediment in the 100-F/IU Area near-shore environment. Based on these findings, no further evaluation is warranted in the FS to address sediment contaminants near the 100-F/IU OUs.

*Direct Toxicity Measures.* Risks to aquatic macroinvertebrates based on toxicity testing showed some relationships with confounding factors and some chemicals. Histopathology measures differed in study sites compared to reference sites; these measures also showed some negative relationships with chemicals. Sediment bioassays representing 100-F/IU showed statistical difference in amphipod (*Hyalella azteca*) survival relative to reference sites at 2j and 2l, and 4c (low survival and growth) (RCBRA [DOE/RL-2007-21]; Section 6.3.5.2 and Table 6-105). However, there was no overall correlation between amphipods and chemistry data, with the exception of mercury.[16] Correlation between abiotic media chemistry and any observed differences in measured effects from bioassays was conducted across the whole Hanford Reach, instead of at individual OU areas. Across the Hanford Reach, mercury was the only chemical with a significant correlation that showed a potential negative effect with a significant regression for amphipods in sediment (RCBRA [DOE/RL-2007-21]; Table 6-104); however, mercury was below sediment ESLs at the 100-F/IU study sites. Clams were also monitored for survival. There was a statistical decrease in survival at study sites compared to reference sites, but there was no correlation of clam survival with COPECs. Together these measures do not indicate that substrate concentrations were toxic. However, they do represent only a snapshot in time and do not represent all seasonal conditions and river-stage fluctuations.

*Community Structure Measures.* Key community metrics do not suggest that contaminant-related impacts to benthic macroinvertebrates are indicate in aquatic study sites as a group, as evident by the comparison of EPT (Ephemeroptera, Plecotera, and Trichoptera) data from study sites relative to reference sites. Most of the aquatic community measures did not differ between the study sites and reference sites. There were exceptions among the large number of aquatic community measures evaluated, but the agreement among measures was weak and the biological significance to populations is not evident.

*Measures of Exposure.* Within the RCBRA (DOE/RL-2007-21), clear measures of exposure (accumulation), primarily for inorganic COPECs, were detected in water, sediment, and tissues. However, as shown in the RCBRA (DOE/RL-2007-21), there were no statistically significant correlations between COPEC concentrations in pore water or sediment with tissues of aquatic organisms, indicating a lack of significant COPEC bioaccumulation. Further, no tissue effect levels for COPECs in invertebrate tissue were exceeded.

[16] Sediment bioassays were not conducted on the sample measured at 286 mg/kg or 190 mg/kg. However, as explained in detail in Appendix L, these samples were collected in the vicinity 100-F-59 in an area that is dry more than half of the year, at a location where environmental conditions will not support establishment of a benthic community.

Most histopathology measures of clams and mussels showed no significant differences between study and reference sites. While some exceptions were noted, COPEC concentrations generally did not correlate with differences in histopathology measures.

*Weight of Evidence.* As stated previously, both the abiotic and biotic measures collected for the RCBRA (DOE/RL-2007-21) represent only a snapshot in time and do not represent all seasonal conditions and river-stage fluctuations. Abiotic measurements do exceed literature-based screening values for some COPECs. Generally, this line of evidence is given the lowest weight given the lack of site specificity in the literature-based values. Although biological measures give a different perspective than the chemistry, given the limited dataset and the uncertainty with full representation of seasonal measurements, the results of the chemistry cannot be ignored.

Of the key groundwater plume contaminants investigated, none of the contaminants has been detected at concentrations of ecological relevance in the near-shore environment for the 100-F/IU OUs decision area. However, while Cr(VI) has not been determined to be an ongoing risk for aquatic communities in the 100-F/IU OUs, there is some potential for groundwater discharge above AWQS at discharge points to surface water. Therefore, monitoring is recommended to ensure that ARARs are met.

#### *7.5.5.4 Risk to Near-Shore Wildlife*

The RCBRA (DOE/RL-2007-21) evaluated risk to middle trophic level wildlife, including the kingbird, mink, and bufflehead. Risks to wildlife in the near-shore environment are primarily from ingestion of prey consisting of aquatic invertebrates, clams, and fish, and from incidental ingestion of sediment. Only chromium risk to bufflehead at one study site represented a risk within the 100-F/IU near-shore environment. Although chromium exposures are greater than the LOAEL, and sediment and pore water concentrations are statistically greater than reference, it does not necessarily indicate risk to populations of wintering bufflehead or other waterfowl found near the site.

Scatterplots (Attachment L-1) of paired sediment and benthic invertebrate chromium data (Appendix L, Table L-69) from the RCBRA (DOE/RL-2007-21) showed a single observation falling outside the distribution of the other observations. An outlier test was therefore performed to determine whether this sample was a statistical outlier. Grubb's test was performed on the tissue and sediment chromium data and on the station-specific BAFs (Appendix L, Table L-70). Chromium in tissue and the associated BAF for the samples from the 2m location were statistically identified as outliers; chromium in sediment from this location was not identified as an outlier. This indicates that chromium concentrations in tissue but not sediment from 2m are anomalous and unrepresentative of tissue concentrations of chromium observed at the other 34 sample locations for which collocated tissue and sediment data are available. Exclusion of sample 2m from the wildlife exposure calculations results in no point estimates for the bufflehead above the LOAEL (RCBRA [DOE/RL-2007-21); Table 6-124).

In addition to chromium in the clam tissue sample from 2m being an outlier, the risk estimate for the bufflehead was calculated with several conservative assumptions, which may not be realistic. First, the LOAEL of 1.2 represented a point estimate for sample 2m collected in the backwater slough downstream of the 100-F/IU OUs and assumes that all foraging would occur in this area, or at least in areas with a similar concentration. However, it is very unlikely that ducks will be foraging exclusively in this one backwater slough. Further, detected concentrations of chromium in benthic invertebrate tissue samples from many other areas up and downstream on the Columbia River were much lower (Appendix L Table L-69). In addition, several studies have shown that chromium ingested by wildlife is not readily assimilated (absorbed) and, thus, the majority is excreted. As summarized in "Bioaccumulation and Toxicology of Chromium: Implications for Wildlife" (Outridge and Scheuhammer, 1993), gastrointestinal uptake of Cr(VI) is 2 to 10 percent of the presented dose, compared with 0.5 to 3 percent for Cr(III)

(*Handbook on the Toxicology or Metals* ["Chromium," Langard and Norseth, 1979]; "Chromium Intake, Absorption and Excretion of Subjects Consuming Self-Selected Diets" [Anderson and Kozlovsky, 1985]; "Effects of Chromium Supplementation on Urinary Cr Excretion of Human Subjects and Correlation of Cr Excretion with Selected Clinical Parameters" [Anderson et al., 1983]; "Experimental Study of Adsorportion, Distribution and Excretion of Trivalent and Hexavalent Chromium" [Ogawa, 1976]; and "Chromium" [EPA, 1988]). The HQ of 1.2 represents the ratio of ingested dose to the TRV without accounting for differences in assimilation from the laboratory study used to establish the TRV versus the modeled diet of the bufflehead, which included a clam tube sample measured at 15.4 mg/kg fresh weight. Assimilation of chromium in a spiked laboratory food may be more readily absorbed than chromium bound within the tissue of ingested clam. While not applied to the entire ingestion dose, the EPA has previously used absorption factors within an ERA to account for the assimilation of chromium from incidentally ingested soil. The risk assessment for the Tex Tin site assumed that only 6 percent of incidentally ingested soil and sediment was absorbed, thus reducing the incidental ingestion dose by multiplying by a gut absorption factor of 0.06 (*Final Report Tex Tin Site Texas City, Texas* [EPA, 1997]). Given the low level of risk originally identified in the RCBRA (DOE/RL-2007-21) by just one point estimate from the Hanford Reach of the Columbia River, as well as the results of the additional data evaluation presented above and in Appendix L, Section L.4.7, risk to omnivorous waterfowl from chromium concentrations in sediment and aquatic prey from the Hanford Reach is considered unlikely.

### 7.5.6 Summary of the Evaluation of Aquatic Risks in the Near Waste Site, Slough Area, Northern Shore, and 100-F-59 (Formerly 128-F2 Area C)

The area in and around the former 128-F-2 Burn Pit and the 100-F-59 Area C represents unique conditions that warrant special consideration and evaluation. The 128-F-2 Burn Pit site was excavated and backfilled with 36 cm (12 in.) of gravel. Concentrations of verification samples indicated that the inland-most portion of the burn pit site that abuts a steep cliff were sufficiently low to meet remediation goals, but the samples in the proportion closer to the Columbia River were not (*Remaining Sites Verification Package for the 128-F-2, 100-F Burning Pit Waste Site* [WSRF 2008-031]). Hence, the riparian portion abutting the Columbia River was assigned a new waste site status as 100-F-59. Additional verification samples were collected downstream of the 100-F-59 site boundary in a slough area and an area known as the Northern Shore. These areas are all identified in Appendix L, Figures L-12 and L-13.

The Near Waste Site, Slough Area, Northern Shore Area, and 128-F-2 Area C are located within or adjacent to the 100-F-59 waste site. While these areas were initially classified as soil, the areas are inundated from river-stage fluctuations. To address the potential for adverse effects to aquatic life during periods of inundation, when aquatic life could be exposed to constituents in this riparian sediment, an assessment of risk to benthic organisms was completed. Data were evaluated separately from the riparian sediment evaluation in Appendix L because data for these areas are within a waste site unit and may contain source material, while other sediment data were collected from within the Columbia River. The analysis included terrestrial receptors because the site is dry more than half of the year. The analysis on aquatic invertebrates (primarily benthic invertebrates) was also included because these organisms are opportunistic and the most likely to use the riparian habitats during the relatively short periods of surface water inundation. Furthermore, aquatic invertebrates generally have limited mobility and, therefore, provide a conservative indication of the potential for adverse effects to aquatic life. However, as is described above in Sections 7.5.1 and 7.5.2, this scenario is unrealistic, as no community is present and the unique environmental conditions do not support survival of a benthic community.

This iterative evaluation was completed (Section L4.7 of Appendix L) for the four separate riparian areas along the Columbia River: Near Waste Site, Slough Area, Northern Shore, and 100-F-59 Area C. The benthic invertebrate evaluation included the comparison of site data to sediment ESLs, to the range of

RCBRA (DOE/RL-2010-21) riparian reference soil and sediment concentrations (comparison to range of reference concentrations), Columbia River background sediment concentrations (comparison to 95 percent UCL concentration), and background soil concentrations (comparison to maximum reference concentration) (RCBRA [DOE/RL-2010-21]). The analytes detected above sediment ESLs, background, and reference concentrations were further evaluated for their potential to adversely affect ecological receptors by estimating and evaluating chemical concentrations in pore water and comparing those estimated concentrations to surface water ESLs established for the protection of aquatic life. The evaluation concluded that there were no unacceptable risks in the riparian environments for the Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C waste sites. Therefore, no further aquatic evaluation is warranted in the FS.

For the evaluation of the areas in a terrestrial environment, data were compared to SSLs and PRGs with the conclusion that there were no unacceptable risks. No EPCs exceeded plant PRGs, and only chromium exceeded the invertebrate PRG. However, the PRG is a NOEC with no corresponding LOEC (e.g., the highest concentration tested form Hanford Soils has shown no risk). Chromium, vanadium, and bis(2-ethylhexly) phthalate exceeded PRGs for the killdeer. Additional refined exposure models were developed for these three chemicals, demonstrating that there are no significant risks to insectivorous birds at the waste site.

Risk to waterfowl were also considered by developing exposure dose models for the bufflehead (assumed to be eating benthic organisms) and mallard. Site-specific data were used to the extent possible. The same chemicals (chromium, vanadium, and bis[2-ethylhexly] phthalate) exceeded PRGs. Refined models were developed with the same conclusions, indicating there are no significant risks to waterfowl that may forage at the waste site.

### 7.5.7 Conclusions

Table 7-13 presents the 10 COECs identified by the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) in the riparian and near-shore media. For each COEC, RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) abiotic media data (soil, sediment, groundwater, pore water, aquifer tubes, seeps, and surface water) from reference areas, upstream sources, and onsite riparian and near-shore areas are presented and discussed in Appendix L to establish the likelihood that 100-F/IU was the source of the COECs identified. However, while Cr(VI) has not been determined to be an ongoing risk for aquatic communities within the area of discharge of the 100-F/IU OUs, there is some potential for groundwater discharge above ambient water quality standards at discharge points to surface water. Therefore, monitoring is recommended to ensure that ARARs are met. Potential sources other than Hanford Site operations are summarized in the RCBRA (DOE/RL-2007-21) and the CRC (DOE/RL-2010-117).

In addition, riparian soil located within the Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C waste sites were evaluated as sediment for those periods when the sites are inundated, and as soil for periods when the sites were not inundated with water. No chemicals in soil/sediment represent an unacceptable risk to aquatic invertebrates, plants, or wildlife; therefore, no further evaluation is warranted in the FS.

## 7.6 Risk Conclusions and Scientific Management Decision Point

One or more COPCs from the RCBRA (DOE/RL-2007-21) were identified in 23, 2, and 8 source OUs or waste sites for 100-F, 100-IU-2, and 100-IU-6, respectively, which had been reclassified as "interim closed" or "no action." RCBRA (DOE/RL-2007-21) COPCs were evaluated in this ERA for each decision unit (e.g., shallow, shallow-focused, and overburden) at each waste site by comparing the EPCs to the plant/invertebrate SSL, the wildlife SSL, background, the plants/invertebrates PRG, and wildlife

PRG values. Analytes that exceeded an SSL, background, and a PRG were considered COPECs. Within the 100-F, 100-IU-2, and 100-IU-6, 33 waste sites were identified for additional consideration in this SMDP based on concentrations of 13 COPECs (arsenic, barium, boron, copper, dieldrin, lead, mercury, molybdenum, nickel, selenium, silver, vanadium, and zinc).

At the SMDP, the results of the ERA were considered in the context of other factors (e.g., spatial coverage, data, chemical specifics, receptors at risk, and confidence in PRGs) to support recommendations on the COECs. This included agreement on the assessment endpoints, representative receptors, and complete exposure pathways that correspond to those COECs. The final recommendation for the SMDP is a conclusion that there were no unacceptable risks to terrestrial ecological receptors.

As part of the assessment of contributions to ecological risks identified in the riparian and near-shore environments of the Columbia River (RCBRA [DOE/RL-2007-21]) and the main channel, far-shore and island environment of the Columbia River in the CRC (DOE/RL-2010-117), one chemical is recommended for further evaluation in the FS. Cr(VI) has some limited potential to discharge to surface water above AWQS; thus, it is recommended to be monitored at discharge points to surface water.

### 7.6.1 SMDP Considerations

Within the process for conducting ERAs at CERCLA sites, several decision points occur at which risk managers, risk assessors, and other stakeholders can provide input on a path forward with respect to ecological risk associated with a site. Typical variations include the following risk assessment outcomes:

- No unacceptable potential risks to ecological receptors (e.g., risks are sufficiently low and below risk-based thresholds such as SSLs or PRGs)
- Potential for risks to ecological receptors, but the risks do not warrant the evaluation of remedial alternatives in the FS due to a number of considerations[17]
- Potential for risks to ecological receptors, but there is uncertainty in one or more components of the ERA that warrants the evaluation of remedial alternatives in the FS
- Need to evaluate remedial alternatives in the FS based on the protection of another receptor or exposure pathway (e.g., human health) that would address any potential ecological risks
- Potential for risk to ecological receptors warranting evaluation of remedial alternatives in the FS

With the various risk assessment outcomes listed above, agreement is needed on the following elements to assist in the evaluation of remedial alternatives in the FS: the COCs, assessment endpoints, exposure pathways, and risk questions. To confidently achieve one of the risk assessment outcomes, a number of factors and supporting information were considered in the conclusion of the risk assessment to assist risk management decisions. These outcomes were considered within the context of other exposure pathways and receptors evaluated at the same site. Factors that were considered to interpret the results of the risk characterization and determine whether the site requires evaluation of remedial alternatives in the FS included the following:

- Spatial characteristics of the remediated waste site (area and excavation depth of the remediated waste site)

[17] For example, a wildlife risk for a specific contaminant was driven by an estimated exposure to a badger but the size of the site is 20 $m^2$, representing a minimal portion of the total required foraging area for a badger and the site does not represent a preferential feeding area.

- Proximity and size of nearby unremediated waste sites and unimpacted habitat
- Number and location of samples collected at the site
- Data quality (presence of qualifiers, adequacy of detection limits)
- Frequency that risk-based thresholds are exceeded and the location(s) of those exceedances
- Chemical-specific properties of each COC (e.g., does it have the potential to biomagnify in the food web or is it persistent in the environment)
- Identification of specific receptors that have the potential for adverse health effects (feeding guild [plants, insects, or omnivorous, herbivorous, insectivorous, or carnivorous wildlife], proportion of receptors affected, likelihood of population- or community-level effects, and home range of the receptors at risk relative to the area exceeding risk-based thresholds)
- Recalculation of the EPC based on the home range of the receptor or to estimate the residual risk after the removal action has been implemented
- Evaluation of PRG (i.e., level of confidence, basis, relation to other PRGs such as those for human health or groundwater protection)

Within the 100-F/IU OUs, 33 waste sites were reported with concentrations of COPECs greater than their respective PRGs. Figures showing the location and concentration of COPECs reported with a HQ greater than one are provided in Appendix H. During development of the evaluation, the factors above were evaluated and resulted in a recommendation, as part of the SMDP, that no waste sites be carried forward into the FS for evaluation of remedial alternatives. The decisions for the 100-F/IU OUs were based on a subset of the factors described above, including the following:

- Depth of samples exceeding thresholds relative to the 4.6 m (15 ft) bgs standard point of compliance for ecological receptors defined by MTCA (WAC 173-340)
- Number and frequency of exceedances of the risk thresholds (PRGs)
- Magnitude of exceedance relative to the risk thresholds (the HQ)
- Confidence in the ecological risk thresholds defining the exceedances
- Quality of the sample data defining the exceedances
- Location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances
- Area of exceedance relative to home range of receptor exceeding and relative to area of unimpacted nearby habitat

Based on the factors discussed above, it was concluded there was no unacceptable risk to wildlife, plants, or invertebrates, and a recommendation is made for no further evaluation of any of the waste sites within the 100-FR-1, 100-FR-2, 100-IU-2, or 100-IU-6 OUs based on ecological risk. A summary of the rationale by chemical and receptor is provided below, with details for each specific waste site decision unit-chemical combination provided in Appendix H, Table H-19. For unremediated waste sites, remedial actions will consider the PRGs through the SMDP process outlined here. More detail in applying the SMDP process to unremediated sites is described in Sections 7.6.2 and 7.6.3.

- **Plants:** Mercury (16 waste site decision units), vanadium (1 waste site decision unit), molybdenum (2 waste site decision units), arsenic (1 waste site decision unit), nickel (1 waste site decision unit), boron (7 waste site decision units), selenium (3 waste site decision unit s), and copper (2 waste site decision units) were all measured at concentrations above plant PRGs. Molybdenum is not expected to adversely affect the plant communities, as it is not documented as phytotoxic in the published literature. The nickel and copper exceedances were collected below the maximum depth at which plant roots have been observed at the Hanford Site (3 m [9.8 ft]) (*Rooting Depth and Distributions of Deep-Rooted Plants in the 200 Area Control Zone of the Hanford Site* [PNL-5247]). The magnitude and frequency of exceedance for the selenium, boron, arsenic, and nickel samples were all low and, for most of these chemicals, represent exceedances of NOEC, as Hanford Site-specific LOECS have not been established. Risk to plants from mercury is unlikely because of low confidence in the PRG and no exceedance of wildlife PRGs for a bioaccumulative compound. These were infrequent and, in most cases, spatially distinct exceedances that would not cause a community-level effect. If localized adverse effects did occur, habitat fragmentation in the 100-D OU would not be likely given the level of ecological services that the habitat is providing in the current condition and the available habitat refugia nearby (see Section 7.6.3).

- **Invertebrates:** Barium (6 waste site decision units), boron (7 waste site decision units), copper (5 waste site decision units), arsenic (1 waste site decision unit), nickel (1 waste site decision unit), and silver (2 waste site decision units) were measured at concentrations above terrestrial invertebrate PRGs. For most of these chemicals, the PRGs represent NOEC, as Hanford Site-specific LOECS have not been established. These exceedances were infrequent and, in most cases, spatially distinct exceedances that would not cause a community-level effect. The barium, nickel, and copper, and one of the silver exceedances were collected below the maximum depth at which invertebrates have been observed at the Hanford Site (2.7 m [8.9 ft]) (*Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport* [PNL-2774]). The arsenic exceedance was from an area too small to impact the local invertebrate community (14 $m^2$ [151 $ft^2$]). Considering these infrequent exceedances, if deep excavation were to occur, the elevated concentrations would be mixed with much lower concentration material, resulting in a lower exposure concentration. At three of the waste site decision units, samples were from a depth below the maximum at which invertebrates have previously been observed at the Hanford Site (2.7 m [8.9 ft]) (*Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport* [PNL-2774]). Risk to the terrestrial invertebrate community is not expected at these waste site decision units, and there is ample unimpacted habitat for available invertebrates in adjacent areas and along the River Corridor.

- **Wildlife:** Selenium (7 waste site decision units), boron (7 waste site decision units), mercury (3 waste site decision units), vanadium (2 waste site decision units), copper (2 waste site decision units), arsenic (1 waste site decision unit), dieldrin (1 waste site decision unit), and lead (6 waste site decision units) were measured at concentrations above wildlife PRGs. Vanadium was rarely detected above background, but exceedances noted as the conservative PRG for killdeer (43 mg/kg) are roughly half of background (85 mg/kg). Many of the exceedances (copper, arsenic, and some selenium and mercury) were deep (i.e., below the maximum depth at which Hanford Site wildlife have been observed to burrow [1 m {3.3 ft} pocket mouse] "Loose Rock As Biobarriers in Shallow Land Burial" [Cline et al., 1980]). Exceedances for mercury, boron, selenium, lead, arsenic, and dieldrin were small and infrequent (e.g., few of the samples at a waste site decision units exceeded the PRG). For many of the exceedances for all of these chemicals, the size of the sites was considered relative to the home range of wildlife receptors (i.e., application of an AUF), and HQs were below 1.0. The population density of small mammals and the number of individuals expected to reside within these small sites were also considered. The final conclusion was that there are no population-

level effects to avian and mammalian receptors at any of the remediated waste sites that were evaluated, including those with some measured samples of selenium and lead above PRGs.

- **SMDP conclusion:** As indicated in Table H-19 (Appendix H), consideration of the factors listed above resulted in the conclusion of no unacceptable risks to terrestrial wildlife or plants and invertebrates exposed to vadose zone soil, and a recommendation of no further action for the waste sites within the 100-FR-1, 100-FR-2, 100-IU-2, or 100-IU-6 Source OUs. For unremediated waste sites, remedial actions will consider the PRGs through the SMDP process. More detail in applying that process to unremediated sites is described in Sections 7.6.2 and 7.6.3.

### 7.6.2 Recommendations for Evaluating Wildlife in Future Assessments at Unremediated Waste Sites

Data and process knowledge indicate that ecological PRGs will be exceeded at unremediated waste sites. Those exceedances will be evaluated through the risk management process, including consideration of such factors as waste site size and wildlife home ranges within a scientific management decision point, to determine the need for remedial action beyond that required to protect human health. PRGs will be presented in the Proposed Plans for protection of wildlife receptors. The PRGs will achieve protection of the populations of wildlife species constituting the food web found at the Hanford Site (Figure 7-2), including a range of feeding guilds. The receptor species selected for quantitative development of PRGs are intended to be representative of the species within those feeding guilds.

As discussed in the technical support documents for ecological values in soil for wildlife (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]; *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-01311]), the values used to calculate PRGs are based on the assumption that the size of the waste site inhabited by a receptor is the same size as the area used by the animal (e.g., the home range, breeding range, or feeding/foraging range). In other words, the PRGs assume that a wildlife receptor is exposed 100 percent of the time to the contaminants in a waste site at uniform concentrations equal to the EPC. This ratio of the area of contamination to the home range is known as an AUF. An AUF equaling 1 is another way of stating the assumption that the contaminated area and home range are identical. An AUF of 1.0 means that an animal is exposed to site contaminants 100 percent of the time; depending on the home range of the animal in relation to the size of the waste site, assuming that the AUF is 1 in development of SSLs or PRGs may considerably overstate ecological risks. However, several wildlife receptors, particularly the carnivorous mammals and most birds, have home ranges much larger than most of the waste sites; therefore, applying PRGs for those receptors to most waste sites would overstate ecological risks.

The home ranges for the wildlife receptors used for PRG development are shown in Appendix H, Table H-5. In considering the home range data available for each species, recognition must be given to the fact that these ranges are reduced during the breeding season. On the other hand, food sources in a semiarid environment such as the Hanford Site may be scarcer than what is reflected in the studies available, some of which were not conducted in similar habitats. While many biological studies have been conducted at the Hanford Site, studies specifically on home range or population density are not available for all species or guilds being evaluated.

Completion of remedial actions as part of the cleanup verification process, which is based on ecological PRGs, will incorporate a SMDP on a case-by-case basis to determine that the action is protective of ecological receptors. The SMDP approach and its use in remediation decision making would be presented in detail in RDR/RAWPs. Further, in cases where verification samples exceed the PRGs and these PRGs represent the limiting value (i.e., the wildlife PRGs are lower than all other applicable PRGs), then a risk

management decision should be made similar to the SMDP described in Section 7.6.1. Particular attention should be given to the number of samples exceeding the PRGs, the spatial area represented by the samples, and the depth at which samples exceed the PRGs. Other key factors that would be considered in the SMDP process would include the following:

- Size of the waste site relative to home range of wildlife receptors (e.g., developing and applying an AUF in the comparison of an EPC to the PRGs)
- Estimation of exposure using a central tendency estimate such as the 95 percent UCL
- Size of the waste site relative to area of adjacent uncontaminated habitat
- Nature and extent of residual contamination following remediation
- Potential presence of exposure pathways following remediation
- The number and frequency of exceedances of the risk thresholds (PRGs)
- The location of the samples exceeding thresholds, sample frequency, and proximity of other exceedances

PRGs are typically based on a concentration that may elicit adverse effects (i.e., reduce survival, growth, or reproduction), as observed in low number of individuals exposed to chemicals in laboratory toxicity tests. For some chemicals, this is based on toxicity tests reporting a 20 percent effect level (e.g., mortality observed in 20 percent or more tested organisms or growth reduced by 20 percent). For other chemicals, this is the lowest concentration tested with undefined adverse effects. In considering the results of verification data for future remedial actions relative to the PRGs, consideration must be given to the origins of the toxicity data upon which the exceeded PRGs are based. This should be considered in the context of the risk management goal (protection of populations of wildlife), the selected assessment endpoint (reproduction, survival, and growth), and specific life history data for the selected wildlife receptors selected to represent the end points (e.g., home rang and population density).

### 7.6.3 Recommendations for Evaluating Plants and Invertebrates in Future Assessments at Unremediated Waste Sites

PRGs for terrestrial plants and invertebrates have been established for the Hanford Site (*Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* [ECF-HANFORD-11-0158]) and have been a useful tool in screening waste sites for the potential to adversely impact these communities. However, the use of these PRGs in selecting final remediation goals in the FS or the Proposed Plan should be considered on a site-specific basis, except for waste sites where listed protected species are identified (i.e., federal or state-listed and protected threatened or endangered species). This recommendation is based upon the following lines of evidence: no significant adverse toxicological effects observed at the highest available concentrations tested in site-specific bioassays; historical and ongoing biological surveys (*Surface Environmental Surveillance Procedures Manual, PNL-MA-580, Rev. 5* [PNNL-16744]); and the limited likelihood of habitat fragmentation due to areas with elevated contaminants in soil. The plant and invertebrate PRGs can help identify where remedial actions have been effective. However, in cases where verification samples exceed these PRGs and the PRGs represent the limiting value (i.e., the plant or invertebrate PRG is lower than all other applicable PRGs), a risk management decision should be made similar to the SMDP described in Section 7.6.1. Particular attention should be given to the number of samples exceeding the PRGs, the spatial area represented by the samples, and the depth at which samples exceed the PRGs.

### 7.6.4 Evaluations of Sediment in Future Assessments and at Unremediated Waste Sites Below the Ordinary High Water Mark

Waste sites extending below the ordinary high water mark of the Columbia River should be assessed as an aquatic environment and, as such, should be evaluated for the protection of aquatic organisms described in the conceptual model in Appendix L. The evaluation of surface sediment data for any future assessments will be against the freshwater sediment ESLs presented in Appendix L, Table L-4. These values are obtained from a number of sources and are intended for screening measured concentrations for potential adverse effects to aquatic organisms exposed to sediments.

However, not all of the ESLs presented in Appendix L, Table L-4 are specifically designed to be used as cleanup levels for evaluating remedial actions. The primary source of freshwater sediment PRGs are the cleanup screening levels published in *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* (Ecology Publication 11-09-054). These values were specifically selected as thresholds for freshwater sediments in Washington, Oregon, and Idaho through the evaluation of field collected toxicological data. When data were not available for a specific chemical, then other sources were relied upon; however, the selection process remained consistent with the methodology presented in the CRC (DOE/RL-2010-117) and RCBRA (DOE/RL-2007-21). Recommended freshwater sediment PRGs are presented in Table 7-14. As with the soil investigations described above, future assessments should include SMDP considerations (Section 7.6.2).

Table 7-14. Freshwater Sediment PRGs

| Chemical | PRG |
|---|---|
| Antimony | 12 |
| Arsenic | 120 |
| Cadmium | 5.4 |
| Chromium | 88 |
| Copper | 1,200 |
| Lead | >1,300 |
| Mercury | 0.8 |
| Nickel | 110 |
| Selenium | >20 |
| Silver | 1.7 |
| Zinc | >4,200 |
| TPH-diesel | 510 |

Note: A “greater than (>)” value indicates that the toxic level is unknown but is above the concentration shown.

# 8 Identification and Screening of Technologies

This chapter begins the feasibility study portion of the RI/FS. The RI defines the nature and extent of contamination at the site and the potential risks to HHE posed by site contaminants. The FS identifies and evaluates alternative strategies to address the risks. The FS consists of three phases: screening of remedial technologies, development of remedial alternatives, and detailed analysis of selected alternatives. Remedial technologies are assembled into alternatives that address contamination on a media- or source-specific basis. Technologies are evaluated in this chapter to determine their effectiveness in treating or removing contaminants (described in Chapter 4) or interrupting exposure pathways (described in Chapters 6 and 7).

Chapter 8 presents discussion on the following:

- RAOs, ARARs, and PRGs (Section 8.1)
- General response actions (GRAs) (Section 8.2)
- Identification and screening of remedial technologies and associated process options to clean up the contamination (Section 8.3)

Chapter 9 assembles the technologies into alternatives, and Chapter 10 provides a detailed and comparative analysis of the alternatives to address contaminated media at 100-F/IU.

*Highlights*

- Media-specific RAOs are identified for soil, groundwater, and surface water.
- To meet RAOs, PRGs are established for each environmental medium of interest, contaminants, receptors, and exposure pathways.
- Of the 400 sites considered at 100-F/IU, 133 are evaluated in the FS. Ongoing interim remedial actions are expected to be substantially complete for 81 of these sites before a final action decision is issued. Thirty-six waste sites are identified for interim remedial action and are expected to remain for remediation under the ROD.
- The groundwater evaluation identified areas where concentrations of nitrate, Cr(VI), trichloroethene, and strontium-90 were greater than PRGs.
- Process options retained for vadose zone actions include no action, standard and deep excavation, disposal, and institutional controls.
- Process options retained for groundwater include no action, institutional controls, MNA, containment, pump-and-treat, in situ treatment (biological—anaerobic), injection/flushing, ion exchange, and air stripping.

## 8.1 Remedial Action Objectives

RAOs are general descriptions of what the remedial action is expected to accomplish (medium-specific or site-specific goals for protecting HHE). They are defined as specifically as possible to address the following concerns:

- Media of interest (soil, groundwater, or surface water)
- Types of contaminants (radionuclide and chemical constituents)
- Potential receptors (humans, flora, and fauna)
- Exposure pathways (external radiation, direct contact, or ingestion)

The RAOs provide a basis for evaluating the capability of a specific remedial alternative to achieve compliance with potential ARARs and/or an intended level of risk protection for HHE in accordance with the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(2)(i)]) and CERCLA RI/FS Guidance (EPA/540/G-89/004). The RAOs for the 100-F/IU Source and Groundwater OUs are presented in Section 8.1.3. Background information used in developing the RAOs is presented in Sections 8.1.1 through 8.1.3.

### 8.1.1 Identify Contaminants of Concern

In the RI/FS process, contaminants are initially referred to as COPCs. The contaminants identified that exceed ecological and human health PRGs, developed through the risk assessment process, are referred to as COCs.

#### *8.1.1.1 Waste Site Soil*

The evaluation of remedial actions for specific waste sites relies upon a comprehensive review of all available data for each site, including field data, radiological surveys, process history, analogous site information, personal interviews, engineering drawings and as-builts, and any other available information. As evaluated in Chapters 5, 6, and 7, and further described in Section 8.2.1, 144 waste sites in 100-F/IU had closeout verification data for quantitative evaluation as of June 30, 2012.

The evaluation of waste sites in Chapter 5 determined that conditions at the waste sites are protective based on comparison to PRGs, except for 116-F-14. The results of the site-specific analysis indicated that residual Cr(VI) at 116-F-14 is protective of groundwater and surface water under native vegetation-conservation land use (PRG basis) and protective of groundwater under irrigated agriculture land use (SSL basis), but could potentially exceed the surface water SSL as measured by the peak groundwater concentration at the waste site boundary under the irrigated agricultural land use. Therefore, this site is evaluated in the FS.

The risk evaluations for the previously remediated waste sites presented in Chapters 6 and 7 evaluated sites against the PRGs presented in Chapter 6, Table 6-12. The soil risk assessment identified 16 waste sites (including collocated sites) with concentrations of radionuclides that were greater than direct contact human health risk-based screening levels (RBSLs). The data for 15 of the 16 sites identified the radionuclide contamination in samples collected below a depth of 4.6 m (15 ft) bgs, so there is currently an incomplete exposure pathway. The data for one additional waste site also showed concentrations of radionuclides greater than RBSLs. The data for the EPC at this waste site are based on the maximum result from a small statistical verification dataset that is representative of both shallow and deep portions of the waste site after remediation. Chapter 6, Table 6-53 presents a summary of remediated waste sites and COPCs for evaluation in the FS.

For waste sites that have not been remediated, COPCs are identified based on review of available characterization data, waste site history/processes, and characterization of analogous waste sites. As a result of this comprehensive review, the characteristics of each site are sufficiently defined for the purpose of alternative development and comparison in the FS. Table 8-1 summarizes the site description, basis for action, and known or suspected contaminants for waste sites anticipated to be addressed under interim actions or remaining for remedial action in 100-F/IU. During implementation of remedial actions, if field conditions vary from those presented in the FS and indicate a need to re-evaluate the efficacy of the selected remedial action, the appropriate remedy modification will be used, consistent with CERCLA guidance. Section 8.2.1 presents additional information on the waste sites. As discussed in Chapter 4, Section 4.1.1, waste sites collocated within historic orchard lands will be remediated as needed to meet the cleanup levels for contaminants attributable to Hanford Site operations. Orchard-related contamination will be evaluated in the 100-OL-1 OU.

Soil COPCs are sampled and analyzed to determine the constituents present following the interim remedial actions at 100-F/IU. These COPCs include radionuclides, metals, PCBs, PAHs, TPHs, and VOCs. Results of these analyses are used to determine the constituents requiring development of PRGs. PRGs are presented in Section 8.1.4.

Table 8-1. Waste Sites Anticipated to be Addressed under Interim Action or Remaining for Remedial Action

| Waste Site | WIDS Site Type | Site Description | Basis for Action | Known or Suspected Contaminants |
|---|---|---|---|---|
| **Waste Site Anticipated to be Addressed under Interim Action (81)** | | | | |
| 100-F-57:2 | Foundation | The site consists of the western half of the remaining below-grade pump room facilities and foundation of the 190-F Process Water Pump House. | Soil contamination exceeded interim action RAGs, particularly the Cr(VI) RAG for SWP | Cr(VI), Cr (total), and Hg |
| 100-F-65 | Unplanned Release | The site consists of green-stained soil along the railroad tracks immediately west of the 190-F Building. The site was discovered on March 28, 2011, while remediating 100-F-57. | Small site within the larger 100-F-57 remediation footprint | Cr (VI), Cr (total), and Hg |
| 600-298:1 through 600-298:8 | Unplanned Release | These sites consists of various stained soil areas, and debris. | Soil contamination exceeded interim action RAGs | PAHs and PCBs |
| 600-299:1 through 600-299:6 | Unplanned Release | Discarded batteries, surface debris, and stained soil. | Solid hazardous debris (batteries) and suspect soil contamination exceeding interim action RAGs | Cd, Cr (total), Cu, Ni, and Pb |
| 600-300:1 through 600-300:12 | Unplanned Release | Various sizes of drums and containers with paint, tar, petroleum products, and unknown substances, and scattered debris. | Visible suspect hazardous waste (batteries and paint) and suspect soil contamination exceeding interim action RAGs | Metals, PAHs, and PCBs |
| 600-303 | Unplanned Release | The site consists of a 3 by 3 m (10 by 10 ft) area with four vertical pipes, 4 to 6 cm (1 to 1.5 in.) in diameter sticking out of the ground. The purpose of the pipes is unknown. | Soil contamination exceeded interim action RAGs, particularly the human health RAGs for lead and individual PAHs | Cd, Cr, Cu, Pb, Hg, Ni, Zn, and PAHs |
| 600-305:1 through 600-305:5 | Unplanned Release | Roofing and insulating materials. | Visible regulated asbestos containing material debris present at the site | Asbestos |
| 600-306 | Burn Pit | The site consists of a burned area with metal, wood, nails, iron plate, tar paper, and the underlying soil. The site was used to burn various materials. It is not known if it is from pre-Hanford or Hanford activities. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, & PCBs |
| 600-307 | Burn Pit | The site consists of a burned area with metal, wood, nails, iron plate, tar paper, and the underlying soil. The site was used to burn various materials. It is not known if it is from pre-Hanford or Hanford activities. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, & PCBs |
| 600-308 | Unplanned Release | This site consists of underlying soil and scattered garnet sand. Garnet sand was typically used as a sand blasting material for painting preparation. | Soil contamination exceeded interim action RAGs at analogous River Corridor garnet sand sites | Metals and PCBs |
| 600-309 | Burn Pit | The site consists of a burned area with wood, clay pipe, fabric (suspect asbestos-containing material) rubber hoses, and the underlying soil. The site was used as a dump and to burn various materials. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |
| 600-310 | Burn Pit | The site consists of a burned area with wood, clay pipe, fabric (suspect asbestos-containing material) rubber hoses, and the underlying soil. The site was used as a dump and to burn various materials. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |
| 600-311 | Burn Pit | The site consists of a 2 by 2 m (6 by 6 ft) area of concentrated burned debris and the underlying soil. Remnants of the burned debris include nails and tar-like roofing material. It appears to be next to an area where a building had once been. The site was used to burn various materials. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |

Table 8-1. Waste Sites Anticipated to be Addressed under Interim Action or Remaining for Remedial Action

| Waste Site | WIDS Site Type | Site Description | Basis for Action | Known or Suspected Contaminants |
|---|---|---|---|---|
| 600-312 | Burn Pit | The site consists of a 3 by 3 m (10 by 10 ft) area of concentrated burn debris and the underlying soil. Remnants of the burned debris include nails and tar-like roofing material. It appears to be next to a fomer building. The site was used to burn various materials. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |
| 600-313 | Burn Pit | The site consists of potentially contaminated soil that is either an oil stain or burned area. The process for which the site was burned is unknown. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |
| 600-314:1 through 600-314:5 | Unplanned Release | Probable telecommunications equipment with hardened balck liquid on surface. | Visible solid hazardous debris (solid lead components) and potential soil contamination exceeding interim action RAGs | Hg, Pb, PAHs, and PCBs |
| 600-316:1 through 600-316:6 | Unplanned Release | Mixed farmstead debris and batteries. | Solid hazardous debris (batteries) and suspect soil contamination exceeding interim action RAGs | Cd, Cr (total), Cu, Ni, and Pb |
| 600-317 | Unplanned Release | The site consists of underlying soil with scattered surface debris including wet cell battery plates, burned material, and a white granular substance. It is located in the bottom of a borrow pit. The process for this site is unknown. | Solid hazardous debris (battery components) and suspect soil contamination exceeding interim action RAGs | Metals, PAHs, and PCBs |
| 600-318:1 through 600-318:5 | Unplanned Release | Batteries and automotive shop debris. | Solid hazardous debris (battery components) and suspect soil contamination exceeding interim action RAGs | Metals |
| 600-319:1 through 600-319:3 | Unplanned Debris | Metal turnings, glass, stained soil, and paint products. | Soil contamination exceeded interim action RAGs at analogous River Corridor paint debris sites | Metals |
| 600-320:1 through 600-320:9 | Unplanned Release | Suspected oil dump location with visible tar in a subsite area. | Soil contamination exceeded interim action RAGs at analogous River Corridor oil-staining sites | Metals, PAHs, and PCBs |
| 600-321:1 through 600-321:4 | Unplanned Release | An area with insulation, metal, fire brick, and pipe lagging. | Visible asbestos containing material present at the site | Asbestos |
| 600-324 | Burn Pit | The site consists of the underlying soil, and a concrete pad with miscellaneous pipe and auto parts debris, with burnt wood and metal debris. The site may be associated with the Hanford Aggregate Pit 16 and 61 Hot Mix Plant. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |
| 600-325:1 and 600-325:2 | Burn Pit | An area of burned roofing material. | Soil contamination exceeded interim action RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |
| 600-326:1 and 600-326:2 | Unplanned Release | An area of gray suspected insulating material and black porous material. | Soil contamination exceeded interim action RAGs | Metals and PAHs |
| 600-328 | Unplanned Release | The site consists of the underlying soil and scattered slag with a small stained soil area. The vegetation appears to be stressed. The lead may have been used for pouring joints in cast iron sewer systems. | Visible solid hazardous debris (batteries) and potential soil contamination exceeding interim action RAGs | Hg, Pb, PAHs, and PCBs |

Table 8-1. Waste Sites Anticipated to be Addressed under Interim Action or Remaining for Remedial Action

| Waste Site | WIDS Site Type | Site Description | Basis for Action | Known or Suspected Contaminants |
|---|---|---|---|---|
| **Waste Sites Remaining for Remedial Action (36)** | | | | |
| 600-20 | Depression/Pit | The site was originally described as two abandoned asphalt tanks, each with a volume capacity of 45,420 to 52,990 L (12,000 to 14,000 gal). A 1999 waste site walkdown identified several valve pits and a depression that contains discarded asphalt material, several pails, and drums. There was no evidence of hazardous or radiological waste in the area. | Visible asphalt and tar slag wastes and suspect soil contamination | Metals and PAHs |
| 600-279 | Dumping Area | The site is a large area of white ash surrounded by dried grass. The site is apparently related to an old orchard. It is suspected that the site is the remains of a burned storage shed. The yellow material has a sulfur odor. Sulfur was used in orchards to control mold on fruit. The burned metal pieces could be pieces of farm equipment. | Small expected remediation footprint; soil contamination exceeded RAGs at similar sites in the River Corridor | Metals and PAHs |
| 600-293 | Unplanned Release | The service station supported the White Bluffs central shops. This site may include USTs, associated piping, and the underlying soil. This facility was used to dispense fuel for automotive use. The service station was demolished in 1975, but no documentation was found related to removing any USTs. A subsidence area was noted at the site. | Presence of pipelines and potential UST with residual petroleum products; underlying soil contamination exceeded RAGs | Metals, PAHs, and PCBs |
| 600-294 | Unplanned Release | The site was the location of a service station with the potential for USTs, associated piping, and underlying soil. The service station contained two gasoline pumps and two buried tanks with a total capacity of 15,000 L (4,000 gal), one diesel fuel pump, and a 3,785 L (1,000 gal) buried tank. The waste includes petroleum product-contaminated soil, USTs, and associated piping. COPCs may include petroleum products (TPH and PAH) and possibly ICP metals. The service station was demolished and buried in place in 1975. | Visible asbestos containing material present at the site; soil contamination exceeded RAGs | Metals, PAHs, and asbestos |
| 600-301 | Sanitary Sewer | The site consists of the White Bluffs shops, sewer system, and underlying soil, as well as four suspected related features that are isolated discrete locations. The site does not include the Imhoff septic tank or the sanitary tile field (see 600-106) but does include the sanitary sewer piping from the Imhoff tank to the tile field. | Soil contamination exceeded interim action RAGs | Metals, nitrate, and PAHs |
| 600-329 | Unplanned Release | The site consists of the underlying soil and an unknown concrete structure near the construction shop of the Hanford Townsite operations, on the high-water line of the river edge. Ground-penetrating radar located debris typical of demolition. There are several concentrations of anomalies in the area that have the characteristics of buried debris. There also are several linears in the area that may or may not be related to the structure. The abundance of shallow anomalies may be masking any deeper features in the area. The site appears to be related to the movement of water. | To be determined based on confirmatory sampling; potential contamination is expected to be limited to sediments within the concrete structure and/or immediately underlying soil | Metals, PAHs, and PCBs |

Table 8-1. Waste Sites Anticipated to be Addressed under Interim Action or Remaining for Remedial Action

| Waste Site | WIDS Site Type | Site Description | Basis for Action | Known or Suspected Contaminants |
|---|---|---|---|---|
| 600-331 | Unplanned Release | The site is the previous location of the lime sulfur barrel location (UPR-600-19). The site was remediated in 1997; however, sample data indicate that high levels of lead and arsenic remain in the soil column. | To be determined based on confirmatory sampling; potential soil contamination is expected to be limited to the immediate vicinity of the former barrel. Site is within former orchard areas | Metals |
| 600-332 | Sanitary Sewer | The site consists of the underlying soil, septic tank, associated piping, and drain field for a septic system. The septic system supported the range house building at the firing range, which was located on the opposite side of the access road from the firing range. | Residual septage and underlying soil exceeded RAGs at analogous River Corridor sites | Metals and PAHs |
| 600-334:2 | Burn Pit | This subsite consists of a 4.6 m (15.1 ft) diameter burn area of unknown origin found off the northwest corner of the former CMX Building complex. | To be determined based on confirmatory sampling; potential soil contamination expected to be limited to shallow soil at the burn area | Metals (including Cr[VI], PAHs, and PCBs |
| 600-349 | Dumping Area | The site consists of potential unexploded ordnance in an area southwest of the 600-149 Small Arms Range, extending from the perimeter of 600-149 as far as a fired rifle grenade could travel. The area with the highest potential to contain munitions and explosives of concern includes a portion of Gable Mountain south of Prid Canal. The site operated from the mid-1940s through the 1950s as a practice range for handguns, rifles, shotguns, machine guns, hand grenades, smoke bombs, and other small arms and incendiary devices. | Hazardous debris expected based on the analogous 600-149 site | Metals |
| 600-358 | Dumping Area | The site consists of scattered CERCLA-regulated debris identified during the unexploded ordnance characterization and clearance of the 600-149:1 waste site. The debris was described as being a lead battery, a lead chunk, a burn area, and a suspect drum or pipe. There is no process history associated with the site. | Solid hazardous debris (battery components) and suspect soil contamination exceeding interim action RAGs | Cd, Cr (total), Cu, Ni, and Pb |
| 600-368 | Unplanned Release | The site consists of a 15 $m^2$ (157 $ft^2$) area covered with green granules. The feature is approximately 130 m (427 ft) west of the Leazer Spur. In 1944, temporary construction buildings housed there included various warehouse, the crane operators' loft, riggers' loft, and an ice storage pit. The salvage/scrap yard was a kilometer south of the warehouses and operated as late as December 1948. It is not known what, if any, relationship existed between the two complexes. | Small expected remediation footprint; soil contamination exceeded RAGs at similar sites in the River Corridor | Metals |
| 600-369:1 through 600-369:8 | Dumping Area | Burn pit, drum lids, and areas with no vegetation and stressed vegetation. | Soil contamination exceeded RAGs at analogous River Corridor sites | Metals, PAHs, and PCBs |
| 600-370 | Dumping Area | The site consists of a large disturbed area with surface debris consisting of multiple burn sites with burn remnants, transite, insulators, wood, and concrete. There is no process history associated with the site. | Soil contamination exceeded RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |
| 600-371 | Dumping Area | The site consists of multiple locations having a white chalky substance that resembles either grout or bentonite. There is no process history associated with the site. | Small expected remediation footprint; soil contamination exceeded RAGs at similar sites in the River Corridor | Metals |

Table 8-1. Waste Sites Anticipated to be Addressed under Interim Action or Remaining for Remedial Action

| Waste Site | WIDS Site Type | Site Description | Basis for Action | Known or Suspected Contaminants |
|---|---|---|---|---|
| 600-372:1 and 600-372:2 | Unplanned Release | Area with discarded oil filter and devoid of vegetation. | Soil contamination exceeded interim action RAGs at analogous River Corridor oil filter sites | PAHs |
| 600-373 | Dumping Area | The site consists of a 28 $m^2$ (303 $ft^2$) area devoid of vegetation and covered by a white stain and crusted soil/grass debris. There is no process history associated with the site. | Small expected remediation footprint; soil contamination exceeded RAGs at similar sites in the River Corridor | Metals |
| 600-374 | Dumping Area | The site consists of an empty 55 gal drum (crushed) surrounded by a small area devoid of vegetation. There is no process history associated with the site. | Small expected remediation footprint; soil contamination exceeded RAGs at similar sites in the River Corridor | Metals, PAHs, and PCBs |
| 600-375:1 through 600-375:5 | Dumping Area | Battery debris and stained soil. | Solid hazardous debris (batteries) and suspect soil contamination exceeding RAGs | Cd, Cr (total), Cu, Ni, and Pb |
| 600-376:1 and 600-376:2 | Unplanned Release | Stained soil, patches of bare ground, and dried yellow material on surface. | Small expected remediation footprint; soil contamination exceeded RAGs at similar sites in the River Corridor | Metals, PAHs, and PCBs |
| 600-377 | Unplanned Release | The site consists of a 3 $m^2$ (32 $ft^2$) area devoid of vegetation and containing multiple filters. This is no process history associated with the site. | Soil contamination exceeded interim action RAGs at analogous River Corridor oil filter sites | PAHs |
| 600-378 | Storage Tank | The site is the historical location of a 379 L (100 gal) underground storage tank used to store fuel for the 506 Telephone Exchange Emergency Generator Building. | Suspected residual petroleum products in UST and potential underlying soil contamination based on similar sites in the River Corridor | Metals, PAHs, and PCBs |
| 600-379 | Dumping Area | The site consists of a burn area with visible remnants. There is no process history associated with the site. | Soil contamination exceeded RAGs at analogous River Corridor burn sites | Metals, PAHs, and PCBs |

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC = contaminant of potential concern
ICP = inductively coupled plasma
PAH = polycyclic aromatic hydrocarbon
PCB = polychlorinated biphenyl
RAG = remedial action goal
SWP = Surface Water Protection
UST = underground storage tank
WIDS = Waste Information Data System

#### 8.1.1.2 Groundwater

Cr(VI), strontium-90, TCE, and nitrate were identified as COCs, as presented in Chapters 6 and 7. The COCs are not substantially above the relevant standards. While nitrate exceeds the DWS of 45 mg/L, the range of concentrations is similar to the MTCA (WAC 173-340) risk threshold of 113.6 mg/L. The EPC for TCE is approximately two times the MCL of 5 mg/L in small, localized plumes. The EPC for strontium-90 is less than the DWS of 8 pCi/L, although there are localized exceedances in some wells. Cr(VI) concentrations are generally below the DWS of 48 µg/L in the relatively small plume near the river. While the plume exceeds the 10 µg/L state water quality standard in groundwater, aquifer tubes and pore water sampling indicate infrequent exceedances of this level near the surface water interface. The 10 µg/L state water quality standards for Cr(VI) is considered at the groundwater/surface water interface, and the 48 µg/L "Groundwater Cleanup Standards" (WAC 173-340-720) for Cr(VI) is applicable at inland areas of the aquifer.

While the mass of nitrate entering the river is relatively large, at about 40 kg/day, it represents about 1.1 percent of the 3,500 kg/day that enters the Columbia River from upstream irrigation return flows (*Irrigation Return Flow Quality South Columbia Basin Irrigation District May-August 1980* [WA-36-1010]). A recent USGS study (National Ambient Water-Quality Assessment Program) of groundwater quality in the central Columbia Plateau identified the presence of nitrate at concentrations above the federal drinking water standard in 19 percent of the wells surveyed. Nitrogen fertilizers applied to crop fields are the primary source of the elevated nitrate concentrations observed at the surveyed wells.

Groundwater contamination beneath the 100-IU-2/IU-6 Source OUs is generally attributed to contaminants that originate from the 200 East Area that have dispersed from the 200-BP-5 Groundwater OU or 200-PO-1 Groundwater OU, respectively. It has also been influenced by groundwater contaminants that originate from the 200 West Area that have dispersed from the 200-ZP-1 Groundwater OU. Additionally, the "eastern" portion of the 100-IU-2/IU-6 groundwater area contains groundwater contaminants that originate from the 100-FR-3 Groundwater OU. Groundwater contaminants within the 100-IU-2/IU-6 groundwater area are addressed by other OUs, including the 200 Area and 100-FR-3 Groundwater OUs.

### 8.1.2 ARARs

Substantive standards of promulgated regulations pertaining to CERCLA response actions are identified through the ARAR identification process, which is based on "Cleanup Standards, " "Degree of Cleanup" (CERCLA [Section 121(d)]) and CERCLA RI/FS Guidance (EPA/540/G-89/004); *CERCLA Compliance with Other Laws Manual: Interim Final* [EPA/540/G-89/006]; and *CERCLA Compliance with Other Laws Manual: Part II* [EPA/540/G-89/009]). Section 121(d) requires, with exceptions, that any promulgated substantive ARAR standard, requirement, criterion, or limitation under any federal environmental law, or any more stringent state requirement pursuant to a state environmental statute, or facility siting law be met (or a waiver justified) for any hazardous substance, pollutant, or contaminant that will remain onsite after completion of remedial action. Additionally, the NCP ("Remedial Design/Remedial Action, Operation and Maintenance" [40 CFR 300.435(b)(2)]) requires that ARARs be attained (unless waived) during the remedial action. Identifying ARARs is part of the 100-F/IU FS process.

Vadose zone soils (including waste sites) and groundwater in 100-F/IU will be remediated under a CERCLA decision document. Any remedial action(s) implemented will be required to meet ARARs. In many cases, the ARARs form the basis for the PRGs to which contaminants must be remediated to protect HHE. ARARs also define or restrict how specific requirements of a remedial alternative can be implemented based on the nature of the activity or the location of the site.

#### *8.1.2.1 ARARs Evaluation Process*

The ARARs evaluation prepared for this RI/FS was conducted in accordance with the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(f)(1)(ii)(B)(2)]).

A distinction and clarification related to ARARs involves onsite and offsite actions. Onsite actions are defined to be "the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action" (NCP [400 CFR 300]). Onsite actions must comply with ARARs but need only comply with the substantive parts of those requirements. Offsite actions must comply with both the substantive and administrative requirements. For onsite activities, a requirement under federal and state environmental laws may be either applicable or relevant and appropriate, but not both.

The identification of ARARs is a two-step process. First, it must be determined whether the law or regulation is applicable. If not applicable, it must be determined if the law or regulation is both relevant and appropriate. The terms "applicable" and "relevant and appropriate" are defined in the NCP ("Definitions" [40 CFR 300.5]) as follows:

- "Applicable requirements" are substantive standards that specifically address the situation at a CERCLA site and would legally apply to remedial actions in the absence of CERCLA authority. All jurisdictional prerequisites of the requirement must be met in order for the requirement to be applicable, including specific application to federal agencies (e.g., through a waiver of federal sovereign immunity).
- "Relevant and appropriate" are environmental requirements such as cleanup standards that address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site (NCP "General" [40 CFR 300.400(g)(2)]). A requirement that is relevant and appropriate may not meet one or more jurisdictional prerequisites for applicability but still makes sense at the site, given the circumstances of the site and the release.

In evaluating the relevance and appropriateness of a requirement, the eight comparison factors in the NCP ("General" [40 CFR 300.400(g)(2)]) are considered:

1. The purpose of the requirement and the purpose of the CERCLA action.
2. The medium regulated or affected by the requirement, and the medium contaminated or affected at the CERCLA site.
3. The substances regulated by the requirement, and the substances found at the CERCLA site.
4. The actions or activities regulated by the requirement, and the remedial action contemplated at the CERCLA site.
5. Any variances, waivers, or exemptions of the requirement, and their availability for the circumstances at the CERCLA site.
6. The type of place regulated, and the type of place affected by the release or CERCLA action.
7. The type and size of structure or facility regulated, and the type and size of structure or facility affected by the release or contemplated by the CERCLA action.
8. Any consideration of use or potential use of affected resources in the requirement, and the use or potential use of the affected resource at the CERCLA site.

To be considered (TBC) information represents another category of nonpromulgated advisories or guidance issued by federal or state governments that is not legally binding and does not have the status of ARARs. In some circumstances, TBC information will be evaluated, along with ARARs, in determining the remedial action necessary to protect HHE. TBC information complements ARARs in determining protectiveness at a CERCLA site or in assessing implementation of certain actions. For example, because cleanup standards do not exist for all contaminants, health advisories, which would be TBC information, may be helpful in defining cleanup levels.

"General Provisions" (Section 161 of the AEA, as amended) provides DOE the authority to establish DOE orders containing instructions and operational requirements considered important to protect HHE from nuclear material, source material, and byproduct materials. While the requirements of DOE orders must be met, they are not ARARs and are independent of the TBC and ARARs identification process at the Hanford Site.

Potential ARARs for the 100-F/IU were reviewed to determine if they fall into one of three categories: chemical-specific, location-specific, or action-specific requirements. These categories are defined as follows:

- Chemical-specific requirements are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of public and worker safety levels and site cleanup levels.
- Location-specific requirements are restrictions placed on the concentration of dangerous substances or the conduct of activities solely because they occur in special geographic areas.
- Action-specific requirements are usually technology- or activity-based requirements or limitations triggered by remedial actions performed at the site.

#### 8.1.2.2 Waivers from ARARs

The CERCLA lead agency delegated authority under Section 121 may waive ARARs, with EPA's concurrence, and select a remedial action that does not attain the same level of cleanup as that identified by the ARARs. In *Superfund Implementation* (Executive Order 12580), the President delegated "Cleanup Standards" (Section 121 of SARA) authority to DOE for cleanup of DOE facilities. "Cleanup Standards" (Section 121 of SARA) identifies the following circumstances in which DOE may waive ARARs for onsite remedial actions:

- The remedial action selected is only a part of a total remedial action (e.g., an interim action), and the final remedy will attain the ARAR upon its completion.
- Compliance with the ARAR will result in a greater risk to HHE than alternative options.
- Compliance with the ARAR is technically impracticable from an engineering perspective.
- An alternative remedial action will attain an equivalent standard of performance using another method or approach.
- The ARAR is a state requirement that the state has not consistently applied (or demonstrated the intent to apply consistently) in similar circumstances.

ARAR waivers can be established in the ROD or through a ROD modification

#### 8.1.2.3 Potential ARARs Identified

Table 8-2 presents potential federal and Washington State ARARs. When the final remedy selection is documented in the ROD, all federal and state ARARs with which the final remedy must comply are also finalized. Key potential ARARs are identified in the following discussion.

*Potential Chemical-Specific ARARs*. The chemical-specific ARARs and TBCs that may affect 100-F/IU remedial actions are the elements of the *Washington Administrative Code* regulations that implement MTCA (WAC 173-340). Within this branch of the *Washington Administrative Code*, there are detailed regulations with developing standards for remedial actions involving MTCA soil cleanup standards ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) and groundwater cleanup standards (MTCA, "Groundwater Cleanup Standards" [WAC 173-340-720]).

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| **Groundwater** | | | | | |
| ***Safe Drinking Water Act of 1974* (Public Law 93-523, as amended; 42 USC 300f, et seq.); "National Primary Drinking Water Regulations" (40 CFR 141)** | | | | | |
| "Maximum Contaminant Levels for Organic Contaminants" (40 CFR 141.61)<br>"Maximum Contaminant Level Goals for Organic Contaminants"<br>(40 CFR 141.50) | | Establishes MCLs and non-zero MCLGs as criteria for groundwater and surface water that are or may be used for drinking water. The standards/ goals are designed to protect human health from adverse effects of organic contaminants in the drinking water. | Groundwater in 100-F/IU contains contaminants that require remediation. Although groundwater is not currently used for drinking water, it is a potential drinking water source and discharges into the Columbia River, which is used for drinking water. | ARAR | Groundwater remediation and management activities (e.g., groundwater treatment, discharge of treated groundwater, in situ remediation of groundwater, and MNA). |
| "Maximum Contaminant Levels for Inorganic Contaminants"<br>(40 CFR 141.62)<br>"Maximum Contaminant Level Goals for Inorganic Contaminants"<br>(40 CFR 141.51) | | Establishes MCLs and nonzero MCLGs as criteria for groundwater and surface water that are or may be used for drinking water. The standards/goals are designed to protect human health from adverse effects of inorganic contaminants in the drinking water. | Groundwater in 100-F/IU contains contaminants that require remediation. Although groundwater is not currently used for drinking water, it is a potential drinking water source and discharges into the Columbia River, which is used for drinking water. | ARAR | Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA). |
| "Maximum Contaminant Levels for Radionuclides"<br>(40 CFR 141.66) | | Establishes MCLs as criteria for groundwater and surface water that are or may be used for drinking water. The standards are designed to protect human health from the adverse effects of radionuclides in the drinking water. | Groundwater in 100-F/IU contains contaminants that require remediation. Although groundwater is not currently used for drinking water, it is a potential drinking water source and discharges into the Columbia River, which is used for drinking water. | ARAR | Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA). |
| **"Water Pollution Control" (RCW 90.48, as amended); "Underground Injection Control Program" (WAC 173-218)** | | | | | |
| "UIC Well Classification Including Allowed and Prohibited Wells"<br>(WAC 173-218-040) | Action | Establishes criteria and standards for an underground injection control program. | Groundwater in 100-F/IU contains contaminants that require remediation; treated groundwater may be discharged through underground injection wells. | ARAR | Groundwater remedial activities involve underground injection. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| **"Hazardous Waste Cleanup—Model Toxics Control Act" (RCW 70.105D, as amended); "Model Toxics Control Act—Cleanup" (WAC 173-340)** | | | | | |
| "Groundwater Cleanup Standards" (WAC 173-340-720)<br>"Method B Cleanup Levels for Potable Ground Water" (WAC 173-340-720[4][b][i-iii][A]&[B])<br>"Adjustments to Cleanup Levels" (WAC 173-340-720[7]) | Chemical | Groundwater cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use conditions.<br>Method B equations (720-1 and 720-2) are used to calculate groundwater cleanup levels for noncarcinogens and carcinogens, respectively, only if "sufficiently protective, health-based criteria or standards have not been established under applicable state and federal laws. Groundwater cleanup levels are established at concentrations that do not directly or indirectly cause violations of surface water, sediment, soil, or air cleanup standards. | Groundwater in 100-F/IU contains contaminants that require remediation. It is not currently used for drinking water but is a potential drinking water source (it discharges into the Columbia River, which is used for drinking water). | ARAR | Groundwater remediation and management (e.g., discharge of treated groundwater, in situ remediation of groundwater, MNA). |
| **"Water Well Construction" (RCW 18.104, as amended); "Minimum Standards for Construction and Maintenance of Wells" (WAC 173-160)** | | | | | |
| "How Shall Each Water Well Be Planned and Constructed?" (WAC 173-160-161) | Action | Identifies well planning and construction requirements. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |
| "What Are the Requirements for the Location of the Well Site and Access to the Well?" (WAC 173-160-171) | Action | Identifies the requirements for locating a well. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |
| "What Are the Requirements for Preserving the Natural Barriers to Ground Water Movement Between Aquifers?" (WAC 173-160-181) | Action | Identifies the requirements for preserving natural barriers to groundwater movement between aquifers. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |
| "What Are the Minimum Standards for Resource Protection Wells and Geotechnical Soil Borings?" (WAC 173-160-400) | Action | Identifies the minimum standards for resource protection wells and geotechnical soil borings. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |
| "What Are the General Construction Requirements for Resource Protection Wells?" (WAC 173-160-420) | Action | Identifies the general construction requirements for resource protection wells. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| "What Are the Minimum Casing Standards?" (WAC 173-160-430) | Action | Identifies the minimum casing standards. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |
| "What Are the Equipment Cleaning Standards?" (WAC 173-160-440) | Action | Identifies the equipment cleaning standards. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |
| "What Are the Well Sealing Requirements?" (WAC 173-160-450) | Action | Identifies the well sealing requirements. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |
| "What Is the Decommissioning Process for Resource Protection Wells?" (WAC 173-160-460) | Action | Identifies the decommissioning process for resource protection wells. | Groundwater monitoring and treatment wells and borings occur in 100-F/IU. | ARAR | Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| **Radionuclide ARAR Dose Compliance Concentrations for Superfund Sites** | | | | | |
| "Establishment of Cleanup Levels for CERCLA Sites with Radioactive Contamination" (Luftig and Weinstock, 1997)<br>"Distribution of OSWER Radiation Risk Assessment Q&A's Final Guidance" (Luftig and Page, 1999) | Chemical | This memorandum presents clarification for establishing protective cleanup levels in media for radioactive contamination at CERCLA sites. EPA has determined that the dose limits established by the NRC in "Radiological Criteria for License Termination" (62 FR 39058) (25 mrem/yr, which is equivalent to $5 \times 10^{-4}$ increase lifetime risk), will not provide a protective basis for establishing PRGs under CERCLA. A dose of 15 mrem/yr effective dose (approximately equivalent to $3 \times 10^{-4}$ increase in lifetime risk) is preferred as the maximum dose limit for humans.<br>In the final guidance, EPA further clarifies that 15 mrem/yr is not a presumptive cleanup level under CERCLA. Rather, site decision makers should continue to use the CERCLA risk range when ARARs are not used to set cleanup levels. This is for several reasons, as using dose based guidance would result in unnecessary inconsistency regarding how radiological and nonradiological (chemical) contaminants are addressed at CERCLA sites. | Groundwater in 100-F/IU contains radioactive contaminants that, if not remediated, could pose unacceptable risk to human health. | TBC | Development of groundwater cleanup levels. |
| *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P) | Action | Provides the framework and appropriateness for using MNA as a remedy component for organic and inorganic contaminants. | Groundwater in 100-F/IU contains contaminants that require remediation. The use of MNA as a remedy may be appropriate. | TBC | Groundwater remediation activities, including MNA. |
| **Surface Water** | | | | | |
| ***Clean Water Act of 1972* (Public Law 107-303, as amended; 33 USC 1251, et seq.), Section 303c; "Water Quality Standards" (40 CFR 131)** | | | | | |
| "Toxics Criteria for Those States Not Complying with Clean Water Act Section 303(c)(2)(B)" (40 CFR 131.36[b][1]) | Chemical | Establishes numeric water quality criteria for the protection of human health and aquatic organisms. Toxic criteria for the protection of aquatic life is provided in the water quality criteria regulations "Toxics Criteria for Those States Not Complying with Clean Water Act Section 303(c)(2)(B)" (40 CFR 131.36[b][1]), "EPA's Section 304(a), Criteria for Priority Toxic Pollutants," supersede criteria adopted by the state, except where the state criteria are more stringent than the federal criteria. | Groundwater in 100-F/IU contains contaminants that require remediation and discharges into the Columbia River. | ARAR | Groundwater remediation activities that affect surface water (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA). |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| **"Hazardous Waste Cleanup—Model Toxics Control Act" (RCW 70.105D, as amended); "Model Toxics Control Act—Cleanup" (WAC 173-340)** | | | | | |
| "Surface Water Cleanup Standards" (WAC 173-340-730) | Chemical | Surface water cleanup levels are based on estimates of the highest beneficial use and the reasonable maximum exposure expected to occur under both current and potential future site use conditions. | Groundwater in 100-F/IU contains contaminants that require remediation and discharges into the Columbia River. The Columbia River is a current and future source of drinking water. | ARAR | Groundwater, remediation activities that affect surface water (e.g., discharge of treated groundwater, in-situ remediation of groundwater, and MNA). |
| **"Water Pollution Control" (RCW 90.48, as amended); "Water Quality Standards for Surface Waters of the State of Washington" (WAC 173-201A)** | | | | | |
| "Toxic Substances" (WAC 173-201A-240[3]) | Chemical | Establishes water quality standards for surface waters of the State of Washington consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife. | Groundwater in 100-F/IU contains contaminants that require remediation and discharges into the Columbia River. The Columbia River is a current and future source of drinking water. The use designations for the Columbia River include aquatic life use (spawning and rearing), primary contact recreation, water supply (drinking, irrigation, and agriculture), and miscellaneous uses (wildlife habitat, harvesting, commerce, boating, and aesthetics). | ARAR | Groundwater, remediation activities that affect surface water (e.g., discharge of treated groundwater, in situ remediation of groundwater, and MNA). |
| **Soil and Vadose Zone** | | | | | |
| **"Hazardous Waste Cleanup—Model Toxics Control Act" (RCW 70.105D, as amended); "Model Toxics Control Act—Cleanup" (WAC 173-340)** | | | | | |
| "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740[3]) | Chemical | Establishes soil cleanup levels where residential land use represents the reasonable maximum exposure under both current and future site use conditions. Cleanup standards require specification of the following:<br>• Hazardous substance concentrations that protect HHE (cleanup levels)<br>• Location of the site where cleanup levels must be attained ("points of compliance")<br>• Other regulatory requirements that apply to the cleanup action because of the type of action or location of the site<br>These requirements are generally established in conjunction with the selection of a specific cleanup action. | Soil in 100-F/IU contains contaminants that require remediation. The requirements corresponding to Method B soil cleanup levels may be used to calculate cleanup levels based on an unrestricted land use, which is more conservative than the conservation/mining land use assigned to this area. | ARAR | Soil cleanup actions where concentration of hazardous substances in the soil exceeds Method B cleanup levels using "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740[3][b] and [c]). |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747[3] through [8]) | Chemical | Establishes soil concentrations that will not cause contamination of groundwater at levels that exceed the groundwater cleanup levels established under "Groundwater Cleanup Standards" (WAC 173-340-720). Provides an overview of the methods for deriving these soil concentrations to meet relevant criteria. Certain methods are tailored for particular types of hazardous substances or sites and certain methods are more complex than others and/or require the use of site-specific data. | Soil in 100-F/IU contains contaminants that require remediation. The requirements corresponding to soil cleanup levels may be used to calculate cleanup levels to ensure protection of groundwater. Although groundwater is not currently used for drinking water, it is a potential drinking water source and discharges into the Columbia River (which is used for drinking water). | ARAR | Soil cleanup actions where concentration of hazardous substances in the soil exceeds soil concentration for protection of groundwater. As allowed, "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747[8]), Alternative fate and transport models, one of the seven allowable methods under "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747) will be used to determine appropriate cleanup levels. |
| *Guidance for Developing Ecological Soil Screening Levels* (OSWER Directive 9285.7-55) | Chemical | Provides a set of risk-based soil screening levels (EcoSSLs) for several soil contaminants that are of ecological concern for terrestrial plants and animals at hazardous waste sites. Also describes the process used to derive these levels and provides guidance for their use. | Soil in 100-F/IU contains contaminants that require remediation. Comparison to SSLs may be appropriate for defining potential COPCs or to default to an EcoSSL for COPCs that lack corresponding published state cleanup criteria. | TBC | Soil cleanup actions to protect ecological receptors. |
| "Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7490)<br>"Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493)<br>"Priority Contaminants of Ecological Concern" (WAC 173-340-7494) | Chemical | Defines goals and procedures for determining whether a release of hazardous substances to soil may pose a threat to the terrestrial environment. Characterizes existing or potential threats to terrestrial plants or animals exposed to hazardous substances in soil; establishes site-specific cleanup standards for the protection of terrestrial plants and animals.<br>"Priority Contaminants of Ecological Concern" (WAC 173-340-7494) provides for numeric concentrations of hazardous substances determined to persist, bioaccumulate, or be highly toxic to terrestrial ecological receptors. | Soil in 100-F/IU contains contaminants that require evaluation to determine if ecological exposures have the potential to cause significant adverse effects. | TBC | Soil remediation activities including containment, RTD, and MNA. After using the generic screening levels available in Table 749-3, site-specific terrestrial ecological cleanup levels have been developed using "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493). |
| *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P) | Action | Provides the framework and appropriateness for using MNA as a remedy component for organic and inorganic contaminants. | Soil in 100-F/IU contains contaminants that require remediation. The use of MNA as a remedy may be appropriate. | TBC | Soil remediation activities, including MNA. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| **Air** | | | | | |
| **"Washington Clean Air Act" (Chapter 70.94 RCW, as amended); "General Regulations for Air Pollution Sources" (WAC 173-400)** | | | | | |
| "General Regulations for Air Pollution Sources" (WAC 173-400) | Action | Defines methods of control to be employed to minimize the release of air contaminants associated with fugitive emissions resulting from materials handling, construction, demolition, or other operations. Emissions are to be minimized through application of best available control technology. | Soil and/or groundwater remedial actions implemented in 100-F/IU have the potential to emit emissions subject to these standards because soil and groundwater hazardous contaminants detected in 100-F/IU include covered hazardous air pollutants. | ARAR | Actions performed at 100-F/IU that result in the emission of hazardous air pollutants, including decontamination, demolition, and excavation activities implemented during a remedial action that have the potential to emit visible, particulate, fugitive, and hazardous air emissions and odors. |
| "General Standards for Maximum Emissions" (WAC 173-400-040) | Action | All sources and emission units are required to meet the general emission standards unless a specific source standard is available. General standards apply to visible emissions, particulate fallout, fugitive emissions, odors, emissions detrimental to health and property, sulfur dioxide, and fugitive dust. | Soil and/or groundwater remedial actions implemented in 100-F/IU have the potential to emit emissions subject to these standards because hazardous contaminants detected in 100-F/IU include covered regulated hazardous air pollutants. | ARAR | Remedial actions that have the potential to release hazardous air emissions. |
| "Emission Standards for Sources Emitting Hazardous Air Pollutants" (WAC 173-400-075) | Action | Establishes national emission standards for hazardous air pollutants. Adopts, by reference, "National Emission Standards for Hazardous Air Pollutants" (NESHAP [40 CFR 61]) and appendices. | Soil and/or groundwater hazardous contaminants detected in 100-F/IU include covered regulated hazardous air pollutants. | ARAR | Actions performed at 100-F/IU that result in the emission of hazardous air pollutants, including decontamination, demolition, and excavation activities implemented during the remedial action that have the potential to emit visible, particulate, fugitive, and hazardous air emissions and odors. |
| **"Washington Clean Air Act" (Chapter 70.94 RCW, as amended); "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460)** | | | | | |
| "Purpose" (WAC 173-460-010)<br>"Applicability" (WAC 173-460-030)<br>"Control Technology Requirements" (WAC 173-460-060)<br>"Ambient Impact Requirement" (WAC 173-460-070)<br>"First Tier Review" (WAC 173-460-080)<br>"Table of ASIL, SQER and de Minimis Emission Values" (WAC 173-460-150) | Action | Establishes control of new sources emitting toxic air pollutants to prevent air pollution, reduce emissions to the extent reasonably possible, and maintain such levels of air quality as will protect human health and safety. Toxic air pollutants include carcinogens and noncarcinogens listed in "Table of ASIL, SQER and de Minimis Emission Values" (WAC 173-460-150). Three major requirements of this regulation are implementation of best available control technology for toxics, quantification of toxic air pollutant emissions, and demonstration of health and safety protection. | Hazardous contaminants detected in soil and/or groundwater in 100-F/IU include constituents that would constitute toxic air pollutants if released to the air. | ARAR | Groundwater and soil remediation activities, such as 100-F/IU treatment systems with the potential to emit hazardous air emissions and that would be considered a new source. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| **"Washington Clean Air Act" (Chapter 70.94 RCW, as amended); "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480)** | | | | | |
| "Ambient Standard" (WAC 173-480-040) | Action | Defines the maximum allowable level for radionuclides in the ambient air, which shall not cause a maximum accumulated dose equivalent of 25 mrem/yr to the whole body or 75 mrem/yr to any critical organ. However, ambient air standard under NESHAP "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H) and "National Emission Standards for Radionuclide Emissions from Federal Facilities Other Than Nuclear Regulatory Commission Licensees and Not Covered by Subpart H" (40 CFR 61, Subpart I) are not to exceed amounts that result in an effective dose equivalent of 10 mrem/yr to any member of the public. | Hazardous contaminants detected in soil and groundwater at 100-F/IU include radionuclides that could be emitted to ambient air during remedial actions. | ARAR | Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, vacuuming/exhaust) that have the potential to emit radionuclides above maximum acceptable levels. |
| "General Standards for Maximum Permissible Emissions" (WAC 173-480-050) | Action | At a minimum, all emission units shall make every reasonable effort to maintain radioactive materials in effluents to unrestricted areas; control equipment at sites operating under ALARA shall be defined as reasonably available control technology and as low as reasonably achievable control technology. | The potential for fugitive and diffuse emissions because of demolition and excavation and related activities will require efforts to minimize those emissions. | ARAR | Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, vacuuming/exhaust) that have the potential to emit radionuclides above maximum acceptable levels. |
| "Emission Monitoring and Compliance Procedures" (WAC 173-480-070) | Action | Requires that radionuclide emissions shall be determined by calculating the dose to members of the public using Department of Health approved sampling procedures at the point of maximum annual air concentration in an unrestricted area where any member of the public may be located. | Hazardous contaminants detected in soil and groundwater in 100-F/IU include radionuclides that could be emitted to unrestricted areas during remedial actions. | ARAR | Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, and vacuuming/exhaust) that have the potential to emit radionuclides to unrestricted areas above maximum acceptable levels. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| "Emission Standards for New and Modified Emission Units" (WAC 173-480-060) | Action | Requires that construction, installation, or establishment of new air emission control units use best available radionuclide control technology. | Hazardous contaminants detected in soil and groundwater in 100-F/IU includes radionuclides that could be emitted from air emission control units during remedial actions. | ARAR | Investigative and remediation activities (e.g., excavation, RTD, demolition, ventilation, and vacuuming/exhaust) that require air pollution control equipment and have the potential to emit radionuclides. |
| **"Nuclear Energy and Radiation" (RCW 70.98, as amended); "Radiation Protection—Air Emissions" (WAC 246-247)** | | | | | |
| "National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035[1][a][i]) (adopts by reference, "Prohibited Activities"[40 CFR 61.05]) | Action | Identifies prohibition of any owner or operator of any stationary source subject to a national emission standard for hazardous air pollutants from constructing or operating the new or existing source in violation of any such standard. | Substantive requirements of this standard are applicable because the remedial actions in 100-F/IU may be subject to NESHAP air pollutant standards, and resultant requirements have the potential to be detected in, and potentially emitted from, structures, components, debris, soil, or groundwater involved in the remedial action. | ARAR | Investigative and remedial activities. |
| "National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035[1][a][i]) (adopts by reference, "Compliance with Standards and Maintenance Requirements" [40 CFR 61.12]) | Action | Requires the owner or operator of each stationary source of hazardous air pollutants subject to a national emission standard for a hazardous air pollutant to determine compliance with numerical emission limits in accordance with emission tests established in NESHAP "Emission Tests and Waiver of Emission Tests" (40 CFR 61.13) or as otherwise specified in an individual subpart. Compliance with design, equipment, work practice, or operational standards shall be determined as specified in the individual subpart. Also, maintain and operate the source, including associated equipment for air pollution control, in a manner consistent with good air pollution control practice for minimizing emissions. | Hazardous contaminants that would be subject to NESHAP air pollutant standards and resultant requirements have the potential to be detected in, and potentially emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 100-F/IU. Associated design, equipment, work practice, or equipment for air pollution control may also be maintained and operated. | ARAR | Investigative and remedial actions involve stationary sources that provide a potential to emit regulated hazardous air pollutants (e.g., vapor extraction systems, decontamination stations, deactivation, demolition, or waste removal or storage activities). Associated design, equipment, work practice, or air emissions controls may be maintained and operated. |
| "National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035[1][a)][i]) (adopts by reference, "Monitoring Requirements" [40 CFR 61.14]) | Action | Requires the owner or operator to maintain and operate each monitoring system as specified in the applicable subpart, and in a manner consistent with good air pollution control practice for minimizing emissions. Approvals of alternatives to any monitoring requirements or procedures are obtained from the regulatory agency. | Hazardous contaminants that would be subject to NESHAP air pollutant standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 100-F/IU. The hazardous contaminants will be monitored as identified under each applicable NESHAP subpart. | ARAR | Investigative and remedial soil, air, and groundwater monitoring systems, and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums that produce airborne emissions of hazardous pollutants to unrestricted areas. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| "National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035[1][a][ii]) (adopts by reference, "Standard" [40 CFR 61.92]) | Chemical | Establishes emission standards for radionuclides equivalent to NESHAP "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H), by reference. Hanford Site radionuclide airborne emissions shall be controlled so as not to exceed amounts that would cause an exposure to any member of the public of greater than 10 mrem/yr effective dose equivalent. | Hazardous radionuclide contaminants that would be subject to NESHAP radionuclide air pollutant standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil or groundwater involved in the remedial actions in 100-F/IU. | ARAR | Investigative and remedial soil, air, groundwater monitoring systems and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous radionuclide pollutants to unrestricted areas. |
| "National Standards Adopted by Reference for Sources of Radionuclide Emissions" (WAC 246-247-035[1][a][ii]) (adopts by reference, "Emission Monitoring and Test Procedures" [40 CFR 61.93]) | Action | Specifies that radionuclide emissions shall be determined and effective dose equivalent values to members of the public calculated to determine compliance with the 10 mrem/yr effective dose equivalent standard. Radionuclide emissions shall be collected and measured using approved methods. A quality assurance program shall be conducted that meets the performance requirements described in Appendix B, Method 114. Measurement by methods specified in the paragraph (b) shall be made at all release points that have the potential to discharge radionuclides to the air in quantities that cause an effective dose equivalent in excess of 1 percent of the 10 mrem/yr standard. For other release points that have a potential to release radionuclides into the air, periodic confirmatory measurements shall be made to verify the low emissions. | Hazardous radionuclide contaminants that would be subject to NESHAP radionuclide air pollutant standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 100-F/IU. The hazardous contaminants will be monitored as identified under each applicable NESHAP subpart. | ARAR | Investigative and remedial soil, air, and groundwater monitoring systems, and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous radionuclide pollutants to unrestricted areas. |
| "General Standards" (WAC 246-247-040[3]) "General Standards" (WAC 246-247-040[4]) | Action | Requires that emissions be controlled to ensure ALARA-based and best available control standards are not exceeded. | Hazardous contaminants that would be subject to radionuclide air emission standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions in 100-F/IU. | ARAR | Investigative and remedial soil, air, and groundwater monitoring systems, and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous radionuclide pollutants to unrestricted areas. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| "Monitoring, Testing and Quality Assurance" (WAC 246-247-075) | Action | Establishes the monitoring, testing, and quality assurance requirements for radioactive air emissions.<br>Emissions from nonpoint and fugitive sources of airborne radioactive material will be measured. Measurement techniques may include but are not limited to sampling, calculation, smears, or other reasonable method for identifying emissions as determined by the lead agency. | Hazardous contaminants at 100-F/IU waste sites that would be subject to radionuclide air emission standards and resultant requirements have the potential to be detected in, and emitted from, structures, components, debris, soil, or groundwater involved in the remedial actions. | ARAR | Investigative and remedial soil, air, and groundwater monitoring systems, and decontamination and stabilization of contaminated structures, treatment of sludge, and operation of exhausters and vacuums, that produce airborne emissions of hazardous radionuclide pollutants to unrestricted areas. |
| ***Clean Air Act of 1990* and amendments; "National Emission Standard for Asbestos" (40 CFR 61, Subpart M),** | | | | | |
| "Applicability" (40 CFR 61.140)<br>"Standard for Demolition and Renovation" (40 CFR 61.145) | Action | Defines regulated ACM and regulated removal and handling requirements.<br>Specifies sampling, inspection, handling, and disposal requirements for regulated sources having the potential to emit asbestos. Specifically, no visible emissions are allowed during handling, packaging, and transport of ACM. | Encountering ACM on pipelines or buried asbestos within the 100-F/IU area is possible during the during remediation activities. | ARAR | Site investigation and remediation activities that include demolition and/or renovation and associated handling, packaging, and transportation of ACM, including IDW management and disposal. |
| Standard for Waste Disposal for Manufacturing, Fabricating, Demolition, Renovation, and Spraying Operations (40 CFR 61.150) | Action | Identifies requirements for the removal and disposal of asbestos from demolition and renovation activities. | Encountering ACM on pipelines or buried asbestos within the 100-F/IU area is possible during the during remediation activities. | ARAR | Site investigation and remediation activities that include demolition and/or renovation and associated handling, packaging, and transportation of ACM including IDW management and disposal. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| **Solid Wastes** | | | | | |
| ***Toxic Substances Control Act of 1976* (Public Law 107-377, as amended; 15 USC Section 2605, et seq.); "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions" (40 CFR 761)** | | | | | |
| "Applicability," "PCB Waste" (40 CFR 761.50[b]1, 2, 3, 4 and 7)<br>"Applicability," "Storage for Disposal" (40 CFR 761.50[c]) | Action | Establishes general PCB disposal requirements for the storage and disposal of PCB wastes including liquid PCB wastes, PCB items, PCB remediation waste, PCB bulk product wastes, and PCB/radioactive wastes at concentrations greater than 50 ppm. | PCB wastes encountered and or generated during the remediation of 100-F/IU. | ARAR | Soil excavation and remediation, equipment and debris handling and disposal, and IDW management and disposal. |
| "Disposal Requirements," "PCB Liquids" (40 CFR 761.60[a])<br>"Disposal Requirements," "PCB Articles" (40 CFR 761.60[b])<br>"Disposal Requirements," "PCB Containers" (40 CFR 761.60[c]) | Action | Establishes requirements applicable to the handling and disposal of PCB liquids, PCB articles, and PCB containers. | PCB liquids, articles, and/or containers encountered and/or generated during the remedial actions for 100-F/IU. | ARAR | Equipment and debris handling, storage, and disposal; IDW management and disposal. |
| "PCB Remediation Waste" (40 CFR 761.61) | Action | Provides cleanup and disposal options for PCB remediation waste based on the concentration at which the PCBs are found. | PCB remediation wastes encountered and/or generated during the remedial actions for 100-F/IU. | ARAR | Soil remediation, RTD, and IDW management and disposal. |
| **Solid Wastes** | | | | | |
| **"Hazardous Waste Management" (RCW 70.105, as amended); "Dangerous Waste Regulations" (WAC 173-303)** | | | | | |
| "Identifying Solid Waste" (WAC 173-303-016)<br>"Recycling Processes Involving Solid Waste" (WAC 173-303-017) | Action | Establishes criteria for solid and recycled solid wastes. | Solid wastes and/or recycled solid wastes will be generated during 100-F/IU remedial actions. | ARAR | Investigative and remediation activities. |
| "Designation of Dangerous Waste" (WAC 173-303-070) | Action | Establishes the method for determining if a solid waste is a dangerous waste (or an extremely hazardous waste). | Dangerous/hazardous waste will be generated during 100-F/IU remedial actions. | ARAR | Investigative and remediation (including waste treatment) activities that generate wastes (e.g., drums, barrels, tanks, containers, bulk wastes, debris, and contaminated soil). |
| "Conditional Exclusion of Special Wastes" (WAC 173-303-073) | Action | Establishes the conditional exclusion and the management requirements of special wastes, as defined in "Definitions" (WAC 173-303-040). | Special wastes have the potential to be generated during 100-F/IU remedial actions. | ARAR | Remediation activities (disposal, storage, recycling, and onsite treatment) that manage special wastes consistent with the requirements of the *Washington Administrative Code*. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| "Requirements for Universal Waste" (WAC 173-303-077) | Action | Identifies those wastes exempted from regulation under "Land Disposal Restrictions" (WAC 173-303-140) and "Requirements for Generators of Dangerous Waste" (WAC 173-303-170) through "Reserved" (WAC 173-303-9907) (excluding, "Special Powers and Authorities of the Department" [WAC 173-303-960]). These wastes are subject to regulation under "Standards for Universal Waste Management" (WAC 173-303-573). | Universal wastes have the potential to be generated during the 100-F/IU remedial actions. | ARAR | Remediation activities (disposal, storage, recycling, and onsite treatment) that manage universal wastes consistent with the requirements of the *Washington Administrative Code*. |
| "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120) "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120[3]) "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120[5]) | Action | Defines the requirements for the recycling of materials that are solid and dangerous waste. Specifically, "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120[3]) provides for the management of certain recyclable materials, including spent refrigerants, antifreeze, and lead acid batteries. "Recycled, Reclaimed, and Recovered Wastes" (WAC 173-303-120[5]) provides for the recycling of used oil. | Recycled, reclaimed, and recovered wastes have the potential to be generated during 100-F/IU remedial actions. | ARAR | Remediation recycling activities consistent with the requirements of the *Washington Administrative Code* and not otherwise subject to CERCLA as hazardous substances. |
| "Land Disposal Restrictions" (WAC 173-303-140) | Action | Establishes treatment requirements and disposal prohibitions for land disposal of dangerous waste and incorporates by reference "Land Disposal Restrictions" (WAC 173-303-140[2][a]), and the federal land disposal restrictions of "Land Disposal Restrictions" (40 CFR 268) that are applicable to solid waste that is a dangerous or mixed waste in accordance with "Designation of Dangerous Waste" (WAC 173-303-070[3]). | Onsite land disposal at ERDF may be a component of the selected remedy for 100-F/IU dangerous waste and debris. | ARAR | Investigative and remediation wastes destined for onsite land disposal. |
| "Requirements for Generators of Dangerous Waste" (WAC 173-303-170) | Action | Establishes the requirements for dangerous waste generators. "Requirements for Generators of Dangerous Waste" (WAC 173-303-170[3]) includes the substantive provisions of "Accumulating Dangerous Waste On-Site" (WAC 173-303-200) by reference. "Accumulating Dangerous Waste On-Site" (WAC 173-303-200) further includes certain substantive standards from "Use and Management of Containers" (WAC 173-303-630) and "Tank Systems" (WAC 173-303-640) by reference. Specifically, the substantive standards for management of dangerous/mixed waste are applicable to the management of dangerous waste that will be generated during the remedial action. | Dangerous wastes will be generated from the remedial actions in 100-F/IU. | ARAR | IDW and remediation wastes (contaminated soil and groundwater, personnel protective gear, treatment chemicals). |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| "Accumulating Dangerous Waste On-Site" (WAC 173-303-200) | Action | Establishes the requirements for accumulating wastes onsite. "Accumulating Dangerous Waste On-Site" (WAC 173-303-200) further includes certain substantive standards from "Use and Management of Containers (WAC 173-303-630) and "Tank Systems" (WAC 173-303-640) by reference. | Dangerous waste will be generated from the remedial actions in 100-F/IU. | ARAR | Management of dangerous waste during remedial and investigative actions. |
| "Requirements" (WAC 173-303-64620[4]) | Action | Establishes the standards for implementing corrective action for releases of dangerous waste and constituents under the HWMA. Requires corrective action to be "consistent with" specified sections of "Model Toxics Control Act—Cleanup" (WAC 173-340) and "Dangerous Waste Regulations," "Requirements" (WAC 173-303-64620[4]). | Corrective action applies to all releases of dangerous waste and dangerous constituents during Hanford operations as stated in "Requirements" (WAC 173-303-64620[1]). CERCLA may be the authority being used to clean up the release; the cleanup must be "consistent with" corrective action. The substantive portions of "Model Toxics Control Act—Cleanup" (WAC 173-340) establish minimum requirements for HWMA corrective action. | ARAR | Corrective action applies to environmental media at the Hanford site where dangerous waste and dangerous constituents have been placed, whether intentional or unintentional, during Hanford operations. |
| **"Solid Waste Management—Reduction and Recycling" (RCW 70.95, as amended); "Solid Waste Handling Standards" (WAC 173-350)** | | | | | |
| "Owner Responsibilities for Solid Waste (WAC 173-350-025)<br>"Performance Standards" (WAC 173-350-040)<br>"On-Site Storage, Collection and Transportation Standards" (WAC 173-350-300)<br>"Remedial Action" (WAC 173-350-900) | Action | Establishes minimum functional performance standards for the proper handling and disposal of solid waste. Details requirements for the proper handling of solid waste materials originating from residences, commercial, agricultural and industrial operations, and other sources, and identifies those functions necessary to ensure effective solid waste handling programs at both the state and local level. | Solid, nondangerous waste will be generated during implementation of 100-F/IU remedial actions. | ARAR | Investigative and remedial actions that generate solid, nondangerous waste. |
| **Historical and Archeological Resources** | | | | | |
| ***National Historic Preservation Act of 1966* (Public Law 89-665, as amended, 16 USC 470, et seq.)** | | | | | |
| "Protection of Historic Properties" (36 CFR 800) | Location | Legislation intended to preserve historical and archaeological sites in the United States of America. Requires federal agencies to consider the impacts of their undertaking on cultural properties through identification, evaluation, mitigation processes, and consultation with interested parties. | Cultural and historic sites have been identified within 100-F/IU. | ARAR | Investigation and remediation activities that occur in areas near cultural or historic sites. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| ***Protection and Enhancement of the Cultural Environment*** **(Executive Order 11593)** | | | | | |
| "National Historic Landmarks Program" (36 CFR 65)<br>"National Register of Historic Places" (36 CFR 60) | Location | Requires federal agencies to consider the impacts of their undertaking on cultural properties through identification, evaluation, mitigation processes, and consultation with interested parties. | Cultural and historic sites have been identified within 100-F/IU. | ARAR | Investigation and remediation activities that occur in areas near cultural or historic sites. |
| ***Native American Graves Protection and Repatriation Act of 1990*** **(Public Law 101-601, as amended, 25 USC 3001, et seq.); "Native American Graves Protection and Repatriation Regulations" (43 CFR 10)** | | | | | |
| "Native American Graves Protection and Repatriation Regulations" (43 CFR 10) | Location | Establishes federal agency responsibility for discovery of human remains, associated and unassociated funerary objects, sacred objects, and items of cultural patrimony. Requires Native American Tribal consultation in the event of discovery. | Native American archaeological, cultural, and historic sites have been identified within 100-F/IU; Native American remains and associated objects have the potential to be present. | ARAR | Investigations and remedial activities that affect Native American archaeological, cultural areas and historic sites that contain associated remains and objects. |
| ***Archeological and Historic Preservation Act of 1974*** **(Public Law 93-291, as amended; 16 USC 469a-1 through 469a-2(d))** | | | | | |
| "Applicant Requirements" 16 USC 469a-1 through 469a-2(d) | Location | Requires that remedial actions do not cause the loss of any archaeological or historic data. This act mandates preservation of the data; it does not require protection of the actual waste site or facility. | Archaeological and historic sites have been identified within 100-F/IU. | ARAR | Investigation and remediation activities that occur in areas near archeological or historic sites. |
| **Natural and Ecological Resources** | | | | | |
| ***Floodplain Management*** **(Executive Order 11988)** | | | | | |
| "Compliance with Floodplain and Wetland Environmental Review Requirements" (10 CFR 1022) | Location | Take action to avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values of the floodplain. | Some of the waste sites within 100-F/IU subject to remediation are located within the Columbia River floodplain. | ARAR | Remedial actions will occur in the floodplain. |
| ***Endangered Species Act of 1973*** **(Public Law 93-205, as amended; 7 USC Section 136; 16 USC Ch. 1531, et seq.)** | | | | | |
| "Interagency Cooperation—Endangered Species Act of 1973, as Amended" (50 CFR 402) | Location | Prohibits actions by federal agencies that are likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of habitat critical to them. Mitigation measures must be applied to actions that occur within critical habitats or surrounding buffer zones of listed species, in order to protect the resource. | Federal endangered and/or threatened species including fish, plants, and animals are found within 100-F/IU. | ARAR | Remediation actions and investigation activities that occur within critical habitats or designated buffer zones of federal listed species. |

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-F/IU

| Regulatory Citation | ARAR Category | Description of Regulatory Requirement | Rationale for Including | Potential Relevancy | Possible Application |
|---|---|---|---|---|---|
| ***Migratory Bird Treaty Act of 1918* (16 USC 703-712; Ch. 128; July 13, 1918; 40 Stat. 755), as amended** | | | | | |
| *Migratory Bird Treaty Act of 1918* (16 USC 703-712) | Location | Protects all migratory bird species and prevents "take" of protected migratory birds, their young, or their eggs." | Migratory birds occur in 100-F/IU. | ARAR | Remedial actions that require mitigation measures to deter nesting by migratory birds on, around, or within remedial action site and methods to identify and protect occupied bird nests. |
| **"Powers and Duties," "Habitat Buffer Zone for Bald Eagles—Rules" (RCW 77.12.655); "Permanent Regulations," "Bald Eagle Protection Rules" (WAC 232-12-292)** | | | | | |
| "Permanent Regulations," "Bald Eagle Protection Rules" (WAC 232-12-292) | Location | Protects eagle habitat to maintain eagle populations so the species is not classified as threatened, endangered, or sensitive in Washington State. | Bald eagles nest, feed, and overwinter along the shores of the Columbia River in 100-F/IU. | ARAR | Investigative and remediation activities that affect bald eagle habitat. |
| ***Fish and Wildlife Conservation Act of 1980* (Public Law 96-366, as amended; 16 USC 2901-2911)** | | | | | |
| "Rules Implementing the Fish and Wildlife Conservation Act of 1980" (50 CFR 83) | Location | Preserve and promote conservation of non-game fish and wildlife and their habitats. | Wildlife and their habitats have the potential to occur in 100-F/IU. | ARAR | Remedial action that affect non-game fish, and wildlife and/or their habitats. |
| **Land Use and Exposure Scenarios** | | | | | |
| *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE/EIS-0222-F) | Location | Establishes the future land-use projections for the Hanford Site which includes 100-F/IU. | Land use, as stated in the Hanford Comprehensive Land Use Plan, is conservation/mining for land outside either (1) the Hanford Reach National Monument, or (2) the River Corridor, which includes 100-F/IU. | TBC | |

Note: Complete reference citations are provided in Chapter 11.

ACM = asbestos-containing material
ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate requirement
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC = contaminant of potential concern
EcoSSL = ecological soil screening level
EPA = U.S. Environmental Protection Agency
HHE = human health and the environment
HWMA = Hazardous Waste Management Act
IDW = investigation-derived waste
MCL = maximum contaminant level
MCLG = maximum contaminant level goal
MNA = monitored natural attenuation
NRC = U.S. Nuclear Regulatory Commission
PCB = polychlorinated biphenyl
RTD = removal, treatment, and disposal
TBC = to be considered

These standards are in the form of risk-based concentrations that help establish soil and groundwater cleanup standards for nonradioactive contaminants. Following is a list of additional Washington State and federal regulations:

- Substantive portions of MTCA ("Selection of Cleanup Actions" [WAC 173-340-360] and MTCA "Overview of Cleanup Standards" [WAC 173-340-700] through MTCA "Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]).
- Nonzero MCL goals and MCLs promulgated under the SDWA, "National Primary Drinking Water Regulations" (40 CFR 141) and/or by the State of Washington ("Group A Public Water Supplies" [WAC 246-290]) as they apply to primary DWS constituents.
- AWQC and state water quality standards at the groundwater/surface water interface developed under the CWA (Section 304) and/or promulgated by the state of Washington ("Water Quality Standards for Groundwaters of the State of Washington" [WAC 173-200] and "Water Quality Standards for Surface Waters of the State of Washington" [WAC 173-201A])
- *Toxic Substances Control Act of 1976* (TSCA) (implemented via "Polychlorinated Biphenyls [PCBs] Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions" [40 CFR 761])
- "National Primary and Secondary Ambient Air Quality Standards" (40 CFR 50)
- "National Emission Standards for Hazardous Air Pollutants" (40 CFR 61)

*Potential Location-Specific ARARs*. Potential location-specific ARARs that have been identified for the 100-F/IU include those that protect cultural, historic, and Native American sites and artifacts under the *Native American Graves Protection and Repatriation Act of 1990*, *Archeological and Historic Preservation Act of 1974*, and *National Historic Preservation Act of 1966* (NHPA) and those that protect listed endangered and threatened species or their critical habitat under the *Endangered Species Act of 1973*. The *Migratory Bird Treaty Act of 1918* has been identified as a substantive standard for DOE compliance in executive orders and *Memorandum of Understanding Between the United States Department of Energy and the United States Fish and Wildlife Service Regarding Implementation of Executive Order 13186, "Responsibilities of Federal Agencies to Protect Migratory Birds"* (DOE and USFWS, 2006), and is pertinent for CERCLA response actions when there is potential for adverse effects on protected bird species.

*Potential Action-Specific ARARs*. Action-specific ARARs that could be pertinent to possible remediation activities at 100-F/IU relate to waste management activities; solid and dangerous waste regulations (for management of characterization and remediation wastes, and performance standards for waste left in place); and radioactive waste management under AEA regulations. The other major category of action-specific ARARs concerns standards for controlling emissions to the environment.

#### 8.1.2.4 Waste Management Standards

Remedial action alternatives proposed in Chapter 9 have the potential to produce a variety of waste that contains both radioactive and chemical constituents. It is anticipated that most radioactive waste will be a low-level waste. However, quantities of PCB- contaminated waste, and asbestos and asbestos-containing material could be included in the remediation waste. The majority of the waste will be in a solid form.

The management of CERCLA waste would be subject to the substantive provisions of RCRA. In the state of Washington, RCRA is implemented through "Dangerous Waste Regulations" (WAC 173-303), which is an EPA-authorized state RCRA program. Treatment standards for dangerous or mixed waste that is subject to RCRA land disposal restrictions are specified in "Dangerous Waste Regulations," "Land

Disposal Restrictions" (WAC 173-303-140), which incorporates "Land Disposal Restrictions" (40 CFR 268) by reference. Radioactive waste is managed by DOE under the authority of the AEA. EPA has regulatory authority over release of radioactive waste in context of a CERCLA action.

Waste generated through the CERCLA remedial actions and is a low-level radioactive waste that meets ERDF acceptance criteria (*Environmental Restoration Disposal Facility Waste Acceptance Criteria* [WCH-191]) is planned to be disposed at ERDF, which is engineered to meet appropriate performance standards for mixed radioactive and hazardous waste. ERDF is considered onsite with Hanford remedial actions for the purpose of management and/or disposal of waste.[1]

CERCLA waste would be treated, as appropriate to meet land disposal restrictions and ERDF acceptance criteria, and disposed at ERDF. ERDF is an engineered facility that provides a high degree of protection for HHE and is designed to meet RCRA minimum technical requirements for landfills, including standards for a double liner, a leachate collection system, leak detection, monitoring, and final cover. Construction and operation of ERDF was authorized under a separate CERCLA ROD (*Declaration of the Interim Record of Decision for the Environmental Restoration Disposal Facility* [hereinafter called ERDF ROD (EPA/ROD/R10-95/100)]; *Record of Decision Amendment: U.S. Department of Energy Environmental Restoration Disposal Facility Hanford Site – 200 Area Benton County, Washington* [EPA/AMD/R10-02/030]). *Explanation of Significant Differences: USDOE Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington* (hereinafter called ERDF ESD [EPA/ESD/R10-96/145]) modified the ERDF ROD (EPA/ROD/R10-95/100) to clarify the eligibility of waste generated during cleanup of the Hanford Site. Per ERDF ESD (EPA/ESD/R10-96/145), ERDF is eligible for disposal of any Hanford cleanup waste, provided the waste meets ERDF waste acceptance criteria.

The TSCA and regulations in "Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions" (40 CFR 761) generally govern the management and disposal of PCB wastes. The TSCA regulations contain specific provisions for PCB waste, including PCB waste that contains a radioactive component. The PCBs also are considered underlying hazardous constituents under RCRA and, thus, could be subject to "Dangerous Waste Regulations" (WAC 173-303) and "Land Disposal Restrictions" (40 CFR 268) requirements.

Removal and disposal of asbestos and asbestos-containing material are regulated under the *Clean Air Act of 1990* and "National Emission Standards for Hazardous Air Pollutants" (NESHAP), "National Emission Standard for Asbestos" (40 CFR 61, Subpart M). These regulations provide for special precautions to prevent environmental releases or exposure to personnel of airborne emissions of asbestos fibers during remedial actions.

Some of the aqueous waste would be transported to the Effluent Treatment Facility (ETF) for treatment and disposal. The ETF is a RCRA-permitted facility authorized to treat aqueous waste streams generated

[1] "Response Authorities" (CERCLA Section 104[d][4]), "...where two or more noncontiguous facilities are reasonably related on the basis of geography, or on the basis of the threat or potential threat to the public health or welfare or the environment, the President may, at his discretion, treat these facilities as one." The preamble to the NCP (40 CFR 300) clarifies the stated EPA interpretation that when noncontiguous facilities are reasonably close to one another, and wastes at these sites are compatible for a selected treatment or disposal approach, "Response Authorities" (CERCLA Section 104[d][4]) allows the lead agency to treat these related facilities as one for response purposes. This allows the lead agency to manage waste transferred between such noncontiguous facilities without having to obtain a permit. The ERDF is considered to be onsite for response purposes under this remedial/removal/removal action. It should be noted that the scope of work covered in this remedial/removal/removal action is for a facility and waste contaminated with hazardous substances.

on the Hanford Site and dispose of these streams at a designated state-approved land disposal facility in accordance with applicable requirements.

#### 8.1.2.5 Standards Controlling Emissions to the Environment

Remedial action alternatives proposed in Chapter 9 have the potential to generate airborne emissions of both radioactive and toxic/criteria airborne emissions. Implementation of these activities and associated air monitoring will be discussed in the RD/RA work plan for 100-F/IU.

#### 8.1.2.6 Radiological Air Emissions

The federal CAA and the "Washington Clean Air Act" (RCW 70.94) each require regulation of radioactive air emissions. The state implementing regulation "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480) sets standards that are as stringent or more stringent than the standards under the federal CAA, including the federal implementing regulation ("National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" [40 CFR 61, Subpart H]). EPA's partial delegation of "General Provisions" (40 CFR 61, Subpart A); and "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (Subpart H) authority to the state of Washington includes all substantive emissions monitoring, abatement, and reporting aspects of the federal regulation. These state standards protect the public by conservatively establishing exposure standards applicable to the maximally exposed public individual.

"Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480) limits emissions of radionuclides to the ambient air by requiring that emissions of radionuclides in the air shall not cause a maximum effective dose equivalent of more than 10 mrem/yr to the whole body to any member of the public. Under the state implementing regulations, "Radiation Protection—Air Emissions" "Definitions" (WAC 246-247-030[15]) defines the member of the public (real or hypothetical) as one who abides or resides in an unrestricted area and may receive the highest total effective dose equivalent from the emission unit(s) under consideration, taking into account all exposure pathways affected by the radioactive air emissions. (Members of the public can travel on the Columbia River through the Hanford Reach, but they cannot "abide or reside" there.) In addition, by its adoption of the federal NESHAP "Standard" (40 CFR 61.92), the state limits radionuclide airborne emissions from the Hanford Site (i.e., facility) to not exceed amounts that would cause an exposure to any member of the public of greater than 10 mrem/yr effective dose equivalent. The state implementing regulation "Radiation Protection—Air Emissions" (WAC 246-247), which references the "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480) standards and adopts the "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H), requires verification of compliance with the 10 mrem/yr standard and would be applicable to the remedial action.

"Radiation Protection—Air Emissions" (WAC 246-247) further addresses sources emitting radioactive airborne emissions by requiring monitoring of such sources (emission units). Such monitoring may involve various methods depending upon the configuration of the source. Most stacks or vents are monitored by extracting representative samples of the effluent stream from the stack or vent, with subsequent analysis of the samples. Emissions that do not pass through a stack, vent, or functionally equivalent structure are termed diffuse emissions, and these are normally monitored by extraction of samples of the ambient air, with subsequent laboratory analyses. The substantive provisions of "Radiation Protection—Air Emissions" (WAC 246-247) that require monitoring of radioactive airborne emissions would potentially be applicable to remedial action and would generally be an "applicable" ARAR.

The above-stated implementing regulations further require control of radioactive airborne emissions to the extent economically and technologically feasible ("Radiation Protection—Air Emissions," "General Standards" [WAC 246-247-040(3) and -040(4)]). To address the substantive aspect of these requirements, best or reasonably achieved control technology could be addressed by ensuring that applicable emission control technologies (those successfully operated in similar applications) would be used when economically and technologically feasible (i.e., based on cost/benefit). Controls will be administered, as appropriate, using the best methods from among those that are reasonable and effective.

#### 8.1.2.7 Criteria/Toxic Air Emissions

Under "General Regulations for Air Pollution Sources" (WAC 173-400) and "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460), requirements are established for the regulation of emissions of criteria/toxic air pollutants. The primary nonradioactive emissions resulting from remedial actions will be fugitive particulate matter. In accordance with "General Regulations for Air Pollution Sources," "General Standards for Maximum Emissions" (WAC 173-400-040), reasonable precautions must be taken to (1) prevent the release of air contaminants associated with fugitive emissions resulting from excavation, materials handling, or other operations; and (2) prevent fugitive dust from becoming airborne from fugitive sources of emissions. The use of treatment technologies that would result in emissions of toxic air pollutants that would be subject to the substantive applicable requirements of "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460) is not anticipated to be a part of remedial action selected for 100-F/IU.

If treatment of some waste encountered during the remedial action is required to meet ERDF waste acceptance criteria, the type of treatment anticipated would consist of solidification/stabilization techniques such as microencapsulation or grouting, and "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460) would not be considered an ARAR. If more aggressive treatment is required that would result in the emission of regulated air pollutants, the substantive requirements of "General Regulations for Air Pollution Sources," "Requirements for New Sources in Attainment or Unclassifiable Areas" (WAC 173-400-113[2]) and "Controls for New Sources of Toxic Air Pollutants," "Control Technology Requirements" (WAC 173-460-060) would be evaluated to determine potential applicability.

Emissions to the air will be minimized during implementation of remedial actions through use of standard industry practices such as the application of water sprays and fixatives. These techniques are considered reasonable precautions to control fugitive emissions as required by the regulatory standards.

#### 8.1.2.8 Groundwater Beneficial Use

CERCLA and the NCP (40 CFR 300) establish separate requirements for a groundwater remedy: to be protective of HHE, and to meet ARARs. This is a concept of central importance to the development of the groundwater remedy for the 100-FR-3 OU. These separate requirements are further clarified in the memorandum, "Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA" (Fields, 1997).

The requirement to achieve threshold protectiveness and ARAR-based requirements is established by the NCP (40 CFR 300). The NCP (40 CFR 300) also establishes the requirement to return useable groundwater to beneficial use within a reasonable time frame. EPA generally defers to state agency definitions of useable groundwater provided under state groundwater protection programs, administered by the states across the United States, and a state's determination of groundwater usability at CERCLA sites (*Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites* [EPA/540/G-88/003]). The state of Washington defines groundwater as potable in MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720(2)]), unless the exclusion criteria in MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720(2)(a) through (c)]) can be demonstrated (e.g., insufficient yield

or natural constituents that make it unsuitable as a drinking water source). The groundwater within the100-FR-3 OU does not meet the exclusion criteria; therefore, it is classified as potable and must be restored to beneficial use wherever practicable and within a time frame that is reasonably consistent with NCP (40 CFR 300) requirements. The state of Washington has further determined that the highest beneficial use for potable groundwater at most of the cleanup sites within the state, including the Hanford site, is as a potential source of domestic drinking water (MTCA, "Groundwater Cleanup Standards" [WAC 173-340-720(1)(a)]).

Groundwater within the 100-FR-3 OU is currently contaminated, and withdrawal is prohibited as a result of ICs placed on it by DOE. Under current site-use conditions, no groundwater wells are available for public consumption specific to 100-F/IU. Further, groundwater within this OU is not anticipated to become a future source of drinking water until cleanup criteria are met. However, groundwater was evaluated for drinking water use to support the determination of the basis for action and to support the development of PRGs for evaluating remedial alternatives in the FS.

#### *8.1.2.9 Surface Water Beneficial Use*

Surface water beneficial use is considered because groundwater within the 100-FR-3 OU currently discharges to the Columbia River through seeps and upwelling. "Water Quality Standards for Surface Waters of the State of Washington," "Use Designations—Fresh Waters" (WAC 173-201A-600) and "Water Quality Standards for Surface Waters of the State of Washington," "Table 602—Use Designations for Fresh Waters by Water Resource Inventory Area (WRIA)" (WAC 173-201A-602) identify the beneficial use (or designated uses) for rivers and streams of Washington State. Designated uses for waters of Washington State can include public water supply; protection for fish, shellfish, and wildlife; and recreational, agricultural, industrial, navigational, and aesthetic purposes. Water quality criteria are designed to protect the designated uses and are used to assess the general health of Washington surface waters and set permit limits. The surface water quality standards are considered at the groundwater/surface water interface.

Designated uses of the Columbia River, identified in "Water Quality Standards for Surface Waters of the State of Washington," "Table 602—Use Designations for Fresh Waters by Water Resource Inventory Area (WRIA)" [WAC 173-201A-602]), include the following:

- Aquatic life uses: spawning and rearing
- Recreational uses: primary contact
- Water supply uses: drinking water, industrial water, agricultural water, and stock water
- Miscellaneous uses: wildlife habitat, harvesting, commercial/navigation, boating, and aesthetics

The groundwater risk assessment presented in Chapter 6, Section 6.3 evaluates potential exposure of aquatic organisms to contaminants present in 100-F/IU groundwater. This assessment uses the most stringent federal and state water quality criteria to support the basis for action and to support PRG development. Surface water state and/or federal ARARs would only apply to groundwater at points of discharge to surface water.

### 8.1.3 Remedial Action Objectives

Under CERCLA and the NCP (40 CFR 300), all soil and groundwater remedies must be protective of HHE and meet ARARs (or satisfy criteria for an ARAR to be waived). RAOs must be developed to address COCs, media of concern, potential receptors, and exposure pathways. RAOs are general descriptions of what a cleanup under CERCLA is expected to accomplish. They are narrative statements that define the extent to which waste sites and groundwater require cleanup to protect HHE.

The RAOs presented below are based on existing River Corridor regulatory documents (e.g., interim action RODs) and were expanded to cover gaps when integrating all media and resources for an area. Media-specific RAOs were developed for groundwater (RAO 1), surface water (RAO 2), and soil (RAOs 3 through 5). The combined RAO list is as follows:

- **RAO 1:** Prevent unacceptable risk to human health from ingestion of and exposure to groundwater containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO 2:** Prevent unacceptable risk to human health and ecological exposure to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO 3:** Prevent unacceptable risk from contaminants migrating and/or leaching through soil that will result in groundwater concentrations that exceed federal and state standards and risk-based thresholds for protection of surface water and groundwater.
- **RAO 4:** Prevent unacceptable risk to human health and ecological receptors from exposure to the upper 4.6 m (15 ft) of soil, structures, and debris contaminated with nonradiological constituents at concentrations above the unrestricted land-use criteria for human health (provided in MTCA Method B) or soil contaminant levels protective of ecological receptors.
- **RAO 5:** Prevent unacceptable risk to human health and ecological receptors from exposure to the upper 4.6 m (15 ft) of soil, structures, and debris contaminated with radiological constituents. For human health and ecological receptors:
  - Prevent exposure to radiological constituents at concentrations at or above a dose rate limit that causes an excess cancer lifetime risk threshold of $10^{-6}$ to $10^{-4}$ above background for the residential exposure scenario.
  - Protect ecological receptors based on a dose rate limit of 0.1 rad/day for terrestrial wildlife populations, which is a TBC criterion.

### 8.1.4 Preliminary Remediation Goals

To meet the RAOs, PRGs are established. These goals generally are quantitative cleanup levels that would meet ARARs and risk-based levels and would be protective of HHE. The PRGs are used to assess the effectiveness of the selected remedial alternatives in meeting the RAOs. A summary of the 100-F/IU human health, groundwater protection, and surface water protection PRGs is provided in Table 8-3. The interim action ROD RAGs identified in the 100 Area RDR/RA Work Plan (DOE/RL-96-17) are also listed in Table 8-3 for a direct comparison to the PRGs from this RI/FS. The evaluation of completed interim remedial actions for protection of HHE is summarized in Chapters 5, 6, and 7. The evaluations for the previously remediated waste sites indicate there are currently no waste sites with complete pathways that represent unacceptable risk. Contamination attributable to orchard lands is evaluated in the 100-OL-1 OU. Evaluation of ongoing interim remedial actions will be conducted at their completion to confirm that there are no unacceptable risks remaining. The PRGs in Table 8-3 will be used to evaluate interim remedial actions for protectiveness.

In Table 8-3, the human health PRGs for radionuclides (highlighted in yellow) are selected from the lower of the residential exposure scenario (based on a target cancer risk level) or the residential interim action ROD RAG (based on radiological dose) as defined in the 100 Area RDR/RA Work Plan (DOE/RL-96-17). For nonradionuclides, except arsenic and lead, the selected human health PRGs (also highlighted in yellow) are the RI/FS MTCA (WAC 173-340) Method B values that are calculated based on the most recent guidance for the residential scenario. Green highlighting denotes the selected PRG

(calculated in this RI/FS) above background for each analyte for groundwater/surface water protection except for Cr(VI), which is compared to the interim action ROD RAG of 2.0 mg/kg.

Table 8-4 presents a summary of ecological PRGs. Ecological PRGs are presented for the four receptor categories (plants, invertebrates, birds, and mammals). If ecological PRGs are exceeded, the site managers will evaluate this exceedance using the SMDP process described in Chapter 7.

PRGs represent a core component of the overall technology screening and remedial alternative development process in the FS. PRGs are numerical values expressed as concentrations for a chemical or radionuclide in an environmental media. A remedial action achievement of PRGs results in residual contamination that is protective of HHE (NCP, "Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(2)(i)]). PRGs are also used to identify the area and volume of environmental media that must be addressed; therefore, PRGs are determined before the development of the remedial alternatives.

Meeting PRGs and the potential ARARs and, by extension, achieving RAOs, can be accomplished by reducing concentrations (or activities) of contaminants to PRG levels or by eliminating potential exposure pathways/routes. Contaminant-specific and numeric soil PRGs for direct exposure, protection of groundwater, and protection of surface water typically are presented as concentrations, which for nonradionuclides are in milligrams per kilogram (mg/kg) for soil and in picocuries per gram (pCi/g) for radionuclides.

Contaminant-specific and numerical cleanup levels for groundwater are typically expressed in micrograms per liter (μg/L) for nonradiological COCs and picocuries per liter (pCi/L) for radiological COCs.

PRGs for residual risks to human health following completion of remediation of the waste sites must meet the $10^{-4}$ to $10^{-6}$ ELCR CERCLA risk range for radiological and carcinogenic COCs, and must be less than or equal to an HI value of 1.0 for noncarcinogenic hazardous substances (as described in Chapter 6).

If selected ecological PRGs are exceeded, the site managers will evaluate this exceedance using the SMDP process described in Chapter 7.

Finally, to demonstrate that waste site cleanups have achieved the groundwater and surface water protection PRGs, the cleanup verification process can involve the evaluation of the CSM against the assumptions used to develop these PRGs (described in Chapter 5). To the extent a significant deviation from the groundwater/surface water protection PRGs assumptions is observed, site-specific conditions can be used to revise the fate and transport models to evaluate the potential for the waste site to act as a source of groundwater and surface water contamination.

#### *8.1.4.1 Development Approach*

PRGs are presented for each environmental media of interest (soil and groundwater), each type of contaminant (hazardous substances and radionuclides), human and ecological receptors, and each potentially complete exposure pathway. The following subsections describe the approach that was taken to develop PRGs for each media, receptor, and exposure pathway.

#### *8.1.4.2 Direct-Contact Exposure PRGs for Nonradiological Contaminants*

Development of the PRGs for direct-contact exposure to nonradiological contamination for both human and ecological receptors is described in the following subsections.

*Human Exposure.* For human receptors, soil PRGs developed for direct-contact and inhalation exposure pathways are risk-based standards for hazardous substances. Risk-based standards for individual

hazardous substances are established using applicable federal and state laws and risk equations. Risk-based standards for individual carcinogens in an unrestricted exposure scenario are based on an ELCR of $1 \times 10^{-6}$ (ELCR of $1 \times 10^{-5}$ cumulative risk) and an HQ of 1.0 for individual noncarcinogenic substances as described in MTCA ("Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740(3)(b)(iii)(B)]).

Consistent with this approach, the methodology described for unrestricted land use under MTCA ("Unrestricted Land Use Soil Cleanup Levels" [WAC 173-340-740(3)]) is used to calculate the risk-based standards for soil ingestion. Risk-based standards for inhalation pathways use equations and input parameters described in MTCA ("Cleanup Standards to Protect Air Quality" [WAC 173-340-750(3)]) and EPA-published volatilization factors and particulate emission factors.

Table 8-3. Summary of 100-F/IU OUs Human Health, Groundwater Protection, and Surface Water Protection Soil PRGs

| Analyte Name | CAS No. | Units | Hanford Site Background Concentration[a] | Human Health PRGs | | | | | | PRGs Protective of Groundwater and Surface Water | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RI/FS Soil MTCA B—Direct Contact PRG[b] | RI/FS Residential PRG[c] | RI/FS Soil Method B Inhalation PRG[d] | RI/FS Casual Recreational User—Direct Contact PRG[e,f] | RI/FS Resident Monument Worker—Direct Contact PRG[g] | DOE/RL 96-17 Residential RAG[h] | 100-F 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP PRG[i] | DOE/RL 96-17 GWP RAG[h] | 100-F 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP PRG[i] | DOE/RL 96-17 SWP RAG[h] |
| **Radionuclides** | | | | | | | | | | | | | | | | | | | | | | | |
| Americium-241 | 14596-10-2 | pCi/g | -- | -- | 155 | -- | 2,570 | 275 | 32 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Carbon-14 | 14762-75-5 | pCi/g | -- | -- | 81 | -- | 328,000 | 52,000 | 8.7 | 80 | 284 | 507 | 195 | 518 | 924 | -- | 80 | 284 | 507 | 195 | 518 | 924 | -- |
| Cesium-137 | 10045-97-3 | pCi/g | 1.1 | -- | 4.4 | -- | 100 | 6.2 | 6.2 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 1,470 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 2,930 |
| Cobalt-60 | 10198-40-0 | pCi/g | 0.0084 | -- | 3.1 | -- | 63 | 3.3 | 1.4 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 13,900 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 27,800 |
| Curium-243 | 15757-87-6 | pCi/g | -- | -- | 30 | -- | 527 | 37 | 22 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Europium-152 | 14683-23-9 | pCi/g | -- | -- | 3.7 | -- | 66 | 3.8 | 3.3 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Europium-154 | 15585-10-1 | pCi/g | 0.033 | -- | 4.4 | -- | 78 | 4.8 | 3.0 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Europium-155 | 14391-16-3 | pCi/g | 0.054 | -- | 327 | -- | 5,870 | 354 | 125 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Iodine-129 | 15046-84-1 | pCi/g | -- | -- | 0.076 | -- | 3,035 | 434 | 0.25 | 0.61 | 3.1 | 5.5 | --[j] | --[j] | --[j] | 0.25 | 0.61 | 3.1 | 5.5 | --[j] | --[j] | --[j] | 0.25 |
| Neptunium-237 | 13994-20-2 | pCi/g | -- | -- | 8.9 | -- | 202 | 15 | 2.4 | 209 | 842 | 1,500 | --[j] | --[j] | --[j] | 0.90 | 209 | 842 | 1,500 | --[j] | --[j] | --[j] | 1.8 |
| Nickel-63 | 13981-37-8 | pCi/g | -- | -- | 608 | -- | 575,000 | 91,600 | 4,013 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 83 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 166 |
| Niobium-94 | 14681-63-1 | pCi/g | -- | -- | 1.4 | -- | 26 | 1.7 | 2.4 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| Plutonium-238 | 13981-16-3 | pCi/g | 0.0038 | -- | 236 | -- | 3,820 | 605 | 39 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Plutonium-239/240 | PU-239/240 | pCi/g | 0.025 | -- | 203 | -- | 3,340 | 539 | 35 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Technetium-99 | 14133-76-7 | pCi/g | -- | -- | 1.5 | -- | 114,449 | 17,322 | 5.8 | 36 | 127 | 227 | 88 | 233 | 415 | 0.46 | 36 | 127 | 227 | 88 | 233 | 415 | 0.92 |
| Total beta radiostrontium (strontium-90) | SR-RAD | pCi/g | 0.18 | -- | 2.3 | -- | 5,060 | 518 | 4.5 | 24,600[p] | 64,200[p] | 104,000[p] | --[j] | --[j] | --[j] | 28 | 24,600[p] | 64,200[p] | 104,000[p] | --[j] | --[j] | --[j] | 55 |
| Tritium | 10028-17-8 | pCi/g | -- | -- | 623 | -- | 15,400 | 1,265,000 | 459 | 1,660 | 7,460 | 13,300 | 2,670 | 9,111 | 16,200 | 13 | 1,660 | 7,460 | 13,300 | 2,670 | 9,111 | 16,200 | 25 |
| Uranium-233/234 | U-233/234 | pCi/g | 1.1 | -- | 133 | -- | 5,810 | 931 | 1.1 | --[k] | --[k] | --[k] | --[k] | --[k] | --[k] | 1.1 | --[k] | --[k] | --[k] | --[k] | --[k] | --[k] | 1.1 |
| Uranium-235 | 15117-96-1 | pCi/g | 0.11 | -- | 16 | -- | 295 | 22 | 0.61 | --[k] | --[k] | --[k] | --[k] | --[k] | --[k] | 0.50 | --[k] | --[k] | --[k] | --[k] | --[k] | --[k] | 0.50 |
| Uranium-238 | U-238 | pCi/g | 1.1 | -- | 54 | -- | 1,093 | 93 | 1.1 | --[k] | --[k] | --[k] | --[k] | --[k] | --[k] | 1.1 | --[k] | --[k] | --[k] | --[k] | --[k] | --[k] | 1.1 |
| **Metals** | | | | | | | | | | | | | | | | | | | | | | | |
| Antimony | 7440-36-0 | mg/kg | 0.13 | 32 | -- | -- | 365 | -- | 32 | 13 | 75 | 134 | --[j] | --[j] | --[j] | 5.0 | 12 | 70 | 125 | --[j] | --[j] | --[j] | 5.0 |
| Arsenic | 7440-38-2 | mg/kg | 6.5 | 20 | -- | 42,414 | 4.5 | -- | 20 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 20 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 20 |
| Barium | 7440-39-3 | mg/kg | 132 | 16,000 | -- | >1,000,000 | 182,000 | -- | 5,600 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 200 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 400 |
| Beryllium | 7440-41-7 | mg/kg | 1.5 | 160 | -- | 75,991 | 1,825 | -- | 10 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 1.5 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 1.5 |
| Boron | 7440-42-8 | mg/kg | 3.9 | 16,000 | -- | >1,000,000 | 183,000 | -- | 7,200 | 5,073 | 30,156 | 53,813 | --[j] | --[j] | --[j] | 320 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| Cadmium | 7440-43-9 | mg/kg | 0.56 | 40 | -- | 101,000 | 821 | -- | 14 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.81 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.81 |
| Chromium | 7440-47-3 | mg/kg | 19 | 120,000 | -- | -- | >1,000,000 | -- | 80,000 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 19 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 19 |
| Cobalt | 7440-48-4 | mg/kg | 16 | 24 | -- | 20,264 | 274 | -- | 24 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 16 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |

Table 8-3. Summary of 100-F/IU OUs Human Health, Groundwater Protection, and Surface Water Protection Soil PRGs

| Analyte Name | CAS No. | Units | Hanford Site Background Concentration[a] | Human Health PRGs | | | | | | PRGs Protective of Groundwater and Surface Water | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RI/FS Soil MTCA B—Direct Contact PRG[b] | RI/FS Residential PRG[c] | RI/FS Soil Method B Inhalation PRG[d] | RI/FS Casual Recreational User—Direct Contact PRG[c,f] | RI/FS Resident Monument Worker—Direct Contact PRG[g] | DOE/RL 96-17 Residential RAG[h] | 100-F 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP PRG[i] | DOE/RL 96-17 GWP RAG[h] | 100-F 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP PRG[i] | DOE/RL 96-17 SWP RAG[h] |
| Copper | 7440-50-8 | mg/kg | 22 | 3,200 | -- | -- | 36,500 | -- | 2,960 | 23,402 | 27,133 | 110,711 | --[j] | --[j] | --[j] | 59 | 329 | 382 | 1,557 | --[j] | --[j] | --[j] | 22 |
| Cr(VI) | 18540-29-9 | mg/kg | -- | 240 | -- | 2,171 | 2,740 | -- | 2.1 | 6.0[l] | 6.0[l] | 6.0[l] | 6.0[l] | 6.0[l] | 6.0[l] | 4.8 | 5.0 | 6.0[l] | 6.0[l] | 6.0[l] | 6.0[l] | 6.0[l] | 2.0 |
| Lead | 7439-92-1 | mg/kg | 10 | 250 | -- | -- | -- | -- | 353 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 10 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 10 |
| Lithium | 7439-93-2 | mg/kg | 13 | 160 | -- | -- | 1,825 | -- | 160 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 34 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| Manganese | 7439-96-5 | mg/kg | 512 | 11,200 | -- | >1,000,000 | 128,000 | -- | 3,760 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 512 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 512 |
| Mercury | 7439-97-6 | mg/kg | 0.013 | 24 | -- | >1,000,000 | 274 | -- | 24 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.33 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.33 |
| Molybdenum | 7439-98-7 | mg/kg | 0.47 | 400 | -- | -- | 4,563 | -- | 400 | 2,465 | 2,781 | 11,847 | --[j] | --[j] | --[j] | 8.0 | 39,950 | 45,067 | 191,967 | --[j] | --[j] | --[j] | -- |
| Nickel | 7440-02-0 | mg/kg | 19 | 1,600 | -- | 701,000 | 18,250 | -- | 1,600 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 19 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 27 |
| Selenium | 7782-49-2 | mg/kg | 0.78 | 400 | -- | >1,000,000 | 4,560 | -- | 400 | 141 | 861 | 1,537 | --[j] | --[j] | --[j] | 5.0 | 14 | 86 | 154 | --[j] | --[j] | --[j] | 1.0 |
| Silver | 7440-22-4 | mg/kg | 0.17 | 400 | -- | -- | 4,563 | -- | 400 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 8.0 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.73 |
| Strontium | 7440-24-6 | mg/kg | -- | 48,000 | -- | -- | 547,500 | -- | 48,000 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 960 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Thallium | 7440-28-0 | mg/kg | 0.19 | -- | -- | -- | -- | -- | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Tin | 7440-31-5 | mg/kg | -- | 48,000 | -- | -- | 547,500 | -- | 48,000 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 960 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | -- |
| Uranium (soluble salts) | 7440-61-1 | mg/kg | 3.2 | 240 | -- | >1,000,000 | 2,737 | -- | 240 | 36 | 180 | 321 | --[j] | --[j] | --[j] | 3.2 | 930 | 4,668 | 8,330 | --[j] | --[j] | --[j] | 3.2 |
| Vanadium | 7440-62-2 | mg/kg | 85 | 400 | -- | -- | 4,560 | -- | 560 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 85 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| Zinc | 7440-66-6 | mg/kg | 68 | 24,000 | -- | -- | 274,000 | -- | 24,000 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 480 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 68 |
| **Other Inorganics** | | | | | | | | | | | | | | | | | | | | | | | |
| Chloride | 16887-00-6 | mg/kg | 100 | -- | -- | -- | -- | -- | -- | 9,965 | 35,329 | 63,038 | 24,300 | 64,705 | 115,389 | 25,000 | 9,168 | 32,503 | 57,995 | 22,356 | 59,529 | 106,158 | -- |
| Cyanide | 57-12-5 | mg/kg | -- | 1,600 | -- | -- | 18,250 | -- | 1,600 | 1,213 | 6,942 | 12,555 | --[j] | --[j] | --[j] | 20 | 32 | 180 | 326 | --[j] | --[j] | --[j] | 1.0 |
| Fluoride | 16984-48-8 | mg/kg | 2.8 | 4,800 | -- | >1,000,000 | 54,750 | -- | 4,800 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 96 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 400 |
| Nitrate | 14797-55-8 | mg/kg | 52 | 568,000 | -- | -- | >1,000,000 | -- | 567,000[n] | 1,794 | 6,359 | 11,347 | 4,374 | 11,647 | 20,770 | 4,430[m] | 1,794 | 6,359 | 11,347 | 4,374 | 11,647 | 20,770 | 8,860[m] |
| Nitrite | 14797-65-0 | mg/kg | -- | 24,000 | -- | -- | 274,000 | -- | 26,300[n] | 132 | 466 | 832 | 321 | 854 | 1,523 | 329[m] | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 658[m] |
| Sulfate | 14808-79-8 | mg/kg | 237 | -- | -- | -- | -- | -- | -- | 9,965 | 35,329 | 63,038 | 24,300 | 64,705 | 115,389 | 25,000 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| **Polychlorinated Biphenyls** | | | | | | | | | | | | | | | | | | | | | | | |
| Polychlorinated biphenyls (PCBs) | 1336-36-3 | mg/kg | -- | -- | -- | >1,000,000 | 13 | -- | 0.50 | -- | -- | -- | -- | -- | -- | 0.017 | -- | -- | -- | -- | -- | -- | 0.017 |
| Aroclor-1016 | 12674-11-2 | mg/kg | -- | 5.6 | -- | >1,000,000 | 46 | -- | 0.50 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 |
| Aroclor-1221 | 11104-28-2 | mg/kg | -- | 0.50 | -- | 320,000 | 2.0 | -- | 0.50 | 0.28 | 1.6 | 2.9 | --[j] | --[j] | --[j] | 0.017 | 0.017 | 0.017 | 0.017 | --[j] | --[j] | --[j] | 0.017 |
| Aroclor-1232 | 11141-16-5 | mg/kg | -- | 0.50 | -- | 320,000 | 2.0 | -- | 0.50 | 0.28 | 1.6 | 2.9 | --[j] | --[j] | --[j] | 0.017 | 0.017 | 0.017 | 0.017 | --[j] | --[j] | --[j] | 0.017 |
| Aroclor-1242 | 53469-21-9 | mg/kg | -- | 0.50 | -- | 320,000 | 2.6 | -- | 0.50 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 |
| Aroclor-1248 | 12672-29-6 | mg/kg | -- | 0.50 | -- | 320,000 | 2.6 | -- | 0.50 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 |

Table 8-3. Summary of 100-F/IU OUs Human Health, Groundwater Protection, and Surface Water Protection Soil PRGs

| Analyte Name | CAS No. | Units | Hanford Site Background Concentration[a] | Human Health PRGs | | | | | | PRGs Protective of Groundwater and Surface Water | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RI/FS Soil MTCA B—Direct Contact PRG[b] | RI/FS Residential PRG[c] | RI/FS Soil Method B Inhalation PRG[d] | RI/FS Casual Recreational User—Direct Contact PRG[c,f] | RI/FS Resident Monument Worker—Direct Contact PRG[g] | DOE/RL 96-17 Residential RAG[h] | 100-F 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP PRG[i] | DOE/RL 96-17 GWP RAG[h] | 100-F 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP PRG[i] | DOE/RL 96-17 SWP RAG[h] |
| Aroclor-1254 | 11097-69-1 | mg/kg | -- | 0.50 | -- | 320,000 | 2.6 | -- | 0.50 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 |
| Aroclor-1260 | 11096-82-5 | mg/kg | -- | 0.50 | -- | 320,000 | 2.6 | -- | 0.50 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 |
| **Pesticides** | | | | | | | | | | | | | | | | | | | | | | | |
| 2,4,5-TP(2-(2,4,5-Trichlorophenoxy)propionic acid) (Silvex) | 93-72-1 | mg/kg | -- | 640 | -- | -- | 5,703 | -- | 640 | 4.1 | 19 | 33 | 11 | 33 | 59 | 5.0 | 0.83 | 3.7 | 6.7 | 2.2 | 6.6 | 12 | -- |
| 2,4,5-T(2,4,5-Trichlorophenoxyacetic acid) | 93-76-5 | mg/kg | -- | 800 | -- | -- | 7,129 | -- | 800 | 10 | 46 | 81 | 27 | 80 | 143 | 16 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| 2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid) | 94-82-6 | mg/kg | -- | 640 | -- | -- | 5,703 | -- | 640 | 12 | 55 | 98 | 34 | 98 | 175 | 13 | 614 | 2,827 | 5,044 | 1,731 | 5,020 | 8,951 | -- |
| 2,4-Dichlorophenoxyacetic acid | 94-75-7 | mg/kg | -- | 800 | -- | -- | 8,004 | -- | 640 | 3.8 | 16 | 28 | 9.5 | 28 | 50 | 7.0 | 5.5 | 22 | 40 | 14 | 40 | 71 | -- |
| 4,4'-DDD (Dichlorodiphenyldichloroethane) | 72-54-8 | mg/kg | -- | 4.2 | -- | >1,000,000 | 24 | -- | 4.2 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.037 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0033 |
| 4,4'-DDE (Dichlorodiphenyldichloroethylene) | 72-55-9 | mg/kg | -- | 2.9 | -- | >1,000,000 | 17 | -- | 2.9 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.026 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0033 |
| 4,4'-DDT (Dichlorodiphenyltrichloroethane) | 50-29-3 | mg/kg | -- | 2.9 | -- | >1,000,000 | 20 | -- | 2.9 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.026 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0033 |
| Aldrin | 309-00-2 | mg/kg | -- | 0.059 | -- | 37,220 | 0.33 | -- | 0.059 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0017 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0017 |
| Alpha-BHC | 319-84-6 | mg/kg | -- | 0.16 | -- | 101,322 | 0.90 | -- | 0.16 | 0.014 | 0.068 | 0.12 | --[j] | --[j] | --[j] | 0.0017 | 0.0025 | 0.013 | 0.023 | --[j] | --[j] | --[j] | 0.0017 |
| Alpha-Chlordane | 5103-71-9 | mg/kg | -- | 2.9 | -- | >1,000,000 | 19 | -- | 2.9 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.025 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 |
| Beta-BHC | 319-85-7 | mg/kg | -- | 0.56 | -- | 344,111 | 3.1 | -- | 0.56 | 0.060 | 0.31 | 0.56 | --[j] | --[j] | --[j] | 0.0049 | 0.011 | 0.058 | 0.10 | --[j] | --[j] | --[j] | 0.0055 |
| Dalapon | 75-99-0 | mg/kg | -- | 2,400 | -- | -- | 21,387 | -- | 2,400 | 8.2 | 30 | 53 | 20 | 54 | 97 | 20 | 444 | 1,602 | 2,858 | 1,083 | 2,924 | 5,215 | -- |
| Delta-BHC | 319-86-8 | mg/kg | -- | -- | -- | -- | -- | -- | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| Dicamba | 1918-00-9 | mg/kg | -- | 2,400 | -- | -- | 21,387 | -- | 2,400 | 26 | 108 | 192 | 65 | 192 | 342 | 48 | 1,349 | 5,526 | 9,859 | 3,346 | 9,834 | 17,535 | -- |
| Dieldrin | 60-57-1 | mg/kg | -- | 0.063 | -- | 39,648 | 0.35 | -- | 0.063 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0033 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0033 |
| Dinoseb(2-secButyl-4,6-dinitrophenol) | 88-85-7 | mg/kg | -- | 80 | -- | -- | 713 | -- | 80 | 13 | 79 | 141 | --[j] | --[j] | --[j] | 0.70 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| Endosulfan I | 959-98-8 | mg/kg | -- | 480 | -- | -- | 4,277 | -- | 480 | 116 | 587 | 1,047 | --[j] | --[j] | --[j] | 9.6 | 0.068 | 0.34 | 0.61 | --[j] | --[j] | --[j] | 0.011 |
| Endosulfan II | 33213-65-9 | mg/kg | -- | 480 | -- | -- | 4,277 | -- | 480 | 116 | 587 | 1,047 | --[j] | --[j] | --[j] | 9.6 | 0.068 | 0.34 | 0.61 | --[j] | --[j] | --[j] | 0.011 |
| Endosulfan sulfate | 1031-07-8 | mg/kg | -- | -- | -- | -- | -- | -- | 480 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 9.6 | 1.1 | 5.7 | 10 | --[j] | --[j] | --[j] | 0.011 |
| Endrin | 72-20-8 | mg/kg | -- | 24 | -- | -- | 214 | -- | 24 | 14 | 76 | 136 | --[j] | --[j] | --[j] | 0.20 | 0.016 | 0.087 | 0.16 | --[j] | --[j] | --[j] | 0.039 |
| Endrin aldehyde | 7421-93-4 | mg/kg | -- | -- | -- | -- | -- | -- | 24 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 0.20 | 2.0 | 11 | 20 | --[j] | --[j] | --[j] | 0.039 |
| Endrin ketone | 53494-70-5 | mg/kg | -- | -- | -- | -- | -- | -- | 24 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 0.20 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 0.039 |
| Gamma-BHC (Lindane) | 58-89-9 | mg/kg | -- | 0.91 | -- | 588,319 | 6.0 | -- | 0.77 | 0.059 | 0.30 | 0.53 | --[j] | --[j] | --[j] | 0.0067 | 0.014 | 0.071 | 0.13 | --[j] | --[j] | --[j] | 0.0038 |
| Gamma-chlordane | 5566-34-7 | mg/kg | -- | 2.9 | -- | >1,000,000 | 19 | -- | 2.9 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.025 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.017 |
| Heptachlor | 76-44-8 | mg/kg | -- | 0.22 | -- | 140,292 | 1.3 | -- | 0.22 | 0.11 | 0.65 | 1.2 | --[j] | --[j] | --[j] | 0.0020 | 0.0017 | 0.0026 | 0.0047 | --[j] | --[j] | --[j] | 0.0020 |
| Heptachlor epoxide | 1024-57-3 | mg/kg | -- | 0.11 | -- | 70,146 | 0.62 | -- | 0.11 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0020 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.0020 |

Table 8-3. Summary of 100-F/IU OUs Human Health, Groundwater Protection, and Surface Water Protection Soil PRGs

| Analyte Name | CAS No. | Units | Hanford Site Background Concentration[a] | Human Health PRGs | | | | | | PRGs Protective of Groundwater and Surface Water | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RI/FS Soil MTCA B—Direct Contact PRG[b] | RI/FS Residential PRG[c] | RI/FS Soil Method B Inhalation PRG[d] | RI/FS Casual Recreational User—Direct Contact PRG[e,f] | RI/FS Resident Monument Worker—Direct Contact PRG[g] | DOE/RL 96-17 Residential RAG[h] | 100-F 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model GWP PRG[j] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP PRG[j] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP PRG[j] | DOE/RL 96-17 GWP RAG[h] | 100-F 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model SWP PRG[j] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP PRG[j] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP PRG[j] | DOE/RL 96-17 SWP RAG[h] |
| Methoxychlor | 72-43-5 | mg/kg | -- | 400 | -- | -- | 3,564 | -- | 400 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 4.0 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 1.7 |
| Toxaphene | 8001-35-2 | mg/kg | -- | 0.91 | -- | 569,934 | 5.1 | -- | 0.91 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.20 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.20 |
| **Polycyclic Aromatic Hydrocarbons** | | | | | | | | | | | | | | | | | | | | | | | |
| Acenaphthene | 83-32-9 | mg/kg | -- | 4,800 | -- | -- | 40,139 | -- | 4,800 | 3,415 | 20,917 | 37,326 | --[j] | --[j] | --[j] | 96 | 2,286 | 14,006 | 24,992 | --[j] | --[j] | --[j] | 129 |
| Acenaphthylene | 208-96-8 | mg/kg | -- | -- | -- | -- | -- | -- | 4,800 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 96 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 129 |
| Anthracene | 120-12-7 | mg/kg | -- | 24,000 | -- | -- | 200,696 | -- | 24,000 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 240 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 1,920 |
| Benzo(a)anthracene | 56-55-3 | mg/kg | -- | 1.4 | -- | >1,000,000 | 1.7 | -- | 1.4 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.015 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.015 |
| Benzo(a)pyrene | 50-32-8 | mg/kg | -- | 0.14 | -- | 165,799 | 0.17 | -- | 0.14 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.015 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.015 |
| Benzo(b)fluoranthene | 205-99-2 | mg/kg | -- | 1.4 | -- | >1,000,000 | 1.7 | -- | 1.4 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.015 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.015 |
| Benzo(ghi)perylene | 191-24-2 | mg/kg | -- | -- | -- | -- | -- | -- | 2,400 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 48 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 192 |
| Benzo(k)fluoranthene | 207-08-9 | mg/kg | -- | 1.4 | -- | >1,000,000 | 1.7 | -- | 1.4 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.015 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.015 |
| Chrysene | 218-01-9 | mg/kg | -- | 14 | -- | >1,000,000 | 17 | -- | 14 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.12 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.10 |
| Dibenz[a,h]anthracene | 53-70-3 | mg/kg | -- | 1.4 | -- | >1,000,000 | 1.7 | -- | 1.4 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.030 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.030 |
| Fluoranthene | 206-44-0 | mg/kg | -- | 3,200 | -- | -- | 26,760 | -- | 3,200 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 64 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 18 |
| Fluorene | 86-73-7 | mg/kg | -- | 3,200 | -- | -- | 26,760 | -- | 3,200 | 2,845 | 17,432 | 31,107 | --[j] | --[j] | --[j] | 64 | 4,890 | 29,961 | 53,465 | --[j] | --[j] | --[j] | 260 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | mg/kg | -- | 1.4 | -- | >1,000,000 | 1.7 | -- | 1.4 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.33 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.33 |
| Naphthalene | 91-20-3 | mg/kg | -- | 1,600 | -- | 1.4 | 62 | -- | 1,600 | 108 | 543 | 969 | --[j] | --[j] | --[j] | 16 | 3,332 | 16,766 | 29,915 | --[j] | --[j] | --[j] | 988 |
| Phenanthrene | 85-01-8 | mg/kg | -- | -- | -- | -- | -- | -- | 24,000 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 240 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 1,920 |
| Pyrene | 129-00-0 | mg/kg | -- | 2,400 | -- | -- | 20,070 | -- | 2,400 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 48 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 192 |
| **Volatile Organic Compounds and Semivolatile Organic Compounds** | | | | | | | | | | | | | | | | | | | | | | | |
| 1,1-Dichloroethene | 75-35-4 | mg/kg | -- | 4,000 | -- | 102 | 8,773 | -- | -- | 0.52 | 2.3 | 4.1 | 1.4 | 4.1 | 7.3 | -- | 0.010 | 0.019 | 0.034 | 0.011 | 0.033 | 0.059 | -- |
| 1,2,4-Trichlorobenzene | 120-82-1 | mg/kg | -- | 34 | -- | 14 | 257 | -- | 800 | 1.4 | 6.8 | 12 | --[j] | --[j] | --[j] | 7.0 | 1.8 | 8.9 | 16 | --[j] | --[j] | --[j] | 45 |
| 1,2-Dichlorobenzene | 95-50-1 | mg/kg | -- | 7,200 | -- | 546 | 34,038 | -- | 7,200 | 150 | 734 | 1,309 | 876 | 1,585 | 2,825 | 60 | 105 | 514 | 916 | 613 | 1,109 | 1,978 | 540 |
| 1,3-Dichlorobenzene | 541-73-1 | mg/kg | -- | -- | -- | -- | -- | -- | 2,400 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 24 | 90 | 443 | 790 | 608 | 1,013 | 1,806 | 80 |
| 1,4-Dichlorobenzene | 106-46-7 | mg/kg | -- | 185 | -- | 1.5 | 64 | -- | 42 | 3.2 | 16 | 28 | 33 | 44 | 78 | 0.33 | 8.4 | 42 | 74 | 89 | 117 | 208 | 0.97 |
| 2,4,5-Trichlorophenol | 95-95-4 | mg/kg | -- | 8,000 | -- | -- | 71,289 | -- | 8,000 | 693 | 3,482 | 6,212 | --[j] | --[j] | --[j] | 80 | 421 | 2,117 | 3,777 | --[j] | --[j] | --[j] | -- |
| 2,4,6-Trichlorophenol | 88-06-2 | mg/kg | -- | 80 | -- | 95 | 515 | -- | 91 | 1.00 | 4.9 | 8.7 | 5.9 | 11 | 19 | 0.80 | 0.35 | 1.7 | 3.1 | 2.1 | 3.7 | 6.6 | 0.42 |
| 2,4-Dichlorophenol | 120-83-2 | mg/kg | -- | 240 | -- | -- | 2,139 | -- | 240 | 2.7 | 13 | 23 | 8.4 | 23 | 41 | 4.8 | 8.7 | 41 | 73 | 27 | 74 | 131 | 19 |
| 2,4-Dimethylphenol | 105-67-9 | mg/kg | -- | 1,600 | -- | -- | 14,258 | -- | 1,600 | 24 | 118 | 210 | 91 | 219 | 391 | 32 | 58 | 280 | 499 | 216 | 520 | 928 | 111 |
| 2,4-Dinitrophenol | 51-28-5 | mg/kg | -- | 160 | -- | -- | 1,426 | -- | 160 | 1.3 | 4.5 | 8.1 | 3.1 | 8.3 | 15 | 3.2 | 2.8 | 9.8 | 17 | 6.7 | 18 | 32 | 14 |

Table 8-3. Summary of 100-F/IU OUs Human Health, Groundwater Protection, and Surface Water Protection Soil PRGs

| Analyte Name | CAS No. | Units | Hanford Site Background Concentration[a] | Human Health PRGs | | | | | | PRGs Protective of Groundwater and Surface Water | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RI/FS Soil MTCA B—Direct Contact PRG[b] | RI/FS Residential PRG[c] | RI/FS Soil Method B Inhalation PRG[d] | RI/FS Casual Recreational User—Direct Contact PRG[c,f] | RI/FS Resident Monument Worker—Direct Contact PRG[g] | DOE/RL 96-17 Residential RAG[h] | 100-F 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP PRG[i] | DOE/RL 96-17 GWP RAG[h] | 100-F 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP PRG[i] | DOE/RL 96-17 SWP RAG[h] |
| 2,4-Dinitrotoluene | 121-14-2 | mg/kg | -- | 3.2 | -- | >1,000,000 | 18 | -- | 160 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.37 | 3.2 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| 2,6-Dinitrotoluene | 606-20-2 | mg/kg | -- | 80 | -- | -- | 714 | -- | 80 | 1.2 | 5.5 | 9.8 | 3.2 | 9.7 | 17 | 1.6 | 9.0 | 40 | 72 | 24 | 71 | 127 | 136 |
| 2-Butanone | 78-93-3 | mg/kg | -- | 48,000 | -- | 28,673 | 464,234 | -- | -- | 202 | 738 | 1,316 | 494 | 1,344 | 2,397 | -- | 20,736 | 75,638 | 134,962 | 50,625 | 137,821 | 245,774 | -- |
| 2-Chloronaphthalene | 91-58-7 | mg/kg | -- | 6,400 | -- | -- | 73,000 | -- | | 1,008 | 5,992 | 10,692 | --[j] | --[j] | --[j] | 64 | 1,575 | 9,362 | 16,707 | --[j] | --[j] | --[j] | 206 |
| 2-Chlorophenol | 95-57-8 | mg/kg | -- | 400 | -- | -- | 4,563 | -- | 400 | 10 | 50 | 89 | 62 | 109 | 195 | 4.0 | 21 | 102 | 181 | 125 | 222 | 395 | 19 |
| 2-Hexanone | 591-78-6 | mg/kg | -- | 400 | -- | 160 | 3,599 | -- | -- | 1.9 | 7.4 | 13 | 4.7 | 13 | 24 | -- | 163 | 634 | 1,130 | 401 | 1,141 | 2,035 | -- |
| 2-Methylnaphthalene | 91-57-6 | mg/kg | -- | 320 | -- | -- | 2,676 | -- | 320 | 50 | 300 | 535 | --[j] | --[j] | --[j] | 3.2 | 219 | 1,300 | 2,319 | --[j] | --[j] | --[j] | -- |
| 2-Methylphenol (cresol, o-) | 95-48-7 | mg/kg | -- | 4,000 | -- | 52,024 | 35,645 | -- | 4,000 | 113 | 553 | 987 | 760 | 1,266 | 2,258 | 80 | 3,417 | 16,758 | 29,896 | 23,024 | 38,357 | 68,385 | -- |
| 2-Nitroaniline | 88-74-4 | mg/kg | -- | 800 | -- | >1,000,000 | 7,129 | -- | 240 | 11 | 47 | 84 | 28 | 83 | 148 | 2.4 | 175 | 767 | 1,368 | 449 | 1,349 | 2,405 | -- |
| 2-Nitrophenol | 88-75-5 | mg/kg | -- | -- | -- | -- | -- | -- | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| 3,3'-Dichlorobenzidine | 91-94-1 | mg/kg | -- | 2.2 | -- | 536,409 | 13 | -- | 2.2 | 0.33 | 0.44 | 0.78 | 1.2 | 1.4 | 2.5 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| 3-Nitroaniline | 99-09-2 | mg/kg | -- | 24 | -- | >1,000,000 | 214 | -- | 24 | 0.33 | 1.2 | 2.2 | 0.71 | 2.1 | 3.8 | 0.33 | 6.9 | 30 | 54 | 18 | 53 | 94 | -- |
| 4,6-Dinitro-2-methylphenol | 534-52-1 | mg/kg | -- | 8.0 | -- | -- | 71 | -- | 8.0 | 0.49 | 2.4 | 4.3 | 5.0 | 6.7 | 12 | 0.33 | 5.0 | 25 | 44 | 51 | 68 | 121 | -- |
| 4-Bromophenylphenyl ether | 101-55-3 | mg/kg | -- | -- | -- | -- | -- | -- | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| 4-Chloro-3-methylphenol | 59-50-7 | mg/kg | -- | 8,000 | -- | -- | 71,289 | -- | 4,000 | 508 | 2,496 | 4,452 | 3,997 | 6,108 | 10,889 | 80 | 9,682 | 47,577 | 84,873 | 76,190 | 116,438 | 207,581 | -- |
| 4-Chloroaniline | 106-47-8 | mg/kg | -- | 5.0 | -- | -- | 28 | -- | 320 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 6.4 | 0.36 | 1.6 | 2.9 | 0.96 | 2.9 | 5.1 | -- |
| 4-Chlorophenylphenyl ether | 7005-72-3 | mg/kg | -- | -- | -- | -- | -- | -- | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| 4-Methyl-2-pentanone | 108-10-1 | mg/kg | -- | 6,400 | -- | 13,103 | 69,370 | -- | -- | 30 | 114 | 203 | 73 | 206 | 367 | -- | 2,832 | 10,854 | 19,367 | 6,937 | 19,597 | 34,946 | -- |
| 4-Methylphenol (cresol, p-) | 106-44-5 | mg/kg | -- | 400 | -- | 55,967 | 3,564 | -- | 400 | 11 | 55 | 99 | 76 | 127 | 226 | 8.0 | 413 | 2,026 | 3,615 | 2,784 | 4,638 | 8,268 | -- |
| 4-Nitroaniline | 100-01-6 | mg/kg | -- | 50 | -- | >1,000,000 | 283 | -- | 48 | 0.33 | 1.3 | 2.3 | 0.75 | 2.3 | 4.0 | 0.33 | 5.4 | 24 | 42 | 14 | 42 | 74 | -- |
| 4-Nitrophenol | 100-02-7 | mg/kg | -- | 640 | -- | -- | 5,703 | -- | 640 | 27 | 131 | 235 | 132 | 265 | 473 | 13 | 849 | 4,144 | 7,393 | 4,169 | 8,368 | 14,920 | 1,254 |
| Acetone | 67-64-1 | mg/kg | -- | 72,000 | -- | 189,926 | 789,195 | -- | 72,000 | 289 | 1,030 | 1,838 | 705 | 1,885 | 3,362 | 720 | 29,666 | 105,651 | 188,515 | 72,349 | 193,339 | 344,782 | -- |
| Benzene | 71-43-2 | mg/kg | -- | 18 | -- | 0.57 | 22 | -- | -- | 0.058 | 0.26 | 0.46 | 0.15 | 0.45 | 0.81 | -- | 0.087 | 0.39 | 0.69 | 0.23 | 0.68 | 1.2 | -- |
| bis(2-Chloro-1-methylethyl)ether | 108-60-1 | mg/kg | -- | 14 | -- | 4.8 | 71 | -- | 14 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.51 | 0.33 | 2.3 | 9.7 | 17 | 5.7 | 17 | 30 | 7.5 |
| bis(2-Chloroethoxy)methane | 111-91-1 | mg/kg | -- | 240 | -- | -- | 2,139 | -- | 0.91 | 2.0 | 7.1 | 13 | 4.8 | 13 | 23 | 0.33 | 97 | 349 | 622 | 236 | 637 | 1,135 | 0.33 |
| bis(2-Chloroethyl) ether | 111-44-4 | mg/kg | -- | 0.91 | -- | 0.27 | 4.4 | -- | 0.91 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| bis(2-Ethylhexyl) phthalate | 117-81-7 | mg/kg | -- | 71 | -- | >1,000,000 | 405 | -- | 71 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.60 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.36 |
| Butylbenzylphthalate | 85-68-7 | mg/kg | -- | 526 | -- | -- | 2,981 | -- | 16,000 | 525 | 866 | 4,131 | --[j] | --[j] | --[j] | 320 | 94 | 155 | 739 | --[j] | --[j] | --[j] | 250 |
| Carbazole | 86-74-8 | mg/kg | -- | 50 | -- | -- | 283 | -- | 50 | 7.9 | 47 | 84 | --[j] | --[j] | --[j] | 0.44 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| Carbon tetrachloride | 56-23-5 | mg/kg | -- | 14 | -- | 0.24 | 9.2 | -- | 7.7 | 0.039 | 0.18 | 0.33 | 0.12 | 0.33 | 0.59 | 0.034 | 0.027 | 0.12 | 0.22 | 0.083 | 0.23 | 0.40 | 0.050 |

Table 8-3. Summary of 100-F/IU OUs Human Health, Groundwater Protection, and Surface Water Protection Soil PRGs

| Analyte Name | CAS No. | Units | Hanford Site Background Concentration[a] | Human Health PRGs | | | | | | PRGs Protective of Groundwater and Surface Water | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RI/FS Soil MTCA B—Direct Contact PRG[b] | RI/FS Residential PRG[c] | RI/FS Soil Method B Inhalation PRG[d] | RI/FS Casual Recreational User—Direct Contact PRG[c,f] | RI/FS Resident Monument Worker—Direct Contact PRG[g] | DOE/RL 96-17 Residential RAG[h] | 100-F 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP PRG[i] | DOE/RL 96-17 GWP RAG[h] | 100-F 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP PRG[i] | DOE/RL 96-17 SWP RAG[h] |
| Chlorobenzene | 108-90-7 | mg/kg | -- | 1,600 | -- | 73 | 5,447 | -- | -- | 16 | 76 | 136 | 60 | 142 | 254 | -- | 20 | 99 | 176 | 78 | 185 | 330 | -- |
| Chloroform | 67-66-3 | mg/kg | -- | 32 | -- | 0.24 | 11 | -- | -- | 0.096 | 0.42 | 0.75 | 0.24 | 0.74 | 1.3 | -- | 0.39 | 1.7 | 3.0 | 0.99 | 3.0 | 5.3 | -- |
| Dibenzofuran | 132-64-9 | mg/kg | -- | 80 | -- | -- | 913 | -- | 160 | 122 | 235 | 1,140 | --[j] | --[j] | --[j] | 3.2 | 13 | 25 | 122 | --[j] | --[j] | --[j] | -- |
| Diethylphthalate | 84-66-2 | mg/kg | -- | 64,000 | -- | -- | 570,313 | -- | 64,000 | 1,071 | 4,856 | 8,665 | 2,899 | 8,594 | 15,324 | 1,280 | 1,423 | 6,450 | 11,508 | 3,850 | 11,414 | 20,353 | 4,600 |
| Dimethyl phthalate | 131-11-3 | mg/kg | -- | -- | -- | -- | -- | -- | 80,000 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 1,600 | 15,171 | 62,734 | 111,933 | 37,736 | 111,387 | 198,627 | 14,400 |
| Di-n-butylphthalate | 84-74-2 | mg/kg | -- | 8,000 | -- | -- | 71,289 | -- | 8,000 | 1,357 | 6,822 | 12,173 | --[j] | --[j] | --[j] | 160 | 1,696 | 8,528 | 15,217 | --[j] | --[j] | --[j] | 540 |
| Di-n-octylphthalate | 117-84-0 | mg/kg | -- | -- | -- | -- | -- | -- | 1,600 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 32 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| Ethylbenzene | 100-41-4 | mg/kg | -- | 91 | -- | 2.3 | 90 | -- | -- | 0.59 | 2.8 | 5.1 | 2.2 | 5.3 | 9.4 | -- | 2.3 | 11 | 20 | 8.6 | 21 | 37 | -- |
| Ethylene glycol | 107-21-1 | mg/kg | -- | 160,000 | -- | >1,000,000 | >1,000,000 | -- | 160,000 | 646 | 2,308 | 4,119 | 1,576 | 4,222 | 7,529 | 320 | 66,237 | 236,619 | --j | 161,551 | --[j] | --[j] | -- |
| Hexachlorobenzene | 118-74-1 | mg/kg | -- | 0.63 | -- | 396,476 | 3.5 | -- | 0.63 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.33 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.33 |
| Hexachlorobutadiene | 87-68-3 | mg/kg | -- | 13 | -- | >1,000,000 | 73 | -- | 13 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.33 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 0.33 |
| Hexachlorocyclopentadiene | 77-47-4 | mg/kg | -- | 480 | -- | >1,000,000 | 4,277 | -- | 480 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 5.0 | --[j] | --[j] | --[j] | --[j] | --[j] | --[j] | 48 |
| Hexachloroethane | 67-72-1 | mg/kg | -- | 71 | -- | >1,000,000 | 405 | -- | 71 | 3.1 | 16 | 28 | --[j] | --[j] | --[j] | 0.31 | 1.4 | 7.0 | 12 | --[j] | --[j] | --[j] | 0.38 |
| Isophorone | 78-59-1 | mg/kg | -- | 1,053 | -- | 50,482 | 5,962 | -- | 1,050 | 3.0 | 13 | 23 | 7.5 | 23 | 40 | 9.2 | 0.54 | 2.3 | 4.2 | 1.4 | 4.1 | 7.4 | 1.7 |
| Nitrobenzene | 98-95-3 | mg/kg | -- | 160 | -- | 2.0 | 91 | -- | 160 | 1.6 | 7.5 | 13 | 4.7 | 13 | 24 | 1.6 | 1.7 | 7.9 | 14 | 5.0 | 14 | 25 | 3.4 |
| n-Nitrosodi-n-dipropylamine | 621-64-7 | mg/kg | -- | 0.14 | -- | 91,190 | 0.81 | -- | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 | 0.33 |
| n-Nitrosodiphenylamine | 86-30-6 | mg/kg | -- | 204 | -- | >1,000,000 | 1,156 | -- | 204 | 13 | 64 | 114 | --[j] | --[j] | --[j] | 1.8 | 2.4 | 12 | 21 | --[j] | --[j] | --[j] | 1.9 |
| Methylene chloride | 75-09-2 | mg/kg | -- | 133 | -- | 11 | 337 | -- | 133 | 0.23 | 0.86 | 1.5 | 0.55 | 1.5 | 2.8 | 0.50 | 0.21 | 0.79 | 1.4 | 0.51 | 1.4 | 2.5 | 0.94 |
| Pentachlorophenol | 87-86-5 | mg/kg | -- | 8.3 | -- | >1,000,000 | 35 | -- | 8.3 | 0.33 | 1.4 | 2.4 | 2.7 | 3.7 | 6.6 | 0.33 | 0.33 | 0.50 | 0.89 | 1.0 | 1.4 | 2.4 | 0.33 |
| Phenol | 108-95-2 | mg/kg | -- | 24,000 | -- | 11,614 | 213,867 | -- | 24,000 | 131 | 537 | 959 | 326 | 957 | 1,706 | 480 | 547 | 2,239 | 3,995 | 1,357 | 3,986 | 7,107 | 4,200 |
| Styrene | 100-42-5 | mg/kg | -- | 16,000 | -- | -- | 115,430 | -- | -- | 56 | 282 | 502 | 1,025 | 1,077 | 1,919 | -- | 21,521 | 108,151 | 192,973 | --[j] | --[j] | --[j] | -- |
| Tetrachloroethene | 127-18-4 | mg/kg | -- | 1.9 | -- | 0.88 | 10 | -- | -- | 0.015 | 0.073 | 0.13 | 0.065 | 0.14 | 0.25 | -- | 0.071 | 0.35 | 0.62 | 0.31 | 0.68 | 1.2 | -- |
| Tributyl phosphate | 126-73-8 | mg/kg | -- | 109 | -- | -- | 616 | -- | 185 | 10 | 52 | 92 | --[j] | --[j] | --[j] | 3.3 | 26 | 132 | 236 | --[j] | --[j] | --[j] | -- |
| Trichloroethene (TCE) | 79-01-6 | mg/kg | -- | 11 | -- | 0.17 | 7.2 | -- | -- | 0.044 | 0.20 | 0.36 | 0.12 | 0.36 | 0.64 | -- | 0.23 | 1.0 | 1.8 | 0.63 | 1.8 | 3.3 | -- |
| Toluene | 108-88-3 | mg/kg | -- | 6,400 | -- | 4,774 | 63,832 | -- | 6,400 | 70 | 328 | 585 | 213 | 589 | 1,051 | 64 | 143 | 666 | 1,189 | 432 | 1,197 | 2,134 | 1,360 |
| Vinyl chloride | 75-01-4 | mg/kg | -- | 1.4 | -- | 0.52 | 0.07 | -- | -- | 0.0050 | 0.012 | 0.021 | 0.0075 | 0.022 | 0.038 | -- | 0.0050 | 0.0050 | 0.0088 | 0.0050 | 0.0089 | 0.016 | -- |
| Xylenes (total) | 1330-20-7 | mg/kg | -- | 16,000 | -- | 103 | 10,346 | -- | 16,000 | 258 | 1,255 | 2,239 | 1,011 | 2,366 | 4,219 | 160 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | -- |
| **Other Organics** | | | | | | | | | | | | | | | | | | | | | | | |
| TPH-diesel range | TPHDIESEL | mg/kg | -- | 2,000 | -- | -- | -- | -- | 200 | 2,000[o] | 2,000[o] | 2,000[o] | 2,000[o] | 2,000[o] | 2,000[o] | 200 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 200 |
| TPH-motor oil (high boiling) | TPH/OILH | mg/kg | -- | 2,000 | -- | -- | -- | -- | 200 | 2,000[o] | 2,000[o] | 2,000[o] | 2,000[o] | 2,000[o] | 2,000[o] | 200 | --[n] | --[n] | --[n] | --[n] | --[n] | --[n] | 200 |

Table 8-3. Summary of 100-F/IU OUs Human Health, Groundwater Protection, and Surface Water Protection Soil PRGs

| Analyte Name | CAS No. | Units | Hanford Site Background Concentration[a] | Human Health PRGs | | | | | | PRGs Protective of Groundwater and Surface Water | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | RI/FS Soil MTCA B—Direct Contact PRG[b] | RI/FS Residential PRG[c] | RI/FS Soil Method B Inhalation PRG[d] | RI/FS Casual Recreational User—Direct Contact PRG[e,f] | RI/FS Resident Monument Worker—Direct Contact PRG[g] | DOE/RL 96-17 Residential RAG[h] | 100-F 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model GWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model GWP PRG[i] | DOE/RL 96-17 GWP RAG[h] | 100-F 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP SSL[i] | 100-F 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-2 70:30/100:0 Contaminant Source Model SWP PRG[i] | 100-IU-6 70:30/100:0 Contaminant Source Model SWP PRG[i] | DOE/RL 96-17 SWP RAG[h] |

Notes:

Yellow highlighting denotes the PRG selection for protection of human health. For radionuclide human health PRGs, the lowest of the PRGs calculated for the residential exposure scenario and the residential Interim Action ROD RAG defined in *Remedial Design Report/Remedial Action Work Plan for the 100 Area* (DOE/RL-96-17) is highlighted in yellow. For nonradionuclide PRGs, the PRG is the RI/FS MTCA Method B value, except for arsenic and lead which set to the "Soil Cleanup Levels for Unrestricted Land Uses" (WAC 173-340-900, "Tables"), Table 740-1, "Method A Soil Cleanup Level for Unrestricted Land Uses."

Green highlighting denotes the most conservative PRG above background for each analyte for GW/SW protection except for Cr(VI), which is compared to the interim action RAG of 2.0 mg/kg.

a. Hanford Site background values for nonradionuclides: DOE/RL-92-24, Vol. 1, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*; ECF-HANFORD-11-0038, *Soil Background Data for Interim Use at the Hanford Site;* DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides*.

b. ECF-HANFORD-10-0444, *Documentation of Standard Method B Contact Cleanup Levels for Unrestricted Land Use*. PRGs for arsenic, lead, and total petroleum hydrocarbons are based on WAC 173-340-900, Table 740-1, "Method A Soil Cleanup Levels for Unrestricted Land Uses."

c. ECF-HANFORD-10-0429, *Documentation of Preliminary Remediation Goals (PRGs) for Radionuclides Using the IAROD Exposure Scenario for the 100 and 300 Area Remedial Investigation/Feasibility Study (RI/FS) Report*.

d. ECF-HANFORD-11-0033, *Calculation of Inhalation Pathway Preliminary Remediation Goals Using Standard Method B Air Cleanup Levels for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

e. ECF-HANFORD-10-0445, *Calculation of Nonradionuclides Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

f. ECF-HANFORD-10-0446, *Calculation of Radiological Preliminary Remediation Goals in Soil for a Casual Recreational User Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

g. ECF-HANFORD-11-0142, *Calculation of Radiological Preliminary Remediation Goals in Soil for a Resident Monument Worker Scenario for the 100 Areas and 300 Area Remedial Investigation/Feasibility Study Reports*.

h. DOE/RL 96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*.

i. ECF-HANFORD-11-0064, *STOMP 1-D Modeling for Determination of Preliminary Remediation Goals for 100 Area Vadose Zone Source Areas F, IU2, and IU6*. A 70:30 initial source distribution is used for analytes with $K_d \geq 2$ mL/g; a 100:0 initial source distribution is used for analytes with $K_d < 2$ mL/g. The SSL and PRG value for all analytes defaults to the EQL when the calculated value is less than the EQL. The EQL values are obtained from the Sampling and Analysis Plan for 100-F/IU (DOE/RL-2009-43).

j. The SSL or PRG value for GWP or SWP is considered nonrepresentative because there is no breakthrough of the analyte simulated within 1,000 years for the majority of soil columns (breakthrough is defined as concentrations above 1E-04 µg/L or 1E-04 pCi/L).

k. An SSL is calculated for total uranium (CAS No. 7440-61-1) but not isotopic uranium because an MCL is not available for isotopic uranium. When total uranium analytical results (µg/kg) are available, exposure point concentrations are compared to the total uranium SSL. When only isotopic uranium results (pCi/g) are available, uranium is addressed by converting the isotopic uranium from activity-based (pCi/g) to mass-based (µg/kg) concentrations and summing to provide a mass-based total uranium exposure point concentration (identified as Total_U_Isotopes), as described in ECF-100FR1-11-0020, "Computation of Exposure Point Concentrations for the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Source Operable Units." The Total_U_Isotopes exposure point concentration is then compared to the total uranium SSL.

l. The SSL and PRG values for Cr(VI) are set to a maximum value of 6.0 mg/kg because the $K_d$ value used in the model was derived from experiments with soil concentrations less than 6 mg/kg.

m. Value converted from "as nitrogen" values in DOE/RL-96-17 using the following conversion factors as applicable: 4.43 g NO3-/g N and 3.29 g NO2-/ g N.

n. A GWP or SWP SSL or PRG is not calculated because a groundwater or surface water cleanup level or MCL is not available for the analyte.

o. The SSL for TPH is a default screening level obtained from WAC 173-340-900, "Tables," Table 747-5, "Residual Saturation Screening Levels for TPH."

p. Strontium-90 is calculated based on a 100:0 initial source distribution, an exception to the convention that analytes with a $K_d \geq 2$ were calculated based on a 70:30 initial source distribution, because of data that indicated strontium-90 was distributed throughout the vadose zone at some locations in these operable units.

CAS = Chemical Abstract Services
EQL = estimated quantitation limit
GW = groundwater
GWP = groundwater protection
$K_d$ = distribution coefficient
MTCA = Model Toxics Control Act
PRG = preliminary remediation goal
RAG = remedial action goal
RI/FS = remedial investigation/feasibility study
SSL = soil screening level
SW = surface water
SWP = surface water protection
TPH = total petroleum hydrocarbon

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Table 8-4. Summary of 100-F/IU OUs Ecological Soil PRGs

| Analytes | Hanford Site Background Concentration[a] | Preliminary Remediation Goals for Protection of Ecological Receptors | | | |
|---|---|---|---|---|---|
| | | Plant PRG[b] | Plant PRG[b] | Avian PRG[b] | Mammal PRG[b] |
| **Radionuclides (pCi/g)** | | | | | |
| Americium-241 | -- | 21,500 | --[c] | 11,900 | 4,840 |
| Carbon-14 | -- | 60,700 | --[c] | 50 | 32 |
| Cesium-137 | 1.1 | 2,210 | --[c] | 1,430 | 924 |
| Cobalt-60 | 0.0084 | 6,130 | --[c] | 805 | 805 |
| Curium-243 | -- | --[c] | --[c] | --[c] | --[c] |
| Europium-152 | -- | 14,700 | --[c] | 1,740 | 1,740 |
| Europium-154 | 0.033 | 12,500 | --[c] | 1,610 | 1,610 |
| Europium-155 | 0.054 | 153,000 | --[c] | 33,400 | 33,400 |
| Iodine-129 | -- | --[c] | --[c] | --[c] | --[c] |
| Neptunium-237 | -- | 8,150 | --[c] | 7,880 | 7,880 |
| Nickel-63 | -- | --[c] | --[c] | --[c] | --[c] |
| Niobium-94 | -- | --[c] | --[c] | --[c] | --[c] |
| Plutonium-238 | 0.0038 | 17,500 | --[c] | 20,900 | 5,980 |
| Plutonium-239/240 | 0.025 | 12,700 | --[c] | 22,300 | 6,270 |
| Strontium-90 | 0.18 | 3,580 | --[c] | 112 | 91 |
| Technetium-99 | -- | 21,900 | --[c] | 5,360 | 8,670 |
| Tritium | -- | 1,680,000 | --[c] | 936 | 420 |
| Uranium-233/234 | 1.1 | 51,600 | --[c] | 6,370 | 14,200 |
| Uranium-235 | 0.11 | 27,400 | --[c] | 4,360 | 8,060 |
| Uranium-238 | 1.1 | 15,700 | --[c] | 5,150 | 11,000 |
| Total uranium (summed) | -- | --[c] | --[c] | --[c] | --[c] |
| **Metals (mg/kg)** | | | | | |
| Aluminum | 11,800 | --[d] | --[d] | --[d] | --[d] |
| Antimony | 0.13 | 842 | 842 | --[c] | 92 |
| Arsenic | 6.5 | 128 | 128 | 2,284 | 127 |
| Barium | 132 | 500 | 358 | 1,690 | 2,270 |
| Beryllium | 1.5 | 10 | 40 | --[c] | 14 |
| Bismuth | -- | --[c] | --[c] | --[c] | --[c] |
| Boron | 3.9 | 30 | 29 | 54 | 32 |
| Cadmium | 0.56 | 9.8 | 20 | 29 | 624 |
| Chromium | 19 | 259 | 149 | 109 | 517 |
| Cobalt | 16 | 16 | 16 | 484 | 2,140 |
| Copper | 22 | 70 | 58 | 213 | 193 |

Table 8-4. Summary of 100-F/IU OUs Ecological Soil PRGs

| Analytes | Hanford Site Background Concentration[a] | Preliminary Remediation Goals for Protection of Ecological Receptors | | | |
|---|---|---|---|---|---|
| | | Plant PRG[b] | Plant PRG[b] | Avian PRG[b] | Mammal PRG[b] |
| Cr(VI) | -- | --[c] | --[c] | --[c] | 1,250 |
| Lead | 10 | 9,090 | 1,700 | 156 | 1,580 |
| Lithium | 13 | 2.0 | --[c] | --[c] | 1,664 |
| Manganese | 512 | 1,260 | 1,260 | 14,400 | 3,320 |
| Mercury | 0.013 | 0.30 | 13 | 2.0 | 1.6 |
| Molybdenum | 0.47 | 2.0 | 28 | 95 | 5.7 |
| Nickel | 19 | 38 | 280 | 361 | 247 |
| Selenium | 0.78 | 2.0 | 4.1 | 2.4 | 1.4 |
| Silver | 0.17 | 560 | 3.0 | 983 | 9,810 |
| Strontium | -- | --[c] | --[c] | --[c] | 1,210 |
| Thallium | 0.19 | 1.0 | 0.46 | --[c] | 6.2 |
| Tin | -- | 838 | 838 | 204 | 279 |
| Total_U_Isotopes | 3.2 | 250 | 100 | 82 | 40 |
| Uranium (soluble salts) | 3.2 | 250 | 100 | 82 | 40 |
| Vanadium | 85 | 89 | 116 | 43 | 260 |
| Zinc | 68 | 621 | 8,980 | 856 | 1,040 |
| **Other Inorganics (mg/kg)** | | | | | |
| Chloride | 100 | --[c] | --[c] | --[c] | --[c] |
| Cyanide | -- | --[c] | --[c] | --[c] | 20,700 |
| Fluoride | 2.8 | -- | -- | 2,280 | 13,800 |
| Nitrate | 52 | -- | --[c] | --[c] | 340,000 |
| Nitrite | -- | -- | --[c] | --[c] | 340,000 |
| Sulfate | 237 | -- | --[c] | --[c] | --[c] |
| **Polychlorinated Biphenyls (PCBs) (mg/kg)** | | | | | |
| Aroclor-1016 | -- | 40 | --[c] | 1.8 | 4.9 |
| Aroclor-1221 | -- | 40 | --[c] | 1.8 | 1.5 |
| Aroclor-1232 | -- | 40 | --[c] | 1.8 | 1.4 |
| Aroclor-1242 | -- | 40 | --[c] | 1.8 | 1.5 |
| Aroclor-1248 | -- | 40 | --[c] | 1.8 | 0.33 |
| Aroclor-1254 | -- | 40 | --[c] | 1.8 | 1.5 |
| Aroclor-1260 | -- | 40 | --[c] | 1.8 | 1.5 |

Table 8-4. Summary of 100-F/IU OUs Ecological Soil PRGs

| Analytes | Hanford Site Background Concentration[a] | Preliminary Remediation Goals for Protection of Ecological Receptors | | | |
|---|---|---|---|---|---|
| | | Plant PRG[b] | Plant PRG[b] | Avian PRG[b] | Mammal PRG[b] |
| **Pesticides (mg/kg)** | | | | | |
| 4,4'-DDE (Dichlorodiphenyl-dichloroethylene) | -- | --[c] | --[c] | 0.80 | 0.40 |
| 4,4'-DDT (Dichlorodiphenyl-trichloroethane) | -- | --[c] | --[c] | 1.2 | 0.88 |
| Aldrin | -- | --[c] | --[c] | 0.16 | 9.8 |
| Alpha-Chlordane | -- | --[c] | 1.0 | 50 | 204 |
| Beta-BHC | -- | --[c] | --[c] | 4.1 | 8.7 |
| Dieldrin | -- | --[c] | --[c] | 0.079 | 0.021 |
| Endosulfan I | -- | --[c] | --[c] | 41 | 0.71 |
| Endosulfan II | -- | --[c] | --[c] | 41 | 0.71 |
| Endosulfan sulfate | -- | --[c] | --[c] | 41 | 0.56 |
| Endrin Aldehyde | -- | --[c] | --[c] | 0.23 | 1.4 |
| Gamma-Chlordane | -- | --[c] | 1.0 | 50 | 204 |
| Methoxychlor | -- | --[c] | --[c] | --[c] | 22 |
| **Polycyclic Aromatic Hydrocarbons (PAHs) (mg/kg)** | | | | | |
| Acenaphthene | -- | 20 | 29 | 1,100 | 2,420 |
| Acenaphthylene | -- | --[c] | 29 | 74 | 156 |
| Anthracene | -- | --[c] | 29 | 678 | 4,210 |
| Benzo(a)anthracene | -- | --[c] | 18 | 2.0 | 64 |
| Benzo(a)pyrene | -- | --[c] | 18 | 2.4 | 76 |
| Benzo(b)fluoranthene | -- | --[c] | 18 | 1.3 | 39 |
| Benzo(ghi)perylene | -- | --[c] | 18 | 1.1 | 32 |
| Benzo(k)fluoranthene | -- | --[c] | 18 | 1.3 | 39 |
| Chrysene | -- | --[c] | 18 | 1.4 | 45 |
| Dibenz[a,h]anthracene | -- | --[c] | 18 | 1.4 | 44 |
| Fluoranthene | -- | --[c] | 18 | 1.1 | 839 |
| Fluorene | -- | --[c] | 29 | 175 | 267 |
| Indeno(1,2,3-cd)pyrene | -- | --[c] | 18 | 1.2 | 36 |
| Naphthalene | -- | --[c] | 29 | 340 | 100 |
| Phenanthrene | -- | --[c] | 29 | 943 | 5,920 |
| Pyrene | -- | --[c] | 18 | 1.9 | 600 |

Table 8-4. Summary of 100-F/IU OUs Ecological Soil PRGs

| Analytes | Hanford Site Background Concentration[a] | Preliminary Remediation Goals for Protection of Ecological Receptors | | | |
|---|---|---|---|---|---|
| | | Plant PRG[b] | Plant PRG[b] | Avian PRG[b] | Mammal PRG[b] |
| **Volatile and Semivolatile Organic Compounds (mg/kg)** | | | | | |
| 1,1-Dichloroethene | -- | --[c] | --[c] | 165 | 301 |
| 1,1,1-Trichloroethane | -- | --[c] | --[c] | 165 | 10,016 |
| 1,2,4-Trichlorobenzene | -- | --[c] | --[c] | -- | -- |
| 1,2-Dichlorobenzene | -- | --[c] | --[c] | 164 | 282 |
| 1,3-Dichlorobenzene | -- | --[c] | --[c] | 164 | 310 |
| 2,4-Dinitrotoluene | -- | --[c] | --[c] | 26 | 28 |
| 2-Butanone | -- | --[c] | --[c] | 3,123 | 412,224 |
| 2-Hexanone | -- | --[c] | --[c] | 1,856 | 1,708 |
| 2-Methylnaphthalene | -- | --[c] | 29 | 8.4 | 6.0 |
| 2-Methylphenol (cresol, o-) | -- | --[c] | --[c] | --[c] | 9,290 |
| 4-Chlorophenylphenyl ether | -- | --[c] | --[c] | --[c] | --[c] |
| 4-Methyl-2-pentanone | -- | --[c] | --[c] | 1,927 | 227,119 |
| 4-Methylphenol (cresol, p-) | -- | --[c] | --[c] | --[c] | 9,360 |
| Benzene | -- | --[c] | --[c] | 195 | 70 |
| Bis(2-ethylhexyl) phthalate | -- | 100 | --[c] | 0.14 | 45 |
| Carbon tetrachloride | -- | --[c] | --[c] | 165 | 160 |
| Chloroform | -- | --[c] | --[c] | 165 | 412 |
| Diethylphthalate | -- | 100 | --[c] | --[c] | --[c] |
| Ethylbenzene | -- | --[c] | --[c] | 159 | 1,027 |
| Methylene chloride | -- | --[c] | --[c] | 166 | 504 |
| Phenol | -- | 70 | 30 | --[c] | 1,510 |
| Tetrachloroethene | -- | --[c] | --[c] | 164 | 70 |
| trans-1,2-Dichloroethene | -- | --[c] | --[c] | 165 | 453 |
| Toluene | -- | 200 | --[c] | 195 | 5,200 |
| Trichloroethene (TCE) | -- | --[c] | --[c] | 165 | 70 |
| Xylenes (total) | -- | --[c] | --[c] | 149 | 826 |
| **Other Organics (mg/kg)** | | | | | |
| TPH–diesel range | -- | --[c] | 200 | 356,000 | 452,000 |

Note: The need for remedial action to protect ecological receptors will be based on population and community level effects. Exceedance of ecological PRGs initiates a scientific management decision point to determine a basis for action.

a. Hanford Site background values for nonradionuclides: DOE/RL-92-24, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*; ECF-HANFORD-11-0038; Hanford Site background values for radionuclides: DOE/RL-96-12, *Hanford Site Background: Part 2, Soil Background for Radionuclides.*

b. CHPRC-00784, *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*; CHPRC-01311, *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*;

Table 8-4. Summary of 100-F/IU OUs Ecological Soil PRGs

| Analytes | Hanford Site Background Concentration[a] | Preliminary Remediation Goals for Protection of Ecological Receptors | | | |
|---|---|---|---|---|---|
| | | Plant PRG[b] | Plant PRG[b] | Avian PRG[b] | Mammal PRG[b] |

ECF-HANFORD-11-0158, *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site*. These PRGs will be used within the SMDP process described in Chapter 7 of this RI/FS.

c. A PRG is not calculated because a toxicity value is not available for this receptor or analyte.

d. Aluminum ecotoxicity is only identified in soils with pH less than 5.5 (*Ecological Soil Screening Level for Aluminum: Interim Final* [OSWER Directive 9285.7-60]). Most soil pH measures at the Hanford Site are greater than 5.5 (*River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* [DOE/Rl-2007-21]; *Central Plateau Ecological Risk Assessment Data Package Report* [DOE/RL-2007-50]; ECF-HANFORD-11-0158). Thus, aluminum at the Hanford Site does not present an ecological risk.

PRG = preliminary remediation goal

TPH = total petroleum hydrocarbon

Table 8-3 presents the soil based RAGs reported in the 100 Area RDR/RAWP (DOE/RL-96-17) and MTCA ("Unrestricted Land Use Soil Cleanup Levels" [WAC 173-340-740(3)]). Although residential land use is not consistent with DOE's reasonably anticipated future land use, DOE has proposed residential cleanup levels for chemicals and radionuclides present in soil for consistency with interim action ROD cleanup requirements. The direct contact PRGs for radionuclides in soil were set as the lower of the radionuclide dose (interim action cleanup values) or risk-based calculations. Direct contact PRGs for nonradionuclides are based on current MTCA methods (WAC 173-340).

Nonradiological soil PRG values were also developed for the direct-contact and inhalation pathways, combined, using the casual recreational user exposure scenario. The casual recreational user scenario is used to represent reasonably anticipated future land use. The casual recreational user scenario is a site-specific scenario representing occasional recreational use that focuses on activities such as walking and picnicking in areas along the Columbia River where paths and benches may exist. Adults and children could potentially be exposed to site contaminants in shallow vadose zone material along the river through incidental soil ingestion, dermal absorption, and inhalation of vapors and dust in ambient air. PRG values for individual carcinogens are based on an ELCR of $1 \times 10^{-6}$ and an HQ of 1.0 for individual noncarcinogenic substances. The PRG values listed in Table 8-3 for this exposure scenario are provided to aid in potential risk management decisions and in determining whether the cleanup actions achieve the CERCLA threshold criteria.

Risk-based standards for some contaminants are calculated to be less than area background values or PQLs. Where risk-based standards are less than area background concentrations, PRGs may be set at concentrations that are equal to the agreed-upon site or area background concentrations. Area background values for selected nonradioactive contaminants in soil have been characterized for the Hanford Site (Non-Rad Soil Background document [DOE/RL-92-24]). Similarly, where risk-based standards are less than PQLs, PRGs will default to the PQLs. Therefore, the PRGs for individual nonradioactive contaminants in solid waste and particulate reflect the value that is greatest among risk-based standards, area background values, or PQLs.

*Ecological Exposure*. Ecological PRGs for the protection of plants, soil invertebrates, and wildlife (birds and mammals) are developed using a tiered approach (*Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* [CHPRC-00784]). The objective of a tiered approach is to refine available generic screening levels (EcoSSLs in MTCA [WAC 173-340], Table 749-3, or BCGs),

as needed, with additional literature-derived or site-specific information to more realistically represent Hanford Site-specific ecological risks. The ecological PRGs are developed in Chapter 7, Section 7.3.4.

### 8.1.4.3 Direct Contact Exposure PRGs for Radiological Contaminants

The PRGs for direct contact exposure to radiological contaminants for both human and ecological receptors are described in the following subsections.

*Human Exposure—Soil.* PRGs for radioactive wastes and radioactively contaminated soils for human receptor direct-contact exposures are based on EPA radionuclide soil cleanup guidance. As established by the NCP (40 CFR 300), CERCLA cleanup actions generally should achieve a level of risk within the $10^{-4}$ to $10^{-6}$ ELCR, based on the reasonable maximum exposure (RME) for an individual. Furthermore, EPA policy has noted that the upper boundary of the risk range is not a discrete line at $10^{-4}$ and that a specific risk estimate around $10^{-4}$ may be considered acceptable if justified based on site-specific conditions (*Radiation Risk Assessment At CERCLA Sites: Q&A* [EPA 540/R/99/006]). Demonstration that the $10^{-4}$ to $10^{-6}$ residual risk-range goal has been achieved is accomplished through final verification sampling during closeout of individual waste sites. The PRGs are developed for a number of exposure scenarios in the risk assessment. Each of these exposure scenarios are discussed in the following paragraphs.

PRGs for radiological contaminants are developed using a residential exposure scenario. Residents could potentially be exposed to shallow zone soil from residential yards or groundwater from domestic wells. Residents could potentially be exposed to soil from direct external exposure, incidental soil ingestion, or inhalation of dust generated from wind or from yard maintenance activities. Residents could also be potentially exposed to radiological contaminants through food chain pathways (uptake of contamination from soil to plants and animals). From the leaching pathway, residents could potentially consume drinking water from a downgradient well, use the well for irrigation of crops and watering livestock, and consume fish raised in a pond filled with water from the downgradient well. The PRGs are calculated using a target cancer risk level of $1 \times 10^{-4}$, which is comparable with the cleanup achieved through the interim actions as established by the interim action RODs. An annual dose rate of 15 mrem/yr was used in the interim action RODs as an RAO for protection of human health. Table 8-3 presents a summary of the RAGs reported in the 100 Area RDR/RAWP (DOE/RL-96-17) and the PRGs developed for the residential scenario.

Soil radiological PRG values are also developed for the direct-contact and inhalation pathways, combined, using the casual recreational user exposure scenario. PRG values for individual carcinogens are based on an ELCR of $1 \times 10^{-6}$ and an HQ of 1.0 for individual noncarcinogenic substances. PRG values for individual radioisotopes are based on an ELCR of $1 \times 10^{-4}$. The PRG values listed in Table 8-3 for these exposure scenarios are provided to aid in determining whether the cleanup actions achieve the CERCLA threshold criteria.

*Ecological Exposure.* BCGs are proposed for use as ecological PRGs for radionuclides for terrestrial plants and animals (including soil invertebrates). A discussion of the application of BCGs to radionuclide toxicity data is presented in Chapter 7, Section 7.3. BCGs are also evaluated at the SMDP and population basis for decisions. Additional evaluation may be conducted where biological exposures exceed BCGs.

### 8.1.4.4 Soil Concentrations Protective of Groundwater and Surface Water (SSLs and PRGs)

Modeling was conducted to assess the fate and transport of contaminants in the vadose zone and their potential effects on groundwater or surface water. One-dimensional numerical simulations were constructed to represent the key factors of the conceptual model for 100-F/IU using the STOMP code (STOMP: Theory Guide [PNNL-12030]). Modeling with STOMP was performed with different waste

distributions, recharge scenarios, and stratigraphic columns that represented the range of conditions within 100-F/IU. The bounding representation of waste distribution consisted of a uniform distribution through the entire vadose zone thickness beneath the backfill for contaminants with $K_d$ <2 (referred to as the 100:0 initial distribution) and a uniform distribution through the upper 70 percent of the vadose zone thickness beneath the backfill for contaminants with $K_d \geq 2$ (referred to as the 70:30 initial distribution). Calculations for strontium-90 were based on a 100:0 initial source distribution even though the strontium-90 $K_d$ is greater than 2. The 100:0 initial source distribution was selected for strontium-90 because the data indicated distribution throughout the vadose zone. Constituents that were persistent (i.e., do not degrade or decay in a reasonable time frame) and that had a peak concentration in groundwater occurring within 1,000 years in the future were evaluated. This modeling process, including assumptions and inputs, is described in Chapter 5, Section 5.6.

SSL values were developed from STOMP-simulated peak groundwater concentrations obtained for an irrigation recharge scenario representing a bounding future recharge case (based on irrigated agriculture) and for criterion protective of groundwater and surface water. Those sites/contaminants that failed the screening level (based on comparison of EPCs to SSLs) were next evaluated against PRG values developed from STOMP-simulated peak groundwater concentrations obtained for a native vegetation recharge scenario representative of re-establishment of the native xerophytic plant communities on the land surface (Table 8-3) and the same criterion protective of groundwater and surface water. The derivation of these protection levels is described in Chapter 5, Section 5.7.

#### *8.1.4.5 Groundwater and Surface Water PRGs*

The groundwater risk assessment was presented in Chapter 6, Section 6.3. The COCs (Section 8.1.1.2) were identified using the information provided in Chapter 6, Section 6.3. COPCs with EPCs greater than or equal to the DWS, federal or state water quality standards, or calculated cleanup levels per MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]) were retained as COCs. Based on the results of this evaluation, the list of COCs includes Cr(VI), strontium-90, TCE, and nitrate. The PRGs for each COC are presented in Table 8-5.

The COPC identification process (Chapter 6, Section 6.3.2) identified three analytes with an uncertain status for the 100-FR-3 Groundwater OU that are considered COPCs and warrant further evaluation in the FS. The occurrence of antimony, cadmium, and cobalt in groundwater is uncertain because these analytes have historically been detected in groundwater at concentrations above their respective action levels; however, their presence was not associated with a specific location or a trend, and the analytical methods used were not of sufficient accuracy for risk characterization purposes. In addition, the EPCs for these analytes are less than their respective action level. Because of the uncertain status of these COPCs, treatment for the COPCs is not evaluated in the alternatives developed in Chapter 9. To ensure protectiveness and confirm current understanding of the nature and extent of contamination and potential risks, these analytes will be included as part of the performance monitoring. If monitoring identifies that remedial action is necessary for the COPCs, these changes will be addressed through a ROD change.

## 8.2 General Response Actions

GRAs consistent with RAOs were identified for 100-F/IU. GRAs are basic actions that might be undertaken to remediate a site, and the GRAs are identified based on the nature and extent of contamination and risks present at a site, as described in the RI. For each GRA, several possible remedial technologies may exist, which can be further divided into one or more process options. This section discusses the remedial technology selection process.

Remedial technologies are selected for evaluation based on their potential ability to mitigate the identified risks or achieve compliance with ARARs for the remedial action. Technologies and process options selected for evaluation are assessed with respect to their implementability, effectiveness, and relative cost in accordance with CERCLA RI/FS Guidance (EPA/540/G-89/004) and the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)]). The selected final remedy must comply with ARARs and protect HHE.

CERCLA RI/FS Guidance (EPA/540/G-89/004) suggests development and evaluation of a range of responses, including a no action alternative, to ensure identification and selection of an appropriate remedy. The technology screening process consists of the following steps:

1. Identify GRAs that may meet RAOs, either individually or in combination with other GRAs.
2. Identify, screen, and evaluate remedial technology types for each GRA.
3. Select representative process option(s).

Following the technology screening, the retained technologies and their associated process options are assembled into remedial alternatives (presented in Chapter 9) that are evaluated further in the detailed and comparative analyses of alternatives (presented in Chapter 10).

GRAs identified for vadose zone soils at waste sites at 100-F/IU include the following:

- No action
- ICs
- Removal, ex situ treatment, processing, and disposal

GRAs identified for contaminated groundwater at 100-F/IU are as follows:

- No action
- ICs
- MNA
- Containment
- In situ treatment
- Pump-and-treat (collection, ex situ treatment, and discharge)

### 8.2.1 Target Remediation Areas

In accordance with CERCLA RI/FS Guidance (EPA/540/G-89/004), the FS is required to determine the areas or volumes of media to which GRAs might be applied. This section summarizes the vadose zone soil, including waste site areas, and groundwater contaminant plumes to be evaluated in the FS, based on the findings of the HHRA, ERA, and RI presented in the preceding chapters.

#### *8.2.1.1 Waste Sites*

As discussed in Chapter 1, the determination on which 100-F/IU waste sites to be addressed in the RI/FS was performed following specific procedures defined in the TPA (Ecology et al., 1989a) and the TPA Action Plan (Ecology et al., 1989b). Suspected waste sites are described and tracked in the WIDS database. As information is collected on the sites, or as they are remediated and confirmation data collected, they are classified or reclassified, depending on their status. Table 8-6 identifies the disposition for each 100-F/IU waste site through the RI/FS process.

Table 8-5. 100-FR-3 Groundwater OU PRGs

| Contaminant | Units | 90th Percentile Concentration | Dose (mrem/yr) Based on 90th Percentile Concentration | ELCR Based on 90th Percentile Concentration | HI Based on 90th Percentile Concentration | DWS (40 CFR 141) | "Groundwater" (WAC 173-340) Cleanup Levels | | AWQC and State Water Quality Standards at the Groundwater/Surface Water Interface | | "Toxic Substances" (WAC 173-201A) | Water Quality Standards (40 CFR 131) | | 100-F/IU Groundwater PRG[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Noncarcinogens at HQ = 1 | Carcinogens at 1 × 10-5 Risk Level | Freshwater CMC (acute) | Freshwater CCC (chronic) | Freshwater CCC (chronic) | Freshwater CMC (acute) | Freshwater CCC (chronic) | |
| **COCs for Remedial Technology Screening and Alternative Development** | | | | | | | | | | | | | | |
| Strontium-90 | pCi/L | 3.3 | 1.7 | -- | -- | 8 | -- | -- | -- | -- | -- | -- | -- | 8 |
| Cr(VI)[b] | µg/L | 20 | -- | -- | 0.42 | -- | 48 | -- | 16 | 11 | 10 | 15 | 10 | 10[c] |
| Nitrate[d] | µg/L | 109,500 | -- | -- | 0.96 | 45,000 | 113,600 | -- | -- | -- | -- | -- | -- | 45,000 |
| Trichloroethene (TCE) | µg/L | 11 | -- | $2.2 \times 10^{-5}$ | -- | 5 | -- | 4.9 | -- | -- | -- | -- | -- | 4.9 |

Sources:

40 CFR 131, "Water Quality Standards."

40 CFR 141, "National Primary Drinking Water Regulations."

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards."

WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington."

a. The final cleanup levels achieved at the conclusion of the remedial action will correspond to a cumulative ELCR less than $1 \times 10^{-5}$ and HI of less than 1.

b. There is no DWS specific to Cr(VI).

c. The aquatic protection standard applies to groundwater where it discharges to surface water.

d. Nitrate may be expressed as nitrate ($NO_3$) or as nitrate-nitrogen ($NO_3$-N). The DWS for $NO_3$-N is 10,000 µg/L and 45,000 µg/L for $NO_3$.

AWQC = ambient water quality criteria
CCC = criteria continuous concentration
CMC = criteria maximum concentration
DWS = drinking water standard
ELCR = excess lifetime cancer risk
HI = hazard index
HQ = hazard quotient
PRG = preliminary remediation goal

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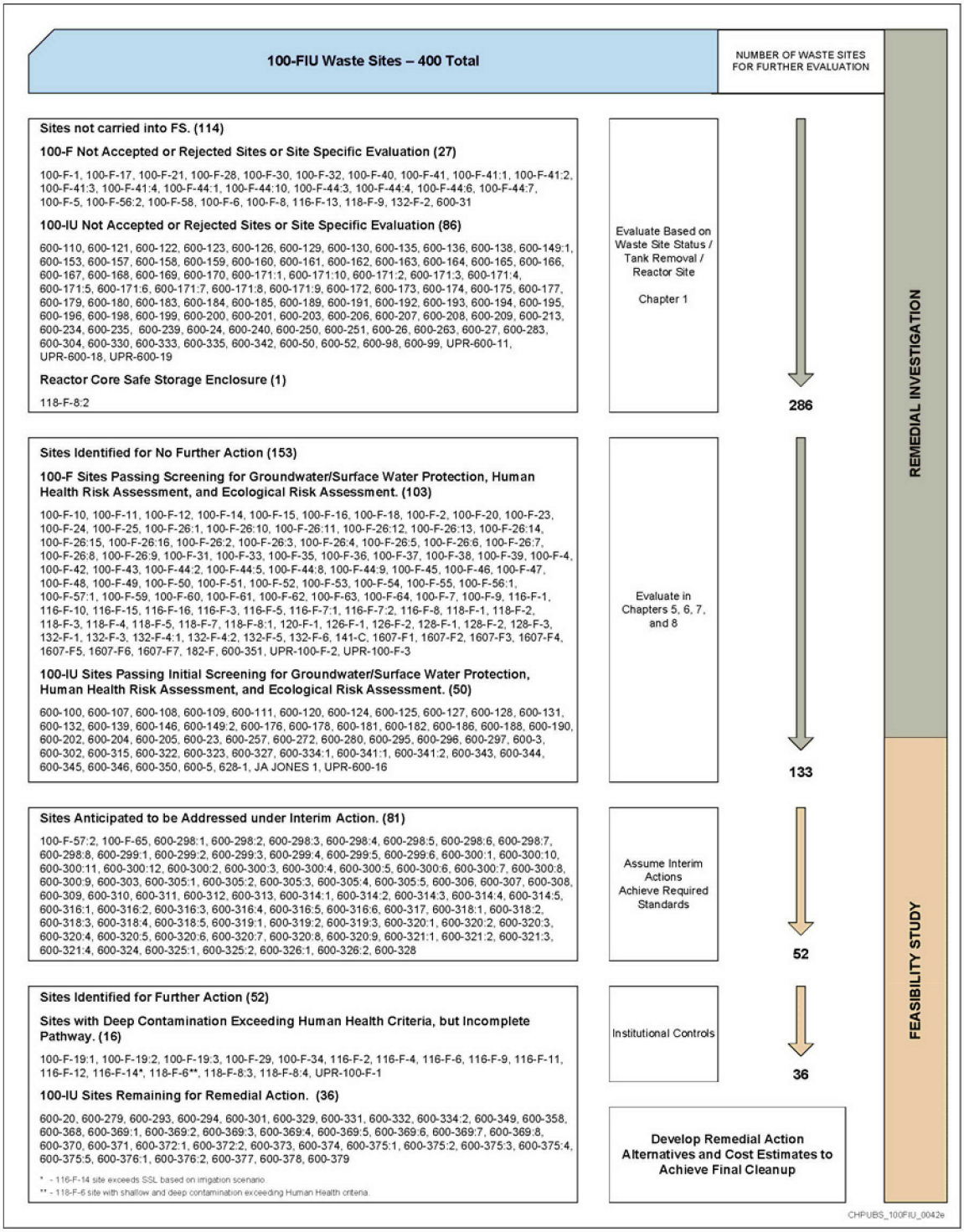
Table 8-6. Waste Site Tally – 100-F/IU RI/FS




*Waste Sites not Carried Forward into the FS—100-FR-1/FR-2.* Of the 149 sites (including subsites) in 100-FR-1/FR-2, 23 sites were classified or reclassified as "Rejected" or "Not Accepted." Four additional sites with other reclassifications were not carried forward based on site-specific consideration, as described in Chapter 1, Section 1.2.3.

Alternatives for the F Reactor safe storage enclosure at 100-F are also not discussed in the FS. In the 1993 NEPA Reactor ROD (58 FR 48509), DOE decided on safe storage of the eight reactors, followed by deferred one-piece removal. The NEPA Reactor ROD (58 FR 48509) also states that DOE intends to integrate and prioritize this decision with the related CERCLA remediation activities scheduled under the Tri-Party Agreement (Ecology et al., 1989a).

DOE issued an *Amended Record of Decision for the Decommissioning of Eight Surplus Reactors at the Hanford Site, Richland, WA* (75 FR 43158) on July 23, 2010. DOE broadened the decommissioning approach for these eight surplus reactors, including the F Reactor, retaining the deferred one-piece removal option, and, based on *Supplement Analysis: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE/EIS-0119F-SA-01), added an option for immediate dismantlement.

DOE uses the CERCLA process to decommission and dismantle reactors based on the joint EPA/DOE policy on decommissioning signed in 1995 and incorporated into the TPA (Ecology et al., 1989a). Since the NEPA Reactor ROD (58 FR 48509) in 1993, documentation has been prepared and implemented under CERCLA, resulting in placement of six of the eight surplus reactors (C, D, DR, F, H, and N Reactors) into ISS, which is designed to prevent deterioration and release of contamination from the reactors. ISS for the reactors was complete in 2005 to ensure the safety of the reactor for up to 75 years as part of the remediation activities in 100-F/IU.

Removal of F Reactor will be conducted as a CERCLA non-time-critical removal action. DOE evaluated the coordination of decommissioning actions with the completion of interim field remediation for 100-F/IU. Based on October 2012 field remediation information, all waste sites in the immediate vicinity of the reactor are interim closed out according to the interim action ROD. Until reactor removal is complete, DOE will continue to conduct routine reactor maintenance, surveillance, and radiological monitoring to ensure continued protection of HHE during the ISS period. All other waste sites in the immediate vicinity of the reactors have been remediated according to the interim action ROD. It is not anticipated that remedial action will be needed for contaminant releases from the ISS reactor structures before their removal. Additional information developed through the groundwater/surface water protection evaluation presented in Chapter 5, and the human health and ecological risk assessments presented in Chapters 6 and 7, respectively, does not change the determination on which waste sites are to be excluded from the FS. Figure 8-1 shows the location of the 100-FR-1/FR-2 waste sites that are not evaluated in the FS. Chapter 1 presents additional information on these waste sites that are not carried forward.

*Waste Sites not Carried Forward into the FS—100-IU-2/IU-6.* Of the 251 sites (including subsites) in 100-IU-2/IU-6, 73 sites were classified or reclassified as “Rejected” or “Not Accepted.” Thirteen additional sites with other reclassification statuses were not carried forward based on site-specific consideration, as described in Chapter 1, Section 1.2.3. The location of these sites is shown on Figure 8-2.

*Waste Sites Identified for No Further Action—100-FR-1/FR-2.* Of the 149 sites present in 100-FR-1/FR-2, 103 sites were identified for no further action based on the risk assessments in Chapters 5, 6, and 7, and specific alternative evaluations are not developed for these sites. Waste site 600-351 reported EPCs for arsenic and lead that were greater than soil cleanup levels for unrestricted land use (Chapter 6, Section 6.5.1.1). This waste site is located proximal to former orchard lands, and the source for these elevated metals concentrations is attributed to pesticide applications and not 100-F/IU operations. This site will be addressed as part of the orchard lands 100-OL-1 OU. The locations of these sites are shown on Figure 8-3.

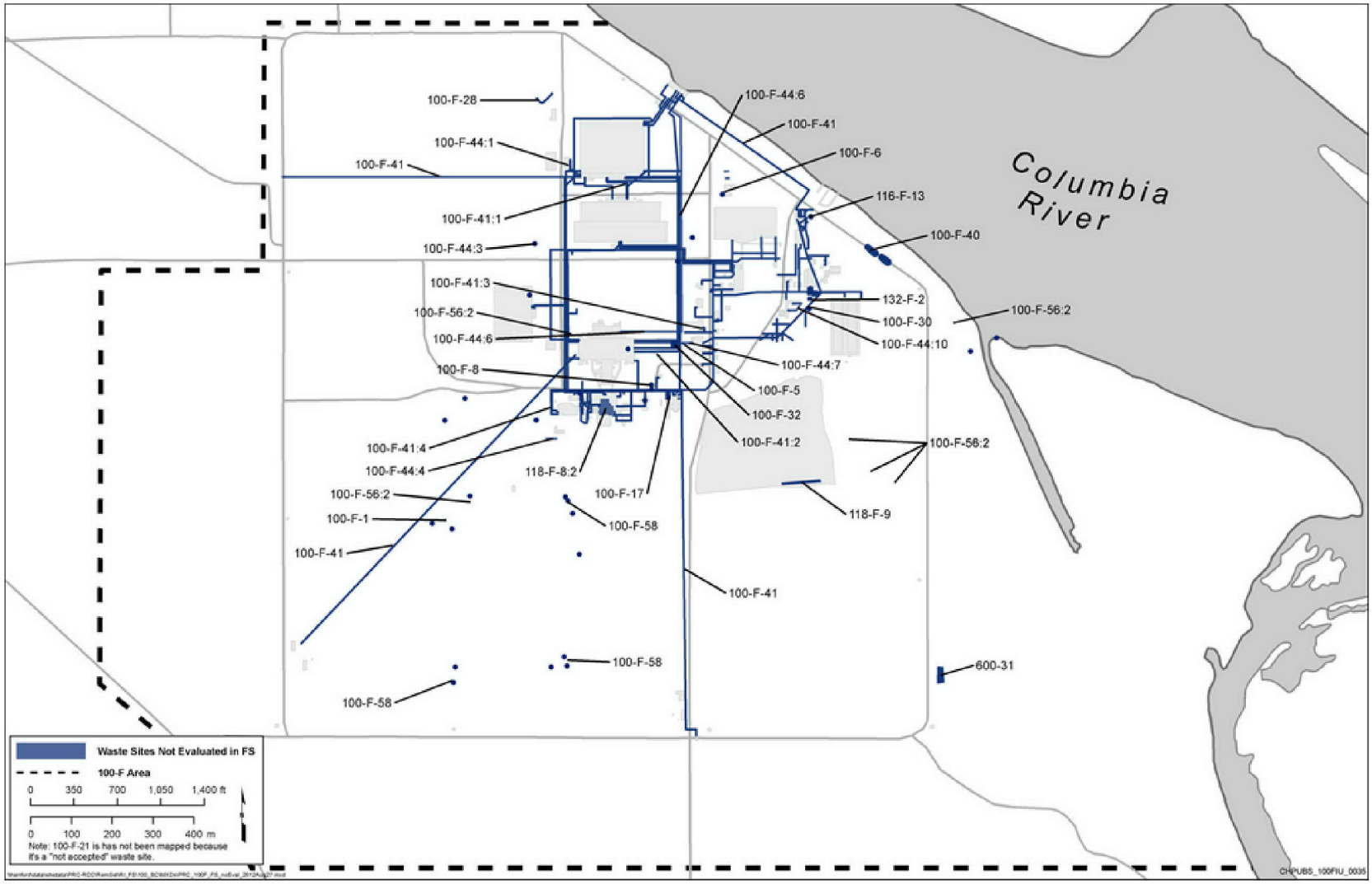



Figure 8-1. Location of 100-FR-1/FR-2 Waste Sites Not Carried Forward to the FS

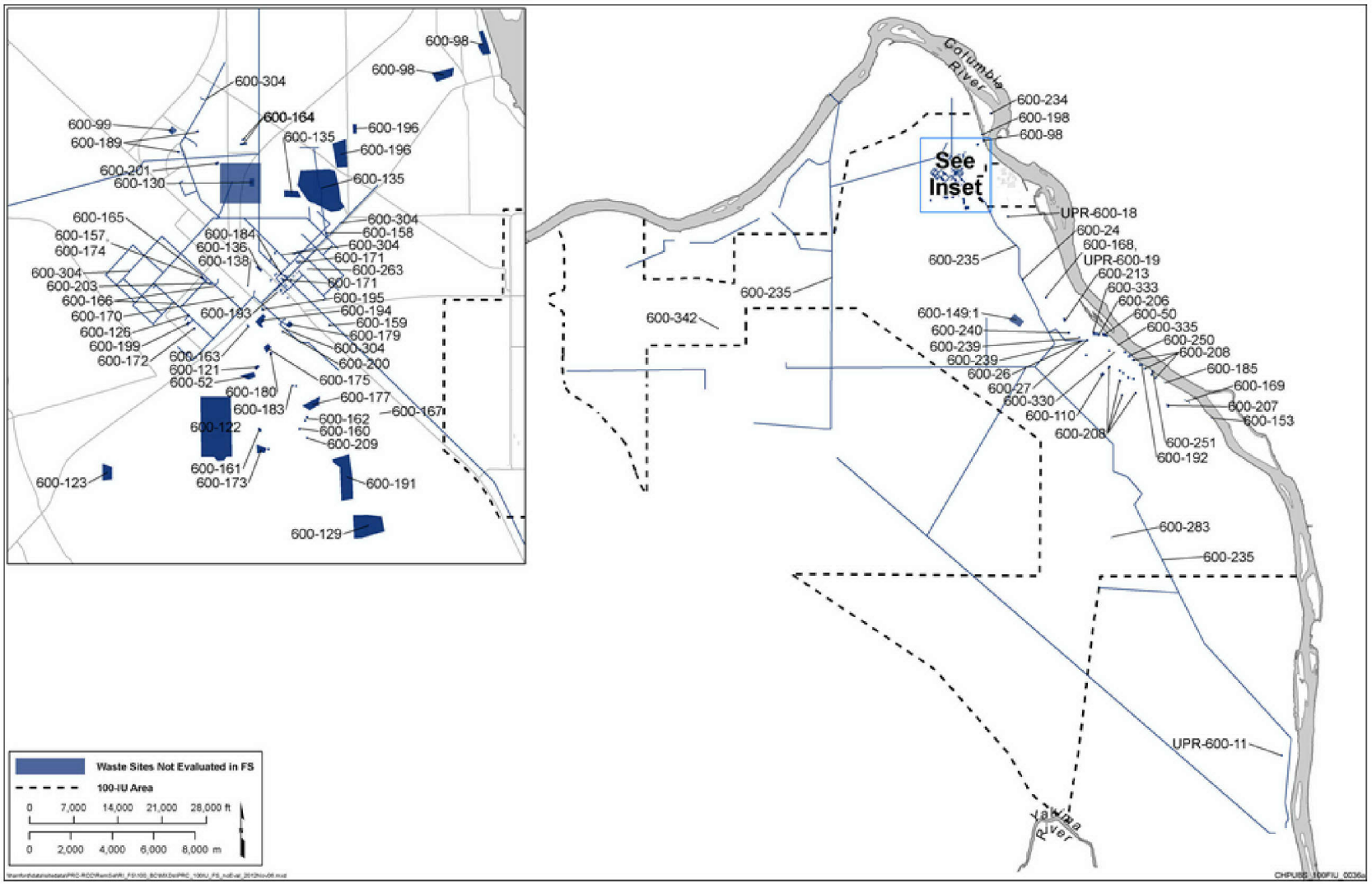



Figure 8-2. Location of 100-IU-2/IU-6 Waste Sites Not Carried Forward to the FS

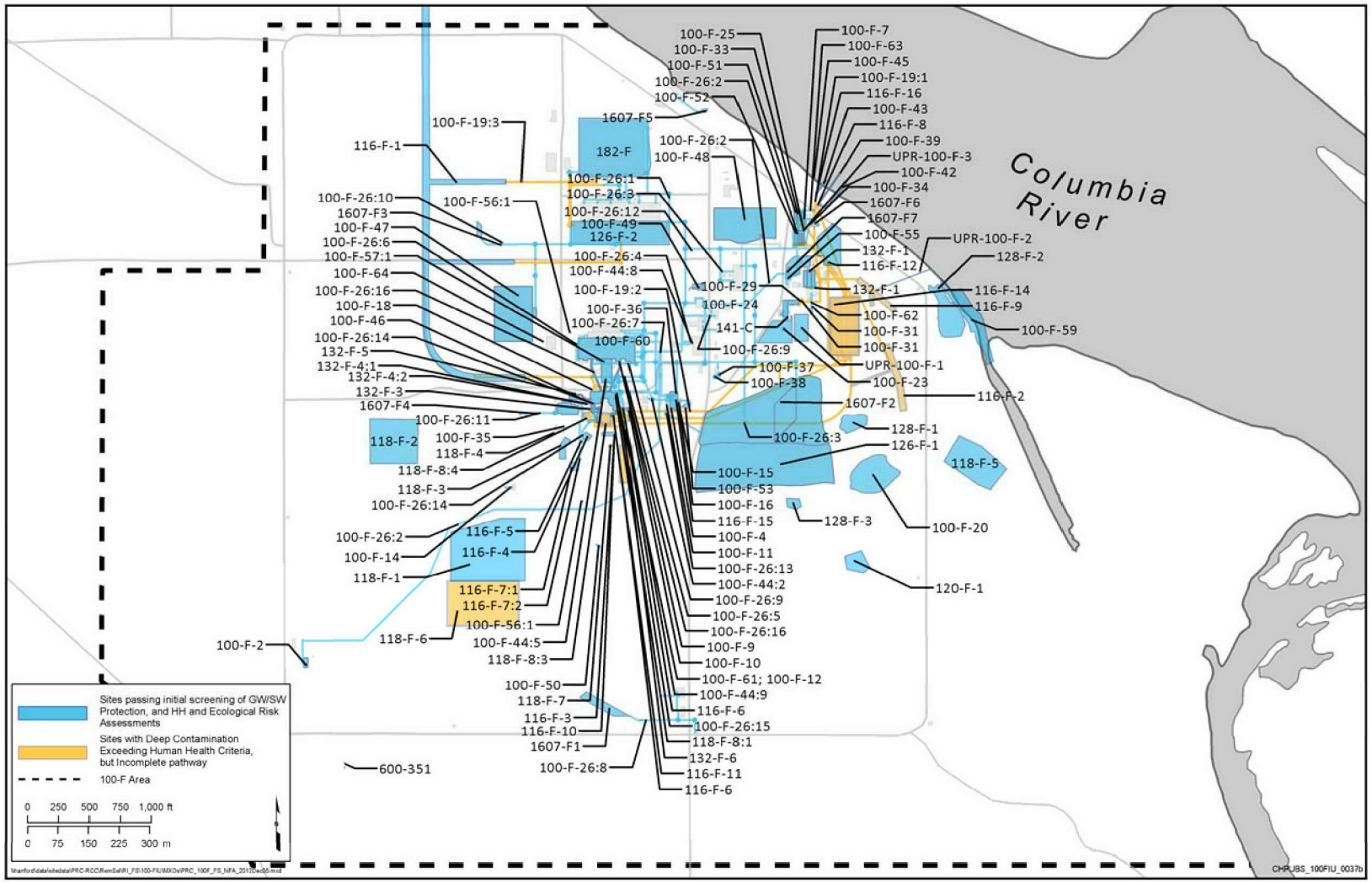



Figure 8-3. Location of 100-FR-1/FR-2 Waste Sites Identified for No Further Action or ICs

One waste site associated with river effluent pipelines (100-F-39) was evaluated for risks as discussed in Chapters 6 and 7. The risk assessments associated with the river effluent pipeline investigation indicate no unacceptable human health risk based on RME scenarios. No technology application is required and remedial action alternatives are not developed for the below river effluent pipeline waste site in this FS. While no IC is required, an annual inspection under *Hanford Facility Resource Conservation and Recovery Act Permit for Treatment, Storage, and Disposal of Dangerous Waste* (WA7890008967) is conducted along the shoreline to identify Hanford debris.

*Waste Sites Identified for No Further Action—100-IU-2/IU-6.* Of the 251 sites present in 100-IU-2/IU-6, 50 sites were identified for no further action based on the risk assessments in Chapters 5, 6, and 7, and specific alternative evaluations are not developed for these sites. These sites are not considered further in this RI/FS. The location of these waste sites is shown on Figure 8-4.

*Waste Sites Anticipated to be Addressed under Interim Actions.* There are 81 waste sites remaining that have been or are expected to be addressed under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039). This includes 27 sites where remediation and verification against interim RAGs have recently been completed, but formal evaluation against PRGs has not yet been performed. The locations of the wastes sites expected to be remediated under interim actions are shown on Figure 8-5. These sites will continue to be remediated under the interim actions until the ROD is signed. The protectiveness of the interim actions will be confirmed by comparison to the PRGs selected in the 100-F/IU OUs ROD.

*Waste Sites Remaining for Remedial Action.* The remaining 52 sites are expected to require further action after the ROD is issued. Fifteen of the 52 sites have been remediated and interim closed and have verification data with radionuclide concentrations above RBSLs at depths greater than 4.6 m (15 ft) bgs. Since these concentrations are not exceeded at shallower depths, there is currently no complete exposure pathway. DOE has proposed to place deep excavation ICs at these waste sites to limit exposure. The rough order of magnitude cost for excavating and removing contaminated soil for all of these sites is $160 million. However, these radionuclides will continue to decay to below human health protection RBSLs within 13 to 175 years, depending on the current concentration of individual constituent(s) of interest at each site. During this time, DOE or the federal government will maintain controls on the land to prevent exposure to these materials. For this reason institutional controls will be maintained for these sites until unrestricted use is allowable. No further technology application is required for these sites. Additional information on ICs is presented in Section 8.3 and Section 9.1.3 (Chapter 9). The radionuclides present at these sites will decay to levels less than RBSLs in the following time frames:

- **100-F-19:1, 100-F-19:3, 100-F-34, and 116-F-12:** year 2088
- **100-F-19:2, 100-F-29, 116-F-11, and UPR-100-F-1:** year 2027
- **116-F-2:** year 2101
- **116-F-4:** year 2102
- **116-F-6:** year 2113
- **116-F-9:** year 2062
- **116-F-14:** year 2076
- **118-F-8:3:** year 2187
- **118-F-8:4:** year 2025

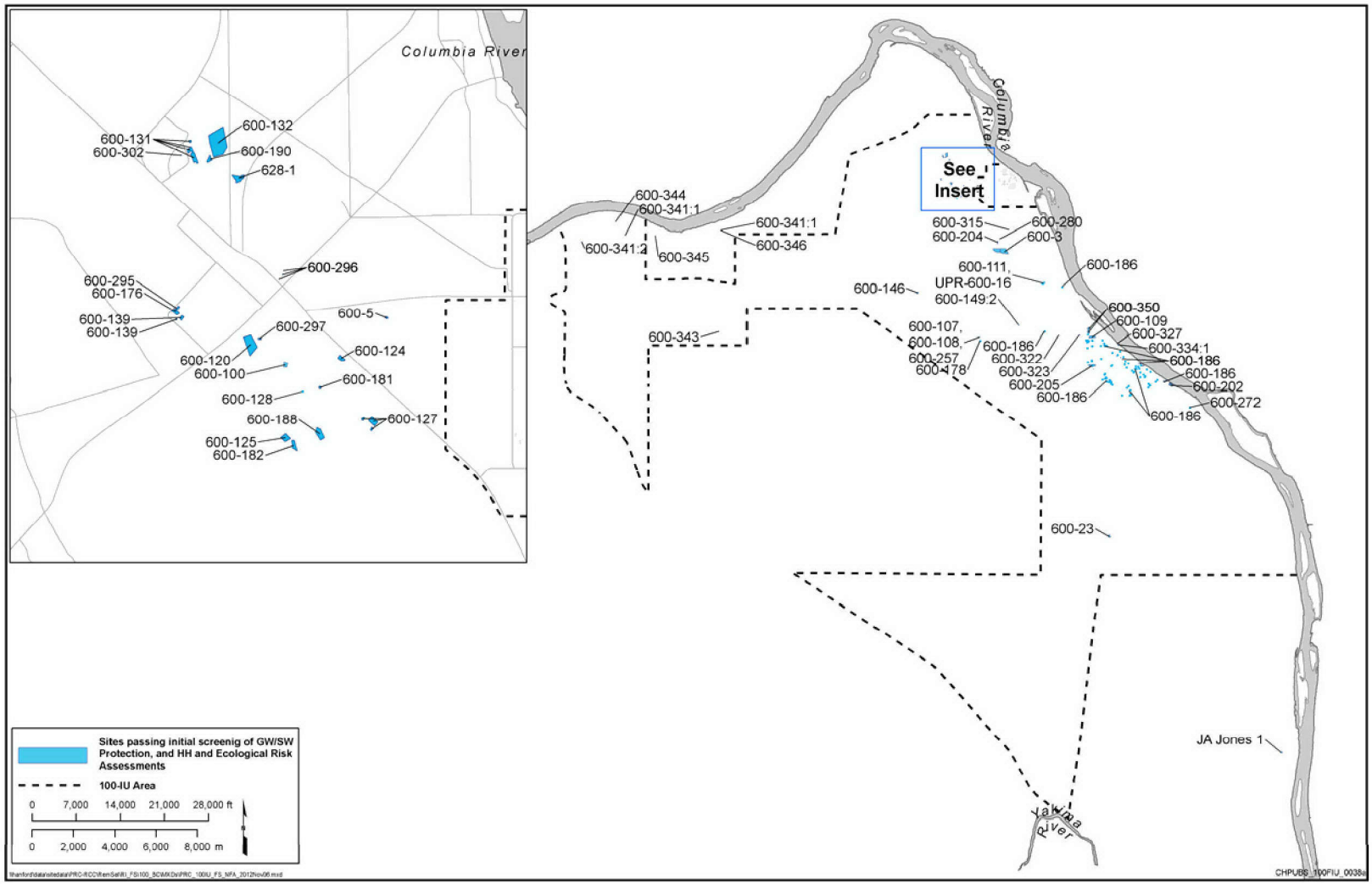



Figure 8-4. Location of 100-IU-2/IU-6 Waste Sites Identified for No Further Action

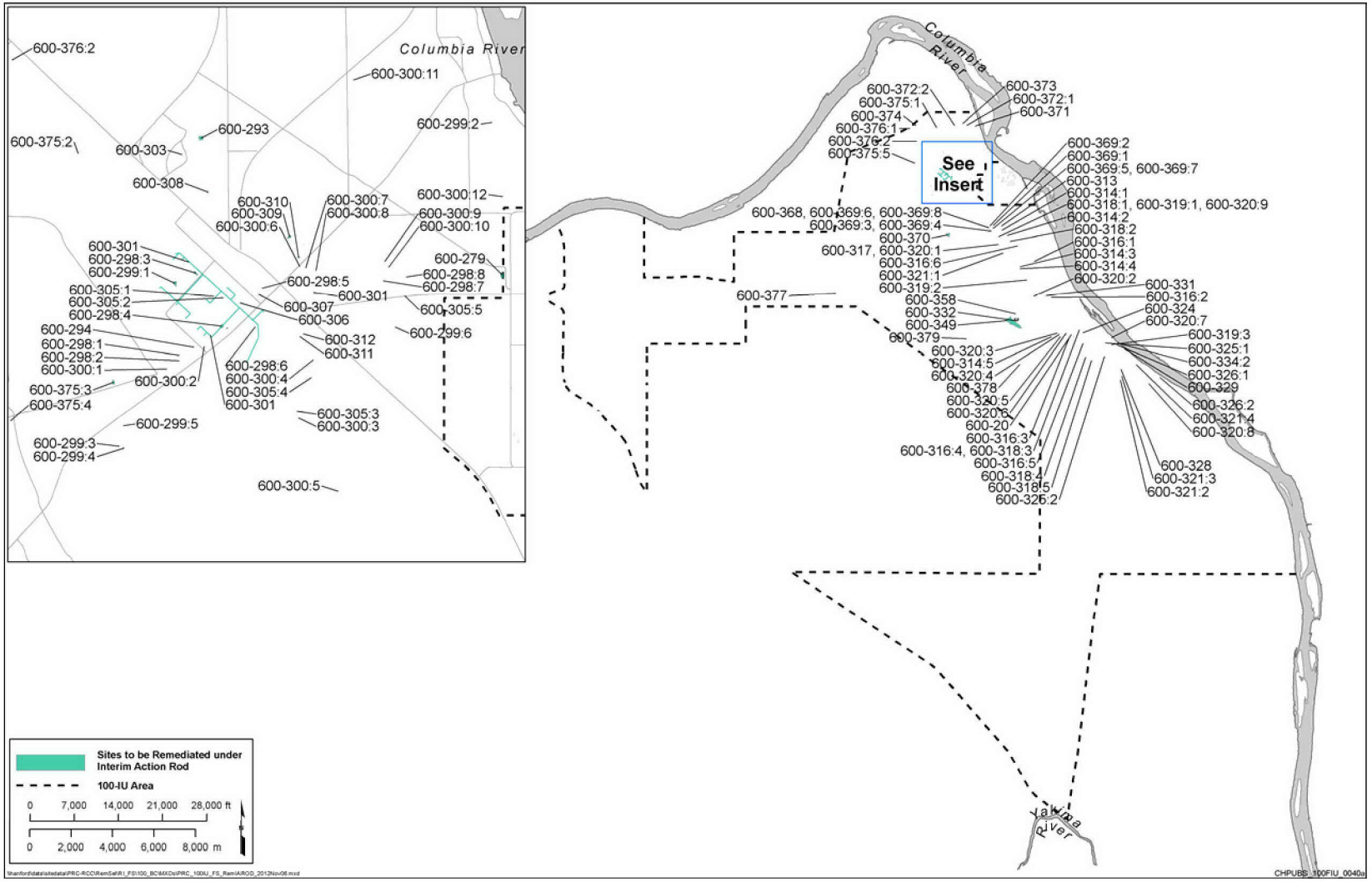



Figure 8-5. Location of 100-IU-2/IU-6 Waste Sites Expected to be Addressed under the Interim Action ROD

Additionally, residual Cr(VI) concentrations present at the 116-F-14 waste site exceed the surface water protection SSL based on an irrigated land-use scenario, but do not exceed PRGs for groundwater and surface water protection. Therefore, DOE has proposed to place an additional IC at this waste site to prevent future irrigation.

The EPC for strontium-90 at waste site 118-F-6 was greater than the RBSL. The EPC is based on the maximum result from a small statistical verification dataset that is representative of both shallow and deep portions of the waste site after remediation. This conservative EPC will continue to decay and be below RBSLs in 2035. DOE has proposed to place an IC at this waste site to prevent unrestricted exposure to residual strontium-90 until levels decay below RBSLs.

The waste sites proposed for ICs based on deep zone radiological contamination but an incomplete exposure pathway, exceedance of the SSL, and shallow radionuclides are not evaluated further in this RI/FS. The location of these waste sites is shown on Figure 8-3.

The remaining 36 sites are expected to be remediated after the ROD is issued. These sites are evaluated for remedial alternatives in Chapter 9. Risk drivers have been determined based on knowledge of the process that was performed at the sites and remediation results at similar sites in the River Corridor. The remedial approaches for the major risk drivers are developed for each alternative and presented in Chapter 9. The locations of the sites remaining for remedial action are shown on Figure 8-6 and include the following:

- Thirty-three sites planned for remediation under interim actions but where interim actions are not expected to be substantially complete before issuance of the 100-F/IU ROD. This includes the previously rejected 600-20 waste site, which will be classified as an accepted site, as described in Chapter 1, Section 1.2.3.

- Three candidate sites that have not yet undergone confirmatory evaluation under interim actions (600-329, 600-331, and 600-334:2).

The 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) established a process whereby new and existing sites that did not have sufficient information to make a remedial action determination could be evaluated to make this decision. These sites are referred to as "candidate sites" or "confirmatory sites" under the interim action framework. There are 3 waste sites identified as candidate sites that have not yet been evaluated as of June 2012. Remedial alternatives have been developed for the three sites under the assumption that remediation is determined to be warranted. Confirmatory evaluation will determine the need for remediation for these three sites.

#### *8.2.1.2 Groundwater*

Four contaminant plumes exceeding groundwater PRGs are present in 100-F/IU (Figure 8-7). Groundwater modeling for remedial alternatives evaluation (*Modeling of RI/FS Design Alternatives for 100 FR-3* [ECF-100FR3-11-0116] in Appendix F) was conducted to establish baseline conditions. The initial distribution of each COC in groundwater within 100-F/IU was established using the maximum reported concentration for each monitoring location from samples collected in 2009 and 2010. Table 8-7 summarizes the area and estimated volume of contaminated groundwater associated with each plume.

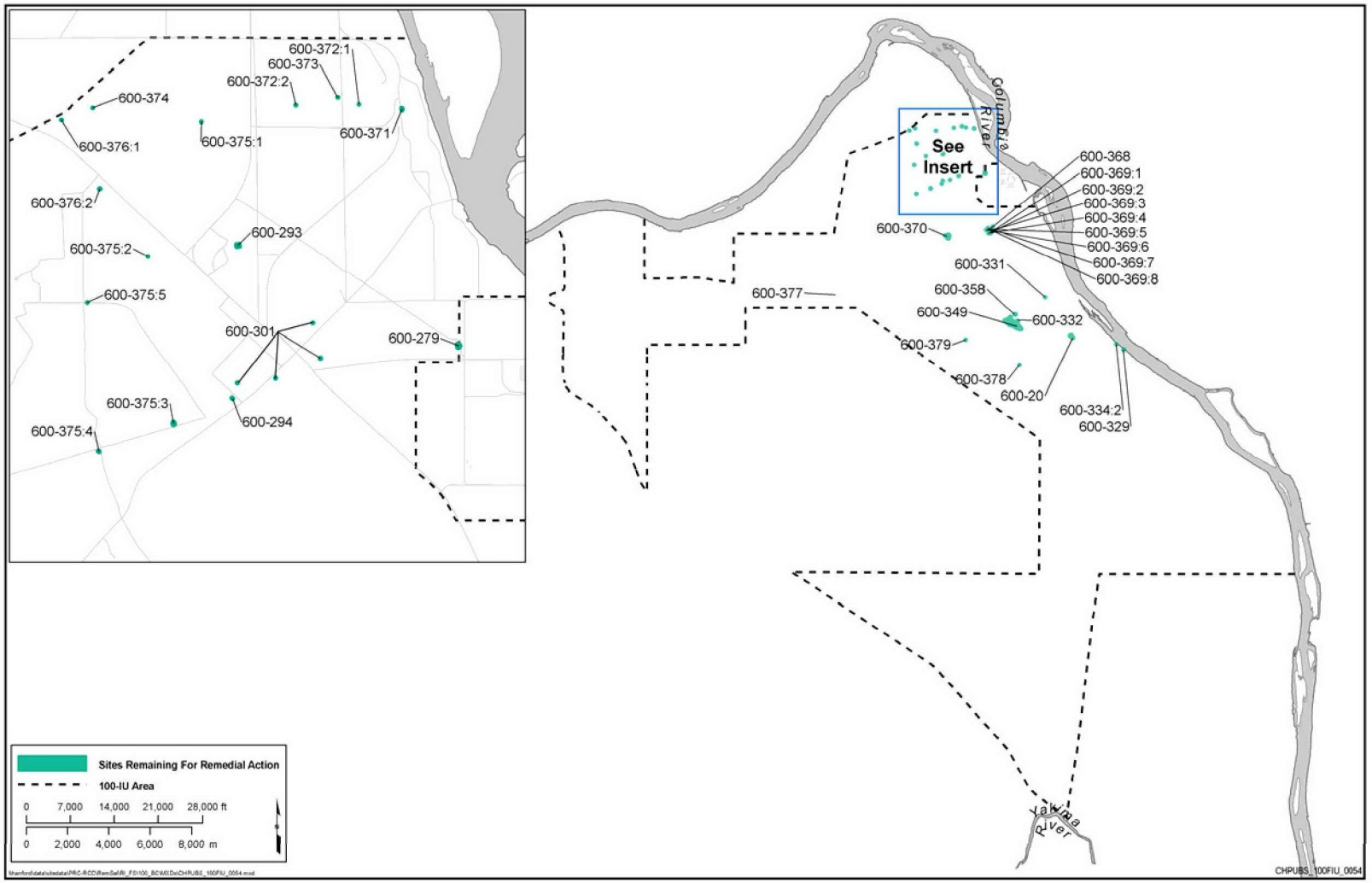



Figure 8-6. Location of 100-IU-2/IU-6 Waste Sites Remaining for Remedial Action

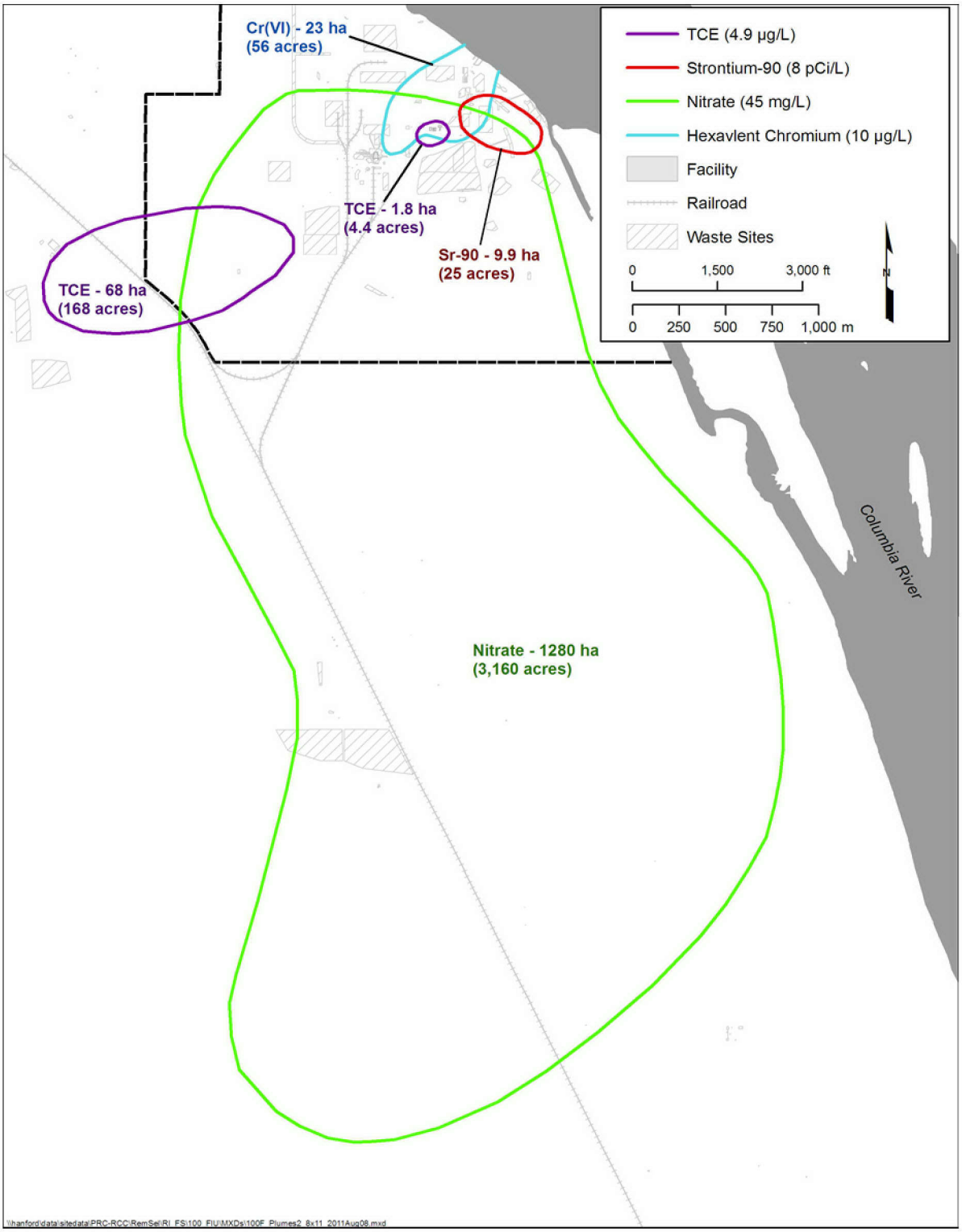



Figure 8-7. 100-F/IU Groundwater Contaminant Plumes (Fall 2010) Evaluated in the FS

Table 8-7. Groundwater Contaminant Plumes Evaluated in the FS

| Groundwater COC | Rationale for Inclusion in FS | Areal Footprint for FS Evaluation | Volume of Contaminated Groundwater for FS Evaluation |
|---|---|---|---|
| **Groundwater** | | | |
| Cr(VI) | 90th percentile EPC of 20 µg/L exceeds 10 µg/L PRG | 23 ha (56 ac) | 46 million gal* |
| Strontium-90 | 90th percentile EPC 3.3 pCi/L less than 8 pCi/L PRG, but localized area with a maximum detected concentration of 19 pCi/L exceeds PRG | 9.9 ha (25 ac) | 21 million gal* |
| Trichloroethene (TCE) | 90th percentile EPC of 11 µg/L exceeds PRG of 4.9 µg/L | 1.8 ha (4.4 ac)<br>68 ha (168 ac) | 140 million gal* |
| Nitrate | 90th percentile EPC of 109,500 µg/L exceeds PRG of 45,000 µg/L | 1,280 ha (3,162 ac) | 2.6 billion gal* |

* Volume estimated by multiplying plume area by porosity of 0.18 and average plume thickness of 4.3 m (14 ft).

COC = contaminant of concern
EPC = exposure point concentration
FS = feasibility study
PRG = preliminary remediation goal

## 8.3 Identification and Screening of Technology Types and Process Options

This section presents remedial technologies and process options that are subsets of the selected GRAs, and that may potentially meet RAOs for contaminated waste sites and groundwater at 100-F/IU. The potential remedial technologies were evaluated and screened for implementability; effectiveness in eliminating, reducing, or controlling risks to HHE; and relative cost. The technologies retained from the screening are combined into a range of remedial alternatives in Chapter 9.

### 8.3.1 Identification and Screening of Technologies

This section summarizes the technologies and process options considered as part of this evaluation. No action and ICs are not considered remedial technologies, but are important response actions to be considered as part of the remediation approach and are discussed herein. No action and ICs are described in Section 8.3.1.1.

Tables 8-8 and 8-9 present the identification and screening of technologies and remedial process options for 100-F/IU. Table 8-8 identifies technologies for treatment of vadose zone soil, while Table 8-9 presents information on technologies for the Cr(VI), strontium-90, TCE, and nitrate groundwater contaminant plumes. Appendix I provides a discussion of the technologies not retained. Technology-specific fact sheets (Figures 8-8 through 8-18) and information contained in Chapter 9 present additional information on the specific technologies retained.

Table 8-8. Technology Screening for Waste Sites at 100-IU-2/IU-6

| General Response Actions | Remedial Technology | Process Option | COC Applicability[a] | Depth Range[b] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[c] | Retained/ Not Retained[d] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action | No Action | No action | All | All | No further actions to address contamination. Source areas and residual contaminants in vadose zone are left untreated. | Low/High<br>No remedial actions are taken, but effectiveness could be high if risk is previously mitigated. | High<br>No administrative or technical implementability challenges are associated with implementation of this option, since no actions are required. | Low<br>No associated cost. | Low<br>No associated cost. | Little impact. | Retained | Retained per the NCP (40 CFR 300). |
| Institutional – Controls | Entry Restrictions | Procedural requirements for access (badging)<br>Fencing/security<br>Excavation/drilling permits | All | All | Uses one or more of the identified process options to control the exposure pathway. | Moderate/High. Reduces or eliminates the potential for direct contact when enforceable provisions are employed for the duration of elevated risk period. Protects integrity of active remedies. | High. Readily implemented, especially when coupled with the Sitewide IC Plan (DOE/RL-2001-41). Requires periodic surveillance and reporting. | Low | Low, especially for radionuclides with short half-lives, such as 100-F COCs. | Little impact. | Retained | DOE has implemented ICs under interim action RODs. These can be readily extended. |
| | Waste Site Information Management | Administrative | All | All | Uses existing information to inform workers and the public of potential hazards so appropriate controls can be implemented to prevent/minimize exposure. | Moderate. Provides access to information on the location and nature of contamination. | High. Readily implemented, but requires maintenance of the information management system. | Low | Low | Little impact. | Retained | DOE already has a waste information program in place. |
| Monitored Natural Attenuation (MNA) | MNA | MNA | Radionuclides | All | Relies on natural radioactive decay to reduce COC concentrations. Nonintrusive data evaluations are performed to identify that COC concentrations are declining in accordance with expectations. | High for radionuclides with short half-lives. | High. Readily implemented technically. | Low | Low | Little impact. | Retained | |
| Containment | Surface Barrier | Surface barriers (e.g., modified RCRA Subtitle C and/or D barrier, asphalt/concrete barrier, vegetative barrier [evapotranspiration barrier], Hanford Barrier) | All | All | Surface barriers are generally designed to be impermeable to prevent surface water infiltration through the vadose zone and limit contaminant leaching to groundwater. Surface barriers may also prevent direct contact to contaminants.<br>Modified RCRA Subtitle C barriers are designed for hazardous waste, Category 3 and Category 1 (mixed) low-level waste.<br>Modified RCRA Subtitle D barriers are designed for nonradiological and nonhazardous solid waste, or Category 1 low-level waste where hazardous constituents are not present.<br>Asphalt/concrete caps can be placed around structures to remain in place (e.g., reactors) in the short term (up to 75 years) to promote drainage, prevent infiltration into possible sources below the reactors, and prevent exposure to contaminated soil.<br>Evapotranspiration barriers consist of a fine-grained soil layer overlying a relatively coarse-grained soil layer designed to functionally increase the water-holding capacity.<br>The Hanford Barrier design was developed for sites containing low-level waste greater than Class C, and/or significant inventories of TRU constituents. | Moderate/High<br>Leaching of near-surface source COCs will be controlled, but residual COCs in capillary fringe and deeper vadose zone pore water may continue to affect groundwater because of water table fluctuation. Prevention of direct contact will depend on specific design. Effectiveness for asphalt caps is high in the short term; for increased effectiveness, barrier needs to be properly sealed, given that asphalt and concrete are permeable. | High<br>No technical or administrative challenges are associated with implementing asphalt/concrete caps (high implementability). Modified RCRA Subtitle C and/or D barrier and evapotranspiration caps are simple to install.<br>For all surface barriers (except asphalt/concrete caps), biointrusion will need to be considered as part of the barrier/cap design.<br>Implementability of the Hanford Barrier is low because the large number of layers makes this technology more difficult to implement. | Low/High<br>Hanford Barrier (High); modified RCRA Subtitle C and/or D barrier (Moderate); asphalt/concrete cap and evapotranspira-tion barrier (Low) | Low<br>Dependent on type of barrier and depth of contamination. | GHG and energy for installation. Continued affect to soil resources. | Not retained | Waste sites with characteristics that could benefit from this technology are not identified in 100-IU-2/IU-6. |

Table 8-8. Technology Screening for Waste Sites at 100-IU-2/IU-6

| General Response Actions | Remedial Technology | Process Option | COC Applicability[a] | Depth Range[b] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[c] | Retained/ Not Retained[d] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Containment (cont.) | Subsurface Barriers | Jet grouting, soil freezing, or wire saw barriers | All | 6 m (20 ft)/ greater than 6 m (20 ft) | Barriers placed beneath the contaminated zone to limit further migration. Jet grouting injects a binding agent (typically cement) that binds fills the voids and binds the soil into a cohesive mass. Soil freezing involves placement of cooling media distribution systems into the subsurface to freeze a soil layer below the contamination. Wire saw barrier involves cutting a thin horizontal trench that is filled with grout using a diamond-wire saw. The saw is placed in an excavation around the soil mass to be contained. | Low<br>Significant uncertainty on the completeness of the barrier with all methods. | Low<br>Would be difficult or impossible to implement at Hanford because of the presence of gravels and cobbles, and/or the depth of application. | High | Low | Large amount of waste would be generated during installation and GHG, and energy for installation. | Not retained | Difficult to implement. |
| | Compaction | Dynamic compaction | All | 6 m (20 ft) | Dynamic compaction is used for consolidation of soils and buried wastes, and can be used to minimize the potential subsidence for a subsequent barrier. The process involves dropping a weight from a predetermined height onto the area to be compacted. | Moderate/High<br>Effective at removing void spaces and compacting surface soil, where voids exist around buried waste. Not effective for native soils.<br>Not effective for treatment of hazardous waste. | Moderate<br>Simple and widely used technology. | Low | Low<br>No associated cost. | GHG and energy for installation. | Not retained | Waste sites with characteristics that could benefit from this technology are not present in 100-IU-2/IU-6. |
| Removal | Excavation | Standard excavation | All | 6 m (20 ft) | Shallow soil is removed using conventional construction equipment. Excavation limited to approximately 6 m (20 ft) bgs. Excavated soil is segregated (automated or laboratory based) to determine disposal or treatment requirements. | High<br>Shallow contaminated soil removed. | High<br>Shallow excavation is typically straightforward. An excavation permit is required for excavation in the 100, 200, and 300 Areas and the Hanford Reach National Monument. | Moderate/High | None<br>No associated cost. | Waste generation if excavated soil is disposed of, GHG and energy for excavation equipment. | Retained | |
| | | Deep excavation | All | 6 m (20 ft)/ greater than 6 m (20 ft) | Soil is removed to deeper depths. Deep excavation would require implementation of more complex technologies, for example, large lay back for open-pit type excavation or alternatively use of shoring. Excavated soil is segregated to determine disposal or treatment requirements. | High<br>Locations of the deep contaminated soil will be difficult to identify, meaning large areas would have to be excavated to depth to ensure that the deep sources were removed. | Moderate<br>Has been performed at the Hanford Site using laybacks. Shoring may be difficult with cobbles and boulders. Increased safety challenges with very deep excavations. An excavation permit is required for excavation in the 100, 200, and 300 Areas and the Hanford Reach National Monument. | High | None<br>No associated cost. | Waste generation if excavated soil is disposed of, GHG and energy for excavation equipment. | Retained | |
| Ex Situ Treatment and Processing | Ex Situ Treatment and Processing[e] | Solidification/stabilization | Mobile to semi-mobile contaminants | All | Contaminants are physically bound or enclosed within a stabilized mass (solidification), or chemical reactions are induced between the stabilizing agent and contaminants to reduce their mobility (stabilization). Agents include: soluble phosphates, pozzolan/Portland cement, polyethylene extrusion, etc. The stabilized mass is returned to its original location, capped to shed water and prevent weathering, and the location is engineered to withstand seismic activity. | Low/Moderate<br>Effective at immobilizing contaminants in excavated material. However, the stabilized mass must be protected from weathering and seismic activity for long-term durability. | Moderate<br>Well established technology. Site-specific studies need to be completed to evaluate equipment required and appropriate solidification/ stabilization agents. Mechanically intense process; additional handling of the excavated soil could increase the potential for contaminant exposure, which could pose risk to workers. | High | Low | GHG and energy for production and delivery of reagent used, and for transport and mixing. | Not retained | Screened out in favor of the safer alternative of disposal in the ERDF, a centralized facility engineered to protect against weathering and seismic activity. |

Table 8-8. Technology Screening for Waste Sites at 100-IU-2/IU-6

| General Response Actions | Remedial Technology | Process Option | COC Applicability[a] | Depth Range[b] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[c] | Retained/ Not Retained[d] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Ex Situ Treatment and Processing (cont.) | Ex Situ Treatment and Processing (cont.) | Soil washing | Cr(VI) | All | Consists of (1) size separation of highly contaminated soil fractions (fines) from minimally contaminated soil fractions (coarse), followed by (2) mechanical abrasion or washing to remove surface contamination. Final contaminated fraction is typically treated by technologies such as solidification/stabilization before onsite or offsite disposal. | Low/Moderate<br>Effectiveness is driven by the binding processes that exist between the contaminants and the soil particles (adsorbed or precipitated). Pilot testing at the Hanford Site suggests many contaminants strongly sorb to all sizes of soil. Pilot test is necessary for Cr(VI). | Low/Moderate<br>Mechanically intense. Conventional aggregate washing and screening technology is used to separate soil particles by size fraction. Contaminated soils and water are disposed of, or further treated. Soils that meet cleanup criteria (remediated coarse soil) can be returned to the site. Rinsate will need to be treated before disposal. | Moderate | Low<br>No associated cost. | Additional resource impact (water used in process), GHG and energy for process, and additional treatment of contaminated fines and water. | Not retained | Mechanically intense. Not proven for conditions similar to the Hanford Site. |
| | | Vitrification | All | All | Thermal treatment process that converts excavated soil and other materials into stable crystalline substances. The thermal treatment process is typically performed inside a chamber using plasma torches or electric arc furnaces to melt the soil. Organic contaminants are typically destroyed during the process by pyrolysis, while metals and radionuclides are retained in the molten soil. | High<br>Metals and radionuclides are incorporated into the glass structure, which is generally resistant to leaching | Low<br>High complexity of equipment required. Ex situ joule heating vitrification uses furnaces that have evolved from the glass industry. Implementability is higher than for in situ application given the use of proven technology (furnaces). | High | Low<br>No associated cost. | GHG and energy for heat generation. High energy requirements to sustain required heat. | Not retained | Complex technology, safety concerns with implementation. |
| Disposal | Disposal | Backfill treated soil | All | All | Excavation and ex situ treatment followed by onsite disposal (backfill). | High<br>Contaminated material has been treated by ex situ technologies. | High<br>Excavated and treated soil will need to be compared to cleanup criteria to verify backfill is appropriate. | Low/Moderate | Low<br>No associated cost. | GHG and energy for backfill. | Not retained | No ex situ treatment technologies are retained. Screened out in favor of the safer alternative of disposal in the ERDF, a centralized facility engineered to protect against weathering and seismic activity. |
| | | Disposal to the ERDF | All | All | Disposal of excavated soil at onsite landfill (ERDF). Treatment performed at the facility as required to meet land disposal restrictions. | High | High<br>Implementability limited by COPC concentrations and onsite landfill requirements. | Low/Moderate | Low | GHG and energy for transport. | Retained | |
| | | Other EPA-approved landfill | All | All | Disposal of excavated soil at an offsite landfill. | High<br>Contaminated material has been treated by ex situ technologies. | High<br>Implementability limited by COC concentrations and offsite landfill requirements. | Moderate | Low | GHG and energy for transport. | Retained | |
| In Situ Treatment | Treatment via Reagent | Reagent approach / Physical/ chemical/ biological / Solidification | All | 6 m (20 ft) | Contaminants are physically bound or enclosed within a stabilized mass. Agents include pozzolan/Portland cement and polyethylene extrusion, etc. With organics, typically only used for free phase to reduce mobility. | Low/Moderate<br>There is debate about the long-term durability of the monolith and whether it is in fact permanent. Potential for exposure still exists if waste is shallow. | Moderate<br>Depends on delivery method. | High | Low/Moderate | GHG and energy for production and delivery of substrate/reagent. | Not retained | Technology not well suited to Hanford formation gravels. |
| | | Reagent approach / Physical/ chemical/ biological / Stabilization/ sequestration | All | All | Chemical reactions are induced between the stabilizing agent and contaminant to reduce mobility. Agents include soluble phosphates and polyphosphates. | Low/Moderate<br>Potential for direct exposure still exists if waste is shallow. | Low/Moderate<br>Depends on delivery method. | High | Low/Moderate | GHG and energy for production and delivery of substrate/reagent. | Not retained | Technology not retained due to uncertainty in effectiveness relative to removal by excavation. |

Table 8-8. Technology Screening for Waste Sites at 100-IU-2/IU-6

| General Response Actions | Remedial Technology | | Process Option | | COC Applicability[a] | Depth Range[b] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[c] | Retained/ Not Retained[d] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In Situ Treatment (cont.) | Treatment via Reagent (cont.) | Reagent approach (cont.) | Physical/ chemical/ biological | Chemical reduction | Cr(VI) | All | Chemical reductant (e.g., calcium polysulfide, dithionite, hydrogen sulfide gas, ferrous sulfate, zero valent iron) is applied to the subsurface to treat contaminants within vadose zone. Chemicals can be combined with solidification/stabilization or other treatment mechanisms. | Low/Moderate<br>Chemical reductants are instantly reactive, which requires overloading to maintain reactive strength at depth. Reduction of uranium is potentially reversible. | Moderate<br>Depends on delivery method. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize COCs toward groundwater. Handling chemical reductants is potential health and safety concern. | Moderate<br>Depends on delivery method | Moderate/High | GHG and energy for production and delivery of chemical agent. | Not retained | Technology not retained due to uncertainty in effectiveness relative to removal by excavation. |
| | | | | Biological reduction | Cr(VI) | All | Biological carbon source (e.g., molasses, sodium lactate, emulsified oil, butane, etc.) is applied to the subsurface to treat contaminants within vadose zone. | Moderate/High<br>Carbon source follows source release pathways. Biological reductants are activated by microbial activity, so reactive strength is maintained over relatively longer distances. Reduction of uranium is potentially reversible. | Moderate<br>Depends on delivery method. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize COPCs (in first pore volume) toward groundwater. | Low/Moderate | Moderate | GHG and energy for production and delivery of substrate. Depends on which substrate is used. | Not retained | Technology not retained due to uncertainty in effectiveness relative to removal by excavation. |
| | | | | Combined chemical/ biological reduction | Cr(VI) | All | Chemical reductant (e.g., calcium polysulfide, hydrogen sulfide gas, ferrous sulfate, zero valent iron, etc.) and biological carbon source (e.g., molasses, sodium lactate, emulsified oil, etc.) are applied in combination to the subsurface to treat contaminants within vadose zone. | Moderate<br>Amendments follow source release pathways. Combined chemical and biological reagents might improve performance. | Moderate<br>Depends on delivery method. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize COPCs (in first pore volume) toward groundwater. Handling chemical reductants is health and safety concern. | Low/Moderate | Moderate | GHG and energy for production and delivery of substrate/reagent. Depends on which substrate is used. | Not retained | Technology not retained due to uncertainty in effectiveness relative to removal by excavation. |
| | | | | Gaseous ammonia injection | Cr(VI) | All | One of a number of possible gaseous reagents that are being investigated (along with ISGR below). It involves the injection of ammonia gas to increase pH to dissolve silica, The pH naturally decreases to ambient conditions over time and aluminosilicate minerals precipitate and possibly coat and immobilize various contaminants. | Unknown<br>Effectiveness is being studied as part of a laboratory-scale investigation.<br>Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil. Reduction of uranium is potentially reversible. | Unknown<br>Implementation is unknown at a full scale level. Containment of injected gases in the shallow vadose zone may be an issue.<br>Vapor extraction wells are installed around injection well at a radial spacing of approximately 4.6 m (15 ft); large number of wells are required. Monitoring and emergency response plan are required for transporting, storing, and handling because of health and safety risks. | Unknown<br>Technology evaluation has been limited to laboratory tests. | Unknown<br>Technology evaluation has been limited to laboratory tests. | GHG emissions from injection activities. | Not retained | Evaluation of results from the ongoing treatability study is needed before making a decision regarding its full-scale use at the Hanford Site. This technology not retained due to uncertainty in effectiveness relative to removal by excavation. |
| | | Delivery Method | Mixing with conventional excavation equipment | | All | 6 m (20 ft) | Use of conventional excavation equipment (backhoes, excavators, front-end loaders, etc.) to mix amendments into the soil. | High<br>Agents are uniformly mixed with soil column, providing good contact and reaction between COPC and chemical. | Moderate<br>Simple technology. Dust mitigation techniques will need to be implemented to control/prevent mechanical dispersion of contaminants. | Low/Moderate | Low<br>No associated cost. | GHG emissions from machinery. | Not retained | Not retained due to the coarse-grained nature of Hanford formation soils. |

Table 8-8. Technology Screening for Waste Sites at 100-IU-2/IU-6

| General Response Actions | Remedial Technology | | Process Option | COC Applicability[a] | Depth Range[b] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[c] | Retained/ Not Retained[d] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In Situ Treatment (cont.) | Treatment via Reagent (cont.) | In Situ Treatment (cont.) | Deep soil mixing (vertical/horizontal) | All | All | Large mixing augers (1.5 to 3 m [5 to 10 ft] in diameter) or horizontally rotating heads are used to blend and homogenize reactants with soil. The reactants may be chemical reductants, biological substrate, or solidification/stabilization agents. | High<br>Chemical agents are uniformly mixed with soil column, providing good contact and reaction between COPC and chemical. Cement or clay can also be mixed with the chemical slurry to reduce the hydraulic conductivity and leachability of the soil. | Low/Moderate<br>Implementation will be more challenging in gravelly/cobbly lithologies. Although deep soil mixing has been performed to depths of 30 m (100 ft) bgs, most field applications have been limited to approximately 15 m (50 ft) bgs. | High | None<br>No associated cost. | GHG emissions from machinery | Not retained | Deep soil mixing implementability will be limited by site conditions (coarse-grained soil) and required depth of treatment. |
| | | | Foam delivery of reagents | Cr(VI) | All | Injection of foam into vadose zone. The foam is a mixture of a surfactant solution to create the foam, and a reagent, such as phosphate to calcium polysulfide. The foam increases the horizontal migration of the reagent away from the injection well. | Unknown<br>Technology evaluation has been limited to laboratory scale tests. The stability of the foam, which will dictate the well spacing, is unknown, as is the ability of the foam to sweep a large volume of the vadose zone. | Unknown<br>Technology evaluation has been limited to laboratory-scale tests. | Unknown<br>Technology evaluation has been limited to laboratory-scale tests. | Unknown<br>Technology evaluation has been limited to laboratory-scale tests. | Waste generation from soil cuttings for well installation. | Not retained | Evaluation of results from the ongoing treatability study is needed before making a decision regarding its full-scale use at the Hanford Site. |
| | | | Gas delivery of reagents | Cr(VI) | All | A gaseous mixture of chemical reagent is injected into and drawn through the vadose zone to reduce mobile COPCs. | Unknown<br>Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil. | Unknown<br>Vapor extraction wells are installed around injection well at a radial spacing of approximately 4.6 m (15 ft); large number of wells are required. Monitoring and emergency response plan are required for transporting, storing, and handling because of health and safety risks. | Unknown | Unknown | GHG emissions from injection activities. Waste generation from soil cuttings for well installation. | Not retained | Evaluation of results from the ongoing treatability study is needed before making a decision regarding its full-scale use at the Hanford Site. |
| | | | Horizontal injection wells | Cr(VI) | All | Delivery of amendments using horizontal wells. Wells are installed using horizontal drilling techniques. | Low/Moderate<br>Effectiveness can be hindered by nonuniform amendment distribution. Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil. Multiple injections could be required. | Low<br>Implementation is challenging in gravelly/cobbly lithologies. Lithology would also pose challenges with maintaining target depth and alignment with horizontal drilling. A pilot test of this technology encountered signification implementation challenges. | Moderate/High | Low | GHG emissions from well installation, development, and injection activities; waste generation from soil cuttings. | Not retained | Testing at the Hanford Site has not been successful. |
| | | | Vertical injection wells | Cr(VI) | All | Delivery of amendments using conventional vertical wells. | Low/Moderate<br>Effectiveness can be hindered by nonuniform amendment distribution. Distribution of liquid amendments is highly ineffective because of gravelly/cobbly lithology. Distribution in lower permeability soil can be enhanced with the use of shear-thinning fluids. | Moderate<br>Radius of influence likely to be low, requiring large number of injection wells. | Moderate/High | Low | GHG emissions from well installation, development, and injection activities; waste generation from soil cuttings. | Not retained | Waste sites with characteristics that could benefit from this technology are not present in 100-IU-2/IU-6. |

Table 8-8. Technology Screening for Waste Sites at 100-IU-2/IU-6

| General Response Actions | Remedial Technology | | Process Option | | COC Applicability[a] | Depth Range[b] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[c] | Retained/ Not Retained[d] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In Situ Treatment (cont.) | Treatment via Reagent (cont.) | In Situ Treatment (cont.) | Surface infiltration | | Cr(VI) | All | Reagent is applied to ground surface to treat contaminants within vadose zone. Surface infiltration can be done through drip irrigation and shallow basin systems. Systems are generally designed to be 30.5 cm (12 in.) below the surface and covered to be protected. | Moderate/High<br>Amendments follow source release pathways. Distribution not likely to be uniform. | High<br>Surface infiltration systems are simple to install and accessible for O&M. | Low | Low | Limited infrastructure. GHG emissions from production and delivery of substrate. | Not retained | Waste sites with characteristics that could benefit from this technology are not present in 100-IU-2/IU-6. |
| | | | Void filling/grouting | | All | Structures and pipelines | Grouting for solidification of buried wastes. Void grouting is considered for filling large voids, specifically pipelines. | High<br>Established and commonly used technology for removing voids in pipelines. | Moderate/High<br>Established and commonly used technology for removing voids in pipelines. Pipe branch lines/breaks need to be identified. Implementability can be more challenging and costly with long or large-diameter pipelines. | Low | Low<br>No associated cost. | GHG and energy for production and delivery of grout used. | Not retained | Waste sites with characteristics that could benefit from this technology are not present in 100-IU-2/IU-6. |
| | In Situ Treatment Other | | Physical/ chemical/ biological | Jet grouting | All | All | High-pressure injection of reactive slurry into soil to hydraulically mix the soil with the slurry. Fluidization of the soil is preferred. | Low/High<br>Jet grouting has been performed to depths of up to 91 m (300 ft). Many closely spaced injection points (approximately 1.5 m [5 ft] spacing) typically required. | Low/High<br>Limited radius of influence would make jet grouting cost-prohibitive over a large area. | High | None | GHG emissions from injection activities. | Not retained | Not retained. Could be considered in the future if technology develops. Currently, jet grouting has potentially limited effectiveness in gravelly material. |
| | | | | Soil blending | Radionuclides | Depends on excavation method. | Contaminated soils are mechanically blended with clean soil or fill to reduce the effective concentration. | High<br>Implementation more challenging in gravelly/cobbly lithologies. | High<br>Conventional equipment can be used. | Moderate | Low<br>No associated cost. | GHG and energy for tilling equipment. | Not retained | Not effective since it relies on contaminant dilution. |
| | | | | Vitri-fication | All | 6 m (20 ft)/ greater than 6 m (20 ft) | Thermal treatment process that converts soil and other materials into stable crystalline substances. Contaminants are incorporated into the glass structure, which is generally strong, durable, and resistant to leaching. | High<br>Heavy metals and radionuclides are retained within the treated soil, which is generally resistant to leaching. | Low<br>High complexity of equipment required. Process uses an electric current to melt soil or other earthen materials at extremely high temperatures (1,600 to 2,000°C or 2,900 to 3,650°F). It is important to also account for safety considerations from exposure to high heat. | High | Low<br>No associated cost. | GHG and energy for heat generation. High energy requirements to sustain required heat. | Not retained | Complex and challenging to implement. |

Table 8-8. Technology Screening for Waste Sites at 100-IU-2/IU-6

| General Response Actions | Remedial Technology | Process Option | | COC Applicability[a] | Depth Range[b] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[c] | Retained/ Not Retained[d] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In Situ Treatment (cont.) | In Situ Treatment Other (cont.) | Physical/ chemical/ biological (cont.) | Soil flushing—vadose zone, water | Cr(VI) | 6 m (20 ft)/ greater than 6 m (20 ft) | Clean or treated water is applied to the ground surface or in infiltration trenches to flush contaminants from the vadose zone to the water table for capture/recovery by groundwater extraction wells and aboveground treatment. | Low/Moderate | High | Low/Moderate | Low | GHG and energy for installation. | Not retained | Waste sites with characteristics that could benefit from this technology are not present in 100-IU-2/IU-6. |
| | | | | | | | Water follows source release pathways, but contaminants that remain in adsorbed phase will not be treated. May create a larger groundwater problem if the groundwater capture is not effective. | Drip irrigation system or trenches are simple to install and accessible for O&M. | | | | | |
| | | | | | | | Effective at removing void spaces and compacting surface soil, where voids exist around buried waste. Not effective for native soils.<br>Not effective for treatment of hazardous waste. | Simple and widely used technology. | | No associated cost. | | | |

Sources: 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan."

DOE/RL-2001-41, *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions*.

a. Indicates the contaminants that can be addressed by a technology based on geochemical properties. A COPC applicability of "All" indicates that implementation of a technology is not dependent on the nature of a chemical.

b. Depth range is based on practical limitations of implementing the given technology.

c. Sustainability includes potential effects to the environment that could arise from implementing this technology (e.g., GHG emissions, waste generation, water use and resource impacts, energy use). Alternative design will dictate the sustainability of an approach.

d. Additional details of technology screening are provided in Appendix I.

e. Ex situ treatment does not include treatment done for disposal at the ERDF or an approved offsite landfill. Treatment performed at the ERDF or at the waste site as required to meet disposal restrictions is assumed to be part of the "disposal to ERDF" or "other approved EPA landfill" process options.

bgs = below ground surface
COC = contaminant of concern
COPC = contaminant of potential concern
EPA = U.S. Environmental Protection Agency
ERDF = Environmental Restoration Disposal Facility
GHG = greenhouse gas
IC = institutional control
ISGR = in situ gaseous reduction
NCP = National Contingency Plan (40 CFR 300)
O&M = operation and maintenance
RCRA = *Resource Conservation and Recovery Act of 1976*
TRU = transuranic

Table 8-9. Technology Screening for Cr(VI), Strontium-90, TCE, and Nitrate in Groundwater at 100-FR-3

| General Response Actions | Remedial Technology | Process Option | COC Applicability[c] | Description | Relative Effectiveness | | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[b] | Retained/Not Retained[a] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No Action | No Action | No action | All | No remedial actions taken. | Low/High<br>No remedial actions are taken, but effectiveness could be high if risk is previously mitigated. | | High | Low | Low | Little impacts | Retained | Retained per the NCP (40 CFR 300). |
| MNA | MNA | MNA | All | Relies on natural attenuation processes to manage the contamination on site. Uses groundwater sampling/analysis/data evaluation to track natural attenuation processes until RAOs are achieved. Typically combined with other technologies that manage the source area(s) and to control exposure. Natural attenuation processes include the following:<br>• Biological reduction: Processes where naturally occurring microorganisms (e.g., yeast, fungi, and bacteria) break down target substances into less toxic or non-toxic substances (Cr[VI], TCE, and nitrate].<br>• Chemical reduction: Geochemical process where natural reductants in sediments reduce contaminants into less toxic or nontoxic substances (Cr[VI], TCE, and nitrate].<br>• Adsorption: Occurs in groundwater, as dissolved chemicals are removed from the solution and attach to soil particles (Cr[VI] and strontium-90].<br>• Dispersion: The spreading of a chemical in groundwater outward from its expected path. As groundwater moves through different soil types and geological features, it travels at different velocities. This creates mechanical mixing, so groundwater spreads away from source areas into wider plumes (all COCs).<br>• Dilution: The decrease in the chemical concentration in a fluid caused by mixing with a fluid containing a lower concentration (all COCs).<br>• Radioactive decay: Spontaneous disintegration of the nucleus of radionuclide resulting in reduction in radionuclide activity (strontium-90). | Biological reduction | Low/Moderate | High | Low/Moderate | Low/Moderate | Little impacts | Retained | Details on MNA processes for the 100-FR-3 groundwater COCs are provided in Appendix M. |
| | | | | | Chemical reduction | Moderate/High | | | | | | |
| | | | | | Adsorption | Low/Moderate | | | | | | |
| | | | | | Dispersion | High | | | | | | |
| | | | | | Dilution | High | | | | | | |
| | | | | | Radioactive decay | Moderate (strontium-90) | | | | | | |
| Pump-and-Treat | Collection | Extraction | Groundwater extraction system | All | Operation of new groundwater extraction wells. | Moderate/High<br>Groundwater extraction is a proven technology for removing Cr(VI) and TCE in groundwater, and it is also effective for nitrate. There is some uncertainty as to its ability to remove strontium-90 from the aquifer because of strontium-90's affinity for aquifer sediments. | High<br>Extraction wells installed elsewhere in River Corridor under interim action RODs. | Low/Moderate<br>Cost determined by number or wells required and depth of the wells. | Moderate/High | Energy consumption and GHG emissions from pumping systems. | Retained | Used at other 100 Area groundwater OUs under interim action RODs. |

Table 8-9. Technology Screening for Cr(VI), Strontium-90, TCE, and Nitrate in Groundwater at 100-FR-3

| General Response Actions | | Remedial Technology | Process Option | COC Applicability[c] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[b] | Retained/Not Retained[a] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pump-and-Treat (cont.) | Ex Situ Treatment | Chemical | Ion exchange | Cr(VI), strontium-90, nitrate | Ions from the aqueous phase are removed by exchange with innocuous ions on the exchange medium. | Moderate/High<br>Effective for Cr(VI) treatment. Variable, depending on COPC. | High<br>Vendors and equipment readily available. Currently used at the site. | Moderate<br>System would have to be installed. Cost determined based on required treatment rates. | Moderate/High | Waste generation from ion exchange regeneration disposal or regeneration. Energy consumption from process equipment. | Retained | Technology used at Hanford Site for Cr(VI) and strontium-90 removal from groundwater. |
| | | | Chemical reduction/ softening and precipitation | Cr(VI), nitrate | Dissolved Cr(VI) transformed into an insoluble solid, which is removal by flocculation, sedimentation, and filtration. Other COPCs or naturally occurring metals are also removed. Dissolved nitrate converted to nitrogen gas or biomass and removed through volatilization or with sludge. | Low/Moderate<br>Effective for Cr(VI) treatment and nitrate. | Moderate/High<br>Vendors and equipment readily available but no experience with the technology at the Hanford Site. Large sludge volumes may be produced depending on COC influent concentrations. | Moderate/High | Moderate | Waste generation from chemical precipitation. Energy consumption from process equipment. | Not retained | For Cr(VI) and nitrate, implementability challenges given potential large sludge volumes and the fact that ion exchange technology is widely used for Cr(VI) in the 100 Area. |
| | | | Electrocoagulation | Cr(VI) | Relies on electrochemical generation of ferrous iron. The ferrous iron reduces metals that are susceptible to reduction and converts them to insoluble solids, which are removed by sedimentation and filtration. | Low/Moderate<br>Not widely used for Cr(VI) removal. Pilot testing at the site had challenges. | Low/Moderate<br>Additional development and testing would be required. Potential negative effects on reinjection of water. | Moderate/High | Moderate | Waste generation from chemical precipitation. Energy consumption from process equipment. | Not retained | Implementability challenges for technology have been observed at Hanford during previous testing. |
| | | Biological | Wetlands | Cr(VI), nitrate | Extracted groundwater is pumped to a constructed wetland where contaminants are biologically reduced, or taken up by plants and algae. TCE may volatilize. | Moderate/High<br>Effective for nitrate, but additional research/pilot testing is required to verify effectiveness for Cr(VI) and other COCs. | Low/Moderate<br>May require large surface area for extended period of time. | Moderate<br>Depends on land requirements | Low | Little impacts, except for land required. | Not retained | Performance uncertainty. Implementability challenges given large area required |
| | | | Anaerobic | Cr(VI), nitrate, TCE | Extracted groundwater is amended with biological carbon source (e.g., glucose, sodium lactate, emulsified oil, ethanol). The amended water is pumped to subsurface infiltration, accomplished through drip irrigation and shallow basin system, where biological denitrification will take place within the vadose zone. | Moderate/High<br>Technology currently in use for 200 West Groundwater Treatment Facility for nitrate. | Moderate | Low/Moderate | Moderate | GHG for energy production and delivery of substrate. | Retained | |
| | | | Subgrade bioreactors | Cr(VI), nitrate, TCE | Extracted groundwater is pumped into a lined excavated area that has been backfilled with organic media (e.g., wood mulch with zero-valent iron). Cr(VI), nitrate and TCE are biologically reduced as water passes through the media. A second stage aeration/filtration stage could be provided to remove any biological byproducts (e.g., iron) and solids before injecting back into aquifer. | Moderate/High<br>Effective for identified COCs based on 200 West Groundwater Treatment Facility experience. | Moderate/High<br>Excavation and backfilling are readily implemented. Piping can be incorporated into the design to facilitate future delivery of liquid carbon sources (e.g., vegetable oil). Treatability testing required to verify implementability. | Low/Moderate<br>Depends on land requirements | Low | Effects include spent media disposal and land requirements. | Not retained | Has not been demonstrated on a full scale for Cr(VI) or nitrate remediation. |
| | | | Bioreactors | Cr(VI), nitrate, TCE | Groundwater is amended with electron donor (carbon source) and passes through a matrix (fixed bed, fluidized bed, or membranes) with microbial films, where contaminants are biologically reduced. Effluent is oxygenated, filtered, and amended before injecting back into aquifer. | Low/Moderate<br>Bioreactors commonly used for nitrate removal, but less commonly for Cr(VI) and TCE reduction. | Moderate/High<br>Vendors and equipment readily available, but no current experience with the technology at the Hanford Site. | High | Moderate | Waste generation from biological sludge. Energy consumption from process equipment. | Not retained | Performance uncertainty for Cr(VI). Considering large and complex system requirements for nitrate removal, and since in situ bioremediation or subgrade bioreactors could be used, ex situ bioreactors have not been retained. |

Table 8-9. Technology Screening for Cr(VI), Strontium-90, TCE, and Nitrate in Groundwater at 100-FR-3

| General Response Actions | | Remedial Technology | Process Option | COC Applicability[c] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[b] | Retained/Not Retained[a] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Pump-and-Treat (cont.) | Ex Situ Treatment (cont.) | Biological (cont.) | Phytoremediation | Cr(VI), nitrate, strontium-90 | Use of plants and their associated rhizospheric microorganisms to remove, reduce/degrade, or contain chemical contaminants in soil or groundwater. Contaminants in groundwater can also be removed by applying it as irrigation water for plants. | Low/Moderate<br>Low/Moderate for Cr(VI). Additional research/pilot testing is required to verify effectiveness for site conditions. Could be used as a barrier approach, but there would be challenges with the depth to the water table even close to the river.<br>Commonly used for nitrate removal. Plants used for remediating strontium-90 would require harvesting. | Low/Moderate<br>Requires large surface area for plants. Potential cultural challenges with implementation near river. | Low | Low | Effects include land required and potential disposal of harvested plants containing strontium-90. | Not retained | Would only be effective for low concentrations of contaminants where groundwater is shallow over long time frames, or when applied as irrigation water. Cr(VI) and strontium-90 would accumulate in the plants and not actually be treated, posing risks to ecological receptors. |
| | | Physical | Air stripping | TCE | Water is passed through an air stripper where air is injected and strips out volatile compounds or carbon dioxide from the water phase. The stripper maybe a packed tower, tray stripper, or similar device. The off-gas is collected and treated in activated carbon or similar process. Off-gas treatment would only be required if emissions exceed discharge limits. | High<br>With appropriate design and operation, can achieve very low concentrations. | High<br>Currently used at the 200 West Groundwater Treatment Facility for VOCs. | Moderate<br>Air strippers are relatively inexpensive. | Low/Moderate | GHG for energy production and electricity for the blower operation. Energy consumption from other process equipment. | Retained | Technology is being used in 200 West Groundwater Treatment Facility. |
| | | | Membrane separation (e.g., reverse osmosis) | All | Water pressure is used to force water molecules through a very fine membrane, leaving the contaminants behind. Purified water is collected from the "clean" or "permeate" side of the membrane, and water containing the concentrated contaminants is disposed. | High<br>With the appropriate design, reverse osmosis can be effective for almost any compound. | Low/Moderate<br>Vendors and equipment readily available, although additional site specific testing would be required. Pre-treatment likely necessary, and a large volume of brine would be produced that would need to be treated and handled. | High | High | Waste generation inform of brine and high energy use. Energy consumption from process equipment. | Not retained | Implementability challenges from large volumes of brine produced would require further reduction and then disposal. |
| | Discharge | Onsite discharge | Groundwater injection wells | All | Treated groundwater is injected into onsite wells. | High<br>Can enhance contaminant flushing, hydraulic control and plume capture. | High<br>Readily implementable at the site, currently used in existing pump-and-treat systems. Wells may be subject to clogging because of the buildup of chemical precipitates or microbial fouling. | Low | Low/Moderate | Waste generation from soil cuttings for well installation. | Retained | Injection wells are being used elsewhere in the 100 Area for treated water disposal. |
| | | | Surface infiltration | All | Treated groundwater is infiltrated into onsite trenches, located outside of zones of known waste sites. | High<br>Effective means of disposal and may enhance contaminant flushing, hydraulic control and capture of plume, if located appropriately. | Moderate/High<br>Infiltration would be easy to engineer and implement. | Low<br>Trenches are lower cost than wells | Low/Moderate | Little impacts. | Not retained | Trenches require large footprint that may adversely affect cultural or ecologically sensitive areas. |
| | | | Beneficial reuse of treated water | All | Use of treated water for a beneficial use such as irrigation or dust control. | High<br>Effective means of treated water disposal, although it may affect the in situ removal mechanisms. | Moderate<br>No nearby facility that could use large quantities of water. May be simple to implement for dust control for nearby earthwork. | Low/Moderate | Low | Water needs to be transported for reuse. | Not retained | May be useful if water can be used for dust control and similar uses. |
| | | Offsite discharge | Discharge to surface water | All | Discharge of treated groundwater directly to the river at an outfall. | High<br>Effective means of treated water disposal. | Low<br>Although surface water discharge is commonly practiced for treated wastewater, no new outfalls are allowed on the Hanford Reach National Monument. | Low | Low<br>Little or no maintenance required | Little impacts. | Not retained | Not allowed. |

Table 8-9. Technology Screening for Cr(VI), Strontium-90, TCE, and Nitrate in Groundwater at 100-FR-3

| General Response Actions | | Remedial Technology | Process Option | COC Applicability[c] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[b] | Retained/Not Retained[a] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In Situ Treatment | Reagent Approach | Chemical | Reduction | Cr(VI), nitrate, TCE | Subsurface delivery of chemical reductants (e.g., calcium polysulfide) within plume to stimulate reduction of contaminant. | Moderate<br>Chemical reductants instantly reactive, thus strongest reduction achieved near injection well, requiring tighter spacing of injection wells. Recirculation approach may increases size of reducing zone, and allows broader well spacing. Iron and sulfate reduction increases reductive capacity of subsurface, which makes the formation less sensitive to rebound. | Moderate<br>May require large number of wells. | Moderate/High<br>Dependent on number and type of wells. Likely higher capital cost compared to in situ biological | Moderate | Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of chemicals. | Not retained | More challenging to implement and costly as compared to biological reduction. |
| | | | Stabilization | Strontium-90 | Subsurface delivery of chemical reagents (such as phosphate) in a regular pattern of wells in the aquifer to sequester strontium-90. Chemical reactions are induced between the stabilizing agent and contaminant to reduce mobility. | Moderate/High<br>Currently being implemented at 100-N in a barrier approach for strontium-90 with favorable results. Achieving even distribution may be difficult. | Moderate<br>Requires large number of wells to cover a large area. | Moderate/High<br>Function of number of injection wells required | Moderate<br>Periodic reinjection may be required. | Waste generation from soil cuttings for well installation. GHG and energy from chemical production and transport. | Retained | Retained for localized treatment of strontium-90. |
| | | Biological | Anaerobic | Cr(VI), nitrate, TCE | Subsurface delivery and recirculation of various organic substrates in a regular pattern of wells in the aquifer to stimulate anaerobic bioreduction of Cr(VI) and reduction of nitrate. Cr(VI) and nitrate in groundwater that is reinjected would be reduced in situ. | High<br>Reactive life of biological electron donors is longer than chemical reductants so reactive strength is maintained over relatively longer distances compared to in situ chemical treatment. Iron and sulfate reduction increases reductive capacity of subsurface, which makes the formation less sensitive to rebound. | Moderate/High<br>Requires large number of wells to cover a large area. | Moderate/High<br>Dependent on number and type of wells | Moderate | Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of substrate. Depends on which substrate is used. | Retained | Preferred over chemical reduction as a more easily implemented and proven technology. |
| | | | Hydrogen or other organic gas sparging | Cr(VI), nitrate, TCE | Injection of biodegradable organic gases (e.g., propone or butane) or hydrogen into sparge wells that are screened below the water table. | Low<br>Distribution of gases likely to be poor in the coarse formation. Has not been demonstrated for Cr(VI). | Low<br>The radius of influence around each sparge well is likely to be low, so a large number of wells would be required. Safety challenges exist because of residual explosive gasses that may accumulate. | High<br>Large number of wells would be required | Moderate | Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of chemicals. | Not retained | Challenge in the distribution of the gases and safety risk associated with using explosive gases. |
| | | Chemical/ biological | Combination of biological and chemical substrates | Cr(VI), nitrate, TCE | Subsurface delivery and recirculation of both chemical reductants and electron donors within plume to stimulate chemical and anaerobic biological reduction of target contaminants. | High<br>Chemical reductants could be used to treat smaller hot spot areas, while biological reductants could be used to sustain treatment over larger dilute plume areas. Recirculation approach increases the size of reducing zone, and allows broader well spacing. Iron and sulfate reduction increases reductive capacity of subsurface. Less sensitive to rebound from residual sources because of residual reactive phase. | Moderate<br>Recirculation will likely be limited by extraction rate. Addition of fresh water can be used to enhance coverage around injection wells. The formation of secondary byproducts may affect restoration to beneficial use. | Moderate/High<br>Dependent on number and type of wells | Moderate | Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of chemicals. | Retained | May be more challenging to implement and more costly compared to biological reduction alone. |
| | | Physical | Flushing—saturated zone, water | Cr(VI), nitrate | Clean/treated water is injected to flush out contaminated groundwater to expedite remediation of plumes. Would be component of a pump-and-treat system. | Moderate/High<br>The extraction wells system should be able to capture any contaminants mobilized. However, performance will depend on residual contamination in lower permeability layers. | High<br>Standard vertical or horizontal wells or infiltration trenches used for injection. | Moderate/High<br>Costs for wells and piping, and transfer stations. | Moderate/High | GHG and energy for installation. Waste generation from soil cuttings for well installation. | Retained | |

Table 8-9. Technology Screening for Cr(VI), Strontium-90, TCE, and Nitrate in Groundwater at 100-FR-3

| General Response Actions | | Remedial Technology | Process Option | COC Applicability[c] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[b] | Retained/Not Retained[a] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| In Situ Treatment (cont.) | | Surface infiltration | Surface infiltration | NA | Trenches, French drains, or drip irrigations systems are used to inject water or reagents. | High<br>With appropriate design, installation and, maintenance they can be effective. | Moderate<br>Location of vadose zone contamination in relation to water table must be known. | Low | Moderate | Less GHG and energy for installation. | Retained | |
| | | Groundwater circulation wells | Groundwater circulation wells | VOCs | Installation of wells with two screened zones. Groundwater is typically pumped out of the formation from the lower screen zone, and injected back into the formation in the upper zone. A circulation pattern is created in the formation. The groundwater can be stripped inside the well to remove VOCs, or the wells can be used to deliver reagents. | Low/Moderate<br>The establishment of a reasonable circulation pattern depends on the formation characteristics. The low-permeability lenses present in some locations may be problematic. Very high permeability may result in a small radius of influence so more wells will be required. | Low/Moderate<br>A large number of wells may be required. | Moderate<br>Depends on the number of wells required | Moderate | Waste generation from soil cuttings for well installation. GHG and energy for operation. | Not retained | Asymmetrical groundwater flow and groundwater flow short-circuiting, may limit the effectiveness of groundwater circulation wells. |
| | | Vertical wells | Vertical wells | NA | Standard vertical wells are used to inject water or reagents. | High<br>Effective with appropriate design, installation, and maintenance. | High<br>Use extensively at Hanford. | Moderate/High<br>Wells at the Hanford are generally expensive | Moderate | Waste generation from soil cuttings, GHG and energy for installation. | Retained | |
| | | Horizontal wells | Horizontal wells | NA | Horizontally drilled wells are used to inject water or reagents. | Low/Moderate<br>Uncertain performance. | Low<br>Hanford pilot test was not successful. | Moderate/High<br>Costs are high but fewer wells are required | Moderate | Waste generation from soil cuttings, GHG and energy for installation. | Not retained | Hanford pilot test was not successful. |
| Containment | | Physical | Containment wall (e.g., slurry wall or grout wall) | All | Slurry or grout wall barriers consist of a vertical barrier perpendicular to the groundwater flow direction, partially filled with bentonite slurry, grout, or other low permeability material. The barrier is typically keyed into a lower permeability zone. The slurry/grout could be jet injected, mixed with the soils using large augers or excavated. | Moderate<br>Effectiveness is dependent on the continuity of the wall and the ability to key into the Ringold Upper Mud, which will be difficult to achieve because of depth. Does not reduce toxicity or volume of contaminants by itself. This technology requires groundwater extraction to control groundwater pressures from building up behind the barrier and potentially damaging the barrier or causing groundwater to flow under, over, or around the barrier. | Low<br>Installation of wall through cobbles and boulders to key into the Ringold upper mud is very difficult and cost-prohibitive. Driven sheet piles near the river have been attempted but failed because of the presence of cobbles. | High | Low/Moderate | GHG and energy for installation, waste from trench spoils. | Not retained | Not required since there is an existing hydraulic containment system and not likely to be implementable. |
| | | Chemical/ biological | Reactive chemical barrier (ISRM) | All | Subsurface delivery and/or recirculation of chemical reductants along cross-gradient rows transecting plume. Residual reducing chemicals are retained in the aquifer matrix so Cr(VI)/nitrate are passively removed as groundwater moves through the treatment zone barriers. Sodium dithionite or zero-valent iron maybe used as reductants. | Moderate/High<br>Effective if barrier treatment zone conditions are maintained. High flows of highly toxic groundwater, and changing water levels are likely to reduce effectiveness and require more frequent amendments. The current ISRM has experienced some breakthrough. Not effective in treating the bulk of the plume. | Moderate/High<br>Can be implemented with injection wells or recirculation dipole wells. Broad zones of secondary byproduct generation within treatment area may occur. | Moderate/High<br>Dependent on number and type of wells | Moderate | ISRM already exists, limited GHG and energy to augment. | Not retained | Eliminated due to plume size. Trenched barriers also have large disturbance footprints which may interfere with cultural resource sites. |

Table 8-9. Technology Screening for Cr(VI), Strontium-90, TCE, and Nitrate in Groundwater at 100-FR-3

| General Response Actions | | Remedial Technology | Process Option | COC Applicability[c] | Description | Relative Effectiveness | Relative Implementability | Relative Capital Cost | Relative O&M Cost | Sustainability[b] | Retained/Not Retained[a] | Screening Comment |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Containment (cont.) | | Chemical/ biological (cont.) | Reactive biological barrier | Cr(VI), nitrate, TCE | Subsurface delivery and recirculation of electron donors along cross-gradient rows transecting plume. Residual reducing byproducts and biomass are retained in the aquifer matrix so that contaminants are passively removed as groundwater moves through the treatment zone barriers. | Low/Moderate<br>Effective if barrier treatment zone conditions are maintained. Given the highly aerobic groundwater, re-amendment of the barrier would need to be frequent. Not effective in treating the bulk of the plume. | Moderate/High<br>Can be implemented with injection wells or recirculation dipole wells—latter option reduces number of wells required and is more cost effective. Broad zones of secondary byproduct generation within treatment area may occur; requires re-oxygenation of groundwater before discharge to the river. | Moderate/High<br>Dependent on number and type of wells | Moderate | GHG and energy for installation. | Not retained | Eliminated due to plume size. Trenched barriers also have large disturbance footprints which may interfere with cultural resource sites. |
| | | Hydraulic Control | Hydraulic containment via extraction | All | Install extraction wells along downgradient edge of plumes to control migration of COPCs to the river. | High<br>Extraction should control plume migration to the river, but upgradient plumes and hot spots are left untreated. | High<br>Compatible with existing infrastructure, and can be designed to work with other remedial technologies. | Moderate<br>Facilities in place | Moderate | GHG and energy for operations. | Retained. | |
| | | | Hydraulic containment via injection | All | Injection of river water or groundwater parallel to the river. Manages hydraulic gradients to create conditions (e.g., an inward gradient) throughout the year that mimic natural conditions of low plume discharge encountered during periods of high river stage. Barrier comprising closely spaced injection wells, infiltration trenches, and/or horizontal wells. Source of water from existing permitted Columbia River supply and/or groundwater. | Low/Moderate<br>Should rapidly control plume migration to the river. However, some flushing and dilution of the contamination already close to the river may occur and may not be viewed favorably. | Moderate<br>Can be accomplished using practically achievable injection rates. Injection only required two to three seasons (6 to 9 months). Infiltration trenches will be more cost effective than injection/horizontal wells but could cause seepage faces to develop along river cliff faces. | Moderate | Moderate | GHG and energy for operations. | Retained | Coupled with extraction. |

Source: 40 CFR 300, "National Oil and Hazardous Substances Pollution Contingency Plan."

a. Additional details of technology screening are provided in Appendix I.

b. Sustainability includes potential effects to the environment that could arise from implementing this technology (e.g., GHG emissions, waste generation, water use and resource impacts, and energy use). Alternative design will dictate the sustainability of an approach.

c. Indicates the contaminants that can be addressed by a technology based on geochemical properties. A COPC applicability of "All" indicates that implementation of a technology is not dependent on the nature of a chemical.

COC = contaminant of concern
COPC = contaminant of potential concern
GHG = greenhouse gas
ISRM = in situ redox manipulation
MNA = monitored natural attenuation
NA = not applicable
OU = operable unit
RAO = remedial action objective
ROD = Record of Decision
TCE = trichloroethene
VOC = volatile organic compound

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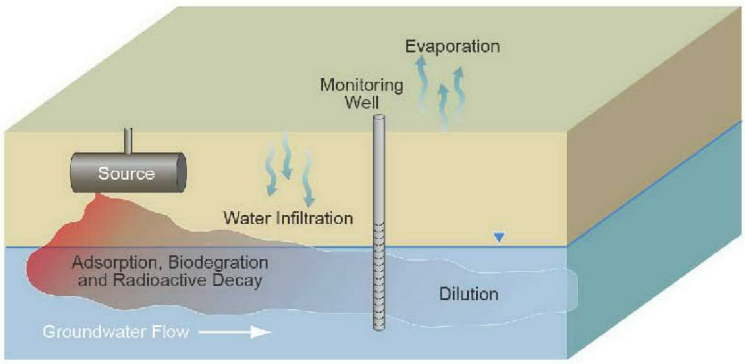
## Monitored Natural Attenuation (MNA)

### Key Components

- Relies on unaugmented natural, intrinsic processes (dilution, volatilization, flushing from surface water infiltration, sorption, microbial degradation, radioactive decay, and chemical reactions) to reduce contaminant concentrations and migration.
- Transport modeling and evaluation of intrinsic processes may be required to evaluate potential groundwater migration and time required to achieve cleanup criteria.
- Incorporates long-term monitoring to track progress towards compliance with cleanup objectives. Typically combined with other technologies that manage source areas and mitigate exposure.

### Conceptual Schematic




### Examples of Relevant Experience

- ROD for 200-ZP-1 indicates additional 100-yr period of MNA needed to reach groundwater cleanup goals. Response action for 200-PO-1 OU may include MNA of existing iodine-129, tritium, and nitrate in groundwater plume. *(DOE-RL-2009-10)*

### Risk Reduction Mechanism

- Contaminant concentrations reduced by dilution, volatilization, adsorption, microbial degradation, radioactive decay, chemical reactions.
- Biodegradation can transform contaminants into benign compounds. Partial degradation may result in formation of more toxic compounds.
- Plume is diluted or dispersed as it moves through groundwater, reducing toxicity but possibly increasing volume.

### Screening Criteria *(dashed line indicates range)*

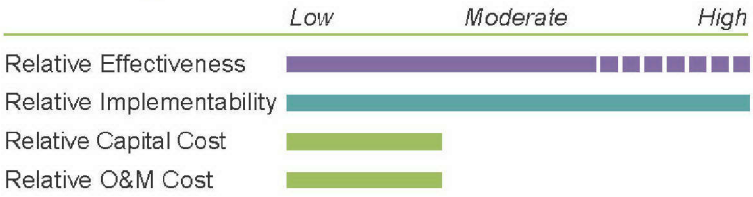



Figure 8-8. Monitored Natural Attenuation

## Standard Excavation

### Key Components

- Completed using standard earthmoving equipment.
- Conventional open-pit (standard) excavation limited to approximately 20 feet below ground surface based on equipment constraints.
- Extent of excavation required will be determined using an observational approach which combines characterization and remediation steps to maximize use of resources.
- The observational approach includes design of remediation based on available data. Additional site characterization will be performed during the removal of the waste. Remedial actions are guided by the observational approach where various methods, including in-situ and ex-situ sampling, process knowledge, and field measurements, guide day-to-day excavation.
- Clean overburden soil is removed and stockpiled.
- Contaminated soil is removed and segregated to determine disposal or treatment requirement, or direct-loaded into containers for disposal.
- Verification sampling can be performed to demonstrate cleanup levels are achieved.
- Excavations are backfilled and compacted using clean overburden and borrow soil.

*Shallow excavation at 100-B-19.*

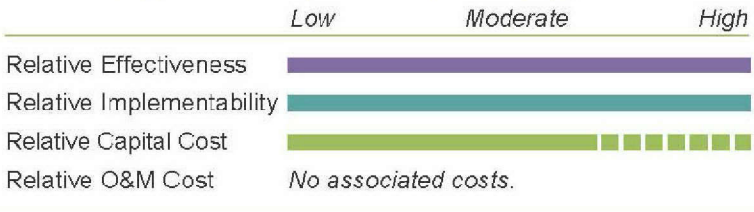
### Examples of Relevant Experience

- Removal, treatment, and disposal (RTD) has been selected as a remedial alternative in previous 100 Area decision documents. Full-scale remediation in the 100 Areas using RTD began in July 1996. Over one million tons of contaminated soil and debris have been disposed of. *(EPA/ROD/R10-99/039)*
- Excavations completed at Trenches 216-B-26 and 216-B-53A and at 216-B-14 Crib for Sr-90 and Cs-137 bearing soils. *(HNF-36881)*
- Uranium-contaminated sediments at Process Trench 316-5 were also excavated. *(WHC-SA-2062-FP)*

### Risk Reduction Mechanism

- Contaminated materials removed, eliminating source of exposure.
- Mitigates further migration of contaminants to groundwater.

### Screening Criteria *(dashed line indicates range)*




CUBUBS_RC_0012b

Figure 8-9. Standard Excavation

## Deep Excavation

### Key Components

- Excavation using standard equipment, requiring implementation of complex mechanisms such as shoring or lay backs to provide stability.
- Excavation complexity increases with greater depth.
- Extent of excavation required will be determined using an observation approach which combines characterization and remediation steps to maximize use of resources.
- The observational approach includes design of remediation based on available data. Additional site characterization can be performed during the removal of the waste. Remedial actions are guided by the observational approach where various methods, including in-situ and ex-situ sampling, process knowledge, and field measurements, guide day-to-day excavation.
- Requires careful evaluation of the side walls and anchoring systems selected to support the excavation, including stability calculations.
- Clean overburden soil is removed and stockpiled.
- Excavated soil is segregated to determine disposal or treatment requirements.
- A combination of in-process and verification sampling can be used to determine extent of excavation required and demonstrate cleanup levels are achieved.
- Excavations are backfilled and compacted using clean overburden and borrow soil.

*Deep excavation at 100-B-27.*

### Examples of Relevant Experience

- Removal, treatment, and disposal (RTD) has been selected as a remedial alternative in previous 100 Area decision documents. Full-scale remediation in the 100 Areas using RTD began in July 1996. Over one million tons of contaminated soil and debris have been disposed of. *(EPA/ROD/R10-99/039)*
- Excavation of contaminated soil was completed to groundwater (approximately 46 feet below ground surface) at waste site 100-B-27 at the Hanford 100-B/C Area with 10,190 cubic meters of contaminated soils removed *(RSVP-2009-040)*
- Remediation of the 100-C-7 waste site at the Hanford 100-B/C Area has included two excavations to approximately 85 feet below ground surface with a combined total of 1.1 million cubic meters of soil and debris excavated. Excavation to remove contaminated soil is still ongoing.

### Risk Reduction Mechanism

- Contaminant sources in deep vadose zone soils are physically removed.
- Mitigates further migration of contaminants to groundwater.

### Screening Criteria *(dashed line indicates range)*

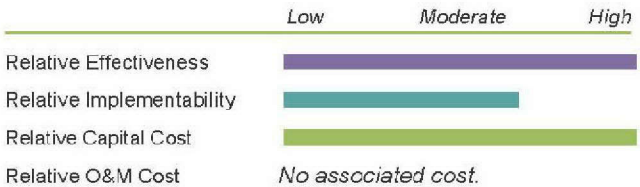



Figure 8-10. Deep Excavation

## On-Site Disposal: Environmental Restoration Disposal Facility (ERDF)

### Key Components

- Contaminated soil and waste material transported from waste site to on-site disposal facility at Hanford—Environmental Restoration Disposal Facility (ERDF).
- Treatment (*e.g.*, macro-encapsulation) performed at the facility as required to meet land disposal restrictions (LDR).
- Engineered to meet appropriate performance standards under 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste," and meet minimum technical requirements for landfills under WAC 173-303-665, "Landfills."
- Facility can accept the majority of remediation waste streams. Liquid wastes that cannot be solidified and certain LDR wastes that cannot be accepted would need to be sent off-site for disposal.
- ERDF consists of a series of disposal areas (cells). Each pair of cells is 70 feet deep, 500 feet by 1,000 feet at the base, and over 1,400 feet wide at the top.
- Cell pairs have a disposal capacity of 3 million tons. As of June 2010, over 11 million tons of contaminated material have been deposited into ERDF.

*Hanford's Environmental Restoration Disposal Facility*

### Examples of Relevant Experience

- Hanford's ERDF, in the 200 West Area, is a landfill regulated by USEPA and capable of receiving about 16,000,000 tons of waste.
- Accepts low-level radioactive, hazardous, and mixed wastes that are generated during the cleanup activities at the Hanford Site.
- First started operations in 1996. Over 11,000,000 tons of contaminated soil and debris have been disposed at the facility. *(RLI-D02-14)*

### Risk Reduction Mechanism

- Waste material is placed in an engineered landfill with physical and regulatory controls to greatly restrict or eliminate environmental mobility.
- Waste material is consolidated at a single location. Risk reduction primarily achieved through excavation.

### Screening Criteria *(dashed line indicates range)*

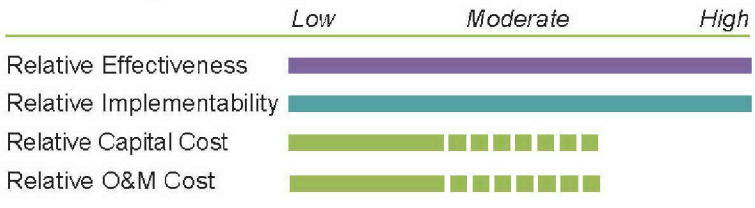



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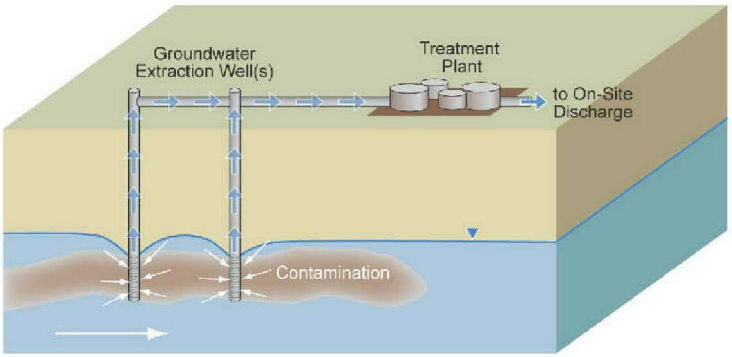
Figure 8-11. Onsite Disposal—Environmental Restoration Disposal Facility

## Groundwater Extraction System and On-Site Discharge

### Key Components

- Groundwater is removed from the aquifer through extraction wells, pumped to a facility and treated to remove contaminants, and then returned to the aquifer. The system is configured to treat the contaminant plume.
- Treated water is discharged on site.
- Groundwater extraction and injection well network provides for hydraulic containment of contamination.
- Groundwater extraction and on-site discharge are components of a pump-and-treat system, where ex-situ treatment of extracted groundwater can include bioreactors, ion exchange, air stripping, etc.
- Incorporates long-term groundwater monitoring to evaluate system performance, effectiveness, and compliance with remedial action objectives.

### Conceptual Schematic




### Examples of Relevant Experience

**Summary of Groundwater Pump-and-Treat Systems Operating at Hanford**

| Pump and Treat System | Startup Date | Contaminant | Volume Treated (millions of liters) | Mass Removed (Kg) |
|---|---|---|---|---|
| 100-DR-5[a] | 2004 | Cr(VI) | 384 | 338 |
| 100-DX[a] | 2010 | Cr(VI) | 974 | 461 |
| 100-HR-3[a] | 1997 | Cr(VI) | 4,171 | 406 |
| 100-HX[a] | 2011 | Cr(VI) | 303 | 11 |
| 100-KR-4[a] | 1997 | Cr(VI) | 5,725 | 355 |
| 100-KW[a] | 2007 | Cr(VI) | 1,410 | 163 |
| 100-KX[a] | 2009 | Cr(VI) | 2,594 | 114 |
| 200-ZP-1[b] | 1994 | CCL4 | 5,833 | 13,503 |
| 200-UP-1[b] | 1994 | CCL4, Nitrate, Tc-99, and U | 887 | 49,463 |

a) DOE/RL-2012-02, Calendar Year 2011 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations, and 100-NR-2 Groundwater Remediation
b) DOE/RL-2012-03, Calendar Year 2011 Annual Summary Report for the 200-ZP-1 and 200-UP-1 Operable Unit Pump-and-Treat Operations

### Risk Reduction Mechanism

- Extraction of groundwater removes contaminants from the subsurface and contains plume to prevent further migration.
- Contaminant volume, toxicity, and mobility are reduced through pump-and-treat process.

### Screening Criteria *(dashed line indicates range)*

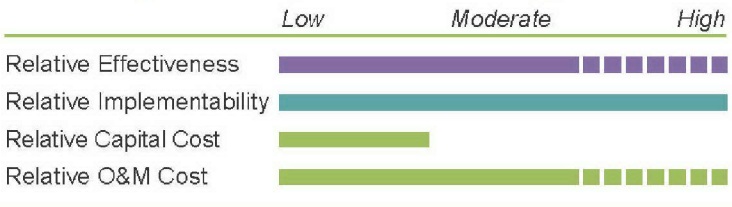



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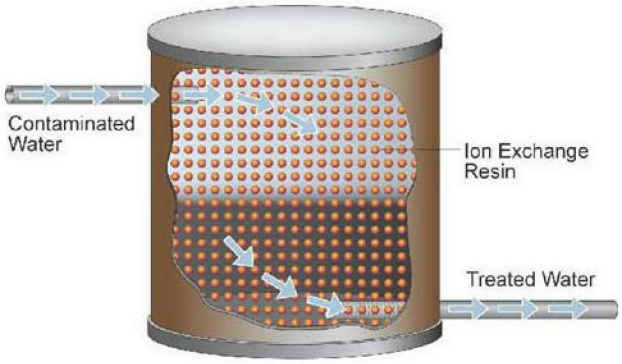
Figure 8-12. Pump-and-Treat

## Ion Exchange

### Key Components

- Ions are removed from an aqueous solution and replaced with innocuous ions from the exchange medium.
- Can remove dissolved metals and radionuclides from water.
- Exchange medium can be synthetic resins and inorganic or natural polymeric materials.
- Resins can be regenerated for reuse or disposed of.
- Ion exchange is a non-destructive technology (removal is achieved through mass transfer).

### Conceptual Schematic




### Examples of Relevant Experience

- Ion exchange (IX) is the current Hanford groundwater treatment for many pump-and-treat systems: *(DOE/RL-2010-11)*
  - 100-DR-5 system: Removed ~326 kg Cr(VI) since startup in 2004 through calendar year 2010 (CY10)
  - 100-HR-3 system: Removed ~393 kg Cr(VI) since startup in 1997 through CY10
  - 100-KR-4 system: Removed ~349 kg Cr(VI) since startup in 1997 through CY10
  - 100-KW system: Removed ~137 kg Cr(VI) since startup in 2007 through CY10
  - 100-KX system: Removed ~78 kg Cr(VI) since startup in 2009 through CY10
  - 100-DX system: Removed ~18 kg Cr(VI) since startup in December 2010
  - 100-HX system is under construction for startup in 2011 using ion exchnage treatment technology for removal of Cr(VI)

### Risk Reduction Mechanism

- Contaminant is transferred to the ion exchange resin which ultimately requires disposal.
- Contaminant volume, toxicity, and migration are reduced through pump-and-treat process.

### Screening Criteria *(dashed line indicates range)*

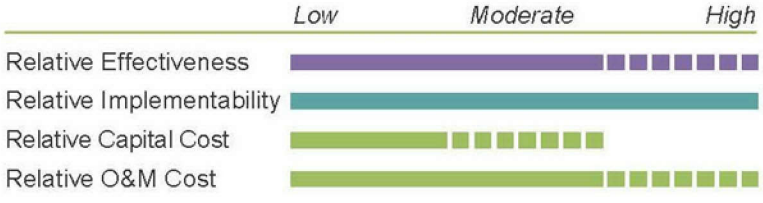



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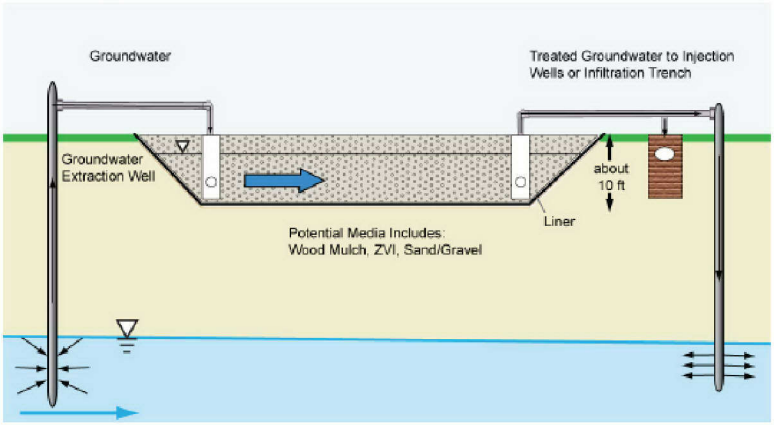
Figure 8-13. Ion Exchange—Groundwater Treatment

## Subgrade Bioreactors (Groundwater)

### Key Components

- Groundwater is pumped into a lined excavation filled with a treatment media for ex-situ treatment.
- Media can be wood mulch, zero-valent iron (ZVI), and/or sand/gravel.
- Cr(VI) is biologically reduced as it passes through the media.
- Additional stages can be added for treatment of other contaminants (nitrate).
- Treatment media may need to be replenished, and will require disposal at an approved facility once remedial action objectives are achieved.
- Additional stages, such as aeration and filtration, can be added for further treatment.
- Groundwater is returned to the subsurface after treatment via infiltration or injection.
- Sulphate-reducing bacteria can be used to reduce Cr(VI).

### Conceptual Schematic




### Example of Relevant Experience

Used in mining for sulfate reduction and metals precipitation:

- Yellow Creek Phase 2B Bioreactor: achieved 99% removal of iron, aluminum, and nickel in 4 years. *(Doshi, 2006)*
- Doe Run West Fork Bioreactor: achieved NPDES requirements for lead; also decreases in zinc and sulfate concentrations in 8 years. *(Doshi, 2006)*
- Lily/Orphan Boy Mine Bioreactor: achieved almost complete removal of aluminum, arsenic, cadmium, copper, and zinc; also 65% removal of iron. *(Doshi, 2006)*

### Risk-Reduction Mechanism

- Extraction of groundwater removes contaminants from the subsurface and contains plume to prevent further migration.
- Contaminant volume, toxicity, and mobility are reduced through treatment.

### Screening Criteria *(dashed line indicates range)*

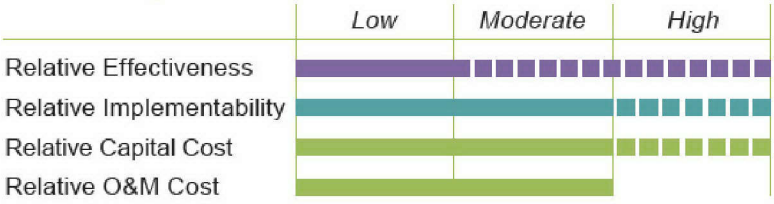



Figure 8-14. Subgrade Bioreactor—Groundwater Treatment

## Air Stripping

### Key Components

- An ex-situ treatment technology for extracted groundwater.
- Air is passed through the contaminated water and volatile contaminants are stripped (volatilized) and transferred into the air stream.
- Stripper configurations include tray-strippers (shown at right) and packed-towers.
- May required additives to prevent scaling or biological fouling.
- Off-gas treatment may be necessary to meet air emission standards.

### Conceptual Schematic

### Examples of Relevant Experience

- The Hanford 200-ZP-1 air stripper is successfully removing carbon tetrachloride (544 kg removed in CY2009) ) *(DOE/RL-2010-11)*

### Risk Reduction Mechanism

- Contaminant volume, toxicity, and mobility are reduced through pump-and-treat process.
- Air stripping is a mass-transfer technology and therefore does not reduce risk as a stand-alone technology.
- Contaminant is transferred from extracted groundwater into air, where further treatment may be required to meet emissions standards, possibly requiring media diposal (*e.g.,* activated carbon).

### Screening Criteria *(dashed line indicates range)*

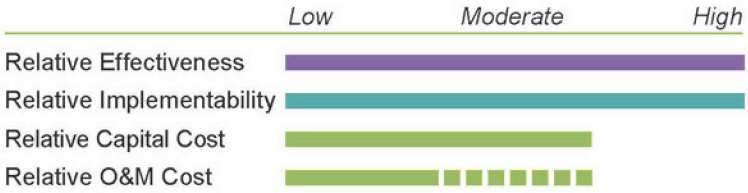



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Figure 8-15. Air Stripping—Groundwater Treatment

## In Situ Biological Treatment – Anaerobic (Groundwater)

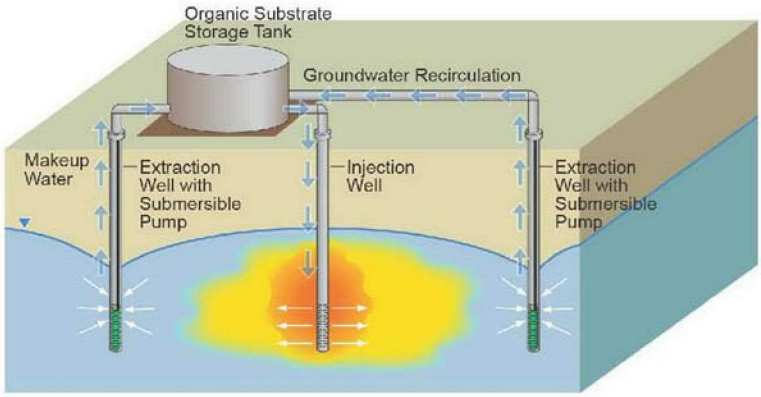
### Key Components

- Uses native microorganisms to transform or break down contaminants into less- or non-toxic substances.
- Natural process enhanced by adding organic substrates to stimulate anaerobic micro-organisms in the subsurface.
- The addition of a recirculation system (extract and reinject groundwater) can enhance substrate delivery and increase the zone of influence.
- In-situ reduction of contaminants that are contained in the recycled groundwater reduces the need for more costly ex-situ treatment.
- Localized temporary generation of secondary byproducts (reduced manganese, iron, and arsenic) could be expected.

### Risk-Reduction Mechanism

- Biological treatment can dechlorinate CVOCs to less toxic substances, and reduce nitrate to nitrogen gas.

### Conceptual Schematic




### Examples of Relevant Experience

- Reports for examples of applications using bio-remediation to convert Cr(VI) to less toxic (Cr(III)) include:
  - Hinkley Remediation Semiannual Status Report (July through December 2009), Pacific Gas and Electric Company (PG&E) Groundwater Remediation Program, Hinkley, California (CH2M HILL, 2010)
  - PNNL-18784, Hanford 100-D Area Biostimulation Treatability Test Results.
  - Faybishenko, B., 2009, In Situ Long-Term Reductive Bioimmobilization of Cr(VI) in Groundwater Using Hydrogen Release Compound, Lawrence Berkeley National Laboratory, Berkeley, California
- PG&E implemented two pilot studies at the site: an Upland reductive zone in situ pilot test (ISPT) to evaluate how well recirculation wells can distribute reductant (ethanol) throughout the aquifer to achieve treatment across a transect of the plume, and a Floodplain ISPT to evaluate the efficacy of using lactate to enhance the existing reducing environment in the floodplain adjacent to the Colorado River. List of the reports referenced regarding the two pilot studies implemented by PG&E are available at the California Department of Toxic Substances Control (DTSC) Project Website: http://dtsc-topock.com/.

### Screening Criteria *(dashed line indicates range)*

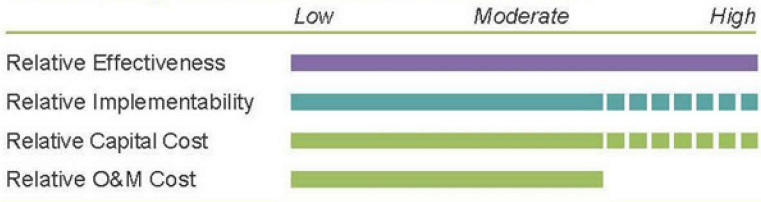



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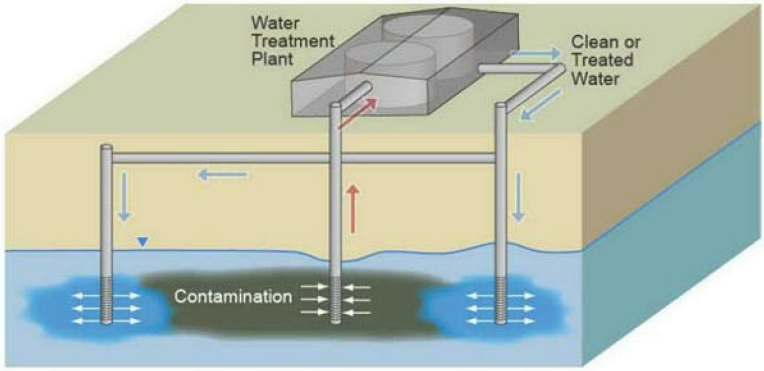
Figure 8-16. In Situ Biological Degradation—Groundwater

## Flushing – Saturated Zone, Water

### Key Components

- Involves the injection of clean or treated water into a zone of contaminated groundwater to expedite remediation of plume.
- Groundwater is captured and treated to meet discharge standards.
- Applicable for media impacted with contaminants with high to moderate solubility (*e.g.*, Cr(VI), Tc-99, uranium, nitrate, and possibly carbon-14).
- Effective groundwater capture is required to contain the plume.
- Groundwater flushing performance depends on residual contamination in lower-permeability layers, lenses, or sorbed to soil.

### Conceptual Schematic




### Examples of Relevant Experience

- At Topock Compressor Station, Needles, California, the U.S. Department of the Interior proposed water flushing as a preferred alternative for remediation of Cr(VI) in groundwater. This alternative involves injection of fresh and carbon-amended water to flush Cr(VI) and push the plume through in-situ biological treatment barriers located downgradient of the water injection wells. *(DOI060410A)*

### Risk Reduction Mechanism

- Extraction of groundwater removes contaminants from the subsurface and contains plume to prevent further migration.
- Reduction in toxicity, mobility, and volume of contaminants is achieved through a groundwater capture and treatment system.

### Screening Criteria *(dashed line indicates range)*

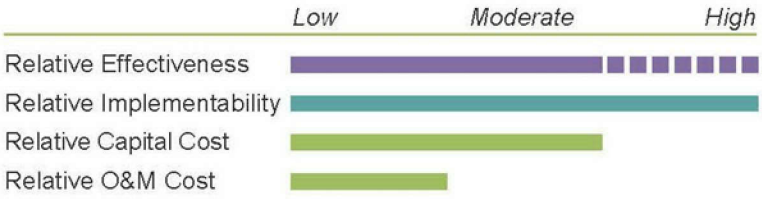



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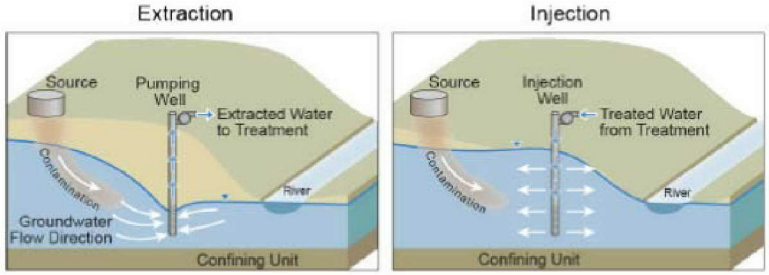
Figure 8-17. Flushing—Saturated Zone, Water

## Hydraulic Containment via Extraction (Groundwater) or Injection

### Key Components

- Vertical wells are used to pump groundwater from the plume's edge to prevent downgradient migration.
- Changes groundwater flow pathway, drawing contaminated groundwater toward the extraction well(s).
- Extracted groundwater may require treatment prior to disposal.
- Vertical wells may also be used to inject water to block contaminant migration.
- Using injection wells in lieu of extraction wells for hydraulic containment may eliminate need for above-ground treatment.

### Conceptual Schematic




### Examples of Relevant Experience

- Eight pump-and-treat systems are successfully operating at the Hanford site to provide hydraulic containment in addition to removing contaminant mass. Information regarding capture zone efficiency for each system can be found in *Hanford Site Groundwater Monitoring and Performance Report for 2009.* *(DOE/RL-2010-11)*

### Risk-Reduction Mechanism

- Reduces mobility by providing a barrier between the contaminated groundwater and the Columbia River.
- Reduces volume by removing dissolved phase contaminant mass; toxicity reduced by subsequent treatment at a temporary or permanent facility.

### Screening Criteria *(dashed line indicates range)*

Figure 8-18. Hydraulic Containment

#### 8.3.1.1 Identification and Screening of Technologies for Vadose Zone Contamination

*No Action.* The no action response means any further action to remove, remediate, monitor, or restrict access to contaminated sites is discontinued. Source areas and residual soil contaminants in the waste sites would be left untreated, and current monitoring activities would cease. The CERCLA RI/FS Guidance (EPA/540/G-89/004) and the NCP (40 CFR 300) require this response to remain in the FS process, where it serves as a baseline against which to compare all other alternatives. Although generally considered unacceptable as a remedial alternative, no action may be an appropriate alternative component where interim actions have been completed as dictated by the interim action RODs, and verification sampling data indicates that the waste site does not pose a risk to HHE.

*Institutional Controls.* ICs are non-engineered instruments (e.g., administrative controls and/or legal restrictions) imposed on land use that help to minimize the potential for human exposure to contamination and/or protect the integrity of a remedy. For soils, ICs will remain in place until the waste site is remediated. ICs work by limiting land or resource use and/or by providing information that helps modify or guide human behavior at the site. The requirements for ICs are evaluated in the FS and recorded in CERCLA decision documents. The decision document is part of the Administrative Record for the selection of remedial actions.

As they are identified, DOE will apply and implement ICs in an integrated manner so the mechanisms in place will ensure that controls are effective, implemented as planned, properly maintained, inventoried, periodically re-evaluated, and modified as necessary to reflect changes in conditions, needs, or technological advancements. DOE will maintain the ICs as long as necessary to perform their intended protective purposes (*Use of Institutional Controls* [DOE P 454.1]).

*Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (hereinafter called the Site-Wide IC Plan [DOE/RL-2001-41]) describes how RL will implement and maintain OU-specific ICs specified in CERCLA decision documents. The Site-Wide IC Plan is updated based on final CERCLA decision documents within 180 days after issuance of the final decision document. The Site-Wide IC Plan addresses the elements of *Institutional Controls: A Site Manager's Guide to Identifying, Evaluating and Selecting Institutional Controls at Superfund and RCRA Corrective Action Cleanups* (EPA 540-F-00-005). In addition, ICs are reviewed during the CERCLA 5-year review process. Table 8-10 identifies DOE categories of ICs and the examples of ICs currently in use at the Hanford Site. ICs are maintained as both waste site and groundwater technologies.

*Removal.* Removal technologies include excavation of contaminated materials. The engineering design is based on existing information. Existing information, including operational process knowledge, vadose zone data, groundwater data, and waste site remediation of similar sites, is used in determining the area for remediation. Excavation of sites with contaminated soil follows the observational approach, allowing waste characterization and treatment to occur as excavation proceeds. The observational approach uses a variety of techniques including field screening, confirmation sampling, and soil borings or test pits as appropriate to determine the extent of contaminant removal required until cleanup goals have been met. Excavation is coupled with analytical assessment, dust control, efficient transportation, treatment as required, and disposal. Excavated soil is segregated to determine disposal or treatment requirements.

Table 8-10. Categories and Types of Current Hanford ICs

| DOE Categories of ICs[a] | DOE Categorical Description | Types of Current Hanford ICs | Examples of ICs |
|---|---|---|---|
| Active/Passive Controls | These controls have long been understood to apply to the long-term management of radioactive waste. Active controls require clear institutional and human responsibilities and the active performance of responsibilities such as controlling access to a disposal site by means such as guards, performing maintenance operations or remedial actions at a site, controlling or cleaning up releases from a site, or monitoring parameters related to disposal system performance. Passive controls are defined by their dependence on the design of controls and structures such as permanent markers placed at a disposal site, public records and archives, government ownership and regulations regarding land or resource use, and other methods of preserving knowledge about the location design and contents of a disposal system. | **Warning Notices:** Provide visual identification and warning of hazardous or sensitive areas. A mechanism of warning notices includes signs that provide visual identification and warning of hazardous or sensitive areas.<br>**Entry Restrictions:** Prevent or limit the access of humans to particular hazardous or sensitive areas. Procedural requirements for access warning signs (in conjunction with an engineering control, such as fencing) can be implemented to provide entry restrictions. | **Warning Notices and Entry Restrictions:**<br>• Requirement for placement of permanent signs and/or markers at specific areas of the site.<br>• Procedural requirements for access excavation/drilling permits.<br>• Applies to all COPCs.<br>• **Effectiveness:** Good. Reduces or eliminates the potential for direct contact with radiological contamination and contaminated groundwater for the duration of elevated risk period, and for preserving knowledge about a specific area or design. Protects integrity of active remedies.<br>• **Implementability:** Very good. Readily implemented, requires periodic surveillance and maintenance.<br>• **Cost:** Low. |
| Proprietary/Government Controls | This type of control is based on the legal authority of landowners to control the use of their land. Proprietary controls, such as easements, are based on the rights associated with ownership of an interest in land. Government controls rely on the powers of governments to protect the public health and safety through zoning, legislation, land ownership, or permit programs. | **Land Use Management:** Ensures that use of the land is compatible with any hazards that exist. As presented in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41), "DOE will restrict the use of land on waste sites and prohibit activities that would interfere with the remedial activity in accordance with the ICs requirements of the CERCLA decision documents and as described in applicable work plans." Implementation of land use management controls can ensure that any changes in use of the land are assessed before being allowed, and that ICs are maintained beyond change of ownership, as appropriate. Mechanisms include land use and real property controls (e.g., proprietary controls including easements and covenants), including irrigation restrictions and excavation permits. Land use and real property controls ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents. Site evaluations are required before any land disturbance activity, and excavation permits are required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. Irrigation restrictions would be placed on sites that have a groundwater/surface water protection risk if irrigation were applied.<br>**Groundwater Use Management:** Ensures proper use of groundwater through groundwater controls. As described in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41), groundwater use on the Hanford Site is generally restricted, except for limited research purposes and for monitoring and treatment, as approved by EPA or Ecology, or as authorized in EPA- or Ecology-approved documents. Excavation permits and the land-use process also control groundwater use. | **Land Use Management:**<br>• Land-use and real property controls (e.g., proprietary controls including easements and covenants).<br>• Applies to all COPCs.<br>• **Effectiveness:** Good. Reduces or eliminates the potential for direct contact with contaminated groundwater when well implemented and maintained for the duration of elevated risk period. Ensures compatible land use.<br>• **Implementability:** Very good. Readily implemented, must identify and comply with all necessary legal requirements.<br>• **Cost:** Low.<br>• Retained.<br>**Groundwater Use Management:**<br>• Groundwater controls.<br>• Applies to all COPCs.<br>• **Effectiveness:** Good. Ensures no improper use of groundwater.<br>• **Implementability:** Very good. Readily implemented, but will likely require ongoing oversight and coordination with state water resource managers.<br>• **Cost:** Low. |
| Informational Tools[b] | Provide information or notification about whether a remedy is operating as designed and/or that residual or contained contamination may remain onsite. Information devices include state registries, deed notices, and advisories. | **Waste Site Information Management:** This is an administrative mechanism implemented to maintain and provide access to information on the location and nature of contamination. The WIDS database identifies waste management units on the Hanford Site, their location, waste type, and status. Other descriptive information contained in WIDS includes size, extent, and appearance; testing or sampling efforts; regulatory information; bibliographic references; images; change history; and data validation. RL maintains the system in accordance with the WIDS change control system, which documents and traces additions, deletions, and/or other changes dealing with the status of waste management units. | **Waste Site Information Management:**<br>• Administrative.<br>• Applies to all COPCs.<br>• **Effectiveness:** Good. Ensures access to information on the location and nature of contamination.<br>• **Implementability:** Very good. Readily implemented, but requires maintenance of the information management system.<br>• **Cost:** Low. |

a. *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41).

b. An "Informational Tool" is an EPA category of an IC that is used at the Hanford Site as discussed in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41).

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COPC = contaminant of potential concern
DOE = U.S. Department of Energy
Ecology = Washington State Department of Ecology
EPA = U.S. Environmental Protection Agency
IC = institutional control
WIDS = Waste Information Data System

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Excavation can use conventional equipment and methods, including excavators, bulldozers, and wheeled loaders. Earthmoving equipment removes clean overburden, which can be staged for later use in backfilling, and contaminated media to stage for appropriate waste management activities. Contaminated media are typically removed in lifts (layers of uniform thickness) to allow screening for contamination. Field screening supports waste characterization and helps determine achievement of remedial goals.

Process options under the removal general response actions GRA include standard excavation (depths up to 6 m [20 ft]) and deep excavation (to depths greater than 6 m [20 ft]). At excavations exceeding 6 m (20 ft) bgs, implementation requires technologies that are more complex, such as large layback for open-pit-type excavation or use of shoring. Given the increased complexity, deep excavations have an increased cost compared to standard excavation.

*Ex Situ Treatment and Processing.* Following excavation, soil can be treated with ex situ methods to reduce contaminant concentrations or toxicity, remove contaminants (transfer to different media), or reduce volume, and to allow for less costly disposal or use as backfill. Treatment can be achieved by applying physical, chemical, biological, or thermal processes.

Additional treatment which may be required to meet ERDF waste acceptance criteria is not included in the costs for this process. This ex situ treatment process option only covers technologies that could be used to treat the soil so that part or all of the soil volume could be backfilled at the location from which it was removed.

Ex situ treatment process options include the following:

- Ex situ solidification/stabilization
- Soil washing
- Ex situ vitrification
- Ex situ thermal desorption

*Disposal.* Following excavation, contaminated soil needs to be properly disposed, either at the onsite or offsite landfill, or by backfilling treated soil. Before implementation of a disposal option, waste acceptance criteria must be evaluated. Treatment required to meet the ERDF waste acceptance criteria is evaluated under the disposal GRA.

Backfilling treated soil involves excavation and ex situ treatment, followed by onsite disposal. Before implementing this disposal option, treated soil will need to be compared to PRGs to verify backfilling is appropriate.

Disposal at the onsite landfill includes transport of excavated soil to EDRF. The waste acceptance criteria for the ERDF are based on regulatory requirements (e.g., RCRA land disposal requirements) and risk-based considerations for long-term protection of HHE. If waste cannot be accepted at the ERDF, a suitable EPA-approved disposal facility will be used. Part of this process option is treatment required to meet ERDF waste acceptance criteria. Therefore, an ex situ treatment process option does not need to be evaluated if excavation and disposal at the ERDF are selected as remedial options.

*In Situ Treatment.* In situ treatment consists of actions that treat contamination in place using physical, chemical, or biological treatment techniques. The main advantage of in situ treatment is that it allows soil to be treated without being excavated and transported, resulting in significantly reduced exposure to site workers relative to removal of contaminated media for disposal or ex situ treatment. Other advantages include reduced disturbances to vegetation and cultural resources relative to excavation. In situ treatment may also provide a larger areal zone of treatment and there is typically little secondary waste generated.

For this evaluation, in situ process options were subdivided by technologies that require delivery of a reagent to the subsurface for treatment and those that implement another technique. Within actions requiring delivery of a reagent, technologies can be further subdivided by the reagent approach (physical, chemical, or biological), and the method for delivering the reagent to the subsurface. For treatment of contaminated soil at 100-F, the following in situ remedial technologies and process options were evaluated:

- Reagent approach:
  - In situ solidification
  - In situ stabilization/sequestration
  - Chemical reduction
  - In situ chemical oxidation
  - Surface bioremediation (land farming)
  - Biological reduction
  - Combined chemical/biological reduction
  - Gaseous ammonia injection
  - Bioventing
  - Reductive dechlorination using zero-valent metals or bioremediation
  - In situ gaseous reduction (ISGR) with chemical reductant or biological substrate
- Delivery method:
  - Mixing with conventional excavation equipment
  - Deep soil mixing (vertical/horizontal)
  - Foam delivery of reagents
  - Gas delivery of reagents
  - Horizontal injection wells
  - Vertical injection wells
  - Jet grouting
  - Surface infiltration
  - Void fill grouting
- In situ treatment—other:
  - Soil blending
  - Desiccation
  - Thermal desorption
  - Vitrification
  - Soil flushing – vadose zone, water
  - Phytoremediation

Technologies for in situ treatment of contaminated soil in 100-IU-2/IU-6 were generally not retained because of the impracticality in implementation for small and scattered surficial sites that are not expected to have substantial contamination at depth.

*Containment.* Containment actions consist of physical measures to restrict contaminant migration to groundwater. Containment remedial technologies include surface barriers, horizontal subsurface barriers,

and compaction. Containment options were evaluated for waste sites affected by mobile contaminants that have the potential to affect groundwater.

Surface barrier technologies are constructed over contaminated waste sites to control the vertical entry of water into contaminated media, which in turn, reduces leaching of contaminants to groundwater. In addition to their hydrological performance, surface barriers can function as physical obstructions to prevent intrusion by human and ecological receptors, limit wind and water erosion, and attenuate radioactivity. Surface barriers include maintaining existing soil cover (when applicable), the Hanford Barrier, modified RCRA Subtitle C or Subtitle D barrier, asphalt/concrete cap, and evapotranspiration barrier. The Hanford Barrier design was developed specifically for use at the Hanford Site for sites containing low-level waste greater than Class C, and/or significant inventories of TRU constituents.

Emplaced horizontal subsurface barriers are set beneath existing in situ contaminants. These bottom barriers have features similar to those of vertical barriers in that they minimize movement of contaminants, restrict infiltration of groundwater, and are constructed of similar materials with similar technologies. Horizontal barrier technologies can include jet grouting, soil freezing, and wire saw barriers.

#### 8.3.1.2 Identification and Screening of Technologies for Groundwater

*No Action.* The No Action response means any further action to remove, remediate, monitor, or restrict access to contaminated groundwater is discontinued. CERCLA RI/FS Guidance (EPA/540/G-89/004) and the NCP (40 CFR 300) require this response to remain in the FS process for comparative purposes, where it is used as a baseline against which all other alternatives will be compared.

*Institutional Controls (ICs).* ICs are administrative controls and legal restrictions imposed on land use to prevent or reduce exposure to hazardous wastes or hazardous constituents and/or to protect the integrity of a remedy. Section 8.3.1.1 and Table 8-10 describe ICs for the Hanford Site.

For groundwater, ICs include administrative controls, access, and drilling restrictions until achievement of RAOs. Groundwater use management controls are in place to ensure proper use of groundwater. Groundwater use on the Hanford Site is generally restricted, except for limited research purposes and for monitoring and treatment, as approved by EPA or Ecology, or as authorized in EPA- or Ecology-approved documents. Table 8-10 presents an evaluation of groundwater use management restrictions.

*Monitored Natural Attenuation (MNA).* MNA relies on natural attenuation degradation and non-degradation processes to decrease contaminant concentrations. MNA includes an evaluation of the natural attenuation mechanisms and implements source control and long-term monitoring to track progress toward complying with RAOs. When relying on natural attenuation processes for site remediation, EPA prefers processes that degrade or destroy contaminants (*Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 1 – Technical Basis for Assessment* [EPA/600/R-07/139]). Therefore, MNA can be an important component of the overall remedy, especially when contaminants are short-lived radionuclides.

As presented in *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P), MNA is an appropriate remedial response only where its use will be protective of HHE, and when it will be capable of achieving site-specific RAOs within a time frame that is reasonable compared with other alternatives. Largely because of the uncertainty associated with the potential effectiveness of MNA to meet remediation objectives that are protective of HHE, EPA expects that source control and long-term performance monitoring will be fundamental components of any MNA remedy

Evaluation of MNA as an appropriate response action for contaminated groundwater was performed in Appendix M in accordance with the guidelines provided in the following:

- *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P),
- *Decision-Making Framework Guide for the Evaluation and Selection of Monitored Natural Attenuation Remedies at U.S. Department of Energy Sites* (DOE, 1999a),
- *Technical Guidance for the Long-Term Monitoring of Natural Attenuation Remedies at U.S. Department of Energy Sites* (DOE, 1999b),
- *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water Volume 2 - Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium, and Volume 3 – Assessment for Radionuclides Including Tritium, Radon, Strontium, Technetium, Uranium, Iodine, Radium, Thorium, Cesium, and Plutonium-Americium* (EPA/600/R-10/093).

MNA may be selected as appropriate technology for remediation of contaminated groundwater under certain circumstances. MNA may be considered as an individual remedial alternative, or it may be combined with other technologies to develop a compound alternative (Figure 8-8 illustrates MNA of groundwater). Determining how MNA fits with other remediation technologies requires evaluation of the specific role that MNA will play in the alternative. Evaluation of a MNA technology application follows an assessment using the following four functional requirements:

- **The condition does not currently present an actual risk to human or ecological receptors.** There must be an expectation that exposure mitigation can and will be maintained throughout the MNA period. Site monitoring must be adequate to confirm exposure mitigation.
- **The source of the observed contamination is no longer contributing to the plume.** The source may have been previously controlled through an engineered remedy or naturally ceased to contribute to the problem. In some cases, a source control element (e.g., vadose zone RTD) may be combined with the MNA alternative to ensure adequate control of secondary sources (e.g., residual mobile contamination in the vadose zone).
- **The target plume is static or retreating, or existing monitoring data otherwise confirm that attenuating processes are present and operating at the site.** This is assessed using historical groundwater and/or soil analytical results that demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood (*Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* [OSWER Directive 9200.4-17P]).
- **Effective monitoring either exists currently, or can be implemented.** This will provide confirmation that the attenuation is proceeding as expected and that remedial goals are achieved.

Development and evaluation of MNA as either a technology, or as a stand-alone alternative for groundwater contaminant plumes, requires thorough understanding and description of current site conditions, knowledge of contaminant characteristics, in addition to representative historical monitoring results to form the basis for evaluation of MNA as an appropriate alternative. The following conditions will be considered in evaluating MNA for COCs at 100-F/IU:

- **Reduction of Cr(VI):** May also occur in reducing conditions within the aquifer, or through chemical reaction with reduced iron and sulfide compounds. Biological and chemical reduction of Cr(VI) produces Cr(III), which is subject to precipitation of chromium oxide and hydroxide compounds that exhibit extremely low water solubility. In groundwater at 100-F/IU, Cr(VI) reduction generally occurs only at locations where the aquifer has been modified through an anthropogenic process (e.g., anaerobic conditions related to EAF septic discharges, septic tank/leach field discharges, or historical releases of reducing constituents). Because the aquifer at 100-F/IU is generally aerobic and chemically oxidizing, biological reduction of Cr(VI) is not generally considered to be a substantial attenuating process. However, within localized, fine-grained hydrostratigraphic zones, chemical reduction may be taking place. These zones are associated with geologic materials containing elevated iron- and sulfide-bearing minerals.

- **Abiotic degradation of TCE:** Abiotic processes can also play an important role in the natural attenuation of TCE (*Identification and Characterization Methods for Reactive Minerals Responsible for Natural Attenuation of Chlorinated Organic Compounds in Ground Water* [EPA 600/R-09/115]). Abiotic degradation of TCE tends to favor dechloroelimination reactions that produce acetylene in lieu of the sequential hydrogenolysis reaction typical of anaerobic biodegradation processes that produce cis-1,2 dichloroethene and vinyl chloride ("Kinetics of the Transformation of Halogenated Aliphatic Compounds by Iron Sulfide" [Butler and Hayes, 2000]). Abiotic processes can also degrade chlorinated ethenes to glycolate, acetate, formate, and carbon dioxide ("Biotic and Abiotic Anaerobic Transformations of Trichloroethene and cis-1,2-dichloroethene in Fractured Sandstone" [Darlington et al., 2008]). The removal or treatment of chlorinated ethenes through abiotic reactions avoids the production of toxic daughter products such as vinyl chloride. Reactive iron minerals such as iron sulfides (disordered mackinawite, mackinawite, and pyrite), iron oxides (magnetite), green rust, and iron-bearing clays have been shown to support complete or nearly complete transformation of perchloroethene, TCE, and carbon tetrachloride. Abiotic processes are important when the concentrations of TCE decline with distance along the flow path, and there is no evidence of cis-1,2-dichloroethene and vinyl chloride accumulation; a condition observed at 100-F/IU. Based on observed conditions, and knowledge of River Corridor geologic conditions, abiotic decomposition of TCE is expected to be an important attenuation process.

- **Anaerobic degradation of TCE:** Not currently confirmed by the presence of common decomposition products (e.g., cis- and trans-1,2 dichloroethene, and vinyl chloride) and geochemical conditions typically associated with reductive dechlorination. TCE degradation via the reductive dechlorination pathway generally occurs under anaerobic (i.e., dissolved oxygen less than 0.5 mg/L) conditions in groundwater. The aquifer at 100-F/IU is generally aerobic and TCE in that system would not be subject to typical reductive dechlorination processes. The TCE concentrations observed in groundwater are relatively low (e.g., less than 15 µg/L). It is possible that degradation is occurring and that the degradation products are not persistent or present at detectable levels. Based on observed conditions (e.g., dissolved oxygen concentrations greater than 0.5 mg/L and absence of cis- and trans-1,2–dichloroethene), anaerobic degradation of TCE is not considered a significant attenuating process at 100-F/IU.

- **Reduction of nitrate:** Primarily facilitated by microbial populations in groundwater, may occur when the dissolved oxygen content water becomes low and the water enters a reduced condition. Indigenous facultative and obligate anaerobic microbes, which are native to the subsurface but frequently electron donor-limited (*Toxic Substances Hydrology Program* [USGS, 2010]) use the oxygen atoms of the nitrate molecule in their metabolic processes, reducing the nitrate to nitrite and nitrogen gas. While these processes may occur in localized areas not detectable with the current

100-F/IU monitoring well network, the aquifer is generally aerobic and, as a result, nitrate tends to be stable and mobile as evident by the size of the current plume. Reduction of nitrate to nitrogen gas in the aquifer system is not considered to be a significant attenuating process at 100-F/IU under current conditions.

- **Radioactive decay of strontium-90:** Occurs within the 100-F/IU aquifer without human intervention and is independent of geochemical conditions. With a half-life of 29.7 years, the 270 pCi/L peak concentration of strontium-90 detected in 100-F/IU aquifer groundwater at the end of 2011 (well 199-F5-55) will require about five half-lives (150 years) to decrease to a concentration less than the 8 pCi/L PRG.

- **Dispersion and diffusion:** Within the aquifer are physical processes that reduce contaminant concentrations in groundwater over time and distance. Dispersion is a physical and scale-dependent process that results in mixing of contaminants within the aquifer because of variations in groundwater flow velocity along the tortuous flow paths that occur within the aquifer. This mixing results in reduction in contaminant concentrations over distance. Diffusion is a concentration-driven process that results in movement of dissolved contaminants from areas of high concentration to areas of lower concentration. The 100-F/IU groundwater plumes cover a relatively large area. The distance along groundwater flow paths between inland areas and points of potential exposure along the river is relatively short. This indicates that the overall portion of the aquifer where dispersion may occur and provide substantial concentration reduction is relatively small. Nevertheless, dispersion is still an important 100-F/IU attenuation process. Diffusion is generally less significant than dispersion, except in low-permeability aquifers. Therefore, diffusion is not expected to be an important attenuation process at 100-F/IU.

- **Groundwater-surface water mixing in the bank storage zone:** Daily and seasonal Columbia River stage fluctuations result in the formation of a groundwater/surface water mixing region within the area where river water intrusion into the aquifer occurs. The location and volume of this mixing region are expected to be relatively constant on a daily basis, but volume increases during the spring months, while contracting in the fall months in response to seasonal runoff. Within this region, contaminated groundwater mixes with noncontaminated surface water, resulting in a significant reduction in contaminant concentrations before groundwater enters the river. This is an important process in the 100-F/IU.

*Pump-and-Treat*. The pump-and-treat GRA includes collection, ex situ treatment, and discharge:

- **Collection:** This process option involves extraction of contaminated groundwater through vertical wells. The groundwater is transferred to a treatment facility through pipes.

- **Ex situ treatment:** Aboveground treatment may involve physical, biological, or chemical processes. Ex situ treatment process options include the following:
  - Ion exchange
  - Chemical reduction and precipitation
  - Electrocoagulation
  - Wetlands
  - Biological treatment (anaerobic)
  - Subgrade bioreactors
  - Bioreactors
  - Phytoremediation

  - Air stripping
  - Membrane separation (reverse osmosis)

- **Discharge:**
  - Onsite discharge includes groundwater injection wells, surface infiltration, and beneficial reuse of treated water.
  - Offsite discharge includes surface water discharge.

*In Situ Treatment*. In situ treatment consists of actions that treat contaminants in place. In situ treatment of contaminated groundwater generally includes methods to degrade contaminants, such as adding reagents to groundwater (via injection wells or permeable barriers) that facilitate chemical or biological destruction or immobilization. For this evaluation, technologies are subdivided by the reagent approach (physical, chemical, or biological), and the method for delivering the reagent to the subsurface. For treatment of contaminated groundwater at 100-F/IU, the following in situ remedial technologies and process options were evaluated:

- **Reagent approach:**
  - Chemical treatment/reduction
  - Biological treatment (anaerobic)
  - Hydrogen or other organic gas sparging
  - Combination of biological and chemical substrates
  - Flushing—saturated zone, water
- **Delivery method:**
  - Surface infiltration
  - Groundwater circulation wells
  - Vertical wells
  - Horizontal wells

*Containment*. Containment technologies assist in preventing or significantly reducing the migration of contaminants in groundwater through physical barriers or treatment barriers. For treatment of contaminated groundwater in 100-F/IU, the following containment process options were evaluated:

- Containment wall (e.g., slurry wall or grout wall)
- Reactive chemical barrier (ISRM)
- Reactive biological barrier
- Hydraulic containment via extraction
- Hydraulic containment via injection

### 8.3.2 Evaluation of Technologies and Selection of Representative Technologies

Tables 8-8 and 8-9 present the identification and screening of technologies and remedial process options for 100-F/IU. Table 8-8 presents general response actions for waste sites. Table 8-9 presents GRAs and process options for the four COCs present in 100-F/IU groundwater.

The various technologies screened in the tables include demonstrated and proven processes, innovative technologies, and potential processes that have undergone laboratory trials or bench-scale testing. Factors considered in this evaluation include the state of technology development, site conditions, waste characteristics, nature and extent of contamination, and presence of constituents that could limit the

effectiveness of the technology. A qualitative comparison of implementability, effectiveness, and cost provided additional evaluation of technologies. The screening tables present information pertaining to the sustainability of a process option. It is important to note, however, that sustainability was not considered as a criterion for screening process options.

Implementability refers to the relative degree of difficulty anticipated in implementing a particular process option under regulatory, technical, and schedule constraints posed by the Site. As suggested by CERCLA RI/FS Guidance (EPA/540/G-89/004), process options and entire technology types can be eliminated from further consideration if a technology or process option cannot be effectively implemented at the site. As discussed in Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004), "technical implementability is used as an initial screen of technology types and process options to eliminate those that are clearly ineffective or unworkable at a site." Institutional or administrative implementability, which includes "the ability to obtain necessary permits for offsite actions, the availability of treatment, storage, and disposal services (including capacity), and the availability of necessary equipment and skilled workers to implement the technology," is also considered in the initial screening.

Effectiveness refers to the ability of the process option to perform as part of a comprehensive remediation plan to meet RAOs under the conditions and limitations present at the site. Additionally, the NCP (40 CFR 300) defines effectiveness as the "degree to which an alternative reduces toxicity, mobility, or volume through treatment; minimizes residual risk; affords long-term protection; complies with ARARs; minimizes short-term effects; and how quickly it achieves protection." This is a relative measure for comparison of process options that perform the same or similar functions. Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004) states that the evaluation of process options with respect to effectiveness should focus on: "(1) the potential effectiveness of process options in handling the estimated areas or volumes of media and meeting the remediation goals identified in the remedial action objectives; (2) the potential impacts to HHE during the construction and implementation phase; and (3) how proven and reliable the process is with respect to the contaminants and conditions at the site."

For the initial screening of technology types and process options, the cost criterion is relative. It compares processes and technologies that perform similar functions and have similar effectiveness. Section 4.2.5 of CERCLA RI/FS Guidance (EPA/540/G-89/004) states that "cost plays a limited role in the screening of process options. Relative capital and operations and maintenance (O&M) costs are used rather than detailed estimates. At this stage in the process, the cost analysis is made on the basis of engineering judgment, and each process is evaluated as to whether costs are high, low, or medium relative to other process options in the same technology type." For this evaluation, cost is used to screen out process options that have a high relative cost if there are other choices that perform similar functions with similar effectiveness. The cost criterion includes a cursory consideration of the rough order-of-magnitude costs of construction and any long-term costs to operate and maintain the technologies.

Technologies that are not technically implementable or feasible based on implementability, effectiveness, and cost were screened out. Technical implementability is the first screening criteria evaluated as part of this process, per EPA guidance. However, for technologies with significant technical implementability challenges, an evaluation of effectiveness and cost was still completed to allow for a more complete evaluation. Technologies that were considered technically impracticable based on unsuccessful case studies at the site, challenges associated with existing site conditions (lithology), a potential increased risk to worker safety, or of increased complexity as compared to other technologies of comparable effectiveness were screened out. Technologies were also removed from further consideration if they were considered to have limited treatment effectiveness for the specified COPC or performance uncertainties. Appendix I discusses the technologies not retained, including a detailed screening rationale. Remedial technology types and process options considered viable for remediating contaminated soil at 100-F/IU are carried

forward into the development (Chapter 9) and detailed analysis of alternatives (Chapter 10). The list of retained options should be considered dynamic, flexible, and subject to revision based on subsequent design investigation findings, results of treatability studies, or technological developments. An evaluation of the state and potential full-scale application of innovative technologies that were not retained may also be considered during the 5-year review process once additional information on these technologies becomes available.

#### *8.3.2.1 Evaluation of Technologies and Selection of Representative Technologies for Vadose Zone Contamination*

For remediation of vadose zone soil including waste sites (Table 8-8) at 100-F, the following response actions were retained:

- ICs—provides controls during and after remediation to interrupt the exposure pathway
- MNA-provides for removal of contaminants through radioactive decay
- Removal
  - Standard excavation—provides for removal of contaminants
  - Deep excavation—provides for removal of contaminants
- Disposal
  - Disposal to ERDF—provides for treatment at the facility (if necessary) and disposal of contaminants
  - Disposal to offsite EPA-approved landfill—provides for disposal of contaminants

The alternatives development process presented in Chapter 9 relies on proven process options and technologies that have demonstrated effectiveness at the Hanford Site. The "No Action" general response action does not provide capability to remove contaminants or interrupt the exposure pathway to receptors but is also retained per the NCP (40 CFR 300).

#### *8.3.2.2 Evaluation of Technologies and Selection of Representative Technologies for Groundwater Contamination*

For treatment of contaminated groundwater (Table 8-9) at 100-F/IU, the following response actions were retained:

- ICs—provides controls during and after remediation to interrupt the exposure pathway
- MNA—treatment of contaminants through biological and chemical reduction, radioactive decay, adsorption, dispersion, and dilution/mixing
- Pump-and-treat—provides for treatment of contaminants
  - Collection through groundwater extraction system (vertical wells)
  - Ex situ physical treatment—ion exchange (Cr[VI], strontium-90, and nitrate)
  - Ex situ biological treatment—anaerobic through liquid substrate (nitrate)
  - Ex situ physical treatment—air stripping (TCE)
  - Discharge—vertical injection wells, surface infiltration, and beneficial reuse of treated water

- In situ treatment—provides for treatment of contaminants
  - Biological treatment (anaerobic) —using liquid substrate
  - Physical treatment—flushing saturated zone with water to facilitate contaminant movement to allow for capture and treatment from the aquifer (i.e., pump-and-treat with hydraulic containment)
  - Delivery methods
    - Surface infiltration—release of water or reagents at the surface or near surface
    - Vertical wells—used to inject water or reagents to enhance contaminant flushing or promote biological treatment
- Containment
  - Hydraulic containment via extraction—provides engineered system to interrupt the exposure pathway

The "No Action" GRA does not provide capability to remove contaminants or interrupt the exposure pathway to receptors but is also retained per the NCP (40 CFR 300).

Figures 8-8 through 8-18 present specific information on technologies that have been retained. For 100-F/IU, Chapter 9 presents technologies that are applicable to waste sites and develops the technology into a remedial action alternative. Appendix I provides a discussion of the technologies not retained, including a technology description, relevant case studies, and the screening rationale.

# 9 Development and Screening of Alternatives

This chapter presents remedial action alternatives for 100-F/IU. The primary sources of information used to develop the remedial action alternatives included the physical characteristics of the site (Chapter 3); waste site and groundwater contaminant plume characterization information (Chapters 4 and 5); the identified risks (Chapters 6 and 7); and the RAOs, remedial action target areas, and remedial technology screening results (Chapter 8).

In this chapter, the remedial technologies retained from the screening presented in Section 8.3 were combined into remedial action alternatives to provide a viable range of technology groupings that address the identified 100-F/IU waste sites and groundwater contaminant plumes. With the exception of the No Action Alternative, the remedial action alternatives were developed to target achievement of the RAOs identified in Chapter 8 by considering the CERCLA Program Goals and Expectations identified in the NCP (40 CFR 300). The remedial action alternatives presented in this chapter are carried forward for detailed and comparative evaluation in Chapter 10.

*Highlights*

- Remedial action alternatives developed for 100-F/IU vadose zone sites include the following:
  - Alternative S-1: No Action
  - Alternative S-2: RTD
- Groundwater remedial action alternatives were developed for the Cr(VI), strontium-90, trichloroethene, and nitrate plumes. The remedial action alternatives included:
  - Alternative GW-1: No Action
  - Alternative GW-2: ICs and MNA
  - Alternative GW-3: Pump-and-Treat Optimized with Other Technologies
  - Alternative GW-4: Enhanced Pump-and-Treat

## 9.1 Development of Remedial Alternatives

The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(a)(1)(iii)]), sets the following expectations for remedial action alternative development:

- To use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely appropriate include liquids, areas contaminated with high concentrations of toxic compounds, and highly mobile materials.
- To use engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable.
- To use a combination of methods, as appropriate, to achieve protection of HHE. In appropriate site situations, treatment of the principal threats posed by a site, with priority placed on treating waste that is liquid, highly toxic, or highly mobile, will be combined with engineering controls (such as containment) and ICs, as appropriate, for treatment residuals and untreated waste.
- To use ICs, such as water use and deed restrictions, to supplement engineering controls as appropriate for short- and long-term management to prevent or limit exposure to hazardous substances, pollutants, or contaminants. ICs may be used during the conduct of the RI/FS and implementation of the remedial action and, where necessary, as a component of the completed remedy. The use of ICs shall not substitute for active response measures (e.g., treatment and/or containment of source material, restoration of groundwater to their beneficial uses) as the sole remedy, unless such active measures are determined not to be practicable, based on the balancing of trade-offs among alternatives that is conducted during selection of the remedy.

- To consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer or lesser adverse effects than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.

- To return usable groundwater to beneficial uses wherever practicable, within a timeframe that is reasonable, given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practicable, the EPA expects to prevent further migration of the plume, prevent exposure to the contaminated groundwater, and evaluate further risk reduction.

The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]) requires consideration of a No Action Alternative. The No Action Alternative (no further action if some removal or remedial action has already occurred at a site) is applicable to each of the waste sites carried forward from the evaluations described in previous chapters of the RI/FS and to the groundwater COC plumes. The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(4)]) also sets the expectation that for groundwater response actions, a limited number of remedial alternatives should be developed to achieve site-specific remediation levels within different restoration periods using one or more technologies.

Where the contaminated groundwater is not currently used, or an alternate water source is readily available, and there is no near-term future need for the resource, it will likely be appropriate to consider a longer timeframe for achieving restoration cleanup levels (*A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents* [EPA 540-R-98-031]).

As suggested by CERCLA RI/FS Guidance (EPA/540/G-89/004), alternatives were developed incorporating process options and technologies retained in Chapter 8 to include an appropriate range of waste management options to ensure the protection of HHE. The conceptual designs presented for each alternative were developed to the level required to prepare a cost estimate that allows for comparison of the alternatives. More detailed information on the selected remedy for 100-F will be developed during remedial design, after the ROD is signed. A RD/RA work plan will be developed that will discuss in detail the design of the specific components for each waste site and groundwater plume.

### 9.1.1 Waste Sites

As presented in Table 8-6 (Chapter 8), 286 sites have been classified as no further action or as needing to be addressed through the FS. The COPCs for waste sites remaining to be addressed are listed in Table 8-1 (Chapter 8). The evaluation of proposed remedial actions relies on the review of available data associated with the waste sites, including field data, radiological surveys, process history, analogous site information, personal interviews, engineering drawings and as-builts, and other information identified during the development of the RI/FS. The comprehensive review and evaluation of this information is provided in Chapters 4 to 7 of this RI/FS.

Of the 286 sites, 153 sites are identified in Chapter 8 as having no identified unacceptable risks and are designated for no further action. Remedial alternatives are not developed for these sites. The alternatives are developed based on the identified risks and known or suspected contaminants present at each of the waste sites, as identified in Table 8-1. During implementation of remedial actions, should field conditions vary from those presented in the FS and indicate a need to re-evaluate the efficacy of the selected remedial action, the appropriate remedy modification will be used, consistent with CERCLA guidance. Waste site groups considered in the alternatives analysis are described in the following sections.

#### 9.1.1.1 Waste Sites Anticipated to be Addressed under Interim Action ROD

The 81 waste sites currently being remediated under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) or anticipated to be remediated by the time the 100-F/IU ROD is issued are shown in Table 8-6. The ROD identifies RTD as the remedial alternative. The cleanup levels in the 100-F/IU ROD will be used to verify that remediation is complete for all waste sites.

#### 9.1.1.2 Waste Sites for Institutional Controls

As discussed in Section 8.2,15 sites have been interim closed and had verification data with exceedances of human health RBSLs (residential scenario) for select radionuclide compounds in the vadose zone below a depth of 4.6 m (15 ft). Contamination was detected in deep zone verification soil samples; however, there is no current direct exposure pathway. Deep excavation institutional controls are considered a common element for the waste site alternatives, except for No Action. Radionuclide contamination at the waste sites will continue to decay to concentrations below human health RBSLs within 13 to 175 years. Institutional controls will be maintained for these sites until unrestricted use is allowable, and remedial action alternatives are not developed for these sites. The 118-F-6 waste site reported an EPC greater than the RBSL. The EPC was based on the maximum value from a small data set that is representative of both shallow (less than 4.6 m [15 ft]) and deep (greater than 4.6 m [15 ft]) waste site soil following remediation. The radionuclides will decay to concentrations less than RBSL within approximately 20 years. DOE has proposed to place an IC on this site during this period to limit exposure. Additionally, residual Cr(VI) concentrations present at the 116-F-14 waste site exceed SSLs based on an irrigation recharge scenario, but do not exceed PRGs for groundwater and surface water protection. Therefore, DOE has proposed to place an additional IC at this waste site to preclude future irrigation.

#### 9.1.1.3 Waste Sites Remaining for Remedial Action

The identified risks and known or suspected contaminants identified in Table 8-1 (Chapter 8) for the 36 sites remaining for remedial action are used to develop the remedial action alternatives and data for cost estimating. The identification of the risk drivers is based on available sample data, process knowledge for site activities, and remediation results at similar sites in the River Corridor. One or more of the following risk drivers were identified for each site:

- Human health direct contact risk in shallow soil (depth less than 4.6 m [15 ft] bgs)
- Ecological risk in shallow soil (depth less than 4.6 m [15 ft] bgs)
- Groundwater/surface water protection risk in soil

### 9.1.2 Groundwater

Under CERCLA, groundwater remedial action is warranted when EPCs for the identified COCs exceed MCLs or nonzero MCLGs where groundwater is deemed a current or future drinking water source. Groundwater remedial action is also required under scenarios where contaminated groundwater discharge to surface water may cause an exceedance of a surface water quality protection ARAR. As summarized in Table 8-7, four COCs were identified for groundwater: Cr(VI), nitrate, strontium-90, and trichloroethene.

To support the development and evaluation of groundwater remedial action alternatives, a numerical groundwater flow and contaminant transport model of the 100 Area was constructed. In *Modeling of RI/FS Design Alternatives for 100-FR-3* (ECF-100FR3-11-0116), provided in Appendix F, COC transport simulations and particle tracking were performed to identify the benefits and differences between each alternative. Because of its much larger size relative to the other COC plumes, the nitrate simulations focused on treatment within two different areas differentiated by concentrations. The model was also used

to perform a limited amount of optimization relative to well location placement and pumping schemes. The designs developed for this FS are conceptual and will be refined in the post-ROD RD/RA work plan.

The groundwater flow model was constructed using the USGS modular groundwater flow model MODFLOW. Particle tracking was performed using the USGS program MODPATH. To simulate contaminant plume response to various remedial action alternatives, the contaminant transport model MT3DMS was used. Model development and calibration are documented in *Geohydrologic Data Package in Support of 100-FR-3 Modeling* (SGW-47040) and *Modeling of RI/FS Design Alternatives for 100-FR-3* (ECF-100FR3-11-0116) in Appendix F. These supplemental documents also discuss potential uncertainty with the model results arising from variability in subsurface conditions and other factors.

100-F/IU groundwater remedial action alternatives were developed for each COC plume based on the target remediation areas described in Section 8.2. The groundwater remedial action alternative descriptions present a range of estimated timeframes for each alternative to achieve PRGs. The lower end of the remediation timeframe range is defined by the time required for the exposure point concentration (estimated using the 90$^{th}$ percentile) to decline to the PRG while the upper end of the range is defined by the time required for the maximum concentration to decline to the PRG.

During the groundwater remedial action alternative simulations, the transport model calculates, for each specified time step, a COC concentration for each model grid block (in three dimensions). The C90 concentration corresponds to the 90$^{th}$ percentile value of all the calculated concentrations across the model domain for a given time step. This C90 concentration is different from the EPC presented in the risk assessment, which is also calculated using a 90$^{th}$ percentile approach, but is determined from actual concentration measurements at existing monitor wells.

From the same set of model calculated COC concentrations described above for the C90 determination, the Cmax concentration is selected as the maximum concentration value calculated across the model domain.

The C90 concentration, which corresponds to the lower end of the remediation timeframe, provides a reasonable estimate for the cleanup timeframe that could be achieved with rigorous monitoring and remedial process optimization. The O&M portion of the remedial action alternative cost estimates is based on the C90 timeframe. The Cmax concentration, which corresponds to upper end of the remediation timeframe, provides a conservative estimate corresponding to isolated point-concentrations that might occur.

Because of the relatively large area of lower concentration measurements within the TCE plume, the C90 model prediction was found to be less representative of field conditions. The exposure point concentration calculated for the risk assessment is about 11 µg/L (Table 6-40), which is above the PRG (and less than the maximum observed concentration value of 20 µg/L). The Cmax value is based on an initial condition which uses the maximum measured concentration. Therefore, the timeframe to complete remediation of the TCE plume was conservatively selected as Cmax to represent future conditions in this case.

Modeling of RI/FS Design Alternatives for 100-FR-3 (ECF-100FR3-11-0116, Rev. 2), presented in Appendix F, presents the calculations and modeling results used for developing remedial action alternatives and estimating remedial action alternative completion timeframes. These timeframes are estimates based on current information. The actual timeframes may vary depending on the final configuration of the selected alternative, as determined during remedial design, the aquifer's response to the remedy, and the scope and effectiveness of remedial process optimization.

For future monitoring results, the EPC will be based on a 95$^{th}$ UCL on the mean groundwater concentration values. Performance monitoring of the 100-F/IU selected groundwater remedy will usethe 95$^{th}$ UCL to evaluate attainment of cleanup levels as described in "Groundwater Cleanup Standards"

[WAC-173-340-720(9)(d)(i)] and *Methods for Evaluating The Attainment of Cleanup Standards Volume 2: Ground Water* [EPA 230-R-92-014]).

## 9.2 Description of Remedial Alternatives

As suggested by CERCLA RI/FS Guidance (EPA/540/G-89/004), alternatives were developed that incorporate process options and technologies that were retained from the screening performed in Section 8.3 and include an appropriate range of waste management options to ensure the protection of HHE. Alternatives were developed separately for soil and groundwater.

The groundwater remedial action alternative descriptions presented in the following subsections provide a range of estimated timeframes for each alternative to achieve PRGs. The lower end of the range is defined by the C90 concentration while the upper end of the range is based on the Cmax concentration. The C90 concentration represents the 90th percentile concentration value for all groundwater model cells within the model domain where the contaminant plume occurs. The lower end of the remediation timeframe provides a reasonable estimate for the cleanup timeframe that could be achieved with rigorous monitoring and remedial process optimization. The O&M portion of the remedial action alternative cost estimates is based on the C90 timeframe. The upper end of the range is defined using the maximum concentration calculated by the model for the same domain. The upper end remediation timeframe provides a worst-case estimate that may occur without a remedial process optimization program. *Modeling of RI/FS Design Alternatives for 100-FR-3* (ECF-100FR3-11-0116), in Appendix F, presents the calculations and modeling results used for developing remedial action alternatives and estimating remedial action alternative completion timeframes. These timeframes are estimates based on current information. The actual timeframes may vary, depending on the final configuration of the selected alternative, as determined during remedial design, the aquifer's response to the remedy, and the scope and effectiveness of remedial process optimization.

### 9.2.1 Common Elements

The remedial action alternatives developed for 100-F/IU contain elements that are common to multiple alternatives. To limit redundancy in the discussion of these common elements, they are discussed in this section.

#### *9.2.1.1 Institutional Controls*

Existing ICs and other measures that place controls on land and groundwater use to prevent exposure are defined and discussed in Section 8.3.1 and Table 8-10. While remediation is underway, ICs will be put in place to control access and prevent exposure to contamination. ICs for 100-F/IU are expected to be implemented independently for each waste site or groundwater COC plume. ICs are currently in place to protect workers and control site access, and will continue during the period of remedial actions. ICs that are in place to prevent exposure to contamination will remain in place until the waste site or groundwater plume is remediated. Post remediation, ICs will remain in place to prevent excavation/drilling at the sites identified with deep (greater than 4.6 m [15 ft]) radiological contamination (although the exposure pathway is incomplete); to prevent irrigation at one waste site where site-specific modeling indicates irrigation may result in an exceedance of a surface water standard in groundwater; and to maintain entry restrictions at the waste site with combined shallow and deep radionuclide contamination (see Table 9-1).

Programs are in place to control access onto and specific uses of the Hanford Site that, in addition to preservation of the national monument, security, and safety, also protect HHE by limiting potential exposure to hazardous substances. Many of these multi-purpose or programmatic controls were put in place under previous interim action CERCLA RODs. The programmatic controls include site access; personnel badging; warning signs along the Columbia River bank and other access points; maintaining a current site wide ICs plan; controls for excavating soil, accessing and using groundwater; and irrigation

restrictions. While these controls transcend any specific CERCLA ROD or even the overall CERCLA cleanup, DOE and EPA recognize the importance of maintaining these controls until unrestricted use, related to the protection of HHE, is permitted.

Table 9-1. ICs Implemented at Waste Sites Post Remediation*

| Risk Driver | IC Type | Waste Site - IC Expiration Year |
|---|---|---|
| Waste sites with groundwater/surface water protection risk if irrigation were applied | Irrigation prohibition | 116-F-14 - indefinite |
| Waste sites with deep (greater than 4.6 m [15 ft] bgs) radiological contamination exceeding HH direct contact PRG levels. | Deep excavation/ drilling restrictions | 100-F-19:1, 100-F-19:3, 100-F-34, and 116-F-12 - 2088<br>100-F-19:2, 100-F-29, 116-F-11, and UPR-100-F-1 – 2027<br>116-F-2 – 2101<br>116-F-4 – 2102<br>116-F-6 – 2113<br>116-F-9 – 2062<br>116-F-14 – 2076<br>118-F-8:3 – 2187<br>118-F-8:4 – 2025 |
| Waste site with combined shallow (less than 4.6 m [15 ft] and deep composite sample indicating radiological contamination exceeding HH direct contact PRG | Excavation restrictions | 118-F-6 – 2033 |

* Additional waste sites may be added through closure reclassifications.

#### 9.2.1.2 *Monitored Natural Attenuation*

As described in Section 8.3.1.2, natural attenuation processes reduce COC concentrations in groundwater. MNA is distinguished from no action in that it measures and documents contaminant concentration reductions arising from various naturally occurring physical, chemical, and biological processes. The primary natural attenuation processes for COCs present in 100-F/IU groundwater include biodegradation and abiotic degradation, radioactive decay, dispersion, volatilization, and sorption.

For each alternative that includes MNA as a component of a broader alternative, MNA complements other actions, including the source control (waste site) remedial actions. The MNA component includes periodic sampling, laboratory analysis, and data evaluation to assess attenuation process and overall protectiveness.

Under Alternatives GW-2, GW-3, and GW-4, a site-specific DQO would be used to identify data gaps required for the design of an effective monitoring and data evaluation program for 100-F/IU groundwater. Existing characterization data and confirmatory sampling data would be used to establish a baseline for use in assessing future contaminant distribution and concentration trends.

MNA for 100-F/IU groundwater is proposed under the following circumstances:

- Alternative GW-2. To address all COC plumes.
- Alternative GW-3. To address the low concentration portion of the nitrate plume where concentrations between one and two times the PRG occur, and to address residual strontium-90 following cessation of pump-and-treat.
- Alternative GW-4. To address residual strontium-90 following cessation of pump-and-treat.

Additional information on MNA, as a standalone alternative and as a component of a broader alternative, is provided in Appendix M.

#### 9.2.1.3 Operations and Maintenance

O&M of each remedial alternative (except the No Action Alternative) is required to ensure that the remedy is operated and maintained in a manner that ensures long-term effectiveness and permanence. O&M requirements of the selected remedy will be described in a separate O&M plan prepared during the post-ROD RD/RA phase. The O&M plan will describe performance monitoring data needs and monitoring requirements, monitoring methods, analytes and sampling frequencies, routine maintenance activities and frequencies, and reporting.

For the groundwater alternatives, O&M activities for a MNA-based remedy would include inspection, maintenance, and periodic replacement of monitoring wells, whereas a groundwater pump-and-treat based remedy would include routine and preventive maintenance programs, as well as replacement of pump-and-treat system components at the end of their design life (typically 25 years).

#### 9.2.1.4 Remedy Performance Monitoring

Remedy performance monitoring will be conducted to evaluate the effectiveness of the selected alternative, with the exception of the No Action Alternative, to attain the remedial goals specified in the 100-F/IU ROD. The nature and scope of the performance monitoring program will vary by alternative, and will be presented in a future performance monitoring plan developed during the post-ROD RD/RA phase. Remedy performance monitoring applies to MNA actions, as well as active engineered remedies.

The largest component of remedy performance monitoring under Alternatives GW-3 and GW-4 is expected to be associated with the groundwater remedial components. Performance monitoring of a pump-and-treat system would be designed to evaluate hydraulic capture, contaminant mass removal from 100-F/IU groundwater, and COC concentration trends. The monitoring program would include both hydraulic and chemical/radionuclide concentration monitoring of extracted groundwater. Hydraulic monitoring would consist of measuring flow rates, total flow, and groundwater elevations at selected monitoring well locations. The injection well network would also be monitored for hydraulic performance. Water-level measurements would be used to evaluate whether extraction and injection wells are operating within their design criteria to capture the plume. Results of the evaluation would be used to optimize the remedy by altering extraction and injection flow rates, adding new wells if necessary, shutting down wells where pumping is no longer required, or shifting to a pulsed pumping strategy.

Chemical/radionuclide monitoring would consist of sampling monitoring wells for COCs, degradation byproducts, and geochemical parameters to support the overall remedy performance evaluation. The geochemical groundwater parameters used for assessing MNA effectiveness, for the groundwater alternatives where MNA is a component, typically include pH, dissolved organic carbon, sulfide, dissolved oxygen, iron (II), specific conductance, temperature, major anions and cations, oxidation-reduction potential, alkalinity, dissolved gases, and isotope ratios (*Monitored Natural Attenuation of*

*Inorganics in Ground Water: Volume 2 – Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium* [EPA/600/R-07/140]). Sampling and analysis will also be conducted for antimony, cadmium, and cobalt, which were analytes identified to have uncertain status (Section 8.1.4.5). To ensure protectiveness and confirm current understanding of the nature and extent of contamination and potential risks, these analytes will be included as part of the performance monitoring.

The number of wells monitored and the frequency of remedy performance monitoring is anticipated to vary, depending on the phase of remediation. A geostatistical analysis will be conducted to determine the optimum spatial distribution for the performance monitoring network. For alternatives where active remediation is occurring, the frequency of monitoring typically varies, depending on site-specific conditions. Frequencies may include quarterly (for new wells during the first year following installation), annually, biennially, or every 5 years. Sampling frequencies are typically reduced once contaminant concentration trends are established.

### 9.2.2 Alternative S-1: No Action

The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]) requires consideration of a No Action Alternative. The No Action Alternative, which serves as a baseline for evaluating other remediation action alternatives, is retained throughout the FS process. No action means that remediation would not be implemented to alter the existing conditions. For this alternative, it is assumed that all site remedial activities and interim actions, with the possible exception of backfilling any unsafe open excavations, will be discontinued. No design or cost estimates are prepared for Alternative S-1 because no actions are proposed.

### 9.2.3 Alternative S-2: RTD

Table 9-2 presents the components of this alternative for waste sites evaluated in the FS.

Table 9-2. Components for Alternative S-2— RTD for Waste Sites

| General Components | |
|---|---|
| No Further Action | No additional remedial actions are taken for the 152 waste sites identified in Chapter 8 as having no identified unacceptable risks based on evaluation. |
| Institutional Controls | Institutional controls to be implemented within 100-F/IU for land use management and waste site information management include the following:<br>• Permits required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents.<br>• Land use and real property controls (for example, easements and covenants) ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents.<br>• Notices providing visual identification and warning of hazardous or sensitive areas.<br>• Procedural requirements for access, warning signs, or fencing implemented to prevent or limit the access of humans to hazardous or sensitive areas.<br>• Administrative mechanisms, such as the WIDS database, to maintain and provide access to information on the location and nature of contamination.<br>Additional information on institutional controls is presented in Section 8.3.1.1 and Table 8-10.<br>Table 9-1 identifies post remediation institutional controls implemented at specific waste sites. |

Table 9-2. Components for Alternative S-2— RTD for Waste Sites

| General Components | |
|---|---|
| **For Waste Sites That Exceed Human Health, Environment, Surface Water, or Groundwater Protection PRGs** | |
| RTD | RTD is effective in meeting the human health, environment, surface water, and groundwater PRGs as reflected in the risk evaluation of completed waste sites with close out/verification data (Chapter 6).<br>RTD includes the following actions:<br>• Collection of confirmatory samples where warranted, based on the expected and actual risk drivers (media and COPCs). Confirmatory evaluation will determine the need for remediation at selected sites and confirmation of COCs.<br>• Demolition of any surface and/or subsurface structures, as required.<br>• Excavation of waste site structures and vadose zone soil where contaminant concentrations are above cleanup levels. RTD to depth of contamination exceeding cleanup levels for direct contact or ecological PRGs, or groundwater and surface water PRGs until groundwater is encountered if contamination extends into groundwater, using standard and deep excavation technologies.<br>• Determination of the extent of excavation required uses an observational approach. Removal actions use in situ and ex situ sampling, process knowledge, and field measurements to guide day-to-day excavation.<br>• Excavation using best practices, which includes appropriately sloped sidewalls based on the type of the material being removed, benching, shoring, and proper placement of the stockpiled material according to Occupational Safety and Health Administration standards.<br>• Sampling and field screening during excavation to ensure that the overall remediation meets the cleanup levels.<br>• Suppression of dust during excavation to ensure that contaminants are not spread by wind.<br>• Disposal of excavated material to ERDF as long as the material meets disposal criteria. Waste is treated as needed to meet land disposal restrictions before disposal at ERDF or an EPA-approved offsite location.<br>• Verification sampling following remediation to demonstrate that soil remaining in the remediation area does not exceed the cleanup levels. Within the SMDP process, ecological PRGs will be considered at a population level for wildlife and at a community level for plants and invertebrates, to determine whether cleanup action is required to protect ecological receptors.<br>• Backfilling and contouring the excavation to match the surrounding ground surface and restore and revegetate the site. Sources for backfill material include local borrow pits and the excavated material determined to be clean (verified as clean by meeting cleanup levels). Sites are revegetated with native plant species after backfilling. |

Figures 8-9, 8-10, and 8-11 (Chapter 8) illustrate the components of RTD, which has been the basic part of the interim remedial actions performed for waste sites at the Hanford Site.

Remediation that has the potential to affect cultural resources will require an analysis of cultural resource effects before any remedial action. The *National Historic Preservation Act of 1966* is an ARAR for remedial actions where cultural resources are present. Such an analysis is required by the ARARs discussed in Chapter 8. This will include an assessment of the cultural resources present at a site in accordance with

*Hanford Cultural Resources Management Plan* (DOE/RL-98-10). The guidelines and strategies have been developed based on the Hanford Site's unique history and cultural resources, and through recurring discussions with the State Historic Preservation Office and the Native American Tribes and Nations regarding the protective and mitigative measures that are needed. If during design or implementation of the remedy, culturally sensitive sites are identified for which mitigation activities to protect cultural resources would be inadequate, DOE and EPA will work with the Tribes to identify an alternative remediation strategy. This alternative remediation strategy would be implemented through a ROD change. Once the waste sites have been remediated and verification sampling demonstrates acceptable levels of the COCs, closure will be obtained following the procedures in the ROD and RDR/RAWP.

### 9.2.4 Alternative GW-1: No Action

The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]) requires consideration of a No Action Alternative. The No Action Alternative, which serves as a baseline for evaluating other remedial action alternatives, is retained throughout the FS process. No action means that no remediation would be implemented to alter the existing conditions. No conceptual designs or cost estimates are prepared for Alternative GW-1 because no actions are proposed..

### 9.2.5 Alternative GW-2: ICs and MNA

Alternative GW-2 uses ICs to prevent exposure to contaminated groundwater until MNA processes reduce COC concentrations to PRGs. Table 9-3 provides a summary of remedy components for Alternative GW-2 including the estimated time frame to achieve PRGs based on the Cmax and C90 concentrations. Groundwater sampling and analysis, and data evaluation and reporting are also an important component of this alternative to confirm that natural attenuation processes are reducing COC concentrations in accordance with expectations, and to provide a basis for determining when remedial action is complete and ICs can be removed.

Groundwater modeling (*Modeling of RI/FS Design Alternatives for 100-FR-3* [ECF-100FR3-11-0116], presented in Appendix F) was conducted to define initial conditions and to estimate the fate and transport of each COC under the GW-2: ICs and MNA alternative. Figure 9-1 shows the initial distribution of Cr(VI), strontium-90, trichloroethene, and nitrate as interpreted by the model. The initial distribution of each COC in groundwater within 100-F/IU was identified using the maximum reported COC concentrations for each monitoring well location from samples collected in 2009 and 2010.

Figure 9-2 presents the groundwater model prediction for Cr(VI) based on Cmax at time steps of 1, 10, 25, and 50 years. The model estimates that the Cr(VI) plume will persist near the river shoreline at concentrations above the 10 µg/L surface water PRG for approximately 35 years based on the Cmax concentration and 25 years based on the C90 concentration[1]. Recent pore water sampling in the river adjacent to the Cr(VI) plume has not shown Cr(VI) concentrations above the 10 µg/L PRG (*Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* [DOE/RL-2010-11]). For the inland portion of the aquifer, where the PRG is 48 µg/L, the model estimates the Cr(VI) plume will persist for up to 20 years based on the Cmax concentration and up to 10 years based on the C90 concentration. The maximum observed Cr(VI) concentration within the inland portion of the aquifer based on the 2011 data set was 41.6 µg/L.

[1] Groundwater model simulations and maps showing COC distribution at the C90 concentration were not prepared for this FS Report.

Table 9-3. Components for Alternative GW-2-ICs and MNA

| Media | Component | Description |
|---|---|---|
| Groundwater Components (Additional information on common elements is provided in Section 9.2.1) | ICs | • Maintain existing sitewide ICs (including groundwater use restrictions) already in place under *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions* (DOE/RL-2001-41).<br>• ICs are maintained for each plume area for the duration required to reach PRGs. |
| | MNA | • Monitoring of Cr(VI), strontium-90, trichloroethene, and nitrate to track the attenuation processes through periodic sampling of the monitoring well network for up to 90 years.<br>• Monitoring well network assumed to be composed of 38 existing monitoring wells, 10 existing aquifer tubes, and installation of 15 new wells to supplement monitoring locations.<br>• Monitoring will be defined in the DQO and SAP developed as part of the RD/RAWP. For cost estimating purposes, it is assumed that monitoring of new wells will be performed quarterly and existing wells sampled annually for the first year to establish baseline conditions, with annual monitoring for years 2 to 10 and biennial monitoring thereafter. |
| | Remedial Action Timeframe | • Cr(VI) based on 10 µg/L PRG – Cmax: 35 years C90: 25 years.<br>• Cr(VI) based on 48 µg/L PRG – Cmax: 20 years C90: 10 years<br>• Nitrate – Cmax: 80 years C90: 30 years<br>• Strontium-90 – Cmax: 150 years C90: 90 years<br>• TCE – Cmax: 45 years |
| | Compliance Monitoring Requirements | • Annual monitoring will be performed for an additional 5 years after PRGs are initially achieved to confirm that PRGs have been met. |

Figure 9-3 illustrates groundwater model predictions for the nitrate plume at time steps of 1, 10, 25, and 75 years. The model estimates that nitrate will persist in groundwater above its 45,000 µg/L PRG for up to 80 years based on the Cmax concentration and up to 30 years based on the C90 concentration.

Figures 9-4 illustrates groundwater model predictions for the strontium-90 plume at time steps of 10, 25, 75, and 150 years. The model estimates that strontium-90 will persist in groundwater at concentrations above its 8 pCi/L PRG for up to 150 years based on the Cmax concentration and up to 90 years based on the C90 concentration. The model does not predict the plume will reach the Columbia River above 8 pCi/L, because of the limited mobility of strontium-90 under current conditions.

Figure 9-5 illustrates groundwater model predictions for the trichloroethene plume at time steps of 1, 10, 25, and 50 years. The model estimate the trichloroethene plume will persist in groundwater at concentrations above its 4.9 µg/L PRG for up to 45 years based on the Cmax concentration. Under conditions simulated using data through 2010, the model predicted C90 concentration is currently less than the PRG. Therefore, for the purposes of the FS, this was deemed not representative and the Cmax timeframe of 45 years used.

### 9.2.6 Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

Alternative GW-3 reduces Cr(VI), nitrate, strontium-90, and trichloroethene concentrations through pump-and-treat optimized with in situ treatment of nitrate and Cr(VI), and incidental in situ treatment of trichloroethene. Strontium-90, and nitrate concentrations within the southern portion of the nitrate plume, will also be reduced through natural attenuation processes.

Pump-and-treat will occur using a network of extraction and injection wells targeting each of the COC plumes combined with ex situ treatment at a central treatment facility before reinjection of treated groundwater into the aquifer. In situ treatment for nitrate and Cr(VI) will be accomplished through amendment of treated groundwater with a substrate[2] before reinjection into the aquifer. The substrate type and concentration would be determined during remedial design. Figure 9-6 shows the extraction and injection well locations for Alternative GW-3, Figure 9-7 the conveyance piping routing while Figure 9-8 depicts the estimated hydraulic capture zone for the extraction and injection wellfield when operating at the model simulated pumping rates. Alternative GW-3 includes substrate injection at nine injection well locations.

Ex situ groundwater treatment will be performed using IX technology for Cr(VI), nitrate, and strontium-90. Separate IX columns will be used to treat flows from each COC plume. Groundwater extracted from the trichloroethene plume will be conveyed separately to the treatment facility for treatment with an air stripper. Individual treatment units will be placed in a series configuration where treatment for multiple COCs is necessary. Figure 9-9 provides a conceptual process flow schematic for the pump-and-treat system and in situ substrate amendments for Alternative GW-3. The final treatment system configuration will be determined during remedial design. Table 9-4 provides a summary of the components comprising Alternative GW-3.

Figure 9-10 presents the Alternative GW-3 groundwater model simulations for the Cr(VI) plume at time steps of 1 and 5 years. The modeling estimates that Cr(VI) concentrations will be reduced to concentrations below the 10 µg/L PRG within 5 years based on the Cmax concentration and 5 years based on the C90 concentration. Within the inland portion of the aquifer, Cr(VI) concentrations would be reduced to concentrations less than the 48 µg/L PRG within 5 years based on the Cmax concentration and 5 years based on the C90 concentration. An O&M period of 5 years was used for cost estimating purposes.

Figures 9-11 and 9-12 present the Alternative GW-3 groundwater model simulations for the nitrate plume at time steps of 1, 5, 10, 15, 20, 25, 50, and 75 years. The modeling estimates that nitrate concentrations within the plume would be reduced to levels below the 45,000 µg/L within 75 years based on the Cmax concentration and 20 years based on the C90 concentration. An O&M duration of 10 years was assumed for estimating pump-and-treat costs and 60 years for estimating MNA costs.

[2] Carbon substrates such as methanol, ethanol, acetate, whey, and sugar can enhance reduction of Cr(VI) to Cr(III) and reduction of nitrate to nitrogen gas (denitrification) by serving as an electron donor and energy supply for indigenous bacteria. For the purposes of Alternative GW-3, ethanol at a concentration of 500 mg/L in the treated injection water was stoichiometrically determined to be the amount required to address the dissolved oxygen, Cr(VI), and nitrate concentrations present in groundwater. The redox conditions resulting from biodegradation of the substrate are also expected to promote reductive dechlorination of trichloroethene to cis 1,2-dichloroethene, although this process was not included in the Alternative GW-3 simulations.

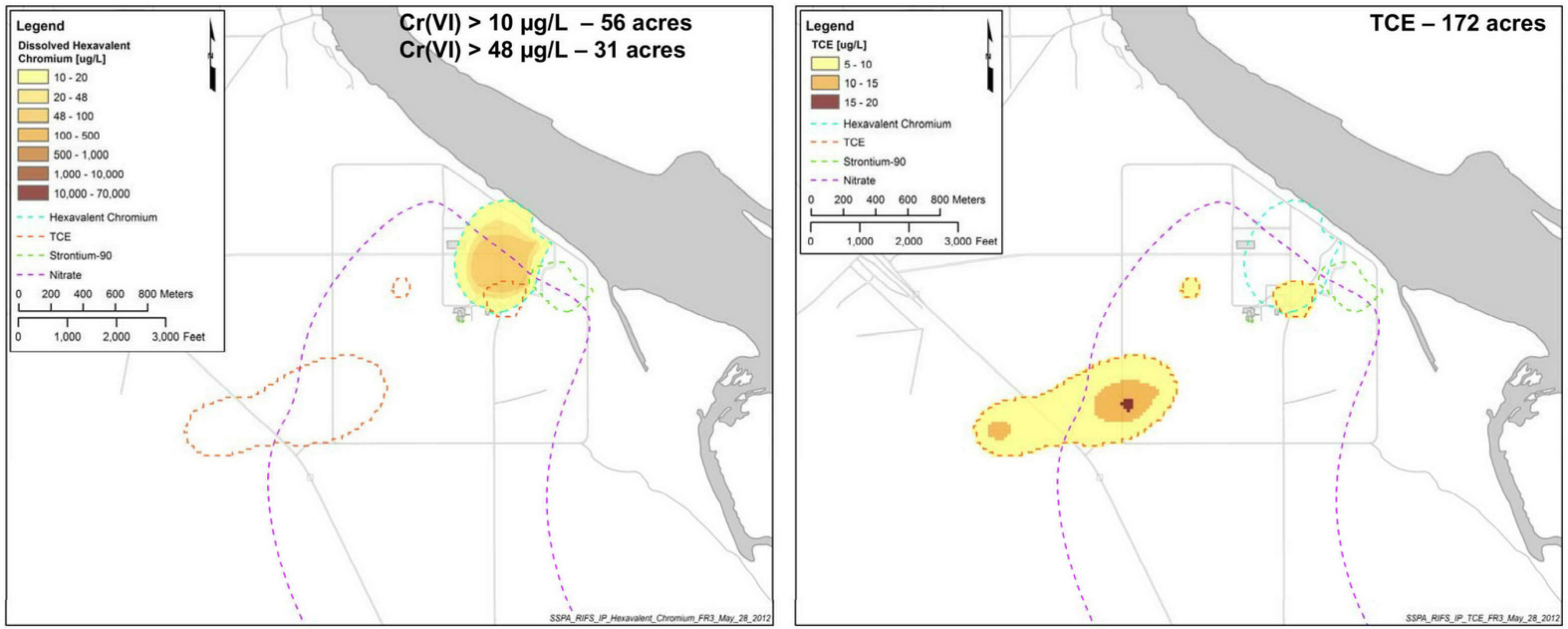


Figure 9-1. Initial Groundwater COC Plume Conditions from Maximum Concentrations Detected in 2009-2010

1

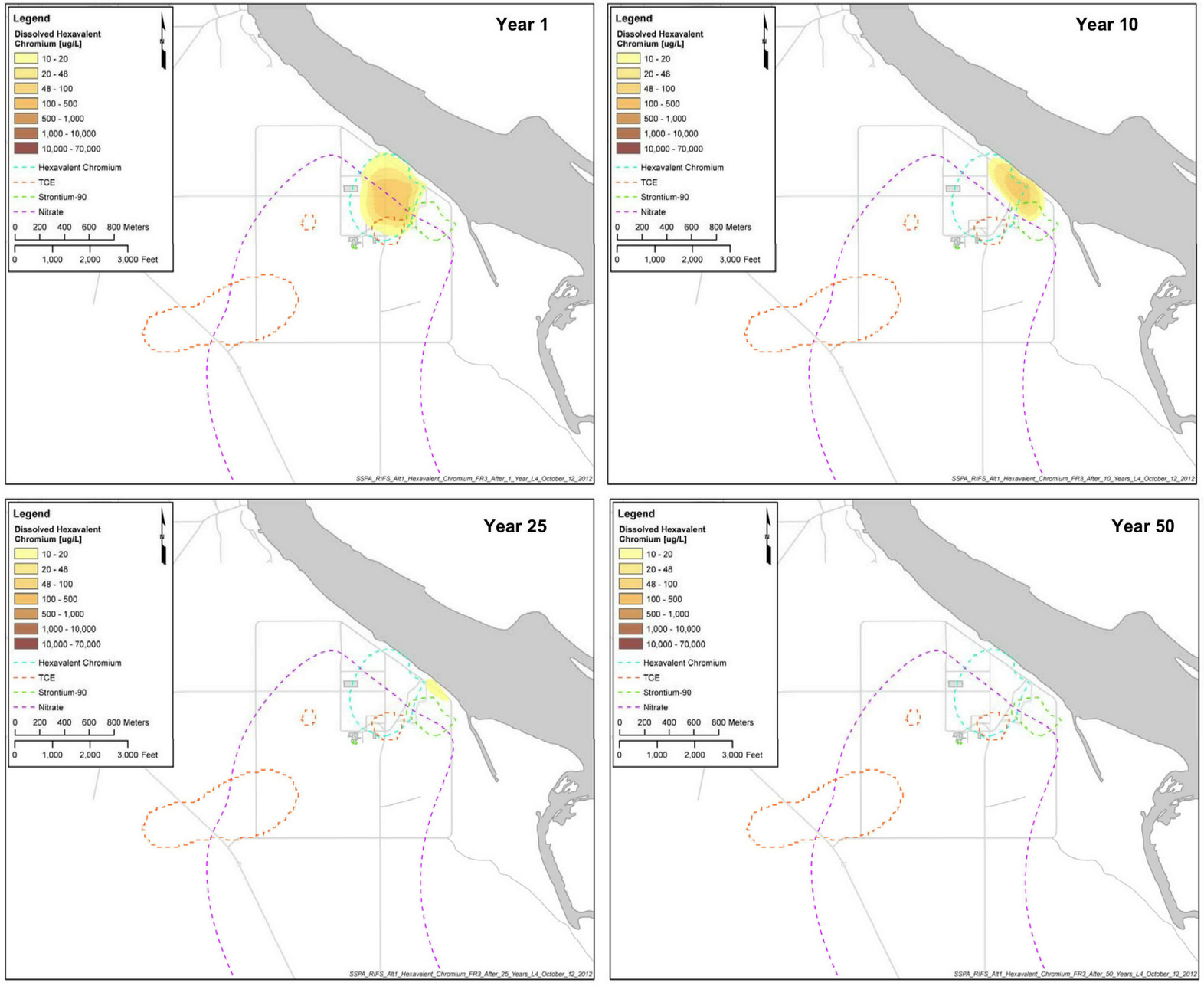


Figure 9-2. Cr(VI) Cmax Plume Projections for Alternative GW-2: ICs and MNA

1

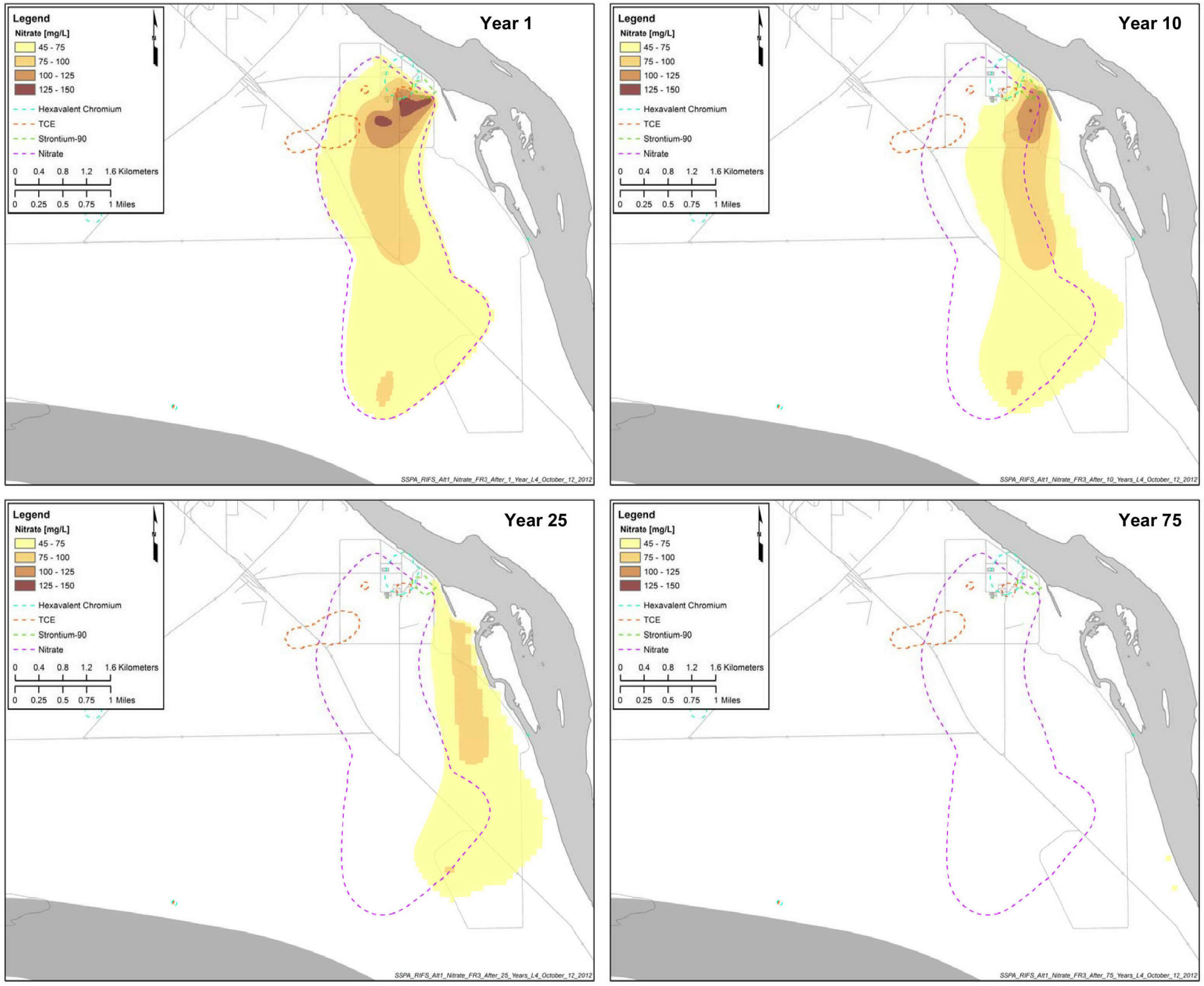


Figure 9-3. Nitrate Cmax Plume Projections for Alternative GW-2: ICs and MNA

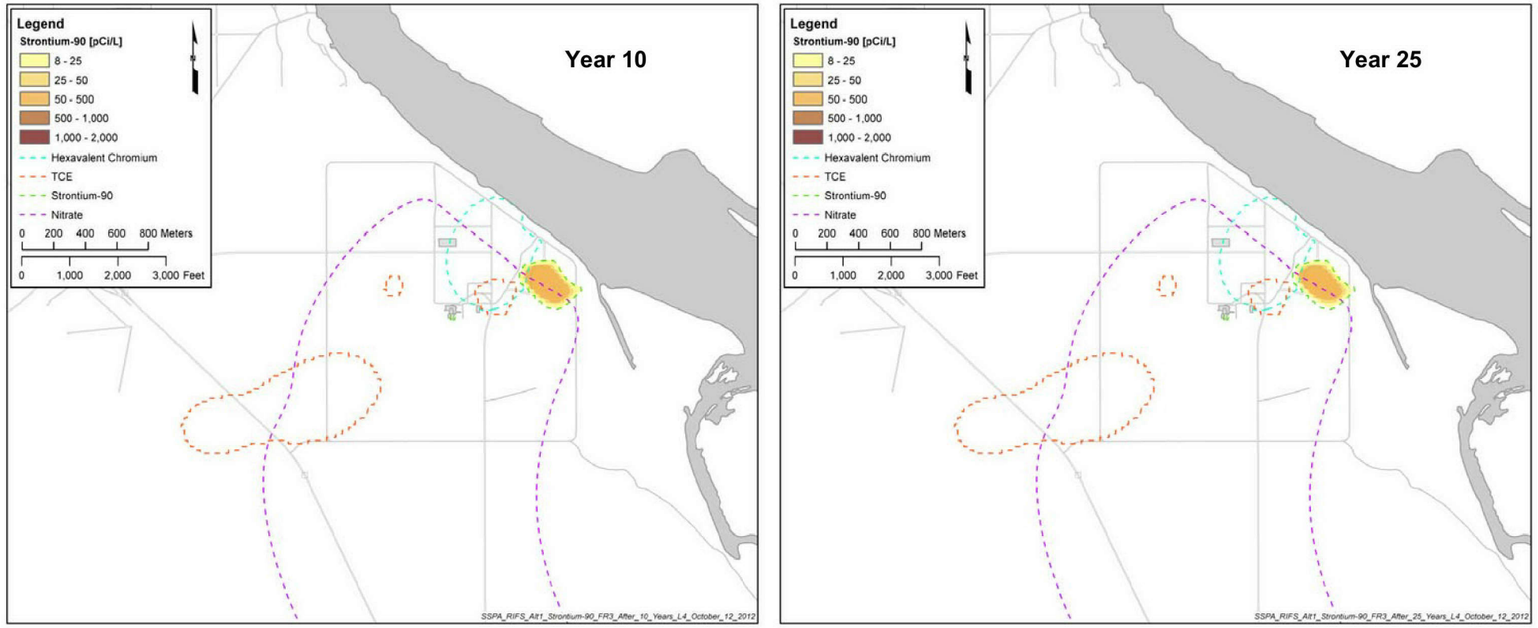


Figure 9-4. Strontium-90 Cmax Plume Projections for Alternative GW-2: ICs and MNA

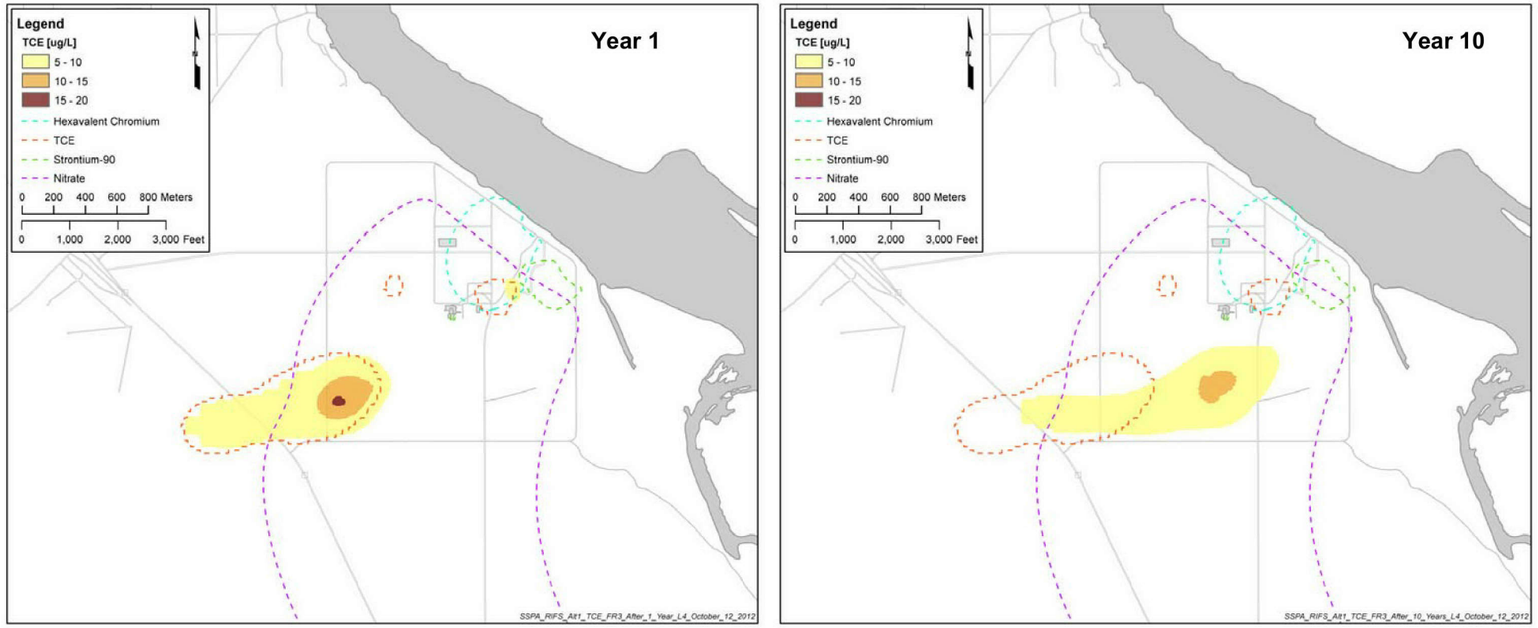


Figure 9-5. Trichloroethene Cmax Plume Projections for Alternative GW-2: ICs and MNA

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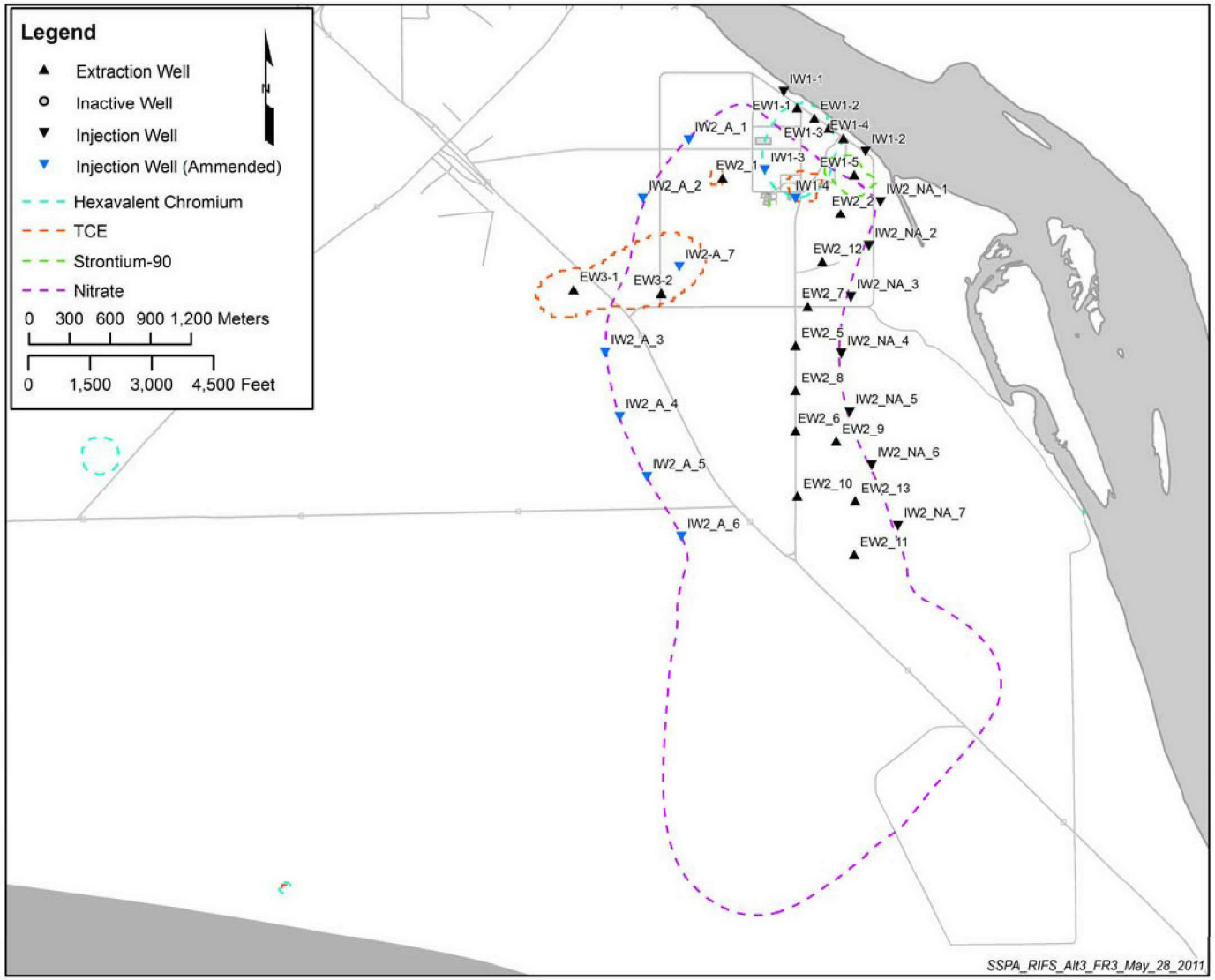


Figure 9-6. Extraction and Injection Well Locations for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

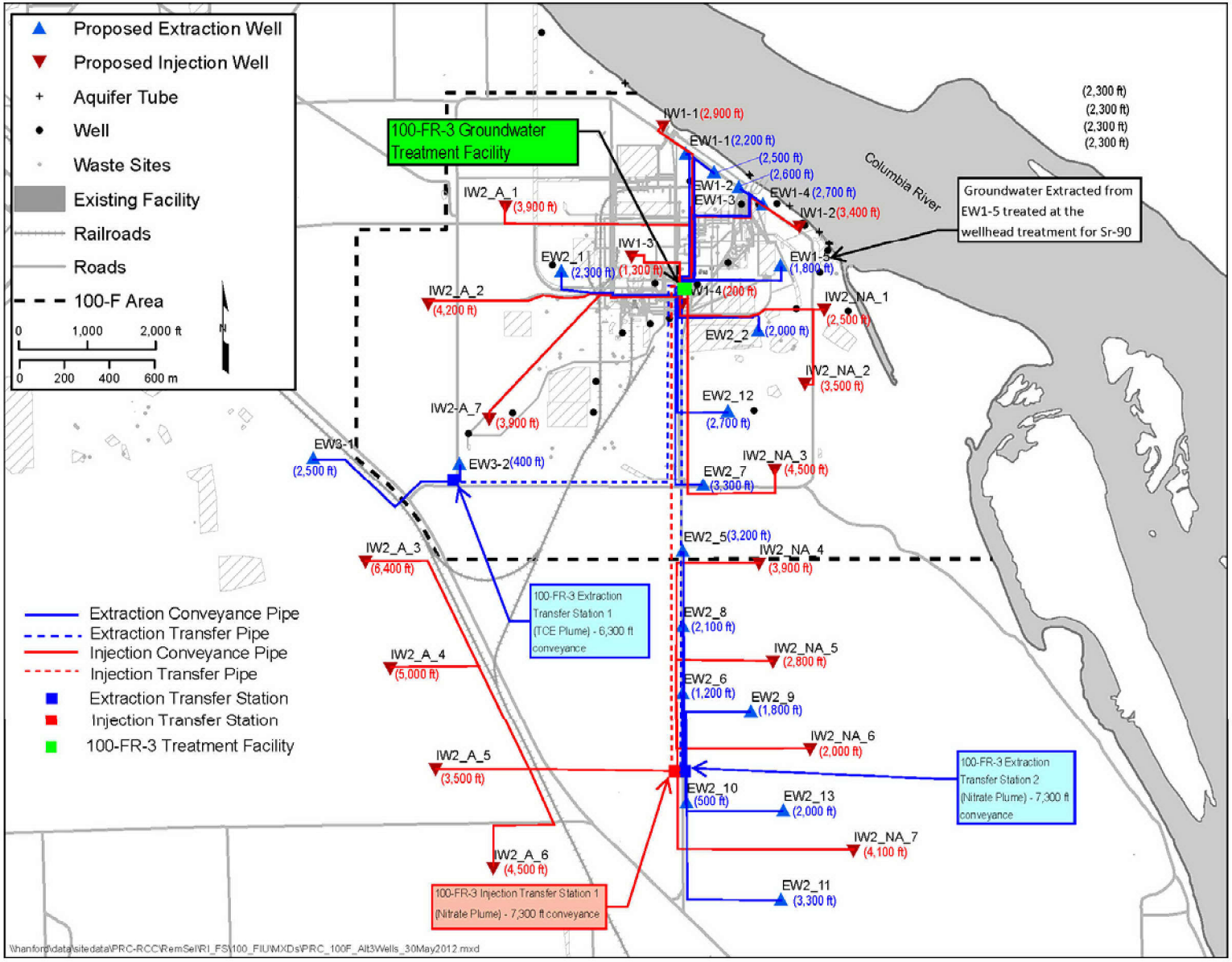


Figure 9-7. Conveyance Piping Layout Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

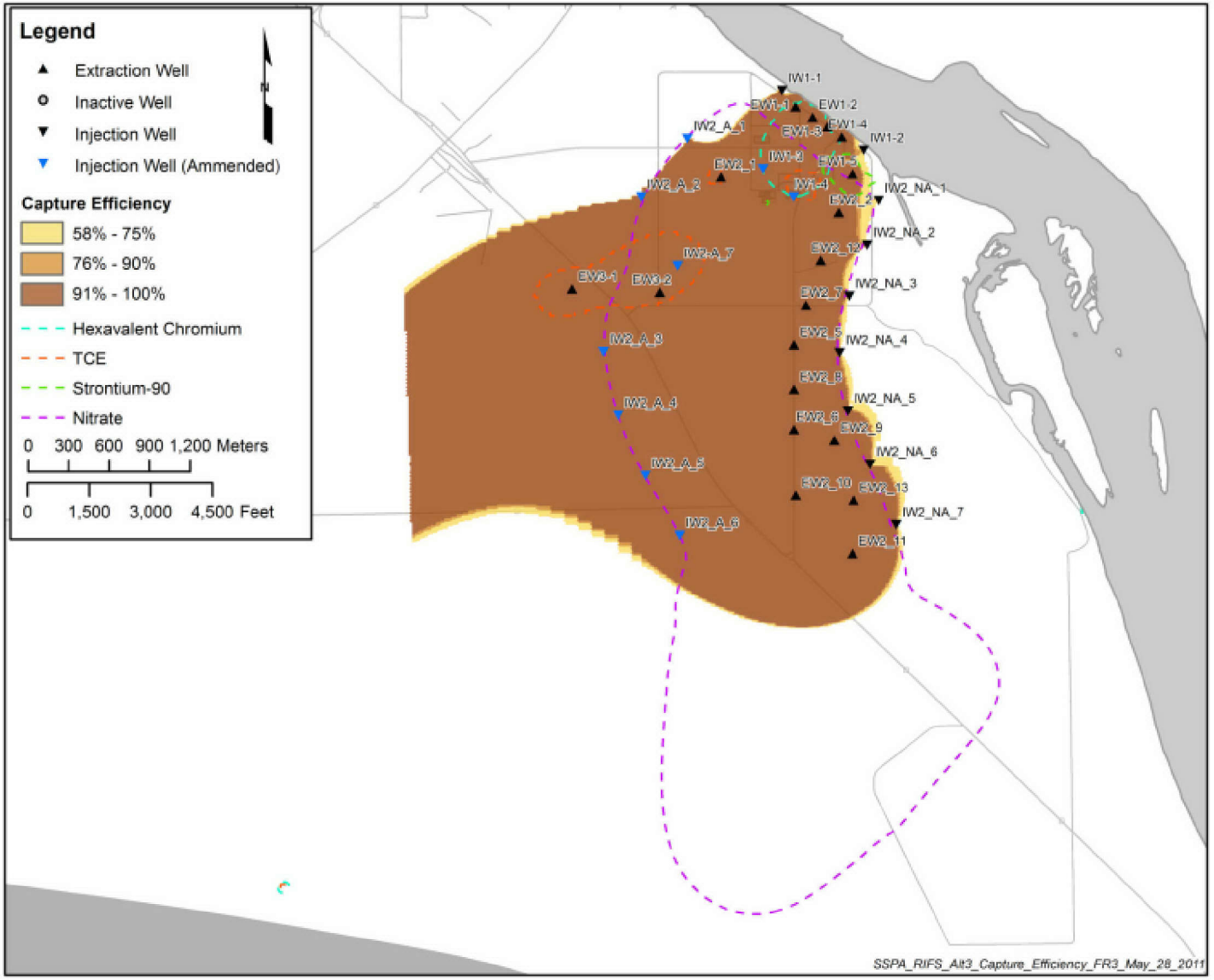


Figure 9-8. Hydraulic Capture Area for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

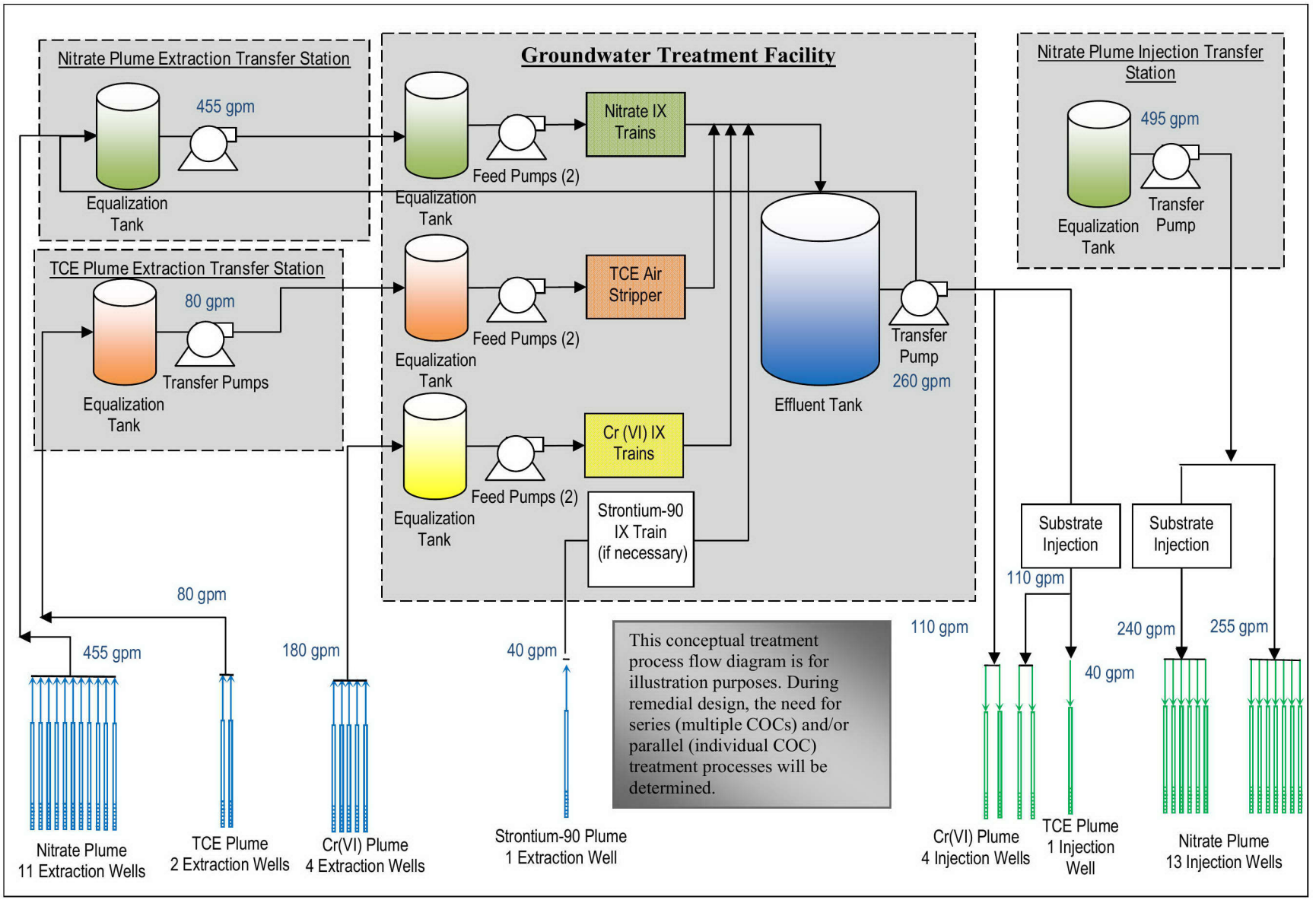


Figure 9-9. Conceptual Process Flow Diagram for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

Table 9-4. Components for Alternative GW-3-Pump-and-Treat Optimized With Other Technologies

| Media | Component | Description |
|---|---|---|
| Groundwater (Additional information on common elements is provided in Section 9.2.1) | ICs | • Maintain existing sitewide ICs (including groundwater use restrictions) already in place under *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41).<br>• ICs are maintained for each plume area for the duration required to reach PRGs. |
| | MNA | • Monitoring of strontium-90 and nitrate concentrations to track natural attenuation progress through periodic sampling of the monitoring well network.<br>• Monitoring network and frequency will be defined in the DQO and SAP developed as part of the RD/RAWP. For cost estimating purposes, it is assumed that monitoring of new wells will be performed quarterly and existing wells sampled annually for the first year to establish baseline conditions, with annual monitoring for years 2 to 10, and biennial monitoring thereafter. |
| | In Situ Treatment | • In situ treatment of nitrate and Cr(VI) consisting of in-situ chemical reduction. Incidental in situ reduction of trichloroethene also expected. Groundwater extracted, treated and amended with a reducing agent (to be identified during remedial design) and reinjected to the aquifer. For cost estimating purposes, it is assumed a total of six nitrate plume injection wells injecting at a total rate of 240 gpm will be amended for up to 10 years. Two Cr(VI) and one trichloroethene plume injection wells injecting at a total rate of 150 gpm will be amended for up to 10 years. The actual number of injection wells, injection rates, and substrate dose may be modified during remedial design.<br>• The extraction and injection well networks will be optimized during the remedial design and remedial action to promote in situ treatment of the plumes, and to enhance flow path control and hydraulic containment of the plumes. |
| | Pump-and-Treat | • Installation of four extraction wells operating at a total extraction rate of 180 gpm for removal of Cr(VI), and installation of two injection wells for Cr(VI) capable of injecting a total of 110 gpm. The operational duration for Cr(VI) extraction and injection wells is estimated at 5 years.<br>• Installation of 11 extraction wells operating at a total extraction rate of 455 gpm for removal of nitrate, and installation of 13 nitrate plume injection wells capable of injecting a total of 495 gpm. The operational duration for nitrate extraction and injection wells is 10 years.<br>• Installation of one extraction well operating at a total extraction rate of 40 gpm for removal of strontium-90. Co-extraction of Cr(VI) and nitrate may also occur. The operational duration for strontium-90 extraction is 10 years.<br>• Installation of two extraction wells operating at a total extraction rate of 80 gpm for removal of trichloroethene, and installation of one injection well capable of injecting a total of 40 gpm. The operational duration for trichloroethene extraction and injection wells is 10 years. Co-extraction of nitrate also expected.<br>• The actual number and placement of extraction and injection wells, and pumping rates, will be refined during remedial design and may differ from the configurations described.<br>• Remedial process optimization will be used to increase system efficiency, potentially resulting in decreased timeframes for achieving PRGs. Remedial process optimization will be used to adjust extraction and injection rates for each well to better achieve capture efficiency and flow path control. |
| | Ex Situ Treatment | • Ion exchange for Cr(VI), strontium-90, and nitrate above drinking water standards. Separate Cr(VI) IX and nitrate IX trains will treat 180 gpm and 455 gpm, respectively. An IX treatment train capable of treating 40 gpm from the strontium-90 plume will be added as needed, depending upon extracted concentrations of strontium-90. |

Table 9-4. Components for Alternative GW-3-Pump-and-Treat Optimized With Other Technologies

| Media | Component | Description |
|---|---|---|
| | | • A separate air stripping treatment train capable of treating 80 gpm of groundwater extracted from the trichloroethene plume will be used. No offgas treatment is anticipated, based on projected trichloroethene concentrations.<br>• Ex situ treatment operations will continue through the 10-year duration of extraction pumping, with reduced flow rates and shutdown of unit treatment processes as COC plume concentrations reach their respective PRGs.<br>• The actual treatment processes, number of treatment vessels, and their final configuration will be determined during remedial design and may differ from the configuration described, which was developed for cost estimating purposes only. |
| | Operations and Maintenance | • O&M of extraction well network, injection well network, conveyance infrastructure, and above-grade infrastructure will be based on the times for COC concentrations to reach their respective PRGs. |
| | Monitoring Requirements | • Monitoring of strontium-90 for up to 85 years to track the attenuation processes through periodic sampling of the monitoring well network.<br>• Remedy performance monitoring to evaluate the progress and effectiveness of pump-and-treat and in situ treatment to attain PRGs.<br>• MNA and remedy performance monitoring will be defined in the DQO and SAP developed as part of the remedial design.<br>• Monitoring well network will include up to 10 existing aquifer tubes, 38 existing monitoring wells, and assumes installation of 15 new wells to supplement the existing monitoring network.<br>• Monitoring will be performed quarterly at each new well location for the first year to establish baseline conditions, and annually for the next 10 years with a reduction to a biennial frequency thereafter.<br>• Monitoring for existing wells will occur annually for the first 10 years and biennially thereafter. |
| | Remedial Action Timeframe | • Cr(VI) based on 10 µg/L PRG – Cmax: 5 years C90: 5 years.<br>• Cr(VI) based on 48 µg/L PRG – Cmax: 5 years C90: 5 years<br>• Nitrate - Cmax: 75 years C90: 20 years<br>• Strontium-90 – Cmax: 150 years C90: 85 years<br>• Trichloroethene – Cmax: 10 yrs |
| | Compliance Monitoring Requirements | • Annual monitoring will be performed for an additional 5 years after PRGs are initially achieved to confirm that PRGs have been met. |

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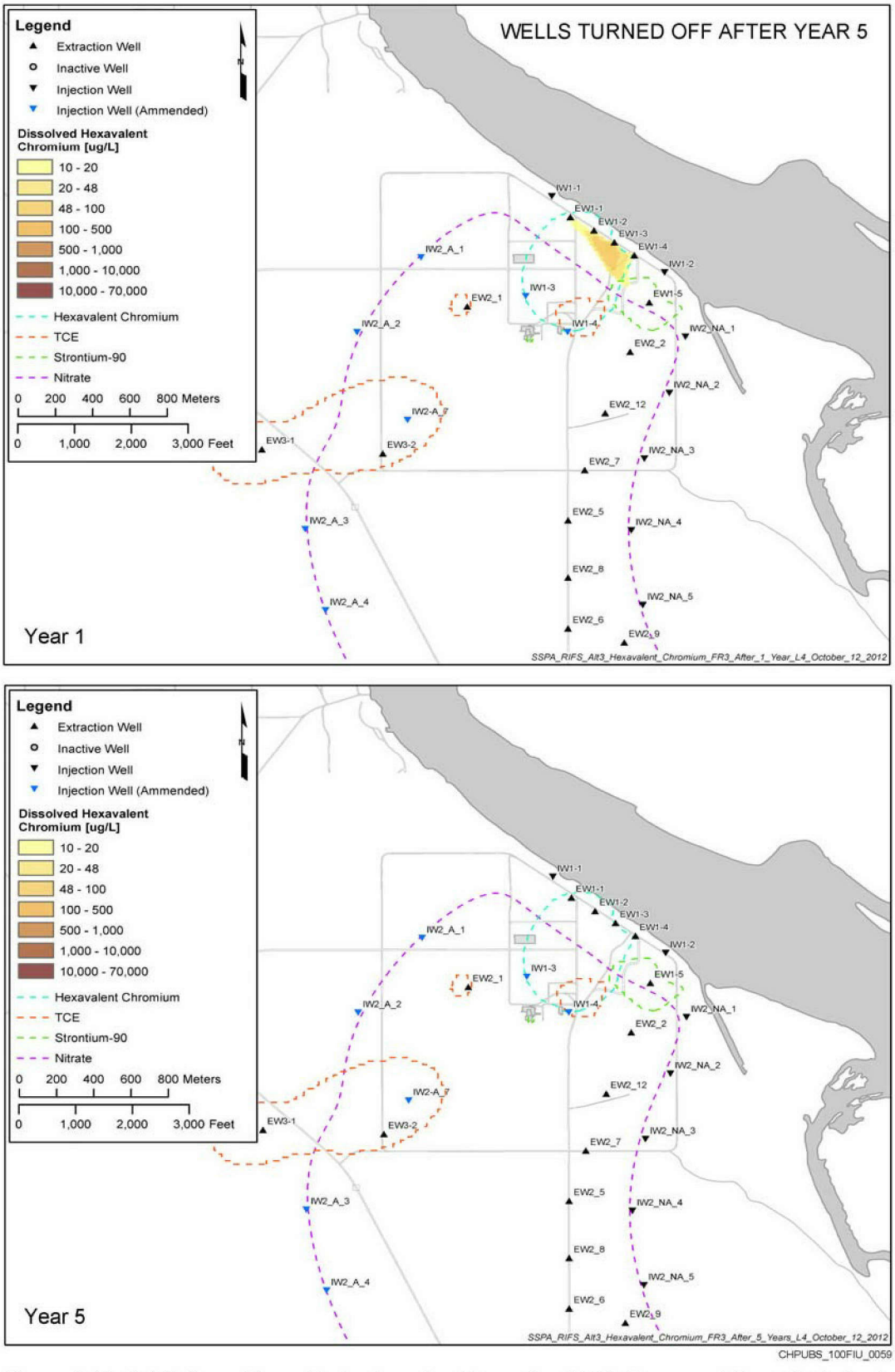


Figure 9-10. Cr(VI) Cmax Plume Projections for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

Figures 9-13 and 9-14 present the Alternative GW-3 groundwater model simulations for the strontium-90 plume at time steps of 1, 5, 10, 15, 20, 25, 50, and 75 years. Because of strontium-90's low mobility, pump-and-treat does not shorten the remediation timeframe significantly. The modeling estimates that strontium-90 concentrations will decline below the 8 pCi/L PRG within 150 years based on the Cmax concentration and 85 years based on the C90 concentration. An O&M duration of 10 years was used for estimating pump-and-treat costs and 75 additional years of MNA costs following cessation of pump-and-treat.

Figure 9-15 presents the Alternative GW-3 groundwater modeling simulation for the trichloroethene plume at time steps of 1, 5, and 10 years. The modeling estimates that trichloroethene concentrations will decline below the 4.9 µg/L PRG within 10 years based on the Cmax concentration. For O&M cost estimating purposes, a timeframe of 10 years was used.

### 9.2.7 Alternative GW-4: Enhanced Pump-and-Treat

This alternative is similar to Alternative GW-3 (see Table 9-5) for the Cr(VI), strontium-90, and trichloroethene plumes but uses additional groundwater extraction wells to accelerate cleanup of the nitrate plume. This alternative uses similar ex situ treatment technologies as employed for many of the 100 Area groundwater interim actions to achieve groundwater protection PRGs within a shorter timeframe. Alternative GW-4 reduces Cr(VI), strontium-90, trichloroethene, and nitrate concentrations through enhanced pump-and-treat. Groundwater pump-and-treat is used to control plume migration through hydraulic containment and to remediate the groundwater plume through extraction and treatment before aquifer reinjection.

Alternative GW-4 consists of a network of extraction and injection wells, conveyance piping and infrastructure, and a central treatment system. The groundwater extraction and injection wells are located to control the groundwater flow path, increase extraction well capture efficiency, and minimize plume migration to the Columbia River. Figure 9-16 shows the extraction and injection well locations for Alternative GW-4, Figure 9-17 the conveyance pipe route, and Figure 9-18 the estimated hydraulic capture zone based on the model simulated pumping rates. The treatment system components for Alternative GW-4 are the same as those described under Alternative GW-3, with the exception of variations in the treatment flow rates and durations, and elimination of substrate injection. Figure 9-19 provides a conceptual process flow schematic for the pump-and-treat system for Alternative GW-4. Table 9-6 provides a summary of the components comprising Alternative GW-4.

Figure 9-20 presents the Alternative GW-4 groundwater model simulations for the Cr(VI) plume at time steps of 1, 5, and 10 years. The modeling estimates that Cr(VI) concentrations will be reduced to concentrations below the 10 µg/L PRG within 5 years based on the Cmax concentration and 5 years based on the C90 concentration. Within the inland portion of the aquifer, Cr(VI) concentrations would be reduced to concentrations less than the 48 µg/L PRG within 5 years based on the Cmax concentration and 5 years based on the C90 concentration. An O&M period of 5 years was used for cost estimating purposes. Although the extraction and injection well configurations are similar, the estimated period to achieve the PRG for Cr(VI) under Alternative GW-4 is slightly longer than Alternative GW-3 because there is no in situ treatment component.

Figure 9-21 presents the Alternative GW-4 groundwater model simulation for the nitrate plume at time steps of 1, 5, 10, and 20 years. The modeling estimates that nitrate concentrations will decline below the 45,000 µg/L PRG within 25 years based on the Cmax concentration and 10 years using the C90 concentration. A pump-and-treat O&M timeframe of 10 years was used for cost estimating purposes.

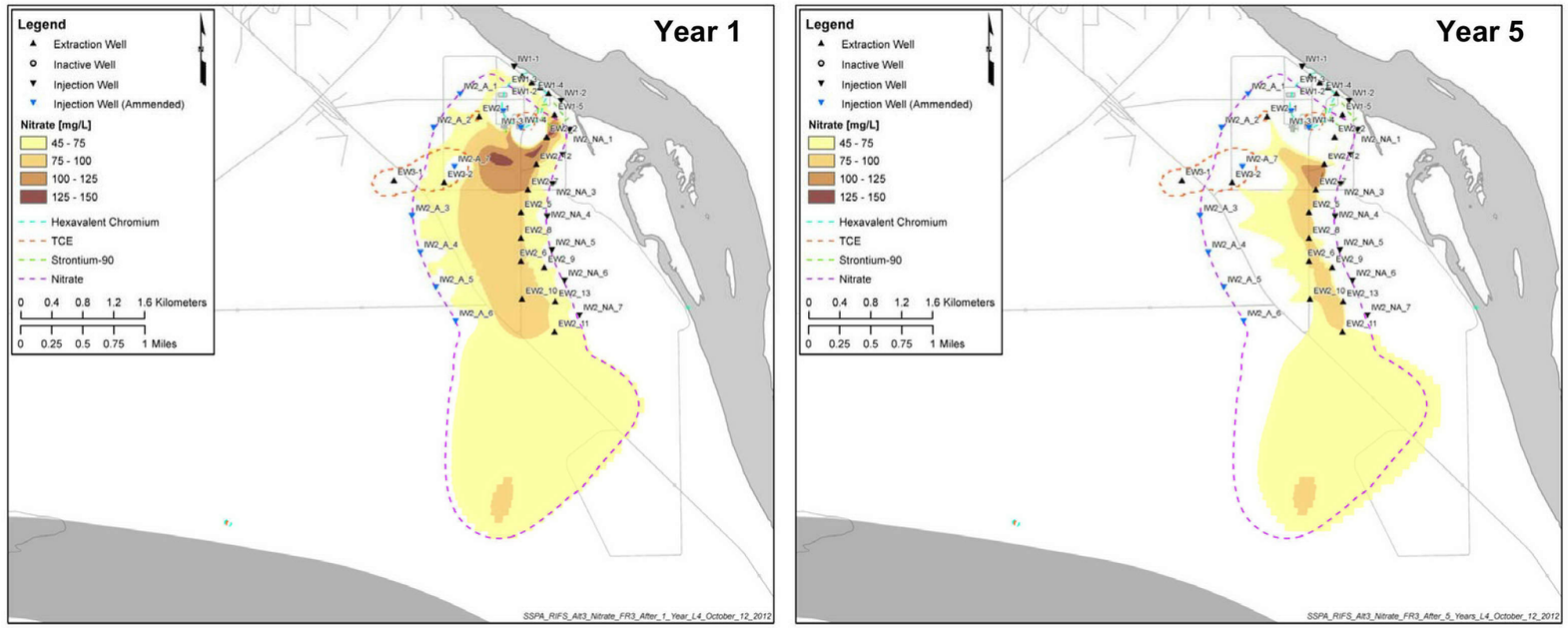


Figure 9-11. Nitrate Cmax Plume Projections for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

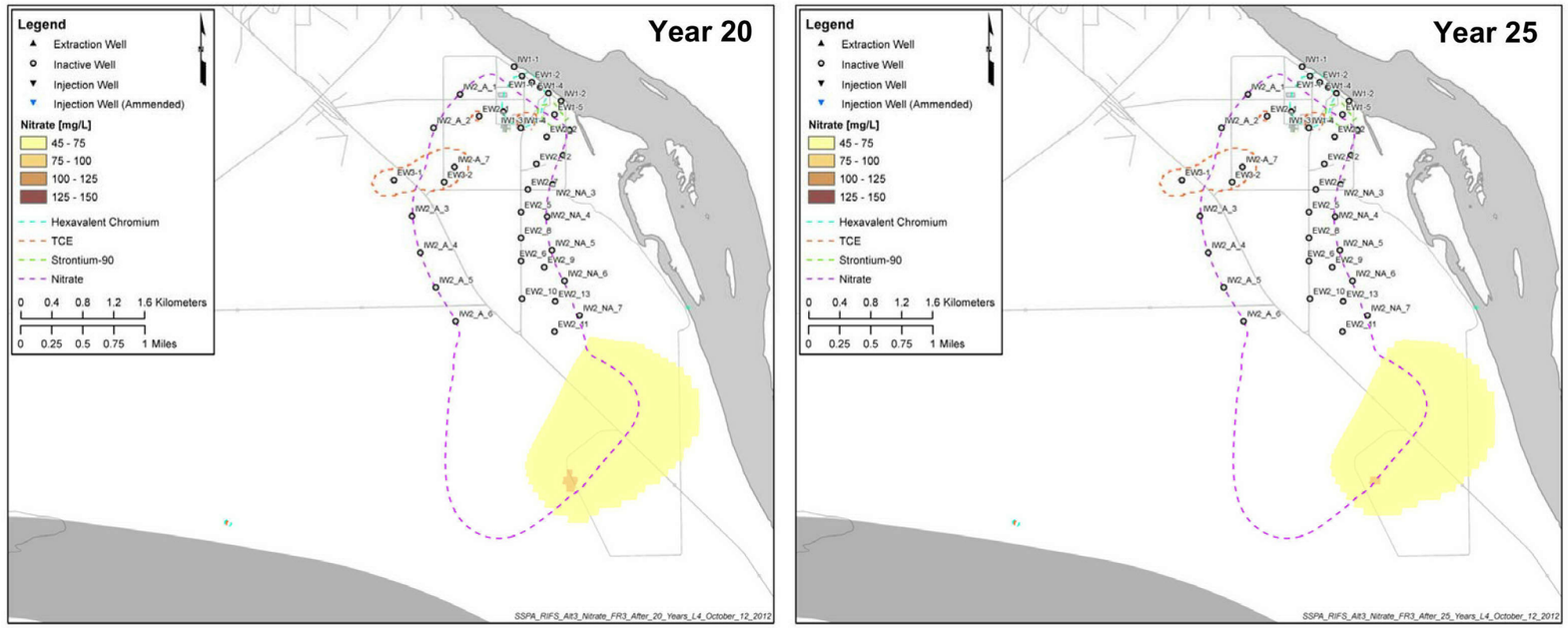


Figure 9-12. Nitrate Cmax Plume Projections for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

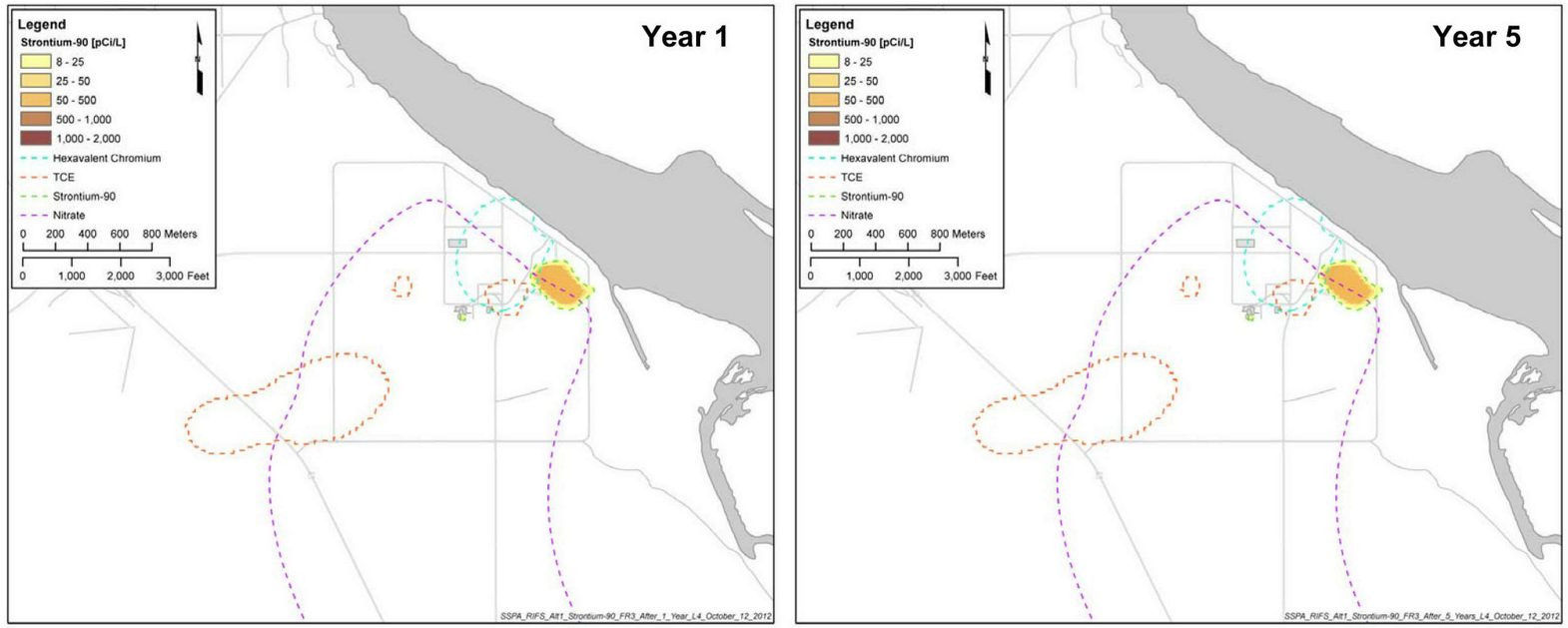


Figure 9-13. Strontium-90 Cmax Plume Projections for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

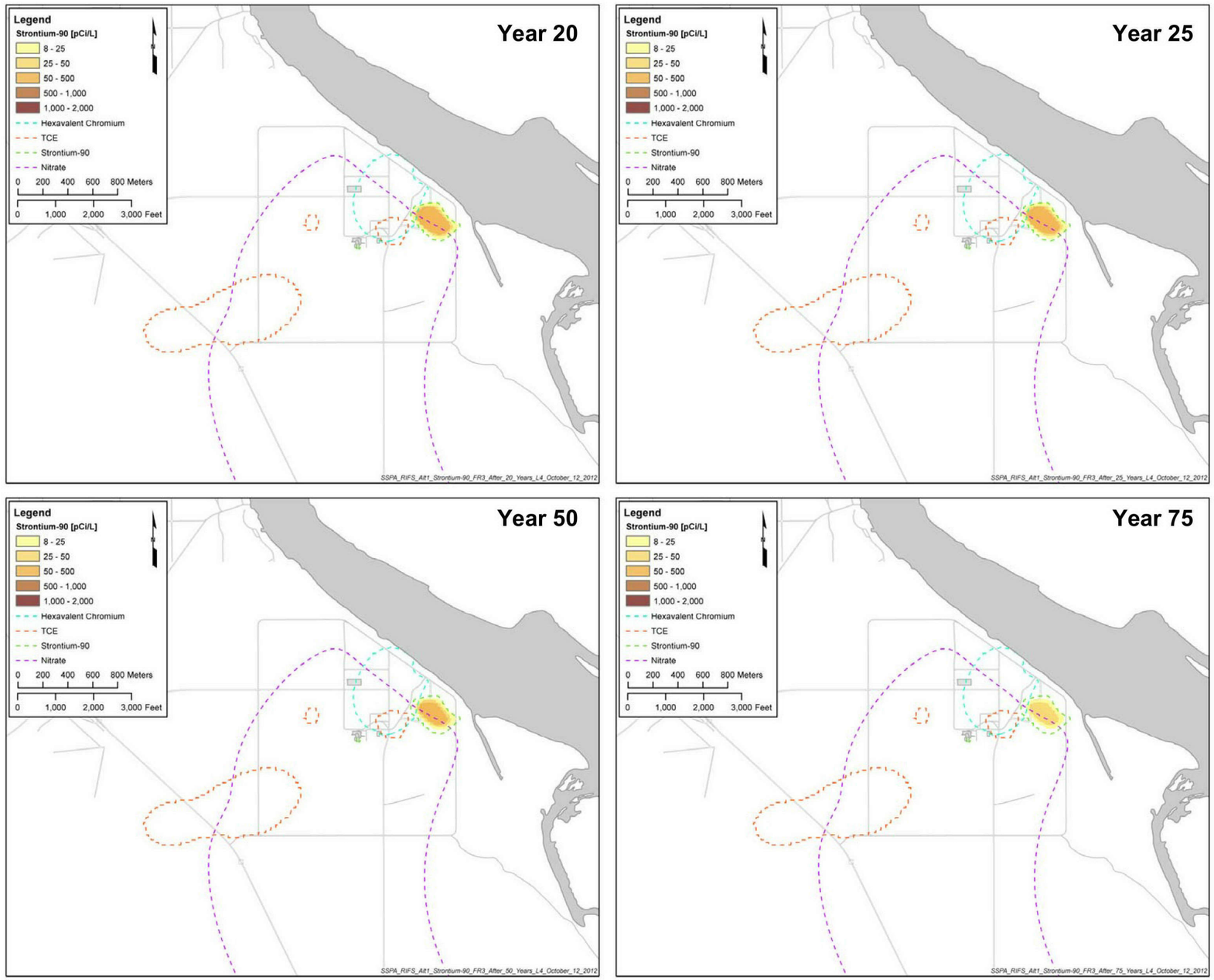


Figure 9-14. Strontium-90 Cmax Plume Projections for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

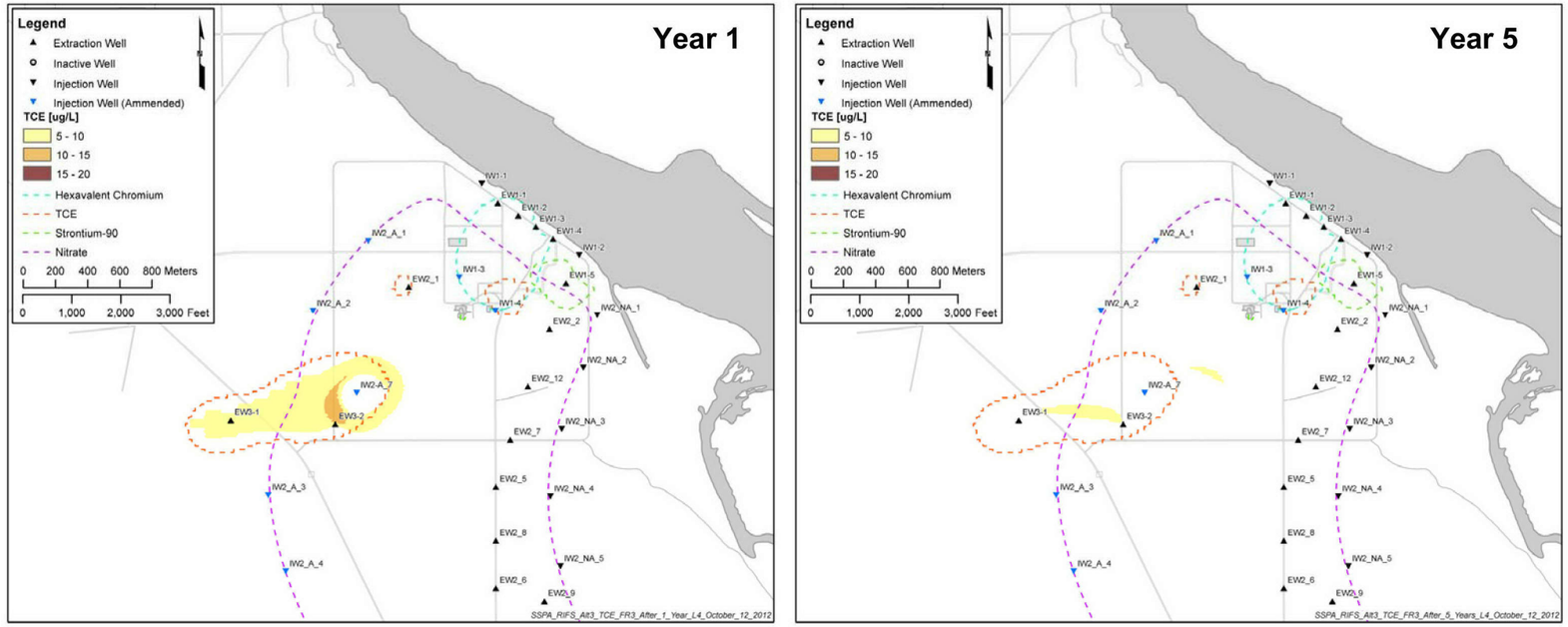


Figure 9-15. Trichloroethene Cmax Plume Projections for Alternative GW-3: Pump and Treat Optimized with Other Technologies

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Figure 9-22 presents the Alternative GW-4 groundwater model simulations for the strontium-90 plume at time steps of 1, 25, 50, and 75 years. The modeling estimates that strontium-90 concentrations will decline below the 8 pCi/L PRG within 150 years based on the Cmax concentration and 85 years using the C90 concentration. The pump-and-treat duration is 10 years, so approximately 75 years of MNA would be required following pump-and-treat operations before the PRG is achieved.

Figure 9-23 presents the Alternative GW-4 groundwater model simulations for the trichloroethene plume at time steps of 1, 5, and 10 years. The modeling estimates that the 4.9 µg/L PRG would be achieved within 10 years based on the Cmax concentration. A pump-and-treat O&M duration of 10 years was used for cost estimating purposes.

## 9.3 Remedial Alternative Screening Evaluation

As discussed in *The Feasibility Study: Development and Screening of Remedial Action Alternatives* (OSWER Directive 9355.3-01FS3), screening of alternatives can be used to provide a preliminary evaluation of alternatives based on effectiveness, implementability, and cost before being carried into the detailed evaluation in Chapter 10. The purpose of this screening step is to eliminate those alternatives that are not effective, implementable, or cost effective. No alternatives were eliminated in the screening evaluation. Consequently, all of the alternatives are carried forward into the detailed evaluation in Chapter 10.

Table 9-5. Comparison of Alternative GW-3 and GW-4 Pump-and-Treat Components

| Component | GW-3: Pump-and-Treat Optimized with Other Technologies | | GW-4: Enhanced Pump-and-Treat | |
|---|---|---|---|---|
| Extraction Wells | 18 | | 24 | |
| Injection Wells | 9 | | 26 | |
| Injection Wells with Substrate Amendment | 9 | | 0 | |
| Total No. of Wells | 36 | | 50 | |
| No. of New Monitoring Wells | 15 | | 15 | |
| Pumping Rate (gpm) | **Years 1-5** | **Years 5-10** | **Years 1-5** | **Years 5-10** |
| | 755 | 635 | 995 | 875-160 |

Table 9-6. Components for Alternative GW-4-Enhanced Pump-and-Treat

| Media | Component | Description |
|---|---|---|
| Groundwater (Additional information on common elements is provided in Section 9.2.1) | ICs | • Maintain existing sitewide ICs (including groundwater use restrictions) already in place under *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41).<br>• ICs are maintained for the duration required to reach PRGs for all COCs (85 years for strontium-90). |
| | MNA | • Monitoring of strontium-90 concentrations to track natural attenuation processes through periodic sampling of the monitoring well network.<br>• Monitoring will be defined in the DQO and SAP developed as part of the RD/RAWP. For cost estimating purposes, it is assumed that monitoring of new wells will be performed quarterly and existing wells sampled annually for the first year to establish baseline conditions, with annual monitoring for years 2 to 10, and biennial monitoring thereafter. |
| | Pump-and-Treat | • Installation of four extraction wells operating at a total extraction rate of 180 gpm for removal of Cr(VI), and installation of four injection wells for Cr(VI) capable of injecting a total of 220 gpm. The operational duration for Cr(VI) extraction and injection wells is 5 years.<br>• Installation of 17 extraction wells operating at a total extraction rate of 695 gpm for removal of nitrate, and installation of 21 injection wells for nitrate capable of injecting a total of 695 gpm. The operational duration for nitrate extraction and injection wells is 10 years.<br>• Installation of 1 extraction well operating at a rate of 40 gpm for removal of strontium-90. The operational duration for strontium-90 extraction is 10 years.<br>• Installation of 2 extraction wells operating at a total extraction rate of 80 gpm for removal of trichloroethene, and installation of 1 injection well capable of injecting a total of 40 gpm. The operational duration for trichloroethene extraction and injection wells is 10 years.<br>• The actual number and placement of extraction and injection wells, and pumping rates, will be refined during remedial design and may differ from the configurations described above.<br>• Remedial process optimization will be used to increase system efficiency, potentially resulting in decreased timeframes for achieving PRGs. Remedial process optimization will be used to adjust extraction and injection rates for each well to better achieve capture efficiency and flow path control. |
| | Ex Situ Treatment | • Ion exchange for Cr(VI), strontium-90, and nitrate above drinking water standards. Separate Cr(VI) IX and nitrate IX trains will treat 180 gpm and 695 gpm, respectively. An IX treatment train capable of treating 40 gpm will be added as needed depending upon extracted concentrations of strontium-90.<br>• A separate air stripping treatment train capable of treating 80 gpm of groundwater extracted from the trichloroethene plume will be used. No offgas treatment is anticipated based on projected trichloroethene concentrations.<br>• Ex situ treatment operations will continue through the 10-year duration of extraction pumping, with reduced flow rates and shutdown of unit treatment processes as COCs reach their respective PRGs.<br>• The actual treatment processes, number of treatment vessels, and their final configuration will be determined during remedial design and may differ from the configuration described above which was developed for cost estimating purposes only. |

Table 9-6. Components for Alternative GW-4-Enhanced Pump-and-Treat

| Media | Component | Description |
|---|---|---|
| | Operations and Maintenance | • O&M of the extraction well network, injection well network, conveyance infrastructure, and ex situ treatment system will be performed over the duration required for all COCs to fall below their respective PRGs. |
| | Monitoring Requirements | • Monitoring of strontium-90 for up to 75 years following cessation of pump-and-treat to track natural attenuation processes through periodic sampling of the monitoring well network.<br>• Performance monitoring for Cr(VI), strontium-90, trichloroethene, and nitrate for up to 10 years to evaluate the progress and effectiveness of pump-and-treat to attain PRGs.<br>• Remedy performance monitoring will be defined in the DQO and SAP developed as part of the remedial design.<br>• Monitoring well network will include up to 10 existing aquifer tubes, 38 existing monitoring wells and assumes installation of 15 new wells to supplement the existing monitoring network.<br>• Performance monitoring will be performed quarterly for the duration of pump-and-treat operations. |
| | Remedial Action Timeframe | • Cr(VI) based on 10 µg/L PRG – Cmax: 5 years C90: 5 years.<br>• Cr(VI) based on 48 µg/L PRG – Cmax: 5 years C90: 5 years<br>• Nitrate – Cmax: 25 years C90: 10 years<br>• Strontium-90 – Cmax: 150 years C90: 85 years<br>• Trichloroethene – Cmax: 10 years |
| | Compliance Monitoring Requirements | • Annual monitoring will be performed for an additional 5 years after PRGs are initially achieved to confirm that PRGs have been met. |

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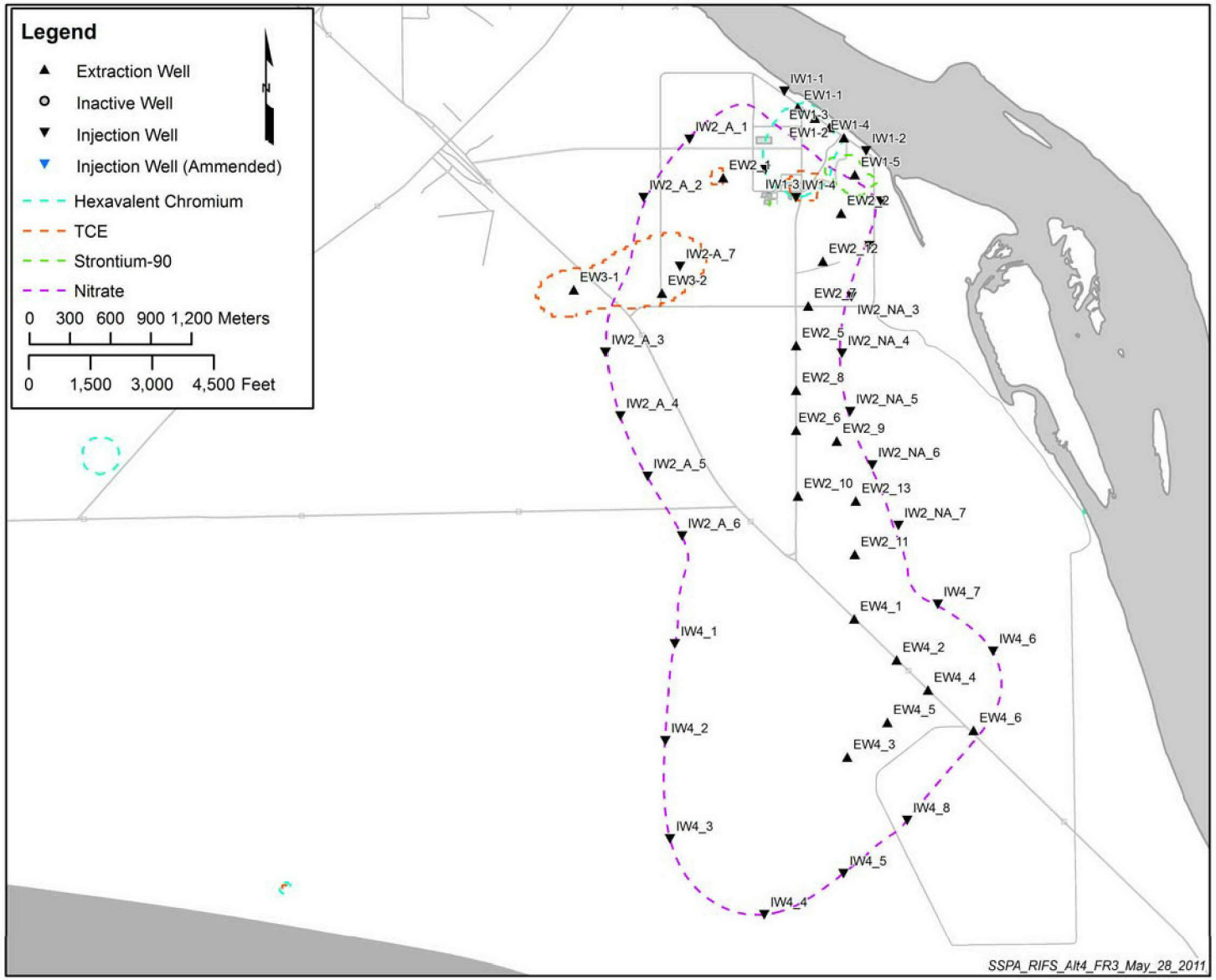


Figure 9-16. Extraction and Injection Well Locations for Alternative GW-4: Enhanced Pump-and-Treat

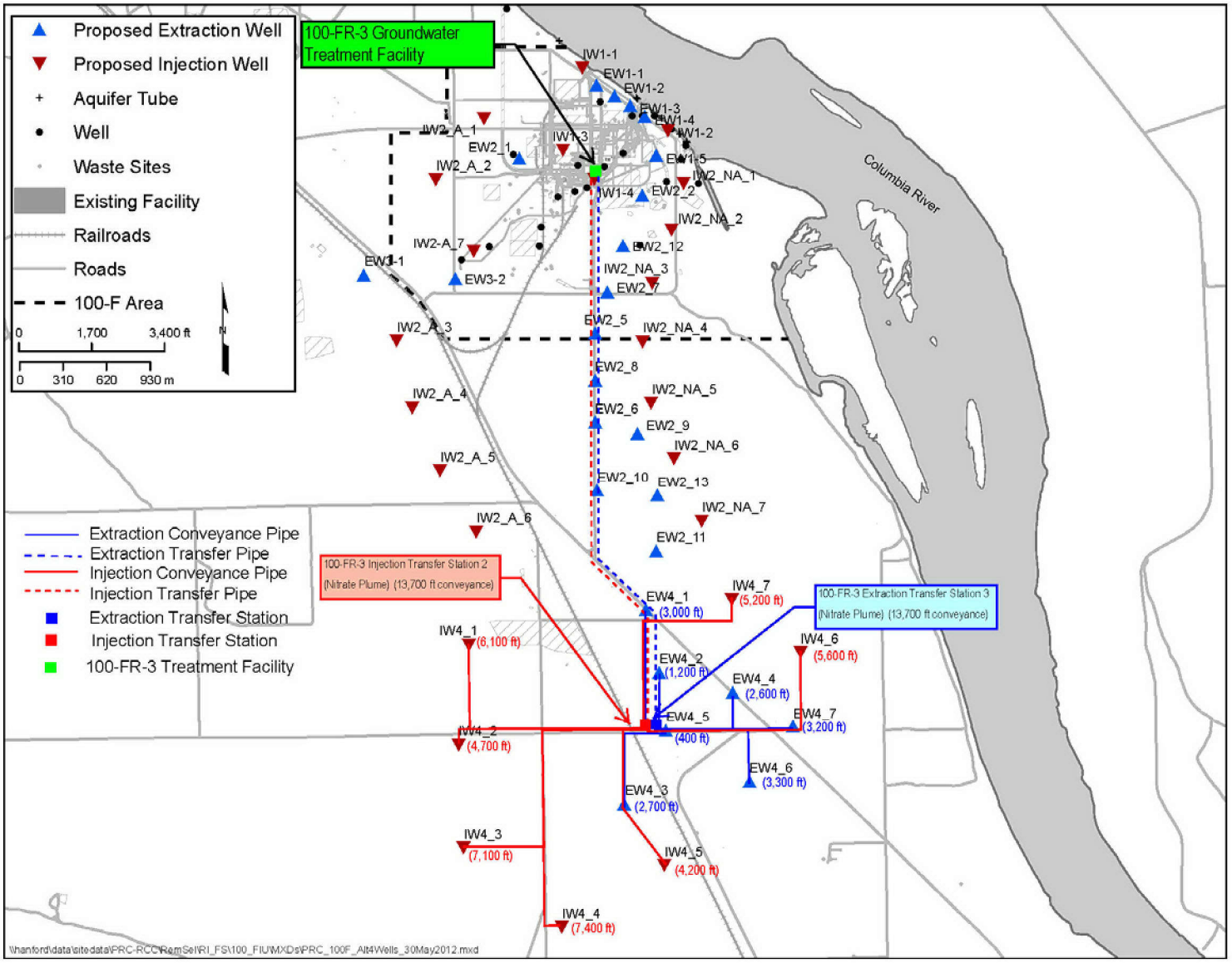


Figure 9-17. Conveyance Piping Layout for Alternative GW-4: Enhanced Pump-and-Treat

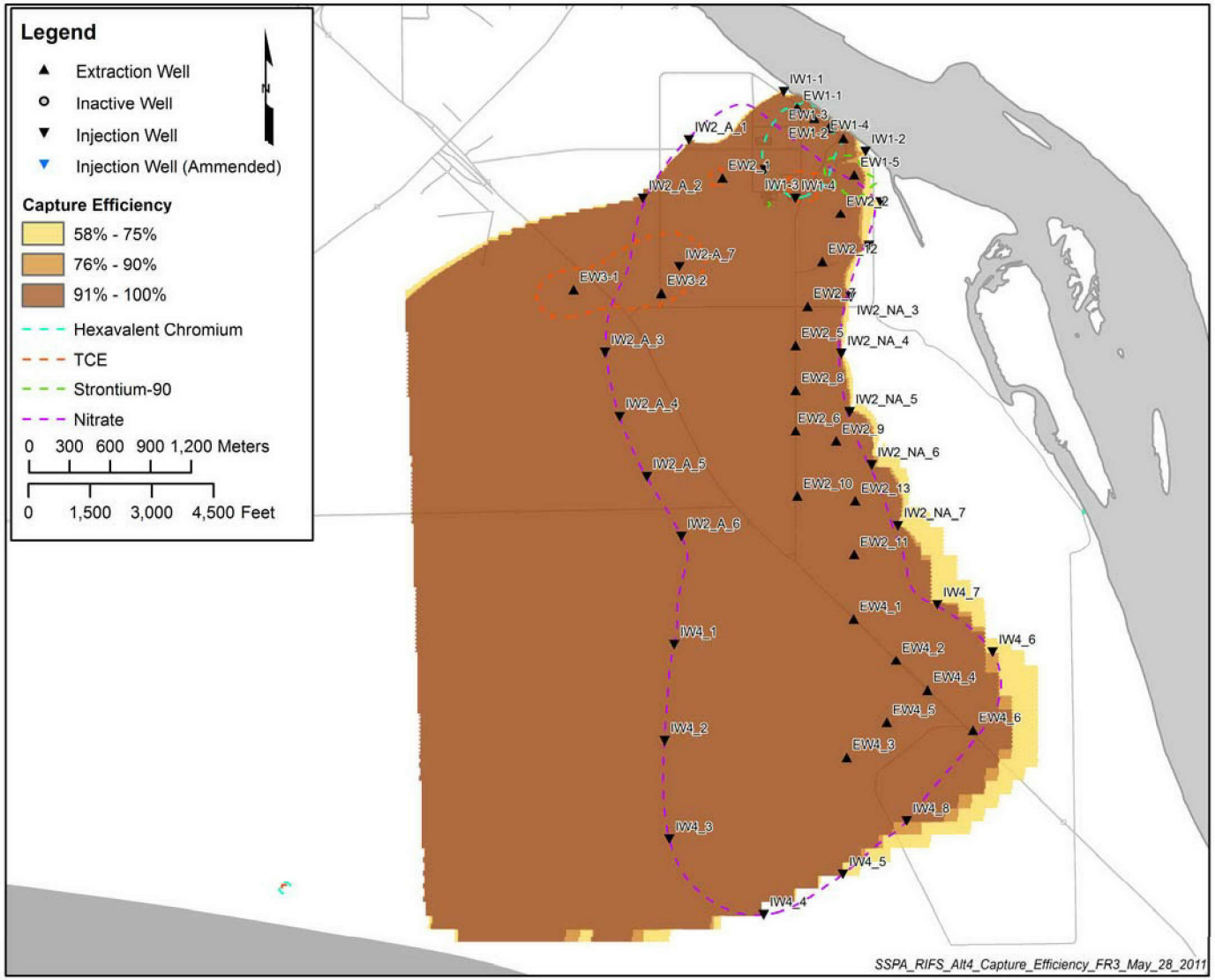


Figure 9-18. Hydraulic Capture Area for Alternative GW-4: Enhanced Pump-and-Treat

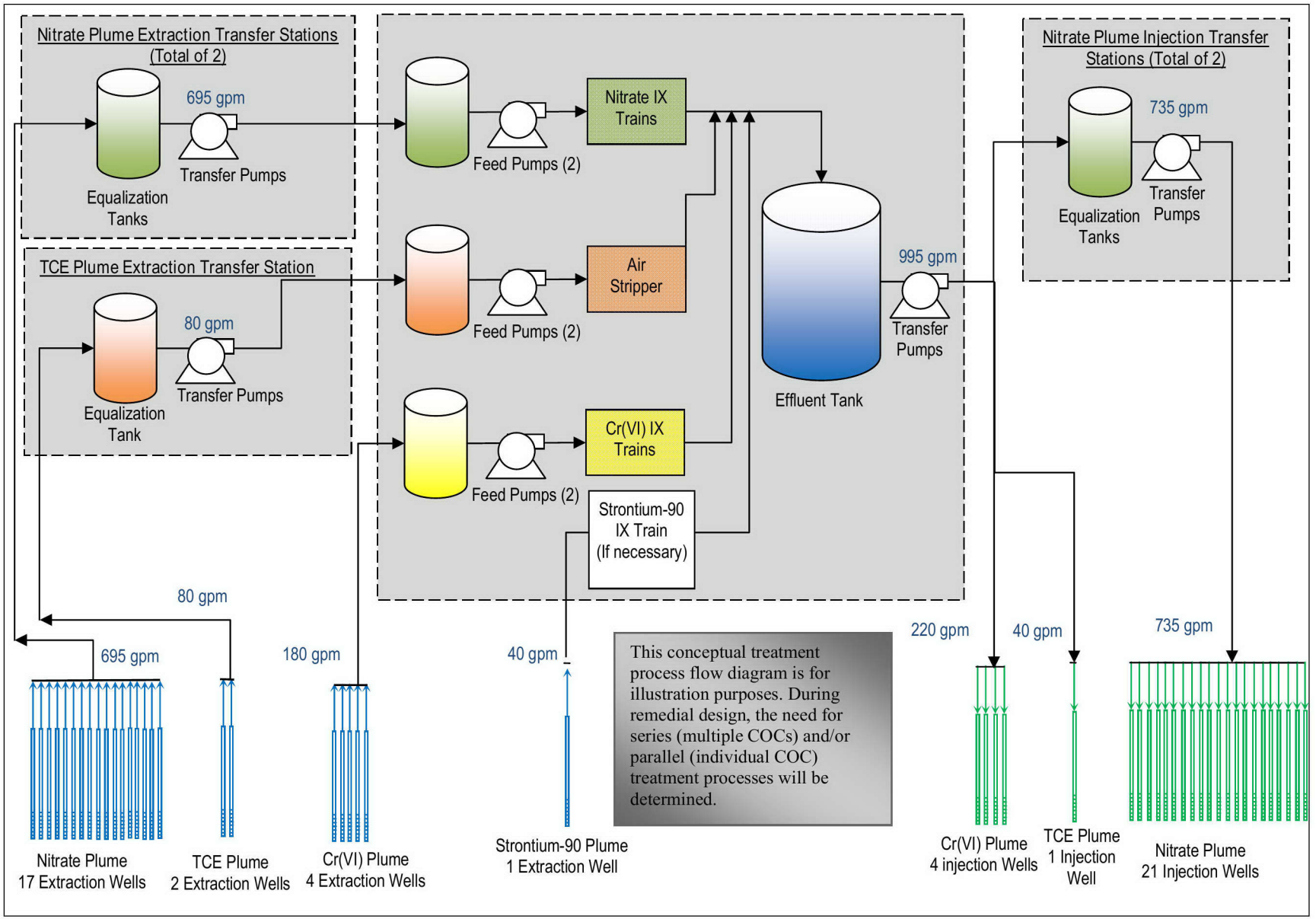


Figure 9-19. Conceptual Process Flow Diagram for Alternative GW-4: Enhanced Pump-and-Treat

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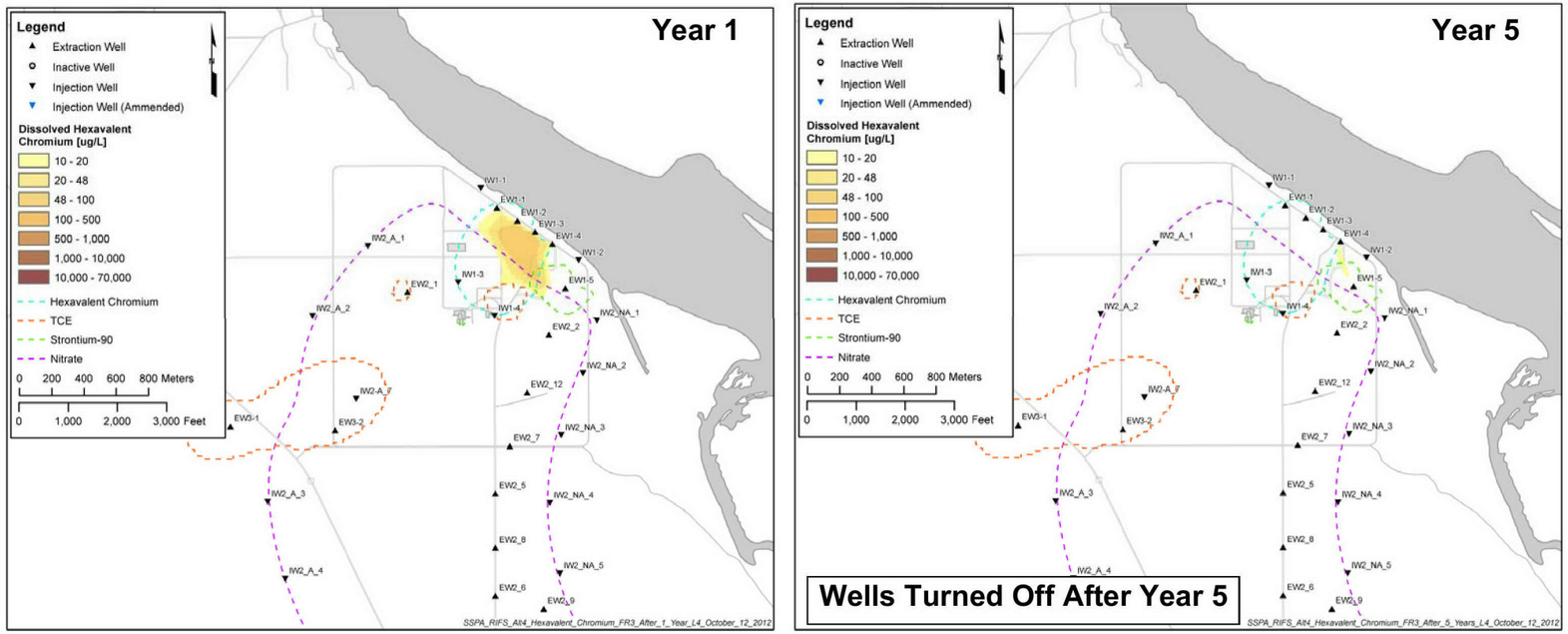


Figure 9-20. Cr(VI) Cmax Plume Projections for Alternative GW-4: Enhanced Pump-and-Treat

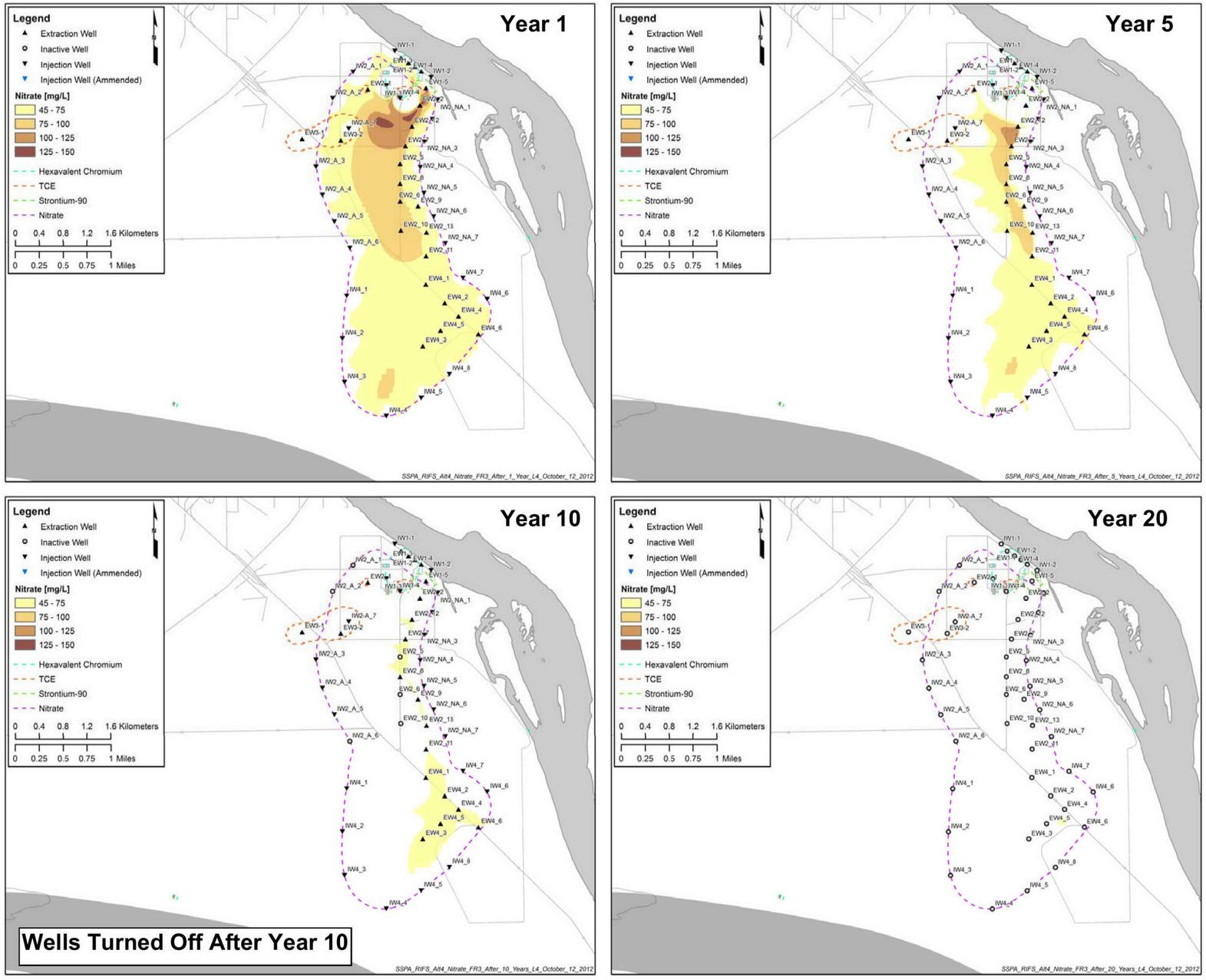


Figure 9-21. Nitrate Cmax Plume Projections for Alternative GW-4: Enhanced Pump-and-Treat

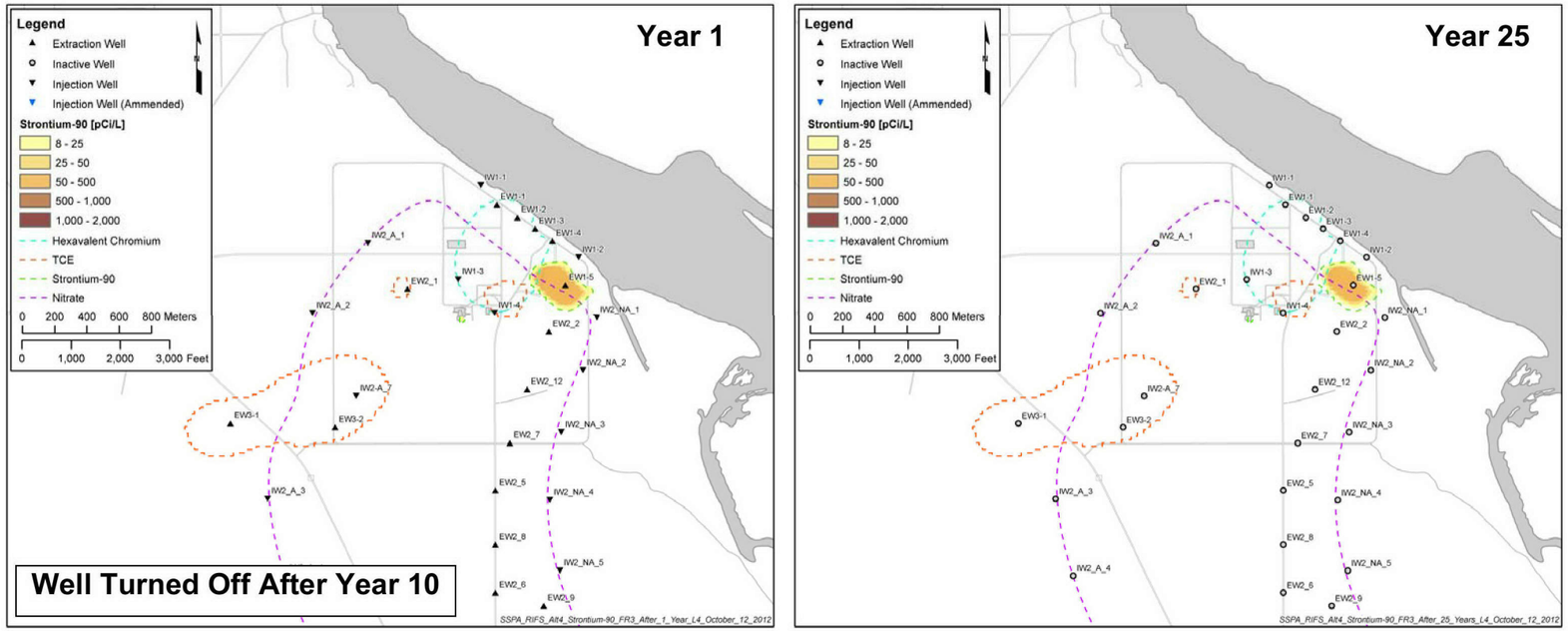


Figure 9-22. Strontium-90 Cmax Plume Projections for Alternative GW-4: Enhanced Pump-and-Treat

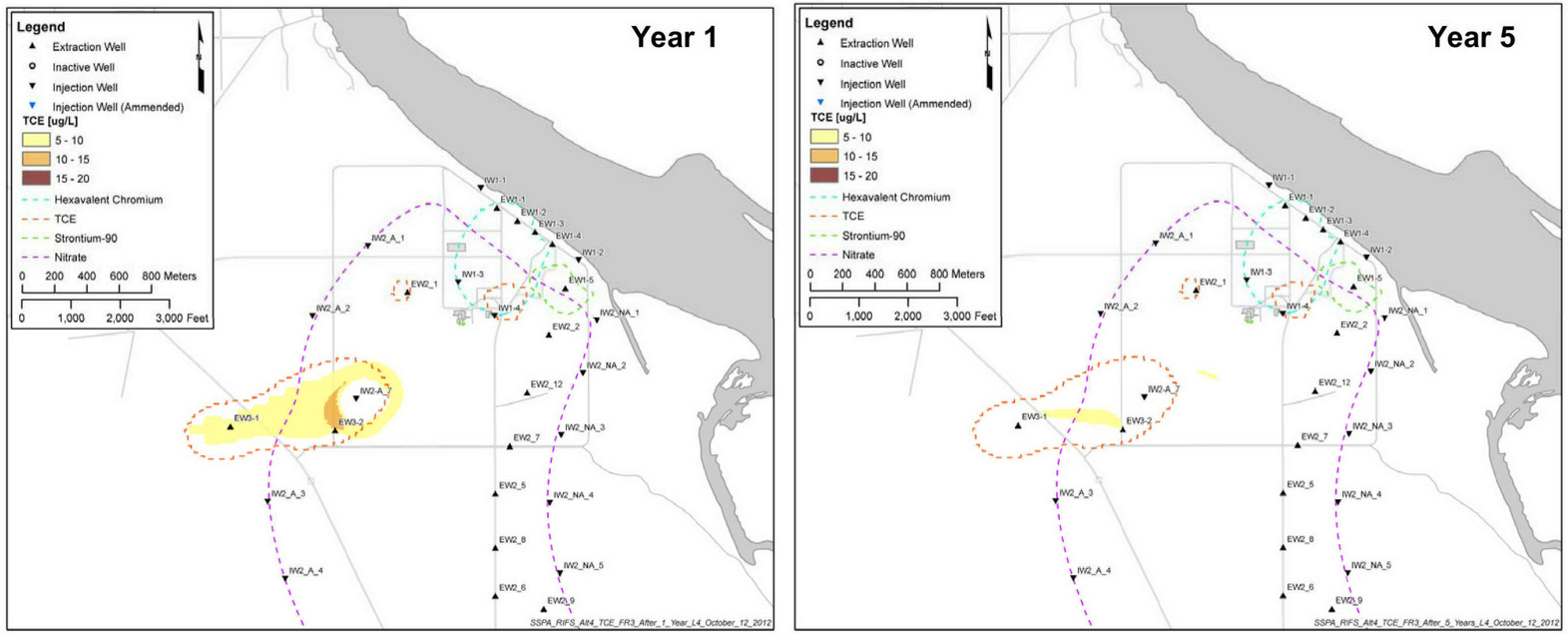


Figure 9-23. Trichloroethene Cmax Plume Projections for Alternative GW-4: Enhanced Pump-and-Treat

# 10 Detailed Analysis of Alternatives

This chapter presents a detailed analysis of the remedial action alternatives developed for waste sites and groundwater at 100-F/IU. This analysis follows the development of alternatives presented in Chapter 9 and precedes the Proposed Plan, which will identify the preferred alternative. The remedial action alternatives are evaluated against seven of the nine CERCLA criteria described in the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(9)]).

The CERCLA evaluation criteria are presented in Section 10.1, and each of the remedial action alternatives evaluated individually and comparatively against the CERCLA criteria in Sections 10.2 and 10.3, respectively. The remaining two criteria, which are identified as modifying criteria, are formally assessed during preparation of the Proposed Plan (State Acceptance) and following review of public and stakeholder comments (Community Acceptance) on the Proposed Plan. The purpose of the detailed and comparative analysis is to develop the information necessary to recommend a preferred alternative in a Proposed Plan. Following public and stakeholder review of the Proposed Plan, EPA and DOE will select final remedial action alternatives for soil and groundwater for 100-F/IU and identify the selected alternative in the ROD.

*Highlights*

- Alternatives S-1: No Action and GW-1: No Action do not satisfy the threshold criteria for protection of HHE. Therefore, these alternatives were not evaluated against the balancing criteria.
- Alternative S-2: satisfies the threshold criteria and performs well against the balancing criteria.
- The total estimated present worth cost for Alternative S-2 is $20.6 million.
- Alternatives GW-2, GW-3, and GW-4 perform very well for long-term effectiveness. Alternative GW-4 performs very well for reduction of toxicity, mobility, or volume through treatment, whereas Alternatives GW-3 and GW-2 are expected to perform moderately well and less well, respectively.
- Alternatives GW-2, GW-3, and GW-4 are expected to perform moderately well relative to short-term effectiveness. Alternative GW-2 is expected to perform very well relative to implementability, while Alternatives GW-3 and GW-4 are expected to perform less well and moderately well, respectively.
- The total estimated present worth cost for Alternative GW-2 is $33.5 million, Alternative GW-3 is $182 million, and Alternative GW-4 is $200 million.
- The analysis provides enough information to recommend a preferred alternative in the Proposed Plan.

## 10.1 Description of CERCLA Evaluation Criteria

The nine CERCLA evaluation criteria upon which the detailed and comparative evaluations are based are designed to enable the analysis of each alternative to address the statutory, technical, and policy considerations necessary for selecting a final remedial alternative. These evaluation criteria (Table 10-1) provide the framework for conducting the detailed analysis of alternatives and selecting an appropriate remedial action. Table 10-1 provides the more detailed questions that CERCLA guidance recommends to address these criteria. The performance or acceptability of each alternative is first evaluated individually, so relative strengths and weaknesses may be identified (Section 10.2). Section 10.3 compares each alternative relative to the CERCLA criteria.

The evaluation criteria are divided into three categories (threshold, balancing, and modifying) based on the function of each category in the remedy selection process. The NCP ("Remedial Investigation/ Feasibility Study and Selection of Remedy" [40 CFR 300.430(f)]) states that the first two criteria—protection of HHE and compliance with ARARs—are "threshold criteria" that must be met by the selected remedial action unless a waiver can be granted under CERCLA ("Cleanup Standards" [Section 121(d)(4)]).

Table 10-1. Summary of CERCLA Criteria

| | |
|---|---|
| **Threshold Criteria** | |
| Overall Protection of HHE | The assessment against this criterion describes how the alternative, as a whole, achieves and maintains protection of human health and the environment. |
| Compliance with ARARs | The assessment against this criterion describes how the alternative complies with ARARs, or if a waiver is required and how it is justified. The assessment also addresses other information from advisories, criteria, and guidance that the lead and support agencies have agreed is "to be considered." |
| **Balancing Criteria** | |
| Long-Term Effectiveness and Permanence | The assessment of alternatives against this criterion evaluates the long-term effectiveness of alternatives in maintaining protection of human health and the environment after response objectives have been met. |
| Reduction of Toxicity Mobility or Volume (TMV) through Treatment | The assessment against this criterion evaluates the anticipated performance of the specific treatment technologies an alternative may employ. |
| Short-Term Effectiveness | The assessment against this criterion examines the effectiveness of alternatives in protecting human health and the environment during the construction and implementation of a remedy until response objectives have been met. |
| Implementability | This assessment evaluates the technical and administrative feasibility of alternatives and the availability of required goods and services. |
| Cost | This assessment evaluates the capital cost, and the operation and maintenance (O&M) costs of each alternative. |
| **Modifying Criteria** | |
| State Acceptance* | This assessment reflects the state's (or support agency's) apparent preferences among or concerns about alternatives. |
| Community Acceptance* | This assessment reflects the community's apparent preferences among or concerns about alternatives. |

* These criteria are not assessed in this report.

The five "balancing criteria" represent technical considerations, upon which the detailed analysis is primarily based, and include long-term effectiveness and permanence; reduction of toxicity, mobility, or volume (TMV) through treatment; short-term effectiveness; implementability; and cost. The preferred alternative will be the alternative that is protective of HHE, is ARAR-compliant, and performs best relative to the balancing criteria factors.

The final two criteria—State and Community Acceptance—are "modifying criteria." State Acceptance is formally assessed during preparation of the Proposed Plan, and Community Acceptance is formally assessed following review of Tribal Nations, public, and stakeholder comments on the Proposed Plan. Community and State Acceptance are not addressed in the FS. Based on information from public participation, EPA and DOE may modify some aspects of the preferred alternative or decide that another alternative is more appropriate.

### 10.1.1 Overall Protection of Human Health and the Environment

Overall protection of HHE is the primary requirement that remedial actions must meet under CERCLA. This evaluation criterion is an assessment of whether an alternative achieves and maintains adequate protection of HHE, in both the short-term and the long-term, from unacceptable risks posed by contaminants. Alternatives are protective by eliminating, reducing, or controlling exposure through the applicable exposure pathways (NCP, "Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(2)(i)]). Overall protection of HHE draws on the assessments of the other evaluation criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

### 10.1.2 Compliance with Applicable or Relevant and Appropriate Requirements

Compliance with ARARs is the second threshold criterion of remedy selection. This evaluation criterion is used to determine whether an alternative meets the federal, state, and local ARARs identified for the site, as presented in Chapter 8. Alternatives are assessed to determine whether they meet ARARs and other requirements, or if a basis exists for invoking one of the waivers cited in the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(f)(l)(ii)(C)]).

### 10.1.3 Long-Term Effectiveness and Permanence

Alternatives are assessed for the long-term effectiveness and permanence they afford, along with the degree of certainty that the alternative will prove successful in meeting the RAOs. The following factors are considered in this assessment:

- The magnitude of residual risk from untreated waste or treatment residuals remaining at the conclusion of the remedial action, including the TMV. The magnitude of residual risk is defined as the risk remaining from untreated waste or treatment residuals after remediation.
- The adequacy and reliability of controls that can be used to manage treatment residuals or residual contamination that remains at the site, such as containment systems or ICs. For example, this factor addresses uncertainties associated with land disposal for providing long-term protection from treatment residuals; the assessment of the potential need to replace technical components of the alternative, such as a treatment system; and the potential exposure pathways and risks posed if the remedial action needs to be replaced.

### 10.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion concerns the statutory preference for remedies that employ treatment to reduce the TMV of the hazardous substances. This preference is satisfied when treatment is used to reduce the principal threats at a site through destruction of toxic contaminants, reduction in contaminant mobility, or reduction of the total mass or total volume of contaminated media. This criterion is specific to evaluating how the treatment reduces TMV.

The degree to which the alternative employs treatment that reduces TMV will be assessed. The following factors are considered for the evaluation:

- The treatment process and the materials treated
- The amount of hazardous substances, pollutants, or contaminants that will be destroyed or treated
- The degree of expected reduction in TMV of the waste as a percentage of reduction
- The degree to which the treatment is irreversible

- The type and quantity of residuals that will remain following treatment, taking into consideration the persistence, toxicity, mobility, and propensity of hazardous substances and their constituents to bioaccumulate
- The degree to which treatment reduces the inherent hazards posed by the principal threats

### 10.1.5 Short-Term Effectiveness

This criterion focuses on short-term effects of the remedial alternatives by examining the effectiveness of alternatives in protecting HHE during the construction and implementation phase until RAOs are met. As outlined by the CERCLA guidance, this criterion includes four analysis factors:

- Protection of the community during remedial actions (e.g., dust from excavations and transportation of hazardous materials)
- Protection of workers during remedial actions
- Potential adverse environmental impacts (e.g., waste and generation of greenhouse gas [GHG] emissions) and the effectiveness and reliability of mitigating measures
- Time until RAOs are achieved[1]

### 10.1.6 Implementability

The implementability criterion relates to the technical and administrative feasibility of executing an alternative and the availability of various services and materials required during its implementation. The ease or difficulty of implementing the alternative is assessed by considering the following types of factors, as appropriate:

- Technical feasibility, including the technical difficulties and unknowns associated with constructing and operating the technology, the reliability of the technology, the ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy
- Administrative feasibility, including activities requiring coordination with other agencies, and the ability and time needed to obtain any necessary approvals and permits for offsite actions
- Availability of required services, personnel, resources, technologies, and materials necessary to construct and operate the alternative

### 10.1.7 Cost

The cost estimate for each remedial alternative typically includes the following items:

- Remedial design costs including preparation of design drawings and specifications, construction bid documents, the RD/RAWP, and the interim remedial action report, which is typically calculated as a percent of the capital cost
- Remedial alternative construction costs, including construction management, capital equipment, general and administrative costs, and construction subcontract costs and fees

[1] For the groundwater alternatives evaluated herein, the time needed to achieve RAOs is based on the model estimated timeframe for COC concentrations to attain their respective PRG based on the C90 concentration, except for TCE where the Cmax concentration was used, as described in Section 9.1.

- Estimated operating, maintenance, and remedy performance monitoring and reporting costs for the duration of the remedial action
- Equipment replacement costs
- Project management
- Oversight costs and preparation of CERCLA five-year reviews until RAOs are achieved

The evaluation of the cost criterion is based on a comparison of the estimated present worth values for each alternative. Actual costs will depend on the final scope and design of the selected remedial action, the implementation schedule, competitive market conditions, and other variables. However, these factors, equally applicable to all alternatives, are not expected to affect the relative cost differences between alternatives.

Life cycle costs are presented as net present worth values. The net present worth cost estimating method establishes a common baseline for evaluating costs that occur during different periods, thus allowing for direct cost comparisons between different alternatives. The net present worth value represents the dollars that would need to be set aside today, at the defined interest rate, to ensure that funds would be available in the future, as they are needed to implement the remedial action alternative.

Net present worth costs were estimated using the real discount rate published in Appendix C ("Discount Rates for Cost-Effectiveness, Lease Purchase, and Related Analyses") of "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs" (OMB Circular A-94), effective through December 2012.

The cost estimates are based on specific response action scenarios and assumptions. Sensitivity analyses were not performed to quantify the potential effect of changing key parametric assumptions.

The cost estimates were prepared in accordance with *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study* (EPA 540-R-00-002), along with Cost Estimating Guide (DOE G 430.1-1). The cost estimates are for comparison purposes and are prepared to meet the -30 to +50 percent range of accuracy recommended in CERCLA RI/FS Guidance (EPA/540/G-89/004). The cost estimate details, uncertainties, and supporting information are included in *Environmental Cost Estimate for 100 FIU Vadose Zone and Groundwater RI/FS* (ECE-100FR111-00010) in Appendix K.

In addition to costs associated with specific alternatives, there are programmatic and sitewide costs associated with ICs and CERCLA five-year reviews. The estimated costs for providing the sitewide or programmatic ICs, including site access; personnel badging; real estate and deeds; warning signs along the Columbia River bank and other access points; maintaining a current sitewide IC plan; and controls for excavating soil, accessing and using groundwater, and restricting irrigation, are also provided.

The programmatic ICs costs are projected for the next 150 years. In 2068, ICs costs are reduced by 50 percent to reflect removal of the 100 Area reactors, as the more active programmatic controls, like site access, would be likewise reduced.

The total non-discounted cost for the ICs for 150 years is estimated at $563,000,000 for the Hanford Site (about $26,000,000 per ROD). The total discounted cost for the ICs at Hanford are estimated at $221,000,000. For the purposes of estimating cost for the 100-F/IU OUs, the proportional cost is $10,000,000.

The total non-discounted cost for the five-year reviews for 150 years is estimated to be $14,000,000 (about $630,000 per ROD). The TPA (Ecology et al., 1989a) currently identifies 22 CERCLA RODs, so each ROD would be allocated an equal portion of the CERCLA Five-Year Review cost. The total discounted cost for the five-year reviews for 150 years is estimated to be $4,000,000 (about $190,000 per

ROD). Cost estimates for programmatic ICs and five-year reviews are in *Institutional Controls Cost Apportioned by ROD Groups* (ECF-HANFORD-12-0067) in Appendix K.

## 10.2 Individual Analysis of Alternatives

This section evaluates each of the remedial action alternatives defined in Chapter 9 against the CERCLA threshold and balancing criteria described in Section 10.1. Criteria evaluation details for the remedial alternatives are documented in tabular form. The ratings provided are based on the following three levels:

★★★ = Expected to perform very well against the criterion with minimal disadvantages or uncertainties
★★☆ = Expected to perform moderately well against the criterion but with some disadvantages or uncertainties
★☆☆ = Expected to perform less well against the criterion with more disadvantages or uncertainty

### 10.2.1 Waste Site Alternatives

This section presents the evaluation of alternatives for the waste sites. The alternatives retained from the preliminary screening conducted in Section 9.3 included:

- S-1: No Action
- S-2: RTD

*Alternative S-1: No Action.* The NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]) requires consideration of a No Action Alternative to serve as a baseline for evaluating other remedial action alternatives. The No Action Alternative is retained throughout the FS process. As described in Chapter 9, this alternative presumes all ongoing site- related activities, including existing ICs and planned interim actions (with the possible exception of backfilling any open excavations), would cease by December 2012. Because all future site-related activities would be discontinued, no costs are associated with implementation of this alternative.

Evaluation of the No Action Alternative against the CERCLA threshold criteria (Table 10-2) indicates that this alternative does not protect human health nor does it comply with ARARs under unrestricted use/unrestricted exposure assumptions. Given that No Action fails the threshold criteria established in NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR300.430(f)]), information regarding the performance of this alternative with respect to the balancing criteria is not included.

Table 10-2. CERCLA Evaluation Summary for Alternative S-1: No Action

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Overall Protection of HHE** | No | ***Not expected to be protective of HHE***<br>RAOs will not be achieved.<br>Potential for exposure to human and ecological receptors and potential for contaminants to leach to groundwater may remain at the waste sites. |
| **Compliance with ARARs** | No | ***Is not compliant***<br>Since there is no action, ARARs for waste sites will not be met. |

Table 10-2. CERCLA Evaluation Summary for Alternative S-1: No Action

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Long-term Effectiveness and Permanence** | Not Applicable (N/A) | Alternative S-1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed. |
| **Reduction of TMV through Treatment** | N/A | Alternative S-1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed. |
| **Short-term Effectiveness** | N/A | Alternative S-1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed. |
| **Implementability** | N/A | Alternative S-1 fails threshold criteria. Therefore, an evaluation against the balancing criteria was not performed. |
| **Cost** | $ 0 | Alternative S-1has no components, therefore, there is no cost. |

*Alternative S-2: RTD.* This alternative uses RTD for waste site contamination to achieve RAOs, building off ongoing and previously completed interim actions. Table 9-2 provides additional information on this alternative.

Evaluation of Alternative S-2 against the CERCLA threshold criteria (Table 10-3) indicates this alternative protects HHE and complies with ARARs. RAOs are achieved in a relatively short timeframe by removing contaminated soil and transferring it to the ERDF, which is designed to provide for long-term management of chemical and radionuclide-contaminated soil. Relative to the CERCLA balancing criteria, this alternative performs very well against the long-term effectiveness criterion and less well against the reduction of TMV through treatment, short-term effectiveness, and implementability criteria. The total net present value (NPV) cost for this alternative is estimated at $20.6 million for all waste sites expected to have remediation performed under the ROD.

Table 10-3. CERCLA Evaluation Summary for Alternative S-2: RTD

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Overall Protection of HHE** | Yes | ***Protects HH***<br>• Potential exposure is eliminated by moving material to the ERDF.<br>• RAOs achieved in a short timeframe.<br>• RTD eliminates direct contact risk at waste sites.<br>• Excavated material transferred to the ERDF, which is designed to provide for long-term management of contaminated soil.<br>***Protects the Environment***<br>• RTD eliminates exposure to terrestrial and aquatic receptors. |
| **Compliance with ARARs** | Yes | ***Complies with ARARs***<br>• Remedial action designed to meet chemical-specific, location-specific, and action-specific ARARs. |

Table 10-3. CERCLA Evaluation Summary for Alternative S-2: RTD

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Long-term Effectiveness and Permanence** | ★★★ | ***Provides high degree of long-term effectiveness and permanence***<br>*Factors that enable this alternative to perform very well against the long-term effectiveness and permanence criterion:*<br>• RTD used successfully for interim actions to achieve remedial action goals established in interim action RODs<br>• RTD using conventional equipment is reliable and practiced extensively at the Hanford Site. ERDF disposal is effective and reliable<br>• Contaminated material is transferred to the ERDF, which is designed to provide for long-term management<br>• Risks are removed from the River Corridor |
| **Reduction of TMV through Treatment** | ★☆☆ | ***Provides no reduction of toxicity, mobility or volume through treatment***<br>• Contaminated soil removal by RTD (with treatment at ERDF, as warranted) is not considered treatment for this criterion. RTD is the primary remediation technology implemented for most of the waste sites, and for this reason, this alternative performs poorly for this criterion |
| **Short-term Effectiveness** | ★★☆ | ***Expected to have moderate short-term effectiveness***<br>*Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:*<br>• No adverse risks to the community from implementation of RTD activities because of the site's remote location and implementation of ICs<br>• Risks to workers minimized through adherence to a HSP and proper PPE<br>• Achieves RAOs in relatively short timeframe (3-5 years)<br>Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:<br>• Physical risks to workers associated with remediation<br>• Generation of GHG from use of excavation equipment and transportation to the ERDF |
| **Implementability** | ★★★ | ***Highly Implementable***<br>• Proven implementable and reliable through interim actions<br>• Conventional equipment and vendors for RTD-related activities are readily available<br>• The ERDF widely used for disposal of contaminated material generated from Hanford site remedial actions |
| **Net Present Worth Cost*** | **All Sites: $20,637,000** | |
| **Total Non-discounted Cost*** | **All Sites: $37,514,000** | |

Table 10-3. CERCLA Evaluation Summary for Alternative S-2: RTD

| Criterion | Rating | Detailed Analysis |
|---|---|---|

* Includes allowance for capital costs

ERDF = Environmental Restoration Disposal Facility
GHG = greenhouse gas
HSP = health and safety plan
IC = institutional control
PPE – personal protective equipment
RAO = remedial action objective
ROD = record of decision
RTD = removal, treatment, and disposal

### 10.2.2 Groundwater Plume Alternatives

This section presents the evaluation of alternatives for the four 100-FR-3 groundwater COC plumes. These plumes are located within 100-F and the east portion of 100-IU-2/IU-6. Following are the four alternatives retained from the initial screening conducted in Section 9.3:

- Alternative GW-1: No Action
- Alternative GW-2: ICs and MNA
- Alternative GW-3: Pump-and-Treat Optimized with Other Technologies
- Alternative GW-4: Enhanced Pump-and-Treat

The primary attributes of the 100-FR-3 COC plumes are summarized in Table 10-4.

Table 10-4. 100-FR-3 Groundwater COC Plume Attributes

| COC | Units | 90th Percentile EPC (through 2010) | Cmax (through 2011) | PRG | Plume Size Based on PRG | Estimated Mass of COC in Plume | Estimated Timeframe Before COC Concentrations Decline to PRGs Based on Cmax/C90 under No Action (years) |
|---|---|---|---|---|---|---|---|
| Cr(VI) | µg/L | 20 | 41.6 | 10 | 23 ha (56 acres) | 16.5 kg | 35/25 |
| | µg/L | 20 | 41.6 | 48 | 12.7 (31 acres) | 9.1 kg | 20/10 |
| Strontium-90 | pCi/L | 3.3 | 285 | 8 | 9.9 ha (24.5 acres) | 2.1 Ci | 150/90 |
| TCE | µg/L | 11 | 14 | 4.9 | 70 ha (172 acres) | 8 kg | 45/--* |
| Nitrate | µg/L | 109,500 | 201.000 | 45,000 | 1280 ha (3,162 acres) | 1.2 million kg | 80/30 |

* The fate and transport model estimates the C90 concentration for TCE within the model domain is currently less than the PRG. Therefore, only the Cmax timeframe is presented as discussed in Section 9.1.

*Alternative GW-1: No Action.* The No Action Alternative was developed per NCP requirements ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]) to provide a baseline for comparison to other alternatives.

The No Action Alternative represents a scenario where no restrictions, controls, or active remedial actions are applied to a site. Under this alternative, COC concentrations in unconfined aquifer groundwater would remain elevated above PRGs for timeframes estimated to range from 10 to 90 years, depending on the COC plume. Sampling from the aquifer tubes located along the river shoreline has historically shown infrequent detections of Cr(VI) and strontium-90 concentrations above PRGs. Although Cr(VI) and strontium-90 may have been detected in individual samples from the aquifer tubes at concentrations above PRGs on occasion, these occurrences are localized to small sections of the river shoreline. Across a typical aquatic receptor exposure area, COC concentrations are not expected to exceed PRGs on a chronic exposure basis.

Evaluation of the No Action Alternative against the CERCLA threshold criteria (Table 10-5) indicates this alternative does not protect HHE. Because this alternative does not protect HHE, it cannot be selected under CERCLA. Therefore, an evaluation against the CERCLA balancing criteria was not performed.

Table 10-5. CERCLA Evaluation Summary for Alternative GW-1: No Action

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Overall Protection of HHE** | No | ***Does not protect HHE***<br>• Contains no provisions to protect against human exposure to COCs by restricting groundwater use.<br>• Adverse effects to the environment are not expected, as COC concentrations in groundwater will not cause exceedances of AWQC or state water quality standards.<br>• Because most sources have been addressed under the interim action ROD, groundwater COC concentrations will continue to decrease in the future. |
| **Compliance with ARARs** | Yes | ***Expected to be compliant within approximately 90 years based on C90 concentration.***<br>ARARs for groundwater will not be met for up to 90 years, based on the concentration of strontium-90. |
| **Long-term Effectiveness and Permanence** | N/A | Alternative GW-1 fails threshold criteria for protection of HHE. Therefore, an evaluation against the balancing criteria was not performed. |
| **Reduction of TMV through Treatment** | N/A | Alternative GW-1 fails threshold criteria for protection of HHE. Therefore, an evaluation against the balancing criteria was not performed. |
| **Short-term Effectiveness** | N/A | Alternative GW-1 fails threshold criteria for protection of HHE. Therefore, an evaluation against the balancing criteria was not performed. |
| **Implementability** | N/A | Alternative GW-1 fails threshold criteria for protection of HHE. Therefore, an evaluation against the balancing criteria was not performed. |
| **Net Present Worth Cost** | $0 | Alternative GW-1 has no components, therefore, there is no cost. |

Table 10-5. CERCLA Evaluation Summary for Alternative GW-1: No Action

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Total Non-discounted Cost** | $0 | Alternative GW-1 has no components, therefore, there is no cost. |

ARAR = applicable or relevant and appropriate requirement
AWOC = ambient water quality criteria
COC = contaminant of concern
ROD = record of decision

Alternative GW-2: ICs and MNA. This alternative includes the following components:

- The scope of the ICs would include a prohibition on groundwater use except for monitoring, remediation, or research purposes as authorized in EPA approved documents. This would be accomplished through the Sitewide IC Plan (DOE/RL-2001-41). ICs would be maintained until COC concentrations achieve cleanup levels.

- MNA to include periodic sampling and analysis from up to 38 existing monitoring wells, 15 new wells, and up to 10 existing aquifer tubes. It is assumed for cost estimating purposes that new monitoring wells would be sampled quarterly for Year 1, annually for Years 2 through 10, and biennially thereafter. Existing monitoring wells and aquifer tubes are sampled annually for years 1 through 10, and biennially thereafter. Groundwater sampling and analysis results would be evaluated and presented in the annual groundwater report.

The duration of the MNA sampling, analysis, and data evaluation period is based on the model-estimated timeframe for each COC to achieve its cleanup level using the C90 calculation approach, except for TCE where a Cmax approach was used, as described in Section 9.1. The estimated timeframes were rounded up to account for model uncertainties. The estimated timeframe for each COC is Cr(VI) = 25 years based on 10 µg/L PRG and 10 years based on 48 µg/L PRG; strontium-90 = 90 years; trichloroethene = 45 years; and nitrate = 30 years. It is assumed that an additional five years of compliance monitoring would be performed once cleanup levels for each COC plume are achieved. This five-year period is not included in these timeframe estimates.

Evaluation of Alternative GW-2 against the CERCLA threshold criteria (Table 10-6) indicates this alternative protects human health by restricting groundwater use until MNA reduces COC concentrations to cleanup levels (ARARs). ICs developed under this alternative will provide a comprehensive array of measures to control and prevent inadvertent exposure to contaminated groundwater. Conditions associated with the 100-F reactor ISS and related controls are expected to remain in place for up to 75 years, thus providing an additional vehicle to monitor the effectiveness of land and groundwater use ICs.

Table 10-6. CERCLA Evaluation Summary for Alternative GW-2: ICs and MNA

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Overall Protection of HHE** | Yes | ***Protects HHE***<br>• Modification to the Sitewide IC Plan (DOE/RL-2001-41) will implement ICs that prohibit groundwater use, thereby preventing exposure until remedial goals are achieved.<br>• Natural attenuation processes are reducing COC concentrations.<br>• Existing groundwater, aquifer tube and pore water monitoring data show that Cr(VI) and strontium-90 concentrations are low enough such that adverse effects to aquatic receptors are unlikely to occur. |
| **Compliance with ARARs** | Yes | ***Complies with ARARs***<br>• Chemical-specific ARARs for protection of groundwater as a drinking water source achieved throughout the aquifer for all COCs in approximately 90 years.<br>• Chemical-specific ARARs for Cr(VI) in surface water have already been achieved at a majority of the aquifer tubes and pore water sample locations.<br>• Monitoring programs will be designed to demonstrate compliance with ARARs. |
| **Long-term Effectiveness and Permanence** | ★★★ | ***Provides high degree of long-term effectiveness and permanence***<br>*Factors that enable this alternative to perform very well against the long-term effectiveness and permanence criterion:*<br>• Drinking water and surface water quality protection-based remedial goals achieved at completion of remedial action.<br>• ICs prohibit exposure until remedial goals are achieved.<br>• The Sitewide IC Plan (DOE/RL-2001-41) and ISS maintenance requirements ensure a high degree of IC reliability.<br>• Radioactive decay reduces strontium-90 concentrations at known rates without human intervention.<br>• Cr(VI), trichloroethene, and nitrate concentrations are being reduced through degradation and non-degrading natural attenuation processes that act without human intervention.<br>*Factors that may represent a disadvantages or uncertainty to long-term effectiveness and permanence:*<br>• None identified. |
| **Reduction of TMV through Treatment** | ★☆☆ | A MNA remedy does not reduce the toxicity, mobility, or volume of contaminants through active treatment. |
| **Short-term Effectiveness** | ★★☆ | ***Provides low to moderate degree of short-term effectiveness***<br>*Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:*<br>• There are no risks to the community from implementation of ICs and MNA because of the remote site location.<br>• Risks to workers from implementation of periodic IC surveillance and MNA groundwater monitoring programs minimized through an HSP, proper PPE, and limited intrusive activity.<br>• Limited effects to environment from implementation of ICs and |

Table 10-6. CERCLA Evaluation Summary for Alternative GW-2: ICs and MNA

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| | | MNA groundwater monitoring program expected.<br>• Estimated time to achieve PRGs: 25 years for Cr(VI) and 30 years for nitrate.<br>*Factors that may provide some disadvantages or uncertainty relative to short-term effectiveness:*<br>Estimated time to achieve PRGs is 45 years for trichloroethene and 90 years for strontium-90. |
| **Implementability** | ★★★ | ***Readily implemented***<br>• No technical or administrative challenges are associated with implementation of ICs or MNA monitoring programs. Both technologies are widely used at the Hanford Site.<br>• ICs have been previously approved and implemented at other 100 Area groundwater OUs under interim action RODs. |
| **Net Present Worth Cost*** | **Total All Plumes:** | $33,514,000 |
| **Total Non-discounted Cost*** | **Total All Plumes:** | $55,039,000 |

* Includes allowances for capital, O&M, and periodic costs.

ARAR = applicable or relevant and appropriate requirement
COC = contaminant of concern
HHE = human health and the environment
IC = institutional control
MNA = monitored natural attenuation
HSP = health and safety plan
PPE – personal protective equipment
PRG = preliminary remediation goal
ROD = record of decision

Groundwater samples collected from aquifer tubes and pore water samples indicate that COC concentrations are below PRGs in nearly all samples in the last three years. Therefore, this alternative is protective of the aquatic environment along the shoreline. The evaluation presented in Appendix M indicates that existing natural attenuation processes are reducing COC concentrations in 100-FR-3 OU groundwater, thus providing protection for the environment. The effectiveness of these processes is evident in the time series charts that show declining COC concentrations at many monitoring well locations and the plume maps shown in Chapter 9 demonstrating a reduced plume size over time.

Future groundwater monitoring results will provide information to evaluate protectiveness of this alternative. Relative to the CERCLA balancing criteria (Table 10-6), this alternative performs very well for long-term effectiveness and implementability, moderately well for short-term effectiveness, and less well relative to TMV through treatment. The total present worth cost for Alternative GW-2 is estimated at $33,514,000, with a capital cost of $4,930,000 and a combined annual O&M and periodic non-discounted cost of $50,110,000. These costs are to develop and implement a monitoring system and evaluate MNA mechanisms over a 90-year period.

*Alternative GW-3: Pump-and-Treat Optimized with Other Technologies.* This alternative includes the following components:

- Implement ICs as described for Alternative GW-2, modified as necessary to reflect the shorter remedial action timeframe.

- Groundwater pump-and-treat for the Cr(VI), strontium-90, and trichloroethene plumes, and the northern portion of the nitrate plume. Eighteen new extraction wells would be installed and the wells pumped at estimated rates of approximately 36 to 40 gpm each (755 gpm total) for the first five years. As the COC plumes contract and remedial goals are achieved on the plume margins, extraction wells would be turned off and the total pumping rate decreased to 635 gpm for years 6 to 10. All pumping would terminate following year 10. Actual pumping rates and durations will be determined during remedial design and may differ from these estimated values.

- The four Cr(VI) extraction wells would be pumped at an estimated rate of 180 gpm for up to five years, the two trichloroethene wells at 80 gpm for up to 10 years, and the single strontium-90 well at 40 gpm for up to 10 years. Pump-and-treat for nitrate occurs in the concentrated northern portion of the plume with 11 extraction wells pumping at a combined rate of up to 455 gpm for up to 10 years. The actual number and placement of extraction and injection wells, and pumping rates, will be refined during remedial design and may differ from these estimated values.

- Treatment of extracted groundwater at a newly constructed central treatment system, and injection of treated groundwater to enhance gradient control and removal of the COCs from the aquifer. The actual treatment processes, number of treatment vessels, and their final configuration will be determined during remedial design and may differ from the configuration shown in Figure 9-9, which was developed for cost estimating purposes.

- In situ treatment of nitrate, Cr(VI), and trichloroethene to accelerate cleanup. A portion of the treated groundwater would be amended with a substrate (to be identified during remedial design) and injected into the upgradient portion of the nitrate, Cr(VI), and trichloroethene plumes transforming nitrate to nitrogen gas, Cr(VI) to Cr(III), and trichloroethene to cis 1,2-dichloroethene. Substrate injection would continue for up to 10 years.

- MNA for strontium-90 for an additional 75 years following shutdown of the extraction well in year 10.

Performance monitoring for this alternative includes periodic sampling and analysis from up to 38 existing monitor wells, 15 new wells, and up to 10 existing aquifer tubes. For cost estimating purposes, it is assumed that the new monitoring wells are sampled quarterly for Year 1, annually for Years 2 through 10, and biennially thereafter. Existing monitoring wells and aquifer tubes are sampled annually for Year 1, annually for Years 2 through 10, and biennially thereafter. Groundwater sampling and analysis results would be evaluated and presented in the annual groundwater report.

The duration of the O&M period for pump-and-treat operations is 5 years for Cr(VI) and 10 years for TCE, strontium-90, and nitrate. The pumping durations will be refined during remedial design and during remedy implementation through remedial process optimization.

The estimated timeframe to achieve the remedial goal using the C90 calculation approach, except for TCE where the Cmax timeframe is used as described in Section 9.1, is as follows: Cr(VI) = 5 years based on the 10 µg/L and 48 µg/L PRGs; strontium-90 = 85 years; trichloroethene = 10 years; nitrate = 20 years.

Evaluation of Alternative GW-3 against the CERCLA threshold criteria (Table 10-7) indicates this alternative protects human health by implementing and maintaining ICs until pump-and-treat and in situ treatment reduces COC concentrations to PRGs. The environment is protected by reducing COC concentrations in groundwater and preventing plume expansion and exposure through hydraulic control.

Reducing COC concentrations to PRGs and documenting these reductions while constructing and operating the remedy in accordance with the remedial design ensures compliance with ARARs. Relative to the CERCLA balancing criteria, this alternative performs moderately to very well against each of the balancing factors, except implementability, where it is expected to perform less well. This alternative will require further design analysis and testing. The total present worth cost is estimated at $181,917,000 with a capital cost of $83,083,000 and combined annual O&M and periodic non-discounted cost of $137,003,000. The total non-discounted cost is estimated at $220,086,000.

Table 10-7. CERCLA Evaluation Summary for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Overall Protection of HHE** | Yes | ***Protects HHE***<br>• Modification to the Sitewide IC Plan (DOE/RL-2001-41) will implement ICs that prohibit groundwater use, thereby preventing exposure to contaminated groundwater until remedial goals are achieved.<br>• Groundwater pump-and-treat reduces the potential for Cr(VI) PRG exceedance at the groundwater/surface water interface.<br>• Concentrations of strontium-90 along the river shoreline are expected to remain below the 8 pCi/L PRG. |
| **Compliance with ARARs** | Yes | ***Complies with ARARs***<br>• Chemical-specific ARARs for protection of groundwater as a drinking water source achieved throughout the aquifer in approximately 85 years.<br>• Chemical-specific ARARs for surface water quality protection for Cr(VI) in groundwater along the shoreline estimated to be achieved within 5 years. |
| **Long-term Effectiveness and Permanence** | ★★★ | ***Provides high degree of long-term effectiveness and permanence***<br>*Factors that enable this alternative to perform well against the long-term effectiveness and permanence criterion:*<br>• Drinking water and surface water quality PRGs for Cr(VI), trichloroethene, and the northern, more concentrated portion of the nitrate plume, are achieved at completion of remedial action using pump-and-treat.<br>• ICs will remain in effect until remedial goals are achieved.<br>• Relies on MNA to address the southern, low concentration portion of the nitrate plume, and the balance of the strontium-90 plume following shutdown of the single strontium-90 extraction well.<br>*Factors that may represent a disadvantages or uncertainty to long-term effectiveness and permanence:*<br>• None identified. |
| **Reduction of TMV through Treatment** | ★☆☆ | Provides moderate degree of TMV through treatment<br>Factors that enable this alternative to perform moderately well against the reduction of TMV by treatment criterion:<br>• Significant mass of nitrate is removed through pumping and IX treatment. Trichloroethene mass is reduced in groundwater |

Table 10-7. CERCLA Evaluation Summary for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| | | through air stripping.<br>• Cr(VI), trichloroethene, and nitrate TMV reduced rapidly in groundwater through above ground and/or in situ treatment.<br>• Strontium-90 toxicity and volume initially reduced through above ground treatment.<br>Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment:<br>• TMV for the southern portion of the nitrate plume occurs primarily through physical (advection and dispersion) natural attenuation processes.<br>• Treatment media (IX resin) will require stabilization and disposal at ERDF.<br>• The balance of toxicity and volume reduction for strontium-90 occurs through radioactive decay. |
| **Short-term Effectiveness** | ★★☆ | ***Provides moderate degree of short-term effectiveness***<br>*Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:*<br>• No adverse risks to the community from implementation of pump-and-treat remedy because of the remote site location and ICs.<br>• Risks to workers from implementation of active treatment actions are minimized through an HSP and proper PPE.<br>• Time to achieve PRGs in actively remediated Cr(VI), TCE, and northern nitrate plume areas is estimated at 5, 10, and 10 years, respectively. Time to achieve PRGs for nitrate in the southern plume area is estimated at 20 years.<br>*Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:*<br>• Strontium-90 plume may require up to 85 years to achieve the PRG. |
| **Implementability** | ★☆☆ | Performs less well against Implementability criterion<br>*Factors that enable this alternative to perform moderately well against the implementability criterion:*<br>• DOE has extensive experience with design and O&M of pump-and-treat systems implemented under previous interim action RODs.<br>• Pump and treat is a widely used and reliable technology for conditions present at the Hanford site.<br>• ICs have been previously approved and implemented at other 100 Area groundwater OUs under interim action RODs.<br>*Factors that may provide some disadvantages or uncertainty to the implementability:*<br>• Injection of organic substrate to stimulate in situ treatment of nitrate and trichloroethene not widely used at the Hanford Site. |

Table 10-7. CERCLA Evaluation Summary for Alternative GW-3: Pump-and-Treat Optimized with Other Technologies

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| | | Will require pilot testing and an injection well rehabilitation program. |
| **Total Present Worth Cost*** | **Total All Plumes:** | $181,917,000 |
| **Total Non-discounted Cost*** | **Total All Plumes:** | $220,086,000 |

* Includes allowances for capital, O&M, and periodic costs.

ARAR = applicable or relevant and appropriate requirement
ERDF = Environmental Restoration Disposal Facility
HHE = human health and the environment
HSP = health and safety plan
IC = institutional control
IX = ion exchange
MNA = monitored natural attenuation
OU = operable unit
PPE – personal protective equipment
PRG = preliminary remediation goal
ROD = record of decision
TMV = toxicity, mobility, and volume

*Alternative GW-4: Enhanced Pump-and-Treat.* The primary components of this alternative include:

Implement ICs as described for Alternative GW-2 modified as necessary to reflect the shorter remedial action timeframe.

- Groundwater pump-and-treat for the Cr(VI), strontium-90, trichloroethene, and entire nitrate plumes. The 24 new extraction wells would be installed and the wells pumped at estimated rates of approximately 40 gpm each (995 gpm total) for the first five years. As the COC plumes contract and PRGs are achieved along the plume margins, extraction wells would be turned off and the total pumping rate reduced to 875 gpm and eventually 160 gpm between years 6 through 10. All pumping would be terminated following year 10.
- The four Cr(VI) extraction wells would initially be pumped at a rate of 180 gpm for up to five years, the two trichloroethene wells at 80 gpm for up to 10 years, the single strontium-90 well at 40 gpm for up to 10 years, and the 17 nitrate wells at 695 gpm for up to 10 years.
- Treatment of extracted groundwater at a newly constructed central treatment system, and reinjection of treated groundwater to enhance gradient control and removal of the COCs from the aquifer. The actual treatment processes, number of treatment vessels, and their final configuration will be determined during remedial design.
- MNA for strontium-90 for an additional 75 years following shutdown of the extraction well in year 10.

Performance monitoring for this alternative includes periodic sampling and analysis from up to 38 existing monitor wells, 15 new wells, and up to 10 existing aquifer tubes. For cost estimating purposes, it is assumed that the new monitoring wells are sampled quarterly for Year 1, annually for Years 2 through

10, and biennially thereafter. Existing monitoring wells and aquifer tubes are sampled annually for Year 1, annually for Years 2 through 10, and biennially thereafter. Groundwater sampling and analysis results would be evaluated and presented in the annual groundwater report.

The duration of the O&M period for pump-and-treat operations is 5 years for Cr(VI) and 10 years for TCE, strontium-90, and nitrate. The pumping durations will be refined during remedial design and during remedy implementation through remedial process optimization.

The estimated timeframe to achieve the remedial goal using the C90 calculation approach, except for TCE where the Cmax timeframe is used as described in Section 9.1, is as follows: Cr(VI) = 5 years based on the 10 µg/L and 48 µg/L PRGs; strontium-90 = 85 years; trichloroethene = 10 years; and nitrate = 10 years.

Evaluation of Alternative GW-4 against the CERCLA threshold criteria (Table 10-8) indicates this alternative protects human health by implementing and maintaining ICs until pump-and-treat reduces COC concentrations to PRGs. The environment is protected by reducing COC concentrations in groundwater and preventing plume expansion and exposure through hydraulic control. Reducing COC concentrations to PRGs, and constructing and operating the remedy in accordance with the remedial design ensure compliance with ARARs. Relative to the CERCLA balancing criteria, this alternative performs very well against the balancing factors of long-term effectiveness and permanence, TMV reduction through treatment, and moderately well against the criterion of short-term effectiveness and implementability. The total present worth cost is estimated at $199,500,000 with a capital cost of $98,365,000 and combined annual O&M and periodic non-discounted cost of $129,550,000. The total non-discounted cost is estimated at $227,915,000.

Table 10-8. CERCLA Evaluation Summary for Alternative GW-4: Enhanced Pump-and-Treat

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Overall Protection of HHE** | Yes | ***Protects HHE***<br>• ICs prohibit exposure to contaminated groundwater until remedial goals are achieved.<br>• PRG exceedance at the groundwater/surface water interface is prevented through pump-and-treat system capture zone.<br>• Concentrations of strontium-90 along the river shoreline are expected to remain below the 8 pCi/L PRG.<br>• Nitrate concentrations in the groundwater plume are reduced to the PRG in 10 years. |
| **Compliance with ARARs** | Yes | ***Complies with ARARs***<br>• Chemical-specific ARARs for protection of groundwater as a drinking water source achieved throughout the aquifer in approximately 85 years.<br>• Chemical-specific ARARs for surface water quality protection for Cr(VI) achieved in groundwater along the shoreline within five years. |

Table 10-8. CERCLA Evaluation Summary for Alternative GW-4: Enhanced Pump-and-Treat

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Long-term Effectiveness and Permanence** | ★★★ | ***Provides high degree of long-term effectiveness and permanence***<br>Factors that enable this alternative to perform moderately well against the long-term effectiveness and permanence criterion:<br>• Pump-and-treat is a widely used and reliable technology for conditions present at the Hanford site.<br>• ICs will remain in effect until remedial goals are achieved.<br>• Ex situ treatment permanently removes COCs from groundwater and returns treated water to the aquifer.<br>*Factors that may represent a disadvantages or uncertainty to long-term effectiveness and permanence:*<br>• None identified. |
| **Reduction of TMV through Treatment** | ★★★ | ***Provides high degree of TMV through treatment***<br>*Factors that enable this alternative to perform well against the reduction of TMV by treatment criterion:*<br>• TMV in groundwater reduced rapidly for Cr(VI), trichloroethene, and nitrate through above ground treatment<br>• Strontium-90 toxicity and volume initially reduced through above ground treatment<br>*Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment:*<br>• Treatment media (IX resin) will require stabilization and disposal at ERDF.<br>• The balance of toxicity and volume reduction for strontium-90 occurs through radioactive decay. |
| **Short-term Effectiveness** | ★★☆ | ***Provides moderate degree of short-term effectiveness***<br>*Factors that enable this alternative to perform moderately well against the short-term effectiveness criterion:*<br>• No adverse risks to the community from implementation of pump-and-treat remedy because of the remote site location and ICs<br>• Risks to workers from implementation of active treatment actions are minimized through an HSP and proper PPE<br>• Time to achieve PRGs ranges from 5 to 10 years in actively remediated Cr(VI), trichloroethene and nitrate plume areas<br>Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:<br>• Strontium-90 plume may require up to 85 years to achieve PRGs. |

Table 10-8. CERCLA Evaluation Summary for Alternative GW-4: Enhanced Pump-and-Treat

| Criterion | Rating | Detailed Analysis |
|---|---|---|
| **Implementability** | ★★☆ | ***Provides moderate degree of implementability***<br>*Factors that enable this alternative to perform well against the implementability criterion:*<br>• DOE has extensive experience with design and O&M of pump-and-treat systems implemented under previous interim action RODs.<br>• Pump and treat is a widely used and reliable technology for conditions present at the Hanford site.<br>• ICs have been previously approved and implemented at other 100 Area groundwater OUs under interim action RODs.<br>*Factors that may provide some disadvantages or uncertainty to the implementability:*<br>• None identified |
| **Total Present Worth Cost*** | **Total All Plumes:** | $199,500,000 |
| **Total Non-discounted Cost*** | **Total All Plumes:** | $227,915,000 |

* Includes allowances for capital, O&M, and periodic costs.

AWQC = ambient water quality criteria
ARAR = applicable or relevant and appropriate requirement
COC = contaminant of concern
ERDF = Environmental Restoration Disposal Facility
HHE = human health and the environment
HSP = health and safety plan
IC = institutional control
IX = ion exchange
O&M = operation and management
OU = operable unit
PPE – personal protective equipment
PRG = preliminary remediation goal
ROD = record of decision
TMV = toxicity, mobility, and volume

## 10.3 Comparative Evaluation of Alternatives

This section summarizes the comparative evaluation of alternatives. The comparative evaluation is designed to assess the advantages and disadvantages of each alternative relative to one another to identify key tradeoffs that should be noted during remedy selection. The waste site alternative comparative evaluation is summarized in Table 10-9 and the groundwater alternative comparison in Table 10-10.

Table 10-9. Comparative Analysis of Waste Site Alternatives

| Criterion | Alternative S-1: No Action | Alternative S-2: RTD |
|---|---|---|
| | **Rating** | **Rating** |
| Overall Protection of HHE | No | Yes |
| Compliance with ARARs | No | Yes |

Table 10-9. Comparative Analysis of Waste Site Alternatives

| Criterion | Alternative S-1: No Action | Alternative S-2: RTD |
|---|---|---|
| | Rating | Rating |
| Long-term Effectiveness and Permanence | N/A | ★★★ |
| Reduction of Toxicity, Mobility, or Volume by Treatment | N/A | ★☆☆ |
| Short-term Effectiveness | N/A | ★★☆ |
| Implementability | N/A | ★★★ |
| Net Present Worth Cost | $ 0 | $20,637,000 |

★★★ = Expected to perform very well against the criterion with no apparent disadvantages or uncertainty.

★★☆ = Expected to perform moderately well against the criterion but with some disadvantages or uncertainty.

★☆☆ = Expected to perform less well against the criterion with more disadvantages or uncertainty.

* Detailed cost estimates are presented in Appendix K.

ARAR = applicable or relevant and appropriate requirement
HHE = human health and the environment

Table 10-10. Comparative Analysis of Groundwater Alternatives

| Criterion | Alternative GW-1: No Action | Alternative GW-2: ICs and MNA | Alternative GW-3: Pump-and-Treat Optimized with Other Technologies | Alternative GW-4: Enhanced Pump-and-Treat |
|---|---|---|---|---|
| | Rating | Rating | Rating | Rating |
| **Overall Protection of HHE** | No | Yes | Yes | Yes |
| **Compliance with ARARs** | Yes | Yes | Yes | Yes |
| **Long-term Effectiveness and Permanence** | N/A | ★★★ | ★★★ | ★★★ |
| **Reduction of Toxicity, Mobility, or Volume by Treatment** | N/A | ★☆☆ | ★★☆ | ★★★ |
| **Short-term Effectiveness** | N/A | ★★☆ | ★★☆ | ★★☆ |

Table 10-9. Comparative Analysis of Waste Site Alternatives

| Criterion | | Alternative S-1: No Action | Alternative S-2: RTD |
|---|---|---|---|
| | | Rating | Rating |
| **Implementability** | N/A | ★★★ | ★☆☆ | ★★☆ |
| **Net Present Worth Cost*** | $ 0 | $33,514,000 | $181,917,000 | $199,500,000 |

★★★ = Expected to perform very well against the criterion with no apparent disadvantages or uncertainty.

★★☆ = Expected to perform moderately well against the criterion but with some disadvantages or uncertainty.

★☆☆ = Expected to perform less well against the criterion with more disadvantages or uncertainty.

* Detailed cost estimates are presented in Appendix K.

ARAR = applicable or relevant and appropriate requirement

HHE = human health and the environment

### 10.3.1 Overall Protection of HHE

*Waste Site Alternatives.* For the waste sites, Alternative S-2: RTD is the only alternative that protects HHE. This is accomplished by removing and transporting contaminated soil and debris to an engineered waste disposal facility (ERDF) or applying ICs at waste sites identified in Table 9-1. Alternative S-1: No Action does not protect HHE because no actions are taken to protect current and future HHE against direct contact with contaminated soil or leaching of contaminants to groundwater.

*Groundwater Alternatives.* Each of the alternatives, except GW-1: No Action, protects current and future human health by preventing exposure to contaminated groundwater through the use of ICs until RAOs are achieved.

Alternative GW-2: Natural attenuation processes reduce COC concentrations to remedial goals. Although some of the Cr(VI) mass of 16 kg, TCE mass of 8 kg, and nitrate mass of 1.2 million kg may enter the river over timeframes up to 30 years (based on C90 concentration), the concentrations in the river substrate pore water will be low and not pose a threat to aquatic receptors. While the mass of nitrate entering the river is relatively large, at about 40 kg/day it represents only 1.1 percent of the 3,500 kg/day that enters the Columbia River from upstream irrigation return flows (*Irrigation Return Flow Quality South Columbia Basin Irrigation District May-August 1980* [WA-36-1010]). A recent USGS study (National Ambient Water-Quality Assessment Program) of groundwater quality in the Central Columbia Plateau identified the presence of nitrate at concentrations above the federal drinking water standard in 19 percent of the wells surveyed. Nitrogen fertilizers applied to crop fields are the primary source of the elevated nitrate concentrations observed at the surveyed wells.

Alternative GW-3: Pump-and-Treat Optimized with Other Technologies provides protection for HHE using ex situ treatment for all COCs in combination with enhanced in situ treatment to transform nitrate, Cr(VI), and trichloroethene to nontoxic or less toxic compounds. Alternative GW-3 enhances in situ treatment by injecting a substrate through a network of injection wells to accelerate the transformation process. The enhancement step provides greater certainty that full treatment will occur and achieves treatment within the nitrate, Cr(VI), and trichloroethene plume footprints within a shorter timeframe relative to Alternative GW-2.

Alternative GW-4: Enhanced Pump-and-Treat is expected to provide protection for HHE because a majority of the COC mass is removed from groundwater in an above ground treatment facility using technology proven successful elsewhere at the Hanford Site. COC mass is concentrated on a sorption type media (IX), which is either regenerated and reused or disposed at the ERDF. Volatile contaminants, such as TCE, are vented by the air stripper to the atmosphere for photodegradation.

### 10.3.2 Compliance with ARARs

*Waste Site Alternatives.* Alternative S-2 is the only waste site alternative that complies with ARARs.

*Groundwater Alternatives.* All of the groundwater alternatives achieve chemical-specific ARARs for the defined remedial action target areas within timeframes that vary, depending on the COC. Exclusive of strontium-90, Alternative GW-4 complies with ARARs within 10 years, Alternative GW-3 within 20 years, and Alternatives GW-2 and GW-1 within 30 years. Relative to strontium-90, all of the alternatives comply with ARARs in timeframes estimated to range from 85 to 90 years.

### 10.3.3 Long-Term Effectiveness and Permanence

*Waste Site Alternatives.* Alternative S-2: RTD performs very well relative to the long-term effectiveness and permanence criterion because COC-contaminated soil and debris exceeding PRGs is removed and transported to the ERDF. Once the contaminated soil is removed, there is no need for any further controls. Although waste is left in place at 16 waste sites where ICs would be implemented, radionuclides are the primary COCs and, therefore, radioactive decay will reduce COC concentrations to PRGs such that ICs can be removed in the future at the dates specified in Table 9-1. At the 116-F-14 waste site, where Cr(VI) leaching poses a groundwater/surface water protection threat, the no irrigation IC needs to be maintained indefinitely based on current information. Because Alternative S-1 does not satisfy threshold criteria, which would preclude its selection, it was not evaluated against this criterion.

*Groundwater Alternatives.* Alternatives GW-2, GW-3, and GW-4 are expected to perform very well relative to the long-term effectiveness and permanence criterion. Each of the alternatives employs varying levels of active and passive treatment that permanently reduce COC concentrations within different timeframes. ICs, which have proven reliable and effective at Hanford, are also an important component of all three alternatives. At the end of the remedial timeframe, COC concentrations for all alternatives are protective of HHE. Above ground treatment residuals generated under alternatives GW-3 and GW-4 will be transported to the ERDF. Because Alternative GW-1 does not satisfy the threshold criteria for protection of HHE, which would preclude its selection, it was not evaluated against this criterion.

### 10.3.4 Reduction of Toxicity, Mobility and Volume through Treatment

*Waste Site Alternatives.* Alternative S-2 performs less well relative to this criterion as there is no TMV reduction through treatment, unless needed to meet ERDF waste acceptance criteria. Because Alternative S-1 does not satisfy threshold criteria, which would preclude its selection, it was not evaluated against this criterion.

*Groundwater Alternatives.* Alternative GW-4 performs very well relative to this criterion, whereas alternatives GW-3 and GW-2 are expected to perform moderately and less well, respectively. Under Alternative GW-4, the majority of the COC mass is removed from the aquifer using groundwater extraction and above ground treatment, and the treatment residuals immobilized and disposed at a secure long-term management facility (ERDF). Groundwater extraction and injection wells are also used to hydraulically contain the COC plumes, preventing their expansion into other areas. Alternative GW-3 provides a moderate degree of TMV reduction because it focuses on the northern portion of the nitrate plume, and relies on MNA for the southern portion. Additionally, incomplete treatment (because of poor substrate distribution) may result in the formation of treatment residuals, a condition that does not occur

when treatment is performed using above ground, physical treatment methods. Alternative GW-2 provides no degree of TMV reduction through treatment. Because Alternative GW-1 does not satisfy the threshold criteria for protection of HHE, which would preclude its selection, it was not evaluated against this criterion.

### 10.3.5 Short-Term Effectiveness

*Waste Site Alternatives.* Alternative S-2 is expected to perform moderately well against this criterion. Risks to the community are low because of the waste site's remote location. While risks to workers and the environment are controlled using engineering measures and personal protective equipment (PPE), excavation sidewall stability and materials handling always pose potential threats. Alternative S-2 achieves RAOs within a three- to five-year timeframe. Because Alternative S-1 does not satisfy threshold criteria, which would preclude its selection, it was not evaluated against this criterion.

*Groundwater Alternatives.* Alternatives GW-2, GW-3, and GW-4 are all expected to perform moderately well relative to this criterion. However, GW-2 has the lowest potential for adverse impact to the community, workers, or the environment (e.g., GHG) because there is less construction-related activity The overall timeframe to achieve all PRGs throughout the aquifer (85 to 90 years) is similar for all three alternatives (Table 10-11) due to strontium-90; however, Alternatives GW-3 and GW-4 do provide faster remediation for the Cr(VI), trichloroethene, and nitrate plumes. Because Alternative GW-1 does not satisfy the threshold criteria for protection of HHE, which would preclude its selection, it was not evaluated against this criterion.

Table 10-11. Comparison of Remedial Action Timeframe Estimates (years)

| COC | PRG | GW-1: No Action | | GW-2: ICs and MNA | | GW-3: Pump-and-Treat Optimized with Other Technologies | | GW-4: Enhanced Pump-and-Treat | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cmax | C90 | Cmax | C90 | Cmax | C90 | Cmax | C90 |
| Cr(VI) | 10 µg/L | 35 | 25 | 35 | 25 | 5 | 5 | 10 | 5 |
| Cr(VI) | 48 µg/L | 20 | 10 | 20 | 10 | 5 | 5 | 5 | 5 |
| Nitrate | 45,000 µg/L | 80 | 30 | 80 | 30 | 75 | 20 | 25 | 10 |
| Trichloroethene | 4.9 µg/L | 45 | --* | 45 | --* | 10 | --* | 10 | --* |
| Strontium-90 | 8 pCi/L | 150 | 90 | 150 | 90 | 150 | 85 | 150 | 85 |

* The model estimated C90 concentration for trichloroethene is currently less than the PRG; therefore, the C90 concentration is not presented or used for the detailed and comparative evaluation of alternatives. The use of Cmax for trichloroethene evaluation is discussed in Section 9.1.

### 10.3.6 Implementability

*Waste Site Alternatives.* Alternative S-2 is readily implemented because the required the administrative and technical resources are readily available due to their frequent use at the Hanford site under interim action RODs. Because Alternative S-1 does not satisfy threshold criteria, which would preclude its selection, it was not evaluated against this criterion.

*Groundwater Alternatives.* Alternative GW-2 performs very well against this criterion because it only involves installation of new monitoring wells and sampling and analysis of groundwater samples from new/existing wells and aquifer tubes. The resources needed to perform this work are readily available. Alternative GW-4 is expected to perform moderately well and Alternative GW-3 less well because of their increased technical complexity. The in situ treatment for Alternative GW-3 will require specialized biological reagents, and although it is a proven technology, it will require design testing for this site. Because Alternative GW-1 does not satisfy the threshold criteria for protection of HHE, which would preclude its selection, it was not evaluated against this criterion.

### 10.3.7 Cost

*Waste Site Alternatives.* The total net present worth cost for Alternative S-2 is $20,637,000. Alternative S-1 has a cost of $0.

*Groundwater Alternatives.* The total net present worth cost for Alternative GW-1: No Action is $0, Alternative GW-2: ICs and MNA $33.5 million, Alternative GW-3: Pump-and-Treat Optimized with Other Technologies $181.9 million, and Alternative GW-4: Enhanced Pump-and-Treat $199.5 million.

## 10.4 NEPA Values

This section addresses the incorporation of NEPA values into CERCLA documents. This is consistent with *National Environmental Policy Act Compliance Program* (DOE O 451.1B Chg 2), which requires that CERCLA actions address and incorporate NEPA values such as socioeconomic, ecological, offsite, and cumulative effects in CERCLA documents to the extent practicable.

The alternatives developed to address COCs present in groundwater in the 100-FR-3 OU include a broad array of media-specific options. The No Action Alternative would not mitigate the environmental impacts from contaminated groundwater. All other alternatives mitigate the effects, using an increasingly more complex array of remedial technologies that achieve RAOs in a progressively shorter timeframe at higher costs.

NEPA values associated with remediation are based on information presented in this RI/FS, including the site characteristics (Chapters 1, 2, and 3), final COCs (Chapter 8), and identification and evaluation of remedial actions (Chapter 9). Applying a "sliding scale" of NEPA analysis to 100-F/IU (using *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements: Second Edition* [DOE, 2004]) and considering CERCLA ARARs (identified in Table 8-2), the principal resource areas of concern include the contaminants in waste sites, contaminants in the groundwater and surface water, solid and liquid radioactive and hazardous waste management, air emissions, potential adverse effects to historic and cultural resources, ecological resources, socioeconomics (including environmental justice concerns), and transportation.

The net anticipated effect from implementation of groundwater alternatives (GW-2, GW-3, or GW-4) could be an overall positive contribution to cumulative environmental effects at the Hanford Site.

In addition, DOE has included the combined effects anticipated from ongoing CERCLA/TPA (Ecology et al., 1989a) response actions as part of the cumulative impact analysis in *Draft Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (DOE/EIS-0391), which includes a sitewide cumulative impact groundwater analysis. This has presented the public with a separate opportunity for comment as part of that NEPA process, and is being used to inform the public concerning ongoing implementing cleanup actions on the Hanford Site. The NEPA values (i.e., resource area and relevant NEPA considerations) most relevant to and potentially affected by the actions taking place under this remedial action are described in Table 10-12.

## 10.5 Coordination of Interim and Final CERCLA Remedial Activities

A feature of each area is the ongoing implementation of interim action RODs, CERCLA removal actions, RCRA corrective actions, treatability tests, and other activities to remediate contaminated areas or to develop more effective methods that advance remediation, as discussed in preceding chapters.

Implementation of these interim action ROD activities is generating information that allows an improved understanding of site complexity, supports refinement of the CSM, and documents the effectiveness of the remedial actions.

Cleanup of waste sites in accordance with the interim action RODs and focused FSs is ongoing and expected to continue until final action RODs are in place. As remedial actions under interim action RODs are completed, verification sampling and laboratory analyses are performed to document the extent to which RAGs established under the interim action RODs have been met. This information will be essential to supporting final action RODs.

Characterization data and information developed through implementation of remedial actions under interim action RODs will be coordinated and evaluated in support of reaching a final action ROD. To support a final action remedy, the current remedial actions under interim action RODs for the 100 Area OUs will continue until issuance of the final action ROD. While these interim remedial actions are underway, data will be generated to support final action decision making through the CERCLA process. The 100 Area integrated RI/FS process will be concluded with a data summary for all media (i.e., surface soil, vadose zone, groundwater, and surface water), as documented in Chapters 1 through 7 of the RI report, and evaluated through remedial alternatives analyses in the FS (Chapters 8 through 10). The final action remedy selection completes the RI/FS process and will be presented in the Proposed Plan. Under CERCLA, five-year reviews continue to be required to evaluate the implementation and effectiveness of remedial actions.

There will be a period of time between when the final action ROD is approved and the required RD/RAWP is prepared and issued. During this period, DOE-RL plans to continue remedial activities, such as waste site RTD. In order for these actions to be consistent with the final action remedy selection, the current interim action RD/RAWPs will be modified using the TPA (Ecology et al., 1989a) change notice process to include the final cleanup levels specified in the final action ROD when it is issued.

Table 10-12. NEPA Values Evaluation

| NEPA Values | Description | Evaluation* |
|---|---|---|
| Transportation | Considers effects of the proposed action on local traffic (i.e., traffic at the Hanford Site) and traffic in the surrounding region. | Implementation of all action alternatives (except No Action) would be expected to produce short-term effects on local traffic. A majority of the effect relates to increased truck traffic associated with the alternatives; they would involve transport of contaminated soil moved from a waste site(s) to the ERDF. Transportation effects were considered in *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility* (DOE/RL-93-99) as part of the evaluation of short-term effectiveness and implementability. NEPA values in the planning for the ERDF operation were explained in detail in *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package* (DOE/RL-94-41). |
| Water Quality | Considers potential water quality concerns associated with the groundwater below the site and the Columbia River. | Performance of waste site excavation requires the application of considerable quantities of water for dust control. The application of this water may result in infiltration to groundwater. This effect could be observed for Alternative S-2 because excavation is a component of this alternative.<br>Contaminants would be removed from groundwater with ex situ treatment under Alternatives GW-3 and GW-4, whereas Alternative GW-2 reduces COC concentrations in situ. Ex situ treatment is expected to provide a greater net benefit for water quality in both groundwater and the Columbia River. Spent IX resin would be generated and managed as solid waste. Volatile contaminants such as trichloroethene would be vented to the atmosphere for photodegradation. |
| Air Quality | Considers potential air quality concerns associated with emissions generated during the proposed action. | Airborne releases associated with Alternatives S-2, GW-3, and GW-4 could occur due to dust generation during excavation, drilling, site grading, and trichloroethene treatment. An estimated 15,000 $m^3$ (20,000 $yd^3$) of contaminated soil and debris would be removed (excludes clean overburden and sideslope soil). Any potential airborne release of contaminants during remedial actions would be controlled in accordance with DOE radiation control and air pollution control standards to minimize emissions of air pollutants at the Hanford Site and protect all communities outside the site boundaries. Operation of trucks and other diesel-powered equipment for these alternatives would be expected to introduce quantities of carbon dioxide, sulfur dioxide, nitrogen dioxide, particulates, and other pollutants to the atmosphere. |

Table 10-12. NEPA Values Evaluation

| NEPA Values | Description | Evaluation* |
|---|---|---|
| Natural, Cultural, and Historical Resources | Considers effects of the proposed action on wildlife, wildlife habitat, archeological sites and artifacts, and historically significant properties. | Effects on ecological resources near the remedial actions could result from excavation of contaminated soil, installation of groundwater extraction and injection wells, and construction of above ground conveyance piping and a treatment facility. Such effects would be mitigated in accordance with *Hanford Site Biological Resources Management Plan* (DOE/RL-96-32) and *Hanford Site Biological Resources Mitigation Strategy* (DOE/RL-96-88), and with the applicable standards of all relevant biological species protection regulations.<br><br>Alternatives GW-3 and GW-4 could pose an effect on cultural resources since they might require installation of wells in a potentially culturally sensitive area ("Protection of Historic Properties" [36 CFR 800]; *National Historic Preservation Act of 1966* [NHPA], Section 106, documentation). However, because many of these sites have already been disturbed and only isolated artifacts would be expected to be encountered during project activities, implementation of *Hanford Cultural Resources Management Plan* (DOE/RL-98-10) and consultation with area Tribes would help ensure appropriate mitigation to avoid or minimize any adverse cultural or historical resource effects and address any relevant concerns.<br><br>Effects to other cultural values will be minimized through implementation of *Hanford Cultural Resources Management Plan* (DOE/RL-98-10), *Revised Mitigation Action Plan for the Environmental Restoration Disposal Facility* (DOE/RL-2005-27), and consultation with area Tribes, as needed. This will help ensure appropriate mitigation to avoid or minimize any adverse effects to natural and cultural resources and address any other relevant concerns.<br><br>Potential effects to cultural and historical resources that may be encountered during the short-term construction activities associated with implementing the action would be mitigated through compliance with the appropriate substantive requirements of NHPA and other ARARs related to cultural preservation. |
| Socioeconomic Effects | Considers effects pertaining to employment, income, other services (e.g., water and power utilities), and the effect of implementation of the proposed action on the availability of services and materials. | The proposed action is within the scope of current DOE-RL environmental restoration activities and would have minimal effect on the current availability of services and materials. This work would be expected to be accomplished largely using employees from the existing contractor workforce. Even if the remedial activities creates additional service sector jobs, the total expected increase in employment would be expected to be less than 1 percent of the current employment levels. The socioeconomic effect of the project would contribute to the continuing overall positive employment and economic effects on eastern Washington communities from Hanford Site cleanup operations. |

Table 10-12. NEPA Values Evaluation

| NEPA Values | Description | Evaluation* |
|---|---|---|
| Environmental Justice | Considers whether the proposed response actions would have inappropriately or disproportionately high and adverse human health or environmental effects on minority or low-income populations. | Per *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* (Executive Order 12898), DOE seeks to ensure that no group of people bears a disproportionate share of negative environmental consequences resulting from proposed federal actions. There were no effects associated with proposed activities associated with 100-F/IU that could reasonably be determined to affect any member of the public; therefore, they would not have the potential for high and disproportional adverse effects on minority or low income groups. |
| Cumulative Effects (Direct and Indirect) | Considers whether the proposed action could have cumulative effects on human health or the environment when considered together with other activities locally, at the Hanford Site, or in the region. | The environmental concern of 100-F/IU is associated directly with the targeted area. Because of the temporary nature of the activities and their remote location, cumulative effects on air quality or noise with other Hanford Site or regional construction and cleanup projects would be minimal. When soil at a site in this area is found to be contaminated with hazardous substances in concentrations presenting a threat to HHE, that threat would be mitigated. The net anticipated effect could be a positive contribution to cumulative environmental effects at the Hanford Site through RTD of such hazardous substances and COCs into a facility that has been designed and legally authorized to contain such contaminants safely, such as the ERDF. Contaminated soil removed under any alternative would meet the ERDF waste acceptance criteria as described in Environmental Restoration Disposal Facility Waste Acceptance Criteria (WCH-191). As noted earlier, the estimated volume of soil and debris that could be generated for disposal during implementation of the remedial action is approximately 15,000 $m^3$ (20,000 $yd^3$) over the expected duration of this action. |
| Cumulative Effects (Direct and Indirect) (cont.) | Considers whether the proposed action could have cumulative effects on human health or the environment when considered together with other activities locally, at the Hanford Site, or in the region. | Wastes generated during implementation of the proposed alternatives would be manageable within the capacities of existing facilities. For perspective, the ERDF received more than 700,000 tons of waste in CY 2008 and more than 430,000 tons in CY 2007. Radiological contamination is expected to be minimal; by definition, these are waste sites that are believed to be shallow in nature, do not affect groundwater, and have relatively small inventories. The ERDF received approximately 22,500 Ci in CY 2008 and approximately 13,000 Ci in CY 2007. |

Table 10-12. NEPA Values Evaluation

| NEPA Values | Description | Evaluation* |
|---|---|---|
| Mitigation | Considers that, if adverse effects cannot be avoided, response action planning should minimize them to the extent practicable. This value identifies required mitigation activities. | Compliance with the substantive requirements of the ARARs would mitigate potential environmental impacts on the natural environment, including migratory birds and endangered species. DOE has established policies and procedures for the management of ecological and cultural resources when actions might affect such resources (*Hanford Site Biological Resources Management Plan* [DOE/RL-96-32], *Hanford Site Biological Resources Mitigation Strategy* [DOE/RL-96-88], and *Hanford Cultural Resources Management Plan* [DOE/RL-98-10]). Cultural resource and biological species reviews/surveys are undertaken that also provide suggested mitigation activities to assure adverse effects associated with implementing the actions are minimized or avoided. Health and safety procedures, documented in the HSPs established by Site contractors, would mitigate risks to workers from the remedial activities. |
| Irreversible and Irretrievable Commitment of Resources | Considers the use of nonrenewable resources for the proposed response actions and the effects that resource consumption would have on future generations.<br>(When a resource [e.g., energy minerals, water, wetland] is used or destroyed and cannot be replaced within a reasonable amount of time, its use is considered irreversible.) | Material that would be used to backfill waste sites could be taken, if needed, from the surrounding area to contour the backfill to match the surrounding area. For all waste site alternatives, normal use of resources during construction activities, such as fuel and water, would be irreversible. Potential effects are expected to be greatest for Alternative S-2 because of the extent of RTD. Restoration of formerly disturbed areas to a more natural state would be expected to result in a net benefit to the ecological and visual resources within the region. |

* Includes the evaluation for each alternative.

ARAR = applicable or relevant and appropriate requirement
COC = contaminant of concern
ERDF = Environmental Restoration Disposal Facility
HHE = human health and the environment
HSP = health and safety plan
IX = ion exchange
NEPA = *National Environmental Policy Act of 1969*
NHPA = *National Historic Preservation Act of 1966*
RTD = removal, treatment, and disposal

## 10.6 CERCLA and RCRA Corrective Action

The TPA (Ecology et al., 1989a) states the intent of the Tri-Parties that CERCLA remediation at the Hanford Site will also fulfill the corrective action requirements for the Hanford Site as a facility containing permitted TSD units. The TPA (Ecology et al., 1989a) guides integration and coordination of CERCLA and RCRA at the Hanford Site. The following articles explain the relations of CERCLA remedial actions and RCRA corrective actions:

- Article IV, Paragraph 17, which cites the Tri-Parties' intent "to integrate DOE's CERCLA response obligations, and RCRA corrective action obligations that relate to the release(s) of hazardous substances, hazardous wastes, pollutants and contaminants" covered by the TPA (Ecology et al., 1989a)
- Article XIV, which applies to the performance of both CERCLA remedial action and RCRA corrective action
- Article XXIII, which acknowledges the potential for overlap between CERCLA and RCRA cleanup
- Article XXIV, which specifies the approach for regulatory oversight

Section 5.4 of the TPA Action Plan (Ecology et al., 1989b) addresses the rationale and approach for past practice cleanup. Two key objectives are to "ensure that only one past practice program will be applied at each operable unit," and that "the process selected be sufficiently comprehensive to satisfy the technical requirements of both statutory authorities and the respective regulations."

DOE's corrective action obligation on the Hanford Site is addressed in *Hanford Facility Resource Conservation and Recovery Act Permit for Treatment, Storage, and Disposal of Dangerous Waste* (WA7890008967), Condition II.Y.2.a, which provides that DOE corrective action obligations are met through adherence to the TPA (Ecology et al., 1989a). In particular, "Overview of Cleanup Standards" (WAC 173-340-700) through "Sediment Cleanup Standards" (WAC 173-340-760) function as ARAR standards for CERCLA remedial actions on the Hanford Site.

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61.93, "Emission Monitoring and Test Procedures."

61.140, "Applicability."

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61.150, "Standard for Waste Disposal for Manufacturing, Fabricating, Demolition, Renovation, and Spraying Operations."

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Subpart A, "General Provisions."

Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities."

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# Appendix A

# Site Map

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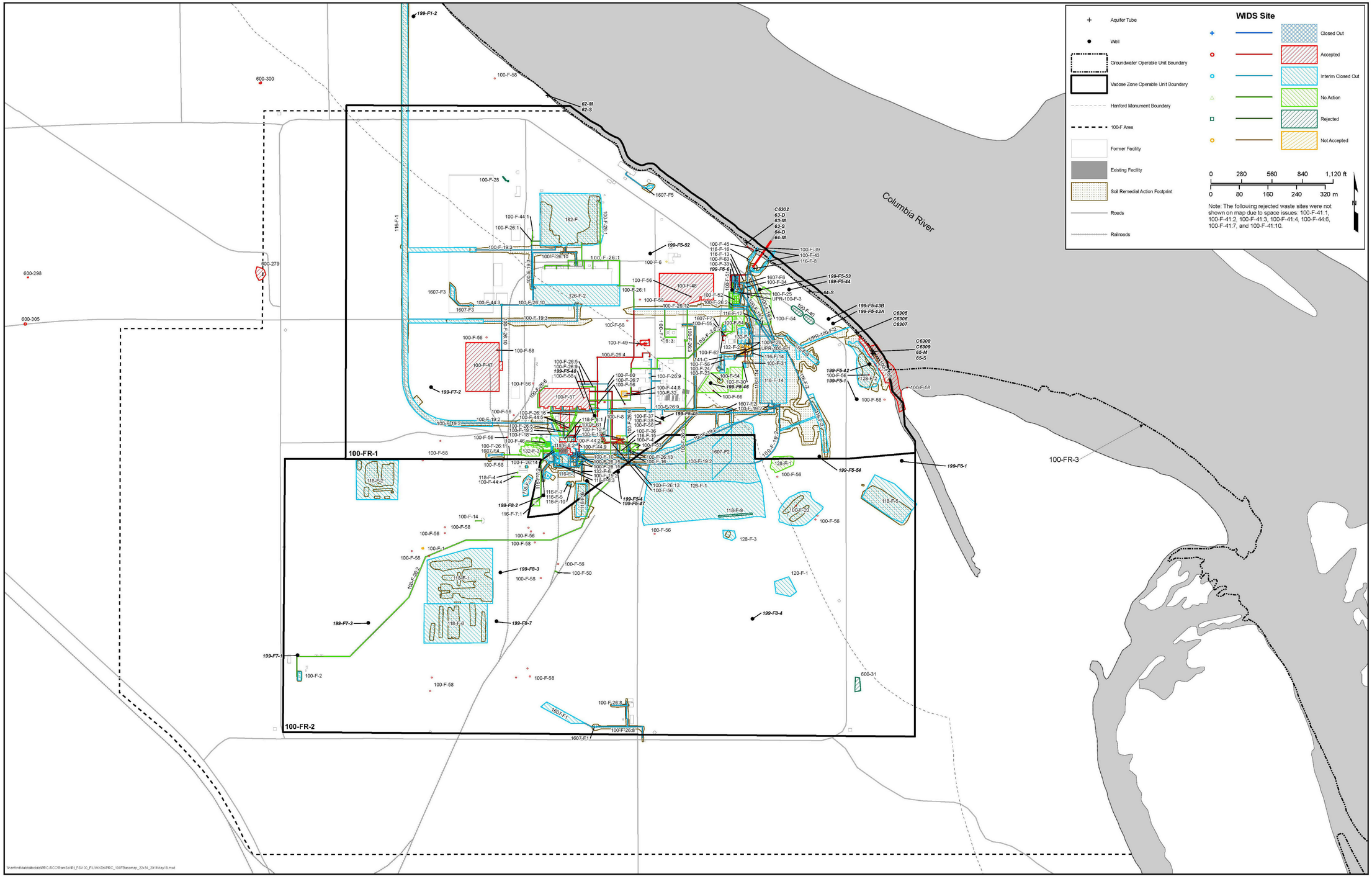
WIDS Site
Aquifer Tube
Well
Groundwater Operable Unit Boundary
Vadose Zone Operable Unit Boundary
Hanford Monument Boundary
100-F Area
Former Facility
Existing Facility
Soil Remedial Action Footprint
Roads
Railroads
Closed Out
Accepted
Interim Closed Out
No Action
Rejected
Not Accepted
0 280 560 840 1,120 ft
0 80 160 240 320 m
N
Note: The following rejected waste sites were not shown on map due to space issues: 100-F-41:1, 100-F-41:2, 100-F-41:3, 100-F-41:4, 100-F-44:6, 100-F-41:7, and 100-F-41:10.
Columbia River
100-FR-1
100-FR-2
100-FR-3
600-300
600-279
600-298
600-305
600-31
199-F1-2
199-F7-2
199-F7-3
199-F7-1
199-F8-2
199-F8-3
199-F8-7
199-F8-4
199-F5-52
199-F5-6
199-F5-53
199-F5-44
199-F5-43B
199-F5-43A
199-F5-42
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199-F5-46
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199-F5-4
199-F5-47
199-F6-1
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62-S
116-F-1
182-F
126-F-2
132-F-2
141-C
128-F-2
128-F-1
128-F-3
118-F-2
118-F-6
118-F-9
120-F-1
607-F2
1607-F1
1607-F2
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## WIDS Site

- Aquifer Tube
- Well
- Groundwater Operable Unit Boundary
- Vadose Zone Operable Unit Boundary
- Hanford Monument Boundary
- Former Facility
- Existing Facility
- Excavation Footprint
- Roads
- Railroads

- Closed Out
- Accepted
- Interim Closed Out
- No Action
- Rejected
- Not Accepted

0 5,000 10,000 15,000 20,000 ft
0 1,500 3,000 4,500 6,000 m

N

Note: Points southeast of the 100-F Area represent accepted waste site 600-186 and no action waste site 600-208 unless otherwise labeled.

Columbia River

100-FR-3

100-F Area

100-FR-2

100-IU-2

100-IU-6

Yakima River