8 Identification and Screening of Technologies

This chapter begins the feasibility study section 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 removing the contaminants (described in Chapter 4) or interrupting the exposure pathway (described in Chapters 6 and 7).

Chapter 8 presents the following discussions:

- RAOs, ARARs, PRGs (Section 8.1)
- General response actions (GRA) (Section 8.2)
- Identification and screening of remedial technologies and associated process options to clean up the contamination (Section 8.3)

Highlights

- Media specific RAOs are identified for groundwater, surface water, and soil.
- To meet RAOs, PRGs are established for each environmental medium of interest, contaminants, receptors, and exposure pathways.
- Of 343 sites in the 100-D and 100-H Areas, 291 are recommended for evaluation in the FS.
- A range of GRAs to meet RAOs is identified for waste sites and contaminated groundwater.
- Process options retained for vadose zone actions include no action, standard and deep excavation, disposal, in situ treatments: biological reduction, solidification, soil flushing, stabilization/ sequestration, and void-fill grouting; surface barriers, and institutional controls.
- Process options retained for groundwater include no action, MNA, pump-and-treat, in situ treatments: chemical stabilization, biological (anaerobic), combined biological and chemical, reactive chemical barrier, and flushing; ion exchange, and institutional controls.
- Process options and technologies for the range of GRAs are evaluated for relative effectiveness, implementability, and cost.

Chapter 9 assembles the alternatives and Chapter 10 provides a detailed analysis of the alternatives to address contaminated media at 100-D/H.

8.1 Remedial Action Objectives

RAOs are general descriptions of what the remedial action is expected to accomplish (that is, medium-specific or site-specific goals for cleanup). They are defined as specifically as possible to address the following concerns:

- Media of interest (soil or groundwater)
- Types of contaminants (radionuclides and chemical constituents)
- Potential receptors (human and ecological)
- Exposure pathways (external radiation, direct contact, ingestion, or inhalation)

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 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). RAOs are presented in Section 8.1.4. Background information used in developing the RAOs is presented in Sections 8.1.1 through 8.1.3.

8.1.1 Contaminants of Concern

In the RI/FS process, the results of the risk assessment and fate and transport evaluation are 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.

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 if available, radiological surveys, process history, analogous site information, personal interviews, engineering drawings and as-builts, and any other available information. The following analytes were identified as COCs in soil based on this risk evaluations for previously remediated waste sites with verification data: cesium-137, cobalt-60, europium-152, europium-154, nickel-63, strontium-90, and technetium-99. For yet-to-be remediated waste sites, additional COPCs are identified based on review of waste site history/processes and characterization of analogous waste sites and listed in Table 8-1. Because of this comprehensive review, the characteristics of each site are sufficiently defined for the purpose of alternative development and comparison in the FS. 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. Section 8.2.1 presents additional information on the waste sites. As discussed in Section 4.1, waste sites collocated within historic orchard lands will be remediated as needed to meet the cleanup levels for contaminants attributable to Hanford Site operations.

Table 8-1. Summary of Soil COPCs Based on Process Knowledge

Radionuclides	Metals	Polychlorinated Biphenyls	Polynuclear Aromatic Hydrocarbons
Carbon-14	Antimony	Aroclor-1016	Benzo(a)pyrene
Cesium-137	Arsenic	Aroclor-1221	Benzo(b)fluoranthene
Cobalt-60	Barium	Aroclor-1232	Benzo(k)fluoranthene
Europium-152	Cadmium	Aroclor-1242	Chrysene
Europium-154	Chromium, Total	Aroclor-1248	Dibenz(a,h)anthracene
Nickel-63	Cr(VI)	Aroclor-1254	Indeno(1,2,3-cd)pyrene
Strontium-90	Copper	Aroclor-1260	Pyrene
Technetium-99	Lead		
	Mercury		
	Nickel		
	Silver		
	Zinc		

COPC = contaminant of potential concern

8.1.1.2 Groundwater

The following contaminants were identified in the groundwater risk assessment in Chapter 6 as COCs for 100-HR-3 OU groundwater: chromium (total), Cr(VI), nitrate, and strontium-90.

The groundwater risk assessment in Chapter 6 retained six analytes for the 100-D and 100-H groundwater areas, 12 analytes for the 100-D ISRM area, and five analytes for the Horn area that are COPCs that

require further monitoring. The results of the nature and extent evaluation and the groundwater risk assessment indicate these analytes historically have been detected in groundwater at concentrations above their DWS, but their presence was not associated with a specific location or a trend. Therefore, these analytes warrant further monitoring. The COPCs in the 100-D Area include antimony, cadmium, cobalt, copper, lead, and silver. The COPCs in the 100-D ISRM Area include antimony, cadmium, cobalt, copper, fluoride, iron, lead, manganese, nitrite, silver, sulfate, and zinc. The COPCs in the 100-H Area include antimony, cadmium, cobalt, copper, lead, and silver. The COPCs in the Horn area include antimony, cadmium, cobalt, copper, and silver. The nature and extent evaluation indicates that historically, these analytes have been detected in groundwater at concentrations above their respective action level (Section 6.3.2.3), but their presence was not associated with a specific location or with a trend. Additionally, seven of the 12 analytes (fluoride, iron, lead, manganese, nitrite, sulfate, and zinc) detected at the 100-D ISRM area occur in a limited number of wells within the ISRM and their presence is associated with the reducing conditions created by the presence of zero valence iron. Because of the uncertain status of the COPCs, treatment for COPCs is not evaluated in the alternatives developed in Chapter 9. To assure protectiveness and confirm current understanding of the nature and extent of contamination and potential risks, these analytes will be analyzed 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. Groundwater contaminants that do not warrant further evaluation in the FS, but have infrequent detections above an action level, will be included in the RD/RAWP for the purpose of continued monitoring at appropriate locations and frequency.

8.1.2 Potential Applicable or Relevant and Appropriate Requirements

Substantive standards of promulgated regulations pertaining to CERCLA response actions are identified through the ARAR identification process. The ARARs identification process is based on CERCLA Section 121(d) and EPA guidance (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, be met (or a waiver justified) for any hazardous substance, pollutant, or contaminant that will remain onsite after completion of remedial action. Additionally, 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.

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]).
The identification of ARARs is a two-step process. First, it must be determined if 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 those substantive standards that specifically address the situation at a CERCLA site. These requirements 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 (for example, through a waiver of federal sovereign immunity).

"Relevant and appropriate" requirements mean those 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 make 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 NCP, "General" (40 CFR 300.400[g][2]) are considered:

- The purpose of the requirement and the purpose of the CERCLA action
- The medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site
- The substances regulated by the requirement and the substances found at the CERCLA site
- The actions or activities regulated by the requirement and the remedial action contemplated at the CERCLA site
- Any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the CERCLA site
- The type of place regulated and the type of place affected by the release or CERCLA action
- 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
- 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 non-promulgated advisories or guidance issued by federal or state governments that are not legally binding and do not have the status of ARARs. In some circumstances, TBC information will be evaluated, along with ARARs, in determining the remedial actions necessary for cleanup. 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.

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 100-D/H are examined 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 Section 121 authority to DOE for cleanup of DOE facilities. Section 121 of the *Superfund Amendments and Reauthorization Act of 1986* 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 (such as 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 text.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

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) "Maximum Contaminant Level Goals for Organic Contaminants" (40 CFR 141.50)	Chemical	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-D/H 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, MNA).
"Maximum Contaminant Levels for Inorganic Contaminants" (40 CFR 141.62) "Maximum Contaminant Level Goals for Inorganic Contaminants" (40 CFR 141.51)	Chemical	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 inorganic contaminants in the drinking water.	Groundwater in 100-D/H 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, MNA).
"Maximum Contaminant Levels for Radionuclides" (40 CFR 141.66)	Chemical	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 adverse effects of radionuclides in the drinking water.	Groundwater in 100-D/H 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, MNA).
"Water Pollution Control" (RCW 90.48, as amended); "Underground Injection Control Program" (WAC 173-218)					
"UIC Well Classification Including Allowed and Prohibited Wells" (WAC 173-218-040)	Action	Establishes criteria and standards for an underground injection control program.	Groundwater in 100-D/H 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-D/H

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)					
"Portable Groundwater Defined" (WAC 173-340-720(2) "Method B Cleanup Levels for Potable Ground Water" (WAC 173-340-720(4)(b)(i, iii)(A)&(B)) "Adjustments to Cleanup Levels" (WAC 173-340-720(7)) "Points of Compliance" (WAC 173-340-720(8)) "Compliance Monitoring" (WAC 173-340-720(9)(b) through (f))	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. Method B equations (720-1 and 720-2) 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, sediments, soil, or air cleanup standards.	Groundwater in 100-D/H 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, 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-D/H.	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-D/H.	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-D/H.	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-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"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-D/H.	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-D/H.	ARAR	Investigative and remediation activities that require siting, installation, construction, operation, maintenance, and decommissioning of wells and borings.
"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-D/H.	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-D/H.	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-D/H.	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-D/H.	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-D/H

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) "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 × 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 × 10–4 increase in lifetime risk) is preferred as the maximum dose limit for humans. 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-D/H 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 the MNA as a remedy component for organic and inorganic contaminants.	Groundwater in 100-D/H contains contaminants that require remediation. The use of MNA as a remedy may be appropriate.	TBC	Groundwater remediation activities, including MNA.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
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-D/H 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).
"Hazardous Waste Cleanup -- Model Toxics Control Act" (RCW 70.105D, as amended); "Model Toxics Control Act—Cleanup" (WAC 173-340)					
"Surface Water Cleanup Standards, Method B (WAC 173-340-730(3)) "Adjustments to Cleanup Levels" (WAC 173-340-730(5)) "Points of Compliance" (WAC 173-340-730(6)) "Compliance Monitoring" (WAC 173-340-730(7)(c))	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-D/H 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).

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"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-D/H 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)) "Adjustments to Cleanup Levels" (WAC 173-340-740(5))	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: • Hazardous substance concentrations that protect human health and the environment (cleanup levels) • Location of the site where cleanup levels must be attained ("points of compliance") • Other regulatory requirements that apply to the cleanup action because of the type of action or location of the site	Soil in 100-D/H 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-D/H

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-D/H 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)), alternate 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 (Eco-SSLs) 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-D/H contains contaminants that require remediation. Comparison to SSLs may be appropriate for defining potential COPCs or to default to an Eco-SSL for COPCs that lacks corresponding published state cleanup criteria.	TBC	Soil cleanup actions to protect ecological receptors.
"Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7490) "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493) "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 and establishes site-specific cleanup standards for the protection of terrestrial plants and animals. "Priority Contaminants of Ecological Concern" (WAC 173-340-7494) provides for numeric concentrations of hazardous substances determined to persist, bio-accumulate, or be highly toxic to terrestrial ecological receptors.	Soil in 100-D/H 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-terrestrial ecological cleanup levels have been developed using "Site-Specific Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7493).

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
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 the MNA as a remedy component for organic and inorganic contaminants.	Soil in 100-D/H contains contaminants that require remediation. The use of MNA as a remedy may be appropriate.	TBC	Soil remediation activities, including MNA.
Air					
"Washington Clean Air Act" (RCW 70.94, 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-D/H have the potential to emit emissions subject to these standards because soil and groundwater hazardous contaminants detected in 100-D/H include covered hazardous air pollutants.	ARAR	Actions performed at 100-D/H that result in emission of hazardous air pollutants, including decontamination, demolition, and excavation activities implemented during a remedial action that have potential to emit visible, particulate, fugitive, 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-D/H have the potential to emit emissions subject to these standards because hazardous contaminants detected in 100-D/H 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-D/H include covered regulated hazardous air pollutants.	ARAR	Actions performed at 100-D/H that result in emission of hazardous air pollutants, including decontamination, demolition, and excavation activities implemented during a remedial action that have potential to emit visible, particulate, fugitive, hazardous air emissions, and odors.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"Washington Clean Air Act" (RCW 70.94, as amended); "Controls for New Sources of Toxic Air Pollutants" (WAC 173-460)					
"Purpose" (WAC 173-460-010) "Applicability" (WAC 173-460-030) "Control Technology Requirements" (WAC 173-460-060) "Ambient Impact Requirement" (WAC 173-460-070) "First Tier Review" (WAC 173-460-080) "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-D/H include constituents that would constitute toxic air pollutants if released to the air.	ARAR	Groundwater and soil remediation activities such as 100-D/H treatment systems with the potential to emit hazardous air emissions and that would be considered a new source.
"Washington Clean Air Act" (RCW 70.94, 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-D/H 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.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"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 ALARA; control equipment of 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.	Hazardous contaminants detected in soil and groundwater in 100-D/H includes 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.
"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-D/H 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 NESHAP "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-D/H 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.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

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)(i) [adopts by reference NESHAP "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-D/H. 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 NESHAP "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-D/H. 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-D/H

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 NESHAP "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-D/H.	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 NESHAP "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-D/H. 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.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"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 controls 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-D/H.	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.
"Monitoring, Testing and Quality Assurance" (WAC 246-247-075)	Action	Establishes the monitoring, testing, and quality assurance requirements for radioactive air emissions. 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 in 100-D/H 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; "Standards of Performance for New Stationary Sources" (40 CFR 60) and "National Emission Standards for Hazardous Air Pollutants for Source Categories" (40 CFR 63)**					
40 CFR 60 Subpart IIII—Standards of Performance for Stationary Compression Ignition Internal Combustion Engines 40 CFR 60 Subpart JJJJ--Standards of Performance for Stationary Spark Ignition Internal Combustion Engine 40 CFR 63 Subpart ZZZZ - National Emission Standard for Hazardous Air Pollutants for Stationary Reciprocating Internal Combustion Engines	Action	The requirements for stationary engines change May 3, 2013 to include timers, maintenance plans, and meeting monitoring requirements.	This applies to all stationary engines.	ARAR	Anywhere a stationary engine is used at the facility.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
***Clean Air Act of 1990* and amendments; NESHAP, "National Emission Standard for Asbestos" (40 CFR 61, Subpart M)**					
"Applicability" (40 CFR 61.140) "Standard for Demolition and Renovation" (40 CFR 61.145)	Action	Defines regulated ACM and regulated removal and handling requirements. 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-D/H 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-D/H 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.
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) "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 remediation of 100-D/H.	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)) "Disposal Requirements," "PCB Articles" (40 CFR 761.60(b)) "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 remedial actions for 100-D/H.	ARAR	Equipment and debris handling, storage, and disposal; IDW management and disposal.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"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 remedial actions for 100-D/H.	ARAR	Soil remediation, RTD, and IDW management and disposal.
"Hazardous Waste Management" (RCW 70.105, as amended); "Dangerous Waste Regulations" (WAC 173-303)					
"Identifying Solid Waste" (WAC 173-303-016) "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-D/H 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-D/H 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-D/H remedial actions.	ARAR	Remediation activities (disposal, storage, recycling, and onsite treatment) that manage special wastes consistent with the requirements of the *Washington Administrative Code*.
"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" (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-D/H remedial actions.	ARAR	Remediation activities (disposal, storage, recycling, and onsite treatment) that manage universal wastes consistent with the requirements of the *Washington Administrative Code*.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"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-D/H 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)) the federal land disposal restrictions of "Land Disposal Restrictions" (40 CFR 268) that are applicable to solid waste that is designated as dangerous or mixed waste in accordance with "Designation of Dangerous Waste" (WAC 173-303-070(3)).	Onsite land disposal will be a selected remedy for 100-D/H dangerous waste and debris.	ARAR	Investigative and remediation wastes destined for onsite land disposal.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"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-D/H.	ARAR	IDW and remediation wastes (contaminated soil and groundwater, personnel protective gear, treatment chemicals).
"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-D/H.	ARAR	Management of dangerous waste during remedial and investigative actions.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
"Requirements" (WAC 173-303-64620(4))	Action	Establishes the standards for implementing corrective action for releases of dangerous waste and constituents under the HWMA. Corrective action is implemented by requiring corrective action follow certain 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) "Performance Standards" (WAC 173-350-040) "On-Site Storage, Collection and Transportation Standards" (WAC 173-350-300) "Remedial Action" (WAC 173-350-900)	Action	Establishes minimum functional performance standards for the proper handling and disposal of solid waste. 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-D/H 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. 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-D/H.	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-D/H

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) "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-D/H.	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-D/H; 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-D/H.	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-D/H subject to remediation are located within the Columbia River floodplain.	ARAR	Remedial actions will occur in the floodplain.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
***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-D/H.	ARAR	Remediation actions and investigation activities that occur within critical habitats or designated buffer zones of federal listed species.
***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-D/H area.	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-D/H.	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.	Non-wildlife and their habitats have the potential to occur in 100-D/H.	ARAR	Remedial action that affect non-game fish, and wildlife and/or their habitats.

Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100-D/H

Regulatory Citation	ARAR Category	Description of Regulatory Requirement	Rationale for Including	Potential Relevancy	Possible Application
Land Use and Exposure Scenarios					
Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement (DOE/EIS-0222-F) *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE/EIS-0222-SA-01)	Location	Establishes the future land use projections for the Hanford Site, which includes 100-D/H.	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-D/H.	TBC	

ACM = asbestos-containing material
ALARA = as low as reasonably achievable
ARAR = applicable or relevant and appropriate
COPC = contaminant of potential concern
EPA = U.S. Environmental Protection Agency
HWMA = *Hazardous Waste Management Act*
IDW = investigation-derived waste
MCL = maximum contaminant level
MCGL = maximum contamination level goal
NRC = U.S. Nuclear Regulatory Commission
PRG = preliminary remediation goal
RTD = removal, treatment, and disposal
SSL = soil screening level
TBC = to be considered

Potential Chemical-Specific ARARs. The chemical-specific ARARs and TBCs that may affect remediation of 100-D/H OU are the substantive elements of the *Washington Administrative Code* regulations that implement the 2007 MTCA (WAC 173-340). Within this branch of the *Washington Administrative Code*, there are detailed regulations for developing standards for remedial actions involving soil cleanup (2007 MTCA, "Unrestricted Land Use Soil Cleanup Standards" [WAC 173-340-740]) and groundwater cleanup standards (2007 MTCA, "Groundwater Cleanup Standards" [WAC 173-340-720]). These standards are in the form of risk-based concentrations, or established by modeling, 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 2007 MTCA (WAC 173-340) ("Selection of Cleanup Actions" [WAC 173-340-360] and 2007 MTCA "Overview of Cleanup Standards" [WAC 173-340-700] through 2007 MTCA "Site-Specific Terrestrial Ecological Evaluation Procedures" [WAC 173-340-7493]) (2007)
- Nonzero MCL goals and MCLs promulgated under the *Safe Drinking Water Act of 1974* (SDWA) ("National Primary Drinking Water Regulations" [40 CFR 141]) and/or by the state of Washington ("Group A Public Water Supplies" [WAC 246-290])
- The AWQC developed under the *Clean Water Act* (Section 304) and/or promulgated by the state of Washington ("Water Quality Standards for Groundwaters of the State of Washington" [WAC 173-200] and Surface Water Quality Standards [WAC 173-201A])
- The *Toxic Substances Control Act of 1976* (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 Emissions Standards for Hazardous Air Pollutants" (40 CFR 61)

Potential Location-Specific ARARs. Potential location-specific ARARs that have been identified for the 100-D/H OU 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*. In addition, those ARARs protect listed endangered and threatened species or their critical habitat under the *Endangered Species Act*. The *Migratory Bird Treaty Act of 1918* has been identified as substantive standards 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 to CERCLA response actions when there is a potential to adversely affect protected bird species.

Potential Action-Specific ARARs. Action-specific ARARs that could be pertinent to possible remediation activities at 100-D/H 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 concern standards for controlling emissions to the environment.

8.1.2.4 Waste Management Standards

Remedial action alternatives proposed in Chapter 9 of this FS have the potential to produce a variety of waste that contains both radioactive and chemical constituents. It is anticipated that most of the waste will be designated as low-level. However, quantities of PCB-contaminated waste, and asbestos and

asbestos-containing material could be included in remediation waste. The majority of the waste will be in a solid form.

The storage, treatment, and disposal of hazardous waste and the hazardous component of mixed waste resulting from the remedial action 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 are 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.

The *Toxic Substances Control Act of 1976* 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 *Toxic Substances Control Act of 1976* regulations contains specific provisions for PCB waste, including PCB waste that contains a radioactive component. 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.

Waste generated through CERCLA remedial actions and designated as 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. ERDF is considered onsite with Hanford remedial actions for the purpose of management and/or disposal of waste.[1]

Waste generated through CERCLA remedial actions and designated as dangerous or mixed waste is 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 to HHE and meets 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 using a separate CERCLA ROD (*Declaration of the Interim Record of Decision for the Environmental Restoration Disposal Facility* [EPA/ROD/R10-95/100], hereinafter called ERDF ROD; *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*

[1] 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, 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. 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. Materials encountered during implementation of the selected remedial/removal/removal action that are not contaminated with hazardous substances are outside the authority of CERCLA and will be dispositioned by DOE.

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 low-level waste, mixed waste, and hazardous/dangerous waste generated as a result of cleanup actions (for example, remedial/removal action waste and investigation-derived waste), provided the waste meets ERDF waste acceptance criteria requirements and appropriate CERCLA decision documents are in place.

8.1.2.5 Standards Controlling Emissions to the Environment

Remedial action alternatives proposed in Chapter 9 of this FS 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/RAWP for the 100-D/H ROD.

8.1.2.6 Radiological Air Emissions

The federal *Clean Air Act of 1990* and amendments, 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 so than the standards under the federal *Clean Air Act of 1990* and amendments, including the Federal implementing regulation, NESHAPs "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H). The EPA's partial delegation of the Subparts A and 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. Members of the public can travel on the Columbia River through the Hanford Reach, but they cannot "abide or reside" there (*Hanford Comprehensive Land-Use Plan Environmental Impact Statement Supplement Analysis* [DOE/EIS-0222-SA-01]).

"Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480) limits emissions of radionuclides to the ambient air by requirement 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" (WAC 246-247) in "Radiation Protection—Air Emissions," "Definitions" (WAC 246-247-030[15]), defines the member of the public (real or hypothetical) who abides or resides in an unrestricted area. This member of the public 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. In addition, by its adoption of the federal standard at NESHAPs, "Standard" (40 CFR 61.92), the state limits radionuclide airborne emissions from the Hanford Site (that is, 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 adopts the "Ambient Air Quality Standards and Emission Limits for Radionuclides" (WAC 173-480) standards, and the NESHAPs, "National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities" (40 CFR 61, Subpart H) standard, 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 a sample of the effluent stream from the stack or vent, with subsequent analysis of the sample. Emissions that do not pass through a stack, vent, or other orifice, are termed diffuse emissions, and these are normally monitored by extraction of a sample of the ambient air, with subsequent

laboratory analysis. The substantive provisions of "Radiation Protection—Air Emissions" (WAC 246-247) that require monitoring of radioactive airborne emissions potentially would be applicable to remedial action and would generally be an "applicable" ARAR.

The above state implementing regulations further require control of radioactive airborne emissions to the extent economically and technologically feasible ("General Standards" and associated definitions [WAC 246-247-040(3) and -040(4)]). To cover 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 (that is, 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 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) are not anticipated to be a part of remedial actions selected for 100-D/H.

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 "Requirements for New Sources in Attainment or Unclassifiable Areas" (WAC 173-400-113[2]) and "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 NCP 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-HR-3 OU. These separate requirements are further clarified in a memorandum ("Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals Under CERCLA" [Fields, 1997]). Specifically, this memorandum clarifies that, in rare instances, 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 requirement to achieve threshold protectiveness and ARAR-based requirements is established by the NCP (40 CFR 300), which also establishes the requirement to return useable groundwater to beneficial use within a reasonable period. EPA generally defers to state agency definitions of useable groundwater provided under the various comprehensive state groundwater protection programs, administered by the states. EPA generally defers to 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 "Groundwater Cleanup Standards" (WAC 173-340-720[2]), unless the exclusion criteria in "Groundwater Cleanup Standards" (WAC 173-340-720[2][a] through [c]) can be demonstrated (that is, insufficient yield, natural constituents that make it unsuitable as a drinking water source). The groundwater within the100-HR-3 OU does not meet the exclusion criteria; therefore, it is classified as potable and must be returned to beneficial uses wherever practicable, within a time frame that is reasonable given the particular circumstances of the site, consistent with NCP requirements. The state of Washington has further determined that the highest beneficial use for potable groundwater at most cleanup sites within the state, including Hanford, is as a potential source of domestic drinking water ("Groundwater Cleanup Standards" [WAC 173-340-720(1)(a)]).

Groundwater within the 100-HR-3 OU is currently contaminated, and withdrawal is prohibited because of ICs placed on it by DOE. Under current site use conditions, no groundwater wells are available for public consumption specific to 100-D/H. Further, regardless of land use designations for soil, 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 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-HR-3 OU currently discharges to the Columbia River through upwelling and seeps. Surface Water Quality Standards, "Use Designations—Fresh Waters" (WAC 173-201A-600) and Surface Water Quality Standards, "Table 602-Use Designations for Fresh Waters by Water Resource Inventory Area" (WAC 173-201A-602), identify the beneficial use (or designated uses) for rivers and streams of Washington. Designated uses for waters of Washington 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 point of compliance for surface water quality standards is defined in the 2007 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. 2007 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.

Designated uses of the Columbia River, identified in Surface Water Quality Standards, "Table 602—Use Designations for Fresh Waters by Water Resource Inventory Area" (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 Section 6.3 evaluates potential exposure of aquatic organisms to contaminants in the 100-HR-3 OU. This assessment uses the most stringent federal and state water quality criteria to support the basis for action and to support PRG development.

8.1.3 Remedial Action Objectives

Under CERCLA and the NCP (40 CFR 300), soil and groundwater remedies must (1) be protective of HHE, and (2) meet ARARs (or satisfy criteria for an ARAR to be waived). RAOs must be developed to address COPCs, 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 require cleanup.

The RAOs were based on existing River Corridor regulatory documents (for example, 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 (RAOs 1 and 7), surface water (RAO 2), and soil (RAOs 3 through 6). The combined RAO list is as follows:

- **RAO 1.** Prevent unacceptable risk to human health from ingestion of and incidental 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 receptors from groundwater discharges containing contaminant concentrations above federal and state standards and risk-based thresholds to surface water.
- **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 contaminated with nonradiological constituents at concentrations above the unrestricted land use criteria for human health (provided in 2007 MTCA B) or soil contaminant levels for 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.
- **RAO 6:** Manage direct exposure to contaminated soils deeper than 4.6 m (15 ft) to prevent an unacceptable risk to HHE.
- **RAO 7:** Restore groundwater impacted from 100-DR-1, 100-DR-2, 100-HR-1, and 100-HR-2 releases to proposed cleanup levels, which include DWSs, within a time frame that is reasonable given the particular circumstances of the site.

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. The PRGs will be used to assess the effectiveness of the selected remedial alternatives in meeting the RAOs. Table 8-3 provides a summary of the 100-D/H Direct Contact Human Health PRGs, and Groundwater Protection and Surface Water Protection SSLs and

PRGs. The interim action ROD remedial action goal identified in the 100 Area RDR/RAWP (DOE/RL-96-17) are also listed in Table 8-3 for direct comparison to the PRGs from this RI/FS. In this table, direct contact human health PRGs for radionuclides (highlighted in yellow) are the lowest of the PRGs calculated for the residential exposure scenario (based on a target cancer risk level) and the residential interim action remedial action goal (based on radiological dose) as defined in the 100 Area RDR/RAWP (DOE/RL-96-17). For non-radionuclides, direct contact human health PRGs (also highlighted in yellow) are the RI/FS 2007 MTCA Method B soil direct contact cleanup values. Green highlighting denotes the PRG described in Chapter 5 of this RI/FS above background for each analyte for groundwater/surface water protection except for Cr(VI), which is compared to the interim action remedial action goal of 2.0 mg/kg.

The 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 contact exposure, protection of groundwater, and protection of surface water typically are presented as concentrations, which for nonradionuclides are in milligrams per kilogram for soil and in picocuries per gram for radionuclides. Contaminant-specific and numerical cleanup levels for groundwater typically are expressed in micrograms per liter for nonradiological COCs and picocuries per liter for radiological COCs.

Residual risks following completion of remediation of the waste sites must meet the 10^{-4} to 10^{-6} ELCR for radiological and carcinogenic COCs and must be less than or equal to an HI value of 1.0 for hazardous substances (as described in Chapter 6 of this RI/FS) for direct contact exposure with soil by humans. These cumulative risk and hazard thresholds must be met for each waste site from the ground surface to 4.6 m (15 ft) bgs.

A summary of the 100-D/H Ecological PRGs is provided in Table 8-4 for the four receptor groups (plants, invertebrates, birds, and mammals) that will be used within the SMDP for ecological protection. If ecological PRGs are exceeded, the site managers will evaluate this exceedance using the SMDP process described in Chapter 7 of this RI/FS.

Finally, to demonstrate that cleanups have achieved the groundwater protection PRGs, the cleanup verification process can involve the evaluation of the conceptual site model at the waste sites against the assumptions used to develop these PRGs (described in Chapter 5 of this RI/FS). To the extent a significant deviation from the groundwater/surface water protection PRG 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 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 sections 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 sections.

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 1×10^{-6} and an HQ of 1.0 for individual noncarcinogenic substances as described in 2007 MTCA, "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740[3][b][iii][B]). Additional information about exposure assumptions and the risk bases is provided in Section 6.2.3.3.1 of this RI/FS.

Consistent with this approach, the methodology described for unrestricted land use under 2007 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 "Cleanup Standards to Protect Air Quality" (WAC 173-340-750[3]) and EPA-published volatilization factors and particulate emission factors.

For arsenic, lead, and total petroleum hydrocarbon, Table 740-1 in the Method A "Soil Cleanup Levels for Unrestricted Land Use" (2007 MTCA "Tables" [WAC 173-340-900]) is used as the PRG for direct contact exposure.

Soil PRG values are 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 the reasonably anticipated future land use for the OU(s). A complete description of the activities, exposure assumptions, and risk bases associated with casual recreational user scenario is provided in Section 6.2.3.3.3 of this RI/FS. The PRG values listed in Table 8-3 for this exposure scenario are provided to aid 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 (*Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* [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 2007 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 Section 7.3.4 of this RI/FS.

Table 8-3. Summary of 100-D and 100-H Operable Units 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 2007 MTCA B—Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil 2007 MTCA 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-D 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model GWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	100-D 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model SWP PRG[i]	100-H 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]	--
Carbon-14	14762-75-5	pCi/g	--	--	81	--	328,000	52,000	8.7	101	1,110	151	1,440	--	101	1,110	151	1,440	--
Cesium-137	10045-97-3	pCi/g	1.1	--	4.4	--	100	6.2	6.2	--[j]	--[j]	--[j]	--[j]	1,470	--[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]	13,900	--[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]	--
Europium-152	14683-23-9	pCi/g	--	--	3.7	--	66	3.8	3.3	--[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]	--
Europium-155	14391-16-3	pCi/g	0.054	--	327	--	5,870	354	125	--[j]	--[j]	--[j]	--[j]	--	--[j]	--[j]	--[j]	--[j]	--
Iodine-129	15046-84-1	pCi/g	--	--	0.076	--	3,035	434	0.25	0.84	9.2	3.6	66	0.25	0.84	9.2	3.6	66	0.25
Neptunium-237	13994-20-2	pCi/g	--	--	8.9	--	202	15	2.4	625	2,110	--[j]	--[j]	0.90	625	2,110	--[j]	--[j]	1.8
Nickel-63	13981-37-8	pCi/g	--	--	608	--	575,000	91,600	4,013	--[j]	>1,000,000	--[j]	--[j]	83	--[j]	>1,000,000	--[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]	--
Plutonium-238	13981-16-3	pCi/g	0.0038	--	236	--	3,820	605	39	--[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]	--
Technetium-99	14133-76-7	pCi/g	--	--	1.5	--	114,449	17,322	5.8	45	501	68	647	0.46	45	501	68	647	0.92
Total beta radiostrontium (strontium-90)	SR-RAD	pCi/g	0.18	--	2.3	--	5,060	518	4.5	29,400	157,000	774,000	--[j]	28	29,400	157,000	774,000	--[j]	55
Tritium	10028-17-8	pCi/g	--	--	623	--	15,400	1,265,000	459	2,060	18,000	2,320	19,700	13	2,060	18,000	2,320	19,700	25
Uranium-233/234	U-233/234	pCi/g	1.1	--	133	--	5,810	931	1.1	--[k]	--[k]	--[k]	--[k]	1.1	--[k]	--[k]	--[k]	--[k]	1.1
Uranium-235	15117-96-1	pCi/g	0.11	--	16	--	295	22	0.61	--[k]	--[k]	--[k]	--[k]	0.50	--[k]	--[k]	--[k]	--[k]	0.50
Uranium-238	U-238	pCi/g	1.1	--	54	--	1,093	93	1.1	--[k]	--[k]	--[k]	--[k]	1.1	--[k]	--[k]	--[k]	--[k]	1.1
Metals																			
Aluminum	7429-90-5	mg/kg	11,800	80,000	--	>1,000,000	912,000	--	--	--[j]	--[j]	--[j]	--[j]	--	--[j]	--[j]	--[j]	--[j]	--
Antimony	7440-36-0	mg/kg	0.13	32	--	--	365	--	32	--[j]	5,590	--[j]	--[j]	5.0	--[o]	--[o]	--[o]	--[o]	5.0
Arsenic	7440-38-2	mg/kg	6.5	20	--	42,400	4.5	--	20	246	20	--[j]	--[j]	20	389,000	50,200	--[j]	--[j]	20
Barium	7440-39-3	mg/kg	132	16,000	--	>1,000,000	182,000	--	5,600	389,000	389,000	--[j]	--[j]	200	--[o]	--[o]	--[o]	--[o]	400
Beryllium	7440-41-7	mg/kg	1.5	160	--	76,000	1,820	--	10	--[j]	--[j]	--[j]	--[j]	1.5	--[o]	--[o]	--[o]	--[o]	1.5
Boron	7440-42-8	mg/kg	3.9	16,000	--	>1,000,000	182,000	--	7,200	7,780	85,900	--[j]	389,000	320	--[o]	--[o]	--[o]	--[o]	--
Cadmium	7440-43-9	mg/kg	0.56	80	--	101,000	821	--	14	27	296	--[j]	93,300	0.81	1.3	15	--[j]	4,670	0.81

Table 8-3. Summary of 100-D and 100-H Operable Units 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 2007 MTCA B—Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil 2007 MTCA 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-D 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model GWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	100-D 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model SWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 SWP RAG[h]
Chromium	7440-47-3	mg/kg	19	120,000	--	--	>1,000,000	--	80,000	--[j]	--[j]	--[j]	--[j]	19	--[j]	--[j]	--[j]	--[j]	19
Cobalt	7440-48-4	mg/kg	16	24	--	20,300	274	--	24	--[j]	4,470	--[j]	--[j]	16	--[o]	--[o]	--[o]	--[o]	--
Copper	7440-50-8	mg/kg	22	3,200	--	--	36,500	--	2,960	286,000	136,000	--[j]	--[j]	59	4,030	1,920	--[j]	--[j]	22
Cr(VI)	18540-29-9	mg/kg	--	240	--	2,170	2,740	--	2.1	6.0[l]	6.0[l]	6.0[l]	6.0[l]	4.8	6.0[l]	6.0[l]	6.0[l]	6.0[l]	2.0
Iron	7439-89-6	mg/kg	32,600	56,000	--	--	639,000	--	--	389,000	389,000	--[j]	--[j]	--	389,000	258,000	--[j]	--[j]	--
Lead	7439-92-1	mg/kg	10	250	--	--	--	--	353	--[j]	--[j]	--[j]	--[j]	10	--[j]	--[j]	--[j]	--[j]	10
Lithium	7439-93-2	mg/kg	13	160	--	--	1,830	--	160	--[j]	--[j]	--[j]	--[j]	34	--[o]	--[o]	--[o]	--[o]	--
Manganese	7439-96-5	mg/kg	512	11,200	--	>1,000,000	128,000	--	3,760	--[j]	389,000	--[j]	--[j]	512	--[o]	--[o]	--[o]	--[o]	512
Mercury	7439-97-6	mg/kg	0.013	24	--	>1,000,000	274	--	24	--[j]	2,830	--[j]	--[j]	0.33	--[j]	17	--[j]	--[j]	0.33
Molybdenum	7439-98-7	mg/kg	0.47	400	--	--	4,560	--	400	18,200	15,100	--[j]	--[j]	8.0	--[o]	--[o]	--[o]	--[o]	--
Nickel	7440-02-0	mg/kg	19	1,600	--	701,000	18,200	--	1,600	--[j]	289,000	--[j]	--[j]	19	--[j]	150,000	--[j]	--[j]	27
Selenium	7782-49-2	mg/kg	0.78	400	--	>1,000,000	4,560	--	400	201	2,220	--[j]	316,000	5.0	20	222	--[j]	31,600	1.0
Silver	7440-22-4	mg/kg	0.17	400	--	--	4,560	--	400	557	5,860	--[j]	389,000	8.0	18	191	--[j]	114,000	0.73
Strontium	7440-24-6	mg/kg	--	48,000	--	--	548,000	--	48,000	389,000	389,000	--[j]	--[j]	960	--[o]	--[o]	--[o]	--[o]	--
Thallium	7440-28-0	mg/kg	0.19	--	--	--	--	--	--	--[j]	627	--[j]	--[j]	--	--[o]	--[o]	--[o]	--[o]	--
Tin	7440-31-5	mg/kg	--	48,000	--	--	548,000	--	48,000	--[j]	--[j]	--[j]	--[j]	960	--[o]	--[o]	--[o]	--[o]	--
Total_U_Isotopes	Total_U_Isotopes	mg/kg	3.2	240	--	>1,000,000	2,740	--	240	NVR[m]	NVR[m]	NVR[m]	NVR[m]	3.2	NVR[m]	NVR[m]	NVR[m]	NVR[m]	3.2
Uranium (soluble salts)	7440-61-1	mg/kg	3.2	240	--	>1,000,000	2,740	--	240	NVR[m]	NVR[m]	NVR[m]	NVR[m]	3.2	NVR[m]	NVR[m]	NVR[m]	NVR[m]	3.2
Vanadium	7440-62-2	mg/kg	85	400	--	--	4,560	--	560	--[j]	--[j]	--[j]	--[j]	85	--[o]	--[o]	--[o]	--[o]	--
Zinc	7440-66-6	mg/kg	68	24,000	--	--	274,000	--	24,000	--[j]	389,000	--[j]	--[j]	480	--[j]	225,000	--[j]	--[j]	68
Other Inorganics																			
Chloride	16887-00-6	mg/kg	100	--	--	--	--	--	--	12,600	139,000	18,800	180,000	25,000	11,600	128,000	17,300	165,000	--
Cyanide	57-12-5	mg/kg	--	48	--	19	432	--	1,600	46	430	--[j]	389,000	20	50	466	--[j]	389,000	1.0
Fluoride	16984-48-8	mg/kg	2.8	4,800	--	>1,000,000	54,750	--	4,800	--[j]	389,000	--[j]	--[j]	96	--[o]	--[o]	--[o]	--[o]	400
Nitrate	14797-55-8	mg/kg	52	568,000	--	--	>1,000,000	--	567,000[m]	2,270	25,100	3,380	32,400	4,430[m]	--[o]	--[o]	--[o]	--[o]	8,860[n]
Nitrite	14797-65-0	mg/kg	--	24,000	--	--	274,000	--	26,300[m]	166	1,840	248	2,370	329[m]	--[o]	--[o]	--[o]	--[o]	658[n]
Sulfate	14808-79-8	mg/kg	237	--	--	--	--	--	--	12,600	139,000	18,800	180,000	25,000	--[o]	--[o]	--[o]	--[o]	--

Table 8-3. Summary of 100-D and 100-H Operable Units 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 2007 MTCA B—Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil 2007 MTCA 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-D 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model GWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	100-D 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model SWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 SWP RAG[h]
Polychlorinated Biphenyls																			
Polychlorinated Biphenyls	1336-36-3	mg/kg	--	0.5	--	320,000	2.6	--	0.50	--	--	--	--	--	--	--	--	--	
Aroclor-1016	12674-11-2	mg/kg	--	5.6	--	>1,000,000	46	--	0.50	--[j]	9,270	--[j]	--[j]	0.017	--[j]	260	--[j]	--[j]	0.017
Aroclor-1221	11104-28-2	mg/kg	--	0.50	--	0.19	2.0	--	0.50	0.15	1.6	--[j]	1,000	0.017	0.099	1.0	--[j]	642	0.017
Aroclor-1232	11141-16-5	mg/kg	--	0.50	--	0.19	2.0	--	0.50	0.15	1.6	--[j]	1,000	0.017	0.099	1.0	--[j]	642	0.017
Aroclor-1242	53469-21-9	mg/kg	--	0.50	--	320,000	2.6	--	0.50	--[j]	241	--[j]	--[j]	0.017	--[j]	77	--[j]	--[j]	0.017
Aroclor-1248	12672-29-6	mg/kg	--	0.50	--	320,000	2.6	--	0.50	--[j]	224	--[j]	--[j]	0.017	--[j]	72	--[j]	--[j]	0.017
Aroclor-1254	11097-69-1	mg/kg	--	0.50	--	320,000	2.6	--	0.50	--[j]	1,850	--[j]	--[j]	0.017	--[j]	591	--[j]	--[j]	0.017
Aroclor-1260	11096-82-5	mg/kg	--	0.50	--	320,000	2.6	--	0.50	--[j]	--[j]	--[j]	--[j]	0.017	--[j]	--[j]	--[j]	--[j]	0.017
Pesticides																			
2,4-DB(4-(2,4-Dichlorophenoxy)butanoic acid)	94-82-6	mg/kg	--	640	--	--	7,300	--	640	16	174	24	261	13	--[o]	--[o]	--[o]	--[o]	--
4,4'-DDD (Dichlorodiphenyldichloroethane)	72-54-8	mg/kg	--	4.2	--	>1,000,000	24	--	4.2	--[j]	357	--[j]	--[j]	0.037	--[o]	--[o]	--[o]	--[o]	0.0033
4,4'-DDE (Dichlorodiphenyldichloroethylene)	72-55-9	mg/kg	--	2.9	--	>1,000,000	17	--	2.9	--[j]	2,070	--[j]	--[j]	0.026	--[o]	--[o]	--[o]	--[o]	0.0033
4,4'-DDT (Dichlorodiphenyltrichloroethane)	50-29-3	mg/kg	--	2.9	--	>1,000,000	20	--	2.9	--[j]	--[j]	--[j]	--[j]	0.026	--[j]	--[j]	--[j]	--[j]	0.0033
Aldrin	309-00-2	mg/kg	--	0.059	--	0.12	0.32	--	0.059	--[j]	3.0	--[j]	--[j]	0.0017	--[j]	2.2	--[j]	--[j]	0.0017
Alpha-BHC	319-84-6	mg/kg	--	0.16	--	101,000	0.90	--	0.16	0.020	0.22	0.17	3.4	0.0017	--[o]	--[o]	--[o]	--[o]	0.0017
Alpha-Chlordane	5103-71-9	mg/kg	--	2.9	--	>1,000,000	19	--	2.9	--[j]	334	--[j]	--[j]	0.025	--[j]	5.7	--[j]	--[j]	0.017
Beta-BHC	319-85-7	mg/kg	--	0.56	--	344,000	3.1	--	0.56	0.085	0.94	489	27	0.0049	--[o]	--[o]	--[o]	--[o]	0.0055
Dalapon	75-99-0	mg/kg	--	2,400	--	--	27,400	--	2,400	11	116	16	151	20	--[o]	--[o]	--[o]	--[o]	--
Delta-BHC	319-86-8	mg/kg	--	--	--	--	--	--	--	--[o]	--[o]	--[o]	--[o]	--	--[o]	--[o]	--[o]	--[o]	--
Dicamba	1918-00-9	mg/kg	--	2,400	--	--	27,400	--	2,400	35	380	51	513	48	--[o]	--[o]	--[o]	--[o]	--
Dieldrin	60-57-1	mg/kg	--	0.063	--	39,600	0.35	--	0.063	8.0	1.5	--[j]	--[j]	0.0033	2.8	0.51	--[j]	--[j]	0.0033
Dinoseb(2-secButyl-4,6-dinitrophenol)	88-85-7	mg/kg	--	80	--	--	713	--	80	24	267	--[j]	26,200	0.70	--[o]	--[o]	--[o]	--[o]	--
Endosulfan I	959-98-8	mg/kg	--	480	--	--	4,280	--	480	160	1,770	389,000	47,900	9.6	0.094	1.0	377	28	0.011
Endosulfan II	33213-65-9	mg/kg	--	480	--	--	4,280	--	480	160	1,770	389,000	47,900	9.6	0.094	1.0	377	28	0.011
Endosulfan sulfate	1031-07-8	mg/kg	--	--	--	--	--	--	480	--[o]	--[o]	--[o]	--[o]	9.6	--[o]	--[o]	--[o]	--[o]	0.011
Endrin	72-20-8	mg/kg	--	24	--	--	214	--	24	24	202	--[j]	263,000	0.20	0.027	0.23	--[j]	302	0.039
Endrin Aldehyde	7421-93-4	mg/kg	--	--	--	--	--	--	24	--[o]	--[o]	--[o]	--[o]	0.20	--[o]	--[o]	--[o]	--[o]	0.039

Table 8-3. Summary of 100-D and 100-H Operable Units 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 2007 MTCA B—Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil 2007 MTCA 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-D 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model GWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	100-D 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model SWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 SWP RAG[h]
Endrin ketone	53494-70-5	mg/kg	--	--	--	--	--	--	24	--[o]	--[o]	--[o]	--[o]	0.20	--[o]	--[o]	--[o]	--[o]	0.039
Gamma-BHC (Lindane)	58-89-9	mg/kg	--	0.91	--	588,000	6.0	--	0.77	0.089	0.97	0.53	10	0.0067	0.089	0.98	0.53	10	0.0038
Gamma-Chlordane	5566-34-7	mg/kg	--	2.9	--	>1,000,000	19	--	2.9	--[j]	334	--[j]	--[j]	0.025	--[j]	5.7	--[j]	--[j]	0.017
Heptachlor	76-44-8	mg/kg	--	0.22	--	140,300	1.3	--	0.22	0.17	1.7	--[j]	1,500	0.0020	0.034	0.33	--[j]	294	0.0020
Heptachlor epoxide	1024-57-3	mg/kg	--	0.11	--	1.3	0.62	--	0.11	--[j]	34	--[j]	--[j]	0.0020	--[j]	27	--[j]	--[j]	0.0020
Methoxychlor	72-43-5	mg/kg	--	400	--	--	3,560	--	400	--[j]	241,000	--[j]	--[j]	4.0	--[j]	181	--[j]	--[j]	1.7
Toxaphene	8001-35-2	mg/kg	--	0.91	--	570,000	5.1	--	0.91	--[j]	951	--[j]	--[j]	0.20	--[j]	2.4	--[j]	--[j]	0.20
Polynuclear Aromatic Hydrocarbons																			
Acenaphthene	83-32-9	mg/kg	--	4,800	--	--	40,100	--	4,800	1,890	20,900	--[j]	389,000	96	--[o]	--[o]	--[o]	--[o]	129
Acenaphthylene	208-96-8	mg/kg	--	--	--	--	--	--	4,800	--[o]	--[o]	--[o]	--[o]	96	--[o]	--[o]	--[o]	--[o]	129
Anthracene	120-12-7	mg/kg	--	24,000	--	--	201,000	--	24,000	389,000	389,000	--[j]	--[j]	240	--[o]	--[o]	--[o]	--[o]	1,920
Benzo(a)anthracene	56-55-3	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[j]	--[j]	--[j]	--[j]	0.015	--[o]	--[o]	--[o]	--[o]	0.015
Benzo(a)pyrene	50-32-8	mg/kg	--	0.14	--	165,800	0.17	--	0.14	--[j]	--[j]	--[j]	--[j]	0.015	--[o]	--[o]	--[o]	--[o]	0.015
Benzo(b)fluoranthene	205-99-2	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[j]	--[j]	--[j]	--[j]	0.015	--[o]	--[o]	--[o]	--[o]	0.015
Benzo(ghi)perylene	191-24-2	mg/kg	--	--	--	--	--	--	2,400	--[o]	--[o]	--[o]	--[o]	48	--[o]	--[o]	--[o]	--[o]	192
Benzo(k)fluoranthene	207-08-9	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[j]	--[j]	--[j]	--[j]	0.015	--[o]	--[o]	--[o]	--[o]	0.015
Chrysene	218-01-9	mg/kg	--	14	--	>1,000,000	17	--	14	--[j]	--[j]	--[j]	--[j]	0.12	--[o]	--[o]	--[o]	--[o]	0.10
Dibenz[a,h]anthracene	53-70-3	mg/kg	--	1.4	--	>1,000,000	1.7	--	1.4	--[j]	--[j]	--[j]	--[j]	0.030	--[o]	--[o]	--[o]	--[o]	0.030
Fluoranthene	206-44-0	mg/kg	--	3,200	--	--	26,800	--	3,200	--[j]	389,000	--[j]	--[j]	64	--[o]	--[o]	--[o]	--[o]	18
Fluorene	86-73-7	mg/kg	--	3,200	--	--	26,800	--	3,200	2,020	21,800	--[j]	389,000	64	--[o]	--[o]	--[o]	--[o]	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]	0.33	--[o]	--[o]	--[o]	--[o]	0.33
Naphthalene	91-20-3	mg/kg	--	1,600	--	1.4	62	--	1,600	158	1,740	813	15,600	16	--[o]	--[o]	--[o]	--[o]	988
Phenanthrene	85-01-8	mg/kg	--	--	--	--	--	--	24,000	--[o]	--[o]	--[o]	--[o]	240	--[o]	--[o]	--[o]	--[o]	1,920
Pyrene	129-00-0	mg/kg	--	2,400	--	--	20,100	--	2,400	--[j]	389,000	--[j]	--[j]	48	--[o]	--[o]	--[o]	--[o]	192
Volatile Organic Compounds and Semivolatile Organic Compounds																			
1,1-Dichloroethene	75-35-4	mg/kg	--	4,000	--	102	8,880	--	--	0.70	7.6	1.0	11	--	--[o]	--[o]	--[o]	--[o]	--
1,1,1-Trichloroethane	71-55-6	mg/kg	--	160,000	--	3,660	320,000	--	--	31	332	47	531	--	--[o]	--[o]	--[o]	--[o]	--
1,2,4-Trichlorobenzene	120-82-1	mg/kg	--	34	--	14	257	--	800	2.1	23	16	319	7.0	--[o]	--[o]	--[o]	--[o]	45
1,2-Dichlorobenzene	95-50-1	mg/kg	--	7,200	--	546	34,000	--	7,200	205	2,200	410	5,860	60	--[o]	--[o]	--[o]	--[o]	540

Table 8-3. Summary of 100-D and 100-H Operable Units 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 2007 MTCA B—Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil 2007 MTCA 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-D 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model GWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	100-D 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model SWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 SWP RAG[h]
1,3-Dichlorobenzene	541-73-1	mg/kg	--	--	--	--	--	--	2,400	--[o]	--[o]	--[o]	--[o]	24	--[o]	--[o]	--[o]	--[o]	80
1,4-Dichlorobenzene	106-46-7	mg/kg	--	185	--	1.5	64	--	42	4.3	46	12	190	0.33	--[o]	--[o]	--[o]	--[o]	0.97
2,4,5-Trichlorophenol	95-95-4	mg/kg	--	8,000	--	--	71,300	--	8,000	1,050	11,500	7,840	155,000	80	--[o]	--[o]	--[o]	--[o]	--
2,4,6-Trichlorophenol	88-06-2	mg/kg	--	80	--	95	460	--	91	1.4	15	2.7	39	0.80	--[o]	--[o]	--[o]	--[o]	0.42
2,4-Dichlorophenol	120-83-2	mg/kg	--	240	--	--	2,140	--	240	3.9	42	6.0	69	4.8	--[o]	--[o]	--[o]	--[o]	19
2,4-Dimethylphenol	105-67-9	mg/kg	--	1,600	--	--	14,300	--	1,600	34	362	55	675	32	--[o]	--[o]	--[o]	--[o]	111
2,4-Dinitrophenol	51-28-5	mg/kg	--	160	--	--	1,430	--	160	1.6	18	2.4	23	3.2	--[o]	--[o]	--[o]	--[o]	14
2,4-Dinitrotoluene	121-14-2	mg/kg	--	3.2	--	>1,000,000	18	--	160	0.42	0.54	0.42	0.56	3.2	--[o]	--[o]	--[o]	--[o]	0.33
2,6-Dinitrotoluene	606-20-2	mg/kg	--	80	--	--	714	--	80	1.6	18	2.4	26	1.6	--[o]	--[o]	--[o]	--[o]	136
2-Butanone	78-93-3	mg/kg	--	48,000	--	28,400	464,000	--	--	258	2,850	384	3,710	--	--[o]	--[o]	--[o]	--[o]	--
2-Chlorophenol	95-57-8	mg/kg	--	400	--	--	4,560	--	400	14	150	28	406	4.0	--[o]	--[o]	--[o]	--[o]	19
2-Chloronaphthalene	91-58-7	mg/kg	--	6,400	--	--	73,000	--	6,400	1,290	14,300	--[j]	--[j]	64	--[o]	--[o]	--[o]	--[o]	206
2-Hexanone	591-78-6	mg/kg	--	400	--	160	3,600	--	--	2.5	27	3.7	36	--	--[o]	--[o]	--[o]	--[o]	--
2-Methylnaphthalene	91-57-6	mg/kg	--	320	--	--	2,680	--	320	65	713	389,000	24,600	3.2	--[o]	--[o]	--[o]	--[o]	--
2-Methylphenol (cresol, o-)	95-48-7	mg/kg	--	4,000	--	52,000	35,400	--	4,000	48	520	71	770	80	--[o]	--[o]	--[o]	--[o]	--
2-Nitroaniline	88-74-4	mg/kg	--	800	--	>1,000,000	7,130	--	240	22	234	32	359	2.4	--[o]	--[o]	--[o]	--[o]	--
2-Nitrophenol	88-75-5	mg/kg	--	--	--	--	--	--	--	--[o]	--[o]	--[o]	--[o]	--	--[o]	--[o]	--[o]	--[o]	--
3,3'-Dichlorobenzidine	91-94-1	mg/kg	--	2.2	--	536,400	13	--	2.2	0.42	1.3	0.42	6.4	0.33	--[o]	--[o]	--[o]	--[o]	0.33
3-Nitroaniline	99-09-2	mg/kg	--	24	--	>1,000,000	214	--	24	0.55	6.0	0.83	9.2	0.33	--[o]	--[o]	--[o]	--[o]	--
4-Bromophenylphenyl ether	101-55-3	mg/kg	--	--	--	--	--	--	--	--[o]	--[o]	--[o]	--[o]	--	--[o]	--[o]	--[o]	--[o]	--
4-Chloro-3-methylphenol	59-50-7	mg/kg	--	8,000	--	--	71,300	--	4,000	685	7,370	1,600	24,500	80	--[o]	--[o]	--[o]	--[o]	--
4-Chloroaniline	106-47-8	mg/kg	--	5.0	--	--	28	--	320	0.42	0.54	0.42	0.54	6.4	--[o]	--[o]	--[o]	--[o]	--
4-Chlorophenylphenyl ether	7005-72-3	mg/kg	--	--	--	--	--	--	--	--[o]	--[o]	--[o]	--[o]	--	--[o]	--[o]	--[o]	--[o]	--
4-Methyl-2-pentanone	108-10-1	mg/kg	--	6,400	--	13,100	69,400	--	--	39	423	57	559	--	--[o]	--[o]	--[o]	--[o]	--
4-Methylphenol (cresol, p-)	106-44-5	mg/kg	--	8,000	--	55,900	70,400	--	400	225	2,410	405	5,450	8.0	--[o]	--[o]	--[o]	--[o]	--
4-Nitroaniline	100-01-6	mg/kg	--	50	--	>1,000,000	283	--	48	0.58	6.3	0.87	9.7	0.33	--[o]	--[o]	--[o]	--[o]	--
4-Nitrophenol	100-02-7	mg/kg	--	--	--	--	--	--	640	--[o]	--[o]	--[o]	--[o]	13	--[o]	--[o]	--[o]	--[o]	1,254
4,6-Dinitro-2-methylphenol	534-52-1	mg/kg	--	6.4	--	--	57	--	8.0	0.82	8.8	2.6	46	0.33	--[o]	--[o]	--[o]	--[o]	--
Acetone	67-64-1	mg/kg	--	72,000	--	194,000	790,000	--	72,000	366	4,040	546	5,230	720	--[o]	--[o]	--[o]	--[o]	--

Table 8-3. Summary of 100-D and 100-H Operable Units 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 2007 MTCA B—Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil 2007 MTCA 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-D 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model GWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	100-D 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model SWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 SWP RAG[h]
Benzene	71-43-2	mg/kg	--	18	--	0.57	22	--	--	0.077	0.84	0.11	1.2	--	--[o]	--[o]	--[o]	--[o]	--
Bis(2-chloro-1-methylethyl)ether	108-60-1	mg/kg	--	14	--	4.8	71	--	14	0.42	0.77	0.42	1.1	0.33	--[o]	--[o]	--[o]	--[o]	7.5
Bis(2-Chloroethoxy)methane	111-91-1	mg/kg	--	240	--	--	2,140	--	0.91	2.9	32	4.3	43	0.33	--[o]	--[o]	--[o]	--[o]	0.33
Bis(2-chloroethyl) ether	111-44-4	mg/kg	--	0.91	--	0.27	4.4	--	0.91	0.42	0.54	0.42	0.54	0.33	--[o]	--[o]	--[o]	--[o]	0.33
Bis(2-ethylhexyl) phthalate	117-81-7	mg/kg	--	71	--	>1,000,000	405	--	71	--[j]	130,000	--[j]	--[j]	0.60	--[o]	--[o]	--[o]	--[o]	0.36
Butylbenzylphthalate	85-68-7	mg/kg	--	526	--	--	2,980	--	16,000	1,300	5,980	--[j]	--[j]	320	--[o]	--[o]	--[o]	--[o]	250
Carbazole	86-74-8	mg/kg	--	50	--	--	283	--	50	12	132	--[j]	7,800	0.44	--[o]	--[o]	--[o]	--[o]	--
Carbon tetrachloride	56-23-5	mg/kg	--	14	--	0.61	22	--	7.7	0.10	1.1	0.16	1.9	0.034	--[o]	--[o]	--[o]	--[o]	0.050
Chloroform	67-66-3	mg/kg	--	32	--	0.24	11	--	--	0.13	1.4	0.19	2.0	--	--[o]	--[o]	--[o]	--[o]	--
Dibenzofuran	132-64-9	mg/kg	--	80	--	--	913	--	160	66	652	--[j]	389,000	3.2	--[o]	--[o]	--[o]	--[o]	--
Diethylphthalate	84-66-2	mg/kg	--	64,000	--	--	570,000	--	64,000	1,440	15,700	2,140	22,900	1,280	--[o]	--[o]	--[o]	--[o]	4,600
Dimethyl phthalate	131-11-3	mg/kg	--	--	--	--	--	--	80,000	--[o]	--[o]	--[o]	--[o]	1,600	--[o]	--[o]	--[o]	--[o]	14,400
Di-n-butylphthalate	84-74-2	mg/kg	--	8,000	--	--	71,300	--	8,000	2,060	22,600	15,000	296,000	160	--[o]	--[o]	--[o]	--[o]	540
Di-n-octylphthalate	117-84-0	mg/kg	--	960	--	--	8,550	--	1,600	--[j]	--[j]	--[j]	--[j]	32	--[o]	--[o]	--[o]	--[o]	--
Ethylbenzene	100-41-4	mg/kg	--	91	--	2.3	90	--	--	0.82	8.8	1.3	16	--	--[o]	--[o]	--[o]	--[o]	--
Hexachlorobenzene	118-74-1	mg/kg	--	0.63	--	396,000	3.5	--	0.63	--[j]	330	--[j]	--[j]	0.33	--[o]	--[o]	--[o]	--[o]	0.33
Hexachlorobutadiene	87-68-3	mg/kg	--	13	--	5.0	55	--	13	--[j]	875	--[j]	--[j]	0.33	--[o]	--[o]	--[o]	--[o]	0.33
Hexachlorocyclopentadiene	77-47-4	mg/kg	--	480	--	4.2	403	--	480	--[j]	--[j]	--[j]	--[j]	5.0	--[o]	--[o]	--[o]	--[o]	48
Hexachloroethane	67-72-1	mg/kg	--	25	--	2.5	63	--	71	1.6	17	14	274	0.31	--[o]	--[o]	--[o]	--[o]	0.38
Isophorone	78-59-1	mg/kg	--	1,050	--	50,500	5,960	--	1,050	4.0	43	5.8	60	9.2	--[o]	--[o]	--[o]	--[o]	1.7
Nitrobenzene	98-95-3	mg/kg	--	160	--	2.0	91	--	160	2.3	24	3.4	38	1.6	--[o]	--[o]	--[o]	--[o]	3.4
n-Nitrosodi-n-dipropylamine	621-64-7	mg/kg	--	0.14	--	91,200	0.81	--	0.33	0.42	0.54	0.42	0.54	0.33	--[o]	--[o]	--[o]	--[o]	0.33
n-Nitrosodiphenylamine	86-30-6	mg/kg	--	204	--	>1,000,000	1,160	--	204	19	209	108	2,090	1.8	--[o]	--[o]	--[o]	--[o]	1.9
Methylene chloride	75-09-2	mg/kg	--	480	--	528	3,230	--	133	0.29	3.2	0.43	4.2	0.50	--[o]	--[o]	--[o]	--[o]	0.94
Pentachlorophenol	87-86-5	mg/kg	--	2.5	--	>1,000,000	10	--	8.3	0.42	1.2	0.42	4.8	0.33	6.6	71	18	283	0.33
Phenol	108-95-2	mg/kg	--	24,000	--	11,500	182,000	--	24,000	174	1,900	256	2,570	480	--[o]	--[o]	--[o]	--[o]	4,200
Tetrachloroethene	127-18-4	mg/kg	--	467	--	20	716	--	--	1.3	14	2.2	29	--	--[o]	--[o]	--[o]	--[o]	--
trans-1,2-Dichloroethylene	156-60-5	mg/kg	--	1,600	--	39	3,350	--	--	7.9	87	12	118	--	--[o]	--[o]	--[o]	--[o]	--
Tributyl Phosphate	126-73-8	mg/kg	--	111	--	--	828	--	185	19	206	221,000	6,600	3.3	--[o]	--[o]	--[o]	--[o]	--

Table 8-3. Summary of 100-D and 100-H Operable Units 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 2007 MTCA B—Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil 2007 MTCA 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-D 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model GWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	100-D 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model SWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 SWP RAG[h]
Toluene	108-88-3	mg/kg	--	6,400	--	4,770	63,800	--	6,400	100	1,090	153	1,760	64	--[o]	--[o]	--[o]	--[o]	1,360
Trichloroethene	79-01-6	mg/kg	--	22	--	1.1	37	--	--	0.12	1.3	0.17	1.9	--	--[o]	--[o]	--[o]	--[o]	--
Vinyl Chloride	75-01-4	mg/kg	--	1.4	--	0.53	0.07	--	--	0.0064	0.043	0.0064	0.058	--	--[o]	--[o]	--[o]	--[o]	--
Xylenes (total)	1330-20-7	mg/kg	--	16,000	--	104	10,400	--	16,000	365	3,940	609	7,710	160	--[o]	--[o]	--[o]	--[o]	--
Other Organics																			
Total Petroleum Hydrocarbons–Diesel Range	TPHDIESEL	mg/kg	--	2,000	--	--	--	--	200	2,000[p]	2,000[p]	2,000[p]	2,000[p]	200	--[o]	--[o]	--[o]	--[o]	200
Total Petroleum Hydrocarbons–Motor Oil (high boiling)	TPH/OILH	mg/kg	--	2,000	--	--	--	--	200	2,000[p]	2,000[p]	2,000[p]	2,000[p]	200	--[o]	--[o]	--[o]	--[o]	200

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 the 100 Area RDR/RAWP (DOE/RL-96-17) is highlighted in yellow. For nonradionuclide PRGs, the PRG is the RI/FS 2007 MTCA Method B soil direct contact cleanup value, except for arsenic and lead which set to the "Soil Cleanup Levels for Unrestricted Land Uses" ["Tables" WAC 173-340-900], Table 740-1, "Method A Soil Cleanup Levels 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; Hanford Site Background Values for Radionuclides"; 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 Tables (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-11-0063, *STOMP 1-D Modeling for Determination of Soil Screening Levels and Preliminary Remediation Goals for Waste Sites in the 100-D and 100-H Source Operable Units*. 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. EQL values are obtained from DOE/RL-2009-41, *Sampling and Analysis Plan for the 100-K Decision Unit Remedial Investigation/Feasibility Study*, and DOE/RL-2009-40, *Sampling and Analysis Plan for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2, and 100-HR-3 Operable Units Remedial Investigation/Feasibility Study*. SSLs and PRGs have not been adjusted by waste site dimensions.

j. The SSL or PRG value for groundwater protection or surface water protection is considered non-representative 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. A SSL is calculated for total uranium (CAS # 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, EPCs 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 EPC (identified as Total_U_Isotopes), as described in ECF-100DR1-11-0004, *Computation of Exposure Point Concentrations for the 100-DR-1, 100-DR-2, 100-HR-1 and 100-HR-2 Source Operable Units*. The Total_U_Isotopes EPC 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 for residual hexavalent chromium was derived from experiments with soil concentrations less than 6 mg/kg.

m. No Value Required. Uranium is not modeled because uranium is not a soil COPC at 183-H or other 100-D/H locations. Uranium will be monitored as a GW COPC.

n. Value converted from "as nitrogen" values in DOE/RL-96-17 using the following conversion factors as applicable: 4.43 g NO_3^-/g N and 3.29 g NO_2^-/ g N.

o. A groundwater protection or surface water protection SSL or PRG is not calculated because a groundwater or surface water cleanup level or MCL is not available for the analyte.

p. The SSL for total petroleum hydrocarbons is a default screening level obtained from "Tables" (WAC 173-340-900), Table 747-5, "Residual Saturation Screening Levels for TPH."

Table 8-3. Summary of 100-D and 100-H Operable Units 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 2007 MTCA B—Direct Contact PRG[b]	RI/FS Residential PRG[c]	RI/FS Soil 2007 MTCA 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-D 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model GWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model GWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model GWP PRG[i]	DOE/RL-96-17 GWP RAG[h]	100-D 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-H 70:30/100:0 Contaminant Source Model SWP SSL[i]	100-D 70:30/100:0 Contaminant Source Model SWP PRG[i]	100-H 70:30/100:0 Contaminant Source Model SWP PRG[i]	DOE/RL-96-17 SWP RAG[h]

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

Table 8-4. Summary of 100-D and 100-H Operable Units Ecological Soil PRGs

Contaminant	Hanford Site Background Concentration[a]	Preliminary Remediation Goals for Protection of Ecological Receptors			
		Plant PRG[b]	Invertebrate 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]
Chemicals (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]

Table 8-4. Summary of 100-D and 100-H Operable Units Ecological Soil PRGs

Contaminant	Hanford Site Background Concentration[a]	Preliminary Remediation Goals for Protection of Ecological Receptors			
		Plant PRG[b]	Invertebrate PRG[b]	Avian PRG[b]	Mammal PRG[b]
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
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
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]
Aroclor 1016	--	40	--[c]	1.8	4.9
Aroclor 1221	--	40	--[c]	1.8	1.5

Table 8-4. Summary of 100-D and 100-H Operable Units Ecological Soil PRGs

Contaminant	Hanford Site Background Concentration[a]	Preliminary Remediation Goals for Protection of Ecological Receptors			
		Plant PRG[b]	Invertebrate PRG[b]	Avian PRG[b]	Mammal PRG[b]
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
4,4'-DDE (Dichlorodiphenyldichloroethylene)	--	--[c]	--[c]	0.80	0.40
4,4'-DDT (Dichlorodiphenyltrichloroethane)	--	--[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
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

Table 8-4. Summary of 100-D and 100-H Operable Units Ecological Soil PRGs

Contaminant	Hanford Site Background Concentration[a]	Preliminary Remediation Goals for Protection of Ecological Receptors			
		Plant PRG[b]	Invertebrate PRG[b]	Avian PRG[b]	Mammal PRG[b]
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
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-Dichloroethylene	--	--[c]	--[c]	165	453
Toluene	--	200	--[c]	195	5,200

Table 8-4. Summary of 100-D and 100-H Operable Units Ecological Soil PRGs

Contaminant	Hanford Site Background Concentration[a]	Preliminary Remediation Goals for Protection of Ecological Receptors			
		Plant PRG[b]	Invertebrate PRG[b]	Avian PRG[b]	Mammal PRG[b]
Trichloroethene	--	--[c]	--[c]	165	70
Xylenes (total)	--	--[c]	--[c]	149	826
Total Petroleum Hydrocarbons–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, *Soil Background for Interim Use at the Hanford Site*; DOE/RL-2010-95, *Remedial Investigation/Feasibility Study for the 100-DR-1, 100-DR-2, 100-HR-1, 100-HR-2,and 100-HR-3 Operable Units*; 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*; 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 (OSWER Directive 9285.7-60). Most soil pH measures at the Hanford Site are greater than 5.5 (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*; DOE/RL-2007-50, *Central Plateau Ecological Risk Assessment Data Package Report*; ECF-HANFORD-11-0158). Thus, aluminum at the Hanford Site does not present an ecological risk.

PRG = preliminary remediation goal

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. 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 RME for an individual.). Demonstration that the 10^{-4} to 10^{-6} residual risk-range goal has been achieved will be accomplished through final verification sampling during closeout of individual sites using the residential exposure scenario. A complete description of the activities, exposure assumptions, and risk bases associated with the residential scenario is provided in Section 6.2.3.3.1 of this RI/FS. Table 8-3 presents a summary of the remedial action goals reported in the 100 Area RDR/RAWP (DOE/RL-96-17) and the PRGs developed for the residential scenario.

Soil PRG values are developed for the direct contact and inhalation pathways, combined, using the resident Monument worker and the casual recreational user exposure scenarios. The resident Monument worker scenario and the casual recreational use are both used to represent the reasonably anticipated future land use. A complete description of the activities, exposure assumptions, and risk bases associated with resident Monument worker and casual recreational user scenarios is provided in Section 6.2.3.3.2 and Section 6.2.3.3.3, respectively, of this RI/FS. PRG values for individual radioisotopes are based on an

ELCR of 1×10^{-4}. The PRG values listed in Table 8-3 for this exposure scenario are provided to aid in determining whether the cleanup actions achieve 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 Section 7.3. BCGs are also evaluated at the SMDP and considers potential population impacts 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)

Fate and transport modeling of contaminants in the vadose zone was conducted to assess their potential impact on groundwater or surface water. Numerical models were constructed to represent the key factors of the conceptual model for 100-D/H and simulated using the STOMP code (*STOMP Subsurface Transport Over Multiple Phases Version 2.0 Theory Guide* [PNNL-12030]). Modeling with STOMP was performed with a bounding representation of waste distribution and for multiple stratigraphic columns representing the range of conditions within 100-D/H. 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). Constituents that were persistent (that is, do not degrade or decay in a reasonable period) and that had a peak concentration in groundwater occurring within 1,000 years in the future were evaluated in this way. This modeling process, including assumptions and inputs, is described in Section 5.4 and modeling results in 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 8-4) and the same criterion protective of groundwater and surface water. The derivation of these protection levels is described in Section 5.7.

8.1.4.5 COC Identification Based on Groundwater and Surface Water PRGs

A groundwater risk assessment was presented in Section 6.3 of this report. The list of COCs presented in Table 8-5 was determined in Section 6.3. The process used to identify COCs is described in Section 6.3.2.3 (COPC Identification Process) and in Section 6.3.5 (Risk Characterization). Based on the results of the groundwater risk assessment, the list of COCs include chromium (total), Cr(VI), strontium-90, and nitrate in the 100-D Area; strontium-90, Cr(VI), and nitrate in the100-H Area; and chromium (total) and Cr(VI) in the Horn area. Nitrate has a 90th percentile concentration less than the DWS in the 100-H Area, but has areas of localized contamination above the DWS; therefore, it is retained as a COC.

8.2 General Response Actions

GRAs consistent with RAOs were identified for 100-D/H. GRAs are basic actions that might be undertaken to remediate a site, and are assembled based on nature and extent of contamination, as presented in the RI. For each GRA, several possible remedial technologies may exist, which can be further divided into a number of process options. This section discusses the remedial technology selection process.

Potential 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:

- Identify GRAs that may meet RAOs, either individually or in combination with other GRAs.
- Identify, screen, and evaluate remedial technology types for each GRA.
- Select representative process option(s).

Following the technology screening, representative 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, including waste sites, in 100-D/H include the following:

- No action
- ICs
- Removal, ex situ treatment, processing, and disposal
- In situ treatment
- Containment

GRAs identified for contaminated groundwater in 100-D/H include the following:

- No action
- ICs
- MNA
- Pump-and-treat (collection, ex situ treatment, and discharge)
- In situ treatment
- Containment

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 waste sites and groundwater areas that will be evaluated in the FS, based on the PRGs and findings of the HHRA, ERA, and RI presented in the preceding chapters.

8.2.1.1 Waste Sites

Table 8-6 summarizes the 343 waste sites (including subsites) evaluated through the RI/FS and groups which sites are, and are not, carried forward into the FS as described below. The evaluation of sites that are, or are not, carried forward into the FS is based on the waste site status as of November 2012 as reflected in Chapter 1.

Waste Sites Not Carried Forward into the FS (Chapter 1). As discussed in Chapter 1, the determination of which areas of 100-D/H are waste sites has been performed following specific procedures defined in TPA documents (TPA [Ecology et al., 1989a] and TPA Action Plan [Ecology et al., 1989b]). The areas

that have been suspected waste sites are summarized and tracked in the WIDS database. As information is learned about the sites, or as they are remediated and confirmation data collected, the sites are classified or reclassified, depending on their status. Of the 343 sites (including subsites) as of June 2011 in 100-D/H, 49 sites were not carried forward per discussion in Chapter 1. Forty-eight sites were classified or reclassified as "Rejected," "Not Accepted," or "Closed Out," and one site will be closed out under Washington Department of Health Regulations (Table 8-6). These sites were not considered further in this RI/FS.

In addition, the waste sites for the three reactor core safe storage enclosures, 105-D, 105-DR, and 105-H, are not discussed in the FS. The waste sites are 118-D-6:1, 118-DR-2:1, and 118-H-6:1, respectively. In September 1993, DOE issued a NEPA ROD (58 FR 48509, "Record of Decision; Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, WA") that established a path forward for the Hanford Site reactors. An "Amended Record of Decision for the Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, WA" (75 FR 43158) was issued in July 2010. The NEPA ROD provided options for immediate dismantlement for reactor decommissioning, and one-piece disposal of the reactor cores or dismantlement after an ISS period of approximately 75 years, which allowed for decay of the radionuclide(s) that presented the major risk for site workers. The three reactor buildings are currently in ISS. As detailed in *Hanford Site Cleanup Completion Framework* (DOE/RL-2009-10), the NEPA ROD (58 FR 48509) indicated DOE's intent to complete these decommissioning actions consistent with the proposed cleanup schedule for remedial actions, which includes the D, DR, and H Reactors. Until reactor removal is complete, DOE will continue to conduct routine maintenance, surveillance, and radiological monitoring activities during the ISS period.

Additional information developed through the risk assessments in Chapters 5, 6, and 7 does not change the determinations from Chapter 1. Figures 8-1 and 8-2 present the location of the 100-D and 100-H waste sites, respectively, that are not evaluated in the FS. Chapter 1 presents additional information on these waste sites not carried forward.

Waste sites Identified for No Further Action. There are 146 waste sites that are 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. Locations of the 100-D and 100-H waste sites for no further action are shown on Figures 8-3 and 8-4, respectively.

The waste sites identified for no further action include the following:

- 125 interim closed or interim no action sites with verification data that have been quantitatively evaluated to the PRGs in Table 8-3 and indicate no unacceptable risk to HHE
- 21 waste sites with site-specific evaluations indicating no further action

Table 8-5. 100-HR-3 Groundwater OU PRGs

Contaminant	Units	90th Percentile Concentration	Dose (mrem/yr) Based on 90th Percentile Concentration	ELCR Based on 90th Percentile Concentration	HQ Based on 90th Percentile Concentration	Drinking Water Standard	2007 WAC 173-340 Cleanup Levels		Clean Water Act (Section 304) Water Quality Criteria		WAC 173-201A	40 CFR 131 Water Quality Standard		100-HR-3 Groundwater OU 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)	
100-D Source Exposure Area														
COCs—for Remedial Technology Screening and Alternative Development														
Total Chromium	µg/L	925	--	--	0.04	100	24,000	--	570	65	156	550	180	65
Cr(VI)[c]	µg/L	992	--	--	21	--	48	--	16	11	10	15	10	10
Nitrate[b]	µg/L	69,500	--	--	0.61	45,000	113,600	--	--	--	--	--	--	45,000
COPCs														
Antimony	µg/L	--	--	--	--	6.0	6.4	--	--	--	--	--	14	6.0
Cadmium	µg/L	0.2	--	--	0.025	5.0	8.0	--	2.0	0.25	0.91	3.9	1.0	0.25
Cobalt	µg/L	1.3	--	--	0.27	--	4.8	--	--	--	--	--	--	4.8
Copper	µg/L	0.73	--	--	<0.01	1,300	640	--	13	9.0	--	17	11	9.0
Lead	µg/L	0.35	--	--	--	15	--	--	65	2.5	2.1	65	2.5	2.1
Silver	µg/L	0.2	--	--	<0.01	100	80	--	3.2	--	2.6	3.4	--	2.6
100-H Source Exposure Area														
COCs—for Remedial Technology Screening and Alternative Development														
Strontium-90	pCi/L	14	7.0	1.5×10^{-5}	--	8	--	--	--	--	--	--	--	8
Cr(VI)[c]	µg/L	26	--	--	0.54	--	48	--	16	11	10	15	10	10
Nitrate[b]	µg/L	39,800	--	--	0.35	45,000	113,600	--	--	--	--	--	--	45,000
COPCs														
Antimony	µg/L	0.61	--	--	0.095	6.0	6.4	--	--	--	--	--	14	6.0
Cadmium	µg/L	--	--	--	--	5.0	8.0	--	2.0	0.25	0.91	3.9	1.0	0.25
Cobalt	µg/L	0.43	--	--	0.090	--	4.8	--	--	--	--	--	--	4.8
Copper	µg/L	1.3	--	--	<0.01	1,300	640	--	13	9.0	--	17	11	9.0
Lead	µg/L	0.23	--	--	--	15	--	--	65	2.5	2.1	65	2.5	2.1
Silver	µg/L	--	--	--	--	100	80	--	3.2	--	2.6	3.4	--	2.6
Horn Area Exposure Area														
COCs—for Remedial Technology Screening and Alternative Development														
Total Chromium	µg/L	76	--	--	<0.01	100	24,000	--	570	65	156	550	180	65
Cr(VI)[c]	µg/L	71	--	--	1.5	--	48	--	16	11	10	15	10	10
COPCs														
Antimony	µg/L	0.74	--	--	0.12	6.0	6.4	--	--	--	--	--	14	6.0

Table 8-5. 100-HR-3 Groundwater OU PRGs

Contaminant	Units	90th Percentile Concentration	Dose (mrem/yr) Based on 90th Percentile Concentration	ELCR Based on 90th Percentile Concentration	HQ Based on 90th Percentile Concentration	Drinking Water Standard	2007 WAC 173-340 Cleanup Levels		Clean Water Act (Section 304) Water Quality Criteria		WAC 173-201A	40 CFR 131 Water Quality Standard		100-HR-3 Groundwater OU 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)	
Cadmium	µg/L	--	--	--	--	5.0	8.0	--	2.0	0.25	0.91	3.9	1.0	0.25
Cobalt	µg/L	0.1	--	--	0.021	--	4.8	--	--	--	--	--	--	4.8
Copper	µg/L	1.4	--	--	<0.01	1,300	640	--	13	9.0	--	17	11	9.0
Silver	µg/L	0.2	--	--	<0.01	100	80	--	3.2	--	2.6	3.4	--	2.6

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.

Notes:

a. The final cleanup levels achieved at the conclusion of the remedial action will correspond to a cumulative ELCR less than 1×10^{-5} and HI of less than 1.

b. 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^-.

c. There is no DWS specific to Cr(VI).

CCC = criteria continuous concentration

CMC = criteria maximum concentration

COC = contaminants of concern

COPC = contaminants of potential concern

DWS = drinking water standard

ELCR = excess lifetime cancer risk

HI = hazard index

HQ = hazard quotient

OU = operable unit

PRG = preliminary remediation goal

Table 8-6. Waste Site Evaluation for 100-D/H RI/FS

100-D/H Waste Sites – 343 Total

NUMBER OF WASTE SITES FOR FURTHER EVALUATION

Sites not carried into FS (52)

Sites Closed, Not Accepted, or Rejected not carried into FS. (48)
100-D-27, 120-D-1, 1607-D3, 122-DR-1:1, 122-DR-1:2, 122-DR-1:3, 122-DR-1:4, 122-DR-1:5, 122-DR-1:6, 122-DR-1:7, 100-D-11, 100-D-26, 100-D-34, 100-D-36, 100-D-37, 100-D-38, 100-D-55, 100-D-57, 100-D-89, 100-D-91, 100-H-6, 100-H-15, 100-H-18, 100-H-19, 100-H-20, 100-H-26, 100-H-27, 600-258, 100-D-17, 100-D-28:2, 100-D-33, 100-D-35, 100-D-40, 100-D-41, 100-D-79, 100-D-92, 100-D-93, 100-D-95, 126-D-1, 126-D-3, 100-H-16, 100-H-32, 100-H-39, 100-H-47, 100-H-55, 116-H-6, 126-H-1, 100-H-49:3

Sites to be Closed under Washington Department of Health Regulations. (1)
100-D-58

Reactor Cores/Safe Storage Enclosures (3)
118-D-6:1, 118-DR-2:1, 118-H-6:1

Evaluate Based on Waste Site Status / Tank Removal / Reactor Site

Chapter 1

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Sites Identified for No Further Action (146)

Sites Pass Screening Levels for Human Health Risk Assessment, Groundwater/Surface Water Protection, Ecological Risk Assessment, Modeling Predictions. (125)
100-D-1, 100-D-2, 100-D-3, 100-D-4, 100-D-7, 100-D-9, 100-D-12, 100-D-13, 100-D-15, 100-D-20, 100-D-21, 100-D-22, 100-D-23, 100-D-24, 100-D-28:1, 100-D-29, 100-D-31:1, 100-D-31:10, 100-D-31:2, 100-D-31:3, 100-D-31:4, 100-D-31:5, 100-D-31:6, 100-D-31:7, 100-D-31:8, 100-D-31:9, 100-D-32, 100-D-42, 100-D-43, 100-D-45, 100-D-47, 100-D-48:4, 100-D-49:3, 100-D-50:5, 100-D-53, 100-D-54, 100-D-56:1, 100-D-56:2, 100-D-61, 100-D-64, 100-D-70, 100-D-74, 100-D-75:3, 100-D-80:1, 100-D-82, 100-D-83:4, 100-D-84:1, 100-D-85:1, 100-D-87, 100-D-88, 100-D-90, 100-D-94, 100-H-2, 100-H-3, 100-H-4, 100-H-7, 100-H-8, 100-H-17, 100-H-24, 100-H-28:1, 100-H-28:6, 100-H-30, 100-H-35, 100-H-37, 100-H-40, 100-H-41, 100-H-45, 100-H-49:2, 100-H-50, 100-H-51:4, 100-H-51:5, 100-H-53, 116-D-2, 116-D-4, 116-D-5, 116-D-6, 116-D-9, 116-D-10, 116-DR-4, 116-DR-5, 116-DR-7, 116-DR-8, 116-DR-10, 116-H-2, 116-H-5, 116-H-9, 118-D-1, 118-D-4, 118-D-5, 118-DR-1, 118-H-1:1, 118-H-1:2, 118-H-2, 118-H-3, 118-H-4, 118-H-5, 118-H-6:4, 118-H-6:5, 120-D-2, 126-D-2, 128-D-2, 128-H-1, 128-H-2, 128-H-3, 130-D-1, 132-D-1, 132-D-2, 132-D-3, 132-DR-1, 1607-D1, 1607-D2:1, 1607-D2:2, 1607-D2:3, 1607-D2:4, 1607-D4, 1607-D5, 1607-H1, 1607-H2, 1607-H3, 1607-H4, 600-151, 600-152, 600-30, 628-3, UPR-100-D-5

No Action Sites based on site specific evaluation. (21)
100-D-50:3, 100-D-50:10, 100-D-67, 100-D-68, 100-D-86:2, 100-H-9, 100-H-10, 100-H-13, 100-H-28:8, 100-H-31, 100-H-33, 116-D-3, 116-H-4, 118-D-6:2, 118-H-6:2, 128-D-1, 132-D-4, 132-DR-2, 132-H-1, 132-H-2, UPR-100-D-1

Evaluate in Chapters 5, 6, 7, and 8

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Waste Sites to be Remediated under the Interim Action RODs. (59)
100-D-8, 100-D-14, 100-D-30, 100-D-31:11, 100-D-31:12, 100-D-50:1, 100-D-50:4, 100-D-50:6, 100-D-50:7, 100-D-50:8, 100-D-50:9, 100-D-62, 100-D-65, 100-D-66, 100-D-69, 100-D-71, 100-D-72, 100-D-73, 100-D-75:2, 100-D-76, 100-D-77, 100-D-78, 100-D-80:2, 100-D-81, 100-D-83:1, 100-D-83:2, 100-D-83:3, 100-D-83:5, 100-D-84:2, 100-D-85:2, 100-D-86:1, 100-D-86:3, 100-D-97, 100-D-99, 100-D-100, 100-D-104, 100-H-28:2, 100-H-28:3, 100-H-28:4, 100-H-28:5, 100-H-42, 100-H-43, 100-H-44, 100-H-46, 100-H-48, 100-H-49:1, 100-H-51:1, 100-H-51:2, 100-H-51:3, 100-H-52, 116-DR-3, 118-D-2:1, 118-D-2:2, 118-D-3:1, 118-D-3:2, 126-DR-1, 126-H-2, 132-H-3, 1607-D2:5

Assume then Verify Interim Actions Achieve Required Standards

86

Sites Identified for Further Action (86)

Sites with Deep Contamination Exceeding Human Health Criteria, but Incomplete Pathway. (32)
100-D-5, 100-D-6, 100-D-18, 100-D-19, 100-D-46, 100-D-48:1, 100-D-48:2, 100-D-48:3, 100-D-49:1, 100-D-49:2, 100-D-49:4, 100-H-1, 100-H-11, 100-H-12, 100-H-14, 100-H-21, 100-H-22, 116-D-1A, 116-D-1B, 116-D-7, 116-DR-1&2, 116-DR-6, 116-H-1, 116-H-3, 116-H-7, 118-D-6:3, 118-D-6:4, 118-H-6:3, 118-H-6:6, UPR-100-D-2, UPR-100-D-3, UPR-100-D-4

River Pipelines. (2)
100-D-60, 100-H-34

Waste Sites Remaining for Remedial Action. (52)
100-D-10, 100-D-50:2, 100-D-52, 100-D-59, 100-D-63, 100-D-75:1, 100-D-96, 100-D-98:1, 100-D-98:2, 100-D-101, 100-D-102, 100-D-103, 100-D-105, 100-D-106, 100-D-107, 100-H-5, 100-H-28:7, 100-H-36, 100-H-38, 100-H-51:6, 100-H-54, 100-H-56, 100-H-57, 100-H-58, 100-H-59, 116-D-8, 116-DR-9 [100-D-25], 118-DR-2:2, 600-380, 600-381, 600-382:1, 600-382:2, 600-382:3, 600-382:4, 600-382:5, 600-383:1, 600-383:2, 600-383:3, 600-383:4, 600-383:5, 600-383:6, 600-383:7, 600-383:8, 600-383:9, 600-383:10, 600-384:1, 600-384:2, 600-384:3, 600-384:4, 600-384:5, 600-385

Institutional Controls

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Develop Remedial Action Alternatives and Cost Estimates to Achieve Final Cleanup

REMEDIAL INVESTIGATION

FEASIBILITY STUDY

CHPUBS_100DH_0124a

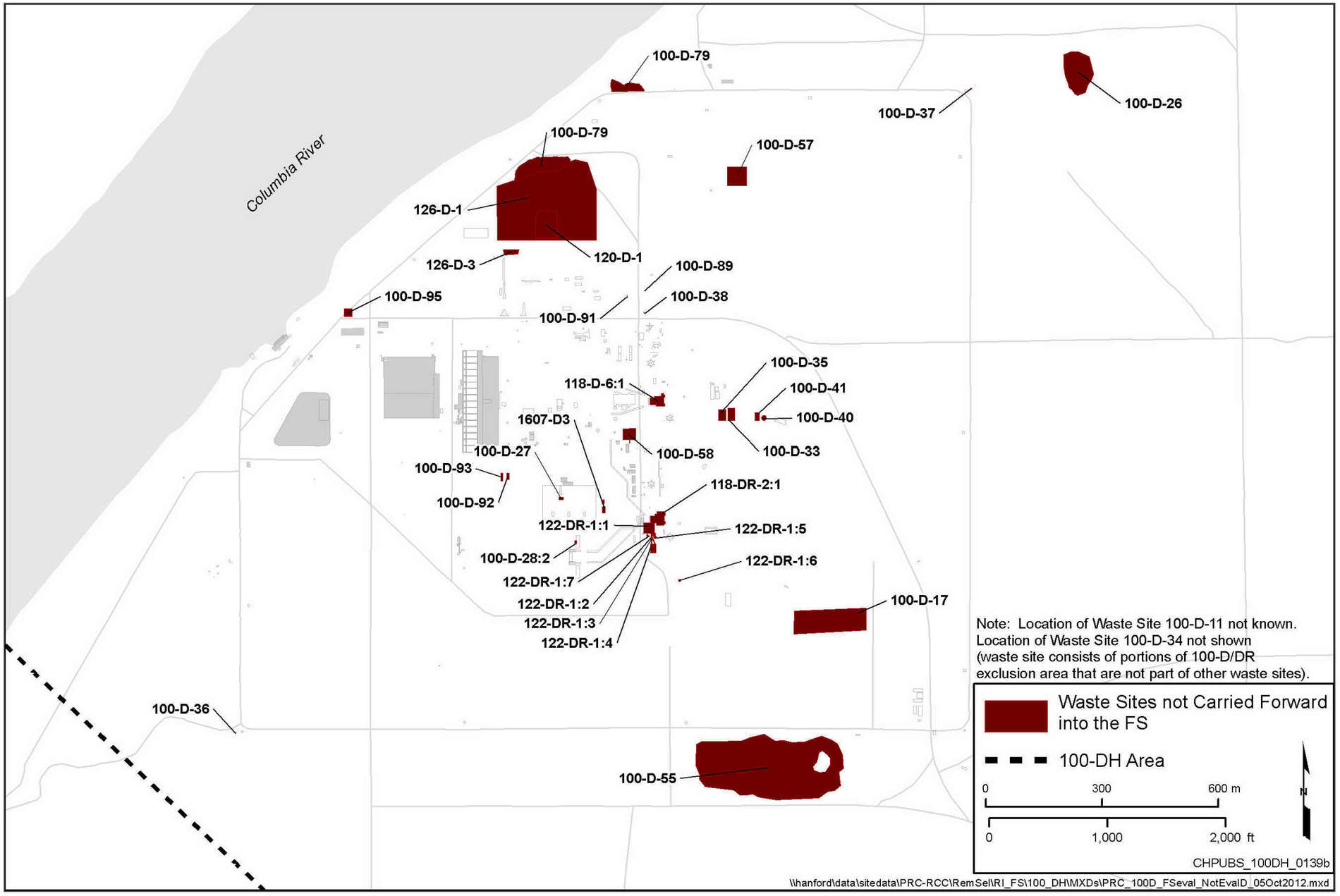

Figure 8-1. 100-D Waste Sites not Carried Forward into the FS

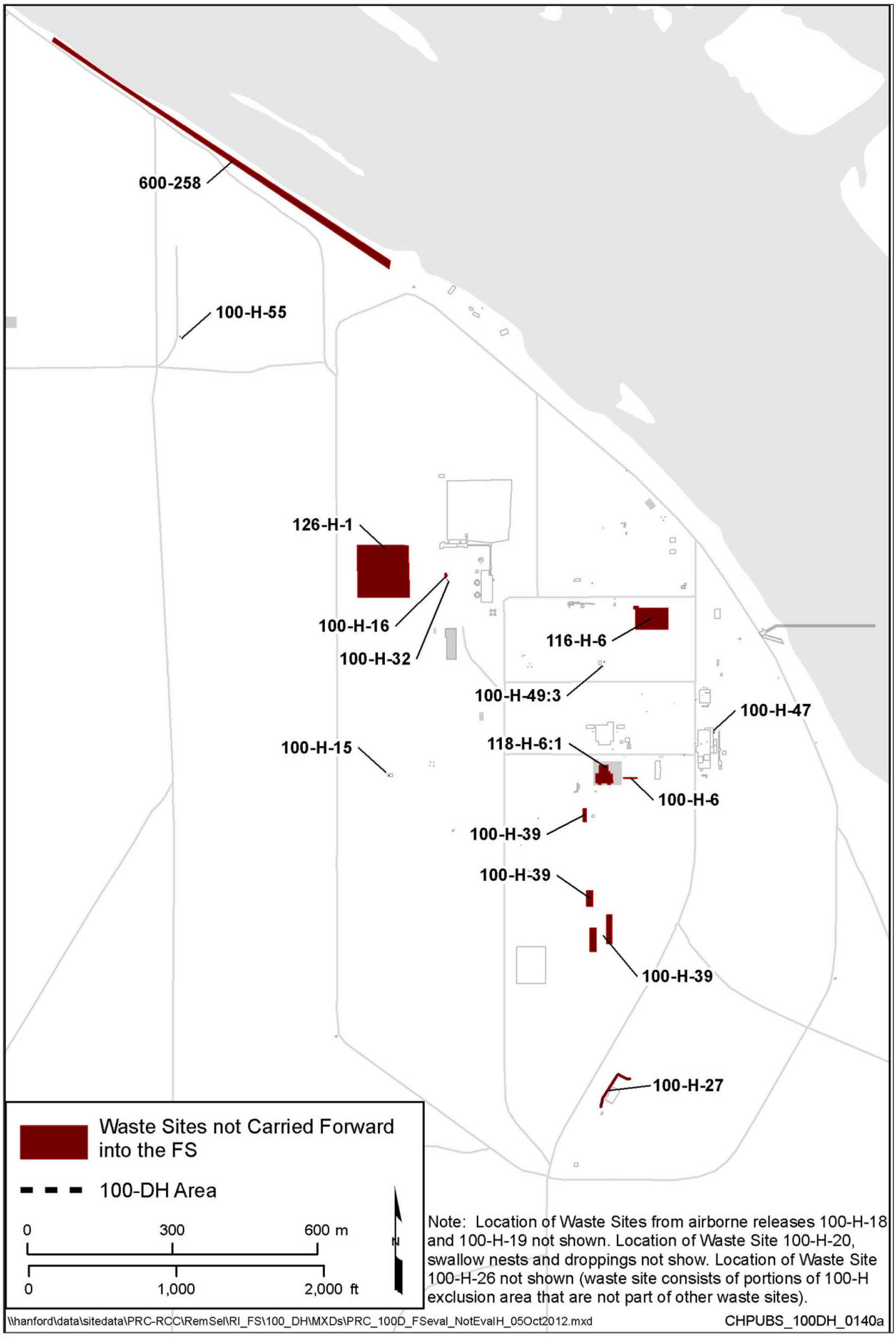

Figure 8-2. 100-H Waste Sites not Carried Forward into the FS

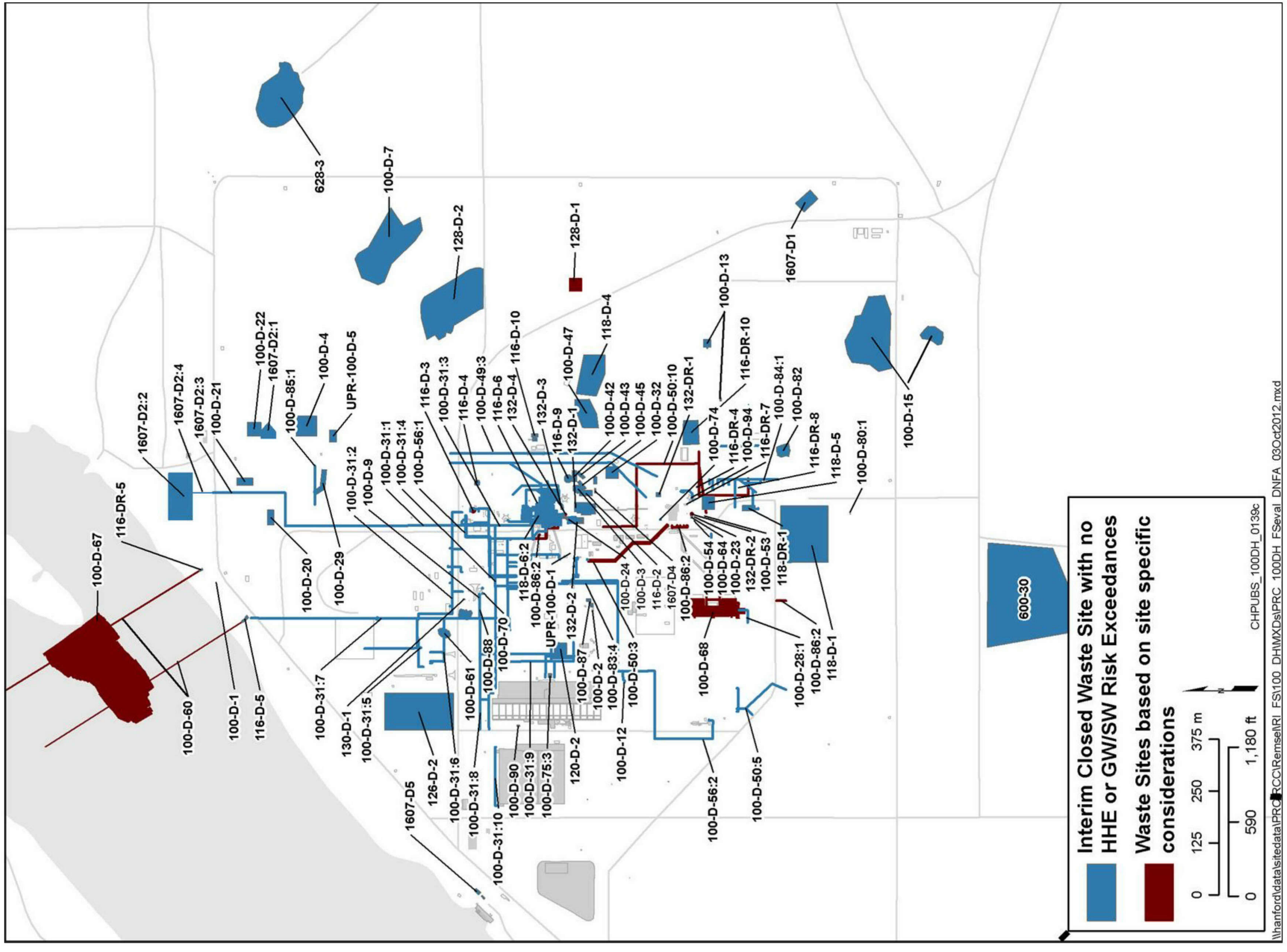

Figure 8-3. 100-D Waste Sites Identified for No Further Action

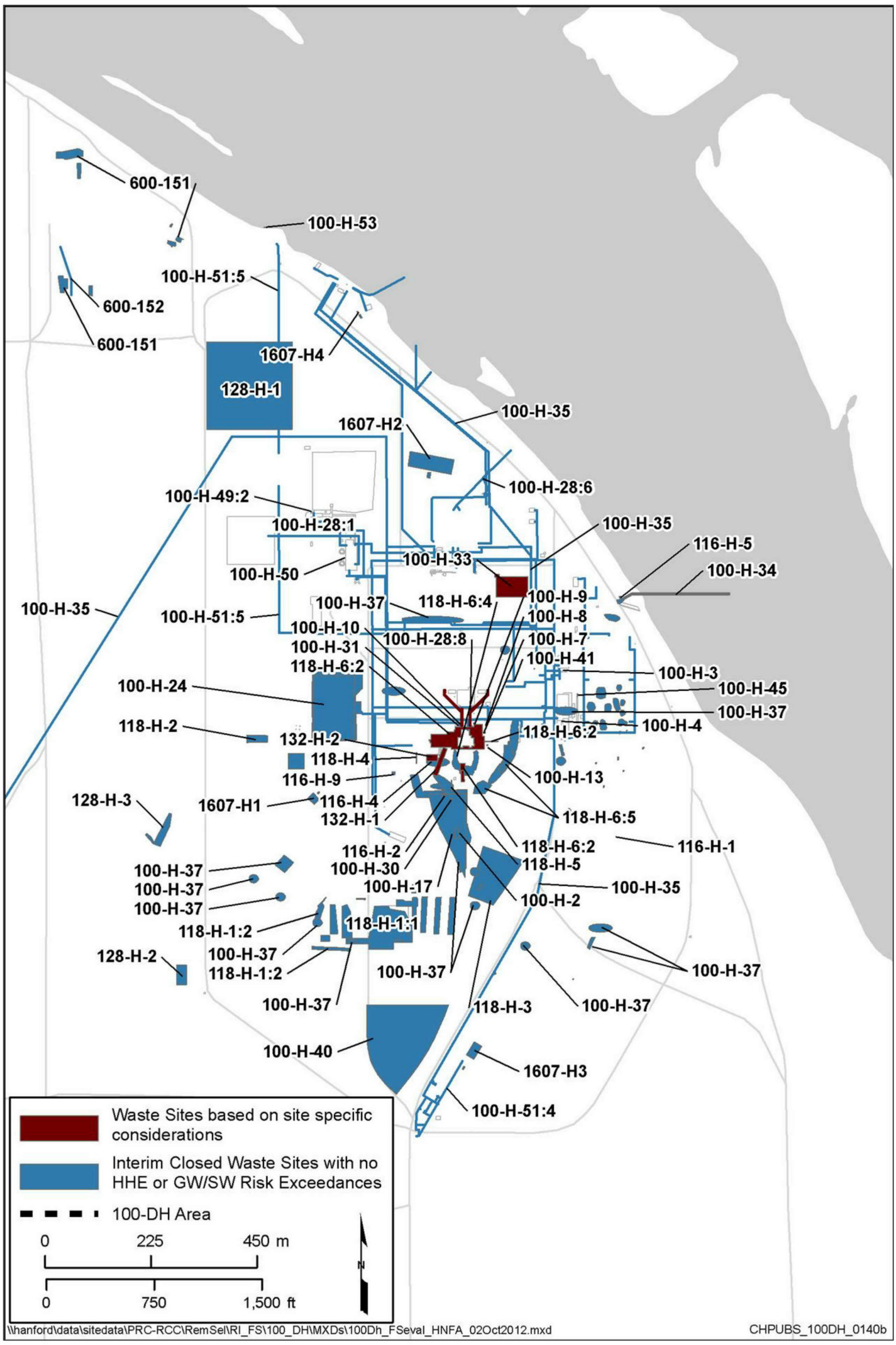

Figure 8-4. 100-H Waste Sites Identified for No Further Action

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The site-specific evaluations for the 21 waste sites identified for no further action are described as follows:

- ***100-D-50:10.*** The 100-D-50:10 construction camp potable water supply pipelines subsite encompasses residual cast iron pipelines formerly used to supply potable water to the temporary construction camp southeast of the DR Reactor. This subsite was reclassified as "no action" based on a determination that potable water supply was not associated with any constituents that would present an adverse risk to HHE. This determination remains appropriate for final action purposes.

- ***100-D-50:3.*** Based on a review of historical documentation, it was concluded that the 100-D-50:3, Reactor Cooling Water Pipelines from 190-D High Bay, were not put into operational use. The original operational plans to use the pipelines to supply process water to the DR Reactor were discontinued after determining that D Reactor could continue to be used. The 100-D-50:3 subsite does not pose a risk to human or ecological receptors, groundwater, or the Columbia River and is rejected from consideration as a waste site.

- ***100-D-67.*** The 100-D-67, D Island waste site was evaluated to investigate further its classification as a waste site in accordance with the RAOs and goals established in the Remaining Sites ROD (EPA, 1999). Evaluation of the 100-D-67 waste site, including risk assessment by the Washington State Department of Health, radiological surveys, and field investigations and sampling, indicate that residual contamination concentrations are protective of HHE. The results of this evaluation indicate that the residual concentrations of radionuclide COCs/COPCs at this waste site do not preclude any future land uses (as bounded by a casual recreational user scenario) and are less than the PRG values in Table 8-3. Both the external exposure risk and ingestion risk in 1993 were below the radioactivity risk threshold of 10^{-6}. Since 1993, cobalt-60 has decayed through almost four half-lives so the present day risks will be considerably less than these values. Based on this evaluation, no further action is identified for the 100-D-67 waste site.

- ***100-D-68.*** The 100-D-68 site consists of the below grade remaining concrete structures for the former 190-DR Pump House. Remaining concrete was evaluated in accordance with an approved facility-specific closure plan and determined to meet the criteria for "no action." This determination remains appropriate for final action purposes.

- ***100-D-86:2.*** The 100-D-86:2 subsite consists of potential process sewer segments that were not captured by other waste sites. All of the potential segments in this subsite were found not to be present by direct test pitting and investigation at the suspected locations and the subsite was reclassified as no action. This determination remains appropriate for final action purposes.

- ***116-D-3.*** The 116-D-3 site was identified as a crib associated with the former 108-D facility. Based on review of historic drawings, geophysical investigation, and excavation, this site was determined to be a duplicate of the 116-D-4 site. The 116-D-3 site was reclassified as "rejected" in 2000; this reclassification was amended to "no action" in 2003. Another potential location for this crib has been identified separately as the 100-D-76 waste site. The 116-D-4 and 100-D-76 sites are addressed further in this RI/FS, but no further action is identified for the redundant 116-D-3 site.

- ***118-D-6:2.*** The 118-D-6:2 subsite consists of the ancillary support areas and below grade structures for the D Reactor. This subsite is not inclusive of the safe storage enclosure and reactor core or the former fuel storage basin, which are addressed as separate subsites. This subsite was reclassified as "interim closed out" based on complete removal of all above- and below grade structures. Sampling was not required under the facility-specific SAP because there were no drivers for potential contamination associated with these facilities to enter into soil. This basis remains appropriate for no further final

action considerations for this subsite. Other portions of the former 105-D facility are considered separately.

- ***128-D-1.*** The 128-D-1 site was identified as a potential burn pit, but was determined to be a duplicate of either the 128-D-2 or the 628-3 burn pit waste sites. The site was reclassified as "no action" based on this determination; this remains appropriate for final action purposes.

- ***132-D-4.*** The 132-D-4 site consists of the former 116-D Exhaust Stack for the D Reactor. The stack and foundation have been demolished and removed to 0.9 m (3 ft) below grade. The 132-D-4 site was reclassified to "interim closed out" based on sampling at the 116-C, 116-F, and 116-H stacks, which determined that contamination penetrated the stack concrete minimally and would be removed by demolition to below grade. A drain line contained within the stack concrete was determined to be analogous to drain lines in the 116-C and 116-F, which were determined to require no action based on dose modeling. These determinations remain appropriate for the residual concrete foundation.

- ***UPR-100-D-1.*** The UPR-100-D-1 site was initially identified as a small area of suspect oil-stained soil. A 2005 walkdown could not locate any evidence of the site, and noted that the area had been highly disturbed by demolition and remediation activities. The site was reclassified as "no action." This determination remains appropriate for final action purposes.

- ***132-DR-2.*** The 132-DR-2 site consists of the former 116-DR Exhaust Stack for the DR Reactor. Use of this stack for the 117-DR Large Sodium Fire Facility was addressed separately as the 122-DR-1:5 subsite. The stack and foundation have been demolished and removed to 0.9 m (3 ft) below grade. This site was reclassified to "interim closed out" based on removal of potentially contaminated concrete and radiological survey of surrounding soil. These determinations remain appropriate for the residual concrete foundation.

- ***100-H-28:8.*** The 100-H-28:8 subsite encompasses the former process water supply pipelines in subgrade concrete tunnels between the 190-H and 105-H facilities. These pipelines were completely removed during demolition of the 190-H facility and ISS activities for the H Reactor. The subsite was reclassified as "no action" based on removal of the pipelines and the absence of any evidence of leakage during operations. This determination remains appropriate for final action purposes.

- **116-H-4.** The 116-H-4 crib was removed in 1960 during construction of the 117-H Building and no requirements for interim action were previously determined. Remedial investigation samples from borehole C7862, as discussed in Chapter 4, were collected to characterize the waste site. The evaluation on the soil data from RI borehole was performed (Chapters 5, 6, and 7) and identified that concentrations did not exceed human health, groundwater protection, or surface water protection PRG values for analyzed constituents. The maximum detected concentrations for aluminum and lithium exceeded ecological PRG values; however, the maximum detectable concentrations were below Hanford background concentrations. Additionally, Cr(VI) and total chromium concentrations from groundwater samples collected at the borehole were both below detection limits. Based on having been previously removed and RI data evaluation, no further action is identified at this site.

  - **100-H-33.** The 183-H Solar Evaporation Basins RCRA waste site (116-H-6) was closed out through a modified RCRA closure in 1997. The 100-H-33 waste site was created to address the radionuclide component of the 183-H Solar Evaporation Basins. Maximum concentrations of dangerous waste constituents of concern in 183-H Soil from the test pit following remediation in 1997, *183-H Solar Evaporation Basins Postclosure Plan* [DOE/RL-97-48]), are less than the PRG values presented in Table 8-3. In addition, sample results presented in Chapter 4 from the RI borehole identified in the 100-D/H Work Plan (DOE/RL-2008-46-ADD1) at the 183-H Solar

Basin (C7860) did not exceed PRG values for analyzed constituents. Fate and transport modeling and risk assessment evaluation in Chapters 5, 6 and 7 did not identify unacceptable HHE, groundwater, or surface water risk. For these reasons, no further action is identified in the remedial action alternatives for the 100-H-33 or 116-H-6 waste site.

- **132-H-1.** The 132-H-1 site encompasses the residual components of the demolished 116-H Reactor Stack, including the demolition burial trench. This stack was decommissioned, demolished, and buried in-place in 1983. Under interim actions, samples collected during decommissioning were used to model the residual condition, and no further actions were determined to be necessary for the site. However, the site was ultimately completely exhumed and removed during remediation of the adjacent 132-H-3 waste site. As such, no further action is warranted for the 132-H-1 site; the 132-H-3 site is addressed further in this RI/FS.

- **132-H-2.** The 132-H-2 site encompasses residual structural components of the demolished 117-H Filter Building. This building was decontaminated, decommissioned, and demolished in 1984, leaving portions of the below-grade structure and demolition rubble in place. Under interim actions, samples collected during decommissioning were used to model the residual condition conservatively, and no further actions were determined to be necessary for the site. However, the residual concrete was ultimately exhumed and removed during remediation of the adjacent 132-H-3 waste site. As such, no further action is warranted for the 132-H-2 site; the 132-H-3 site is addressed further in this RI/FS.

- **100-H-9, 100-H-10, and 100-H-13.** The 100-H-9, 100-H-10, and 100-H-13 sites were French drains adjacent to the H Reactor, likely associated with steam condensate discharges. These French drains and underlying soil were removed and disposed incidentally during ISS activities for the H Reactor. These sites were reclassified as "interim closed out" and the determination remains appropriate.

- **100-H-31.** The 100-H-31 site consisted of an area of PCB soil contamination associated with an unplanned release from a former electrical substation on the north side of the 105-H Reactor Building. PCBs have low mobility in soil based on soil distribution coefficients; therefore, these unplanned releases would not have resulted in contamination migration to significant depth. Soil at the location of the release was removed and disposed to a depth of approximately 4.6 m (15 ft) during ISS activities for H Reactor, and the site was reclassified as "interim closed out" based on removal of potentially contaminated soil. This basis is also appropriate for no further final action considerations.

- **118-H-6:2.** The 118-H-6:2 subsite consists of the ancillary support areas and below grade structures for the H Reactor. This subsite is not inclusive of the safe storage enclosure and reactor core or the former fuel storage basin, which are addressed as separate subsites. This subsite was reclassified as "interim closed out" based on complete removal of all above- and below-grade structures. Soil sampling was not required because the structures that were removed were not subjected to standing contaminated water and there was no mechanism for residual surface concrete contamination to penetrate into the concrete and underlying soil. This basis remains appropriate for no further final action considerations for this subsite. Other portions of the former 105-H facility are considered separately.

The remaining 145 sites will be discussed further in this RI/FS and are evaluated further in Chapter 9 for remedial alternatives. Tables J-1 and J-2 in Appendix J identify the contaminants and basis for action (where there are risks) associated with waste sites remediated under interim actions. Table J-2 is a subset of Table J-1 that shows those sites that have groundwater/surface water protection as a basis for action.

Waste Sites to be Remediated under Interim Action RODs. A total of 59 waste sites are currently or anticipated to be remediated under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039), or are anticipated to be in progress by the time the ROD is signed. The locations of the sites are shown on Figure 8-5.

Waste Sites Remaining for Further Action. The remaining 86 waste sites are expected to require further action after the ROD is issued. Thirty-two of the 86 waste sites have been interim or interim no action closed and had verification data with exceedances of deep zone (>15 ft bgs) direct contact human health exposure criteria (residential scenario) for select radionuclides (Chapter 6). Contamination was detected in deep zone verification soil samples collected from depths greater than 4.6 m (15 ft) bgs and, as a result, there is no direct exposure pathway. DOE has proposed to place deep excavation ICs to limit exposure (Table 9-4). Rough order of magnitude cost for excavating and removing the contaminants at all 32 sites is $320 million. However, these radionuclides will continue to decay to below direct contact human health exposure criteria within 2 to 185 years and during this time (depending on the current concentration of individual constituent(s) of interest at each site), DOE or the federal government will maintain controls on the land to prevent exposure to these materials. For this reason, ICs will be maintained for these sites until unrestricted use is allowable. No further technology application is required and remedial action alternatives are not developed for these sites.

Two other waste sites associated with river effluent pipelines (100-D-60 and 100-H-34) were evaluated for risks, as discussed in Chapters 6 and 7. The risk assessments associated with 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 sites in this FS. While no IC is required, an annual inspection under the RCRA permit (Permit Number WA7 89000 8967) is conducted along the shoreline to identify Hanford debris.

The remaining 52 waste 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 (Table J-1, Appendix J). The remedial approaches for the major risk drivers are developed for each alternative and presented in Chapter 9. These sites include three waste sites completed under interim actions that had exceedances of human health direct exposure risk PRGs for radionuclides.

The following 52 waste sites remain for remedial action; locations are shown on Figure 8-6:

- Twenty-nine sites for which interim remedial actions will not be completed until after the ROD is signed (100-D-50:2, 100-D-75:1, 100-H-36, 100-H-58, 100-D-106, 100-H-51:6, 100-H-59, 600-380, 600-382:1, 600-382:2, 600-382:3, 600-382:4, 600-382:5, 600-383:1, 600-383:2, 600-383:3, 600-383:4, 600-383:5, 600-383:6, 600-383:7, 600-383:8, 600-383:9, 600-383:10, 600-384:1, 600-384:2, 600-384:3, 600-384:4, 600-384:5, and 600-385)
- Four sites that have undergone interim action but risk assessment indicates sites exceed shallow human health direct exposure criteria for radionuclides in a portion of the site (100-D-25, 116-DR-9, 116-D-8, and 118-DR-2:2)

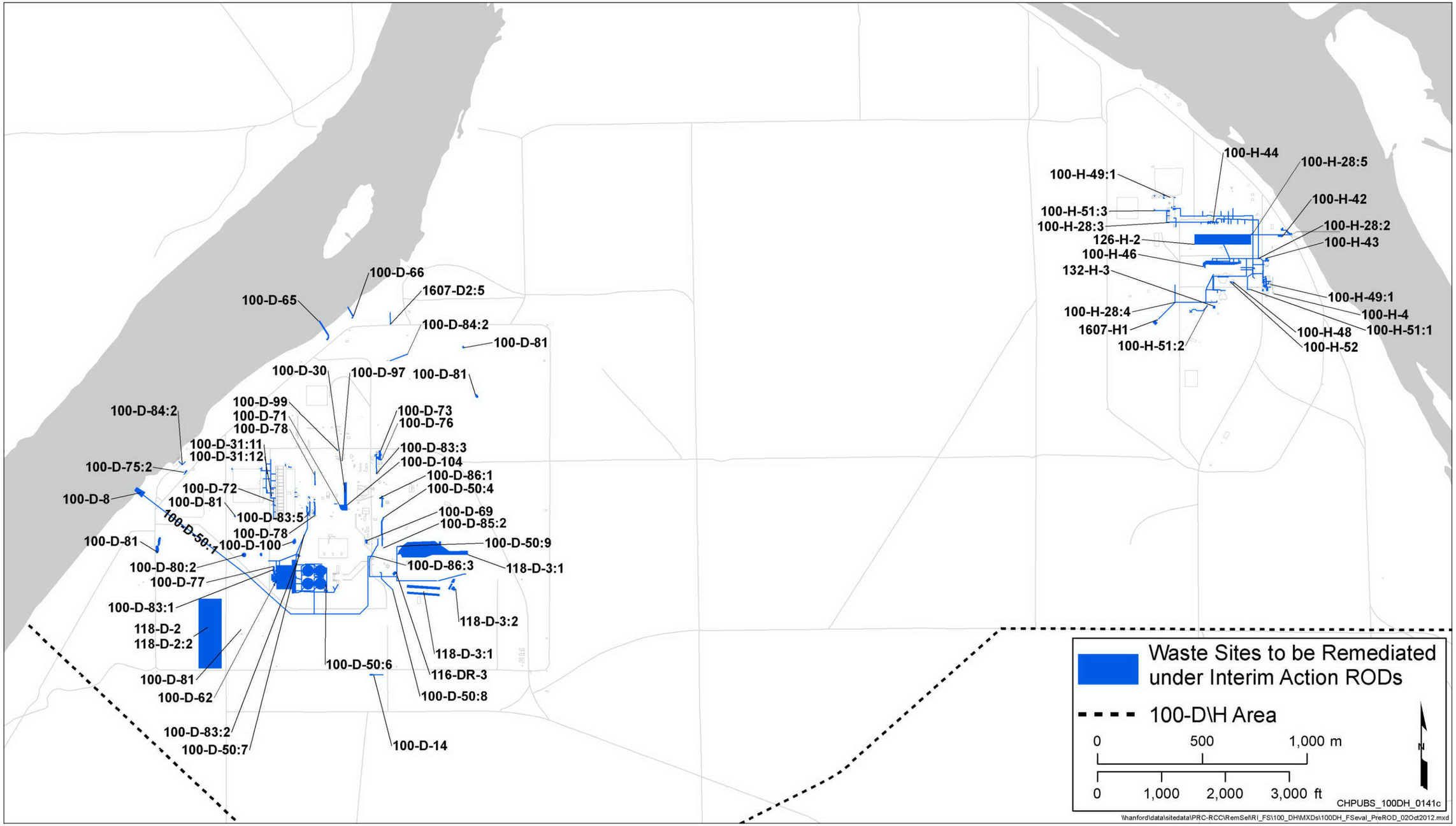

Figure 8-5. Waste Sites to be Remediated under Interim Action RODs

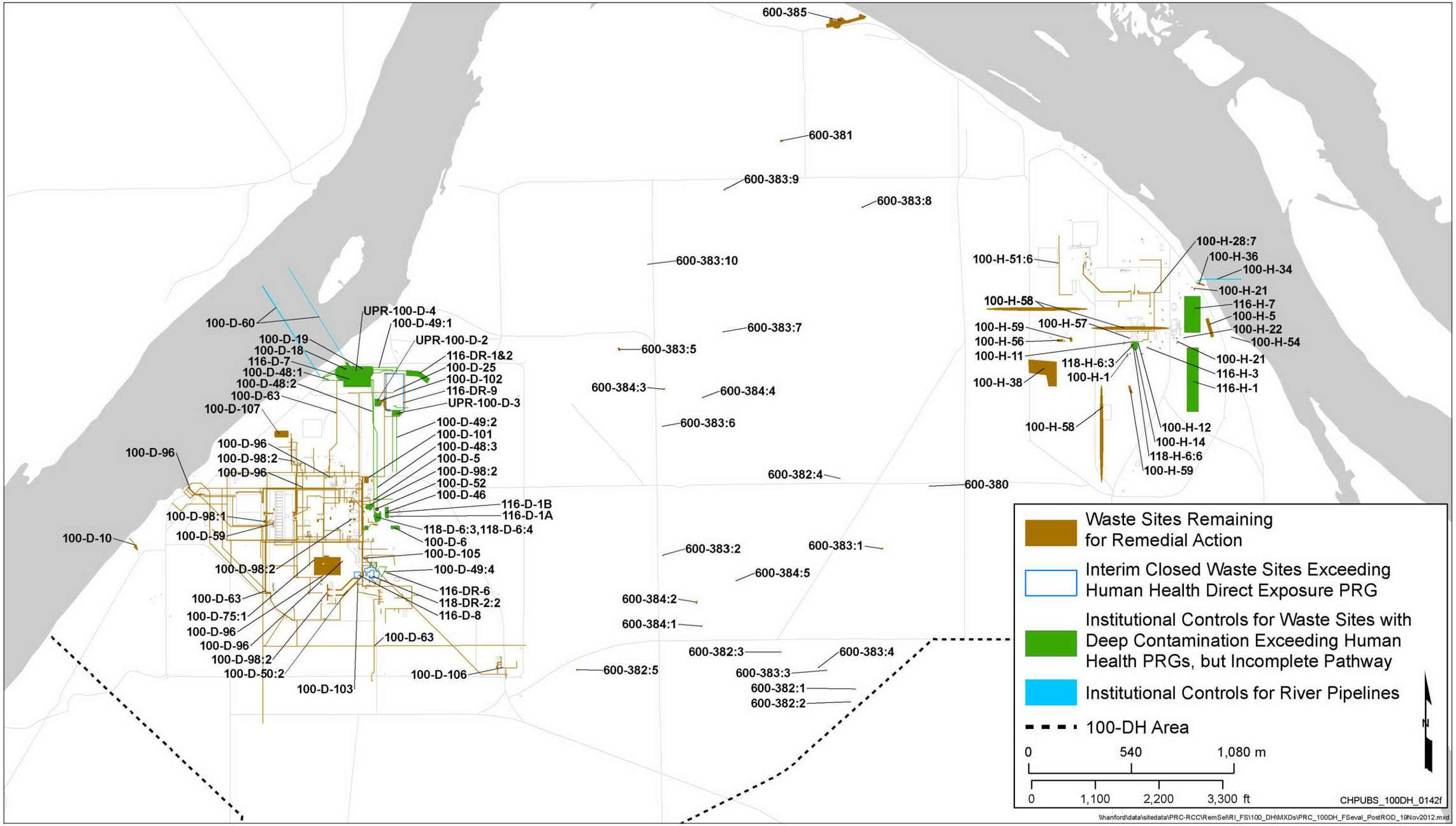

Figure 8-6. Waste Sites Remaining for Further Action

- Four candidate sites that are being carried forward because of site-specific considerations (100-D-10, 100-D-52, 100-D-59, and 100-H-5)
- Fifteen candidate sites that have not yet undergone confirmatory evaluation under interim actions (100-D-63, 100-D-96, 100-D-98:1, 100-D-101, 100-D-102, 100-D-103, 100-D-105, 100-D-107, 100-H-54, 100-H-28:7, 100-H-38, 100-H-57, 100-D-98:2, 600-381, and 100-H-56)

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 15 waste sites identified as candidate sites that have not yet been evaluated as of June 2012. An additional four sites are being considered as candidate sites for final action based on site-specific considerations. Confirmatory evaluation to determine the need for remediation and confirmation of COCs will be performed for the 19 candidate sites. Remedial alternatives have been developed for all 19 under the assumption that remediation is determined to be warranted.

The 4 sites that have been remediated and interim closed under the interim actions ROD include 116-D-8, 116-DR-9, 100-D-25, and 118-DR-2:2. The risk assessment evaluation of verification sample data from the four sites indicates the sites exceed shallow human health direct exposure criteria for radionuclides (cesium-137, strontium-90, and technetium-99) in a portion of the sites (for example, side slopes of excavation in the shallow zone). The four sites are evaluated for remedial action alternatives in the FS for final remediation of residual risks.

The following bullets identify the four sites carried forward for inclusion in the FS, based on site-specific considerations:

- The 100-D-10 and 100-D-59 waste sites are not accepted and rejected waste sites, respectively, for which the existing basis warrants reconsideration as discussed in Section 1.2.3. Therefore, the sites are evaluated in the FS for final actions as candidate sites.
- The 100-D-52, 105-D Downcomer Insulation Space Dry Well waste site has been remediated and interim closed out. The data from verification sampling have been quantitatively evaluated and indicate no unacceptable risk to HHE. However, this site history suggests cooling water effluent from D Reactor as a possible contributor of contamination. Contamination potentially associated with cooling water effluent includes Cr(VI), which was not analyzed in interim closure verification samples. This site warrants consideration as a candidate site for future evaluation under final actions.
- The 100-H-5, 107-H Retention Basin Sludge Burial Site waste site has been remediated and interim closed out. The data from verification sampling have been quantitatively evaluated to the PRGs in Table 8-3 and indicate no unacceptable risk to HHE. However, Cr(VI) analysis was not included in interim closure verification samples, even though the site was used for retention basin sludge disposal, which would contain incidental Cr(VI). This site warrants consideration as a candidate site for future evaluation under final actions.

Tables J-1 and J-2 in Appendix J identify the contaminants and basis for action (where there are risks) associated with waste sites remaining for remedial action. Table J-2 is a subset of Table J-1 that shows those sites that have groundwater/surface water protection as a basis for action.

8.2.1.2 Groundwater

Figures 4-66 and 4-67 illustrates areas exceeding the groundwater PRG for Cr(VI), and by inference, the areas exceeding the groundwater PRG for total chromium, which follows the same contaminant plume as

Cr(VI). Figures 4-90 and 4-95 illustrate areas exceeding the groundwater PRG for nitrate and strontium-90, respectively.

As described in Chapter 4, Cr(VI) contamination has been identified in several locations (primarily in 100-H) in the uppermost water-bearing unit below the unconfined aquifer. There was no contamination deeper than this based on the RI characterization and there is a strong upward gradient within the lower portions of the Ringold Formation. Remediation of Cr(VI) contamination in the confined RUM aquifer is evaluated in the remedial action alternatives.

The CSM described in Section 4.9 identifies locations where confirmation sampling and RI characterization indicate cleanup goals have been achieved at waste sites, but groundwater monitoring indicates that a potential for residual contamination in soil exists. The four general locations where groundwater monitoring indicates potential residual contamination in the vadose zone that may contribute to groundwater contamination include the following:

- D and DR Reactors where FSB leaks, disposal cribs, and trenches were historical sources of Cr(VI) and mixed fission product contamination
- High-concentration sodium dichromate transfer facility locations, including the vicinity of the 100-D-100 waste site and other related conveyance systems
- High-volume, low-concentration cooling water disposal areas
- 183-H Solar Evaporation Basin

8.2.1.3 Riparian Soil

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) risk assessments. Based on the results from this analysis (summarized in Section 6.4), there are no COPCs in riparian soils, near-shore sediments, and surface water that warrant further evaluation in the FS.

Appendix L presents a CSM of the riparian and near shore environment along 100-D/H to supplement the analysis of River Corridor-wide ecological risks presented in the RCBRA (DOE/RL-2007-21). Results from this evaluation identifies that, with the exception of total chromium and Cr(VI), detected concentrations of contaminants in riparian or near shore groundwater, seeps, aquifer tubes, and pore water do not present an ecological concern, or are not associated with contaminated groundwater resulting from Hanford Site operations, and total chromium and Cr(VI) should be considered the only COECs for purposes of alternatives evaluation.

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-D/H. The potential remedial technologies are evaluated or screened for implementability, effectiveness in eliminating, reducing, or controlling risks to HHE, and relative cost. The identified technologies are then combined into a range of remedial alternatives in Chapter 9.

8.3.1 Identification and Screening of Technologies

The discussion summarizes the technologies and process options considered as part of this evaluation. Although no action and ICs are not considered remedial technologies, they are important response actions to be considered as part of the remediation approach and are discussed herein.

Tables 8-7 and 8-8 present the identification and screening of technologies and remedial process options for 100-D/H in tabular form. Table 8-7 presents technologies for waste site treatment for radionuclides, Cr(VI) and other metals, and organic compounds. Table 8-8 presents GRAs and process options for groundwater impacted with Cr(VI) and other COPCs.

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 waste 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 would be an appropriate alternative component for waste sites where interim actions have been completed as dictated by the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039) (as presented in Table 1-2) and verification sampling data suggest the waste site does not present risks to HHE.

Institutional Controls. ICs are non-engineered instruments, such as administrative and/or legal controls, that minimize the potential for human exposure to contamination by limiting land or resource use. They are generally to be used in conjunction with, rather than in lieu of, engineering measures such as waste treatment or containment, and can be used during all stages of the cleanup process to accomplish various cleanup-related objectives. ICs should be "layered" (that is, use multiple ICs) or implemented in a series to provide overlapping assurances of protection from contamination. These administrative controls are imposed on land use to prevent or reduce exposure to hazardous wastes or hazardous constituents and/or to protect the integrity of a remedy. The need for ICs is 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. ICs will be identified for each waste site following completion of the remedial action if the contamination left in place is greater than levels protective of unrestricted land use.

As they are identified, DOE will apply and implement ICs in an integrated manner such that mechanisms in place will ensure 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 ICs as long as necessary to perform their intended protective purposes (*Use of Institutional Controls* [DOE P 454.1]).

The Sitewide IC Plan (DOE/RL-2001-41) developed by DOE-RL describes how OU-specific ICs specified in CERCLA decision documents will be implemented and maintained. The Sitewide IC Plan (DOE/RL-2001-41) is updated based on final CERCLA decision documents within 180 days after issuance of the final decision document. The Sitewide IC Plan (DOE/RL-2001-41) 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). ICs are reviewed during the CERCLA 5-year review process.

Table 8-9 identifies DOE categories of ICs and examples of ICs currently in use at the Hanford Site, including whether the IC will be retained for further evaluation in the FS. ICs will be identified for each waste site following completion of the remedial action if the contamination left in place is greater than levels protective of unrestricted land use.

In September 1993, DOE issued the NEPA ROD (58 FR 48509) that established a path forward for the Hanford Site reactors. The "Amended Record of Decision for the Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, WA" (75 FR 43158) was issued in July 2010.

The NEPA ROD (58 FR 48509) provided options for immediate dismantlement for reactor decommissioning and one-piece disposal or dismantlement of the reactor cores after an ISS period of approximately 75 years, which allowed for the decay of the radionuclides that presented the major risk for the site workers. Until reactor removal is complete, DOE will continue to conduct routine maintenance, surveillance, and radiological monitoring activities to ensure continued protection of HHE during the ISS period.

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 to occur as excavation proceeds. The observational approach uses a variety of techniques including field screening, confirmation sampling, and potholes, 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 additional characterization from the observational approach, analytical assessment of soil and groundwater to support design volumes, dust control, efficient transportation, treatment as required, and disposal. Excavated soil is segregated to determine disposal or treatment requirements.

Excavation can use conventional equipment and methods including excavators, bulldozers, and wheeled loaders. Earthmoving equipment removes clean overburden as appropriate, which can be staged for later use in backfilling, and contaminated media to stage for appropriate waste management activities. Contaminated media typically are 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 GRA include standard excavation (depths up to 6 m [20 ft]) and deep excavation (to depths greater than 6 m [20 ft]). The determination of 6 m (20 ft) for deep excavation is based on engineering considerations. 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 allow for less costly disposal. Treatment can be achieved by applying physical, chemical, biological, or thermal techniques.

Additional treatment that may be required to meet waste acceptance criteria at ERDF 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.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology	Process Option	COPC 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	6 m (20 ft)/ greater than 6 m (20 ft)	No further actions to address contamination. Source areas and residual contaminants in vadose zone are left untreated.	Low/High No remedial actions are taken, but effectiveness could be high if risk is previously mitigated.	High No administrative or technical implementability challenges are associated with implementation of this option, since no actions are required.	Low No associated cost.	Low No associated cost.	Little impacts.	Retained	Retained per the NCP (40 CFR 300).
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 Shallow contaminated soil removed.	High Standard excavation is typically straightforward. An Excavation Permit is required in the 100, 200, and 300 Areas and the Hanford Reach National Monument.	Moderate/High	Low 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 layback for open pit type excavation or alternatively use of shoring. Excavated soil is segregated (automated or laboratory based) to determine disposal or treatment requirements.	High 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 Has been performed at Hanford Site using laybacks. Shoring may be difficult with cobbles and boulders. Increased safety challenges with very deep excavations. An Excavation Permit is required in the 100, 200, and 300 Areas and the Hanford Reach National Monument.	High	Low No associated cost.	Waste generation if excavated soil is disposed of, GHG and energy for excavation equipment.	Retained	
Ex Situ Treatment and Processing[e]	Ex Situ Treatment and Processing[e]	Solidification/Stabilization	Mobile to Semi-Mobile contaminants (Cr[VI], strontium-90)	Depends on excavation method	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 and capped to shed water and prevent weathering. The location is engineered to withstand seismic activity.	Low/Moderate Effective at immobilizing contaminants in excavated material. However, the stabilized mass must be protected from weathering and seismic activity for long-term durability.	Moderate 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 ERDF, a centralized facility engineered to protect against weathering and seismic activity.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology	Process Option	COPC 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[e] (cont.)	Ex Situ Treatment and Processing[e] (cont.)	Soil Washing	Cr(VI), nitrate	Depends on excavation method	Consists of size separation of highly contaminated soil fractions (fines) from minimally contaminated soil fractions (coarse), followed by 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 Effectiveness is driven by the binding processes that exist between the contaminants and the soil particles (adsorbed or precipitated). Pilot testing at Hanford suggests a number of contaminants strongly sorb to all sizes of soil.	Low/Moderate 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 require treatment before disposal.	Moderate/High	Low 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	Depends on excavation method	Thermal treatment process that converts excavated soil and other materials into glass matrix. 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 Heavy metals and radionuclides are incorporated into the glass structure, which is generally resistant to leaching.	Low 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 use of proven technology (furnaces).	High	Low No associated cost.	GHG and energy for heat generation. High energy requirements to sustain required heat.	Not Retained	Complex technology, safety concerns with implementation.
		Thermal Desorption	Organics	Depends on excavation method	Direct application of heat to soil piles to increase the temperature of soil and destroy or volatilize organic compounds. A vapor cover and vacuum system are needed to transport volatilized water and organics to the gas treatment system. Also completed using mechanical systems (for example, rotary drum).	High Technology can achieve rapid removal/destruction of a mix of volatile and semivolatile organics at low residual levels.	Low Equipment readily available and commonly used, but can be mechanically complex.	High	Low No associated cost.	GHG and energy for production of heat vapor treatment.	Not Retained	Complex and challenging to implement.
Disposal	Disposal	Backfill Treated Soil	All	6 m (20 ft)/ greater than 6 m (20 ft)	Excavation and ex situ treatment followed by onsite disposal (backfill).	High Contaminated material has been treated by ex situ technologies.	High Excavated and treated soil will need to be compared to cleanup criteria to verify backfill is appropriate.	Low/Moderate	Low No associated cost.	GHG and energy for backfill.	Not Retained	No ex situ treatment technologies are retained.
		Disposal to ERDF	All	6 m (20 ft)/ greater than 6 m (20 ft)	Disposal of excavated soil at onsite landfill (ERDF). Treatment performed at the facility as required to meet land disposal restrictions.	High	High Implementability limited by COPC concentrations and onsite landfill requirements.	Low/Moderate	Low	GHG and energy for transport.	Retained	
		Other EPA approved Landfill	All	6 m (20 ft)/ greater than 6 m (20 ft)	Disposal of excavated soil at offsite landfill.	High Contaminated material has been treated by ex situ technologies.	High Implementability limited by COPC concentrations and offsite landfill requirements.	Moderate	Low No associated cost.	GHG and energy for transport.	Retained	

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology		Process Option	COPC 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	In Situ Treatment via Reagent	Reagent Approach	Solidification	Mobile COCs to semi-mobile Radionuclides, Other Metals, and Organics	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 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 Depends on delivery method.	High	Low/Moderate Assuming monolith is permanent.	GHG and energy for production and delivery of substrate/reagent.	Retained	Potential for incomplete contact of grout in the targeted treatment zone, and uncertainty regarding the durability of shallow soil encapsulation.
			Stabilization/ Sequestration	Radionuclides and Metals	6 m (20 ft)/ greater than 6 m (20 ft)	Chemical reactions are induced between the stabilizing agent and contaminant to reduce mobility. Agents include soluble phosphates and polyphosphates.	Low/Moderate Potential for direct exposure still exists if waste is shallow.	Low/Moderate Depends on delivery method.	Moderate	Low/Moderate Assuming stabilized mass is permanent	GHG and energy for production and delivery of substrate/reagent.	Retained	Uncertainty with uniform phosphate delivery and adequacy in removing risk associated with strontium-90. However, retained for strontium-90 at locations where excavation is not implementable.
			Chemical Reduction	Cr(VI)	6 m (20 ft)/ greater than 6 m (20 ft)	Chemical reductant (for example, calcium polysulfide, dithionite, hydrogen sulfide gas, ferrous sulfate, zero valent iron) is applied to the subsurface to treat contaminants within vadose zone. Chemical can be combined with solidification/stabilization or other treatment mechanisms.	Low/Moderate Chemical reductants are instantly reactive, which requires overloading to maintain reactive strength at depth.	Moderate Depends on delivery method. Localized temporary generation of secondary byproducts may occur. May temporarily mobilize COPCs toward groundwater. Handling chemical reductants is a health and safety concern.	Moderate	Moderate/High	GHG and energy for production and delivery of chemical agent.	Not Retained	More challenging to implement and costly as compared to biological reduction.
			Chemical Oxidation	Organics	6 m (20 ft)/ greater than 6 m (20 ft)	Subsurface delivery of chemical oxidant (for example, hydrogen peroxide, ozone, permanganate, persulfate, percarbonate) to degrade organic COPCs. Oxidants cause chemical destruction of toxic organic chemicals. Petroleum hydrocarbons and PAHs can be treated with a variety of oxidants (including peroxide, percarbonate, persulfate, and ozone); however, there are limited case studies demonstrating the successful treatment of PCBs with in situ chemical oxidation. Ozone is the most likely oxidant.	Low/Moderate Effectiveness is a function of oxidant distribution and contact. Injection of ozone a possible alternative, but more complex than bioventing alone. Multiple applications may be required to achieve complete treatment.	Low/Moderate Chemical oxidants can be delivered using soil mixing, horizontal injections wells, or vertical injection wells.	Moderate	Low/High O&M costs would be low assuming complete treatment can be achieved with a single application or high if multiple applications are required to achieve treatment.	GHG and energy for production and delivery of substrate/reagent.	Not Retained	Limited case studies demonstrating the successful treatment of PCBs with in situ chemical oxidation.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology		Process Option	COPC 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 via Reagent (cont.)	Reagent Approach (cont.)	Biological Reduction	Cr(VI), nitrate, VOCs, semi-VOAs, some heavy metals (Fe, Mn)	6 m (20 ft)/ greater than 6 m (20 ft)	Biological carbon source (for example, molasses, sodium lactate, emulsified oil, butane) is applied to the subsurface to treat contaminants within vadose zone.	Moderate/High Carbon source follows source release pathways. Biological reductants are activated by microbial activity, so reactive strength is maintained over relatively longer distances.	Moderate 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.	Retained	
			Combined Chemical/ Biological Reduction	Cr(VI), nitrate	6 m (20 ft)/ greater than 6 m (20 ft)	Chemical reductant (for example, calcium polysulfide, hydrogen sulfide gas, ferrous sulfate, zero valent iron) and biological carbon source (for example, molasses, sodium lactate, emulsified oil) are applied in combination to the subsurface to treat contaminants within the vadose zone.	Moderate Amendments follow source release pathways. Combined chemical and biological might improve performance.	Moderate 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 a 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	More challenging to implement and costly as compared to biological reduction.
			Gaseous Ammonia Injection	Mobile COPCs	6 m (20 ft)/ greater than 6 m (20 ft)	One of a number of possible gaseous reagents that are being investigated (along with in situ gaseous reduction). 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 Effectiveness is being studied as part of a laboratory-scale investigation.	Unknown Implementation is unknown at a full-scale level. Containment of injected gases in the shallow vadose zone may be an issue.	Unknown Technology evaluation has been limited to laboratory tests.	Unknown 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 could be evaluated as a remedial alternative later.
			Reductive Dechlorination Using Zero Valent metals and bioremediation	PCBs	6 m (20 ft)/ greater than 6 m (20 ft)	Zero valent metals have the potential to reductively dechlorinate PCBs. Metals include iron, palladium, and other combinations. The contaminated soil and the metals are mixed in some fashion to allow the reactions to occur. Bioremediation, via the addition of an organic substrate, is a very similar process and can be combined with zero-valent metal addition.	Unknown Very few published testing results are available.	Moderate Could be implemented by soil mixing with conventional excavation equipment if the contamination is shallow.	High	Low	No associated cost.	Not Retained	Reductive dechlorination using zero-valent metals and bioremediation are not proven technologies and were not retained for further consideration. More field studies must be conducted to test methods of bioaugmentation and biostimulation for PCB-dechlorinators.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology		Process Option	COPC 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 via Reagent (cont.)	Delivery Method	Gaseous Reduction with Chemical Reductant or Biological Substrate	Cr(VI), nitrate	6 m (20 ft)/ greater than 6 m (20 ft)	A gaseous mixture of chemical reductants (for example, hydrogen sulfide) or biological substrate (for example, butane) is injected into and drawn through the vadose zone to reduce Cr(VI). Research is underway to evaluate other reagents to immobilize contaminants.	Unknown Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil.	Unknown Vapor extraction wells are installed around injection well at a radial spacing of approximately 4.6 m (15 ft). Large numbers of wells are required. Because of health and safety risks, monitoring and emergency response plan are required for transporting, storing, and handling.	Unknown	Unknown	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 could be evaluated as a remedial alternative at a later date.
			Mixing with Conventional Excavation Equipment	Depends on type of reagent used	6 m (20 ft)	Use of conventional excavation equipment (backhoes, excavators, front-end loaders) to mix amendments into the soil.	High Agents are uniformly mixed with soil column, providing good contact and reaction between COPC and chemical.	Moderate Simple technology. Dust mitigation techniques will need to be implemented to control/prevent mechanical dispersion of contaminants.	Low/Moderate	Low No associated cost.	GHG emissions from machinery.	Not Retained	Not retained in favor of surface infiltration. Could be used if shallow mobile contaminants are identified in the future.
			Deep Soil Mixing (Vertical/Horizontal)	Depends on type of reagent used	6 m (20 ft)/ greater than 6 m (20 ft)	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 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 Implementation will be more challenging in gravelly/cobbly lithology. 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	Low No associated cost.	GHG emissions from machinery	Retained	Deep soil mixing implementability will be limited by site conditions and required depth of treatment.
			Foam Delivery of Reagents	Depends on type of reagent used	6 m (20 ft)/ greater than 6 m (20 ft)	Injection of a foam into the vadose zone. The foam is a mixture of a surfactant solution and a reagent, such as phosphate or calcium polysulfide. The foam increases the horizontal migration of the reagent away from the injection well.	Unknown 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 Technology evaluation has been limited to laboratory scale tests.	Unknown Technology evaluation has been limited to laboratory scale tests.	Unknown Technology evaluation has been limited to laboratory scale tests.	GHG emissions from well installation, development, and injection activities; waste generation from soil cuttings.	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 could be evaluated as a remedial alternative later.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology		Process Option	COPC 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 via Reagent (cont.)	Delivery Method (cont.)	Gas Delivery of Reagents	Depends on type of reagent used	6 m (20 ft)/ greater than 6 m (20 ft)	A gaseous mixture of chemical reagent is injected into and drawn through the vadose zone to reduce mobile COPCs.	Unknown Soil heterogeneity will result in preferential flow and limit treatment effectiveness of lower permeability soil.	Unknown Vapor extraction wells are installed around injection well at a radial spacing of approximately 4.6 m (15 ft). Large numbers of wells are required. Because of health and safety risks, monitoring and emergency response plan are required for transporting, storing, and handling.	Unknown	Unknown	GHG emissions from well installation, development, and injection activities; waste generation from soil cuttings.	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 could be evaluated as a remedial alternative later.
			Injection Wells (Horizontal)	Depends on type of reagent used	6 m (20 ft)/ greater than 6 m (20 ft)	Delivery of amendments using horizontal wells. Wells are installed using horizontal drilling techniques.	Low/Moderate 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 Implementation is challenging in gravelly/cobbly lithology. 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.
			Injection Wells (Vertical)	Depends on type of reagent used	6 m (20 ft)/ greater than 6 m (20 ft)	Delivery of amendments using conventional vertical wells.	Low/Moderate 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 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.	Retained	Delivery of liquid substrates in vadose zone through surface infiltration.
			Jet Grouting	Depends on type of reagent used	6 m (20 ft)/ greater than 6 m (20 ft)	High-pressure injection of reactive slurry into soil to mix the soil hydraulically with the slurry. Fluidization of the soil is preferred.	Low/Moderate While jet grouting is capable of reaching the required treatment depth, jet grouting is not likely to achieve uniform distribution or a radius of influence greater about 1.5 m (5 ft). Jet grouting of apatite and phosphate was pilot tested at 100-N for shallow, limited application. Altered/ decreased permeability of soil resulted from amendment precipitation and/or liquefaction of fine-grained sediment fractures.	Low/Moderate Implementation will be more challenging in gravelly/cobbly lithology. 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) will be required.	High Limited radius of influence would make jet grouting cost-prohibitive over a large area.	Low	GHG emissions from injection activities.	Retained	Could be considered in the future if technology develops. Currently, jet grouting has potentially limited effectiveness.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology		Process Option	COPC 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 via Reagent (cont.)	Delivery Method (cont.)	Surface Infiltration	Depends on type of reagent used	6 m (20 ft)/ greater than 6 m (20 ft)	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 Amendments follow source release pathways. Distribution not likely to be uniform.	High Surface infiltration systems are simple to install and accessible for O&M.	Low	Low	Limited infrastructure. GHG emissions from production and delivery of substrate.	Retained	Retained for liquid substrates.
			Void Filling/Grouting	Dependent on type of reagent used	NA (Pipelines/ Structures)	Grouting for solidification of buried wastes. Void grouting is considered for filling large voids, specifically pipelines and structures.	High Established and commonly used technology for removing voids in pipelines and structures.	Moderate/High Established and commonly used technology for removing voids in pipelines and structures. Pipe branch lines/breaks need to be identified. Implementability can be more challenging and costly with long or large diameter pipelines.	Low	Low No associated cost.	GHG and energy for production and delivery of grout used.	Retained	Retained for structures and pipelines near river or groundwater monitoring wells.
	In Situ Treatment Other		Soil Blending	All except mobile COPCs	Depends on excavation method.	Contaminated soils are mechanically blended with clean soil or fill to reduce effective contaminant concentrations.	High	High Conventional equipment can be used.	Moderate/	Low No associated cost.	GHG and energy for tilling equipment.	Not Retained	Not effective since it relies on contaminant dilution.
			Desiccation	Mobile COPCs	greater than 6 m (20 ft)	Remediation by injecting hot dry air and withdrawing moist air from soil, immobilizing contaminants by preventing their aqueous-phase transport.	Unknown A treatability test for this technology will be conducted for waste sites in the Central Plateau contaminated with technetium-99. Theoretically, desiccation would reduce moisture content in the vadose zone. Reduction of COPC migration would be effective until the soil is re-wetted. The technology is not effective in the long term without concurrent infiltration control.	Unknown Implementation requires installation of injection and extraction wells, which are proven technology. However, there is uncertainty related with the number of wells, well spacing, and well configuration details required for optimal field/full-scale implementation. Would also require implementation of infiltration control.	Unknown	Unknown	GHG and energy for air injection. 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. This technology could be evaluated as a remedial alternative later.
			Thermal Desorption	Organics	6 m (20 ft)/ greater than 6 m (20 ft)	Direct application of heat (for example, using electrical heating elements, electrical resistive heating, injection of hot air, steam or hot water, radio frequency) to increase the temperature of soil and destroy or volatilize organic compounds. VOC capture required.	Moderate/High Technology can achieve rapid removal/destruction of a mix of volatile and semivolatile organics, and achieve low residual concentrations.	Low Technology is applied using vertical drilling methods, and requires a spacing of 1.5 to 3 m (5 to 10 ft). Recovery of COPC vapors will require soil vapor extraction network and vapor barrier over entire treatment area.	High	Low No associated cost.	GHG and energy for production of heat and vapor recovery; waste generation from soil cuttings.	Not Retained	Mechanically complex challenging to implement.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology	Process Option	COPC 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.)	Vitrification	All	6 m (20 ft)/ greater than 6 m (20 ft)	Thermal treatment process that converts soil and other materials to glass matrix. Contaminants are incorporated into the glass structure, which is generally strong, durable, and resistant to leaching.	High Metals and radionuclides are retained within the treated soil, which is generally resistant to leaching.	Low 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 also important to account for safety considerations from exposure to high heat.	High	Low No associated cost.	GHG and energy for heat generation. High energy requirements to sustain required heat.	Not Retained	Complex and challenging to implement.
		Soil Flushing – Vadose Zone, Water	Contaminants with high to moderate solubility (for example, Cr(VI) and nitrate)	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 out of the vadose zone to the water table, where it would be captured and treated.	Moderate 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.	High Drip irrigation system or trenches are simple to install and accessible for O&M.	Low/Moderate	Low	GHG and energy for installation.	Retained	
		Phytoremediation	Bio-available Metals and Organics	6 m (20 ft)	Phytoremediation uses plants and their associated rhizospheric microorganisms to remove, degrade, or contain contaminants.	Low Phytoremediation is only effective when plants are active, thus the technology is not effective during the winter. Phytoremediation only treats soils to the approximate depth of the plant roots, and is only appropriate for low concentrations of contaminants. It is a slow process that is applied over long periods, that is, years or decades. Many metals and radionuclides are only taken up by the plants and not transformed to innocuous forms.	Moderate Involves large land requirements, and considerable work would be required to make a plot of land at Hanford Site suitable for plant growth. If used to treat contaminants that are merely taken up and not transformed to innocuous forms, plants would need to be disposed of elsewhere to avoid ultimately returning the contaminants to the soils they came from. Concerns about contaminants in the plants entering the food chain may need to be addressed.	Low	Low	GHG and energy for installation, and potential disposal of harvested plants containing metals. Implementation of phytoremediation could lead to a GHG reduction credit.	Not Retained	Phytoremediation would only be effective for low concentrations of contaminants in shallow soils over long periods, and many metals and radionuclides would accumulate in the plants and would not actually be treated, posing risks to ecological receptors.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology	Process Option	COPC 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	Surface Barrier	Surface Barriers (for example, Modified RCRA Subtitle C and/or D Barrier, Asphalt/Concrete barrier, Vegetative barrier [Evapotranspiration barrier], Hanford Barrier)	All	6 m (20 ft)/ greater than 6 m (20 ft)	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. Modified RCRA Subtitle C Barriers are designed for hazardous waste, category 3 and category 1 (mixed) low-level waste. Modified RCRA Subtitle D Barriers are designed for non-radiological and non-hazardous solid waste, or category 1 low level waste where hazardous constituents are not present. Evapotranspiration barriers consist of a fine-grained soil layer overlying a relatively coarse-grained soil layer designed to functionally increase the water-holding capacity. Asphalt/concrete barriers can be placed around structures to remain in place (for example, reactors) in the short term (75 years) to promote drainage, prevent infiltration into possible sources below the reactors, and prevent exposure to contaminated soil. The Hanford Barrier design was developed for sites containing low-level waste greater than Class C, and/or significant inventories of transuranic constituents.	Moderate/High Leaching of near-surface source COPCs will be controlled, but residual COPCs in capillary fringe and deeper vadose zone pore water will continue to impact 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 No technical or administrative challenges are associated with implementing asphalt/concrete caps (high implementability). Modified RCRA Subtitle C and/or D Barrier and Evapotranspiration barriers are simple to install. Biointrusion may need to be considered as part of the barrier/cap design.	Low/High Hanford Barrier (High); Modified RCRA Subtitle C and/or D Barrier (Moderate); Asphalt/ Concrete Cap and Evapotranspiration Barrier (Low)	High Dependent on type of barrier and depth of contamination.	GHG and energy for installation. Continued impact to soil resources.	Retained	
	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 is as discussed above at one specific depth. 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 Significant uncertainty on the completeness of the barrier with all methods.	Low Would be difficult or impossible to implement at the Hanford Site because of presence of gravels and cobbles, and/or the depth of application.	High	Low	Large amount of wastes would be generated during installation and GHG and energy for installation.	Not Retained	Difficult to implement.
	Compaction	Dynamic compaction	All	6 m (20 ft)/ greater than 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 Effective at removing void spaces and compacting surface soils, where voids exist around buried waste. Not effective for native soils. Not effective for treatment of hazardous wastes.	Moderate Simple and widely used technology.	Low	Low No associated cost.	GHG and energy for installation.	Not Retained	Not effective for treatment of hazardous wastes.

Table 8-7. Screening Table—Technologies for Radionuclides, Hexavalent Chromium, Other Metals, and Organic Compounds in the Vadose Zone—100-D/H

General Response Actions	Remedial Technology	Process Option	COPC 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

a. Indicates the contaminants that can be addressed by a technology based on geochemical properties. A COPC Applicability of "All" indicates implementation of a technology is not dependent on the nature of a contaminant.

b. Depth range is based on practical limitations of implementing the given technology.

c. Sustainability includes potential impacts to the environment that could arise from implementing this technology (for example, GHG emissions, waste generation, water use and resource impacts, and energy use).

d. Additional details on technologies not retained are provided in Appendix I.

e. Ex situ treatment does not include treatment done for disposal at ERDF or an approved offsite landfill. Treatment performed at 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.

COPC = contaminant of potential concern
ERDF = environmental restoration disposal facility
GHG = greenhouse gas
NA = not applicable
O&M = operations and maintenance
PAH = polycyclic aromatic hydrocarbon
VOC = volatile organic compound

Table 8-8. Screening Table—Technologies for Hexavalent Chromium and Other COPCs in Groundwater—100-D/H

General Response Actions	Remedial Technology	Process Option	COPC 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		High	Low	Low	Little impacts	Retained	Retained per the NCP (40 CFR 300).
					No remedial actions are taken, but effectiveness could be high if risk is previously mitigated.							
Monitored Natural Attenuation (MNA)	MNA	MNA	All	Relies on natural attenuation processes to manage the contamination on site. Monitor groundwater plume to track natural attenuation processes until RAOs are achieved. Typically combined with other technologies that manage the source areas and mitigate exposure. Natural attenuation processes include: • Biological reduction – processes where naturally occurring microorganisms, such as yeast, fungi, and bacteria, break down target substances into less toxic or non-toxic substances. • Chemical reduction – geochemical process where natural reductants in sediments reduce contaminants into less toxic or non-toxic substances. • Adsorption - occurs in groundwater, as dissolved chemicals are removed from the solution and attach to soil particles. • 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. • Dilution – the decrease in the chemical concentration in a fluid caused by mixing with a fluid containing a lower concentration. • Radioactive decay – spontaneous disintegration of the nucleus of a radionuclide resulting in reduction in radionuclide activity.	biological reduction	Low/Moderate	High	Low/Moderate	Low/Moderate	Little impacts	Retained	
					chemical reduction	Moderate/High						
					adsorption	Low/Moderate						
					dispersion	High						
					dilution	High						
					radioactive decay	Low/High depending on decay half-life of radioactive contaminant						

Table 8-8. Screening Table—Technologies for Hexavalent Chromium and Other COPCs in Groundwater—100-D/H

General Response Actions		Remedial Technology	Process Option	COPC 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	Collection	Extraction	Groundwater Extraction System	All dissolved	Operation of existing and/or new groundwater extraction wells.	Moderate/High Pump-and-treat is a proven treatment technology for contaminants in groundwater, although there is some uncertainty as to its ability to achieve standards everywhere.	High System already in place for Cr(VI), but existing well field may not be appropriate to capture all of the COPCs.	Low System exists	Moderate/High	Energy consumption and GHG emissions from pumping systems.	Retained	
	Ex Situ Treatment	Chemical	Ion Exchange	Cr(VI), nitrate, strontium-90	Ions from the aqueous phase are removed by exchange with innocuous ions on the exchange medium.	Moderate/High Effective for Cr(VI), nitrate, and strontium-90 treatment. Variable, depending on COPC. SIR-700 (the current ion exchange resin) has limited effectiveness in removal of Sr-90. Other resins, such as KMS-1 or CG8 resin may be more effective in the removal of Sr-90, but would require additional treatment trains.	High Vendors and equipment readily available. Currently used at the site.	Low/Moderate Systems exist, but may need to be expanded or upgraded for other COPCs	Moderate/High	Waste generation from ion exchange resin disposal or regeneration. Energy consumption from process equipment.	Retained	Pump-and-treat technology is expected to have limited success using SIR-700 resin to removeSr-90 from the aquifer where most of the Sr-90 is bound to the aquifer sediments. KMS-1 or CG8 resin may be more effective for Sr-90 removal.
			Chemical Reduction/ Softening and Precipitation	Cr(VI)	Dissolved COPCs are transformed into an insoluble solid, which is removed by flocculation, sedimentation, and filtration. COPCs are removed with the sludge.	Low/Moderate Effective for Cr(VI) treatment.	Moderate/High Vendors and equipment readily available, but no experience with the technology at Hanford. Large volume of sludge would be produced.	Moderate/High	Moderate	Waste generation from chemical precipitation. Energy consumption from process equipment.	Not Retained	For Cr(VI), implementability challenges given large sludge volume. In addition, ion exchange treatment systems are in place.
			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 Not widely used for Cr(VI) removal. Pilot testing at the site had challenges.	Low/Moderate Additional development and testing would be required. Potential negative impacts on reinjection of water.	Moderate/High	Moderate	Waste generation from chemical precipitation. Energy consumption from process equipment.	Not Retained	Implementability challenges. In addition, the ion exchange treatment systems are in place.
		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. Petroleum aerobically degraded.	Moderate/High Effective for nitrate, but additional research/pilot testing is required to verify effectiveness for other COPCs.	Low/Moderate May require large surface area for extended period.	Moderate Depends on land and construction requirements	Low	Little impacts, except for land required	Not Retained	Performance uncertainty will require research to determine effectiveness. Not retained since ion exchange treatment system are in place.
			Subgrade Bioreactors	Cr(VI), nitrate	Extracted groundwater is pumped into a lined excavated area that has been backfilled with organic media (for example, wood mulch with zero valent iron). Cr(VI) and nitrate are biologically reduced as it passes through the media. A second stage aeration/filtration stage could be provided to remove any biological byproducts (for example, iron), petroleum, and solids before infiltrating or injecting back to groundwater.	Moderate/High Effective for nitrate, but treatability testing is required to verify effectiveness for other COPCs.	Moderate/High Excavation and backfilling is easy to implement. Piping can be incorporated into the design to facilitate future delivery of liquid carbon sources (for example, vegetable oil). Treatability testing required to verify implementability.	Low/Moderate Depends on land requirements	Low	Impacts include spent media disposal and land required	Not Retained	Has not been demonstrated on a full scale for Cr(VI) or nitrate remediation.

Table 8-8. Screening Table—Technologies for Hexavalent Chromium and Other COPCs in Groundwater—100-D/H

General Response Actions		Remedial Technology	Process Option	COPC 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.)	Bioreactors	Cr(VI), nitrate	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 recharge into the ground.	Low/Moderate Bioreactors commonly used for nitrate removal, but less commonly for Cr(VI) reduction. Little experience with other COPCs.	Moderate/High 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 could be used, ex situ bioreactors have not been retained.
			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 irrigating water for plants.	Low/Moderate 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. Commonly used for nitrate removal. Plants used for remediating radionuclides would require harvesting.	Low/Moderate Requires large surface area for plants. Potential cultural challenges with implementation near river.	Low	Low	Impacts include land required and potential disposal of harvested plants containing radionuclides.	Not Retained	Would only be effective for low concentrations of contaminants where groundwater is shallow over long periods, or when applied as irrigation water. Many metals and radionuclides would accumulate in the plants and not actually be treated, posing risks to ecological receptors.
		Physical	Membrane Separation (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 With the appropriate design, reverse osmosis can be effective for almost any compound.	Low/Moderate Vendors and equipment readily available, although additional site specific testing would be required. Pretreatment likely necessary, and a large volume of brine would be produced that would need to be treated and handled.	High	High	Waste generation in the form of brine and high energy use. Energy consumption from process equipment.	Not Retained	Implementability challenges from large volumes of brine produced that would require reduction and disposal.
	Discharge	Onsite Discharge	Groundwater Injection Wells	All	Treated groundwater is injected into onsite wells.	High Will enhance contaminant flushing, hydraulic control and capture of plume.	High Readily implementable at the site, currently used in existing pump-and-treat system. The wells may be subject to clogging because of the buildup of chemical precipitates or microbial biofouling.	Low/Moderate	Low/Moderate	Waste generation from soil cuttings for well installation.	Retained	
			Surface Infiltration	All	Treated groundwater is infiltrated into onsite trenches.	High Effective means of disposal and may enhance contaminant flushing, hydraulic control and capture of plume if trenches can be located appropriately.	Moderate/High Infiltration would be easy to engineer and implement.	Low Trenches are lower cost than wells	Low/Moderate	Little impacts	Retained	

Table 8-8. Screening Table—Technologies for Hexavalent Chromium and Other COPCs in Groundwater—100-D/H

General Response Actions		Remedial Technology	Process Option	COPC 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.)	Discharge (cont.)	Offsite Discharge	Discharge to Surface Water	All	Discharge of treated groundwater directly to the river at an outfall.	High	Low	Low	Low	Little impacts	Retained	.
						Effective means of treated water disposal.	Although surface water discharge is commonly practiced for treated wastewater, new outfall(s) would have to be constructed.		Little or no maintenance required			
In Situ Treatment	Reagent Approach	Chemical	Chemical Reduction	Cr(VI)	Subsurface delivery of chemical reductants (such as calcium polysulfide) within plume to stimulate reduction of contaminant.	Moderate	Moderate	Moderate/High	Moderate	Waste generation from soil cuttings for well installation. GHG and energy for production and delivery of chemicals	Not Retained	May be more challenging to implement and costly as compared to biological reduction.
						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.	May require large number of wells.	Dependent on number and type of wells. Likely higher capital cost compared to in situ biological				
			Chemical Stabilization	Strontium-90	Subsurface delivery of chemical reagents (such phosphate) in a regular pattern of wells in the aquifer to sequester the contaminants. Chemical reactions are induced between the stabilizing agent and contaminant to reduce mobility.	Moderate/High	Moderate	Moderate/High	Moderate	Waste generation from soil cuttings for well installation. GHG and energy from chemical production and transport.	Retained	Retained for treatment of strrontium-90 at locations of continuing source to groundwater.
						Currently being implemented at 100-N in a barrier approach for strontium-90 with favorable results. Achieving even distribution may be difficult.	Requires large number of wells to cover a large area.	Function of number of injection wells required	Periodic reinjection may be required.			
		Biological	Biological Treatment (Anaerobic)	Cr(VI), nitrate	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	Moderate/High	Moderate/High	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	
						Reactive life of biological electron donors is longer than chemical reductants so that 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.	Requires large number of wells to cover a large area.	Dependent on number and type of wells				

Table 8-8. Screening Table—Technologies for Hexavalent Chromium and Other COPCs in Groundwater—100-D/H

General Response Actions		Remedial Technology	Process Option	COPC 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.)	Reagent Approach (cont.)	Chemical/ Biological	Hydrogen or other Organic Gas Sparging	Cr(VI)	Injection of biodegradable organic gasses (for example, propone or butane) or hydrogen into sparge wells that are screened below the water table.	Low Distribution of gasses likely to be poor under local heterogeneous geologic conditions. Has not been demonstrated for Cr(VI).	Low 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 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.
			Combination of Biological & Chemical Substrates	Cr(VI), nitrate	Subsurface delivery and recirculation of both chemical reductants and electron donors within plume to stimulate chemical and anaerobic biological reduction of Cr(VI).	High 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 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 impact restoration to beneficial use.	Moderate/High Dependent on number and type of wells	Moderate/High	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 costly as compared to biological reduction.
		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 The extraction wells system should be able to capture any contaminants mobilized. However, performance will depend on residual contamination in lower permeability layers.	High Standard wells or infiltration trenches used for injection.	Moderate Costs for wells and piping	Low	GHG and energy for installation. Waste generation from soil cuttings for well installation.	Retained	
	Delivery Method	Surface Infiltration	Surface Infiltration	NA	Trenches, French drains, or drip irrigations systems are used to apply water or reagents.	High Effective with appropriate design, installation, and maintenance.	Moderate Location of vadose zone contamination in relation to the water table needs to be known.	Low	Moderate	Less GHG and energy for installation	Retained	
		Groundwater circulation wells	Groundwater circulation wells	NA	Installation of wells with two screened zones. Groundwater is typically pumped out of the formation from 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 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 A large number of wells may be required.	Moderate 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 Effective with appropriate design, installation, and maintenance.	High Uses extensively at Hanford.	Moderate/High Wells at Hanford are generally expensive.	Moderate	Waste generation from soil cuttings, GHG and energy for installation	Retained	

Table 8-8. Screening Table—Technologies for Hexavalent Chromium and Other COPCs in Groundwater—100-D/H

General Response Actions		Remedial Technology	Process Option	COPC 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.)	Delivery Method	Horizontal Wells	Horizontal Wells	NA	Horizontally drilled wells are used to inject water or reagents.	Low/Moderate Uncertain performance.	Low Pilot test was not successful.	Moderate/High Costs are high but fewer wells are required	Moderate	Waste generation from soil cuttings, GHG and energy for installation	Not Retained	Pilot test was not successful.
Containment		Physical	Containment Wall (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 Effectiveness is dependent on the continuity of the wall and the ability to key into the RUM, 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 Installation of wall through cobbles and boulders to key into the RUM 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)	Cr(VI)	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) is passively removed as groundwater moves through the treatment zone barriers. Sodium dithionite or zero valent iron may be used as reductants. ISRM is currently in use at 100-D.	Moderate Effective if barrier treatment zone conditions are maintained. High flows of concentrated contaminants in groundwater and changing water levels may reduce effectiveness and require more frequent amendments. The ISRM at 100-D has experienced some breakthrough. Not effective in treating the bulk of the plume.	Moderate/High Can be implemented with injection wells or recirculation dipole wells. Broad zones of secondary byproduct generation within treatment area may occur.	Moderate/High Dependent on number and type of wells	Moderate	ISRM already exists, limited GHG and energy to augment	Retained	Existing ISRM will be allowed to function as it is, but amendments will not be considered as part of the FS evaluation since a barrier approach will not support the cleanup of the plume.
			Reactive Chemical Barrier (apatite, zero valent iron, zeolite, polyphosphate, etc.)	strontium-90	Subsurface injection or trenching in of reducing or sequestering chemicals along cross-gradient rows transecting plume. Chemicals are retained in the aquifer matrix so that contaminates are passively removed as groundwater moves through the treatment zone barriers.	Moderate Effective if barrier treatment zone conditions are maintained. High flows of highly aerobic groundwater and changing water levels are likely to necessitate more frequent amendments and/or reduce permeability of barrier (for zero valent iron). Not effective in treating the bulk of the plume.	Moderate Can be implemented with injection wells or trenching. However, both may be very challenging at this site due to the presence of cobbles/boulders.	High Dependent on number and type of wells	Moderate	GHG and energy for installation	Not Retained	Not retained in favor of existing hydraulic containment system.
			Reactive Biological Barrier	Cr(VI), nitrate	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 Effective if barrier treatment zone conditions are maintained. The aerobic groundwater conditions may require frequent amendment of the barrier. Not effective in treating the bulk of the plume.	Moderate/High 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 Dependent on number and type of wells	Moderate	GHG and energy for installation	Not Retained	Not retained in favor of existing hydraulic containment system.

Table 8-8. Screening Table—Technologies for Hexavalent Chromium and Other COPCs in Groundwater—100-D/H

General Response Actions	Remedial Technology	Process Option	COPC Applicability[c]	Description	Relative Effectiveness	Relative Implementability	Relative Capital Cost	Relative O&M Cost	Sustainability[b]	Retained/Not Retained [a]	Screening Comment
Containment	Hydraulic Control	Hydraulic Containment via Extraction	All	Install extraction wells along downgradient edge of plumes to control migration of COPCs to the river.	Moderate Extraction should control plume migration to the river, but upgradient plumes and hot spots are left untreated.	High Compatible with existing infrastructure, and can be designed to work with other remedial technologies.	Low 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 (for example, 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 Should rapidly control plume migration to the river. However, some flushing and dilution of the contamination already close to the river may occur.	Moderate Can be accomplished using practically achievable injection rates. Injection only required 2 to 3 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	Not Retained	Not retained in favor of existing hydraulic containment system.

Note: COPCs include chromium (total), nitrate, and strontium-90.

a. Additional details on technologies not retained are provided in Appendix I.

b. Sustainability includes potential impacts to the environment that could arise from implementing this technology (for example, GHG emissions, waste generation, water use and resource impacts, energy use). Alternative design will dictate how sustainable an approach is.

c. Indicates the contaminants that can be addressed by a technology based on geochemical properties. A COPC Applicability of "All" indicates implementation of a technology is not dependent on the nature of a contaminant.

Cr(VI) = hexavalent chromium
COPC = contaminant of potential concern
GHG = greenhouse gas
ISRM = in situ redox manipulation
RAO = remedial action objective

Table 8-9. Categories and Types of Current Hanford Institutional Controls

DOE Categories of Institutional Controls[a]	DOE Categorical Description	Types of Current Hanford Institutional Controls	Examples of Institutional Controls
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. **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** – Requirement for placement of permanent signs and/or markers at specific areas of the site. – Procedural requirements for access excavation/drilling permits. – Applies to all COPCs. – *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. – *Implementability:* Very Good. Readily implemented, requires periodic surveillance and maintenance. – *Cost:* Low. *Retained*
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 institutional controls 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 institutional controls are maintained beyond change of ownership, as appropriate. Mechanisms include land use and real property controls (for example, proprietary controls including easements and covenants) 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. **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** – Land use and real property controls (for example, proprietary controls including easements and covenants). – Applies to all COPCs. – *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. – *Implementability:* Very Good. Readily implemented, must identify and comply with all necessary legal requirements. – *Cost:* Low. *Retained* **Groundwater Use Management** – Groundwater controls. – Applies to all COPCs. – *Effectiveness:* Good. Ensures no improper use of groundwater. – *Implementability:* Very Good. Readily implemented, but will likely require ongoing oversight and coordination with state water resource managers. – *Cost:* Low. *Retained*

Table 8-9. Categories and Types of Current Hanford Institutional Controls

DOE Categories of Institutional Controls[a]	DOE Categorical Description	Types of Current Hanford Institutional Controls	Examples of Institutional Controls
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** – Administrative – Applies to all COPCs. – *Effectiveness:* Good. Ensures access to information on the location and nature of contamination. – *Implementability:* Very Good. Readily implemented, but requires maintenance of the information management system. – *Cost:* Low. *Retained*

a. *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41).

b. An "Informational Tool" is an EPA category of an institutional control that is used at the Hanford Site as discussed in DOE/RL-2001-41.

COPC = contaminant of potential concern

WIDS = Waste Information Data System

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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 an offsite landfill, or by backfilling treated soil. Prior to implementation of a disposal option, waste acceptance criteria must be evaluated. Treatment required to meet ERDF waste acceptance criteria is evaluated under the disposal GRA.

Backfilling treated soil involves excavation and ex situ treatment, followed by onsite disposal. Before implementation of this disposal option, treated soil will need to be compared to PRG criteria to verify backfilling is appropriate.

Disposal at the onsite landfill includes transport of excavated soil to EDRF. The waste acceptance criteria for ERDF are based on regulatory requirements (for example, RCRA Land Disposal Requirements) and risk-based considerations for long-term protection of HHE. If waste cannot be accepted at ERDF, an EPA-approved offsite 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 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 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 in 100-D/H, 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
  - Biological reduction
  - Combined chemical/biological reduction
  - Gaseous ammonia injection
  - Reductive dechlorination using zero-valent metals or bioremediation of PCBs
  - In situ gaseous reduction 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 filling/grouting

- In situ treatment—other:
  - Soil blending
  - Desiccation
  - In situ thermal desorption
  - In situ vitrification
  - Soil flushing (vadose zone, water)
  - Phytoremediation

Containment. Containment actions consist of physical measures to restrict contaminant migration to groundwater, and/or break the direct contact exposure pathway. Remedial technologies evaluated under the containment GRA include surface barriers, horizontal subsurface barriers, and compaction.

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 contamination to groundwater. Surface barriers also provide a cover of contaminated waste sites to protect against direct contact exposure to minimize human and ecological risks. In addition to their hydrological performance, 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 Hanford barrier, modified RCRA Subtitle C or Subtitle D barrier, asphalt/concrete cap, and vegetative cap (evapotranspiration cap). 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 transuranic 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.

Dynamic compaction can consolidate soil and buried wastes, and minimize the potential subsidence for a subsequent barrier. The process involves dropping a weight from a predetermined height onto the area to be compacted.

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 NCP (40 CFR 300) guidance 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 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 8-9 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 8-9 presents an evaluation of groundwater use management restrictions.

Monitored Natural Attenuation. MNA relies on natural attenuation processes such as biological and chemical reduction, adsorption, dilution, dispersion, and radioactive decay to manage the contamination onsite. 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 for waste sites with 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 timeframe that is reasonable compared with other alternatives. Largely because of the uncertainty associated with the potential effectiveness of MNA to meet remediation objectives, 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 will be completed in accordance with the guidelines provided in *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* (OSWER Directive 9200.4-17P), in addition to *An Approach for Evaluating Progress of Natural Attenuation in Groundwater* (EPA 600/R-11/204), and *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water 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 8-14, provided later is this chapter, 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 an MNA technology application follows a logical sequence of assessment of the following four essential functional requirements of MNA:

- **The contamination 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 controlled previously through an engineered remedy or naturally ceased to contribute to the problem. In some cases, a source control element (for example, localized pump-and-treat or selected in situ remedy) may be combined with the MNA alternative to ensure adequate control of

secondary sources (for example, residual mobile contamination in the vadose zone, or high-concentration plume segments in groundwater).

- **The target plume is static or retreating, or existing monitoring data otherwise confirm that attenuating processes are present and operating at the site. Effective monitoring either exists currently, or can be implemented**, that will provide confirmation that the attenuation is proceeding as expected and that remedial goals are achieved.

Development and evaluation of MNA either as a technology or as a standalone 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-D/H:

- **Reduction of nitrate**, primarily facilitated by microbial populations in surface and groundwater, may occur when the dissolved oxygen content water becomes low and the water enters a reduced condition. Indigenous facultative and obligate anaerobic microbes may then use the oxygen atoms of the nitrate molecule in their metabolic processes, reducing the nitrate to other forms (for example, nitrite, diatomic nitrogen). While these processes may occur in some locations at 100-D/H, the aquifer is generally well-aerated and, as a result, nitrate tends to be quite stable and mobile in groundwater. Reduction of nitrate in an un-modified aquifer system is not considered an attenuating process at 100-D/H.

- **Reduction of Cr(VI)** may also occur in reducing conditions within the aquifer, or through chemical reaction with reducing compounds. Chemical reduction of Cr(VI) produces trivalent chromium, which is subject to subsequent precipitation of chromium oxide and hydroxide compounds that exhibit extremely low water solubility. In groundwater at 100-D/H, Cr(VI) reduction generally occurs only at locations where the aquifer has been modified to produce reducing conditions, either through application of some remedial process (examples include, the in situ biostimulation treatability test in the southwestern portion of the 100-D Area within the chromate and nitrate plumes, ISRM barrier installed in 100-D. and the calcium polysulfide treatability test at 100-K) or through some pollution-related process (for example, anaerobic conditions related to septic tank/leach field discharges, or historical releases of reducing constituents).

- **Diffusion and dispersion** within the aquifer are physical processes that reduce contaminant concentrations in groundwater over time and distance. Diffusion is a concentration-driven physical process that results in movement of dissolved constituents from areas of high concentration to adjacent areas of relatively low concentrations. Dispersion is a physical process that results in mixing of dissolved constituents within the aquifer water as the result of variations in groundwater flow velocity along varying flow paths within the aquifer. This mixing results in reduction in contaminant concentrations over distance. The 100-D/H groundwater plumes cover a relatively large area; however, the distance along flow paths is relatively short between inland areas of elevated contaminant concentration and locations of potential exposure to receptors at the groundwater/river interface. This indicates that the overall portion of the aquifer where diffusion and dispersion may provide substantial concentration reduction is relatively small. Diffusion and dispersion are, therefore, not considered major contributors to attenuating processes at 100-D/H at higher concentrations of contamination, but may still be considered at concentrations near the cleanup levels.

Pump-and-Treat. The pump-and-treat GRA includes collection, ex situ treatment, and discharge. The following text details the remedial technologies and applicable process options.

- **Collection**—This process option involves collection of contaminated groundwater through operation of groundwater extraction wells. Groundwater is pumped to the surface through vertical wells and then transferred through pipes to a treatment facility. Two pump-and-treat systems currently operate to remediate groundwater in the 100-HR-3 OU. The DX pump-and-treat system and HX pump-and-treat systems remediate groundwater in the 100-D and 100-H Areas, respectively. This process option includes expansion and/or modifications to the existing pump-and-treat systems.

- **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
  - Subgrade bioreactors
  - Bioreactors
  - Phytoremediation
  - Membrane separation (reverse osmosis)

- **Discharge**—Both onsite and offsite:

  - Onsite discharge includes groundwater injection wells and surface infiltration of treated water
  - Offsite discharge includes surface water discharge

In Situ Treatment. In situ treatment consists of actions that treat contamination in place. In situ treatment of contaminated groundwater generally includes methods to degrade contaminants, such as adding agents 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 in 100-D/H, the following in situ remedial technologies and process options were evaluated:

- Reagent approach:

  - In situ chemical reduction
  - In situ chemical stabilization
  - In situ biological treatment (anaerobic)
  - Hydrogen or other organic gas sparging
  - In situ treatment using 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-D/H, the following containment process options were evaluated:

- Containment wall (for example, slurry wall or grout wall)
- ISRM
- Reactive chemical barrier
- Reactive biological barrier
- Hydraulic containment via extraction
- Hydraulic containment via injection

8.3.2 Evaluation of Technologies and Selection of Representative Technologies

Tables 8-7 and 8-8 present the identification and screening of technologies and remedial process options for 100-D/H. Table 8-7 presents GRAs and process options for vadose zone soils, including waste sites, impacted with radionuclides, Cr(VI), and other metals, and organic compounds. Table 8-8 presents GRAs and process options for groundwater impacted with Cr(VI) and other COPCs.

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 also 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 the screening of 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 the 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 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 impacts; 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 RAOs; (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 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 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 provides a thorough discussion of the technologies not retained, including a detailed screening rationale. Remedial technology types and process options considered viable for remediating contaminated soil at 100-D/H are carried forward into the development (Chapter 9) and detailed analysis of alternatives (Chapter 10).

8.3.2.1 Identification of Technologies and Selection of Representative Technologies for Vadose Zone Contamination

For remediation of vadose zone soils, including waste sites, at 100-D/H, the following response actions were retained (Table 8-7) to remove contaminants or interrupt the exposure pathway to receptors:

- Removal:
  - Standard excavation—Provides for removal of contaminants
  - Deep excavation—Provides for removal of contamination
- Disposal:
  - Disposal to ERDF—Provides for treatment at the facility (if necessary) and disposal of contaminants
  - Offsite disposal at an EPA approved landfill—Provides for disposal of contaminants
- In situ treatment via reagent:
  - Solidification—Provides for treatment of contaminants
  - Stabilization/sequestration—Provides for treatment of contaminants
  - Biological reduction—Provides for treatment of contaminants
- In situ treatment via reagent—delivery method:
  - Vertical injection wells—Used to deliver liquid reagent to the shallow or deep vadose zone
  - Jet grouting—Used to deliver liquid reagent to the shallow or deep vadose zone
  - Surface infiltration—Used to deliver liquid reagents
  - Deep soil mixing—Used to deliver reagent to the shallow or deep vadose zone

  - Void-fill grouting—Provides engineered barrier to interrupt the exposure pathway and immobilize contaminants

- In situ treatment—other:
  - Soil flushing (vadose zone, water)—Provides transfer of contaminants to groundwater during remediation; this in situ technology is coupled with groundwater hydraulic containment

- Containment:
  - Surface barrier—Provides engineered structure to interrupt the exposure pathway

ICs, as identified in Table 8-9, are also retained for controls during remediation 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).

8.3.2.2 Identification of Technologies and Selection of Representative Technologies for Groundwater Contamination

For treatment of contaminated groundwater (Table 8-8) at 100-D/H, the following response actions and were retained to remove contaminants or interrupt the exposure pathways to receptors:

- MNA—Treatment of contaminants through biological and chemical reduction, radioactive decay, adsorption, dilution, and dispersion

- Pump-and-treat—Provides for treatment of contaminants:
  - Collection through groundwater extraction system
  - Ex situ ion exchange (for Cr[VI], strontium-90, and nitrate)
  - Groundwater injection wells discharge
  - Discharge through surface infiltration
  - Surface Water discharge

- In situ treatment—Provides for treatment of contaminants:
  - Chemical stabilization—Through subsurface delivery of chemical reagents
  - Biological treatment (anaerobic) —Using liquid substrate
  - Combined chemical and biological reagents—Through subsurface delivery of chemical reductants and electron donors
  - Physical treatment—Flushing the saturated zone with water to facilitate contaminant movement to allow for capture and treatment from the groundwater media (that is, pump-and-treat with hydraulic containment)

- In situ treatment—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
  - Reactive chemical barrier—Existing ISRM

- Containment:
  - Hydraulic containment via extraction and injection - provides engineered system to interrupt the exposure pathways

ICs, as identified in Table 8-9, are also retained for controls during remediation to interrupt the exposure pathway. The "no action" GRA does not provide capability to remove contaminants or interrupt the exposure pathways to receptors but is also retained per the NCP (40 CFR 300).

Figures 8-7 through 8-23 present specific information on technologies that have been retained. For 100-D/H, Chapter 9 presents technologies that are developed into alternatives applicable for each waste site type group. Appendix I provides a discussion of the technologies not retained. This appendix describes the technology, followed by relevant case studies and the screening rationale.

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. Specific 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.
- The excavated site is recontoured to reflect the surrounding terrain to the extent practical and revegetated with native species.

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)*

	Low	Moderate	High
Relative Effectiveness			
Relative Implementability			
Relative Capital Cost			
Relative O&M Cost	*No associated costs.*		

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Sources: 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 (100 Area Remaining Sites)*.

HNF-36881, *Final Frontier at Hanford: Tackling the Central Plateau*.

WHC-SA-2062-FP, *Accelerated Cleanup of Mixed Waste Units on the Hanford Site, Richland, Washington*.

Figure 8-7. 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.
- The excavated site is recontoured to reflect the surrounding terrain to the extent practical and revegetated with native species.

Deep excavation at 100-B-27.

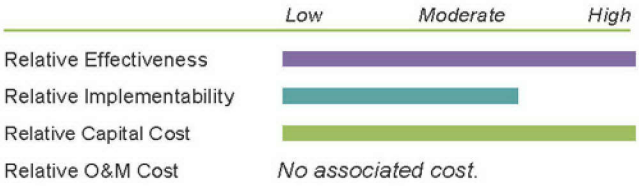
Examples of Relevant Experience

- 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)*



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Sources: 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 (100 Area Remaining Sites)*.

RSVP-2009-040, *Remaining Sites Verification Package for the 100-B-27 Sodium Dichromate Spill*.

Figure 8-8. 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. *(www.handford.gov/page.cfm/ERDF)*

Hanford's Environmental Restoration Disposal Facility

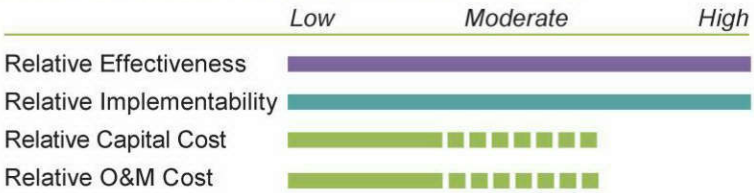
Examples of Relevant Experience

- 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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Sources: 10 CFR 61, "Licensing Requirements for Land Disposal of Radioactive Waste."

RLI-D02-14, *Environmental Restoration Disposal Facility Fact Sheet*.

WAC 173-303-665, "Dangerous Waste Regulations," "Landfills."

Figure 8-9. Onsite Disposal: The Environmental Restoration Disposal Facility

In-Situ Biological Reduction (Vadose Zone)

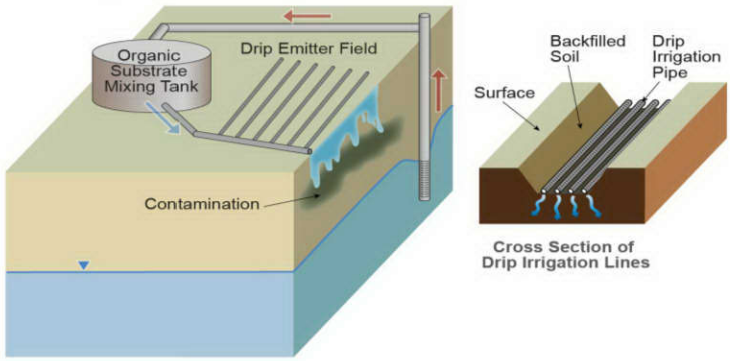
Key Components

- Uses native microorganisms to reduce contaminants to less- or non-toxic compounds, either directly by the microbes through dissimilatory or enzymatic reduction, or indirectly by a reduced electron acceptor (*e.g.*, ferrous iron or sulfide).
- Natural process are enhanced by adding organic substrates (a carbon source) to stimulate microorganisms in the subsurface and change the geochemistry to anaerobic conditions.
- Localized temporary generation of secondary byproducts (reduced manganese, iron, and arsenic) should be expected.
- Organic substrate application methods include surface infiltration (shown in conceptual schematic), aqueous injection using wells, gas injection using wells, and soil mixing using solid reagents.
- Components for surface infiltration include:
  - Reagent tank
  - Subsurface drip irrigation system
  - Infiltration basin

Risk Reduction Mechanism

- Biological treatment can reduce Cr(VI) to the less-toxic and less mobile Cr(III), and nitrate to nitrogen gas.
- Volume of Cr(III) will not change, but toxicity will be reduced.
- Can reduce contaminant volume by removing contaminants as they are completely degraded, and/or mobility and toxicity reduced by transforming contaminants to less-toxic and/or less soluble forms.

Conceptual Schematic



Examples of Relevant Experience

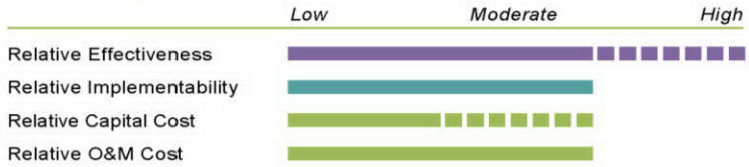
Reports for examples of applications using bio-remediation to convert Cr(VI) to less toxic (Cr(III)) include:

- 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

Pilot studies have demonstrated the processes can be used for applications in the vadose zone:

- A trailer-mounted 10-gpm In Situ Delivery (ISD™) system was used at a former agricultural facility (chrome plating) in Walla Walla, Washington to treat Cr+6-contaminated soil and groundwater that was a result of a leaking UST. (ETEC, Case Study, AGGRESSIVE HEXAVALENT CHROMIUM REMEDIATION USING A 10-GPM IN SITU DELIVERY (ISD™) SYSTEM)
- Laboratory studies have demonstrated the processes, showing that adding water and organic nutrients to columns packed with vadose zone materials contaminated with Cr(VI) cause the effective conversion of Cr(VI) to Cr(III) (Tokunaga et al., 2003, "In-situ reduction of Cr(VI) in heavily contaminated soils through organic carbon amendment," and Oliver, 2001, Microbial Reduction of Hexavalent Chromium Under Vadose Zone Conditions)

Screening Criteria *(dashed line indicates range)*



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Sources: CH2M HILL, 2010, *Hinkley Remediation Semiannual Status Report (July through December 2009) PG&E Compressor Station, Hinkley, California*.

ETEC, 2011, *AGGRESSIVE HEXAVALENT CHROMIUM REMEDIATION USING A 10-GPM IN SITU DELIVERY (ISD™) SYSTEM Agricultural Facility, Walla Walla, WA*

Oliver, 2001, *Microbial Reduction of Hexavalent Chromium Under Vadose Zone Conditions*.

PNNL-18784, *Hanford 100-D Area Biostimulation Treatability Test Results*.

Tokunaga et al., 2003, "In-situ Reduction of Cr(VI) in Heavily Contaminated Soils Through Organic Carbon Amendment."

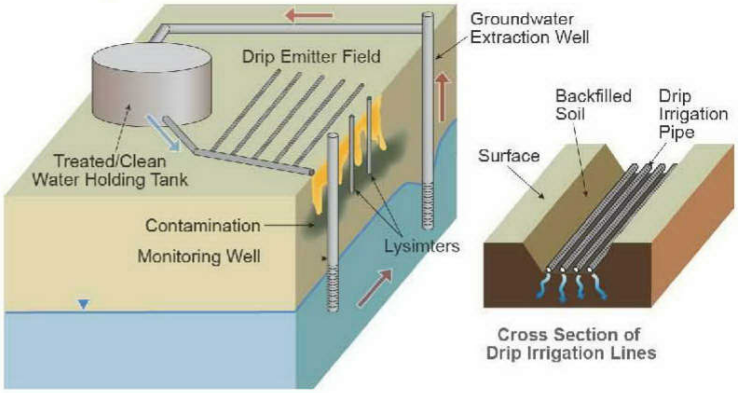
Figure 8-10. In Situ Biological Reduction (Vadose Zone)

Soil Flushing – Vadose Zone, Water

Key Components

- Involves the infiltration of clean or treated water into a zone of contaminated soil to flush contaminants out of the vadose zone to the water table.
- Applicable for media impacted with contaminants with high to moderate solubility (*e.g.*, Cr(VI), Tc-99, uranium, nitrate, and possible C-14).
- Solubility-enhancing solutions may be added to enhance mobility.
- Infiltrating water with desorbed contaminants need to be captured and treated to meet discharge standards.
- Contaminants flushed to the water table are captured by extraction wells coupled to pump-and-treat system(s) in place for groundwater remediation.
- Enhancement of conventional pump and treat with in-situ flushing of source area may speed site remediation and closure; however ineffective groundwater capture may create a larger groundwater plume.

Conceptual Schematic



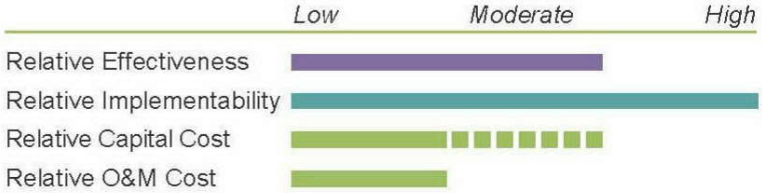
Examples of Relevant Experience

- Soil flushing was used to treat soil and groundwater contaminated with Cr(VI) by United Chrome Products, Corvallis, OR. Delivery of solution was completed through two infiltration basins and one infiltration trench to flush Cr(VI) from the vadose zone to the water table. Extraction wells were used to recover the solution and extract groundwater. A 1998 report indicates 9.7 million gallons of impacted groundwater containing 26,732 pounds of Cr(VI) were removed in a 3-year period. *(TS-98-01)*

Risk Reduction Mechanism

- Toxicity and/or volume of source area in the vadose zone is reduced by mass transfer to groundwater.
- Reduction in toxicity, mobility, and volume of contaminants is achieved through a groundwater capture and treatment system.
- Treatment of impacted media in shallow soil may reduce direct contact risk and exposure to ecological receptors.

Screening Criteria *(dashed line indicates range)*



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Source: TS-98-01, *Technology Status Report In Situ Flushing*.

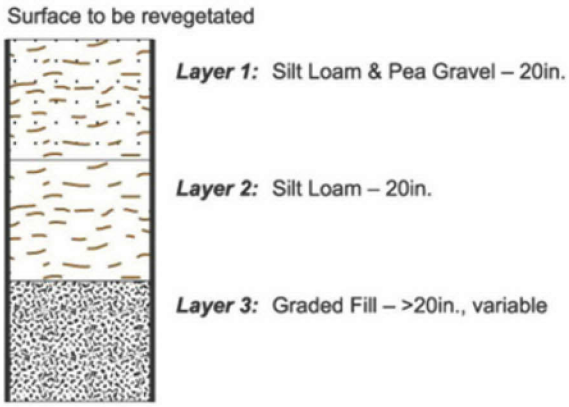
Figure 8-11. Soil Flushing—Vadose Zone, Water

Surface Barriers

Key Components

- Surface barriers are earthen and/or manufactured covers placed on the ground surface above contaminated media.
- Designed to prevent surface water infiltration through the vadose zone, and to limit contaminant leaching to groundwater. May also prevent direct contact to contaminants.
- Types of surface barriers include: Modified RCRA Subtitle C and/ or D, Asphalt/ Concrete, Evapotranspiration, Vegetative and the Hanford Barrier.
- Evapotranspiration (ET) barriers (shown in conceptual schematic) can be placed over structures to remain in place to promote drainage, prevent infiltration to possible sources below barrier, and prevent exposure to contaminated soil/debris.
- Excavation, handling, and transport of contaminated soil are reduced.
- Can also be implemented at the bottom of an excavation to limit infiltration through contaminated soil left in place. Implementation may require soil characterization and soil compaction tests.
- Periodic inspection and repair required.

Conceptual Schematic



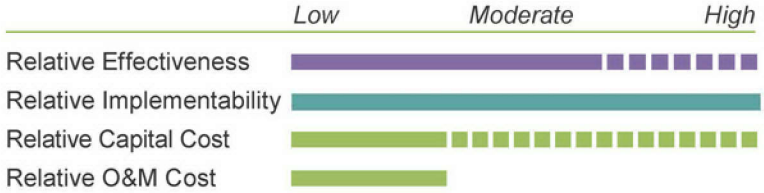
Examples of Relevant Experience

- Examples of sites that have proposed, approved, or installed ET covers and the regulatory program they are operating under are given in EPA *Fact Sheet on Evapotranspiration Cover Systems for Waste Containment*, Appendix A. Details on these sites can be found in the alternative cover profiles database. *(http://cluin.org/products/altcovers)*

Risk Reduction Mechanism

- Prevents surface water infiltration and reduces contaminant migration through vadose zone, limiting potential leaching to groundwater.
- When coupled with Institutional Controls, may reduce direct contact and exposure to ecological receptors.
- Toxicity of contaminants is not reduced.

Screening Criteria *(dashed line indicates range)*



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Source: EPA 542-F-11-001, *Fact Sheet on Evapotranspiration Cover Systems for Waste Containment*.

Figure 8-12. Surface Barrier

Void Fill Grouting

Key Components

- In-situ treatment technology used to immobilize contaminants by solidification of wastes.
- Void grouting may be considered to fill large empty spaces (*e.g.,* pipelines, trenches, pits). Structure is then left in place.
- Grout can be cement-based (*e.g.,* Type I, II, III, IV, and V Portland cement) or chemical-based (*e.g.,* silicates, acrylics, lignosulfonates, phenoplasts, and aminoplasts).
- Portland cement-based grouts may offer an additional benefit to treat certain radionuclides and metals, since the increased pH from grouting may yield increasing precipitation and sorption of these compounds (*e.g.,* Sr-90).
- Grout can be mixed in batches or with a mobile continuous mixer, depending on the size of the grouting project.

Conceptual Schematic

Grouting of the 221-U Canyon Facility

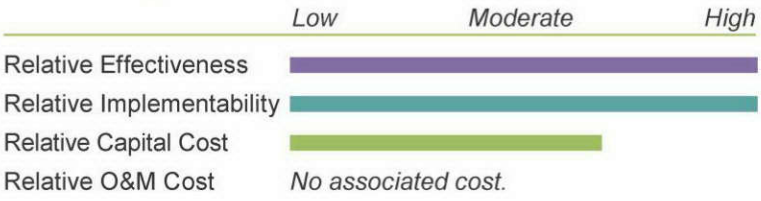
Examples of Relevant Experience

- The *Interim Completion Report for the 221-U Facility* (DOE/RL-2011-80) provides status for void spaces of the 221-U Plant Canyon Facility filled with grout consistent with the remedial action identified in the 221-U Facility ROD. Void spaces included the process cell, hot pipe trench, piping and electrical galleries, drain header, process sewer, and ventilation and tunnel and ducts.

Risk Reduction Mechanism

- Immobilizes residual mobile contaminants that may be present within the structure.
- Reduces the potential of contaminant migration to groundwater.
- Immobilized contaminants left in place; however, volume of contaminated materials increases.

Screening Criteria *(dashed line indicates range)*



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Source: DOE/RL-2011-80, *Interim Completion Report for the 221-U Facility*.

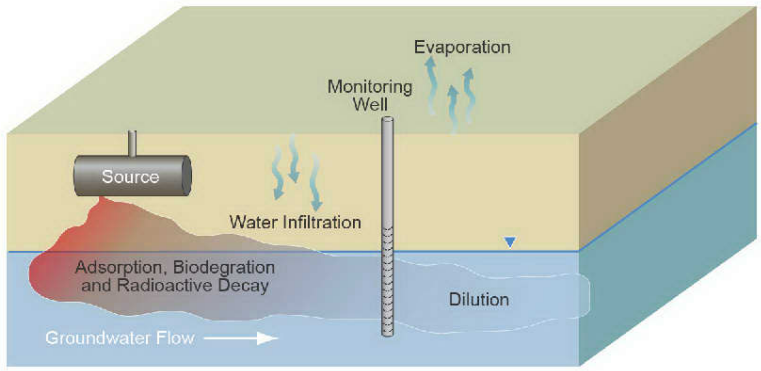
Figure 8-13. Void-fill Grouting

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



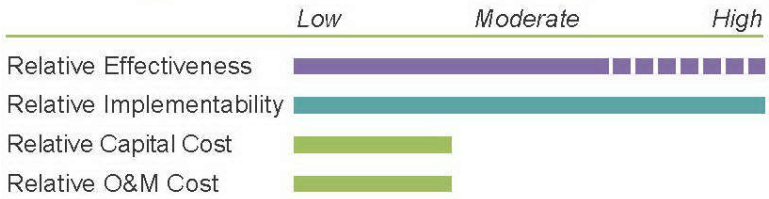
Examples of Relevant Experience

- 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 to be treated.

Screening Criteria *(dashed line indicates range)*



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Source: DOE/RL-2009-10, *Hanford Site Cleanup Completion Framework*.

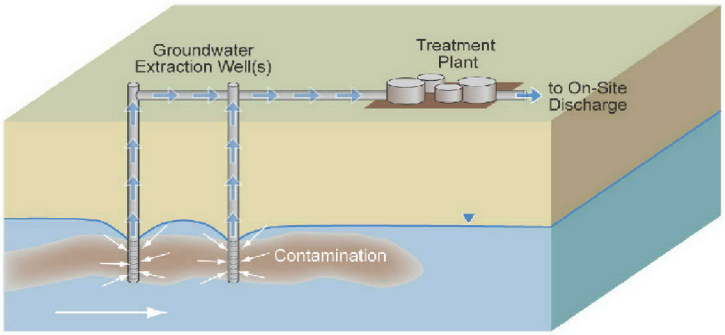
Figure 8-14. Monitored Natural Attenuation

Groundwater Extraction System and On-Site Discharge

Key Components

- Involves continued operation of existing groundwater extraction systems with the potential to expand the system configuration based on remediation goals.
- 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

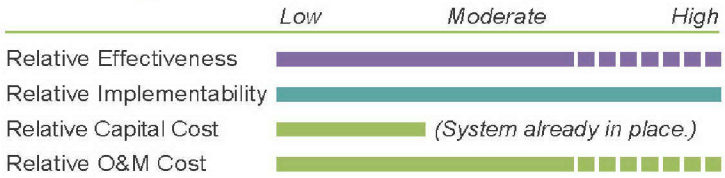
Pump and Treat System	Startup Date	Contaminant	Volume Treated (millions of liters)	Mass Removed (Kg)
100-DR-5[a]	2004	Cr(VI)	384	338
100-DX[a]	2010	Cr(VI)	974	461
100-HR-3[a]	1997	Cr(VI)	4,171	406
100-HX[a]	2011	Cr(VI)	303	11
100-KR-4[a]	1997	Cr(VI)	5,725	355
100-KW[a]	2007	Cr(VI)	1,410	163
100-KX[a]	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-2013-03, 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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Sources: 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*.

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*.

Figure 8-15. Groundwater Extraction System and Onsite Discharge

Ion Exchange

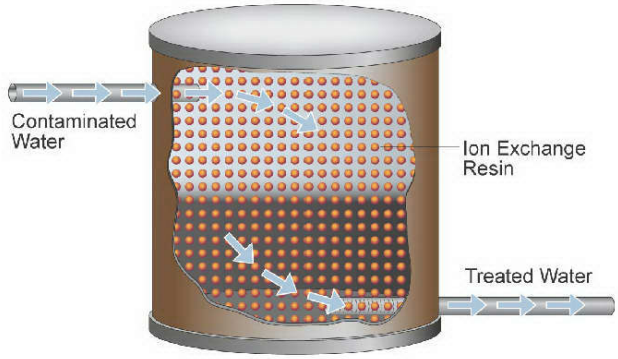
Key Components

- 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).

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.

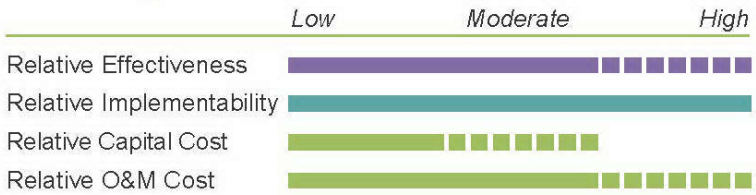
Conceptual Schematic



Examples of Relevant Experience

- Ion exchange (IX) is the current Hanford groundwater treatment for many pump-and-treat systems: *(DOE/RL-2012-02)*
  - 100-DR-5 system: Removed ~338 kg Cr(VI) since startup in 2004 through calendar year 2011 (CY11)
  - 100-HR-3 system: Removed ~406 kg Cr(VI) since startup in 1997 through CY11
  - 100-KR-4 system: Removed ~355 kg Cr(VI) since startup in 1997 through CY11
  - 100-KW system: Removed ~163 kg Cr(VI) since startup in 2007 through CY11
  - 100-KX system: Removed ~114 kg Cr(VI) since startup in 2009 through CY11
  - 100-DX system: Removed ~461 kg Cr(VI) since startup in December 2010 through CY11
  - 100-HX system: Removed ~11 kg Cr(VI) since startup in October 2011 through CY11

Screening Criteria *(dashed line indicates range)*



CHPUBS_RC_0009a

Source: 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*.

Figure 8-16. Ion Exchange

In Situ Biological Treatment – Anaerobic (Groundwater)

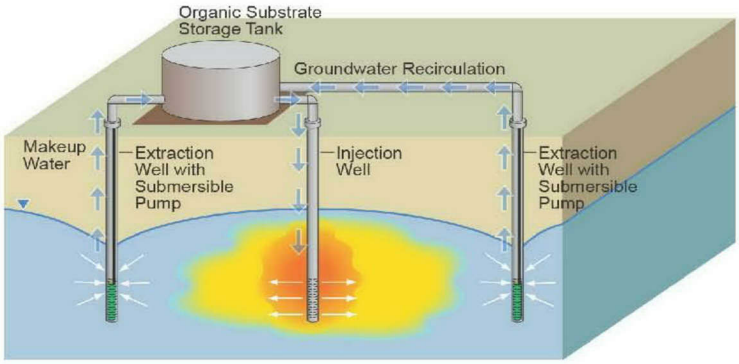
Key Components

- 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.

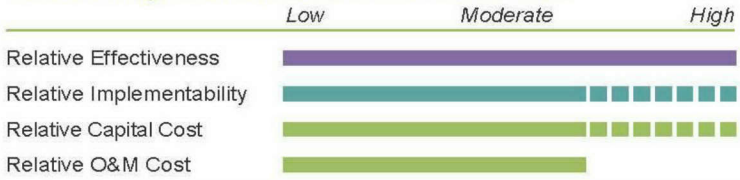
Conceptual Schematic



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)*



CHPUBS_RC_0013

Sources: CH2M HILL, 2010, *Hinkley Remediation Semiannual Status Report (July through December 2009) PG&E Compressor Station, Hinkley, California*.

Faybishenko, B., 2009, *In Situ Long-Term Reductive Bioimmobilization of Cr(VI) in Groundwater Using Hydrogen Release Compound*.

PNNL-18784, *Hanford 100-D Area Biostimulation Treatability Test Results*.

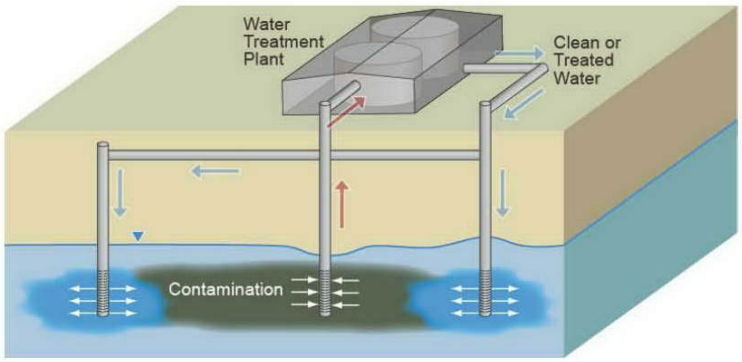
Figure 8-17. In Situ Biological Treatment—Anaerobic (Groundwater)

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



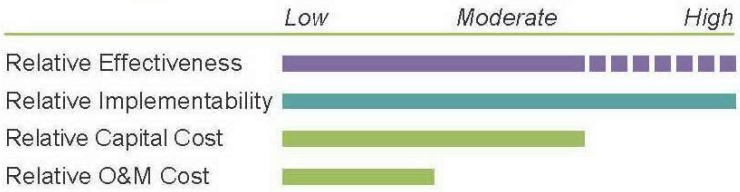
Examples of Relevant Experience

- 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)*



CHPUBS_RC_0006

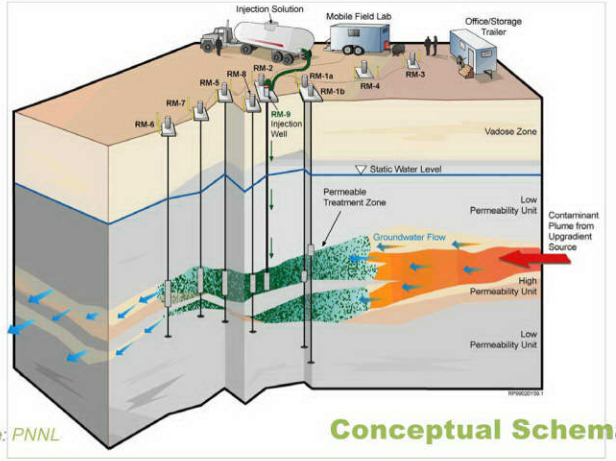
Source: DOI060410A, *Groundwater Proposed Plan, Pacific Gas and Electric Company, Topock Compressor Station, Needles, California*.

Figure 8-18. Flushing—Saturated Zone, Water

Reactive Chemical Barrier (In-Situ Redox Manipulation) (Groundwater)

Key Components

- Zone of chemically reactive material that transforms (reduces) contaminants in groundwater as it flows through.
- Reactive zone can be generated by a series of injection/recirculation wells or a trench that transects the groundwater flow pathway.
- Reactive material is a reducing chemical (*e.g.,* sodium dithionite or zero valent iron).
- Generation of secondary byproducts and/or break-through may occur.
- Occasional amendments/ applications may be necessary.
- Used to control migration; not effective in treating the bulk of the plume.
- Dispersing reactive material into the aquifer can make implementation complex. Varying hydraulic gradients, and varying water levels can reduce the effectiveness.



Source: PNNL

Conceptual Schematic

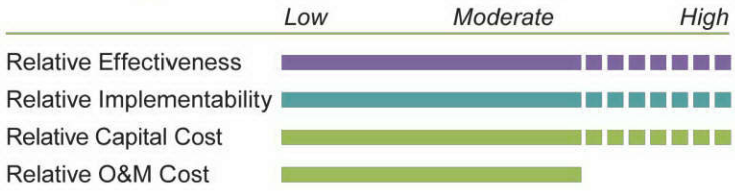
Examples of Relevant Experience

- Currently in use in Hanford 100 D; geochemical parameters indicate success in producing the desired Cr-reducing conditions; concentration reductions have been noted, but concentrations in downgradient wells have been variable (*i.e.,* some breakthrough has occurred). *(DOE/RL-2010-11)*

Risk Reduction Mechanism

- Risk reduction achieved through treatment. Risk reduction limited to zone of active treatment and further migration. Does not adequately reduce risk throughout the bulk of the plume.
- Chemical reagents transform (reduce) contaminant to non-or less-toxic compound [*e.g.,* Cr(VI) to Cr(III)]; generation of secondary byproducts may occur .
- ISRM acts as a barrier; when effective, reduces contaminant plume migration/mobility.

Screening Criteria *(dashed line indicates range)*



CHPUBS1106_2010-95_DD_08.8-18

Source: DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2.*

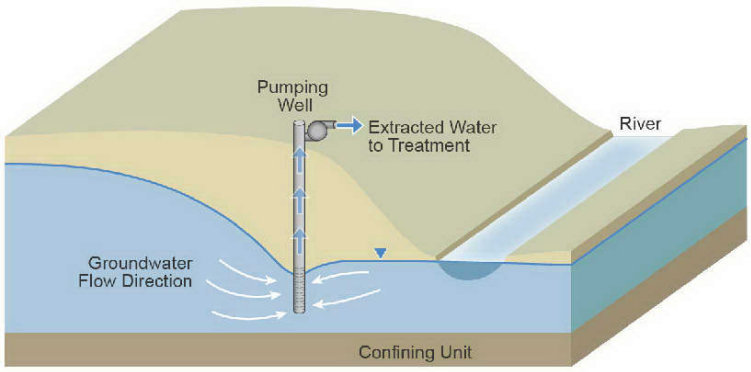
Figure 8-19. Reactive Chemical Barrier (In Situ Redox Manipulation) (Groundwater)

Hydraulic Containment via Extraction (Groundwater)

Key Components

- Extraction wells provide hydraulic containment by pumping groundwater from the plume edge to control contaminant migration.
- Changes groundwater flow characteristics and pulls contaminated groundwater towards the extraction wells.
- Removed groundwater will require treatment or proper disposal.

Conceptual Schematic



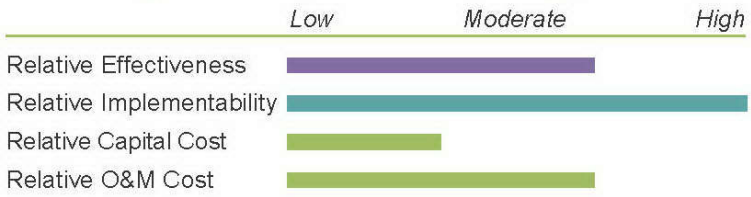
Examples of Relevant Experience

- At least eight pump-and-treat systems are successfully operating at Hanford to provide hydraulic containment in addition to removing contamination. 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)*



CHPUBS_RC_0008

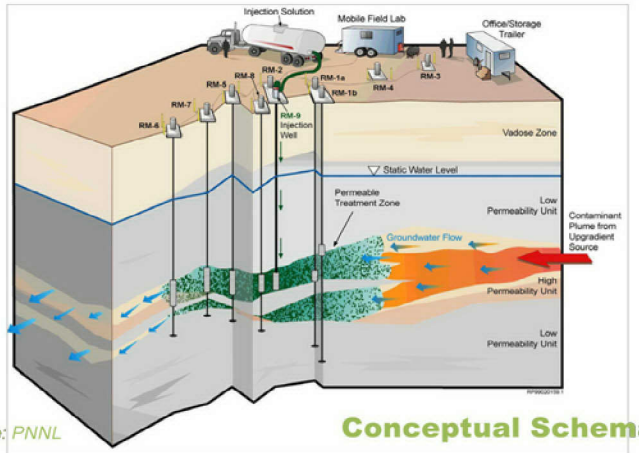
Source: DOE/RL-2010-11, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2.*

Figure 8-20. Hydraulic Containment via Extraction (Groundwater)

In Situ Chemical Stabilization

Key Components

- Zone of chemically reactive material provides for sequestration of contaminants (Sr-90) in groundwater.
- Reactive zone can be generated by a series of injection wells that transects the groundwater flow pathway.
- Calcium-citrate-phosphate solutions form apatite precipitate [Ca6(PO4)10(OH)2] for sequestration of Sr-90 by substitution of Sr for Ca.
- Occasional amendments (reinjection) may be necessary
- Amendments to injection wells are dependant on river stage and geologic formation for effective treatment



Source: PNNL

Conceptual Schematic

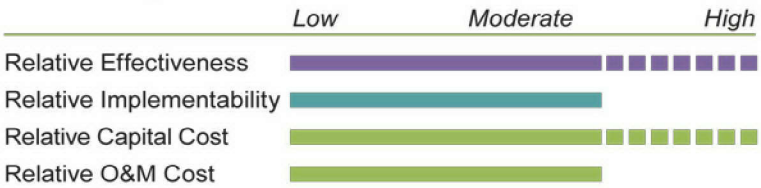
Examples of Relevant Experience

- In situ chemical stabilization is currently in use in Hanford 100-N. An initial 300 foot apatite Permeable Reactive Barrier (PRB) is in place along the 100-N Area shoreline. The PRB uses calcium-citrate-phosphate solution injections for in situ strontium-90 immobilization to reduce the strontium-90 flux to the Columbia River. Strontium-90 concentrations in the groundwater along the PRB have been reduced by 90 percent since injections began in 2006 (DOE/RL-2011-25).

Risk Reduction Mechanism

- Risk reduction achieved through treatment. Risk reduction limited to zone of active treatment.
- Apatite precipitate [Ca6(PO4)10(OH)2] from Ca-citrate-PO4 solutions injected in the PRB sequesters Sr-90 during initial precipitation and additionally slowly incorporates Sr-90 by solid phase substitution for Ca.
- Sufficient apatite needs to be emplaced in sediments to incorporate Sr and Sr-90 and the rate of incorporation needs to exceed the natural groundwater flux rate of strontium in the groundwater.

Screening Criteria *(dashed line indicates range)*



CHPUBS1106_2010-95_DD_08.8-18

Source: DOE/RL-2011-25, *Calendar Year 2010 Annual Summary Report for the 100-HR-3 and 100-KR-4 Pump-and-Treat Operations and 100-NR-2 Groundwater Remediation*.

Figure 8-21. In Situ Chemical Stabilization

In Situ Solidification

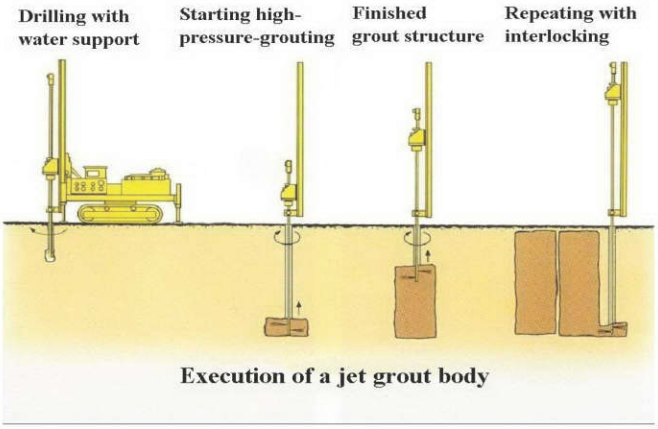
Key Components

- Solidification alters the physical and/or chemical characteristics of a soil through the addition of binders, including cements and chemical grouts, to immobilize contaminants.
- Multiple types of grouting/binding materials and emplacement techniques have been developed and demonstrated.
- The effectiveness of grout emplacement depends on the application method.
- Application for subsurface contaminant solidification in Hanford Site vadose zone sediments include jet grouting and permeation grouting.
- Two types of grout materials may be used: particulate (cement) grouts and chemical grouts. Cement grouts use Portland cement as the primary component. A chemical grout is a solution comprised of a binder (other than Portland cement) that reacts in place to form a gel or solid after injection into a porous subsurface soil, sediment, or rock volume.

Risk Reduction Mechanism

- The immobilization primarily works by coating and isolation processes that make the contaminants less prone to leaching or dissolution.
- The effectiveness of in situ solidification is a function of the distribution of the grout into the formation, the degree of encapsulation of contaminated sediment particles, and the long-term durability of shallow soil encapsulation when exposed to the elements.

Conceptual Schematic



Examples of Relevant Experience

- In situ grouting is a component of the remedial actions implemented at the Old F-Area Seepage Basin (OFASB) at the Savannah River Site. The remedial action was completed on June 9, 2000. The grouting and soil cover remedy at OFASB is protective of human health and the environment for soil contamination and prevents external exposure to radiological contaminants as identified in the Second Five Year Review Report for the Savannah River Site (WSRC-RP-2001-4163).
- Treatability testing for in situ grouting of waste sites was completed at Idaho National Laboratory demonstrating the potential viability of grouting to stabilize waste (in situ solidification) in near surface sites (Final Results Report, In Situ Grouting Technology for Appication of Buried Transuranic Waste Sites, Volume 1: Technology Description and Treatability Study Results for OU 7-13/14 [INEEL/EXT-02-00233]).

Screening Criteria *(dashed line indicates range)*

CHPUBS_100K_157a

Sources: INEEL/EXT-02-00233, *Final Results Report, In Situ Grouting Technology for Application in Buried Transuranic Waste Sites Volume 1, Technology Description and Treatability Study Results for Operable Unit 7-13/14*.

WSRC-RP-2001-4163, *Second Five-Year Review Report for the Savannah River Site Aiken, South Carolina*.

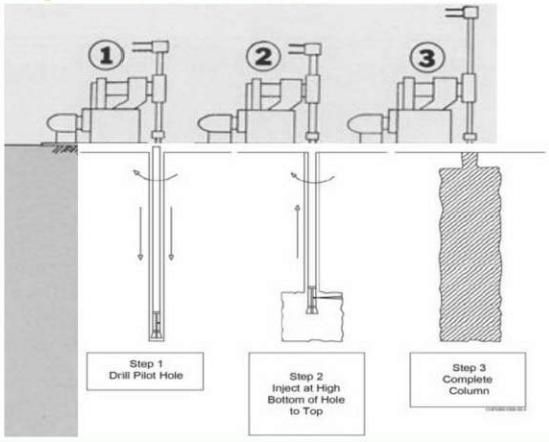
Figure 8-22. In Situ Solidification

In Situ Stabilization/Sequestration

Key Components

- Apatite minerals sequester elements into their molecular structures via isomorphic substitution, whereby elements of similar physical and chemical characteristics replace calcium, phosphate, or hydroxide in the hexagonal crystal structure.
- Phosphate solutions form apatite precipitate [$Ca_6(PO_4)_{10}(OH)_2$] for sequestration of Sr-90 by substitution of Sr for Ca.
- Methods of emplacing apatite in vadose zone soil include injection and infiltration of an aqueous solution containing phosphate.
- Jet injection is capable of delivering a specified amount of solid phase pre-farmed apatite into the vadose zone and upper unconfined aquifer.
- Jet injection delivery overcomes heterogeneity of formation that may impede application of apatite by infiltration.
- Use of heat-treated apatite source (e.g., fish bone or calcined cow bone) being investigated to reduce biomass generation in sediments.

Conceptual Schematic



Examples of Relevant Experience

- Field scale apatite jet injection has been demonstrated in the Hanford 100-N Area. Work was conducted under Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit (DOE/RL-2005-96, Addendum 3). Results from collected sediment cores indicate that jet injection is a viable method for emplacement of phosphate and pre-formed apatite in the vadose zone. These cores also show that jet injection is a viable method for installing a PRB in the vadose zone (*Treatability Test Report for Field-Scale Apatite Jet Injection Demonstration for the 100-NR-2 Operable Unit*, SGW-47062, Rev. 0).

Risk Reduction Mechanism

- Apatite forming materials injected in the vadose zone sequesters Sr-90 during initial precipitation
- Over time, zones that received solid-phase apatite mass will also incorporate additional Sr-90 mass into the apatite.
- The potential effects of increased biomass in the sediments that received pre-formed apatite are still under investigation.

Screening Criteria *(dashed line indicates range)*

CHPUBS_100K_0158a

Sources: DOE/RL-2005-96-ADD3, *100-NR-2 Apatite Treatability Test Plan Implementation*.

SGW-47062, *Treatability Test Report for Field-Scale Apatite Jet Injection Demonstration for the 100-NR-2 Operable Unit*.

Figure 8-23. In Situ Stabilization/Sequestration

9 Development and Screening of Alternatives

This chapter discusses the development of remedial action alternatives for 100-D/H. Primary inputs for this process were the physical characteristics of the site (Chapter 3); waste site characterization information, contaminant transport mechanisms, and the CSM (Chapters 4 and 5); the identified risks (Chapters 6 and 7); and the RAOs, target remediation areas, and the remedial technology screening results (Chapter 8).

Highlights

- Remedial action alternatives were developed for 100-D/H that provide a range of technology groupings for integrated waste site and groundwater remediation.
- Alternatives evaluated include the following:
  - Alternative 1: No Action (as required by the NCP)
  - Alternative 2: RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater
  - Alternative 3: RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater
  - Alternative 4: RTD for Waste Sites and Pump-and-Treat for Groundwater
- Each waste site remaining for remedial action is evaluated for the alternatives.

In this chapter, remedial technologies retained from Chapter 8 are combined into remedial alternatives for 100-D/H that provide a range of technology groupings for integrated waste site and groundwater remediation. With the exception of the No Action Alternative, the remedial alternatives were developed to target achievement of the RAOs by considering the CERCLA program goals and expectations identified in the NCP (40 CFR 300). The remedial alternatives presented in this chapter are carried forward for detailed and comparative evaluation in Chapter 10.

9.1 Development of Remedial Alternatives

The NCP (under "Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(a)(1)(iii)]) sets the following expectations for remedial action alternatives development:

- To use treatment to address the principal threats posed by a site, wherever practicable. Principal threats for which treatment is most likely to be 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 human health and the environment. 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 of 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, during implementation of the remedial action, and where necessary, as a component of the completed remedy. The use of ICs will not substitute for active response measures (for example, treatment or containment of source material or restoration of groundwater to beneficial use) as the sole remedy unless such active measures are determined not to be practicable.

- To consider using innovative technology when such technology offers the potential for comparable or superior treatment performance or implementability, fewer adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies.
- To return usable groundwater to its beneficial uses wherever practicable and within a time frame that is reasonable, given the particular circumstances of the site. When restoration of groundwater to beneficial uses is not practicable, EPA expects that further migration of the plume be prevented, exposure to the contaminated groundwater be prevented, and that further risk reduction be evaluated.
- 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 different technologies.
- The No Action Alternative (no further action if some removal or remedial action has already occurred at a site) will also be developed.

The purpose of the remedy selection process is to implement remedies that eliminate, reduce, or control risks to human health and the environment.

The remedial alternatives for 100-D/H have been developed to encompass all waste sites carried forward into the FS and groundwater plumes within 100-D/H. This section briefly summarizes the target remediation areas, so the alternative development can focus on the specific areas and COCs at 100-D/H and integrate the remedial alternatives for waste sites and groundwater.

The evaluated alternatives 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. Therefore, the evaluated alternative is intended to achieve compliance with CERCLA remedial action requirements and satisfy the corrective action requirements of RCRA.

9.1.1 Waste Sites

As presented in Table 8-5 (Chapter 8), 291 waste sites have been included for evaluation in the FS. The COPCs for waste sites are listed in Table 8-1 (Chapter 8). The evaluation of remedial actions relies on the review of available data associated with the waste sites, including field data as available, 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 through 7 of this RI/FS.

Of the 291 waste sites, 146 waste sites are listed in Chapter 8 as having no identified unacceptable risks and are slated for no further action (see Table 8-5 in Chapter 8). Remedial alternatives are not developed for these sites.

The remaining 145 waste sites are considered in the alternatives analysis. The alternatives are developed based on the risks and known or suspected contaminants for each of the waste sites summarized in Table J-1 (Appendix J). 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 remedy will be re-evaluated using the appropriate change process, as presented in *Preparing CERCLA Records of Decision* (DOE/EH-413-9905).

Additional waste site groups considered in the alternatives analysis are described in the following sections.

9.1.1.1 Waste Sites to be Remediated under Interim Action RODs

The 59 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 ROD is issued are shown in Table 8-5 (Chapter 8). The cleanup levels in the ROD will be used to determine when remediation is complete for all waste sites.

9.1.1.2 Waste Sites for Institutional Controls

As discussed in Section 8.2.1.1 (Chapter 8), 32 waste sites have been interim or interim no action closed and had verification data with exceedances of human health protection criteria (residential scenario) for select radionuclide compounds (Chapter 6). Contamination was detected in deep zone verification soil samples collected from depths greater than 4.6 m (15 ft) bgs and, as a result, there is no direct exposure pathway. Deep excavation ICs will be implemented at the waste sites for remedial alternatives to limit exposure (see Section 9.2.2.1). Radionuclide contamination at the waste sites will continue to decay to below human health protection criteria within 2 to 185 years. ICs will be maintained for these sites until unrestricted use is allowable; therefore, no other remedial action alternatives are developed for these sites.

Two other waste sites associated with river effluent pipelines (100-D-60 and 100-H-34) were evaluated for risks, as discussed in Chapters 6 and 7. The risk assessments associated with 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 sites in this FS. While no IC is required, an annual inspection under the RCRA permit (Permit Number WA7 89000 8967) is conducted along the shoreline to identify Hanford debris.

9.1.1.3 Waste Sites Remaining for Remedial Action

The identified risks and known or suspected contaminants identified in Table J-1 (Appendix J) for the 52 waste sites remaining for remedial action are used to develop the remedial alternatives and design data for cost estimating. The identification of the risk drivers is based on sample data, if available; on knowledge of the process that was performed at the sites; and on 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 (less than 4.6 m [15 ft] bgs)
- Ecological risk in shallow soil (less than 4.6 m [15 ft] bgs)
- Groundwater/surface water protection risk

The final COCs for groundwater at 100-D/H include chromium (total), Cr(VI), nitrate, and strontium-90, as identified in Section 8.1.4.5 (Chapter 8).

As part of the development and evaluation of the groundwater alternatives, a groundwater model has been used as an evaluation and design concept tool. Groundwater flow and transport simulations and particle tracking analyses were performed for each design concept to determine the feasibility of each design. The model was also used to perform a limited amount of optimization of well locations and pumping scenarios, including pumping scenarios that achieve groundwater remediation within the period to meet TPA (Ecology et al., 1989a) target milestones for remediation of groundwater. However, the design concepts developed for this FS are not final. They will be updated with additional modeling, including updating the conceptual site model and initial plume configurations, during the remedial design phase, which follows issuance of the ROD.

Groundwater contaminants that do not warrant further evaluation in the FS, but have infrequent detections above an action level will be included in the RD/RAWP for the purpose of continued monitoring at appropriate locations and frequency.

The groundwater flow model is constructed using the USGS modular groundwater flow model MODFLOW. Particle tracking was performed using the USGS program MODPATH. To simulate the contaminant plume migrations, the model MT3DMS was used. Model development and calibration are documented in a comprehensive modeling report contained in Appendix F (*Conceptual Framework and Numerical Implementation of 100 Areas Groundwater Flow and Transport Model* [SGW-46279]). The initial Cr(VI) plume distribution in the 100-HR-3 OU used in the groundwater model simulation is shown on Figure 9-1. Figures 9-2 and 9-3 show the initial distributions for strontium-90 and nitrate, respectively. The initial distribution plumes for each groundwater COC is based on the concentration dataset and plume contours developed for *Hanford Site Groundwater Monitoring Report for 2011* (DOE/RL-2011-118). The results of the groundwater alternative modeling are included in Appendix F (*Modeling of RI/FS Design Alternatives for 100-HR-3* [ECF-100HR3-11-0114]). These supplemental documents also discuss the uncertainty with the model results because of variability in subsurface conditions and other factors.

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 retained (Chapter 8) and include an appropriate range of waste management options to ensure the protection of human health and the environment. In addition, according to EPA guidance, the alternatives address contamination for affected media at the entire 100-D/H Area (for example, waste sites and groundwater combined in each alternative).

Each alternative was developed based on the application of the retained technologies for waste site and groundwater remediation as identified in Sections 8.3.2.1 and 8.3.2.2, respectively. Four alternatives are evaluated:

- **Alternative 1 – (No Action [as required by the NCP]).** This alternative is required by the NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(e)(6)]). Further description for this alternative is provided in Section 9.2.1.

- **Alternative 2 – RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater.** This alternative uses RTD for removal of contamination to cleanup levels for waste sites. Void-fill grouting will be used for the box flume of waste site 100-H-36 where RTD would have large ecological impacts near the river. For groundwater, a pump-and-treat system and biological treatment targeting Cr(VI) will be used.

  Nitrate and strontium-90 contaminated groundwater are within the treatment footprint of the Cr(VI) plume. Based on operational data from the currently operating pump-and-treat facilities and groundwater simulation modeling results, the groundwater treatment system effluent has not and is not expected to exceed MCLs for co-extracted strontium-90 or nitrate, so no treatment is proposed for these groundwater COCs. However, if, through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated for the respective COCs before reinjection or other approved discharge.

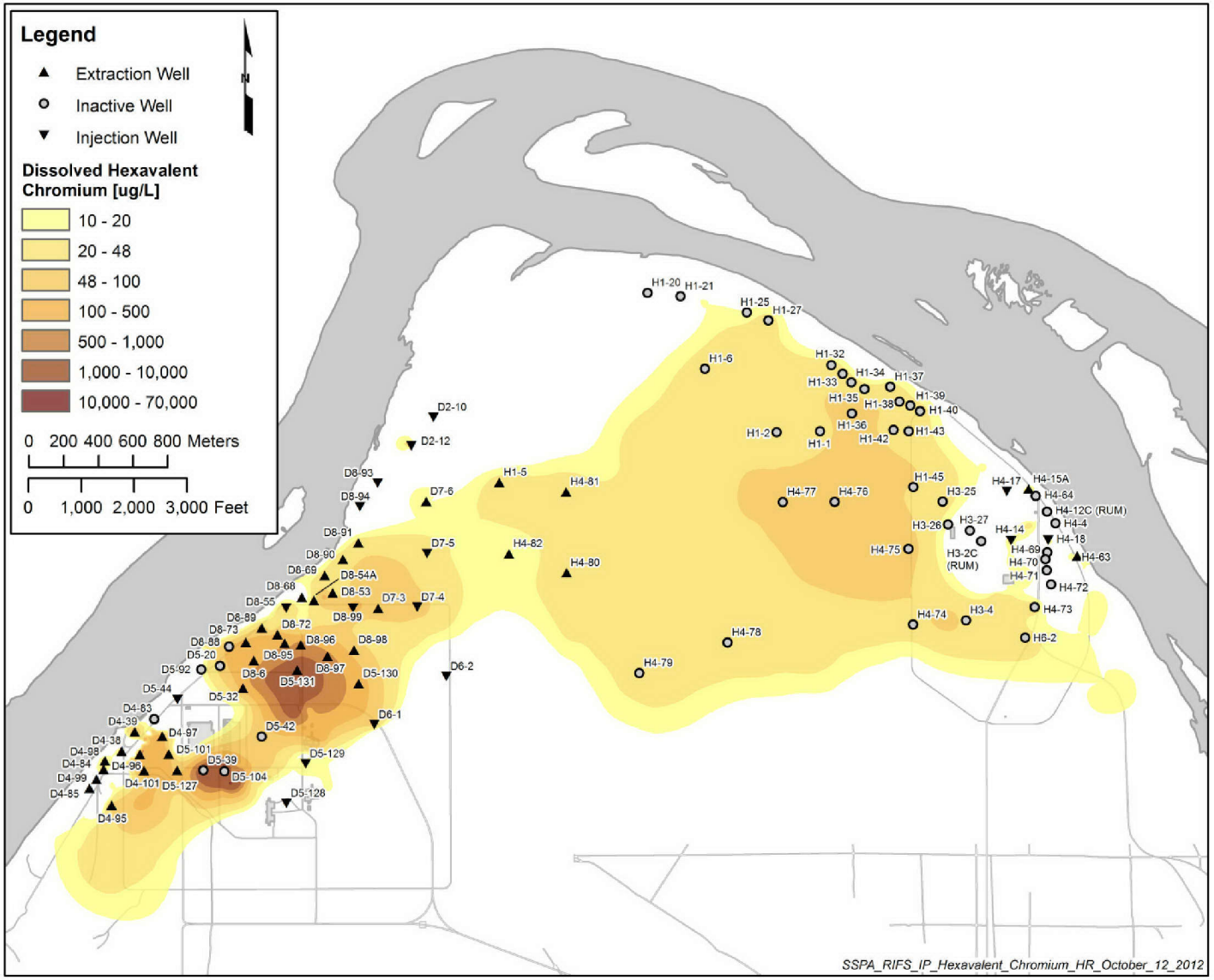


Figure 9-1. Initial Modeled Cr(VI) Plume Based on Hanford Site Groundwater Monitoring Report for 2011 Plume Contours

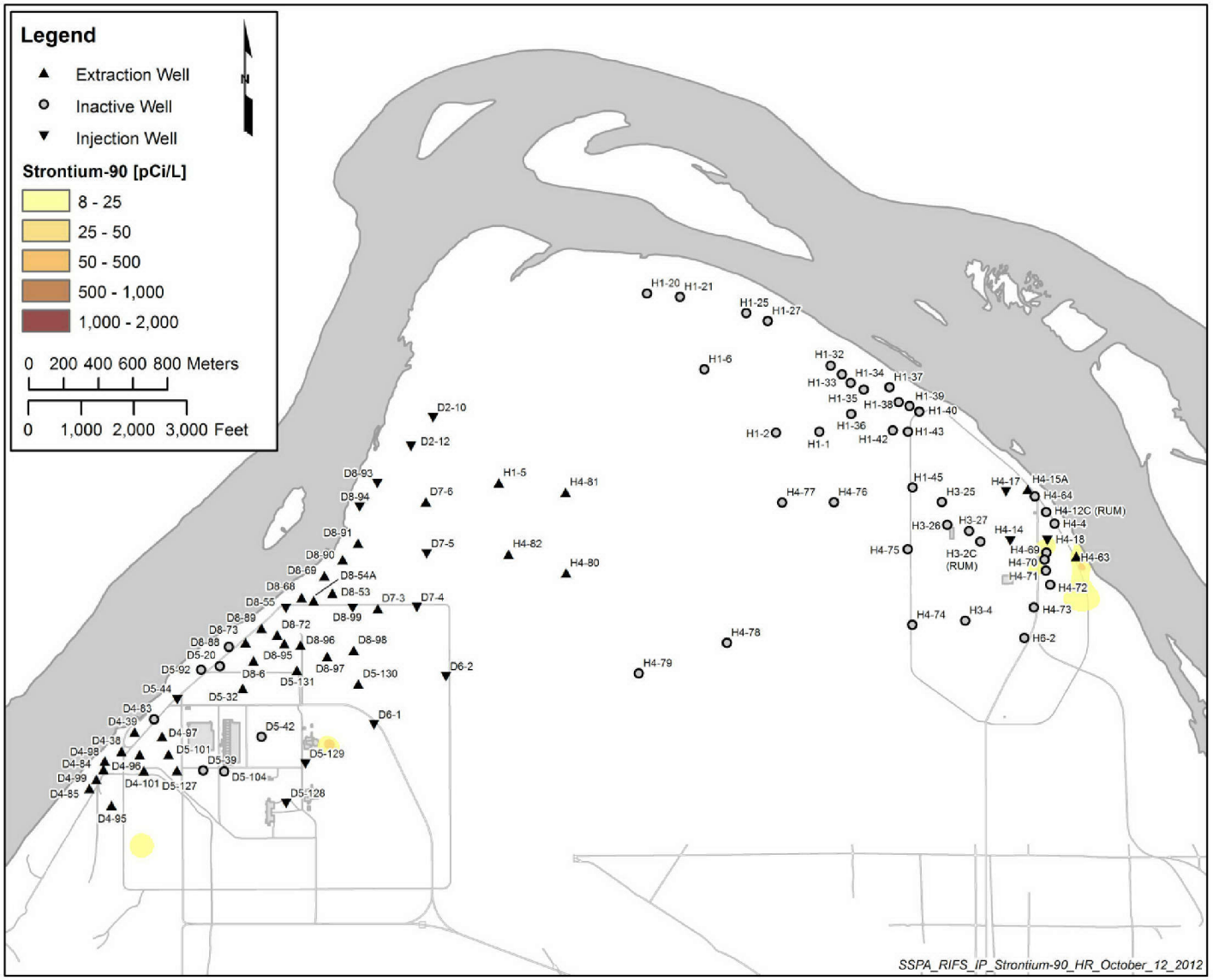
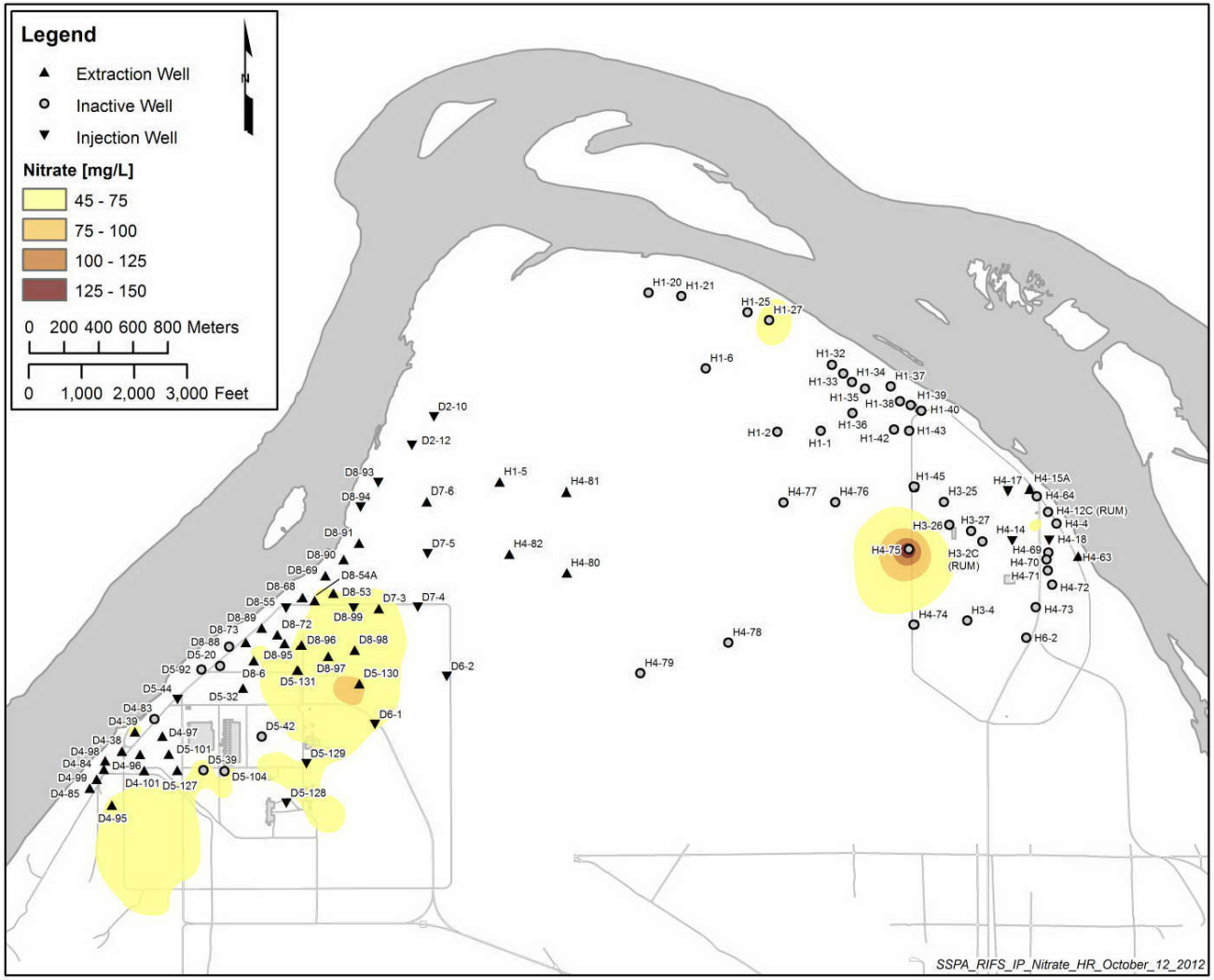


Figure 9-2. Initial Modeled Strontium-90 Plume Based on Hanford Site Groundwater Monitoring Report for 2011 Plume Contours



Note: The elevated nitrate concentration areas evident near wells H4-75 and H1-27 were reported in the source used for development of this initial nitrate condition, but these plume depictions were subsequently investigated and determined to be based on erroneous data; a revised depiction of current nitrate conditions is provided in Figure 4-90. Modeling was not repeated for nitrate to correct for these non-existent nitrate plumes because predictive simulations did not indicate these would lead to a need for action (see Figures 5-28 through 5-31).

Figure 9-3. Initial Modeled Nitrate Plume Based on Hanford Site Groundwater Monitoring Report for 2011 Plume Contours

The application of MNA (such as radioactive decay), the use of dispersion and diffusion, ongoing monitoring, and ICs for each of the groundwater co-extracted contaminants and the vadose zone are discussed under Section 9.2.2 (Common Elements for Alternatives 2, 3, and 4). A detailed description for this alternative is provided in Section 9.2.3.

- **Alternative 3 – RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater.** This alternative uses RTD for removal of contamination to cleanup levels for waste sites. Void-fill grouting will be used for the box flume of waste site 100-H-36 where RTD would have large ecological impacts near the river. For groundwater, an expanded pump-and-treat system for treatment of Cr(VI) will be used. Nitrate and strontium-90 contaminated groundwater plumes are within the treatment footprint for the Cr(VI) plume.

  As identified in Alternative 2, the groundwater treatment system effluent at the 100-D and 100-H pump-and-treat systems has not, and is not, expected to exceed MCLs, so no treatment is proposed for strontium-90 or nitrate. However, if through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated for the respective COCs before reinjection or other approved discharge. The application of MNA (such as radioactive decay), the use of dispersion and diffusion, ongoing monitoring, and ICs for each of the groundwater co-contaminants and the vadose zone are discussed under Section 9.2.2 (Common Elements for Alternatives 2, 3, and 4). A detailed description for this alternative is provided in Section 9.2.4.

- **Alternative 4 – RTD for Waste Sites and Pump-and-Treat for Groundwater.** This alternative uses RTD for removal of contamination to cleanup levels for waste sites. For groundwater, pump-and-treat system for treatment of Cr(VI) will be used. Nitrate and strontium-90 contaminated groundwater plumes are within the treatment footprint for the Cr(VI) plume and will be co-extracted by the extraction well network used for the Cr(VI) plume remediation.

  As identified in Alternative 2, the groundwater treatment system effluent at the 100-D and 100-H pump-and-treat systems has not, and is not, expected to exceed MCLs, so no treatment is proposed for strontium-90 or nitrate. However, if, through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated for the respective COCs before reinjection or other approved discharge. The application of MNA (such as radioactive decay), the use of dispersion and diffusion, ongoing monitoring, and ICs for each of the groundwater co-contaminants and the vadose zone are discussed under Section 9.2.2 (Common Elements for Alternatives 2, 3, and 4). A detailed description for this alternative is provided in Section 9.2.5.

The technology evaluation in Chapter 8 explored options for the treatment of vadose zone and groundwater contamination. A wide range of technologies, such as ISRM for groundwater treatment, have been tested and applied at Hanford with varying success. Waste site remediation using RTD has been the selected alternative for interim actions and has been used successfully over the past 16 years at Hanford. Similarly, treatment of Cr(VI) using pump-and-treat technology has been implemented at 100-D/H to meet cleanup goals.

Table 9-1 summarizes the retained technologies identified in Chapter 8 and shows the application to remedy vadose zone soils, including waste sites, and groundwater for the remedial alternatives (Alternatives 2, 3 and 4). Table 9-2 identifies the technologies applied for each alternative to each of the 291 waste sites that are carried into the FS. ICs applied to the waste sites are discussed separately in Section 9.2.2.1, so IC components are not included in Table 9-2 and identified separately in Table 9-4.

Table 9-1. Retained Technologies Applied to Remedial Action Alternatives

Remedial Technology	Process Option	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Vadose Zone					
No action	No Further Action	X	X	X	X
Excavation	Standard excavation		X	X	X
	Deep excavation		X	X	X
Disposal	Disposal to ERDF or other EPA-approved location		X	X	X
In situ treatment via reagent – delivery method	Void–fill grouting/grouting		X	X	
Groundwater					
No action	No Further Action	X			
Monitored natural attenuation[c]	Monitored natural attenuation		X	X	X
In situ treatment – reagent approach	In situ biological treatment (anaerobic)[a]		X		
	Surface infiltration		X		
	Vertical wells[a]		X		
Containment – Chemical/ Biological	Reactive Chemical Barrier (ISRM)		X	X	X
Pump-and-treat – collection	Groundwater extraction system[b]		X	X	X
Pump-and-treat – ex situ treatment	Ion exchange[b]		X	X	X
Pump-and-treat – discharge	Groundwater injection wells[b]		X	X	X
	Surface infiltration		X	X	X
	Surface water discharge		X	X	X
Containment	Hydraulic containment via extraction and injection		X	X	X

a. In situ biological treatment and vertical wells when used together are called bioinjection.

b. Pump-and-treat includes the combination of groundwater extraction using vertical wells, ex situ ion exchange treatment, and effluent discharge using vertical wells, surface infiltration or surface water discharge.

c. Monitored natural attenuation applies to select contaminants following completion of active remediation, as discussed in Section 9.2.2.

Table 9-2. Components for Remedial Action Alternatives

Vadose Zone Soil Site	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Waste Sites Remaining for Remedial Action				
100-D-10, 100-D-52, 100-D-59, 100-D-63, 100-D-75:1, 100-D-96, 100-D-98:1, 100-D-101, 100-D-102, 100-D-103, 118-DR-2:2, 100-H-5, 100-H-28:7, 100-H-38, 100-H-57, 100-H-58, 100-D-98:2, 100-D-105, 100-D-106, 100-H-56, 100-H-59, 100-H-51:6, 600-380, 600-381, 600-382:1, 600-382:2, 600-382:3, 600-382:4, 600-382:5, 600-383:1, 600-383:2, 600-383:3, 600-383:4, 600-383:5, 600-383:6, 600-383:7, 600-383:8, 600-383:9, 600-383:10, 600-384:1, 600-384:2, 600-384:3, 600-384:4, 600-384:5, 600-385, 100-D-107, 100-H-54	No Further Action	Removal, treatment, and disposal (RTD) to remove contamination using standard and/or deep excavation with disposal at Environmental Restoration Disposal Facility (ERDF)		
100-D-50:2	No Further Action	Cap ends of pipe to contain contamination and maintain institutional control		RTD to remove contamination using standard and/or deep excavation with disposal at ERDF
100-H-36	No Further Action	Void-fill grouting of box flume RTD of spillway to ordinary high water mark		RTD to remove contamination using standard and/or deep excavation with disposal at ERDF
116-DR-9, 100-D-25, 116-D-8	No Further Action	Monitored Natural Attenuation/institutional control		RTD to remove contamination using standard and/or deep excavation with disposal at ERDF
Waste Sites to be Remediated under Interim Action RODs				
100-D-8, 100-D-14, 100-D-31:11, 100-D-31:12, 100-D-50:1, 100-D-50:4, 100-D-50:6, 100-D-50:7, 100-D-50:8, 100-D-50:9, 100-D-62, 100-D-65, 100-D-66, 100-D-69, 100-D-71, 100-D-72, 100-D-73, 100-D-75:2, 100-D-76, 100-D-77, 100-D-78, 100-D-80:2, 100-D-81, 100-D-83:1, 100-D-83:2, 100-D-83:3, 100-D-83:5, 100-D-84:2, 100-D-85:2, 100-D-86:1, 100-D-86:3, 100-D-97, 100-D-99, 100-D-100, 100-D-104, 100-H-28:2, 100-H-28:3, 100-H-28:4, 100-H-28:5, 100-H-42, 100-H-43, 100-H-44, 100-H-46, 100-H-48, 100-H-49:1, 100-H-51:1, 100-H-51:2, 100-H-51:3, 100-H-52, 116-DR-3, 118-D-2:1, 118-D-2:2, 118-D-3:1, 118-D-3:2, 126-DR-1, 126-H-2, 132-H-3, 1607-D2:5, 100-D-30	No Further Action	RTD to remove contamination using standard and/or deep excavation with disposal at ERDF		

Table 9-2. Components for Remedial Action Alternatives

Vadose Zone Soil Site	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Waste Sites Considered for No Further Action				
100-D-1, 100-D-2, 100-D-3, 100-D-4, 100-D-7, 100-D-9, 100-D-12, 100-D-13, 100-D-15, 100-D-20, 100-D-21, 100-D-22, 100-D-23, 100-D-24, 100-D-28:1, 100-D-29, 100-D-31:1, 100-D-31:2, 100-D-31:3, 100-D-31:4, 100-D-31:5, 100-D-31:6, 100-D-31:7, 100-D-31:8, 100-D-31:9, 100-D-31:10, 100-D-32, 100-D-42, 100-D-43, 100-D-45, 100-D-47, 100-D-48:4, 100-D-49:3, 100-D-50:5, 100-D-53, 100-D-54, 100-D-56:1, 100-D-56:2, 100-D-61, 100-D-64, 100-D-70, 100-D-74, 100-D-75:3, 100-D-80:1, 100-D-82, 100-D-83:4, 100-D-84:1, 100-D-85:1, 100-D-87, 100-D-88, 100-D-90, 100-D-94, 100-H-17, 100-H-2, 100-H-24, 100-H-28:1, 100-H-28:6, 100-H-3, 100-H-30, 100-H-35, 100-H-37, 100-H-4, 100-H-40, 100-H-41, 100-H-45, 100-H-49:2, 100-H-50, 100-H-51:4, 100-H-51:5, 100-H-53, 100-H-7, 100-H-8, 116-D-10, 116-D-2, 116-D-4, 116-D-5, 116-D-6, 116-D-9, 116-DR-10, 116-DR-4, 116-DR-5, 116-DR-7, 116-DR-8, 116-H-2, 116-H-5, 116-H-9, 118-D-1, 118-D-4, 118-D-5, 118-DR-1, 118-H-1:1, 118-H-1:2, 118-H-2, 118-H-3, 118-H-4, 118-H-5, 118-H-6:4, 118-H-6:5, 120-D-2, 126-D-2, 128-D-2, 128-H-1, 128-H-2, 128-H-3, 130-D-1, 132-D-1, 132-D-2, 132-D-3, 132-DR-1, 1607-D1, 1607-D2:1, 1607-D2:2, 1607-D2:3, 1607-D2:4, 1607-D4, 1607-D5, 1607-H1, 1607-H2, 1607-H3, 1607-H4, 600-30, 600-151, 600-152, 628-3, UPR-100-D-5, 100-D-50:3, 100-D-50:10, 100-D-67, 100-D-68, 100-D-86:2, UPR-100-D-1, 118-D-6:2, 132-D-4, 132-DR-2, 100-H-9, 100-H-10, 100-H-13, 100-H-31, 100-H-28:8, 100-H-33, 116-D-3, 116-H-4, 118-H-6:2, 128-D-1, 132-H-1, 132-H-2	No Further Action	No further action as discussed in Section 8.2.1.1 (Chapter 8)		

The *National Historic Preservation Act of 1966* is an ARAR for remedial actions where cultural resources are present. Remediation that has the potential to affect cultural resources will require an analysis of cultural resource impacts before any remedial action. 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, EPA, and Ecology will work with the Tribes to identify an alternative remediation strategy. This alternative remediation strategy would be implemented through a ROD change.

Table J-3 (Appendix J) provides additional information for each waste site evaluated in the development of alternatives. Details regarding the development of cost estimates are presented in *100-DH Cost*

Estimate Scoping Forms for Feasibility Study Alternative Costing (ECF-100DR1-12-0022) in Appendix J.

Table 9-3 shows the remedial system components that are used for the cost estimates for the groundwater remediation alternatives. The cleanup period projections included in Table 9-3 are based on the fate and transport models. Estimated quantities for key groundwater remedial components of the selected approach will be refined during remedial design. The fate and transport model's details, assumptions, and implementation are included in Appendix F (*Modeling of RI/FS Design Alternatives for 100-HR-3* [ECF-100HR3-11-0114]), and the target milestones for groundwater remediation are as follows:

- M-016-110-T01, target date of December 31, 2012; take actions to contain or remediate Cr(VI) 100 Area groundwater plumes
- M-016-110-T04, target date of December 31, 2016; implement/start remedial actions in all 100 Area OU RODs for groundwater
- M-016-110-T02, target date of December 31, 2020; take actions such that Cr(VI) meets the 2007 MTCA (WAC 173-340) Method B cleanup level of 48 µg/L

Table 9-3. Groundwater Alternative Remedial Components

Groundwater Alternative Components	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Pump-and-Treat				
Number of extraction wells operating during time frame	NA	70	126	97
Number of injection wells operating during time frame	NA	30	49	35
Number of new/converted extraction wells installed	NA	18	65	32
Number of new injection wells installed	NA	8	25	12
Operation time frame	NA	25 years	12 years	39 years
Extraction rate (L/min [gal/min])	NA	4,500 (1,200)	9,000 (2,400)	4,500 (1,200)
Ion exchange treatment (L/min [gal/min])	NA	4,500 (1,200)	9,000 (2,400)	4,500 (1,200)
Above ground piping (m [ft])	NA	47,000 (154,200)	458,700 (139,900)	211,200 (64,400)
Monitoring				
Number of new monitoring wells installed	NA	12	12	12
Number of groundwater samples collected	NA	720/annually	864/annually	728/annually

Table 9-3. Groundwater Alternative Remedial Components

Groundwater Alternative Components	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Bioinjection for Hexavalent Chromium				
Number of bioinjection extraction wells	NA	13	NA	NA
Number of bioinjection injection wells	NA	5	NA	NA
Injection rate (L/min [gal/min])	NA	1,000 (270)	NA	NA
Biological injection volume (million L [million gal])*	NA	450 (120)	NA	NA
Number of bio node mixing facilities	NA	1	NA	NA
Number of biosubstrate mixing plants	NA	1	NA	NA
Above ground piping (m [ft])	NA	609 (2,000)	NA	NA

Note: The estimated quantities for key groundwater remedial components are projected and were developed for cost estimating purposes for this FS. Estimated quantities of the selected approach would be determined during the RD/RAWP. Extraction and injection rates include new and existing wells, or other approved discharge.

FS = feasibility study

NA = not an applicable component of the alternative

RD/RAWP = remedial design/remedial action work plan

* Total volume of solution at 100 mg/L to 1,000 mg/L as carbon substrate.

Table 9-4. Institutional Controls Implemented at Waste Sites Post Remediation*

Waste Site Risk Driver	Institutional Controls	Alternative 2 Waste Sites	Alternative 3 Waste Sites	Alternative 4 Waste Sites
Waste sites with groundwater/surface water protection risk if irrigation were applied (vadose soil contaminant concentrations exceed SSL but are less than PRG)	Prohibit irrigation	None Identified	None Identified	None Identified

Table 9-4. Institutional Controls Implemented at Waste Sites Post Remediation*

Waste Site Risk Driver	Institutional Controls	Alternative 2 Waste Sites	Alternative 3 Waste Sites	Alternative 4 Waste Sites
Waste sites with deep (greater than 4.6 m [15 ft] bgs) radiological contamination	Excavation restrictions (up to 185 years)	100-D-18, 100-D-19, 100-D-46, 100-D-48:1, 100-D-48:2, 100-D-48:3, 100-D-49:1, 100-D-49:2, 100-D-49:4, 100-D-5, 100-D-6, 100-H-1, 100-H-11, 100-H-12, 100-H-14, 100-H-21, 100-H-22, 100-H-36, 116-D-1A, 116-D-1B, 116-D-7, 116-DR-1 & 2, 116-DR-6, 116-DR-9, (100-D-25), 116-H-1, 116-H-3, 116-H-7, 118-D-6:3, 118-D-6:4, 118-H-6:3, 118-H-6:6, UPR-100-D-2, UPR-100-D-3, UPR-100-D-4, 100-D-60, 100-H-34	100-D-18, 100-D-19, 100-D-46, 100-D-48:1, 100-D-48:2, 100-D-48:3, 100-D-49:1, 100-D-49:2, 100-D-49:4, 100-D-5, 100-D-6, 100-H-1, 100-H-11, 100-H-12, 100-H-14, 100-H-21, 100-H-22, 100-H-36, 116-D-1A, 116-D-1B, 116-D-7, 116-DR-1 & 2, 116-DR-6, 116-H-1, 116-H-3, 116-H-7, 118-D-6:3, 118-D-6:4, 118-H-6:3, 118-H-6:6, UPR-100-D-2, UPR-100-D-3, UPR-100-D-4, 100-D-60, 100-H-34	100-D-18, 100-D-19, 100-D-46, 100-D-48:1, 100-D-48:2, 100-D-48:3, 100-D-49:1, 100-D-49:2, 100-D-49:4, 100-D-5, 100-D-6, 100-H-1, 100-H-11, 100-H-12, 100-H-14, 100-H-21, 100-H-22, 116-D-1A, 116-D-1B, 116-D-7, 116-DR-1 & 2, 116-DR-6, 116-DR-9, (100-D-25), 116-H-1, 116-H-3, 116-H-7, 118-D-6:3, 118-D-6:4, 118-H-6:3, 118-H-6:6, UPR-100-D-2, UPR-100-D-3, UPR-100-D-4, 100-D-60, 100-H-34
Waste site with contamination contained and left in place	Entry restrictions and Excavation restrictions	100-D-50:2	100-D-50:2	NA

NA = not an applicable component of the alternative

PRG = preliminary remediation goal

SSL = soil screening levels

* Additional waste sites may be added through closure reclassifications.

The operating periods (Table 9-3) for Alternatives 2, 3, and 4 reflect the maximum time needed to achieve the groundwater cleanup levels for Cr(VI) throughout the aquifer as indicated by the predicted EPC, prior to conducting rebound testing or compliance monitoring. The EPC is estimated conservatively in the groundwater model as the maximum concentration predicted by the fate and transport simulation, but this will likely be overly conservative and does not take into account design considerations and actual

operations of the pump and treat system. The total flow rate through the existing DX and HX pump-and-treat systems evaluated in ECF-100HR3-11-0114 was 85 percent of the total system capacity, or 4,500 L/min (1,200 gpm), based on history. It is anticipated that future operations will target 95 percent efficiency.

For future monitoring of the selected remedy performance, the EPC can be based on the 95th UCL on the mean groundwater concentration values from a specified group of wells and for a specified time window (e.g., annual or 2 years). These future EPCs can be used to demonstrate groundwater remediation to 48 µg/L (RAO 1) within the four different remediation areas specific to the Cr(VI) plumes, and 10 µg/L where groundwater has the potential to discharge to surface water (RAO 2). Compliance guidance from the state (2007 MTCA, "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]) will be used for these purposes. These activities will require a statistical evaluation of the monitoring well network data, which will be defined in the remedial design phase for this area.

Cr(VI) is the primary groundwater COC and has the largest contaminant plume area at 100-D/H. The other groundwater COCs lie largely within the footprint of the Cr(VI) plumes. The extraction well network installed for remediation of the Cr(VI) plumes is expected to capture the other groundwater COCs. Based on operational data from the currently operating pump-and-treat facilities and groundwater simulation modeling results, the groundwater treatment system effluent has not and is not expected to exceed MCLs for co-extracted nitrate or strontium-90, so no treatment is proposed for these groundwater COCs. In addition, groundwater modeling results for future conditions, presented in Appendix F, show that the nitrate and strontium-90 concentrations in the combined pump-and-treat influent are less than their respective MCLs and will remain below the MCLs upon injection of the pump-and-treat effluent to the aquifer, or other approved discharge. However, if, through normal operation of the groundwater treatment system, concentrations of co-extracted contaminants exceed MCLs in the effluent, specific treatment would be evaluated before reinjection, or other approved discharge.

The application of MNA (such as radioactive decay), the use of dispersion and diffusion, ongoing monitoring, and ICs for each of the groundwater co-contaminants and the vadose zone are discussed under Section 9.2.2.

Alternative development includes the following approaches to treat the COCs in groundwater:

- **Cr(VI):** Interim remedial actions using pump-and-treat systems with ion exchange treatment technology to remediate Cr(VI)-contaminated groundwater have been very effective in removing Cr(VI) mass from the aquifer. The remedial alternatives include expansion of the interim action pump-and-treat systems using ion exchange treatment technology. Alternative 2 also augments the treatment process with in situ biological treatment.

- **Nitrate:** Nitrate-contaminated groundwater will be co-extracted by the extraction well network used for the Cr(VI) plume remediation. Nitrate concentration in the combined pump-and-treat influent will be less than the MCL of 45,000 µg/L and will remain below the MCL upon injection of the pump-and-treat effluent to the aquifer, or other approved discharge. Specific treatment would be evaluated if the combined extracted groundwater in the pump-and-treat effluent stream exceeds the MCL before reinjection, or other approved discharge.

- **Total chromium:** Under the current geochemical conditions at the site, the majority of total chromium in groundwater exists as Cr(VI). Therefore, total chromium will not be specifically addressed in the alternatives but will be treated in conjunction with the selected Cr(VI) remediation alternative. Chromium(III) is the only other form of chromium likely to be at the site. The ISRM

barrier and biostimulation treatability test area at 100-D formed treatment areas with reducing-type environment in the aquifer to reduce Cr(VI) to Cr(III) where the less toxic, immobile Cr(III) precipitates from solution. Cr(III) has very low solubility (K_d = 200 mL/g) and is not likely to be present in the groundwater at high concentrations. Samples from monitoring wells around the ISRM and biostimulation treatment areas with total chromium concentrations exceeding water quality criteria had comparable Cr(VI) concentrations that also exceeded water quality criteria, indicating the total chromium in groundwater is predominantly Cr(VI). Treatment of the chromium groundwater plumes to the Cr(VI) cleanup levels will also result in achievement of the total chromium standard because concentration limits for Cr(VI) are lower (total chromium PRG is 65 µg/L).

- **Strontium-90:** Strontium-90 found at concentrations above the MCL (8 pCi/L) in small, localized areas at 100-D and 100-H will be managed through MNA and ICs. Natural attenuation by radiological decay is an important component for managing the strontium-90 groundwater plume. Strontium-90 has low solubility and mobility, and has a half-life of 29.1 years. Appendix F presents groundwater modeling runs that were performed to evaluate the potential risk from strontium-90. Based on the groundwater modeling results presented in Appendix F, the strontium-90 contamination is likely to remain in small areas that can be monitored. Modeling predicts that the strontium-90 concentration will decrease by radiological decay to below the MCL within 25 years, based on the 90th percentile concentration of 14 pCi/L calculated in Section 6.3.2, and within 61 years based on the maximum nonsuspect concentration of 34 pCi/L. Strontium-90 contaminated groundwater co-extracted with Cr(VI) extraction wells will have concentration in the combined pump-and-treat influent less than the MCL of 8 pCi/L and will remain below the MCL upon injection of the pump-and-treat effluent to the aquifer, or other approved discharge. Specific treatment would be evaluated if the combined extracted groundwater in the pump-and-treat effluent stream exceeds the MCL before reinjection, or other approved discharge.

- **Uranium:** Uranium contamination in the 100-HR-3 Groundwater OU is localized around the 183-H Solar Evaporation Basin. Since 2006 only one well, 199-H4-3, has detected uranium above the 30 µg/L DWS, and in only one sample collected between June 2006 and December 2012. Uranium concentrations in wells downgradient of the 183-H Solar Evaporation Basin have been decreasing overall. The Cr(VI) pump-and-treat system includes extraction wells in the area where uranium has been historically detected. Groundwater and operational data indicate the uranium concentrations in the HX pump-and-treat influent and effluent are less than the DWS. The localized uranium contamination, as detected, will be further reduced by dispersion and diffusion created through co-extraction and injection, or other approved discharge. Any residual uranium contamination in the groundwater following cessation of the pump-and-treat system will continue to be addressed through dispersion and diffusion by normal groundwater flow as discussed in Section 9.2.2.3 (Monitored Natural Attenuation).

Remedy performance monitoring is conducted to evaluate effectiveness of the alternative to attain the cleanup levels as described in Section 9.2.2.7.

The design concepts presented for each alternative were developed to the level required to prepare a cost estimate that will allow comparison of the alternatives. The cost estimate accuracy recommended in CERCLA RI/FS Guidance (EPA/540/G-89/004) is a range of -30 to +50 percent. Significantly, more detail on the selected remedy for 100-D/H will be developed during the design phase, after the ROD is finalized. An RD/RAWP will be developed to discuss in detail the design of the specific components for each waste site and groundwater plume, including the appropriate location and frequency for monitoring contaminants retained for monitoring as identified in Tables 4-6, 4-8, and 4-10.

For each of the remedial action alternatives, the steps for establishing remedial action completion are as follows:

1. **Obtain waste site closure:** 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 RD/RAWP.
2. **Evaluate for groundwater remedial action completion:** Once groundwater cleanup levels are achieved, ongoing performance monitoring will be used to demonstrate that cleanup requirements have been achieved and maintained.

9.2.1 Alternative 1—No Action Alternative

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 serves as a baseline for evaluating against the action alternatives, and 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 in December 2012. Operation of the existing DX and HX pump-and-treat systems and any other monitoring would cease. No designs or cost estimates are prepared for Alternative 1 because no actions are proposed. Figure 9-4 (a-d) presents the groundwater model prediction of Cr(VI) levels for this alternative 3, 18, 38, and 75 years after remedial actions are discontinued in 2012. The groundwater model simulations (*Modeling of RI/FS Design Alternatives for 100-HR-3* [ECF-100HR3-11-0114]) assume no continuing sources for groundwater contamination. Because the pump-and-treat systems are shut down after 2012, extraction wells along the river are turned off and no longer provide containment of inland contamination from migrating and reaching the river, as can be seen in the model prediction after 3 years of terminating interim actions. Some mass removal is predicted to occur through natural flushing, as can be seen in the changes in concentrations out through 75 years. However, relatively large areas with greater than 10 µg/L Cr(VI) are predicted to remain after 75 years. If waste site remediation is not complete, as assumed, then the area with greater than 10 µg/L Cr(VI) would be larger.

The concentration plume depictions shown on Figure 9-4 (a-d) reflect the maximum Cr(VI) concentrations calculated from the model simulation. The groundwater model simulation also provides predicted maximum, 95 UCL, 90th percentile, mean, and median concentrations and trends for the groundwater COCs. Results of the groundwater model simulation for the COCs are provided in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114), with prediction of COC plumes and trends. The 95 UCL and 90th percentile concentration trends indicate that cleanup levels would not be achieved at all areas within the simulation period (75 years) and concentrations along the shoreline, entering the river, would exceed cleanup levels.

The shoreline concentration trends *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114) reflect transient state (that is, time varying) conditions in the aquifer from water level changes resulting from river stage variation. The simulations are discretized into 12 monthly stress periods over the first 25 years to reflect the seasonal variances in river stage. For the remaining simulation period, a single transient stress period is used with the river stage elevation remaining constant to reflect annual average conditions.

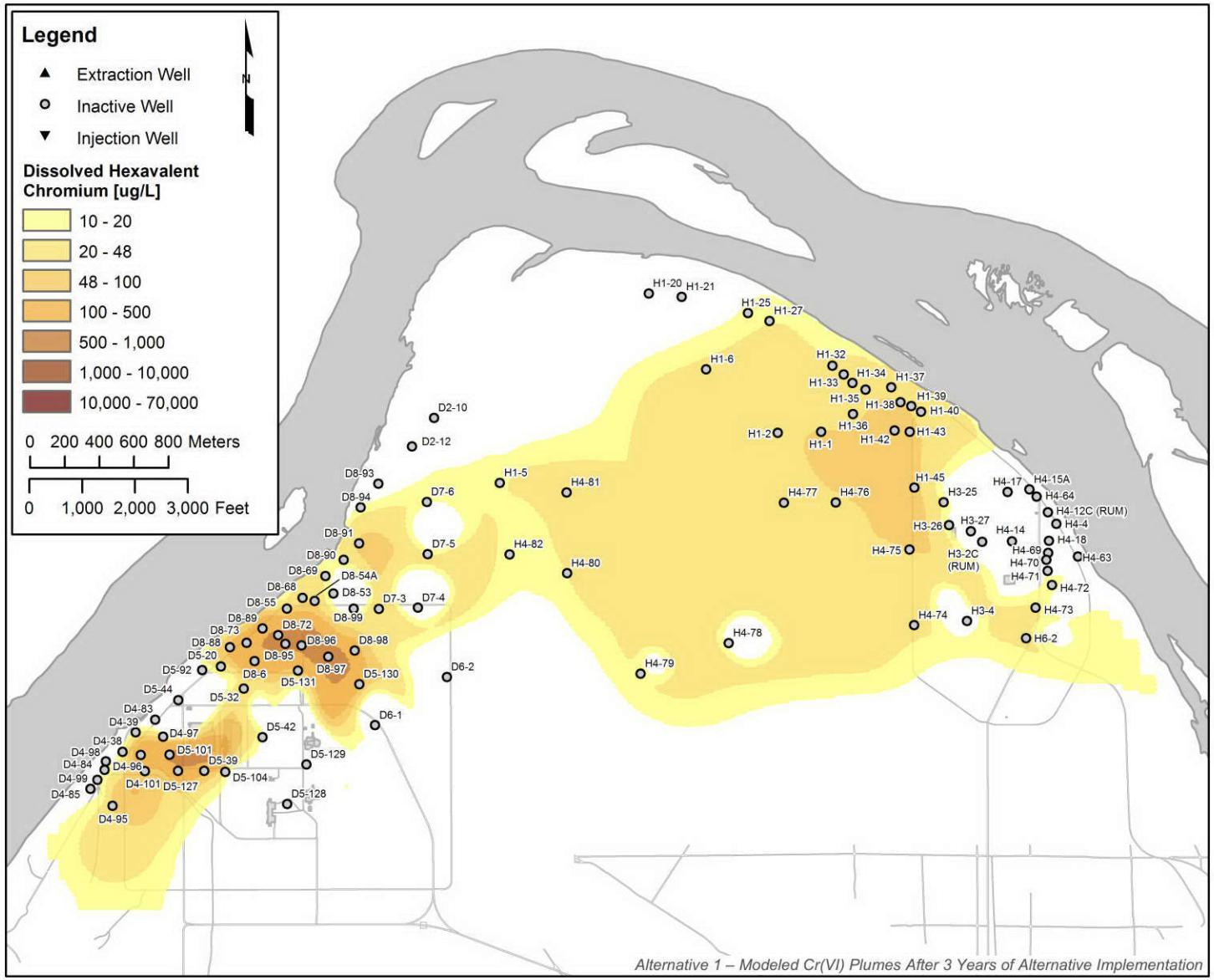


Figure 9-4a. Alternative 1—Modeled Cr(VI) Plumes after 3 Years

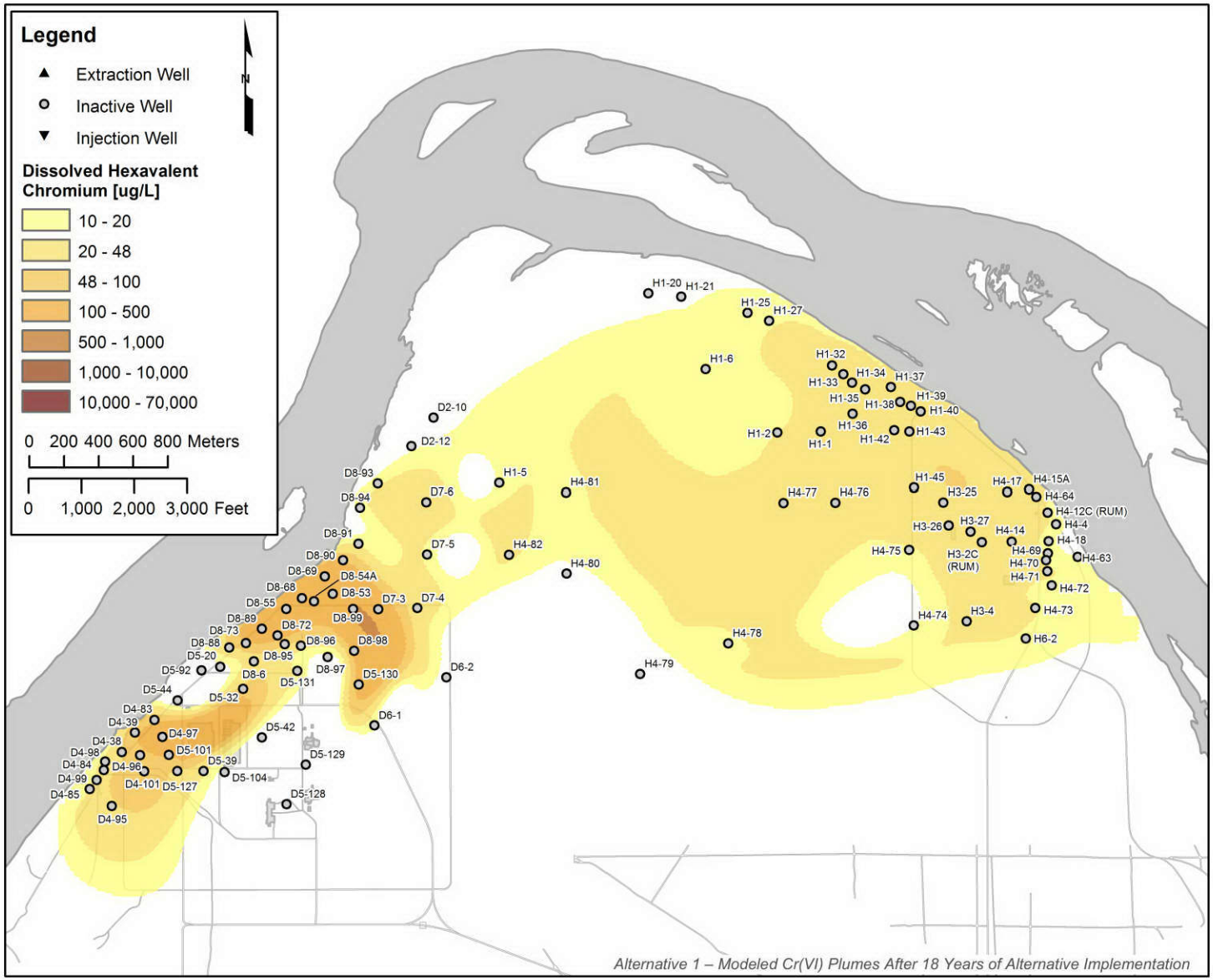


Figure 9-4b. Alternative 1—Modeled Cr(VI) Plumes after 18 Years

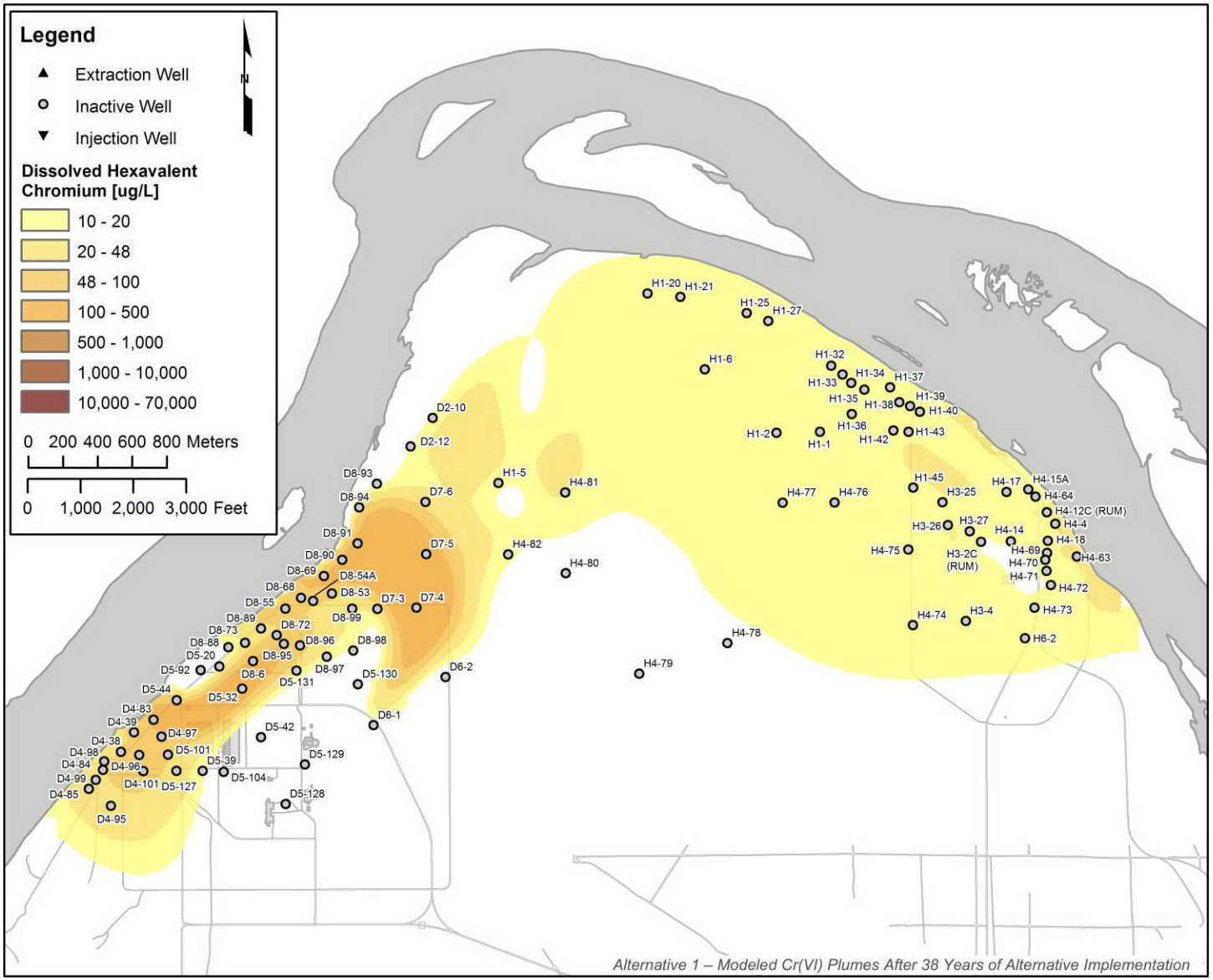


Figure 9-4c. Alternative 1—Modeled Cr(VI) Plumes after 38 Years

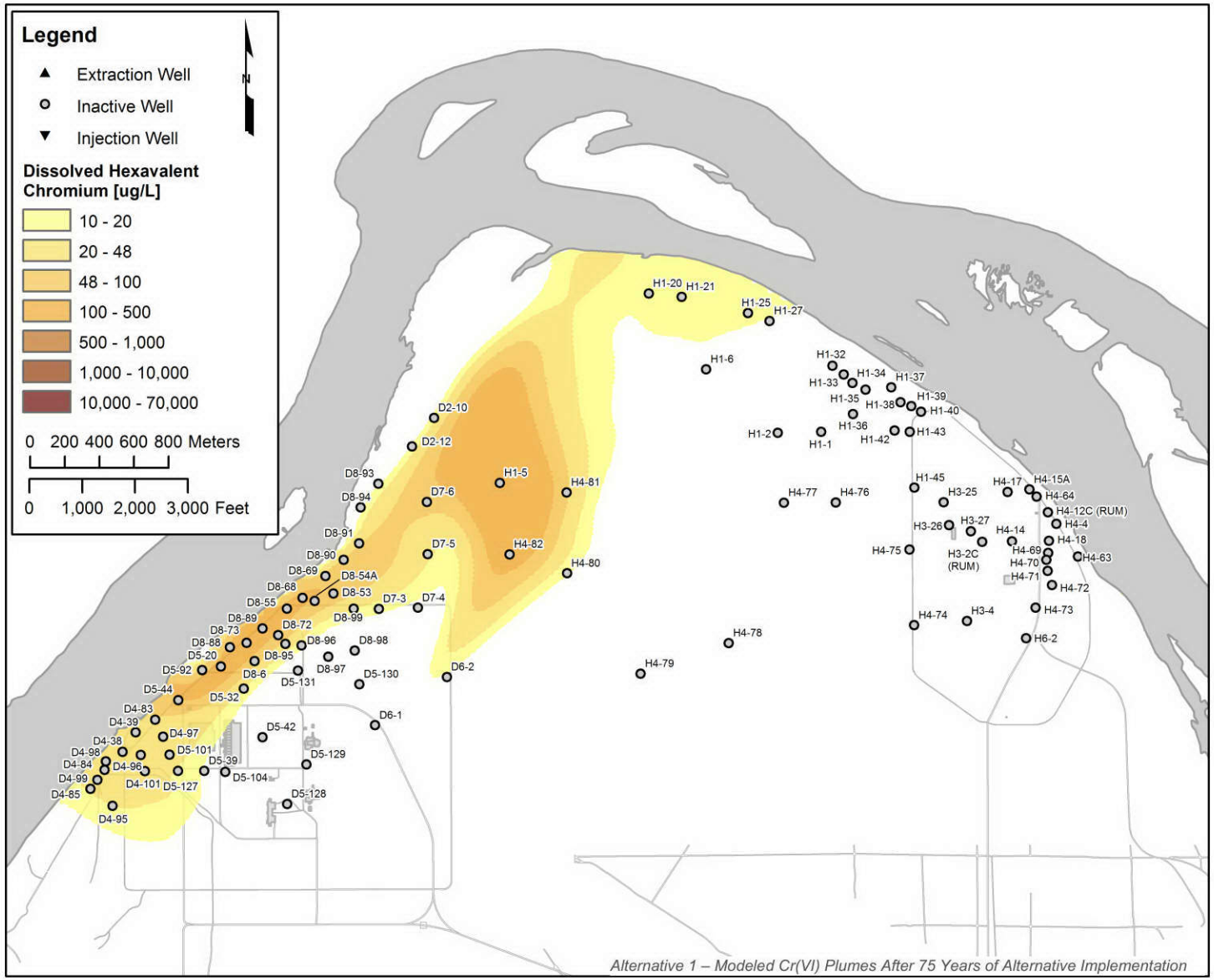


Figure 9-4d. Alternative 1—Modeled Cr(VI) Plumes after 75 Years

Predicted plume depictions for nitrate and strontium-90 COCs are provided on Figures 9-5 (a-d) and 9-6 (a-d).

9.2.2 Common Elements for Alternatives 2, 3, and 4

The remedial action alternatives developed for 100-D/H waste sites and groundwater contain elements that are common to multiple alternatives. To limit redundancy in the discussion, these common elements are described in this section.

9.2.2.1 Institutional Controls

While remediation is underway, ICs will be put in place to control access and to prevent exposure to contamination. ICs for 100-D/H are expected to be implemented independently for each waste site or groundwater plume. ICs are defined and discussed in more detail in Section 8.3.1.1 and Table 8-8 (Chapter 8). ICs are currently in place to protect workers and control site access, and they will be continued 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.

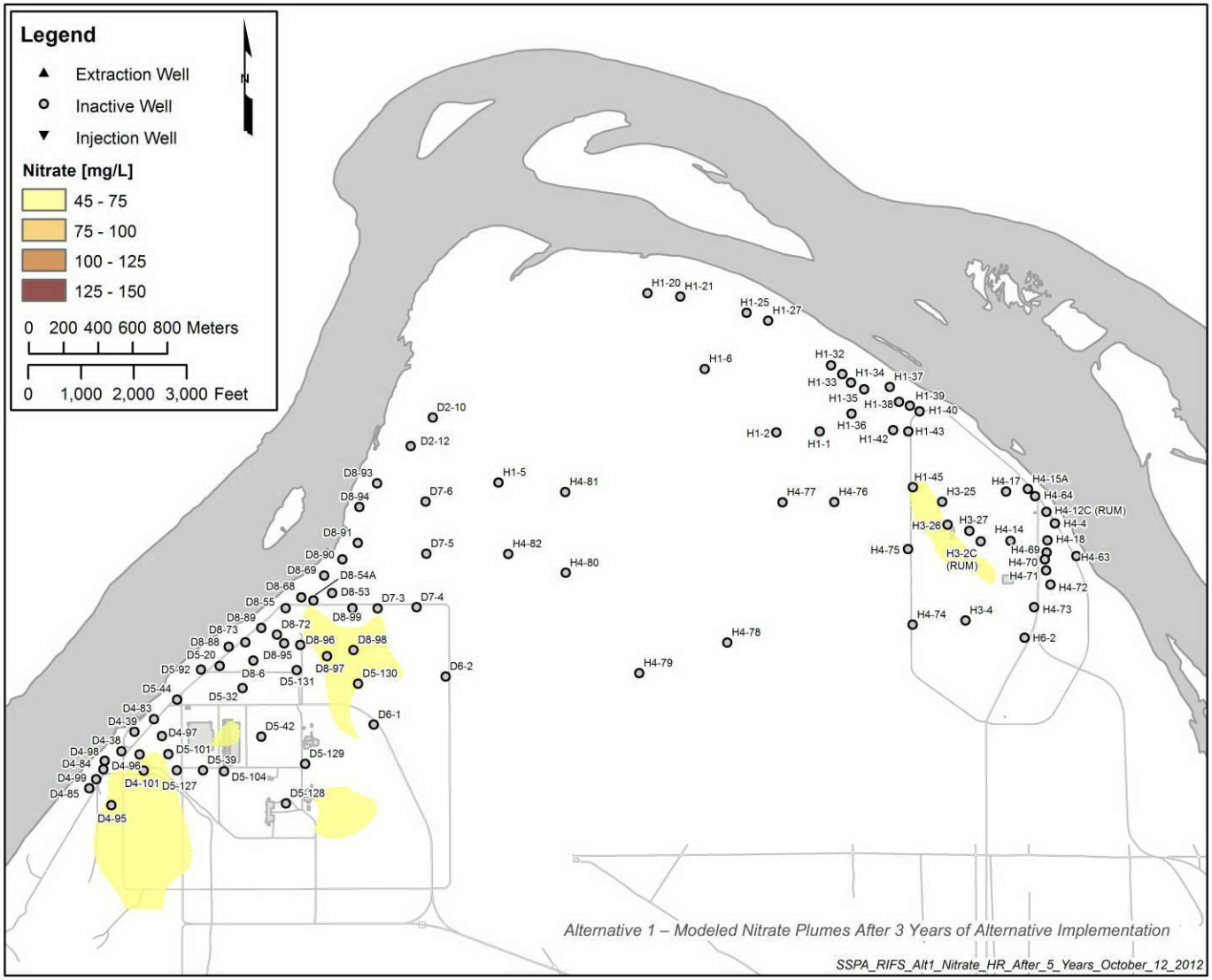
Post-remediation ICs will be put in place to address waste site contamination using excavation and irrigation restrictions, as identified in Table 9-4. Additional waste sites may be added through closure reclassifications.

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 serve to protect human health and the environment by limiting potential exposure to hazardous substances. Many of these multi-purpose or programmatic controls are therefore ICs as required by each CERCLA ROD on the Hanford Site. The programmatic controls include site access; personnel badging; real estate and deeds; warning signs along the Columbia River bank and other access points; maintaining a current Sitewide ICs plan; and controls for excavating soil, accessing and using groundwater, and restricting irrigation. 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 is allowable.

9.2.2.2 Removal, Treatment, and Disposal

RTD, which can be used to eliminate the presence of contamination in soil, consists of the following actions:

- Collection of confirmatory samples based on the expected and actual risk drivers (media and COPCs). Confirmatory evaluation will determine the need for remediation and confirmation of COCs.
- Demolition of any surface structures, as required.
- Excavation of waste site structures and vadose zone soil where contaminant concentrations are above cleanup levels.
- 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.
- 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.



Note: The elevated nitrate concentration areas evident near wells H4-75 and H1-27 were reported in the source used for development of this initial nitrate condition, but these plume depictions were subsequently investigated and determined to be based on erroneous data; a revised depiction of current nitrate conditions is provided in Figure 4-90. Modeling was not repeated for nitrate to correct for these non-existent nitrate plumes because predictive simulations did not indicate these would lead to a need for action (see Figures 5-28 through 5-31).

Figure 9-5a. Alternative 1—Modeled Nitrate Plumes after 3 Years

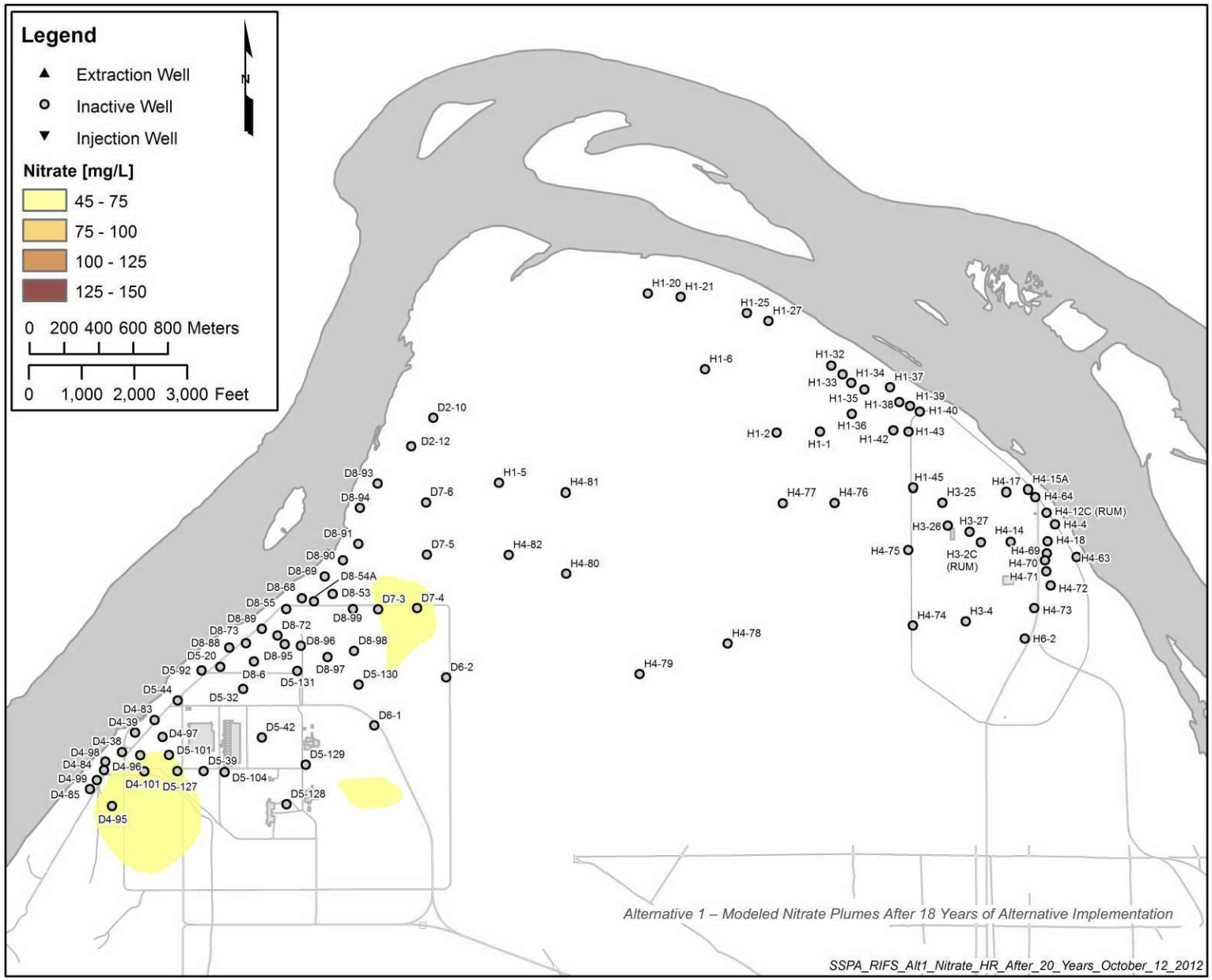


Figure 9-5b. Alternative 1—Modeled Nitrate Plumes after 18 Years

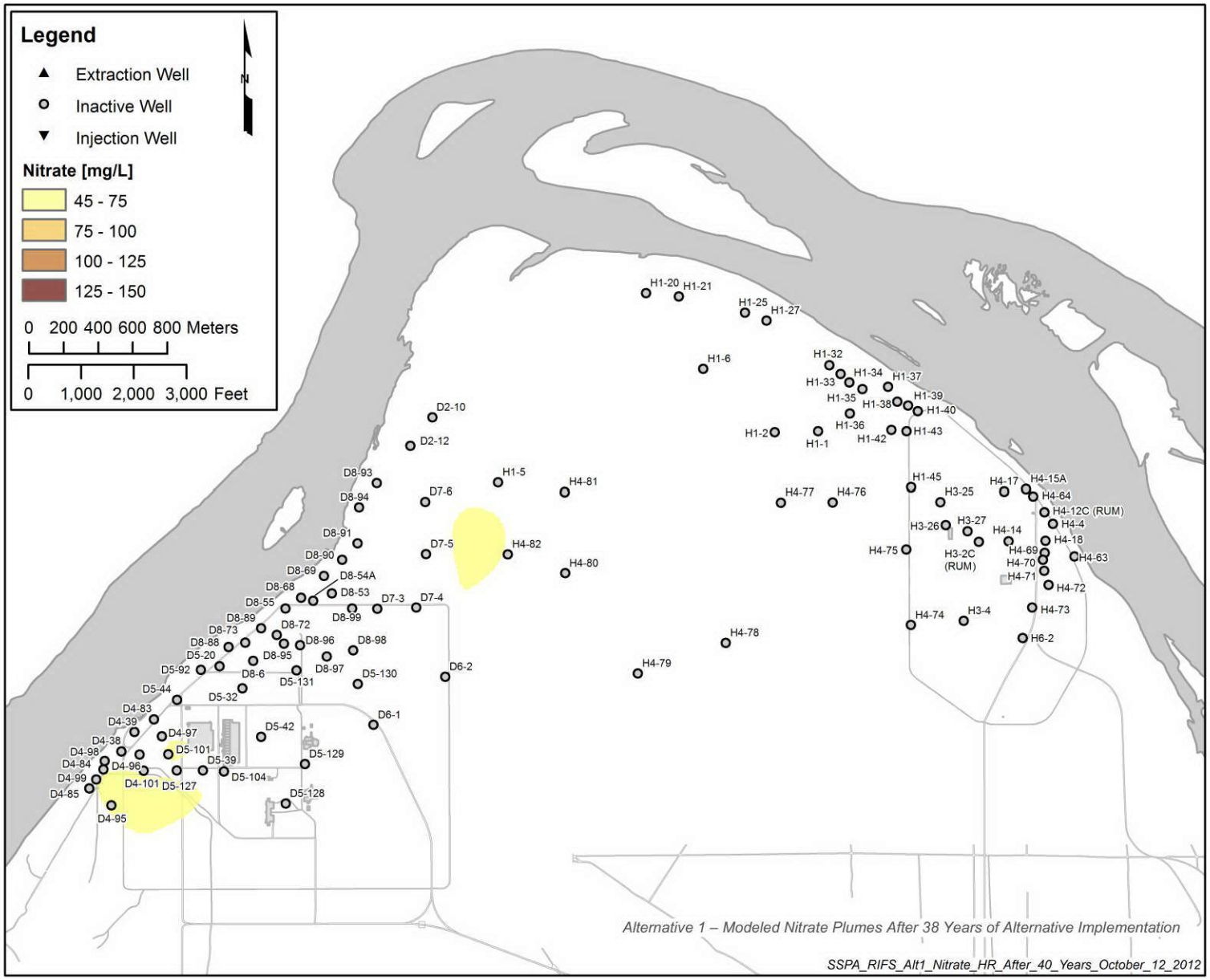


Figure 9-5c. Alternative 1—Modeled Nitrate Plumes after 38 Years

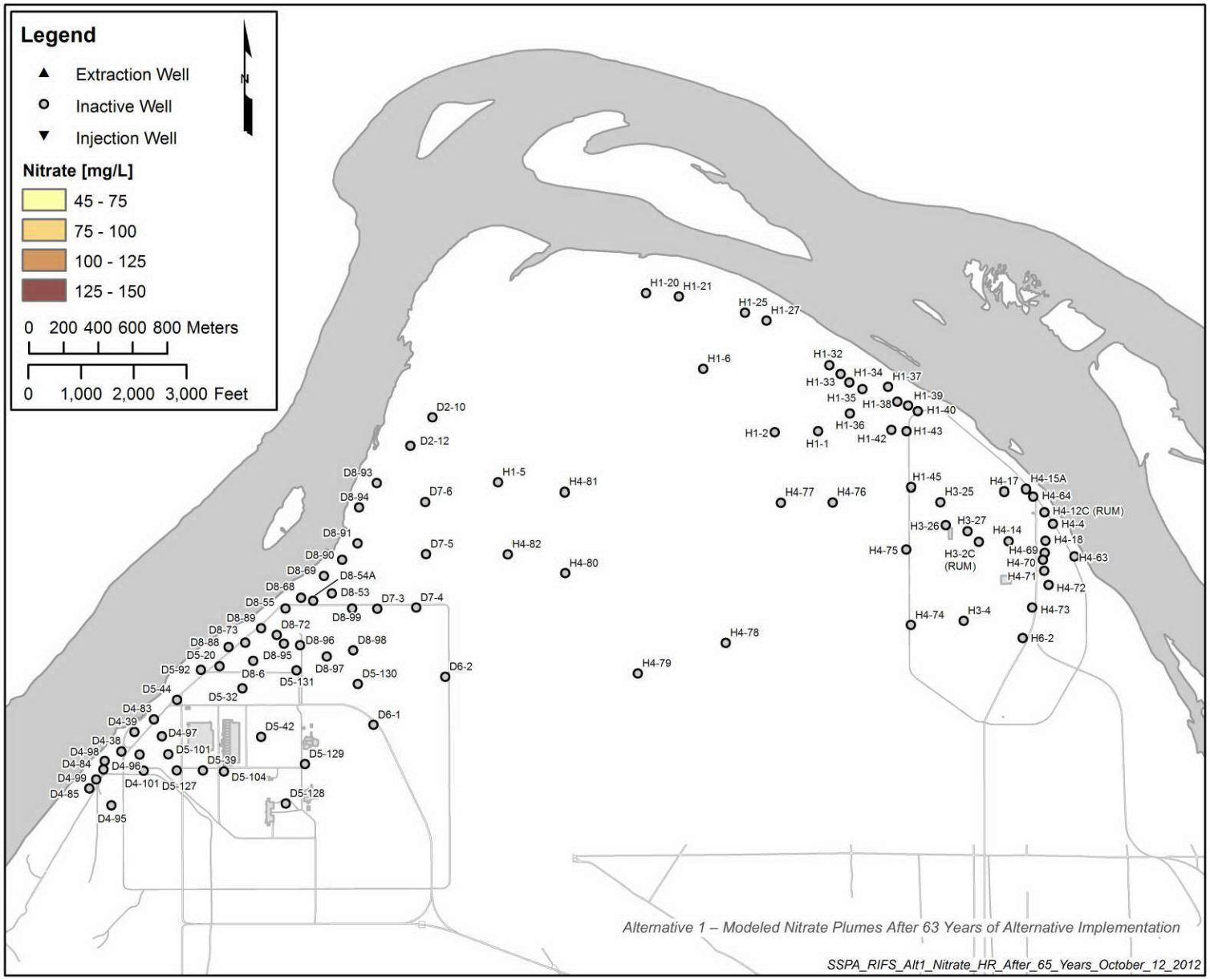


Figure 9-5d. Alternative 1—Modeled Nitrate Plumes after 63 Years

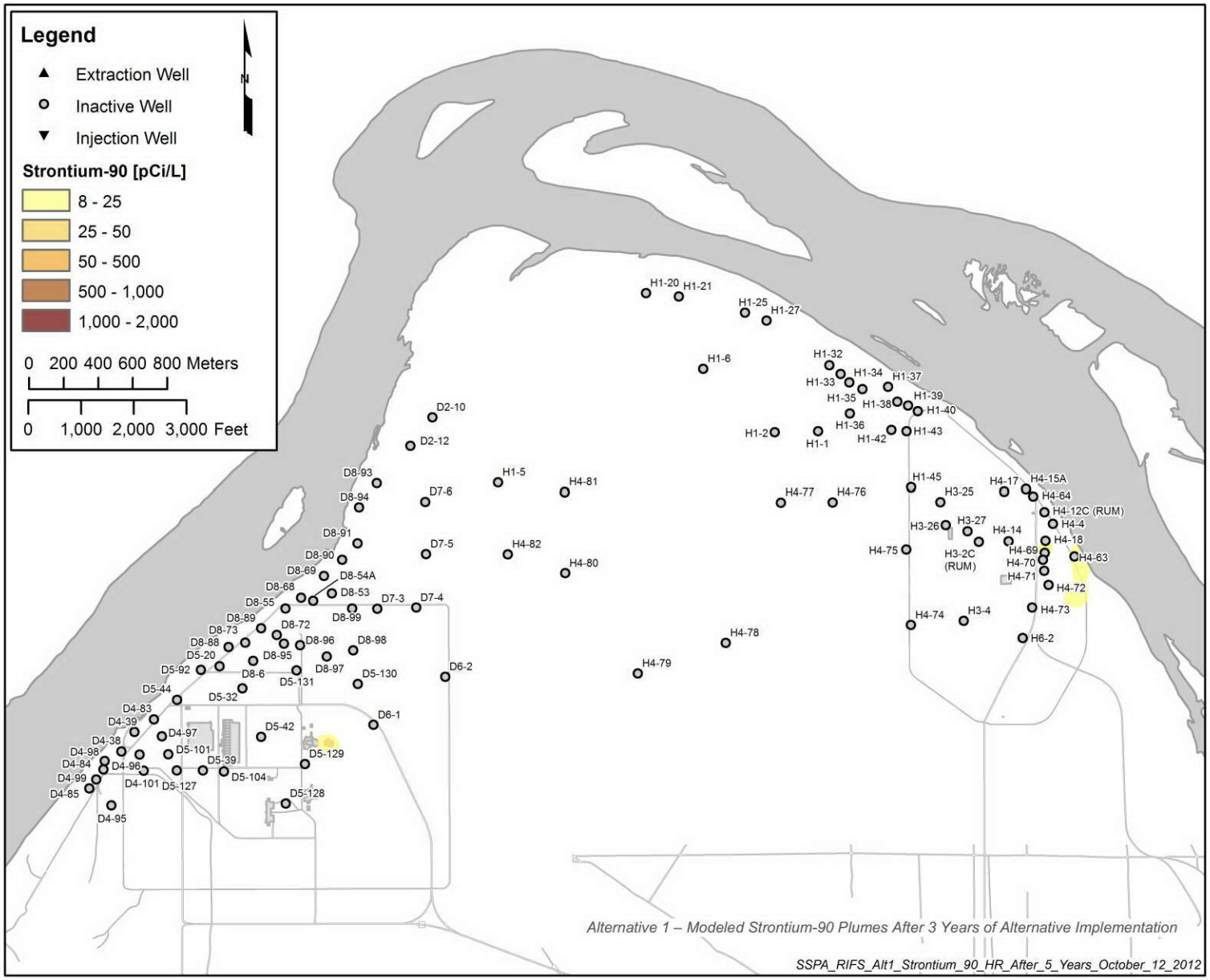


Figure 9-6a. Alternative 1—Modeled Strontium-90 Plume after 3 Years

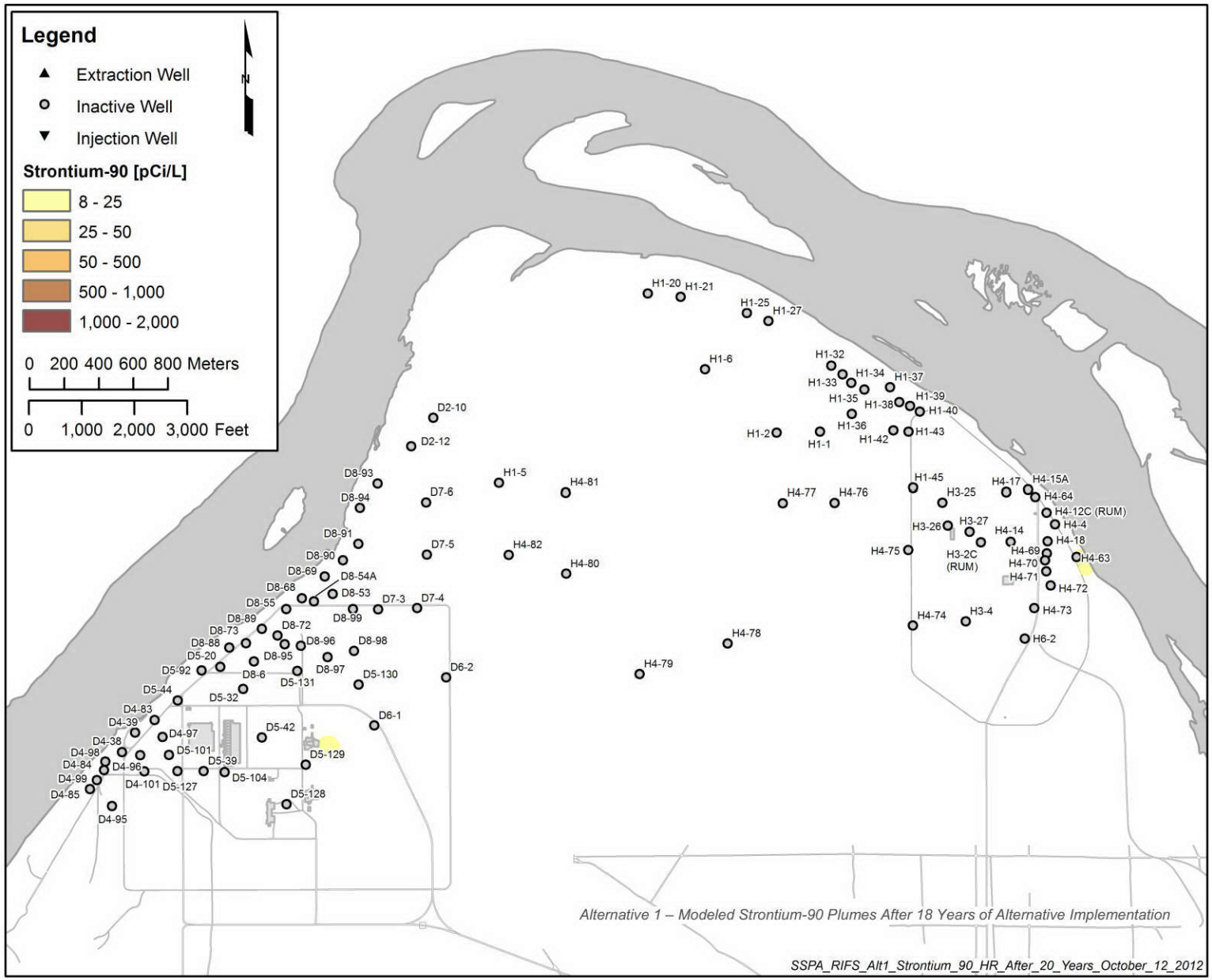


Figure 9-6b. Alternative 1—Modeled Strontium-90 Plume after 18 Years

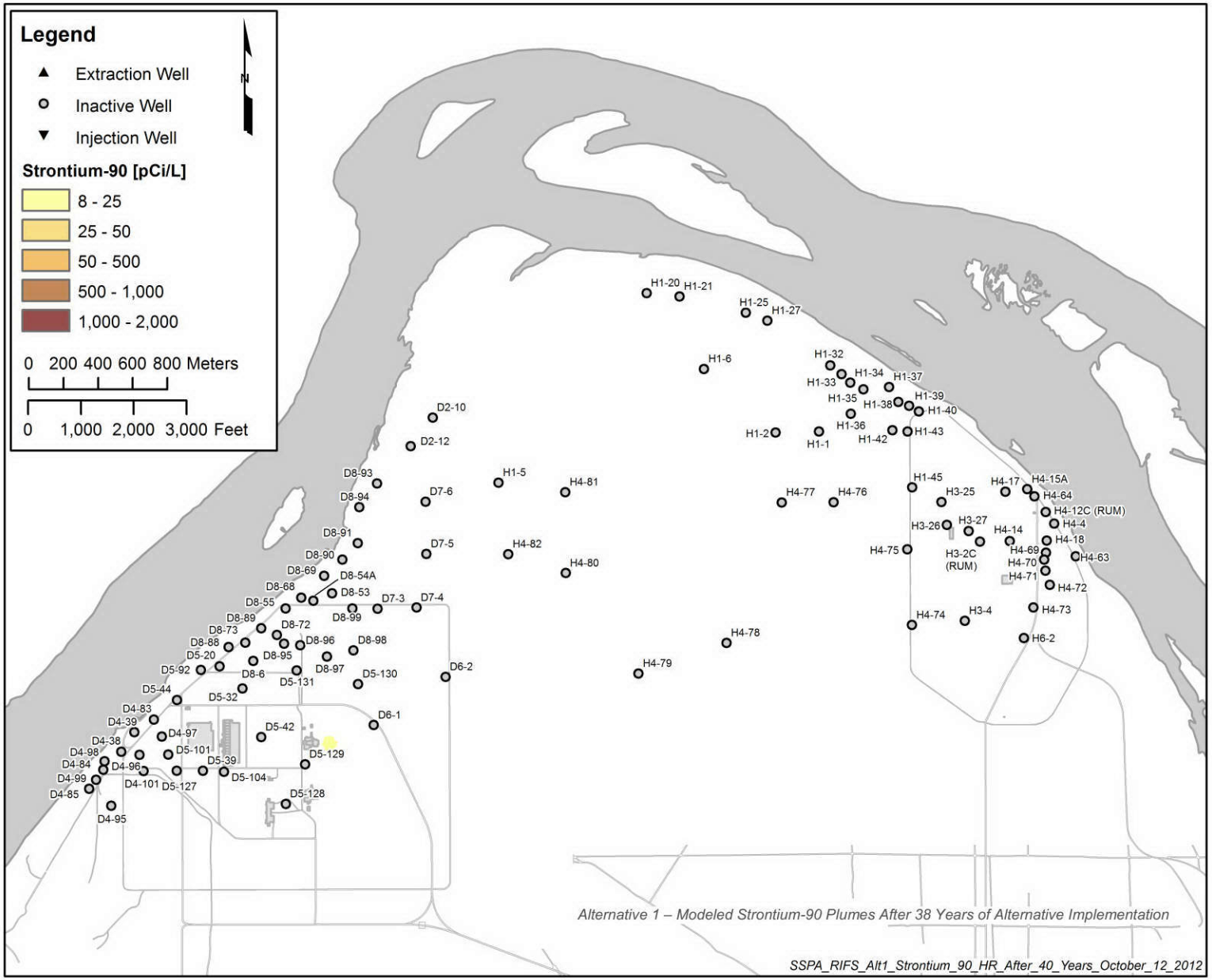


Figure 9-6c. Alternative 1—Modeled Strontium-90 Plume after 38 Years

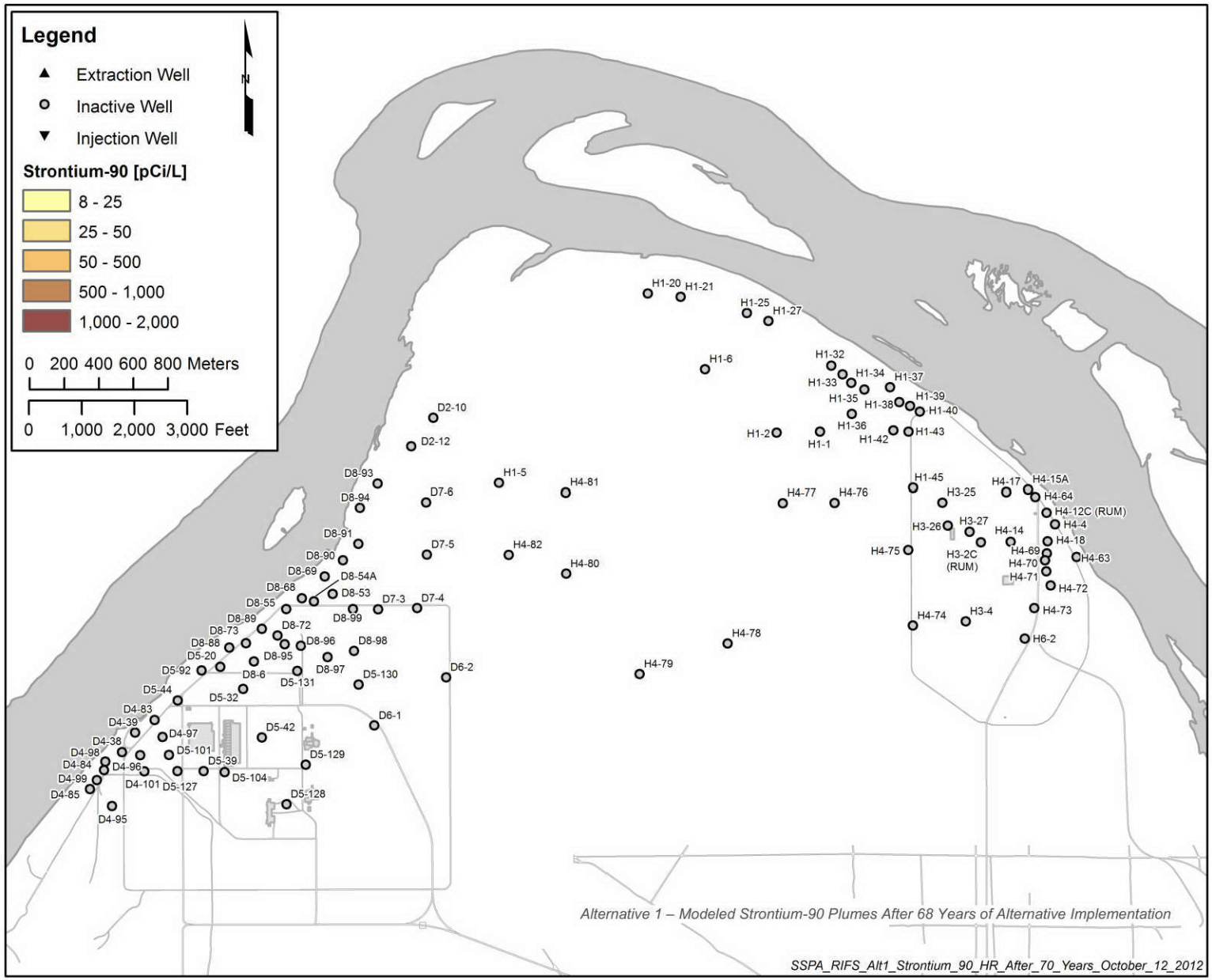


Figure 9-6d. Alternative 1—Model Strontium-90 Plume after 68 Years

- Sampling and field screening during excavation to ensure that remediation meets the cleanup levels. If contamination above the cleanup levels is encountered beyond the planned limits of excavation, the extent of removal will be increased. The sampling design also identifies contaminant concentrations that pose a risk to groundwater or surface water because this risk contributes to additional uncertainty about the extent of contamination from potential lateral migration (discussed in the CSM, Chapter 4).
- Suppression of dust during excavation to ensure that contaminants are not spread by wind and do not drive mobile contamination toward groundwater.
- Disposal of excavated material (low-level waste) to ERDF as long as the material meets disposal criteria. Hazardous or mixed waste is treated to meet land disposal restrictions before disposal at ERDF or an EPA-approved offsite location.
- Verification sampling following excavation to demonstrate that soil remaining in the excavated area does not exceed the cleanup levels.
- Backfilling and contouring to blend the excavation with 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 8-7, 8-8, and 8-9 (Chapter 8) illustrate the components of RTD, which has been the basic part of the interim actions performed for the waste sites at the Hanford Site.

9.2.2.3 Monitored Natural Attenuation

A screening level evaluation of potential application of MNA to the identified COCs in groundwater at 100-D/H indicates that MNA can play an important role in overall remediation of groundwater for strontium-90 (radioactive decay and sorption to aquifer materials). Following completion of Cr(VI) removal through active remediation, MNA may be applied (if action levels are exceeded) to remaining COCs as appropriate as described in item 4, below.

The following discussion provides a preliminary analysis of groundwater plume conditions at 100-D/H with respect to the requirements (bolded below) for application of MNA:

1. **The contamination condition does not currently present an actual risk to human or ecological receptors.** The groundwater contaminant plumes are generally well defined for 100-D/H, and current ICs (for example, prohibitions against use of groundwater as a source of drinking water) prevent current exposure to human receptors. Existing groundwater pump-and-treat systems operating at 100-D/H are exerting groundwater capture forces that have reduced the discharge of contaminated groundwater into the Columbia River. This reduction in discharge mitigates exposure to ecological receptors and downstream human receptors.
2. **The source of the observed contamination is no longer contributing to the plume.** Remedial actions are planned, or have already been implemented, at known source areas that have contributed to groundwater COC plumes at 100-D/H. This is particularly important to supporting selection of MNA for groundwater remediation where unremediated source areas are still associated with persistent groundwater plumes. The expected efficacy of source area remedial alternatives at 100-D/H is considered in the overall assessment of MNA for groundwater plume remediation.
3. **The target plume is static or retreating, or existing monitoring data confirm that attenuating processes are present and operating at the site.** The presence and activity of attenuating processes within the affected aquifer system can be demonstrated by either of two methods: (1) monitoring

history of the plume indicates that the plume is stable or shrinking, which means that sources are no longer contributing and that attenuating processes are working within the plume, or (2) if the plume is not stable or shrinking, then empirical measurements and observations of aquifer and plume conditions confirm that attenuating processes are operable within the aquifer.

Within the 100-HR-3 Groundwater OU, the operating interim groundwater remedial actions have substantially influenced contaminant plumes, reducing the size of some plumes and reducing observed COC concentrations. Historical monitoring for specific contaminants does not indicate static or shrinking plumes at all locations. Observations and measurements of aquifer conditions, however, do indicate that some attenuating processes are at work within the system. Multiple attenuating processes may be effective on any one COC. The following processes are identified as potentially applicable within 100-HR-3 OU:

- Radioactive decay is confirmed for radioactive COC. Strontium-90 exhibits a sufficiently short radioactive half-life (29.1 years), such that radioactive decay is a major attenuating element of an MNA alternative.

- Sorption of constituents to the aquifer matrix reduces the relative groundwater concentration of contaminants that interact substantially with the matrix. The tendency of a constituent to sorb, or bind, to the aquifer matrix is generally described by its relative distribution coefficient (K_d). Constituents with higher K_d exhibit a stronger tendency to bind to the aquifer solid matrix and reduce the relative groundwater concentration. Alternatively, constituents that exhibit lower K_d exhibit a reduced tendency to bind to aquifer solids and, therefore, do not exhibit concentration reduction through sorption to the aquifer matrix. Some constituents exhibit no tendency to sorb to aquifer solids, so sorption does not provide any meaningful attenuation for those constituents. Strontium-90 contamination in groundwater at 100-D/H exhibits meaningful attenuation as a result of sorption effects. Strontium-90 was simulated differently in the vadose zone than in the saturated zone (Chapter 5):

    - In the vadose zone, higher mobility of strontium during very different thermal and hydraulic conditions that prevailed during the operational period led to this COC being distributed throughout the vadose zone. Hence, a 100:0 initial source distribution was used, with the K_d value applicable to current and future conditions (K_d = 25 mL/g).

    - In the saturated zone, this COC was simulated in Chapter 5 for baseline conditions, and in this chapter as well for the alternatives evaluation, using a dual-domain formulation with K_d values appropriate to each domain of this representation (K_d = 7 mL/g for mobile domain, 39 mL/g for immobile domain, which is effectively equivalent to K_d = 15 mL/g for the aquifer in a single-domain formulation)

4. **Effective monitoring either exists currently or can be implemented.** The current groundwater monitoring well network at 100-D/H provided sufficient spatial and temporal data to define COC plumes in groundwater and to evaluate and select remedial technologies. As remediation progresses, the monitoring network will be modified to support the specific data needs. Following active remediation for Cr(VI), the other groundwater COCs are anticipated to meet cleanup levels, with the exception of strontium-90.

    - Nitrate contamination will be reduced through dispersion and diffusion created through co-extraction and injection (or discharge) associated with the pump-and-treat system. Groundwater modeling simulations predict that the dispersion and diffusion will reduce nitrate

concentrations in the groundwater to below cleanup levels prior to system shut off; therefore no specific treatment or MNA will be needed for nitrate.

- Strontium-90 contamination is expected to remain in groundwater above cleanup levels following pump-and-treat system shut down. The remedy for strontium-90 following active remediation is MNA through radioactive decay. As discussed earlier in this section, strontium-90 has low solubility and mobility, and has a half-life of 29.1 years. Appendix F presents groundwater modeling runs that were performed to evaluate the potential risk from strontium-90. Based on the groundwater modeling results presented in Appendix F, the strontium-90 contamination is likely to remain in small areas that can be monitored. Modeling predicts that the strontium-90 concentration will decrease by radiological decay to below the MCL in 56, 44, or 56 years for alternatives 2, 3, and 4 respectively.

- Uranium is s a local COPC associated with the 183-H Solar Evaporation Basin, and is within the capture zone of the pump-and-treat system. Uranium concentrations in monitoring wells around the 183-H Solar Evaporation Basin were below the DWS (30 µg/L) from 2006 until 2012. During 2012, uranium concentrations in a single well (199-H4-3) rose to a concentration above the DWS, but decreased to less than the DWS when next sampled in 2013. Increases in groundwater elevation resulting from seasonal river stage fluctuation could potentially cause uranium to desorb from sediments in the periodically rewetted zone into the groundwater.

- Uranium concentrations have been attenuating in wells downgradient, which have decreasing concentrations trends (Section 4.5.4). If uranium is detected following completion of Cr(VI) remediation and the shutdown of the pump-and-treat system, the localized uranium contamination will continue to be dispersed and diffused by normal groundwater flow. Effectiveness of continued natural attenuation will be monitored through performance monitoring sampling.

9.2.2.4 Groundwater Pump-and-Treat

Groundwater pump-and-treat systems can be used to contain groundwater plumes through hydraulic containment systems or to remediate the entire groundwater plume through extraction of the mass. A pump-and-treat system consists of an extraction well network, a treatment system, and an injection well network (or discharge). Figures 8-15, 8-16, and 8-20 (in Chapter 8) illustrate some of the components of a pump-and-treat system.

Four pump-and-treat systems (DR-5, HR-3, DX, and HX) have been implemented within 100-D/H as part of the interim action. Currently, only the DX and HX pump-and-treat systems are in operation, which replaced DR-5 and HR-3, respectively. The objectives of the existing systems are to provide hydraulic containment of the Cr(VI) from reaching the river, and to begin remediation of the entire plume. The DX and HX pump-and-treat systems were installed as a component of the interim actions to meet TPA (Ecology et al., 1989a) Milestone M-016-110-T01 to take actions necessary to contain or remediate Cr(VI) groundwater plumes in each of the 100 Area NPL (40 CFR 300, Appendix B) OUs, such that ambient water quality standards for Cr(VI) are achieved in the hyporheic zone and river water column.

Figure 8-20 illustrates the concept of hydraulic containment through groundwater extraction and injection (or discharge). Increased groundwater movement through the saturated zone of the aquifer using treated water (Figure 8-18) is another component of pump-and-treat and can be achieved through reinjection of treated groundwater to the 100-D/H aquifer or other approved discharge.

All the groundwater alternative components presented here, with the exception of the No Action Alternative, build upon these existing systems. The alternative specific enhancements of the system are

described under each alternative in Sections 9.2.3, 9.2.4, and 9.2.5. Table 9-5 summarizes the pump-and-treat systems at 100-D/H as part of the interim action.

Table 9-5. Summary of the Existing Groundwater Pump-and-Treat Components

Groundwater Pump-and-Treat Systems	Components include the following: • A combined pump-and-treat capacity of 5,300 L/min (1,400 gal/min): – DX – 2,271 L/min (600 gal/min); replaced 189 L/min (50 gal/min) DR-5 pump-and-treat system – HX – 3,030 L/min (800 gal/min) ; replaced 1,136 L/min (300 gal/min) HR-3 pump-and-treat system • 82 extraction wells • 35 injection wells • Wellhead infrastructure • Cr(VI) treated by ion exchange • Water treated to achieve requirements before injecting into 100-D/H aquifer • Performance and compliance monitoring wells

Note: Pump-and-treat is being carried out under *Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units Interim Remedial Actions, Hanford Site, Benton County, Washington* (EPA/ROD/R10-96/134).

The pump-and-treat components of the remedial alternatives are robust and provide for expansion to address locations where groundwater monitoring indicates Cr(VI) contamination is highest. Waste site 100-D-100 has been identified as the contaminant source for the 100-D Area southern Cr(VI) groundwater plume. Excavation of the vadose zone media to groundwater has been selected as the remedy for this location, and is ongoing. Excavation of the vadose zone source is expected to remove the continuing source of contaminants, minimizing future impacts to groundwater. During source remediation, additional extraction wells have been installed. Extraction of groundwater near the vadose zone source is expected to limit the spread of contaminants, and remove mass more quickly; thereby expedite cleanup of the groundwater plume. Once the vadose zone source and impacted groundwater are remediated, it is expected that natural attenuation processes will further reduce residual Cr(VI) levels to achieve regulatory thresholds for river protection and/or DWSs, as appropriate.

RPO, combined with remedy performance monitoring, provides for robust pump-and-treat system performance over the long term. RPO will be applied to groundwater remedial components to monitor and evaluate remedy performance throughout the duration of the remedial action to assess and implement changes to the pump-and-treat systems to optimize system performance as cleanup progresses. Remedy performance monitoring, described in Section 9.2.2.7, will evaluate effectiveness of the pump-and-treat systems at locations where uncertainty regarding whether residual contamination in the vadose zone potentially constitutes ongoing groundwater contamination sources.

As discussed in Section 4.9.2.1 (Chapter 4), Cr(VI) contamination is present at concentrations above 10 µg/L in the first water-bearing unit of the RUM at 100-H. Two extraction wells, 199-H3-2C and 199-H4-12C, are screened and extract groundwater from the RUM water-bearing unit for treatment through the HX pump-and-treat system. A groundwater analysis conducted to evaluate the effectiveness of the two extraction wells to capture and remediate Cr(VI) contamination within the RUM water-bearing unit at 100-H is included in Appendix F (*Evaluation of Potential Hydraulic Capture and Plume Recovery from the Ringold Upper Mud (RUM) in the 100-HR-3 Operable Unit (OU)* [ECF-100HR3-12-0025]).

The analysis presented in the ECF also evaluated use of additional extraction wells to capture the contamination plume in the RUM.

Sensitivity analysis was performed to evaluate bounding cases for flow through the aquifer, leakage from the overlying unit, and flow from the Columbia River. The evaluation indicated that in the case of high leakage from the overlying aquifer unit, pumping from the two existing wells might not be sufficient to provide capture of the plume in the remediation period. The addition of two extraction wells indicates that pump-and-treat is feasible for recovering contamination identified within the RUM, for the remedial action alternatives. Calculations suggest that the parameters of the confining unit and the degree of connection with the Columbia River play an important role in the effectiveness of pumping from the silty-sand RUM unit for contaminant recovery. For purposes of this FS, the four extraction well configuration is included in the remedial alternatives to remediate Cr(VI) contamination in the RUM water-bearing unit. Further calculations to provide information necessary for the design or scaling for groundwater extraction and monitoring to verify hydraulic containment from the RUM water-bearing unit will be conducted as part of the remedial design phase.

Strontium-90 and nitrate contamination is co-extracted with Cr(VI) contaminated groundwater by the pump-and-treat systems. The co-extracted strontium-90 and nitrate pass through the ion exchange resin (designed for Cr(VI) removal) and their concentrations remain unchanged. Past operational data and groundwater model simulations indicate the strontium-90 and nitrate concentration in the influent and effluent of the pump-and-treat systems is less than their respective MCLs so no further treatment is evaluated for these two contaminants within the existing pump-and-treat system. If the combined extracted groundwater in the pump-and-treat effluent stream is found to exceed the MCL for strontium-90 or nitrate, further treatment, if necessary, would be evaluated.

Strontium-90 and nitrate-contaminated groundwater co-extracted during operation of the pump-and-treat systems are controlled through the hydraulic containment. The strontium-90 plumes are inland and localized in the 100-D and 100-H areas. The plumes are relatively stationary because of the lower mobility of strontium-90 and preference to bind with the aquifer sediments so significant quantities of strontium-90 are not expected to be extracted by the pump-and-treat extraction wells. However, cleanup levels are expected to be achieved faster with pump-and-treat systems operating, as compared to the No Action Alternative, due to enhanced diffusion and dispersion rates induced by pump-and-treat extraction and injection wells near the strontium-90 plumes. Strontium-90 contamination is expected to remain in groundwater following shut down of the pump-and-treat systems following remediation of the Cr(VI) groundwater contamination. The remedy for the remaining strontium-90 contamination is MNA through radioactive decay as described in Section 9.2.2.3.

The extents of the nitrate plumes are within the capture zone of the Cr(VI) pump-and-treat systems. Nitrate is a mobile constituent and will be co-extracted under Alternatives 2, 3, and 4. Nitrate contamination will be reduced by dispersion and diffusion created through co-extraction and injection associated with operations of the Cr(VI) pump-and-treat system. Past operational data and groundwater model simulations indicate the nitrate concentration in the influent to the pump-and-treat systems is less than the DWS (45,000 μg/L). Nitrate passes through the ion exchange resin (designed for Cr(VI) removal) and concentration remains unchanged at less than the DWS in the pump-and-treat system effluent. Groundwater model simulations predict that dispersion and diffusion resulting from pump-and-treat operations will reduce the nitrate plume concentrations to less than cleanup levels within the time frame for completing Cr(VI) remediation and so specific treatment for nitrate is not evaluated.

9.2.2.5 Ion Exchange

Treatment of Cr(VI) contaminated groundwater use of ion exchange technology. The ion exchange process removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. The ion exchange materials may consist of resins made from synthetic organic materials that contain ionic functional groups to which exchangeable ions are attached. The materials may also be inorganic or natural polymeric. After the resin capacity has been exhausted, resins can be regenerated for reuse or disposed of at ERDF or other EPA-approved disposal facility.

Figure 8-16 illustrates the basic components of an ion exchange system.

9.2.2.6 Operations and Maintenance

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 an O&M plan, which details performance monitoring needs, post-closure monitoring requirements, monitoring methods, analytes and intervals, maintenance activities and frequencies, and associated procedures.

The nature and scope of O&M activities vary by alternative component. For example, O&M activities for an MNA component primarily include inspection, maintenance, and periodic replacement of monitoring wells, whereas groundwater pump-and-treat components include routine and preventive maintenance programs and replacement of pump-and-treat system parts at the end of their design life (typically 15 years). Alternatives with longer durations include multiple replacements of system parts every 15 years.

O&M activities include periodic rehabilitation, replacement, reconfiguration and decommissioning of the remediation system components. This consists of:

- Replacement and abandonment of monitoring, extraction, and injection wells (or approved discharge)
- Rehabilitation of extraction and injection wells
- Replacement of extraction well pumps
- Major system renovations for remedial system life extension
- Remedial system decommissioning

The scope and cost of O&M activities are provided in Appendix J (*Environmental Cost Estimate for 100-D/H Vadose Zone and Groundwater RI/FS* [ECE-100HR311-00004]) and included in each of the remedy components as described in Sections 9.2.3, 9.2.4, and 9.2.5.

9.2.2.7 Remedy Performance Monitoring

Remedy performance monitoring will be conducted to evaluate the effectiveness of the selected alternative to attain the cleanup levels that will be identified in the 100-D/H decision document. The nature and scope of the performance monitoring program will vary by alternative component, and will be developed during the remedial design process and included in a performance monitoring plan. Remedy performance monitoring applies to MNA actions as well as actively engineered remedies.

A groundwater monitoring plan has been developed under the interim actions via the 100 Area RD/RAWP (DOE/RL-96-17) and *Interim Action Monitoring Plan for the 100-HR-3 and 100-KR-4 Operable Units* (DOE/RL-96-90). 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 is assumed to be quarterly, semiannually, or annually.

Sampling and analysis will also be conducted for analytes identified to have uncertain status (Section 8.1.1.2). To ensure protectiveness and confirm current understanding of the nature and extent of contamination and potential risks, these analytes will be analyzed as part of the performance monitoring. The CERCLA 5-year reviews will allow an evaluation of the approach taken with these compounds.

Identification of well locations, including identification of new wells for remedy performance monitoring, will be defined in the SAP and developed as part of the remedial design. The following assumptions were made for this FS:

- Monitoring is conducted to evaluate the effectiveness of the selected alternative to attain the cleanup levels (MNA actions are described in Section 9.2.2.3, and actively engineered remedies are described in Section 9.2).
- Nature and scope are specific to alternative components and would be developed during the remedial design process.
- Hydraulic and chemical monitoring of the monitoring wells, including extraction wells, is designed to evaluate contaminant mass removal and containment.
- Sampling locations and frequency for performance monitoring of active groundwater remediation alternatives will be defined in the RD/RAWP for the selected remedy.
- Sampling locations and frequency to evaluate whether or not the analytes identified in Section 8.1.1.2 have uncertain status will be defined in the RD/RAWP for the selected remedy.

9.2.2.8 Reactive Chemical Barrier (ISRM)

The interim action groundwater remedies include the ISRM barrier (described in Chapter 1). This system will continue to operate as is (without enhancement), but it is not critical to the achievement of the plume cleanup. The ISRM is not actively maintained and effectiveness is expected to continue to decrease prior to completion of the pump-and-treat remediation time frame. Therefore, the groundwater simulations do not include Cr(VI) reduction by the ISRM barrier when predicting time to achieve cleanup levels. The ISRM barrier is a passive system, so there is no cost for its continued operation. Figure 8-19 illustrates the ISRM barrier.

The strategy for implementation of the technologies for each alternative is presented in the following sections. Cost estimate details for the alternatives are provided in Appendix J (*Environmental Cost Estimate for 100-D/H Vadose Zone and Groundwater RI/FS* [ECE-100HR311-00004]).

9.2.3 Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

Table 9-6 presents the waste site and groundwater components of this alternative, and Figure 9-7 presents a pictorial summary of the alternative. The cost for this alternative is provided in Table 9-7. Details for the cost estimate are provided in Appendix J (*Environmental Cost Estimate for 100-D/H Vadose Zone and Groundwater RI/FS* [ECE-100HR311-00004]). Additional details on remedial components specific to this alternative are presented in sections identified in Table 9-6.

Table 9-6. Components for Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

Waste Site Components	**General Components**	
	No Further Action	No additional remedial actions are taken for the 146 waste sites identified in Section 8.2.1.1 (Chapter 8).
	Institutional Controls	Institutional controls to be implemented within the 100-D, 100-H, and Horn areas for land use management and waste site information management include the following: • Permits required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land use and real property controls (for example, proprietary controls including easements and covenants) ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents. • Notices providing visual identification and warning of hazardous or sensitive areas. • Procedural requirements for access, warning signs, or fencing implemented to prevent or limit the access of humans to hazardous or sensitive areas. • Administrative mechanisms, such as the WIDS database, to maintain and provide access to information on the location and nature of contamination. Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8). Post remediation institutional controls implemented at specific waste sites are identified in Table 9-4.
Waste Site Components	**For Waste Sites That Exceed Human Health, Environment, Surface Water, or Groundwater Protection PRGs**	
	MNA/institutional control	MNA/institutional controls applied to waste sites 116-D-8, 116-DR-9, and 100-D-25. Waste site 100-D-25 is fully encompassed within waste site 116-DR-9. Risk evaluation of the verification data indicates that the shallow decision units for these sites contain cesium-137 at concentrations greater than the residential RBSL (Chapter 6). No ecological risks are identified for the sites (Chapter 7). Cesium-137 concentrations at the three sites will decay through natural attenuation to levels less than residential RBSLs in year 2035. Institutional controls will be in place through this period. Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8).
	Void-fill Grouting	Void-fill grouting, as described in Section 9.2.3.1, will be used to remediate the box flumes of the 100-H-36 waste site to immobilize contaminants on interior surfaces of the underground concrete box flume sluiceway.

Table 9-6. Components for Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

	RTD	RTD to depth of contamination exceeding cleanup levels, or until groundwater is encountered if contamination extends into groundwater, using standard and deep excavation technologies, as described in Section 9.2.2.2. RTD is applied to waste sites listed in Table 8-5 (Chapter 8) that are expected to be remediated under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039). 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). RTD also applied to waste sites listed in Table 8-5 (Chapter 8) that are yet to be remediated and are not remediated under one of the other waste site remedial components listed above. Table 9-2 identifies applicable waste sites remediated by RTD using standard and deep excavation technologies. 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.
Groundwater Components	Pump-and-Treat System	Operation of existing pump-and-treat systems as described in Section 9.2.2.4, with additional extraction and injection wells to expand treatment coverage, or other approved discharge. Placement of additional extraction and injection wells, extraction and injection flow rates, and well operational periods were determined through groundwater model simulations described in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114) in Appendix F. The RPO process will be used to provide ongoing evaluations to ensure the system meets ROD requirements. Designed with active remediation out to Cr(VI) 10 µg/L contour. Treatment of extracted water through ion exchange. Operation of pump-and-treat system and bioinjection components to meet State surface water quality standard at points of groundwater discharge to the river Periodic rehabilitation, replacement, reconfiguration and decommissioning of the remediation system components as described in Section 9.2.2.6.

Table 9-6. Components for Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

	Bioinjection	Groundwater pump-and-treat system optimized with bioinjection for in situ treatment of Cr(VI) groundwater contamination. Components of bioinjection, described in Section 9.2.3.3, include the following: • Injection of biological substrate (for example, cheese whey or sodium lactate) into bioinjection wells with closed-loop recirculation from downgradient wells • Bionode mixing facilities • Biosubstrate mixing plants Placement of wells for bioinjection, flow rates, and well operational periods were determined through groundwater model simulations described in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114) in Appendix F.
Groundwater Components (cont.)	MNA and Institutional Controls	MNA as described in Section 9.2.2.3. Manage strontium-90 in groundwater through MNA and institutional controls until concentrations meet cleanup standards. Manage the plumes until concentrations are below the cleanup levels and after the pump-and-treat system is shut off. Monitoring of COCs to track the attenuation processes. Institutional controls to be implemented within 100-D/H include land use management and waste site information management. Additional institutional controls for groundwater include the following: • Permits required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land use and real property controls (for example, proprietary controls including irrigation restrictions, easements, and covenants) to ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents. • Groundwater use management, as described in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41), to ensure proper use of groundwater through groundwater controls. • Administrative mechanisms, such as the WIDS database, to maintain and provide access to information on the location and nature of contamination. Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8).

Table 9-6. Components for Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

	Monitoring Requirements	Remedy performance monitoring will be defined as part of the remedial design. Monitoring evaluates the effectiveness of the selected alternative to attain the cleanup levels. The monitoring program will expand by adding a number of specific monitoring wells. For cost estimating purposes, it has been assumed that 12 new monitoring wells will be installed. Groundwater performance monitoring is presented in Section 9.2.2.7 for constituents included in the monitoring program. The constituents include COCs (chromium (total), Cr(VI), nitrate, and strontium 90) and analytes identified for additional monitoring (antimony, cadmium, carbon tetrachloride, cobalt, copper, nickel, silver, and zinc).

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC = contaminant of concern
MNA = monitored natural attenuation
PRG = preliminary remediation goal
RBSL = risk-based screening level
ROD = record of decision
RTD = removal, treatment, and disposal
SMDP = scientific management decision point
WIDS = Waste Information Data System

This alternative optimizes the operation of the interim action pump-and-treat by including bioinjection for treatment of contaminated groundwater. Bioinjection will be used for specific well pairs or clusters in a closed-loop fashion separate from the ion exchange treatment plants. This reduces the likelihood of biodegradation byproducts reaching the ion exchange treatment systems. Bioinjection is implemented to augment groundwater remediation in the Horn area to reduce the amount of groundwater that must be sent to the ion exchange plants, thereby increasing the total capacity of the system and reducing the O&M cost. Remediation components described in Table 9-6 that are specific to Alternative 2 are described in the following sections.

9.2.3.1 Void-fill Grouting

Void-fill grouting is an in situ treatment technology to immobilize contaminants by solidification of wastes. Void-fill grouting can be used to fill large empty spaces (for example, pits and trenches) where the structure would then be left in place. Specifically, waste site 100-H-36 will be remediated by void-fill grouting under this alternative. This waste site is an underground concrete box flume sluiceway that led from the 116-H-5 Outfall Structure to the river shoreline. The site is on the Columbia River shoreline, and void-fill grouting of the box flume presents fewer ecological impacts along the shoreline than remediation through RTD. The three side-by-side channels of box flumes, each with an approximately 1.2 × 2.1 m (4 × 7 ft) interior with 39.6 m (130 ft) of remaining length, will be grout-filled. The spillway run-off pad extending from the box flume to the river will be removed to the ordinary high water mark by RTD.

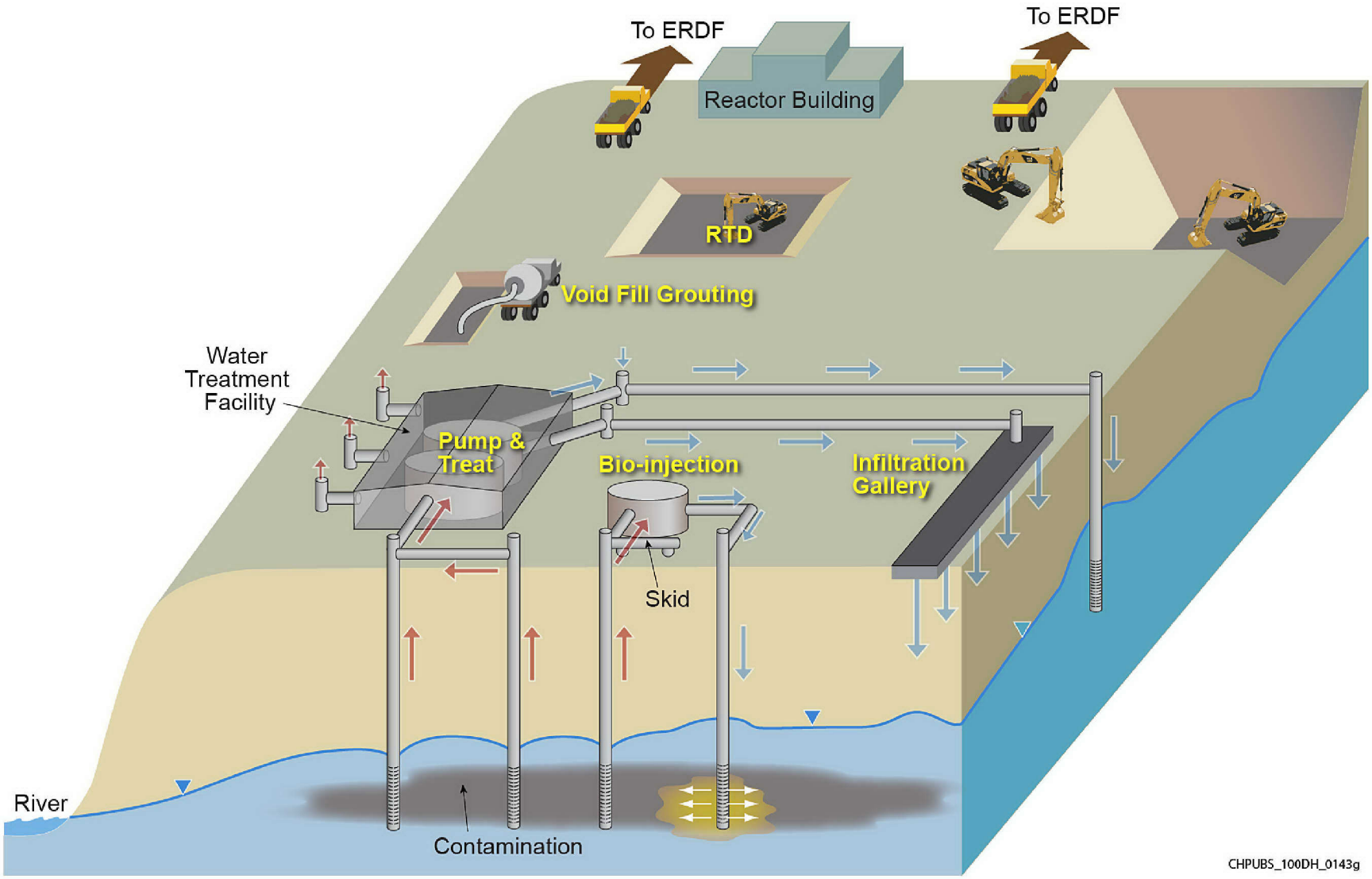


Figure 9-7. Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

Table 9-7. Alternative 2—Cost Estimates (in millions)[a]

Waste Site Treatment	Capital	$56.2
	Annual O&M	$25.7
	Total Periodic[b]	$0.8
	Total Nondiscounted	$82.7
	Net Present Value	$66.7
Groundwater Treatment	Capital	$33.3
	Total O&M	$173.1
	Total Periodic[b]	$143.6
	Total Nondiscounted	$349.9
	Net Present Value	$267.2
Total Nondiscounted Cost of Alternative	$432.6	
Total Net Present Value (Discounted) of Alternative	$333.9	

a. Order of magnitude cost estimates and support information are presented in Appendix J. Costs for institutional controls are included under the costs for waste site treatment.

b. Periodic costs include O&M and/or construction activities, including costs to replace an installed remedy or components of an installed remedy, and services that are not included in initial capital costs or annual O&M costs. Periodic costs may be one-time costs or costs that recur at intervals over the life of the remedy.

O&M = operations and maintenance

When void-fill grouting is done, thermal expansion effects of the interior grout fill on the surrounding structure need to be considered. For large areas, grout pours would be performed in intervals of small area and height, with a considerable time lapse between adjacent pours. This will allow the hardened grout to cool between pours, and the expansion effects should be easy to account for in the grout design. There are several ways to control expansion: proper mix design, fast- or slow-setting cement, or admixtures. The grout mixture would be designed with control of thermal expansion as one of the requirements, using grouting sequence and schedule requirements of the final design.

The void structure to be grout-filled would be prepared to provide access for grout pour and the controlled flow of grout. Flowable grout would be delivered into the structure to fill void spaces. Pressure grouting may also be used to fill voids not reached by previous grouting. Grout amendments, such as fly ash or zeolite clays, may be considered for grouting activities to reduce the potential for leaching of radioactive isotopes. Design components for void-fill grouting included in this FS are as follows:

- Design samples based on the expected and actual risk drivers (media and COPCs)
- Grout mix design and delivery system
- Structure preparation that provides access points for grout pour and controlled grout flow
- Grout pour in lifts to account for thermal expansion effects

Verification sampling is performed to demonstrate that grout matrix has been effective and remaining structure achieves RAOs.

Figure 8-13 illustrates the components of void-fill grouting.

9.2.3.2 Bioinjection

Bioinjection is included in Alternative 2 to enhance the pump-and-treat systems for Cr(VI) remediation. In addition, the nitrate plume, which has concentrations below 80 mg/L, is located within the footprint of the Cr(VI) plume and would be co-extracted with Cr(VI) during any treatment. Bioinjection is the process of adding an organic substrate to water injected into the saturated zone to induce growth or activity of indigenous bacteria for reducing chromate. The injected water will be groundwater extracted from a downgradient well to create a closed-loop injection-extraction system. This will be done, in part, to keep groundwater affected with the organic substrate from reaching an ion exchange treatment plant and potentially fouling the ion exchange resin. Additionally, this approach will biologically reduce Cr(VI) in the extracted groundwater, which will reduce the flow rate to the ion exchange treatment plants, thereby reducing the O&M costs. Figure 8-17 illustrates bioinjection.

The extraction-injection well sets for bioinjection include the following design components:

- Organic substrates include soluble (miscible) substrates (for example, lactate and cheese whey) and immiscible substrates (for example, emulsified vegetable oil).
- Organic substrate will be injected at upgradient wells in pulsed operation to reduce well fouling.
- Groundwater from extraction wells will be used as the source water for the bioinjection and piped directly to the reagent mixing facility.
- After the source groundwater is mixed with a carbon source at the reagent mixing facility, a pipeline will carry fluid from the reagent mixing facility to the injection wells.

System components include the following:

- Reagent mixing facility, pipelines, injection wells, pumps, and valves
- Stand-alone injection wells
- Injection well components to allow the well to operate efficiently without aeration of the injection water:
  - A packer located 3 m (10 ft) from the top of casing to prevent injection well overtopping
  - A pressure transducer to measure pressure on the packer
  - A drop pipe and foot valve at the bottom of the drop pipe to maintain a standing column of water in the drop pipe
  - A water level indicator/transducer to monitor water levels in the injection wells
  - A cleanout for the pipeline from the mainline to the injection well (a tee in the line where cleaning tools can be inserted)
  - A sampling port that would allow sampling of the injection water
  - A pipeline to each injection well, installed on the ground surface (proposed injection rates ranging from 57 to 160 L/min [15 to 43 gal/min] for each well)
- A preventive maintenance program to mitigate well fouling, which includes the following:
  - Visual inspection of injection wellhead piping and fittings

- Evaluation of injection rates with water level measurements at each well to detect changes that potentially affect well performance
- Well rehabilitation with clean water flushes or physically cleaning the wells with appropriate cleaning solutions (for example, acid or bleach)

The specific extraction-injection well layouts for Alternative 2 are presented in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114) and summarized in Section 9.2.3.3. It is likely that a pulsed/intermittent operation will be used to optimize the performance of the bioinjection system. The groundwater flow and transport model (*Modeling of RI/FS Design Alternatives for 100-HR-3* [ECF-100HR3-11-0114]) was used to simulate bioremediation of Cr(VI) through bioinjection of biological substrate reagents and identify locations and well spacing for bioinjection. Bioinjection is simulated in the groundwater flow and transport model (*Modeling of RI/FS Design Alternatives for 100-HR-3* [ECF-100HR3-11-0114]) as a first order decay term applied to the substrate to approximate the consumption of the substrate over time. Appendix I provides additional information on bioremediation as a potential remedial action for Cr(VI) in the groundwater and vadose zone of the 100 Area.

9.2.3.3 Groundwater Model for Alternative 2

This section provides a summary of the groundwater model for Alternative 2. The interim action pump-and-treat system is expanded in Alternative 2 to include additional extraction and injection wells (or other approved discharge), thus encompassing a larger area of the Cr(VI) plumes and co-contaminant plumes to expedite hydraulic containment and recovery. In addition, in situ treatment is considered in the form of bioinjection at selected wells and periods to further enhance the reduction of Cr(VI) concentrations in the aquifer and shorten cleanup times. The treatment of co-contaminants is addressed under Section 9.2.2, Common Elements, and later in this section. This alternative expands the existing pump-and-treat system with 15 new or converted wells for extraction and injection associated with the DX pump-and-treat system, and 29 new or converted wells for extraction and injection at 100-H for the HX pump-and-treat system and bioinjection. Duration of well operation is detailed in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114, Table 3-4).

The groundwater model assumes 85 percent availability of the pump-and-treat system capacity to account for scheduled or unforeseen shutdown periods. As a result, a total capacity of 1,930 L/min (510 gpm) was assumed for the DX pump-and-treat system and 2,575 L/min (680 gpm) for HX pump-and-treat system. During periods of in situ treatment, bio-amended water injected at the designated injection wells is recovered at downgradient extraction wells and recirculated back through the bioinjection system, bypassing the ion exchange treatment system, as described in Section 9.2.3.2. This reduces the likelihood of biodegradation byproducts reaching the ion exchange treatment systems. The treatment rate capacity of the bio-remediation loop is 1,000 L/min (263 gpm).

Alternative 2 is designed to operate until the Cr(VI) groundwater plume's concentrations are substantially reduced to less than the groundwater cleanup level in 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]). Wells along the river will be used to contain concentrations in the plume that are above 10 µg/L, thereby reducing migration to the river, so the State surface water quality standard can be met at points of groundwater discharge to the river.

All waste sites will be remediated before final remediation of groundwater. Remedial action completion for waste site and groundwater remediation is described in Section 9.2.

Results from the groundwater flow and transport model *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114) in Appendix F predict COC plumes and trends over the remediation simulation period.

The groundwater model results predict Cr(VI) plumes will be remediated to meet cleanup levels to the 48 µg/L DWS and 10 µg/L State surface water quality standard throughout the aquifer after 11 and 25 years, respectively, of implementing the groundwater remedy under Alternative 2. Figure 9-8 (a-e) show the modeled Cr(VI) groundwater plumes after 3, 8, 18, 23, and 25 years of operating under this alternative.

EPC calculations will be used to determine completion of groundwater remedial actions following shut down of the pump-and-treat systems to evaluate for rebound conditions within the unconfined aquifer. MTCA compliance requirements (2007 MTCA, "Groundwater Cleanup Standards" [WAC 173-340-720(9)(d)(i)]) and EPA guidance (*Methods for Evaluating The Attainment Of Cleanup Standards Volume 2: Ground Water* [EPA 230-R-92-014]) will be used for the purpose of evaluating completion. The 95th UCL calculation will be used to demonstrate compliance as described in WAC 173-340-720(9)(d)(i).

During performance of the pump-and-treat operations, performance will be evaluated using a number of measures, including monitoring of contaminants and aquifer hydrologic data for use in model predictions and statistical evaluations of measured concentration trends on a well by well basis within 100-D south, 100-D north, Horn area, and 100-H, and along the river shoreline.

As described in Section 9.2.2, groundwater COCs co-extracted for treatment of the Cr(VI) plumes are managed through MNA and ICs to achieve cleanup levels following active remediation. (MNA is discussed in detail in Section 9.2.2.3, and ICs are discussed in Section 9.2.2.1). Predicted concentrations of nitrate and strontium-90 in the combined groundwater influent stream to the pump-and-treat facilities will be at concentrations below their respective cleanup levels. Predicted concentration trends for each COC in the combined influent to the pump-and-treat facilities are provided in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114). Cr(VI) in the treatment system influent will be removed using ion exchange treatment technology. The other COCs in the resulting treatment system effluent injected into the aquifer, or other approved discharge method, remain below cleanup levels.

Nitrate contaminated groundwater is within the capture footprint of the Cr(VI) pump-and-treat system well network and will be reduced through dispersion and diffusion created through co-extraction and injection associated with the pump-and-treat system. The groundwater model simulation for this alternative indicates that nitrate contamination is remediated to cleanup levels within the Cr(VI) remediation period. Nitrate plume depictions after 3, 5, 8, 12, and 13 years of operating under this alternative are provided in Figure 9-9 (a-e) showing nitrate concentrations are below cleanup levels after 13 years. No specific treatment or MNA will be needed for nitrate following the remediation of Cr(VI) through pump-and-treat.

Strontium-90 is localized, and has low solubility and mobility in groundwater. Modelling (Appendix F) indicates that small pockets of strontium-90 contamination will remain in the aquifer above cleanup levels following pump-and-treat system shut down. The remedy for strontium-90 following active remediation is MNA through radioactive decay. Remaining strontium-90 contamination will attenuate to cleanup levels through radiological decay in 31 years after Cr(VI) remediation (i.e., 56 years after implementation of the Alternative 2 remedy). Strontium-90 plume depictions after 3, 18, 48, and 56 years of operating under this alternative are provided in Figure 9-10 (a-d).

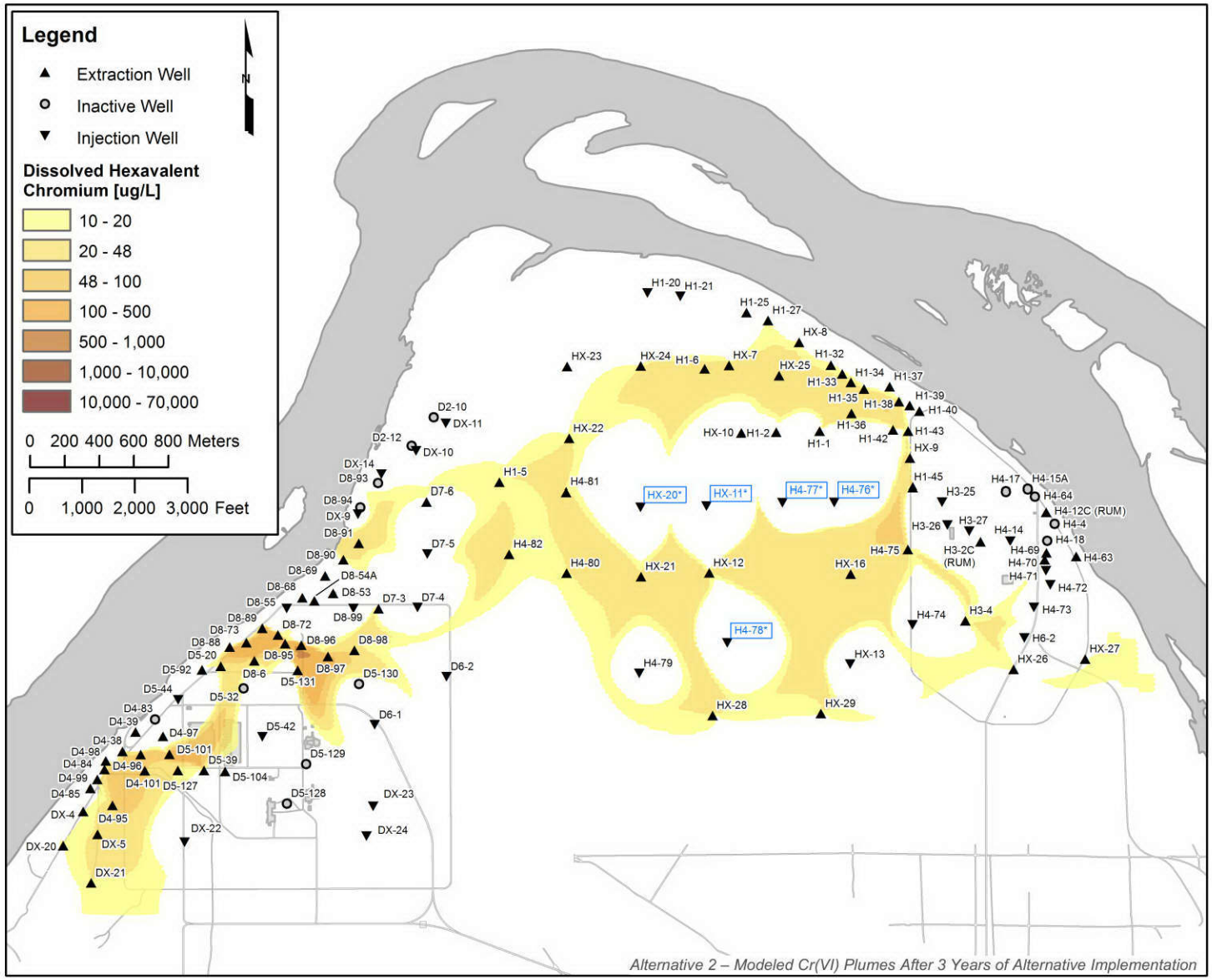


Figure 9-8a. Alternative 2—Modeled Cr(VI) Plumes after 3 Years

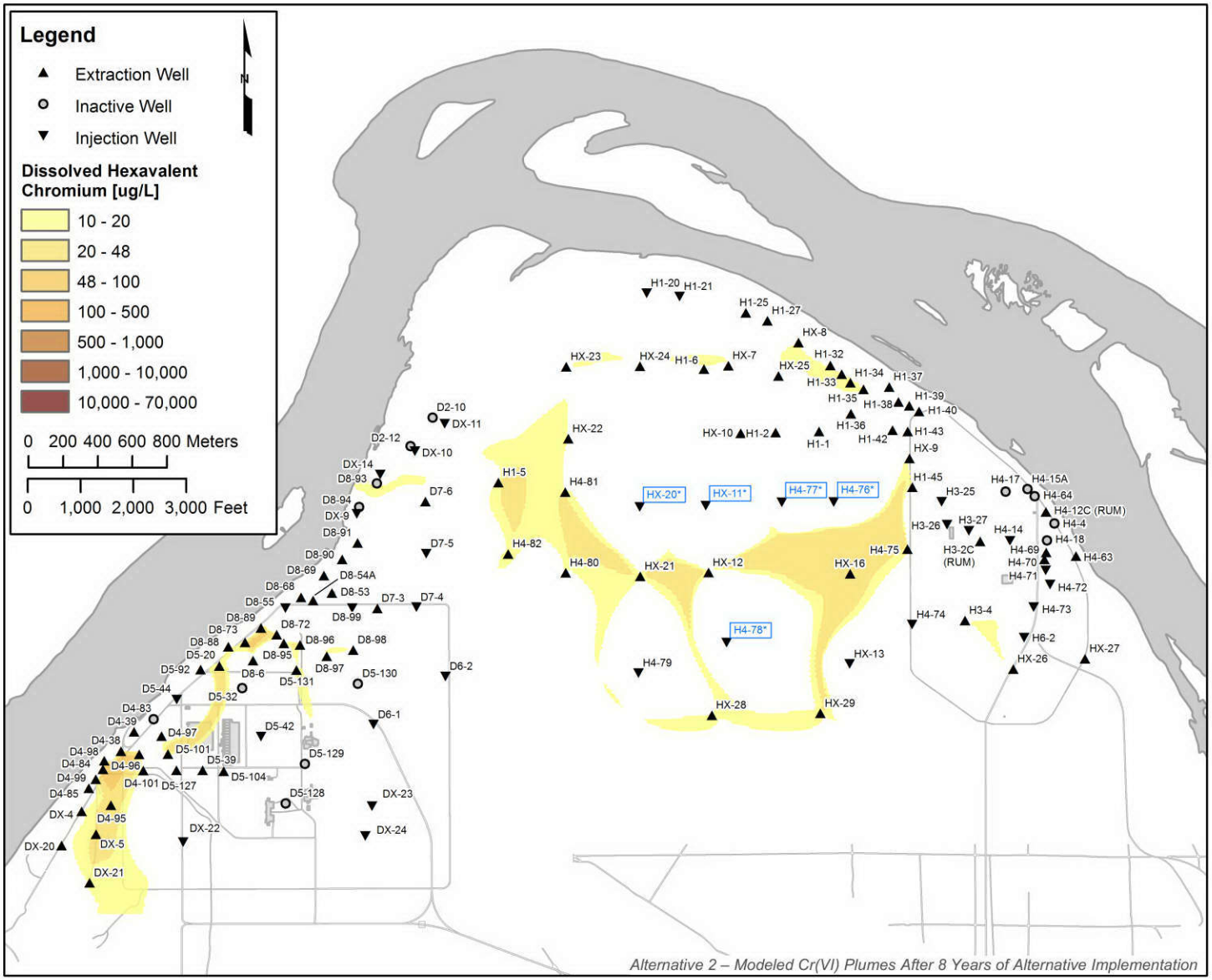


Figure 9-8b. Alternative 2—Modeled Cr(VI) Plumes after 8 Years

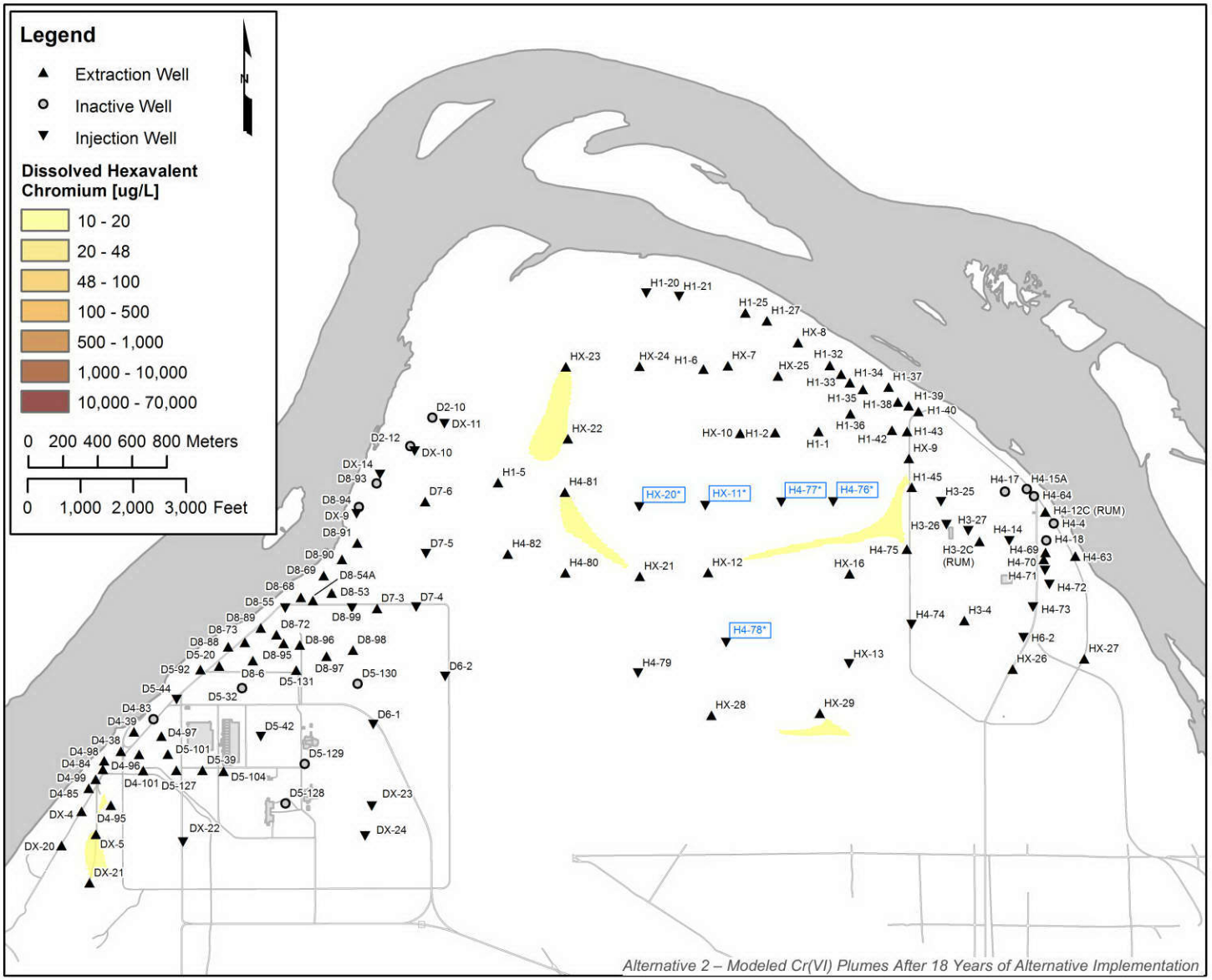


Figure 9-8c. Alternative 2—Modeled Cr(VI) Plumes after 18 Years

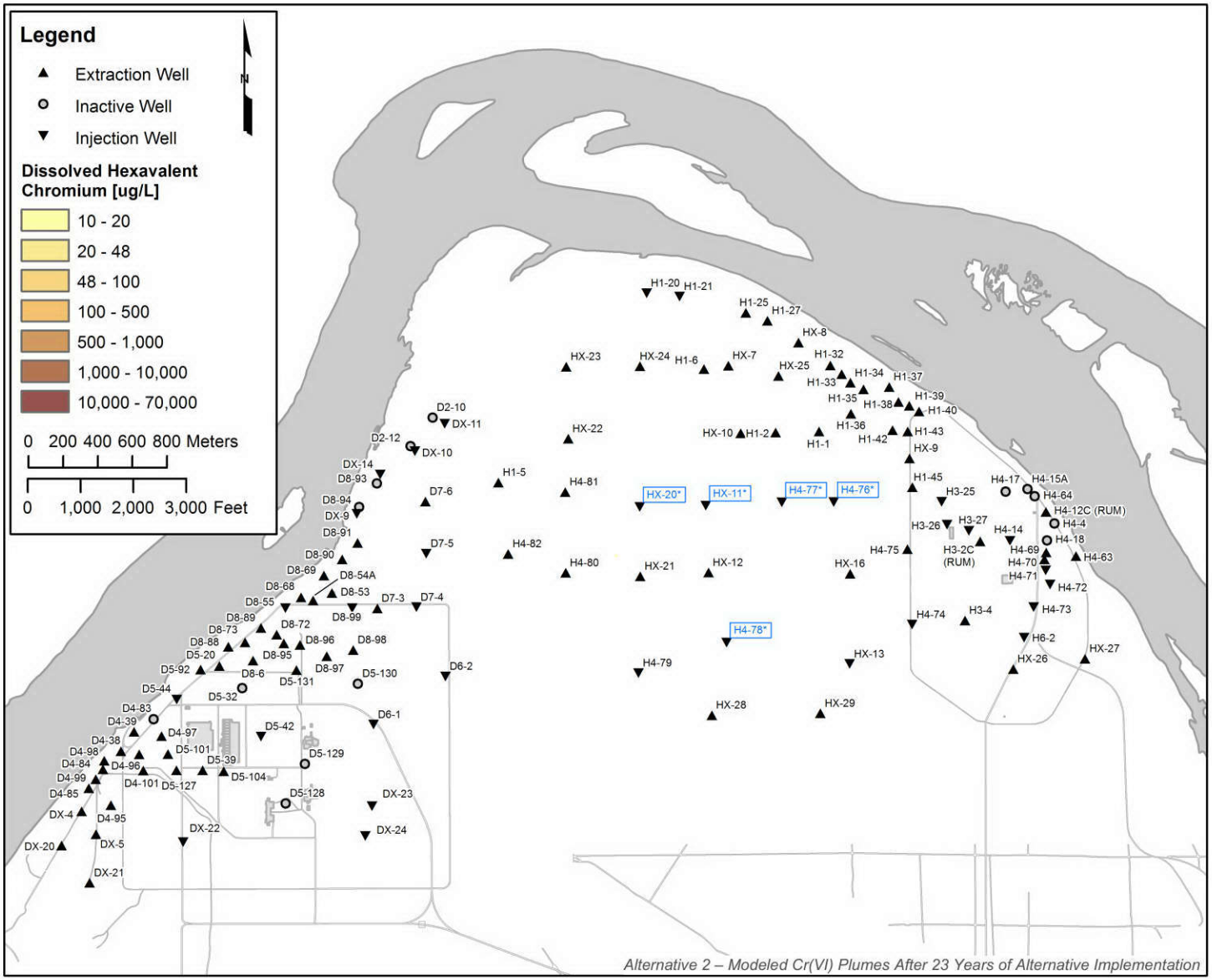


Figure 9-8d. Alternative 2—Modeled Cr(VI) Plumes after 23 Years

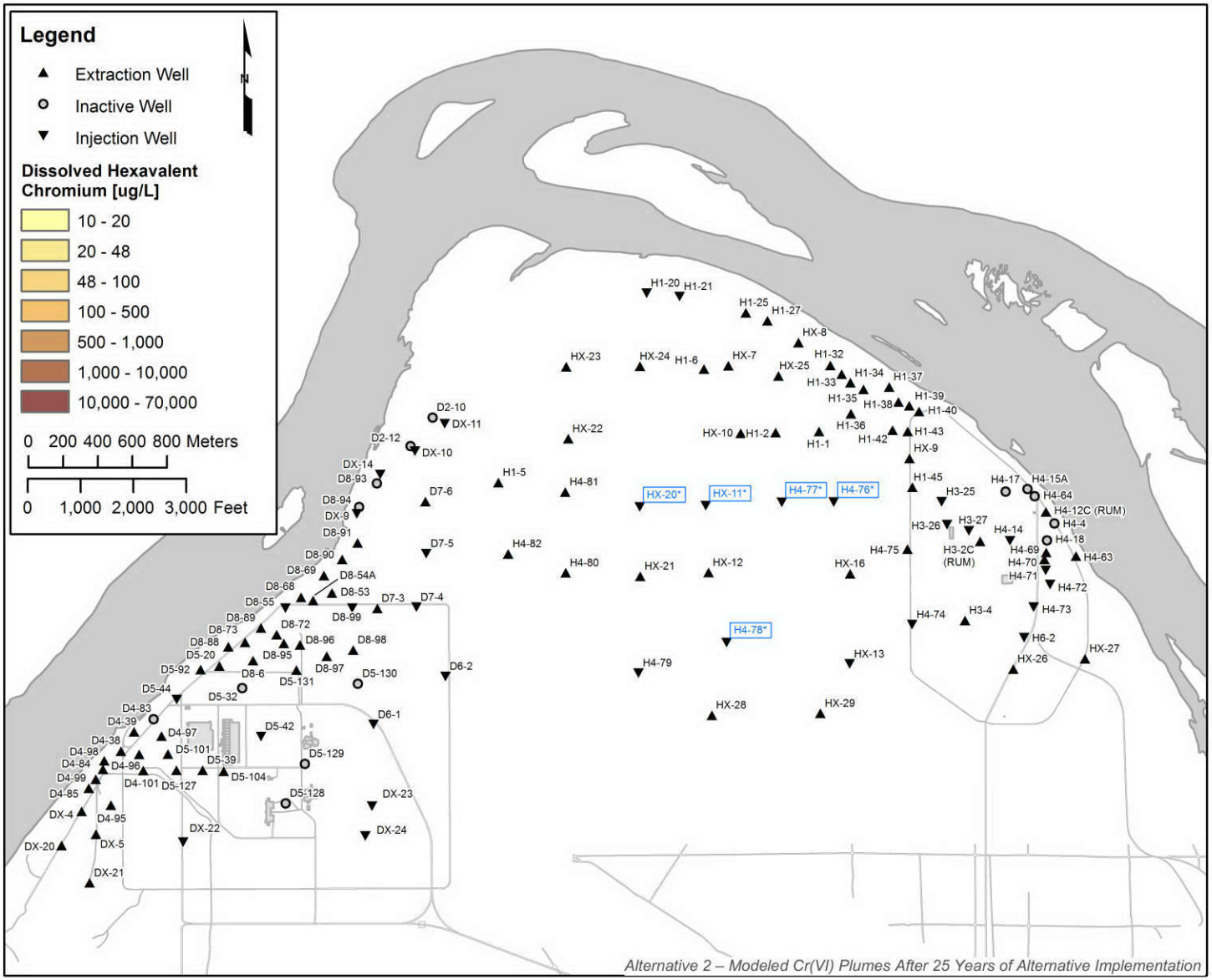


Figure 9-8e. Alternative 2—Modeled Cr(VI) Plumes after 25 Years

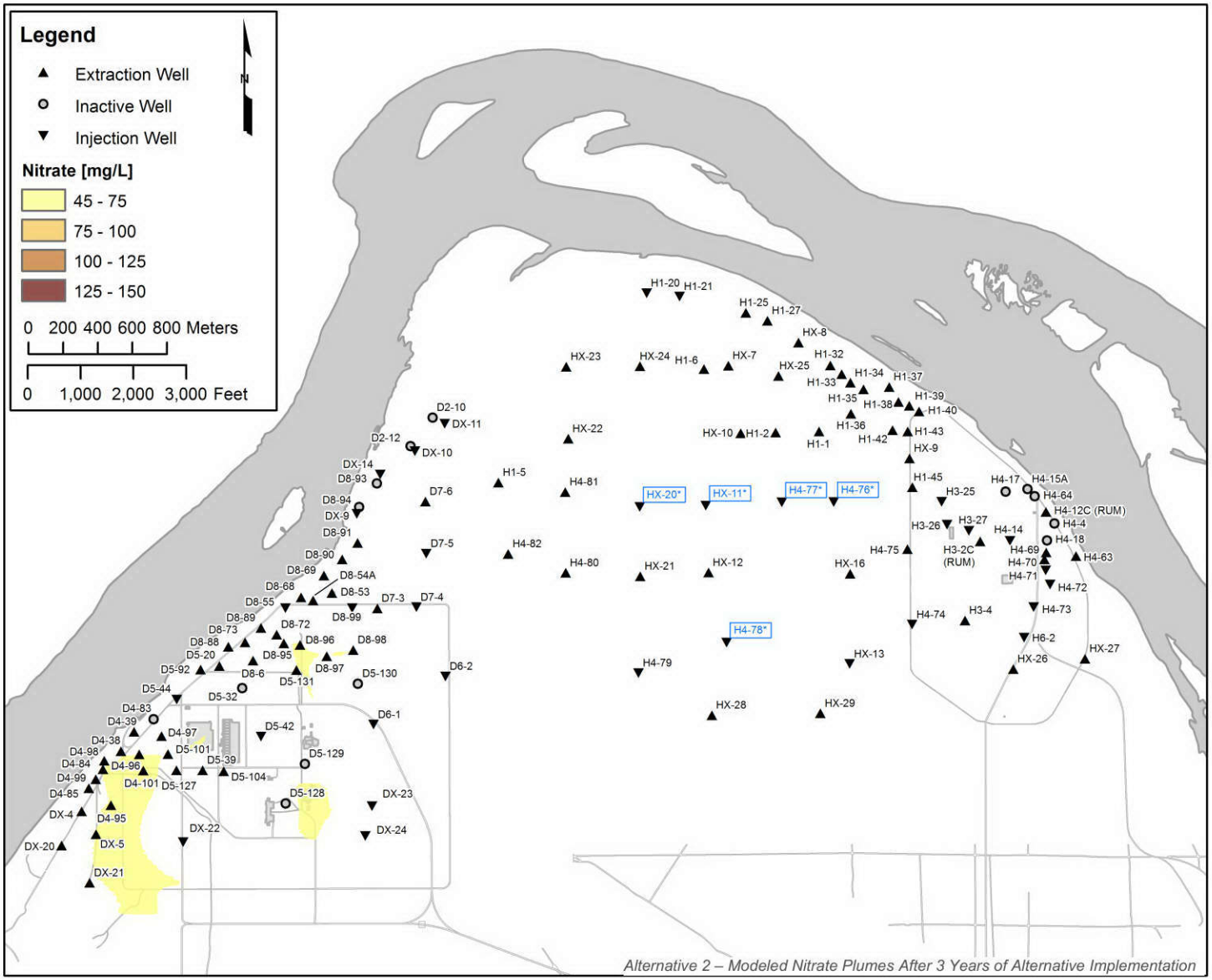


Figure 9-9a. Alternative 2—Modeled Nitrate Plumes after 3 Years

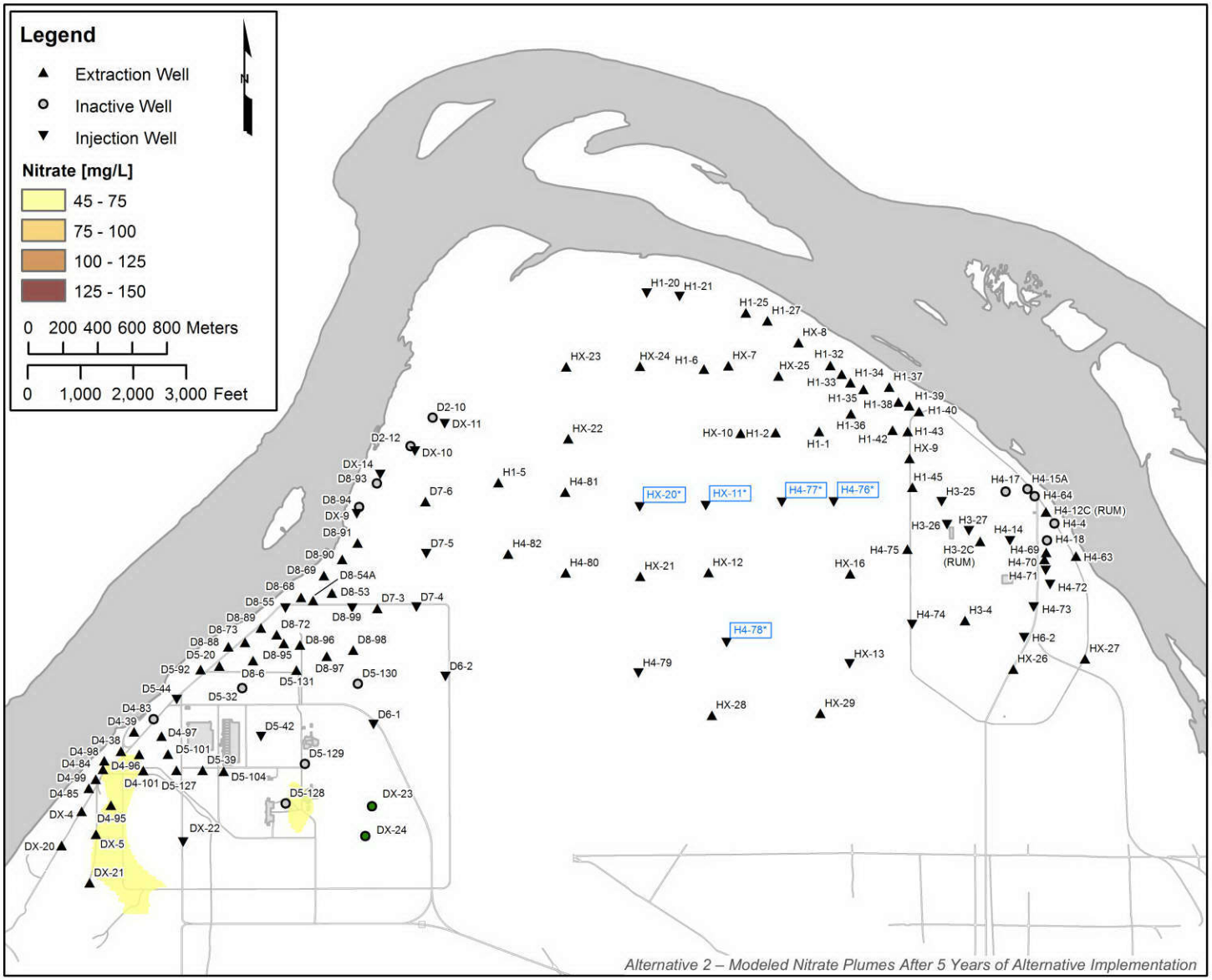


Figure 9-9b. Alternative 2—Modeled Nitrate Plumes after 5 Years

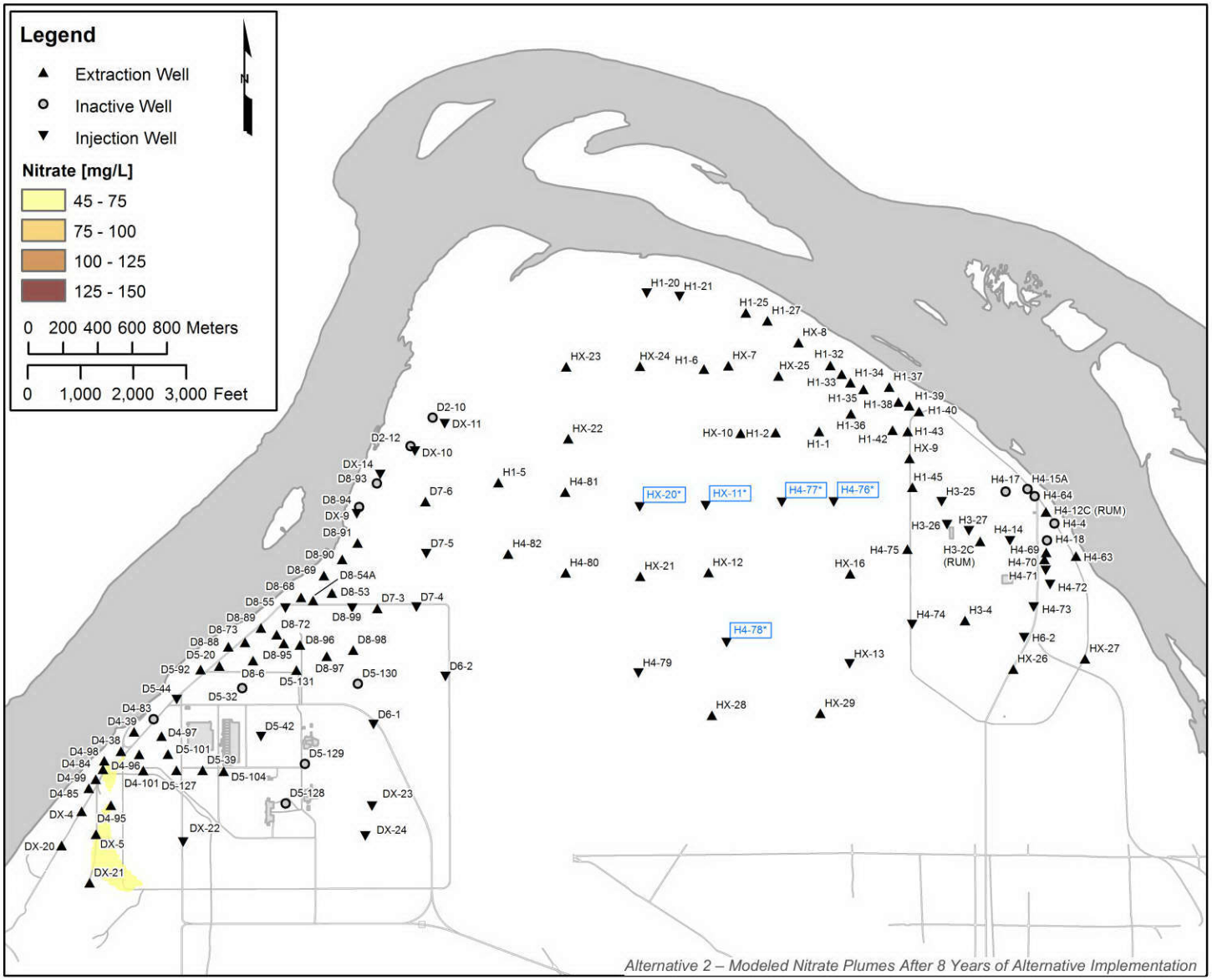


Figure 9-9c. Alternative 2—Modeled Nitrate Plumes after 8 Years

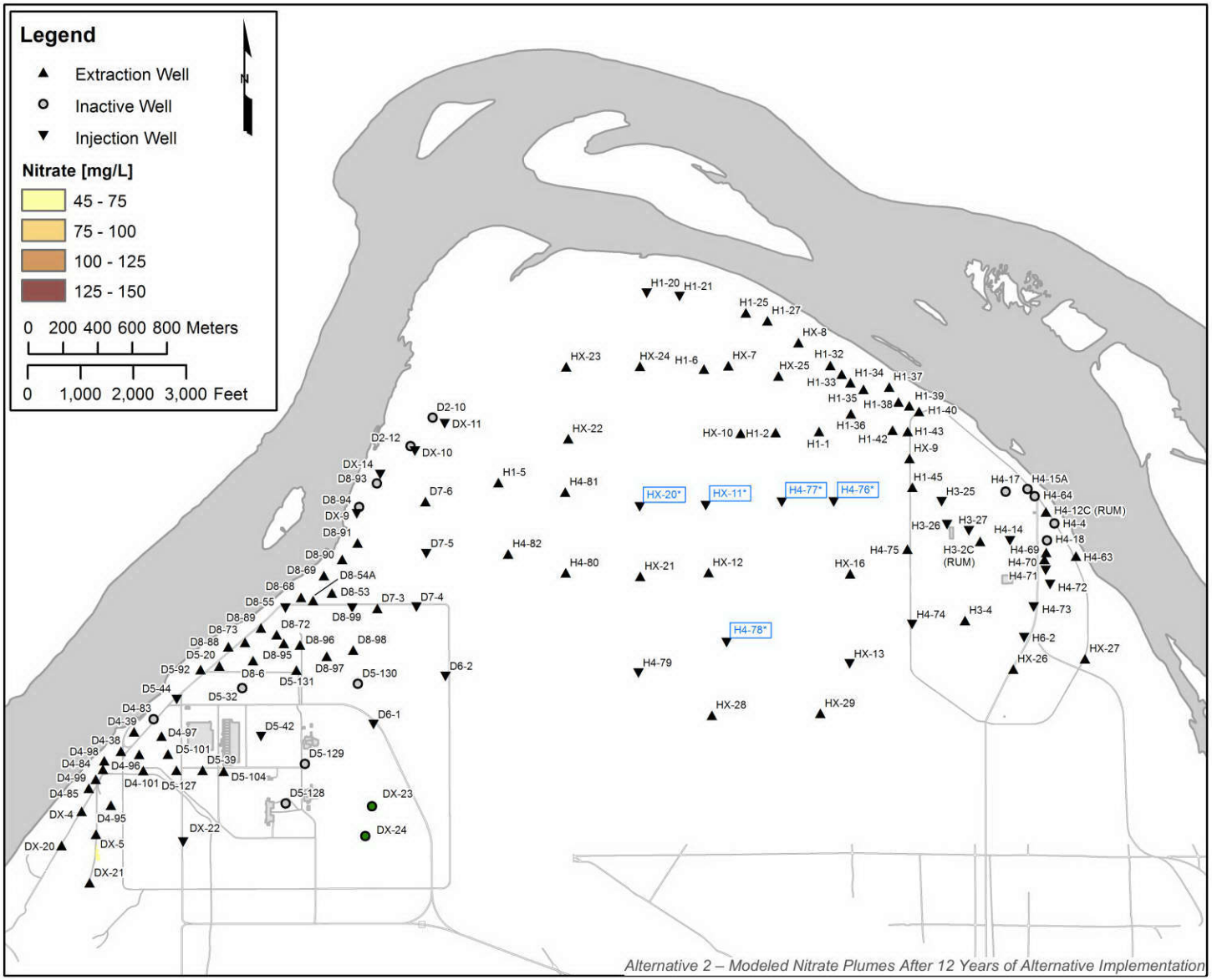


Figure 9-9d. Alternative 2—Modeled Nitrate Plumes after 12 Years

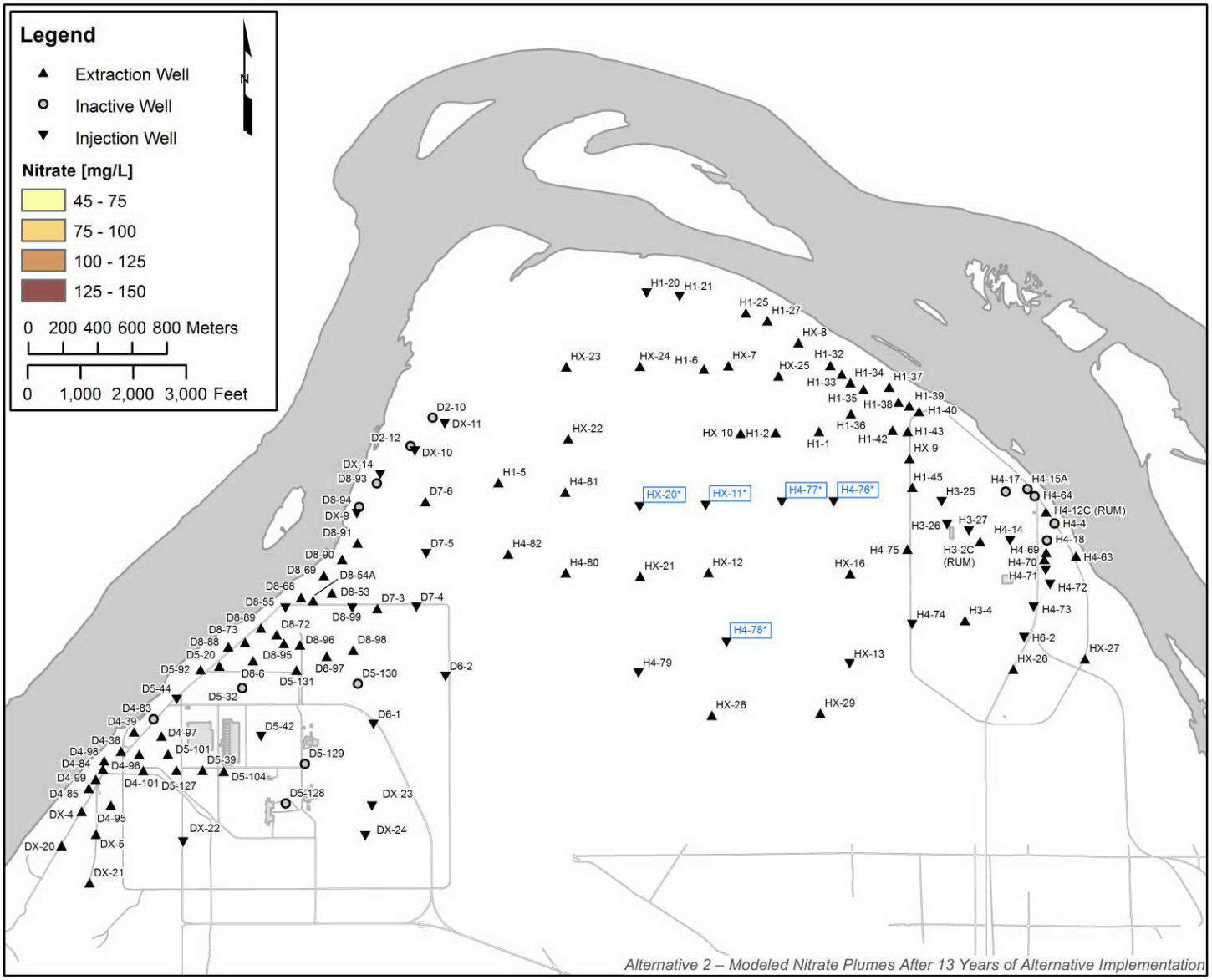


Figure 9-9e. Alternative 2—Modeled Nitrate Plumes after 13 Years

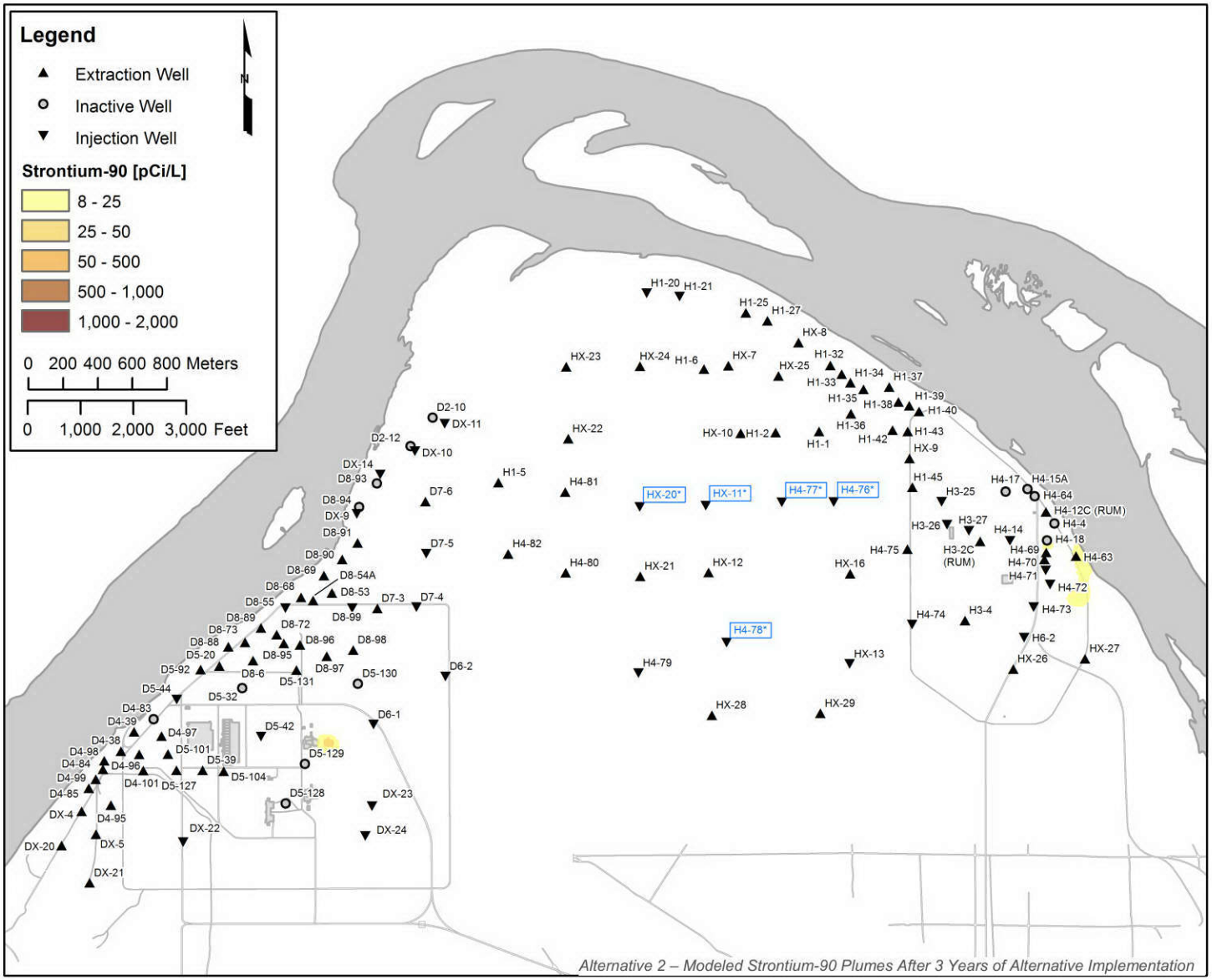


Figure 9-10a. Alternative 2—Modeled Strontium-90 Plumes after 3 Years

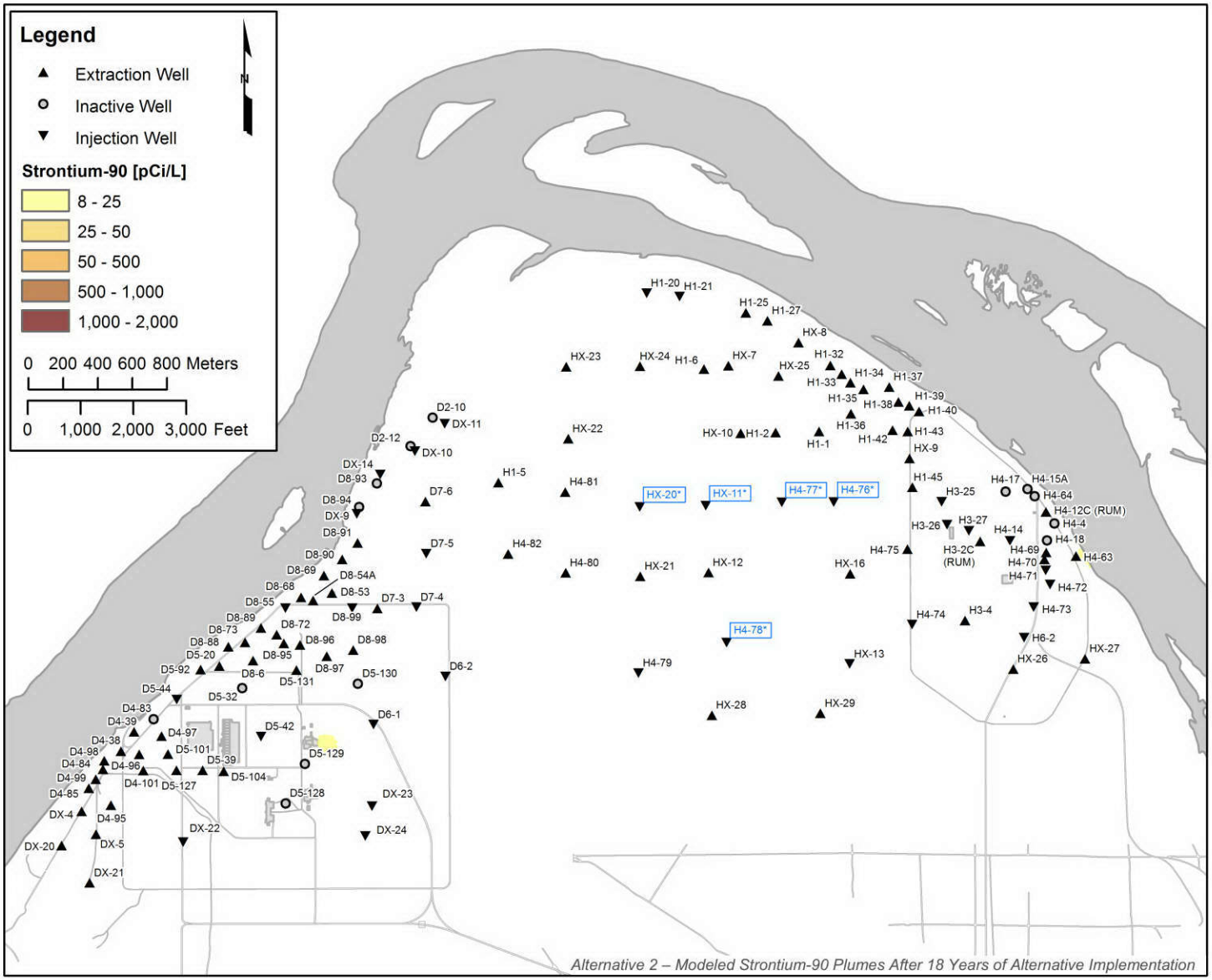


Figure 9-10b. Alternative 2—Modeled Strontium-90 Plumes after 18 Years

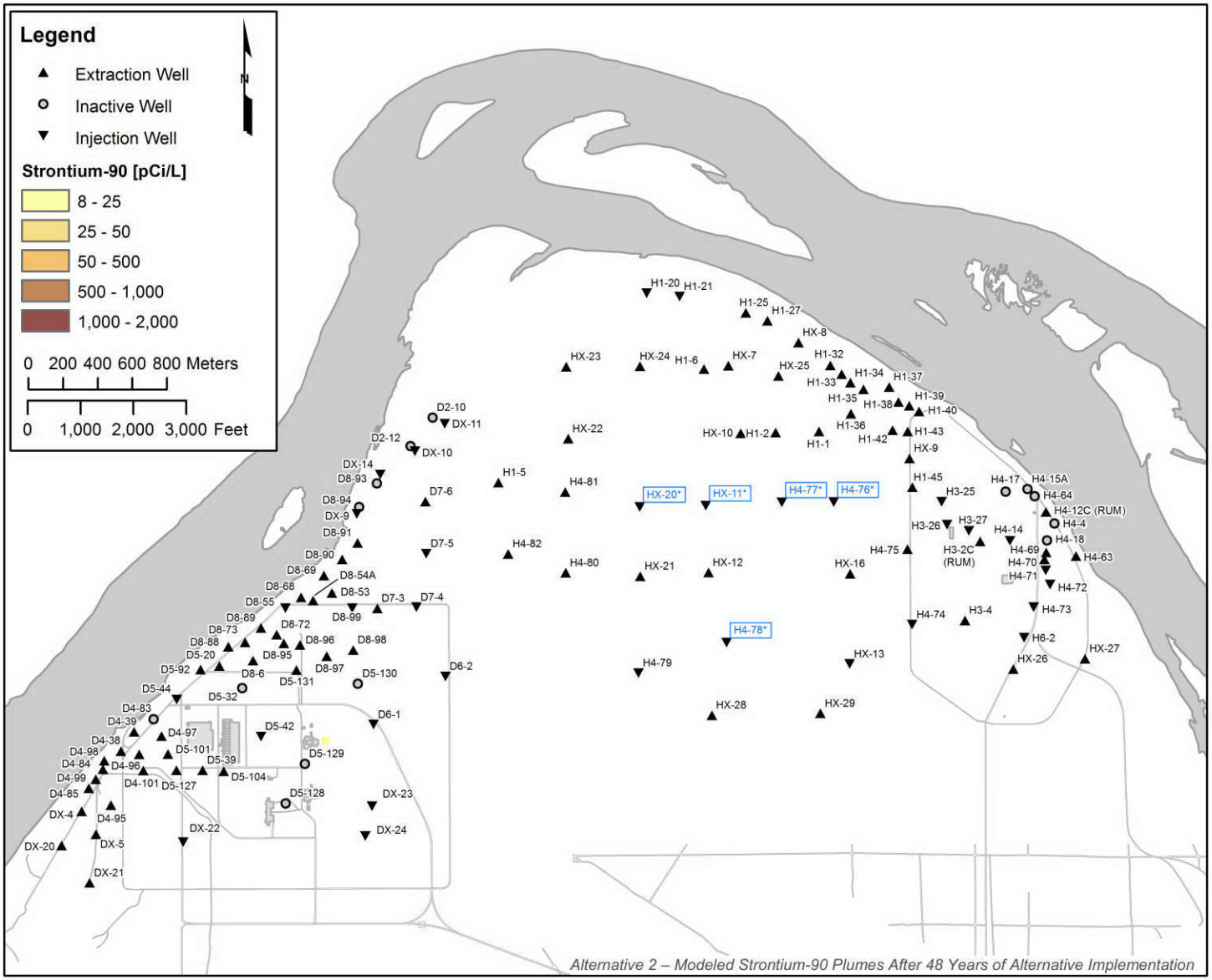


Figure 9-10c. Alternative 2—Modeled Strontium-90 Plumes after 48 Years

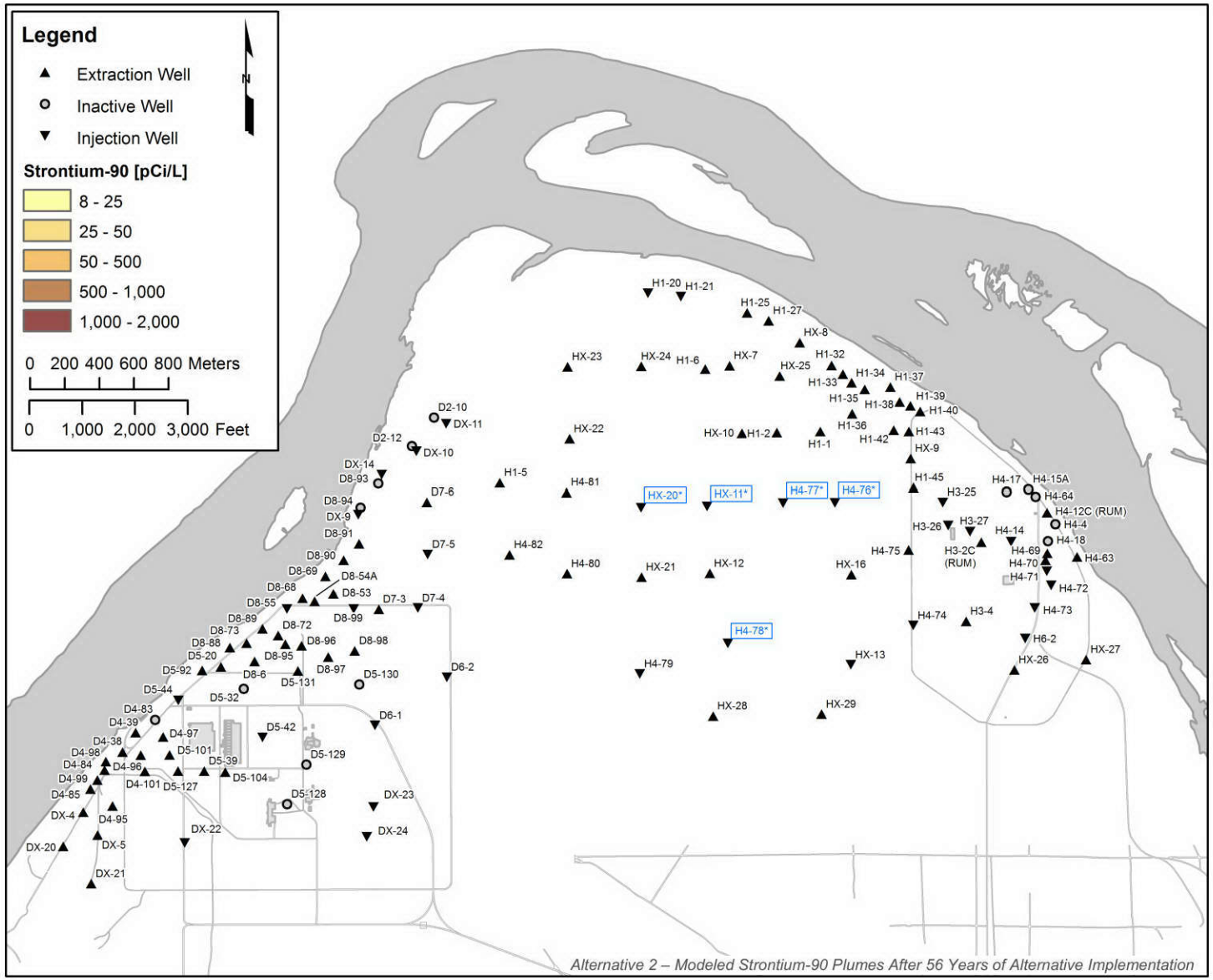


Figure 9-10d. Alternative 2—Modeled Strontium-90 Plumes after 56 Years

Uranium is identified as a localized contaminant associated with the 183-H Solar Evaporation Basin, and is within the capture zone of the pump-and-treat system. Uranium concentrations have been attenuating in wells downgradient, which have concentrations decreasing overall (Section 4.5.4). If uranium is detected following completion of Cr(VI) remediation and the shutdown of the pump-and-treat system, the localized uranium contamination will continue to be addressed through dispersion and diffusion by normal groundwater flow. Effectiveness of continued natural attenuation will be monitored through performance monitoring sampling. Uranium cleanup is not modeled since the concentrations were identified in a single well and have since decreased to below the DWS.

9.2.4 Alternative 3—RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Alternative 3 uses a combination of RTD, void-fill grouting, containment, and MNA/ICs for waste site remediation to achieve the RAOs, and expanded pump-and-treat for groundwater. Table 9-8 presents the waste site and groundwater components of Alternative 3, and Figure 9-11 presents a pictorial summary of Alternative 3. The cost for Alternative 3 is provided in Table 9-9. Details for the cost estimate are provided in Appendix J (*Environmental Cost Estimate for 100-D/H Vadose Zone and Groundwater RI/FS* [ECE-100HR311-00004]). Additional details on remedial components specific to this alternative are presented in sections identified in Table 9-8.

Table 9-8. Components for Alternative 3—RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Waste Site Components	General Components	
	No Further Action	No additional remedial actions are taken for the 146 waste sites identified in Section 8.2.1.1 (Chapter 8).
	Institutional Controls	Institutional controls to be implemented within the 100-D, 100-H, and Horn areas for land use management and waste site information management include the following: • Permits required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land use and real property controls (for example, proprietary controls including easements and covenants) ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents. • Notices providing visual identification and warning of hazardous or sensitive areas. • Procedural requirements for access, warning signs, or fencing to prevent or limit the access of humans to hazardous or sensitive areas. • Administrative mechanisms, such as the WIDS database, to maintain and provide access to information on the location and nature of contamination. Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8). Post remediation institutional controls implemented at specific waste sites are identified in Table 9-4.

Table 9-8. Components for Alternative 3—RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Waste Site Components (cont.)	**For Waste Sites That Exceed Human Health, Environment, Surface Water, or Groundwater Protection PRGs**	
	MNA/institutional control	MNA/institutional controls applied to waste sites 116-D-8, 116-DR-9 and 100-D-25. Waste site 100-D-25 is fully encompassed within waste site 116-DR-9. Risk evaluation of the verification data indicates that the shallow decision units for these sites contain Cs-137 at concentrations greater than the residential RBSL (Chapter 6). No ecological risks are identified for the sites (Chapter 7). Cesium-137 concentrations at the three sites will decay through natural attenuation to levels less than residential RBSLs in year 2035. Institutional controls will be in place through this period. Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8).
	Void-fill Grouting	Void-fill grouting, as described in Section 9.2.3.1, will be used to remediate the box flumes of the 100-H-36 waste site to immobilize contaminants on interior surfaces of the underground concrete box flume sluiceway.
	RTD	RTD to depth of contamination exceeding surface water or groundwater PRGs, or until groundwater is encountered if contamination extends into groundwater, using standard and deep excavation technologies, as described in Section 9.2.2.2. RTD is applied to waste sites listed in Table 8-5 (Chapter 8) that are expected to be remediated under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039). 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). RTD also applied to waste sites listed in Table 8-5 (Chapter 8) that are yet to be remediated and are not remediated under one of the other waste site remedial components listed previously. Table 9-2 identifies applicable waste sites remediated by RTD using standard and deep excavation technologies. 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.

Table 9-8. Components for Alternative 3—RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Groundwater Components	Pump-and-Treat	Operation of existing pump-and-treat systems with additional 2,370 L/min (625 gal/min) treatment capacity at 100-DX and 3,030 L/min (800 gal/min) at100-HX pump-and-treat systems, and extraction and injection wells to expand treatment coverage. Placement of additional extraction and injection wells, extraction and injection flow rates, and well operational periods were determined through groundwater model simulations described in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114). The RPO process will be used to provide ongoing evaluations to ensure the system meets ROD requirements. Designed to treat Cr(VI) with active remediation out to Cr(VI) 10 µg/L contour. Treatment of extracted water through ion exchange. Operation of pump-and-treat system to meet the State surface water quality standard at points of groundwater discharge to the river. Periodic rehabilitation, replacement, reconfiguration and decommissioning of the remediation system components as described in Section 9.2.2.6.
	MNA and Institutional Controls	MNA as described in Section 9.2.2.3. Manage strontium-90 in groundwater through MNA and institutional controls until concentrations meet cleanup standards. Manage the plumes until concentrations are below the cleanup levels in the plume and after the pump-and-treat system is shut off. Monitoring of COCs to track the attenuation processes. Institutional controls to be implemented within 100-D/H include land use management and waste site information management. Additional institutional controls implemented at specific waste sites include the following: • Permits required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents • Land use and real property controls (for example, proprietary controls including easements and covenants) ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents • Groundwater use management, as described in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41), ensures proper use of groundwater through groundwater controls
	MNA and Institutional Controls (cont.)	• Administrative mechanisms, such as the WIDS database, to maintain and provide access to information on the location and nature of contamination Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8).

Table 9-8. Components for Alternative 3—RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Groundwater Components (cont.)	Monitoring Requirements	Remedy performance monitoring will be defined as part of the remedial design. Evaluates the effectiveness of the selected alternative to attain the cleanup levels. The existing monitoring program will be expanded when number of monitoring wells is added. For cost estimating purposes, it has been assumed that 12 new monitoring wells will be installed. Groundwater performance monitoring is presented in Section 9.2.2.7 for constituents included in the monitoring program. The constituents include COCs (chromium (total), Cr(VI), nitrate, and strontium 90) and analytes identified for additional monitoring (antimony, cadmium, carbon tetrachloride, cobalt, copper, nickel, silver, and zinc).

CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC = contaminant of concern
MNA = monitored natural attenuation
PRG = preliminary remediation goal
RBSL = risk-based screening level
ROD = record of decision
RTD = removal, treatment, and disposal
SMDP = scientific management decision point
WIDS = Waste Information Data System

Remediation components specific to Alternative 3 (described in Table 9-8) are described in Section 9.2.2 under common elements and Section 9.2.3.1 for void-fill grouting.

9.2.4.1 Groundwater Model for Alternative 3

This section provides a summary of the groundwater model for Alternative 3. Alternative 3 includes expansion to the interim action pump-and-treat facilities to provide an additional 5,400 L/min (1,425 gal/min) treatment capacity to the interim action 100-D/H pump-and-treat systems. New extraction and injection wells will be installed, along with increased treatment capacity to handle the additional flow. Alternative 3 expands the pump-and-treat systems with 41 new or converted extraction and injection wells to the 100-DX pump-and-treat system and 49 new extraction and injection wells to the 100-HX pump-and-treat system. Well use (that is, extraction or injection) and duration of well operation is detailed in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114). Extraction and injection well locations, specified in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114, Table 3-5), were identified to support alternatives evaluation in this FS. The final placement of wells will be determined in the RD/RAWP.

The model assumes 85 percent availability of the pump-and-treat system capacity to account for scheduled and unforeseen shutdown periods. As a result, a total capacity of 3,940 L/min (1,040 gpm) was assumed for the DX pump-and-treat system and 5,150 L/min (1,360 gpm) for HX pump-and-treat system.

All waste sites will be remediated before final remediation of groundwater. Remedial action completion for waste site and groundwater remediation is described in Section 9.2.

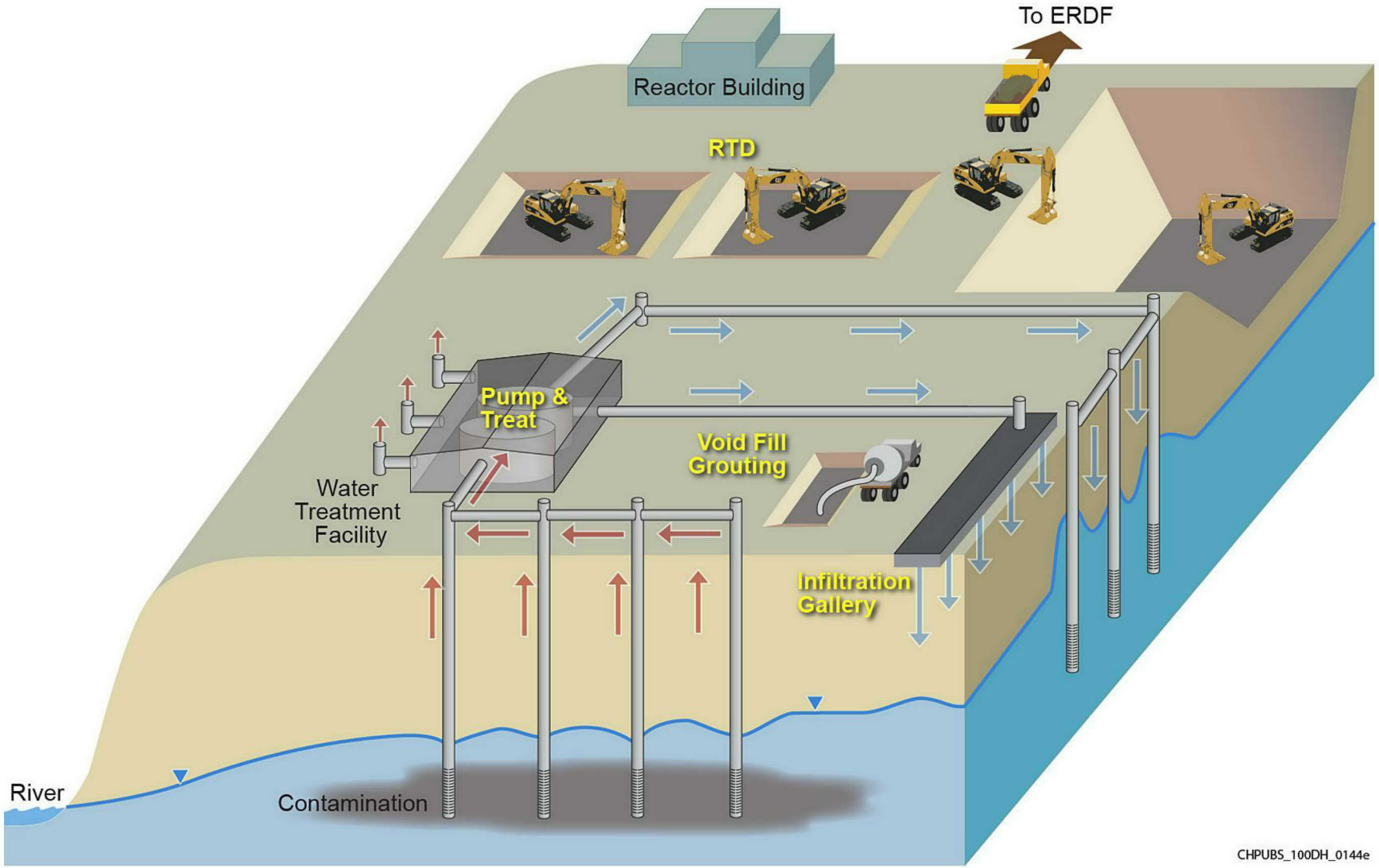


Figure 9-11. Alternative 3—RTD and Void-Fill Grouting for Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Table 9-9. Alternative 3—Cost Estimates (in Millions)[a]

Waste Site Treatment	Capital	$56.2
	Total O&M	$25.7
	Total Periodic[b]	$0.8
	Total Nondiscounted	$82.7
	Net Present Value	$66.7
Groundwater Treatment	Capital	$131.9
	Total O&M	$93.6
	Total Periodic[b]	$113.5
	Total Nondiscounted	$339.0
	Net Present Value	$308.4
Total Nondiscounted Cost of Alternative	$421.7	
Total Net Present Value (Discounted) of Alternative	$375.1	

a. Order of magnitude cost estimates and support information are presented in Appendix J. Costs for institutional controls are included under the costs for waste site treatment.

b. Periodic costs include O&M or construction activities, including costs to replace an installed remedy or components of an installed remedy, and services that are not included in initial capital costs or annual O&M costs. Periodic costs may be one-time costs or costs that recur at intervals over the life of the remedy.

O&M = operations and maintenance

Results of groundwater modeling (*Modeling of RI/FS Design Alternatives for 100-HR-3* [ECF-100HR3-11-0114]) predict COC plumes and trends over the remediation simulation period. The groundwater model results predict Cr(VI) plumes will be remediated to meet cleanup levels to the 48 µg/L DWS and 10 µg/L State surface water quality standard throughout the aquifer after 6 and 12 years, respectively, of implementing the groundwater remedy under Alternative 3. Figure 9-12 (a-d) show the modeled Cr(VI) groundwater plumes after 3, 6, 10, and 12 years of operating under this alternative.

EPC calculations will be used to determine completion of groundwater remedial actions following shut down of the pump-and-treat systems to evaluate for rebound conditions within the unconfined aquifer. MTCA compliance requirements (2007 MTCA, "Groundwater Cleanup Standards" [WAC 173-340-720(9)(d)(i)]) and EPA guidance (*Methods for Evaluating The Attainment Of Cleanup Standards Volume 2: Ground Water* [EPA 230-R-92-014]) will be used for the purpose of evaluating completion. The 95th UCL calculation will be used to demonstrate compliance as described in WAC 173-340-720(9)(d)(i).

During performance of the pump-and-treat operations, performance will be evaluated using a number of measures, including model predictions and statistical evaluations of measured concentration trends for the 100-D south, 100-D north, Horn area, and 100-H, and along the river shoreline.

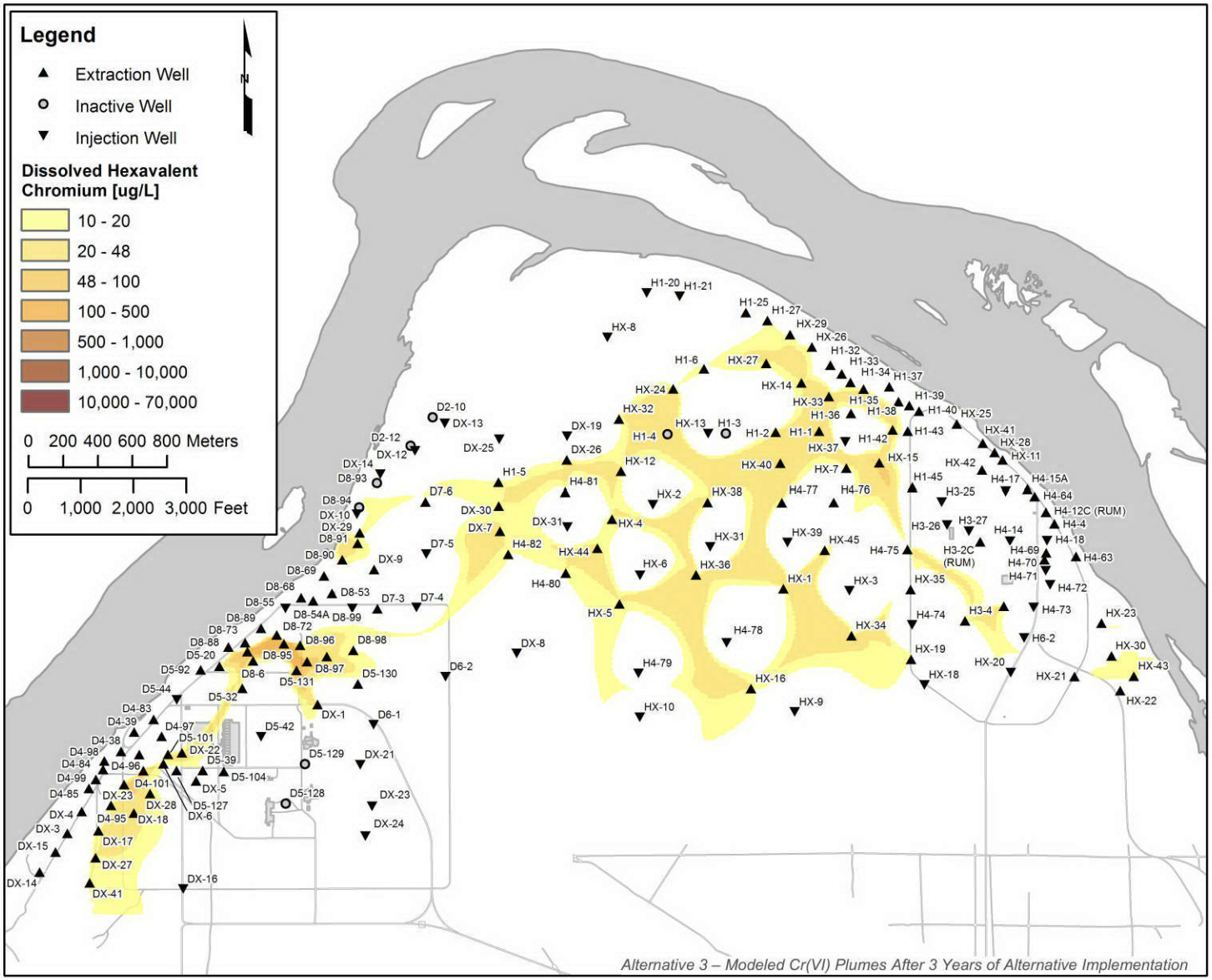


Figure 9-12a. Alternative 3—Modeled Cr(VI) Plumes after 3 Years

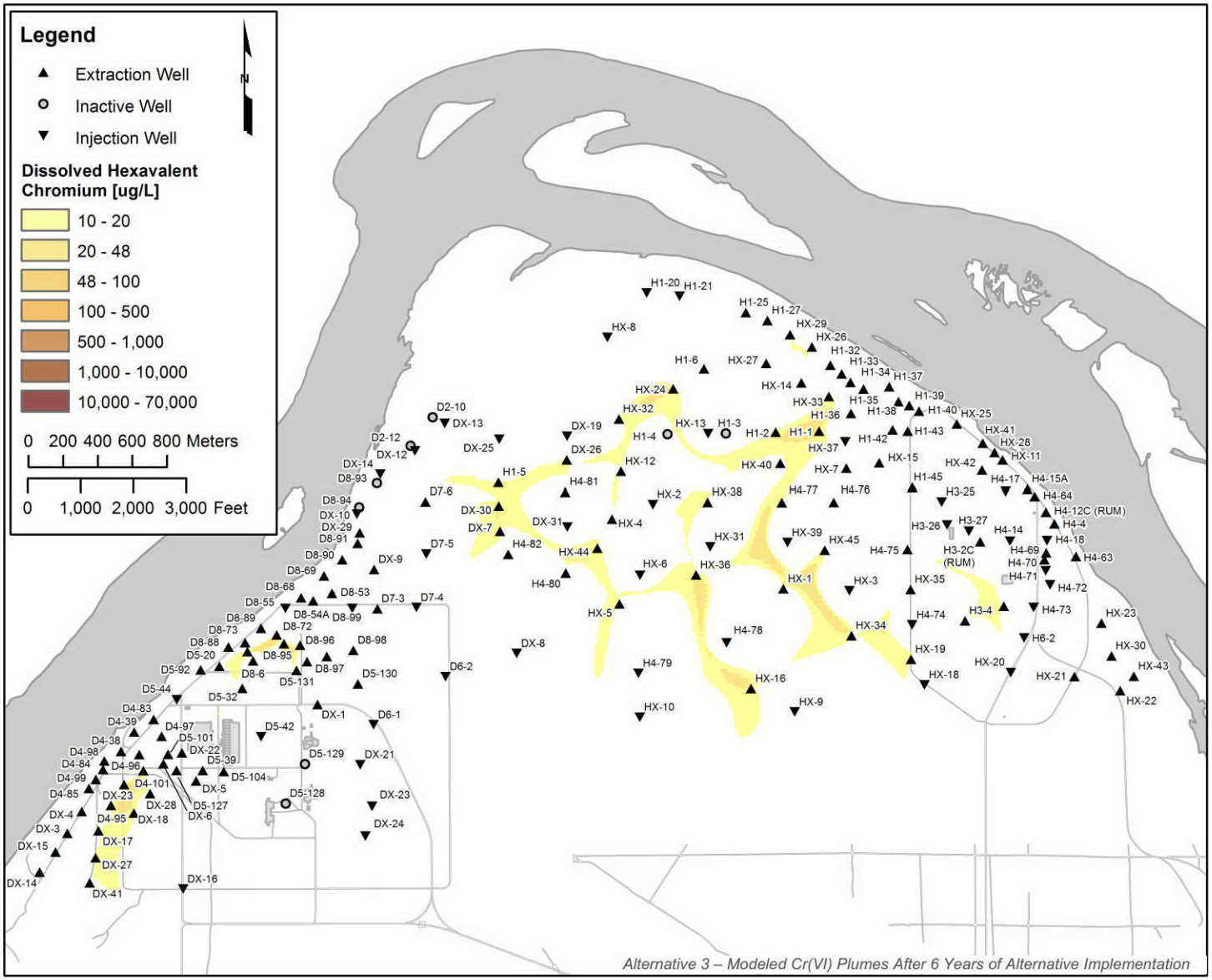


Figure 9-12b. Alternative 3—Modeled Cr(VI) Plumes after 6 Years

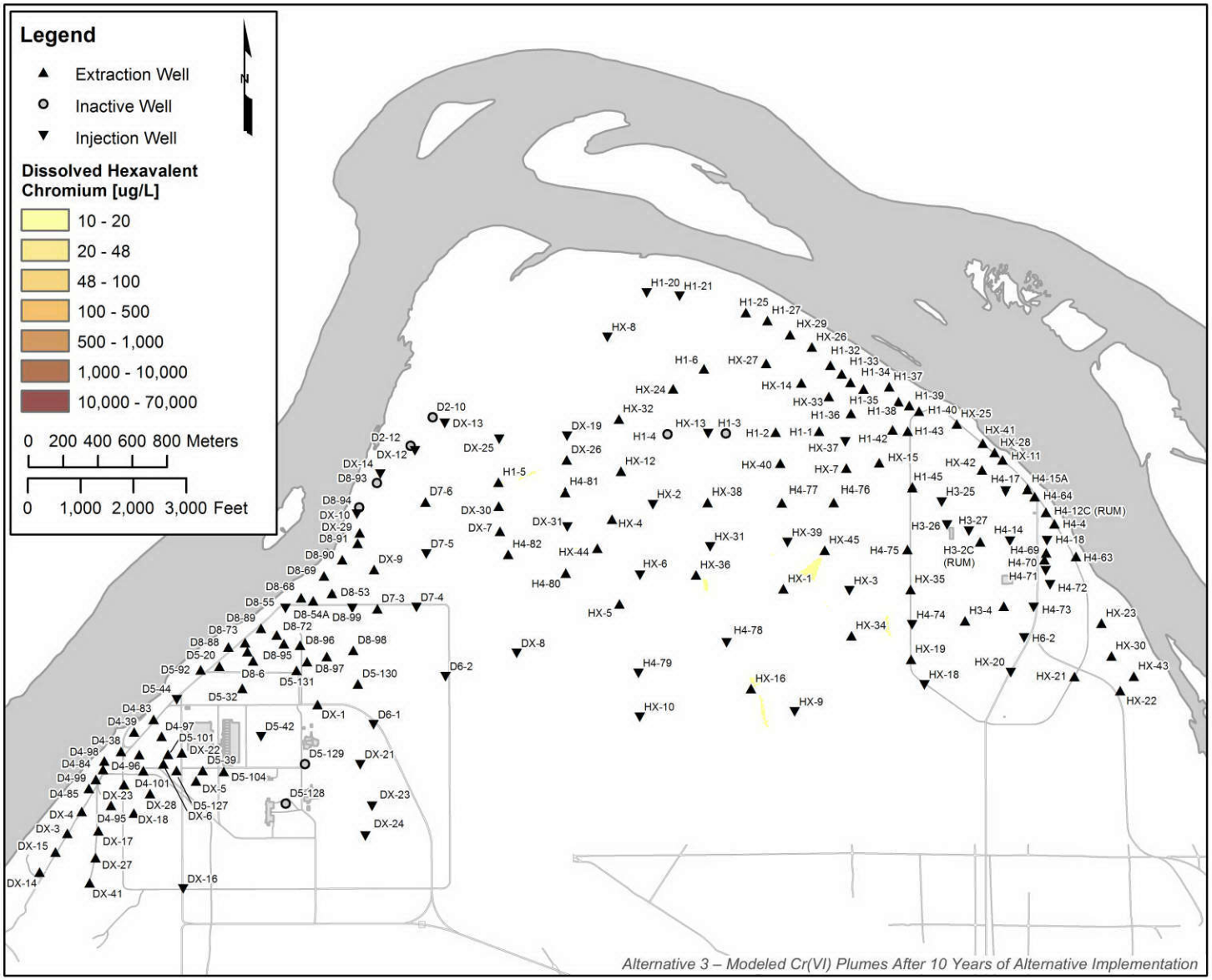


Figure 9-12c. Alternative 3—Modeled Cr(VI) Plumes after 10 Years

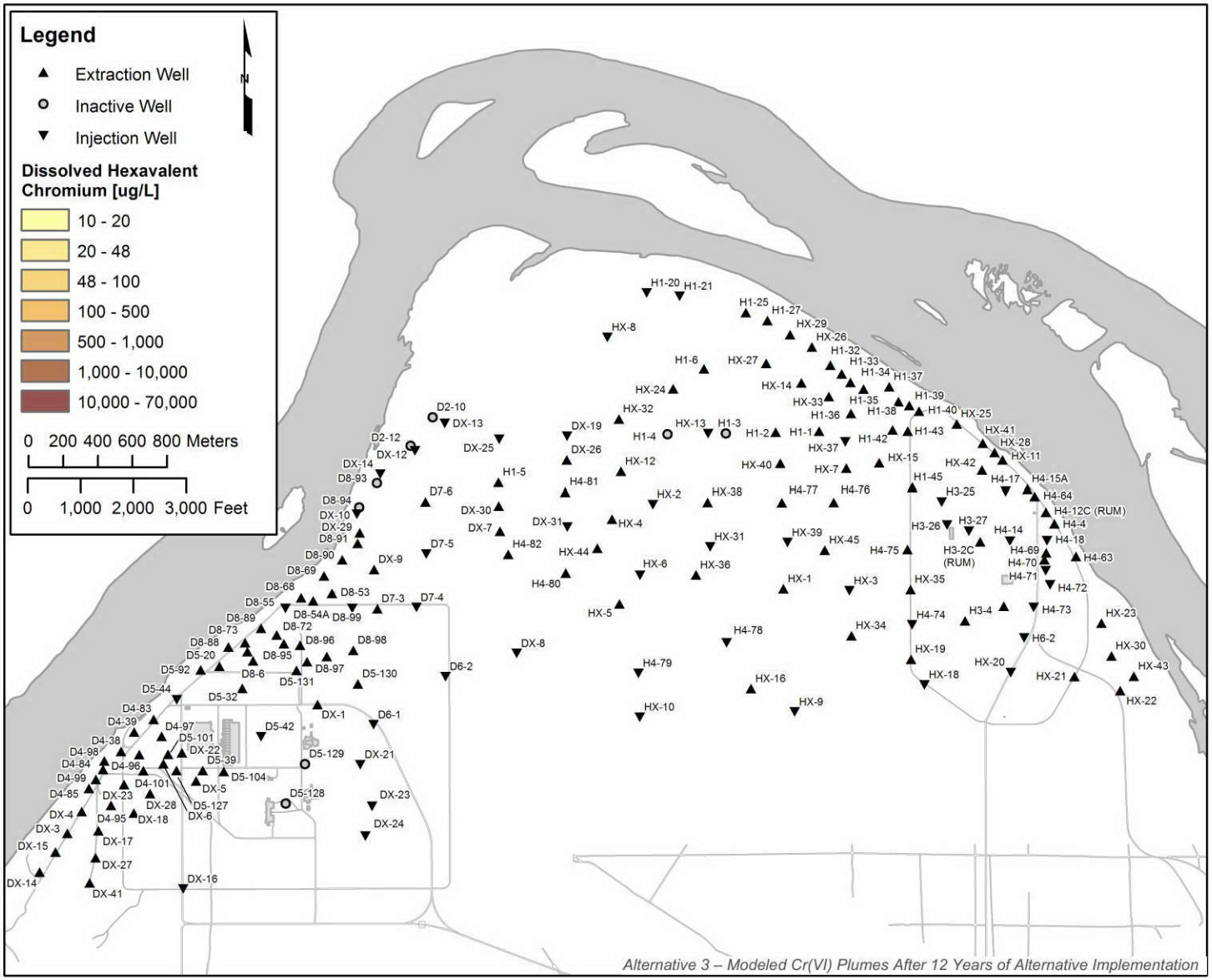


Figure 9-12d. Alternative 3—Modeled Cr(VI) Plumes after 12 Years

As described in Section 9.2, groundwater COCs co-extracted for treatment of the Cr(VI) plumes are managed through MNA and ICs to achieve cleanup levels. Predicted concentrations of the nitrate and strontium-90 COCs in the combined groundwater influent stream to the pump-and-treat facilities will be at concentrations below their respective cleanup levels. Predicted concentration trends for each COC in the combined influent to the pump-and-treat facilities are provided in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114). Cr(VI) in the treatment system influent will be removed using ion exchange treatment technology. The other COCs in the resulting treatment system effluent injected into the aquifer remains below cleanup levels.

Nitrate contaminated groundwater is within the capture footprint of the Cr(VI) pump-and-treat system well network. The groundwater model simulation for this alternative indicates that nitrate contamination is remediated to cleanup levels within the Cr(VI) remediation period. Nitrate plume depictions after 3, 5, and 6 years of operating under this alternative are provided in Figure 9-13 (a-c) showing nitrate concentrations are below cleanup levels after 6 years. No specific treatment or MNA will be needed for nitrate following the remediation of Cr(VI) through pump-and-treat.

Strontium-90 is localized, and has low solubility and mobility in groundwater. Modelling (Appendix F) indicates that small pockets of strontium-90 contamination will remain in the aquifer above cleanup levels following pump-and-treat system shut down. The remedy for strontium-90 following active remediation is MNA through radioactive decay. Remaining strontium-90 contamination will attenuate to cleanup levels through radiological decay in 32 years after Cr(VI) remediation (i.e., 44 years after implementation of the Alternative 3 remedy). Strontium-90 plume depictions after 3, 13, 38, and 44 years of operating under this alternative are provided in Figure 9-14 (a-d).

Uranium is identified as a localized contaminant associated with the 183-H Solar Evaporation Basin, and is within the capture zone of the pump-and-treat system. Uranium concentrations have been attenuating in wells downgradient, which have concentrations decreasing overall (Section 4.5.4). If uranium is detected following completion of Cr(VI) remediation and the shutdown of the pump-and-treat system, the localized uranium contamination will continue to be dispersed and diffused by normal groundwater flow. Effectiveness of continued natural attenuation will be monitored through performance monitoring sampling. Uranium cleanup is not modeled since the concentrations were identified in a single well and have since decreased to below the DWS.

9.2.5 Alternative 4—RTD for Waste Sites and Pump-and-Treat for Groundwater

Alternative 4 uses RTD for waste site contamination removal to achieve the RAOs, with the greatest degree of certainty, and pump-and-treat for groundwater. Table 9-10 presents the waste site and groundwater components of this alternative, and Figure 9-15 presents a pictorial summary of Alternative 4. The cost for this alternative is provided in Table 9-11. Details for the cost estimate are provided in Appendix J (*Environmental Cost Estimate for 100-D/H Vadose Zone and Groundwater RI/FS* [ECE-100HR311-00004]). Additional details on remedial components specific to this alternative are presented in sections identified in Table 9-10.

9.2.5.1 Groundwater Model for Alternative 4

The groundwater model simulation for Alternative 4 expands the interim action pump-and-treat system to include additional extraction and injection wells, thus encompassing a larger area of the COC plumes to expedite hydraulic containment and recovery. This alternative expands the pump-and-treat system with 20 new or converted wells for extraction and injection associated with DX, and 24 new or converted wells for extraction and injection at 100-H. The duration of well operation is detailed in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114, Table 3-6).

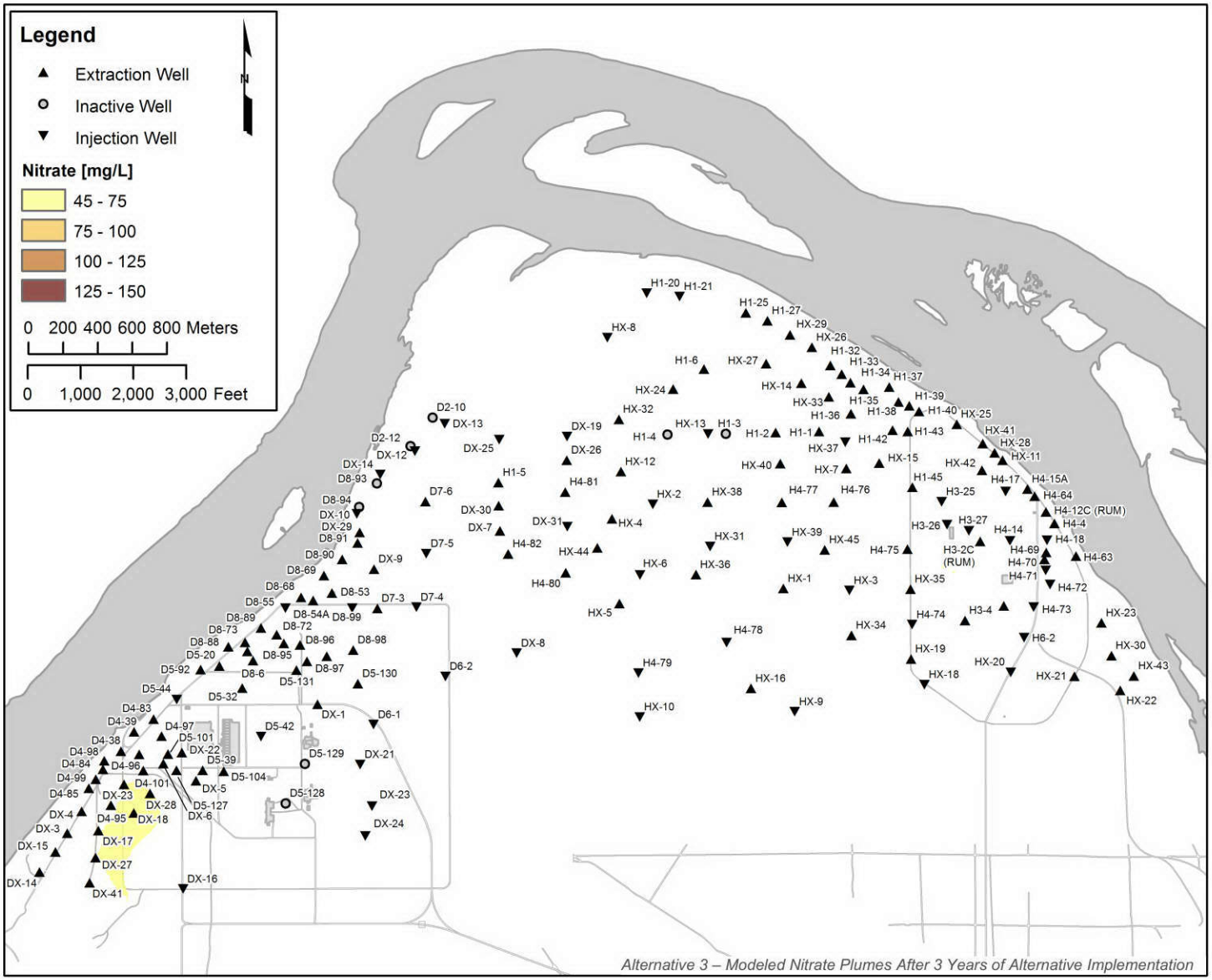


Figure 9-13a. Alternative 3—Modeled Nitrate Plumes after 3 Years

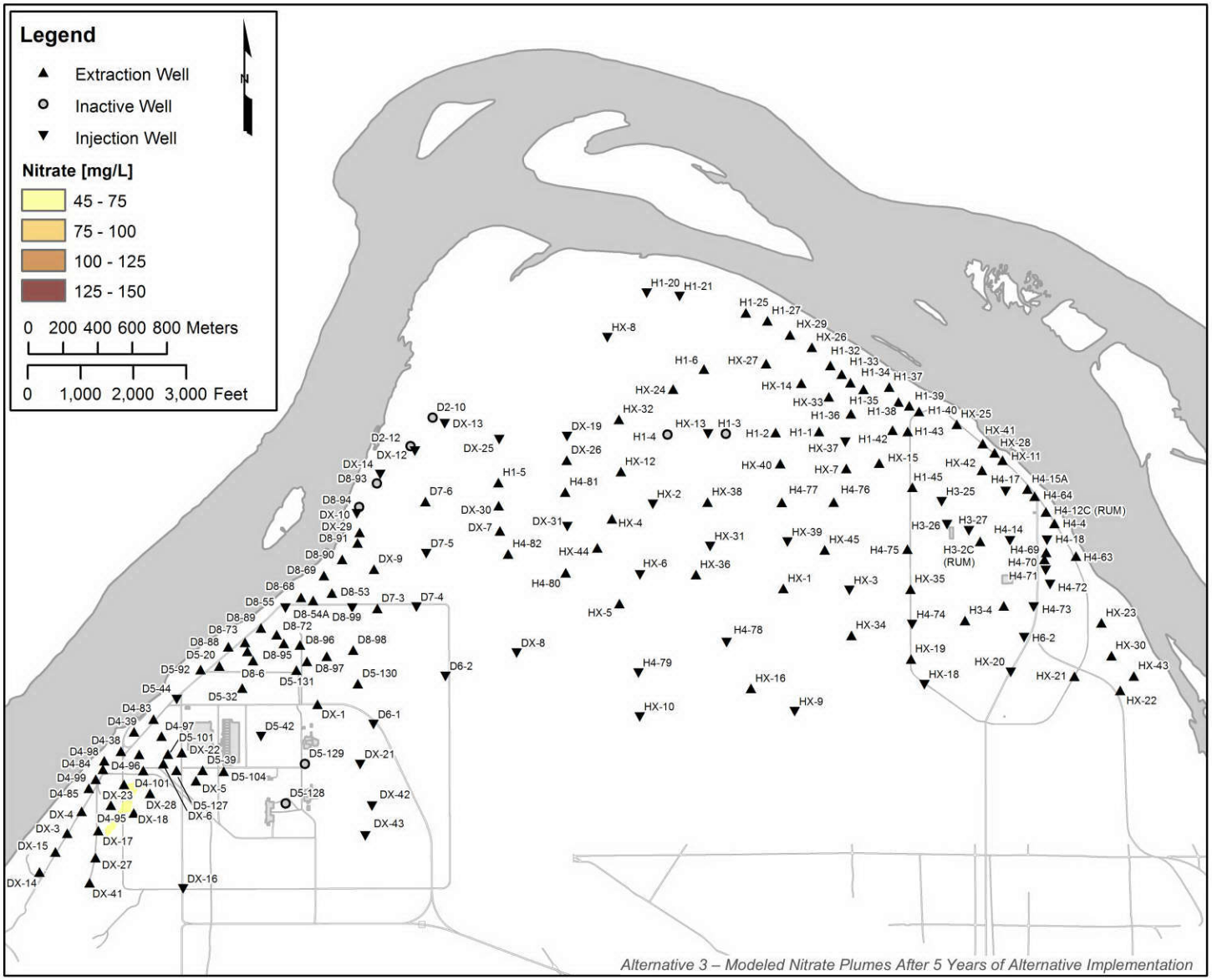


Figure 9-13b. Alternative 3—Modeled Nitrate Plumes after 5 Years

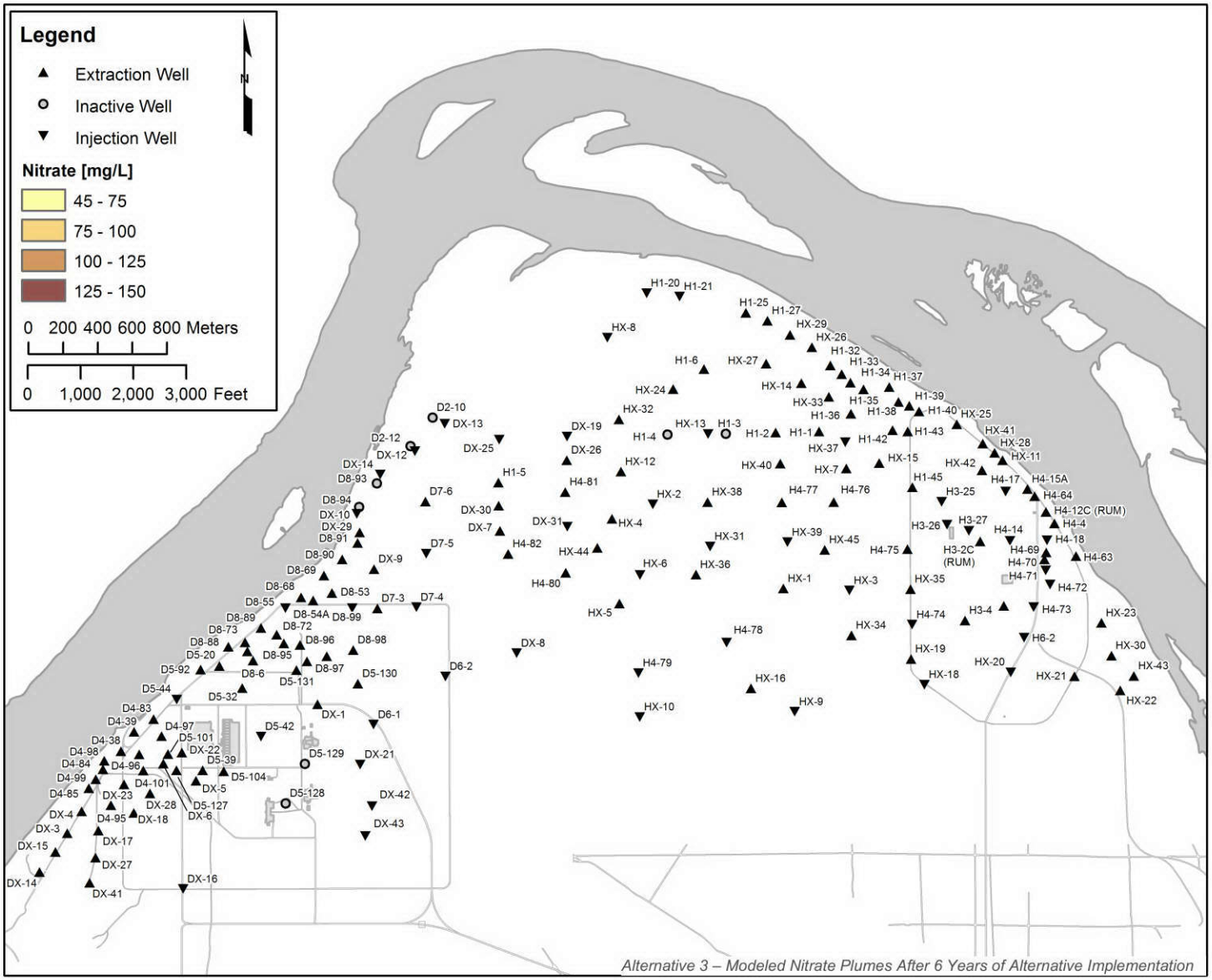


Figure 9-13c. Alternative 3—Modeled Nitrate Plumes after 6 Years

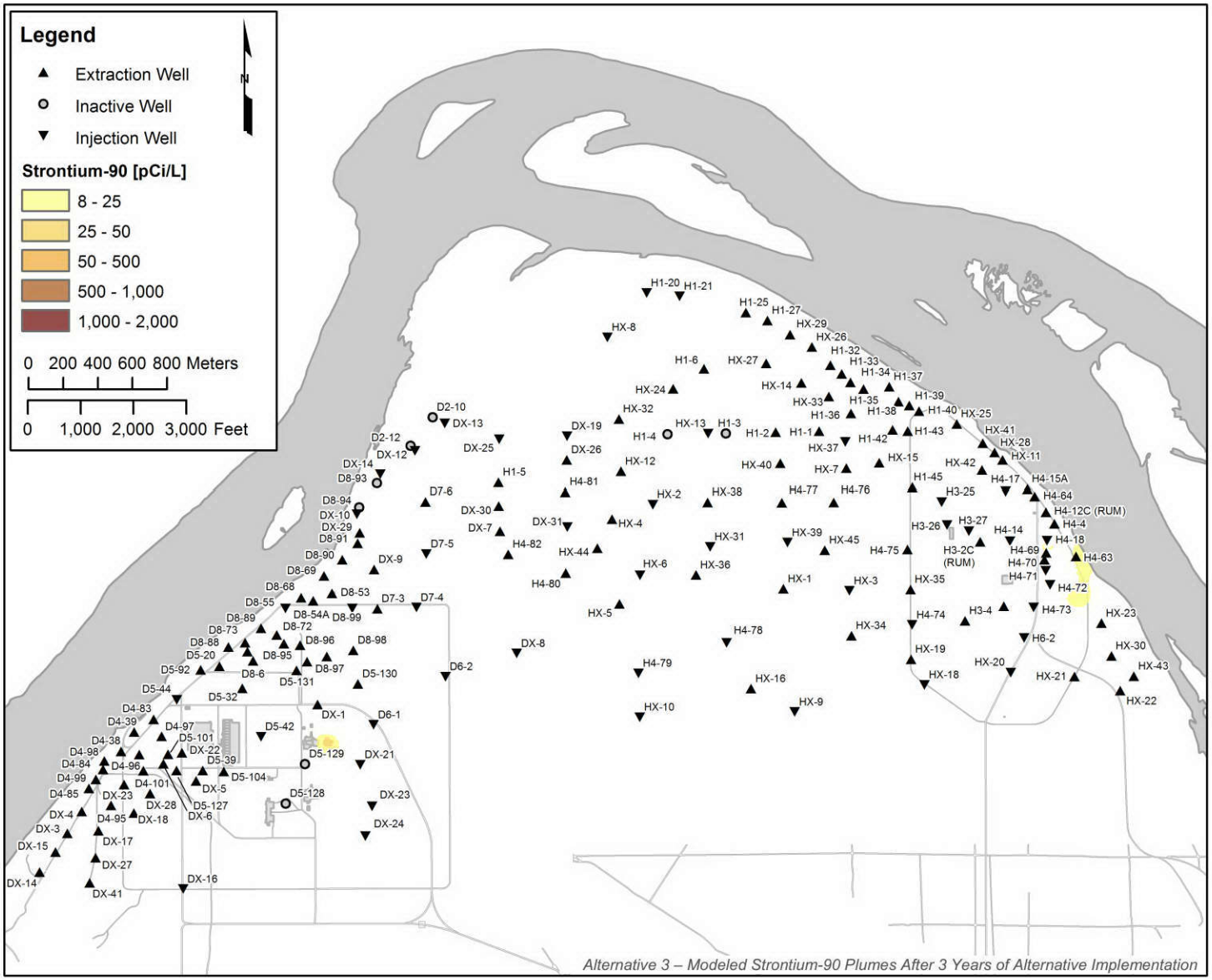


Figure 9-14a. Alternative 3—Modeled Strontium-90 Plumes after 3 Years

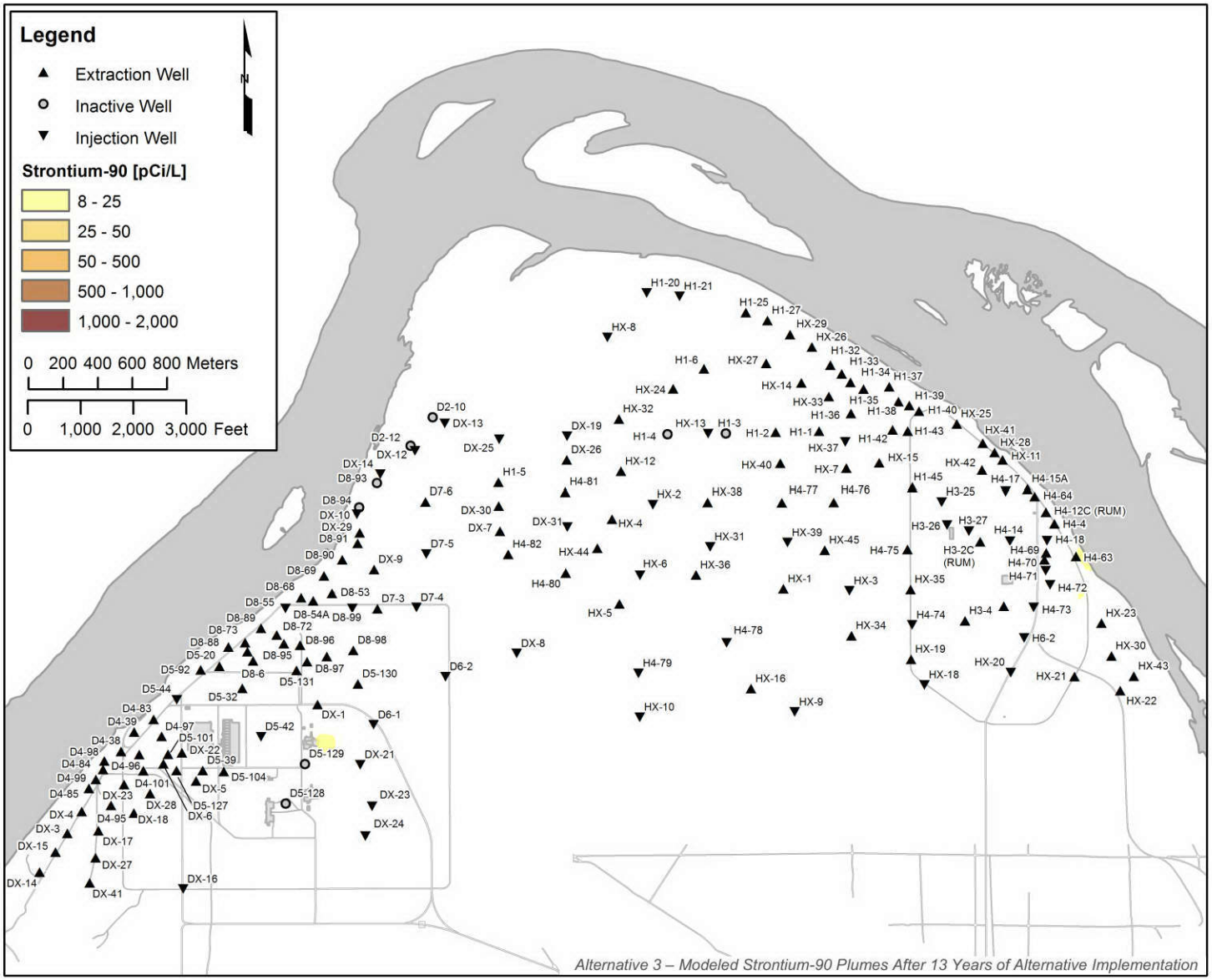


Figure 9-14b. Alternative 3—Modeled Strontium-90 Plumes after 13 Years

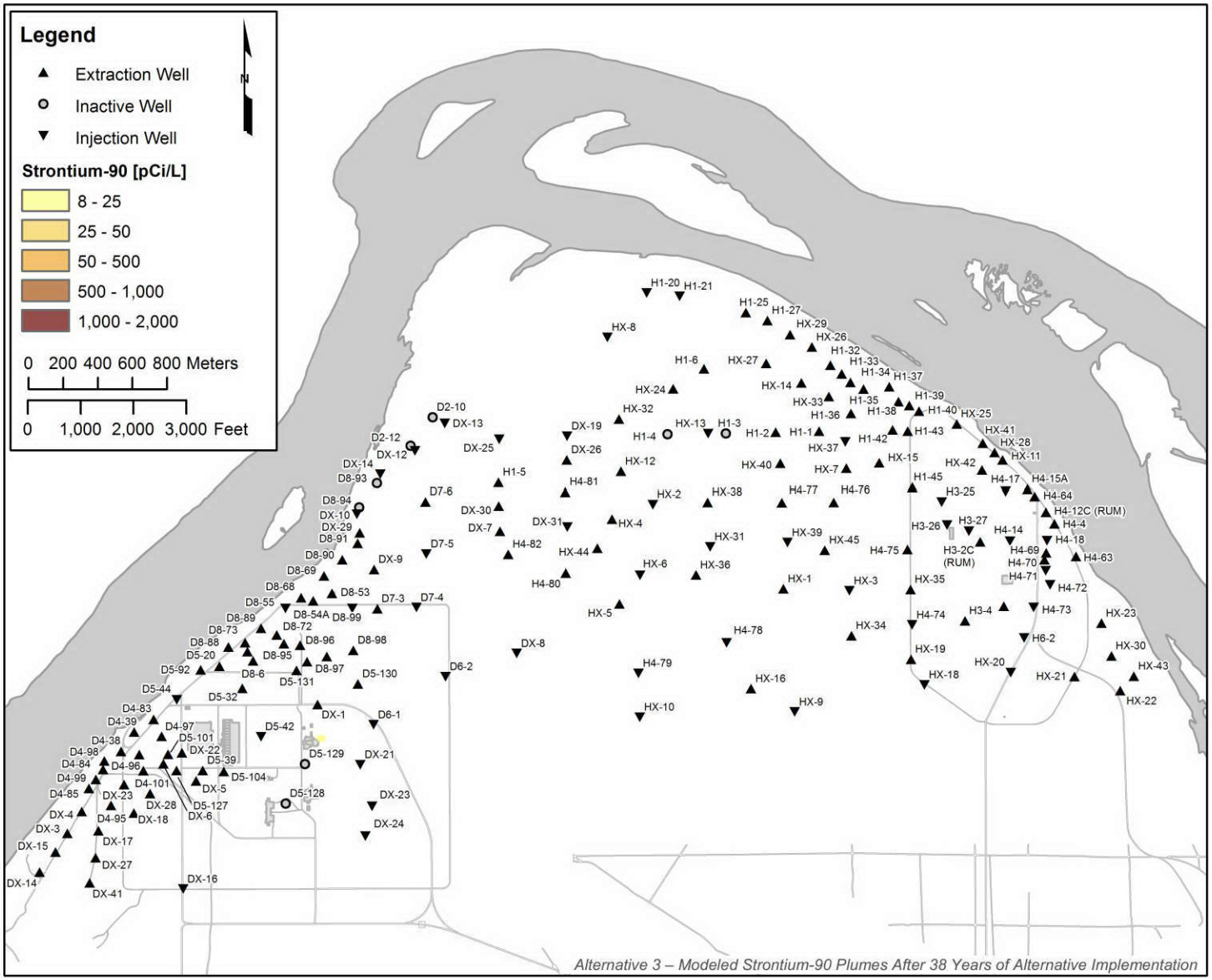


Figure 9-14c. Alternative 3—Modeled Strontium-90 Plumes after 38 Years

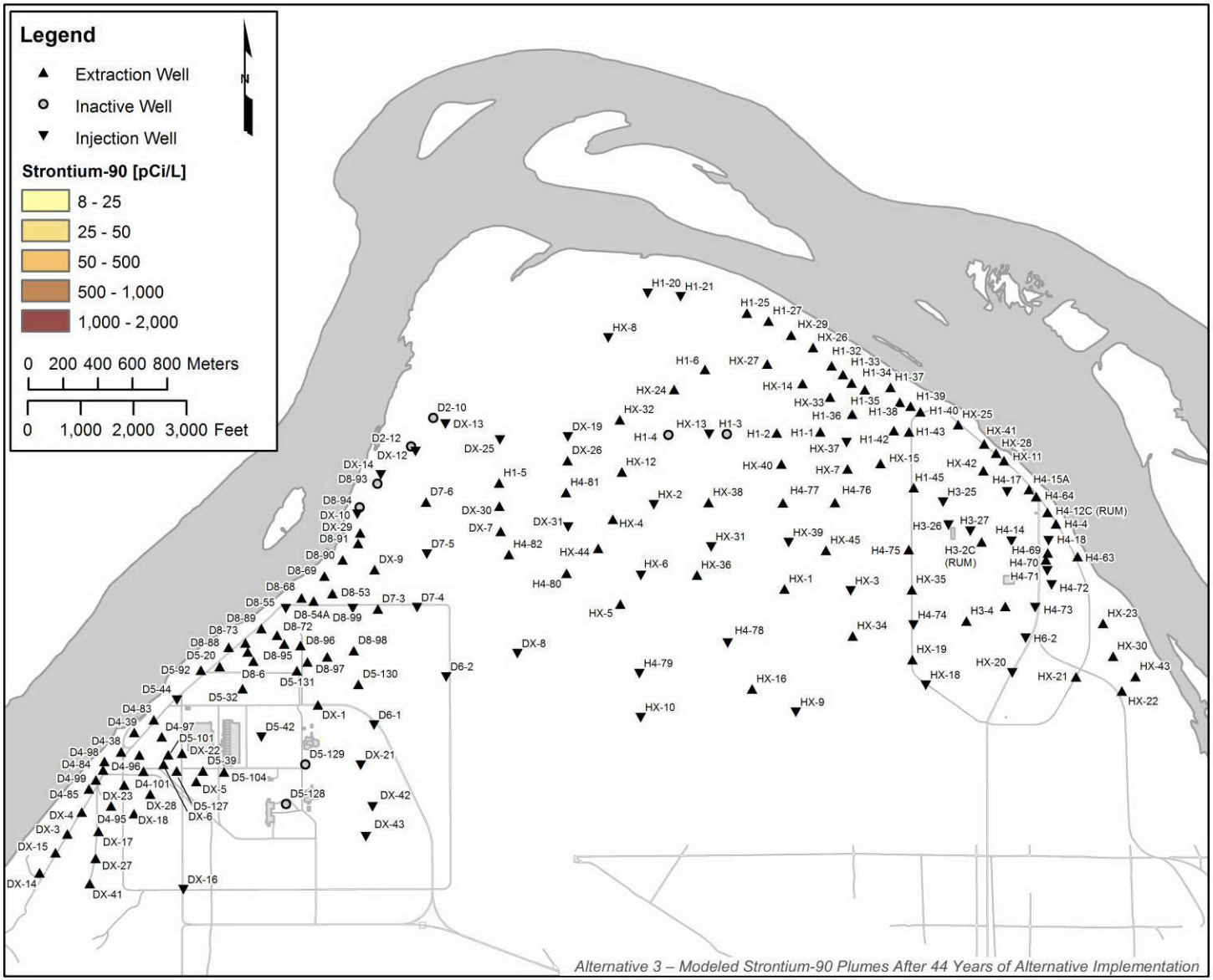


Figure 9-14d. Alternative 3—Modeled Strontium-90 Plumes after 44 Years

Table 9-10. Components for Alternative 4—RTD for Waste Sites and Pump-and-Treat for Groundwater

Waste Site Components	General Components	
	No Further Action	No additional remedial actions are taken for the 146 waste sites identified in Section 8.2.1.1 (Chapter 8).
	Institutional Controls	Institutional controls to be implemented within 100-D, 100-H, and Horn areas for land use management and waste site information management include the following: • Permits required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents. • Land use and real property controls (for example, proprietary controls including easements and covenants) ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents. • Notices providing visual identification and warning of hazardous or sensitive areas. • Procedural requirements for access, warning signs, or fencing implemented to prevent or limit the access of humans to hazardous or sensitive areas. • Administrative mechanisms, such as the WIDS database, to maintain and provide access to information on the location and nature of contamination. Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8). Post-remediation institutional controls implemented at specific waste sites are identified in Table 9-4.
	For Waste Sites That Exceed Human Health, Environment, Surface Water, or Groundwater Protection PRGs	
	RTD	RTD to depth of contamination exceeding cleanup levels, or until groundwater is encountered if contamination extends into groundwater, using standard and deep excavation technologies, as described in Section 9.2.2.2. RTD is applied to waste sites listed in Table 8-5 (Chapter 8) that are expected to be remediated under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039). 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 closeout/ verification data (Chapter 6).
	RTD (cont.)	RTD also applied to waste sites listed in Table 8-5 (Chapter 8) that are yet to be remediated and not remediated under one of the other waste site remedial components listed above. Table 9-2 identifies applicable waste sites remediated by RTD using standard and deep excavation technologies. 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.

Table 9-10. Components for Alternative 4—RTD for Waste Sites and Pump-and-Treat for Groundwater

Groundwater Components	Pump-and-Treat System	Operation of existing pump-and-treat systems as described in Section 9.2.2.4, with additional extraction and injection wells to expand treatment coverage. Placement of additional extraction and injection wells, extraction and injection flow rates, and well operational periods were determined through groundwater model simulations described in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114). The RPO process will be used to provide ongoing evaluations to ensure the system meets ROD requirements. Designed with active remediation out to Cr(VI) 10 µg/L contour. Treatment of extracted water through ion exchange. Operation of pump-and-treat system components to meet the State surface water quality standard at points of groundwater discharge to the river. Periodic rehabilitation, replacement, reconfiguration and decommissioning of the remediation system components as described in Section 9.2.2.6.
	MNA and Institutional Controls	MNA as described in Section 9.2.2.3. Manage strontium-90 in groundwater through a combination of treatment, MNA, and institutional controls until concentrations meet cleanup standards. Manage the plumes until concentrations are below the action levels and after the pump-and-treat system is shut off. Monitoring of COCs to track the attenuation processes. Institutional controls to be implemented within 100-D/H include land use management and waste site information management. Additional institutional controls for groundwater include: • Permits required for excavations on the Hanford Site to prevent unplanned disturbance or infiltration as prohibited by CERCLA decision documents.
	MNA and Institutional Controls (cont.)	• Land use and real property controls (for example, proprietary controls including irrigation restrictions, easements, and covenants) ensure that the use of land is in accordance with Hanford Site plans and CERCLA decision documents. • Groundwater use management, as described in *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions* (DOE/RL-2001-41), ensures proper use of groundwater through groundwater controls. • Administrative mechanisms, such as the WIDS database, to maintain and provide access to information on the location and nature of contamination. Additional information on institutional controls is presented in Section 8.3.1 (Chapter 8).
	Monitoring Requirements	Remedy performance monitoring will be defined as part of the remedial design. Evaluates the effectiveness of the selected alternative to attain the cleanup levels. The existing monitoring program will expand when a number of monitoring wells are added. For cost estimating purposes, it has been assumed that 12 new monitoring wells will be installed. Groundwater performance monitoring is presented in Section 9.2.2.7 for constituents included in the monitoring program. The constituents include COCs (chromium (total), Cr(VI), nitrate, and strontium-90) and analytes identified for additional monitoring (antimony, cadmium, carbon tetrachloride, cobalt, copper, nickel, silver, and zinc).

Table 9-10. Components for Alternative 4—RTD for Waste Sites and Pump-and-Treat for Groundwater

CERCLA	=	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	=	contaminant of concern
MNA	=	monitored natural attenuation
PRG	=	preliminary remediation goal
RBSL	=	risk-based screening level
ROD	=	record of decision
RTD	=	removal, treatment, and disposal
SMDP	=	scientific management decision point
WIDS	=	Waste Information Data System

Alternative 4 is designed to operate until the Cr(VI) groundwater plume is substantially reduced to less than the groundwater cleanup level in 2007 MTCA ("Groundwater Cleanup Standards" [WAC 173-340-720]). Wells along the river will be used to contain concentrations in the plume that are above 10 µg/L, thereby reducing migration to the river, so the State surface water quality standard can be met at points of groundwater discharge to the river. The model assumes 85 percent availability of the pump-and-treat system capacity to account for scheduled or unforeseen shutdown periods. As a result, a total capacity of 1,930 L/min (510 gpm) was assumed for the DX pump-and-treat system and 2,575 L/min (680 gpm) for the HX pump-and-treat system.

All waste sites will be remediated before final remediation of groundwater. Remedial action completion for waste site and groundwater remediation is described in Section 9.2.

Results from the groundwater flow and transport model (*Modeling of RI/FS Design Alternatives for 100-HR-3* [ECF-100HR3-11-0114]) predict COC plumes and trends over the remediation simulation period. The groundwater model results predict Cr(VI) plumes will be remediated to meet cleanup levels to 48 µg/L DWS and 10 µg/L State surface water quality standard throughout the aquifer after 11 and 39 years, respectively, of implementing the groundwater remedy under Alternative 4. Figure 9-16 (a-f) shows the modeled Cr(VI) groundwater plumes after 3, 8, 18, 25, 33, and 39 years of operating under this alternative. Figure 9-16d shows that after 25 years, the majority of Cr(VI) contamination has been remediated and only one small area in the Horn remains above 10 µg/L. It is very likely this area would be remediated within the 25-year period with adjustments to the pumping rates.

EPC calculations will be used to determine completion of groundwater remedial actions following shut down of the pump-and-treat systems to evaluate for rebound conditions within the unconfined aquifer. MTCA compliance requirements (2007 MTCA, "Groundwater Cleanup Standards" [WAC 173-340-720(9)(d)(i)]) and EPA guidance (*Methods for Evaluating The Attainment Of Cleanup Standards Volume 2: Ground Water* [EPA 230-R-92-014]) will be used for the purpose of evaluating completion. The 95th UCL calculation will be used to demonstrate compliance as described in WAC 173-340-720(9)(d)(i).

During performance of the pump-and-treat operations, performance will be evaluated using a number of measures, including model predictions and statistical evaluations of measured concentration trends for the 100-D south, 100-D north, Horn area, and 100-H, and along the river shoreline.

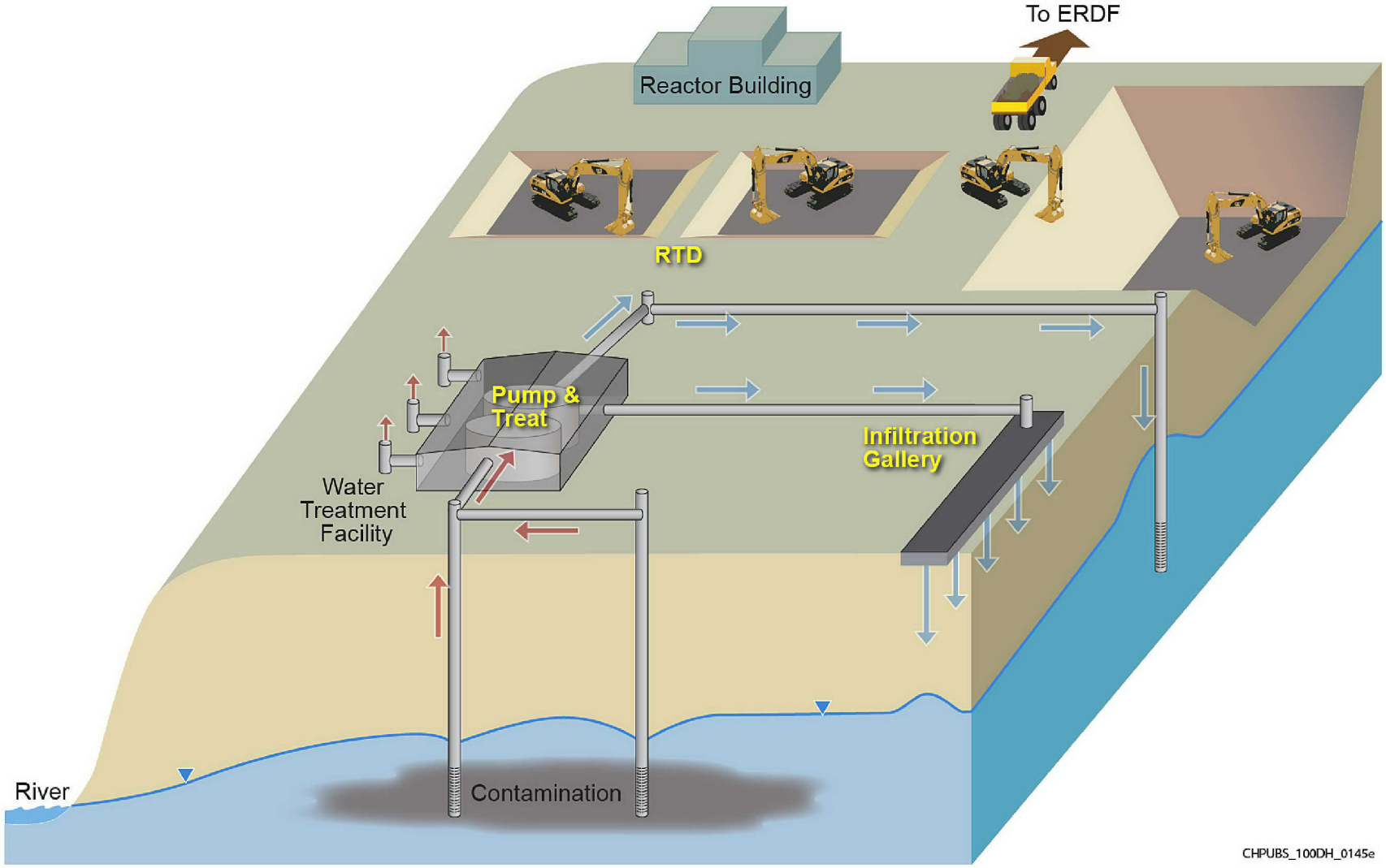


Figure 9-15. Alternative 4—RTD for Waste Sites and Pump-and-Treat for Groundwater

Table 9-11. Alternative 4—Cost Estimates (in millions)[a]

Waste Site Treatment	Capital	$68.0
	Total O&M	$25.6
	Total Periodic[b]	$0.6
	Total Nondiscounted	$94.2
	Net Present Value	$78.3
Groundwater Treatment	Capital	$40.7
	Total O&M	$232.7
	Total Periodic[b]	$251.5
	Total Nondiscounted	$524.9
	Net Present Value	$355.1
Total Nondiscounted Cost of Alternative	$619.1	
Total Net Present Value (Discounted) of Alternative	$433.4	

a. Order of magnitude cost estimates and support information are presented in Appendix J. Costs for institutional controls are included under the costs for waste site treatment.

b. Periodic costs include O&M or construction activities, including costs to replace an installed remedy or components of an installed remedy, and services that are not included in initial capital costs or annual O&M costs. Periodic costs may be onetime costs or costs that recur at intervals over the life of the remedy.

O&M = operations and maintenance

As described in Section 9.2, groundwater COCs co-extracted for treatment of the Cr(VI) plumes are managed through MNA and ICs to achieve cleanup levels. Predicted concentrations of nitrate and strontium-90 in the combined groundwater influent stream to the pump-and-treat facilities will be at concentrations below their respective cleanup levels. Predicted concentration trends for each COC in the combined influent to the pump-and-treat facilities are provided in *Modeling of RI/FS Design Alternatives for 100-HR-3* (ECF-100HR3-11-0114). Cr(VI) in the treatment system influent will be removed using ion exchange treatment technology. The other COCs in the resulting treatment system effluent injected into the aquifer remain below cleanup levels.

Nitrate contaminated groundwater is within the capture footprint of the Cr(VI) pump-and-treat system well network. The groundwater model simulation for this alternative indicates that nitrate contamination is remediated to cleanup levels earlier than the Cr(VI) remediation period since nitrate contamination is not present in the Horn. Nitrate plume depictions after 3, 8, 12, and 13 years of operating under this alternative are provided in Figure 9-17 (a-d) showing nitrate concentrations are below cleanup levels after 13 years. No specific treatment or MNA will be needed for nitrate following the remediation of Cr(VI) through pump-and-treat.

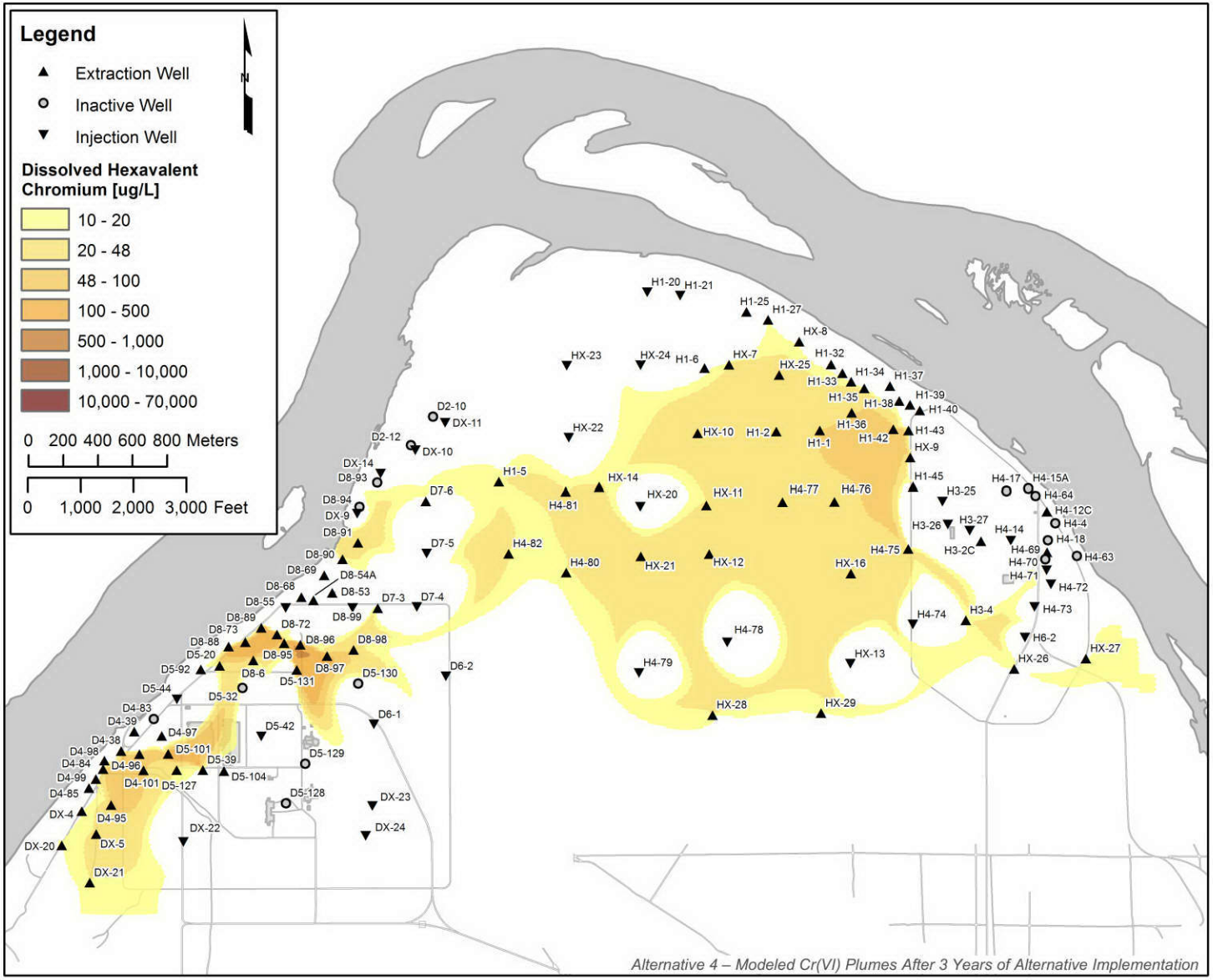


Figure 9-16a. Alternative 4—Modeled Cr(VI) Plume after 3 Years

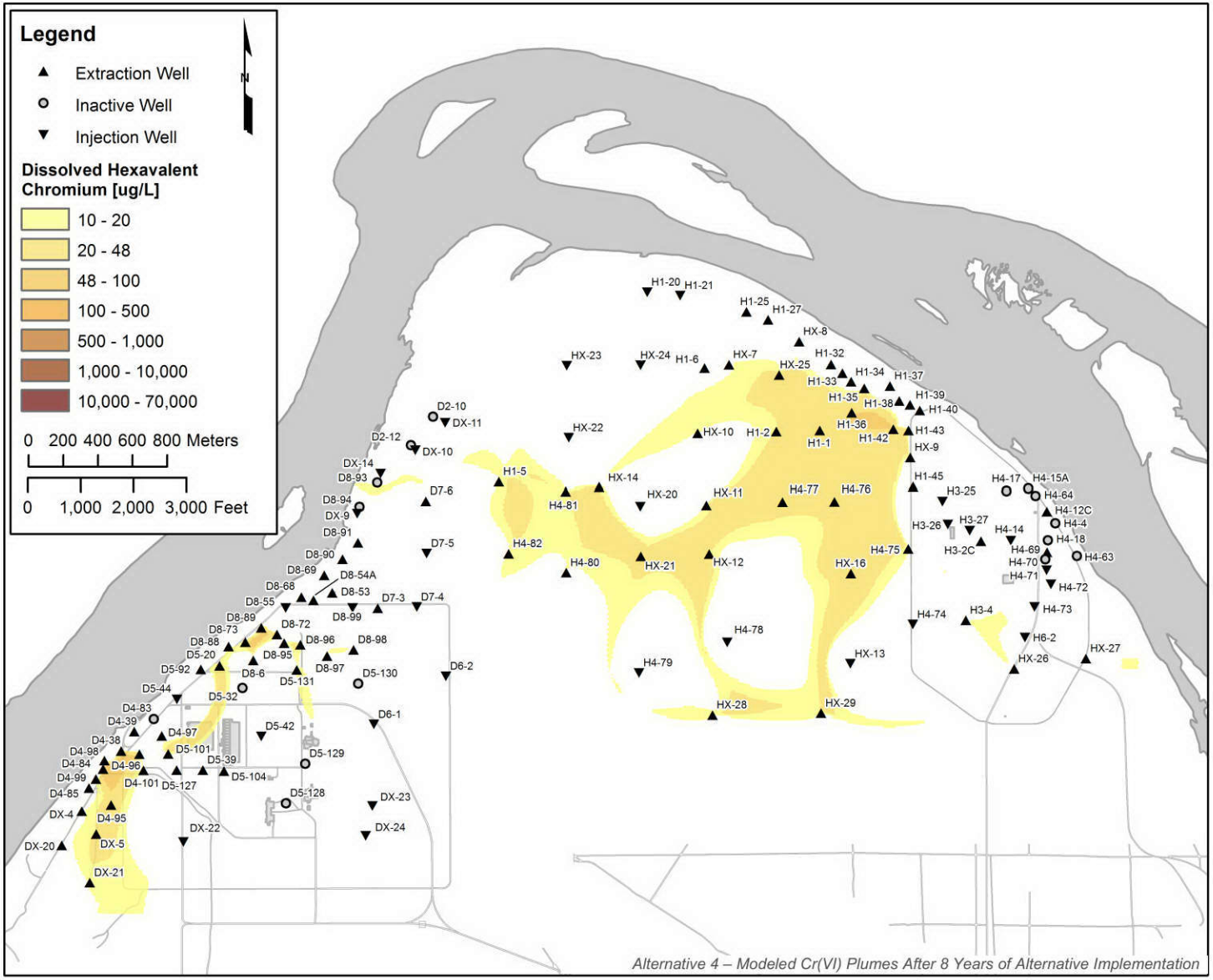


Figure 9-16b. Alternative 4—Modeled Cr(VI) Plume after 8 Years

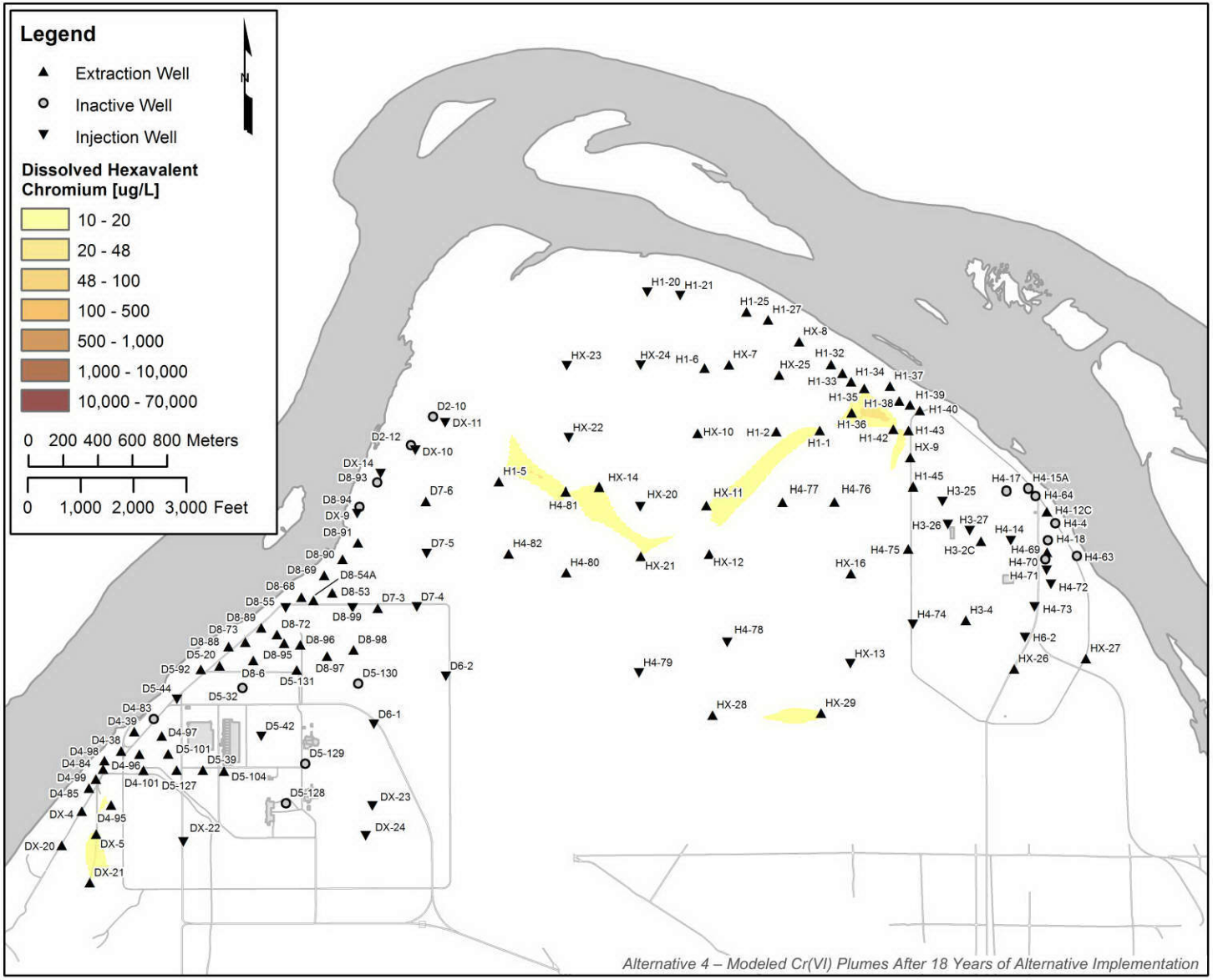


Figure 9-16c. Alternative 4—Modeled Cr(VI) Plume after 18 Years

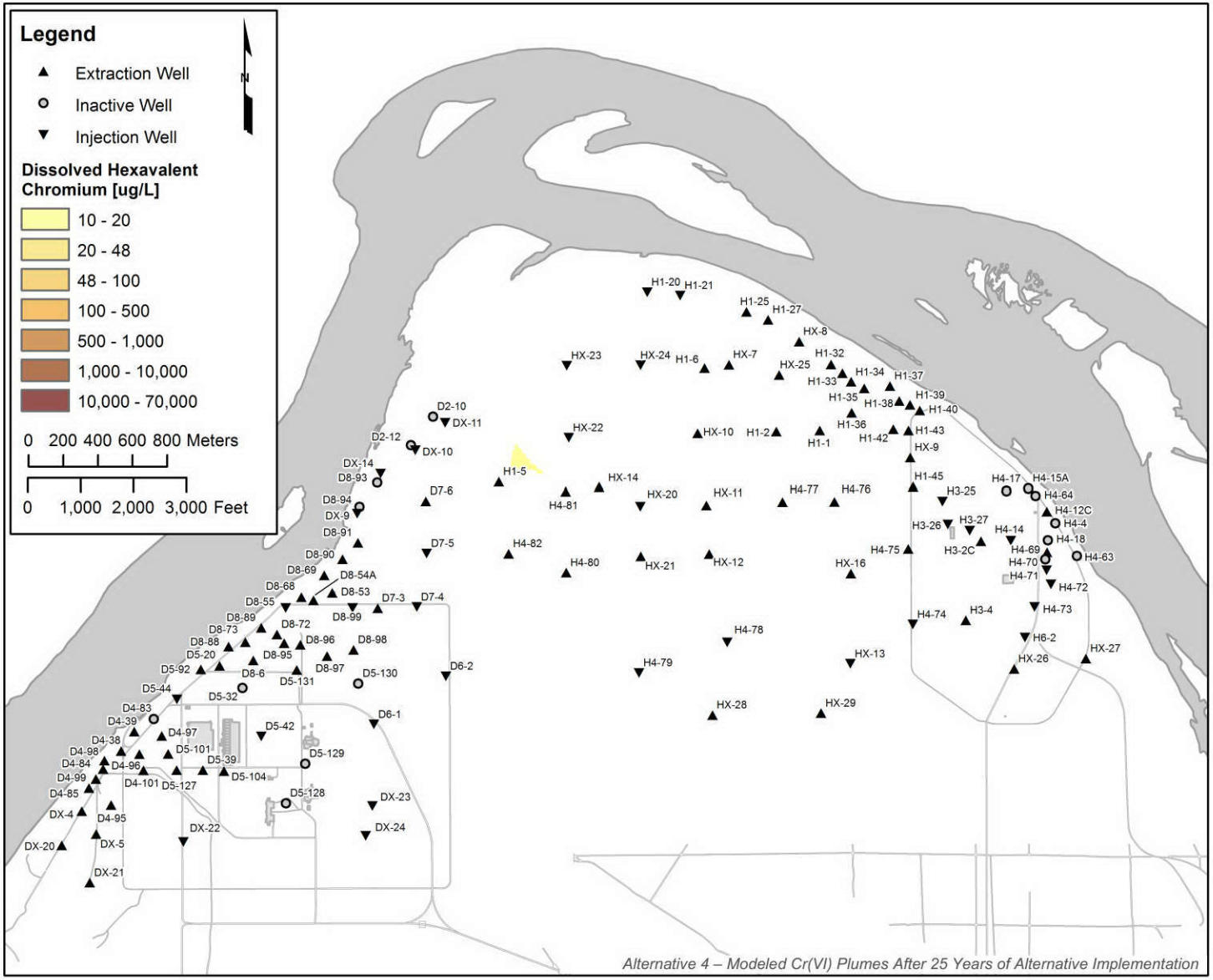


Figure 9-16d. Alternative 4—Modeled Cr(VI) Plume after 25 Years

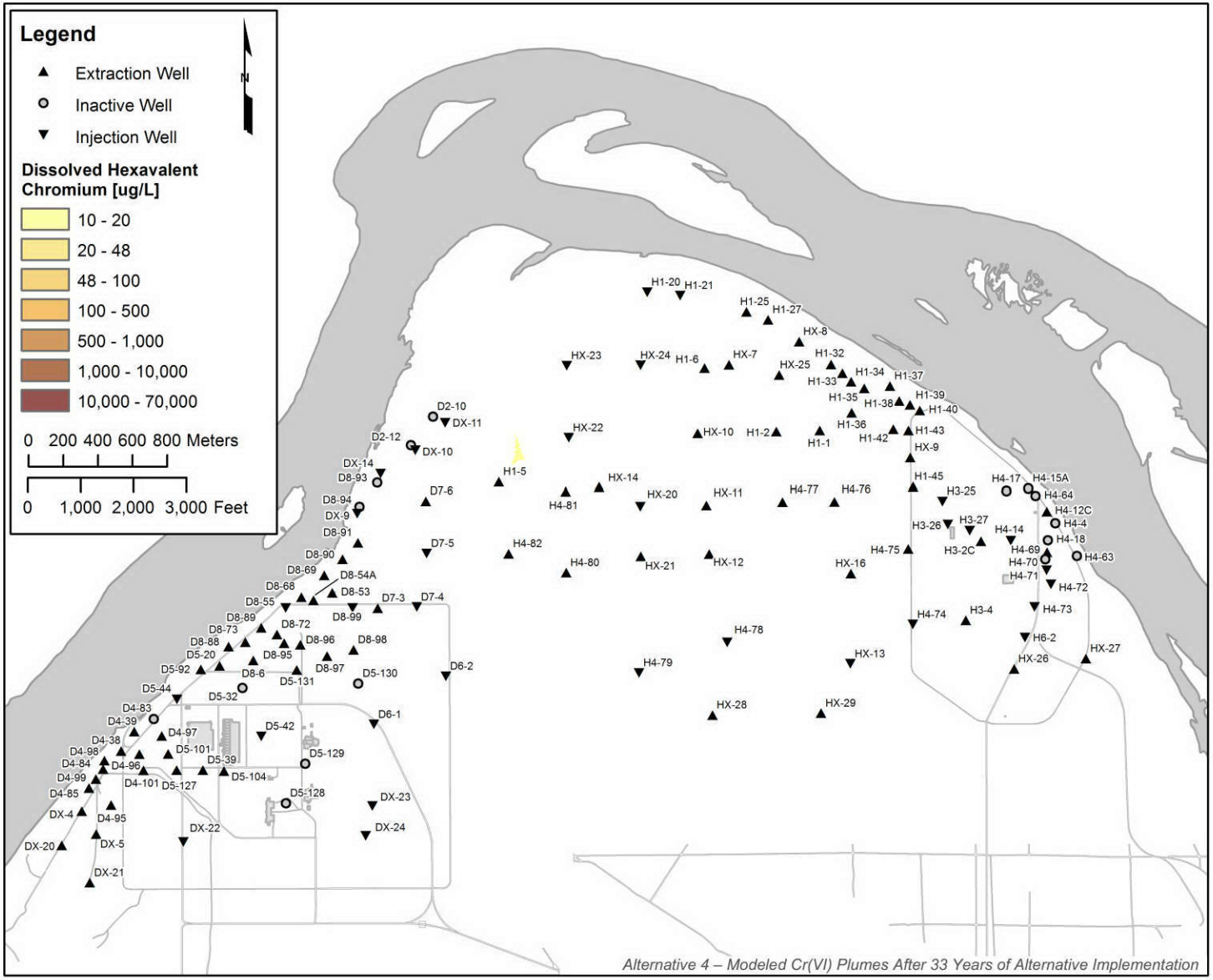


Figure 9-16e. Alternative 4—Modeled Cr(VI) Plume after 33 Years

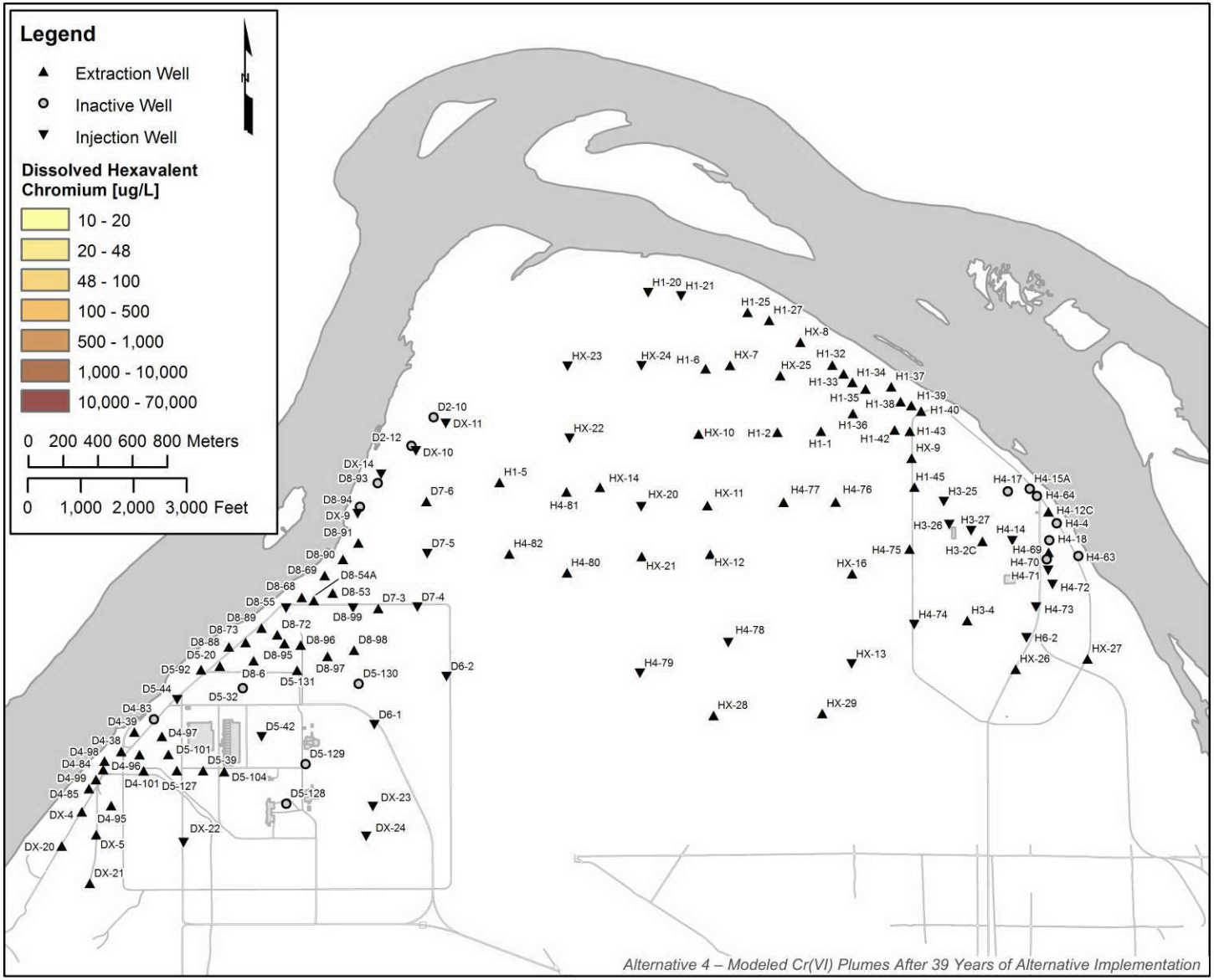
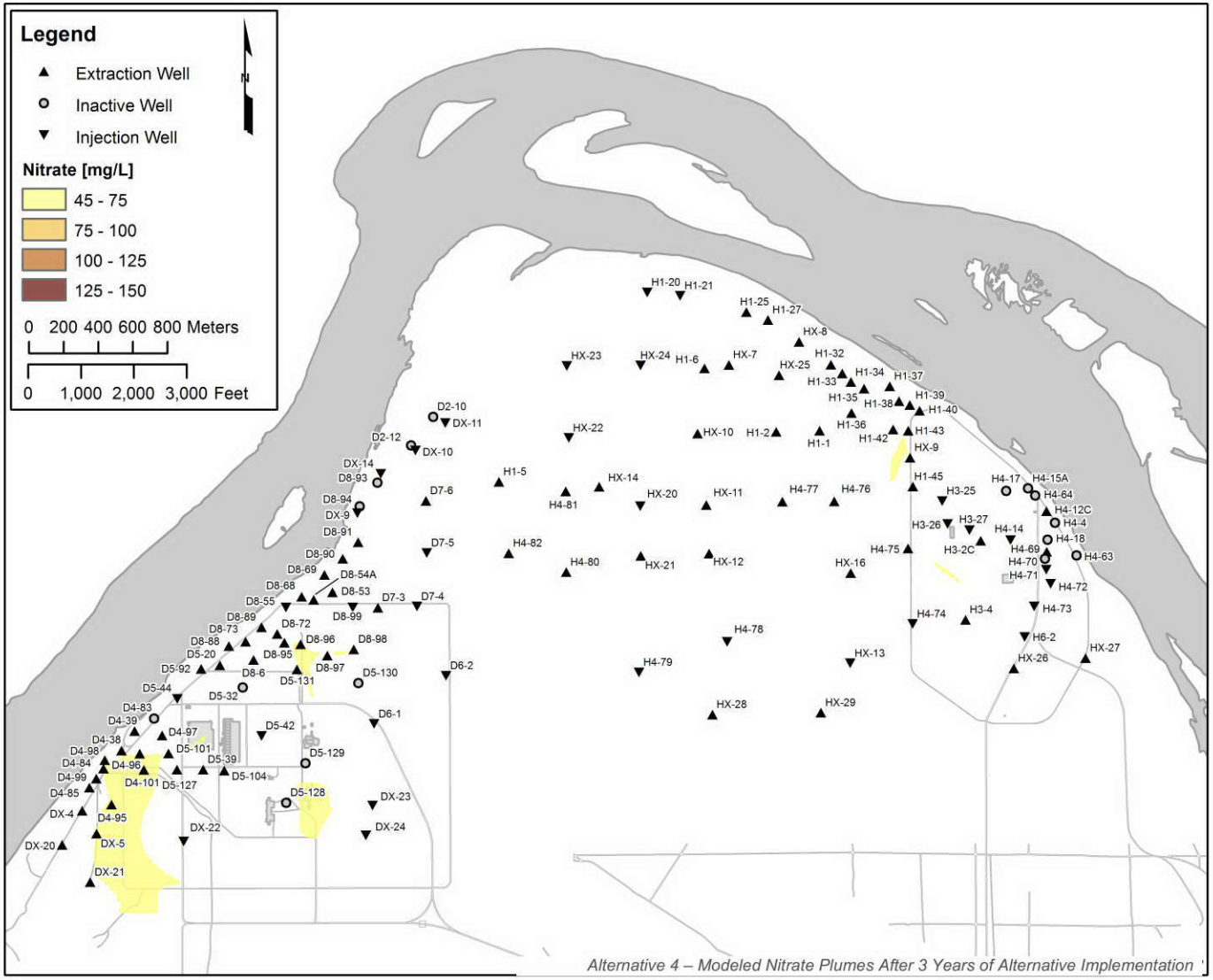


Figure 9-16f. Alternative 4—Modeled Cr(VI) Plume after 39 Years



Note: The elevated nitrate concentration areas evident near wells H4-75 and H1-27 were reported in the source used for development of this initial nitrate condition, but these plume depictions were subsequently investigated and determined to be based on erroneous data; a revised depiction of current nitrate conditions is provided in Figure 4-90. Modeling was not repeated for nitrate to correct for these non-existent nitrate plumes because predictive simulations did not indicate these would lead to a need for action (see Figures 5-28 through 5-31.

Figure 9-17a. Alternative 4—Modeled Nitrate Plume after 3 Years

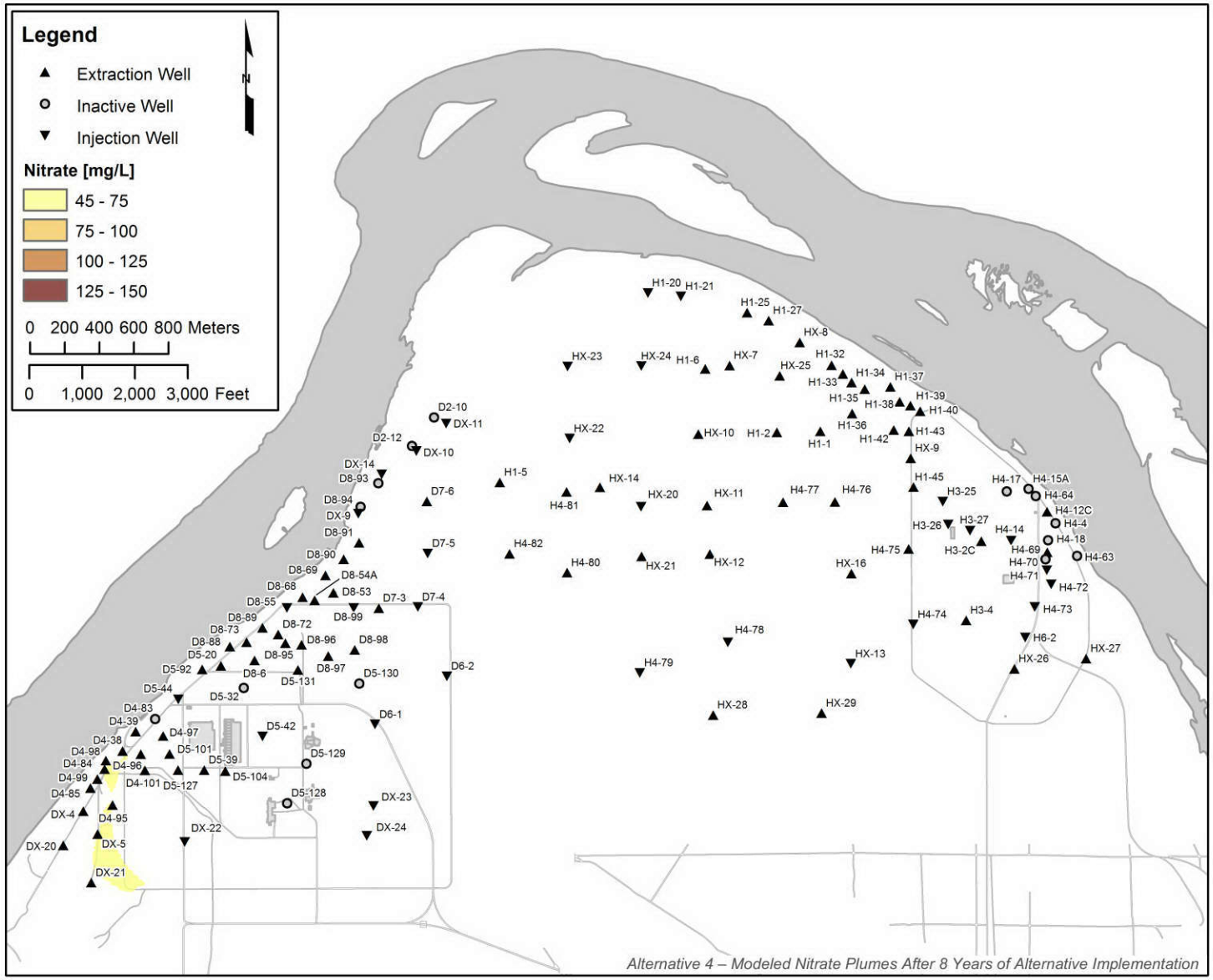


Figure 9-17b. Alternative 4—Modeled Nitrate Plume after 8 Years

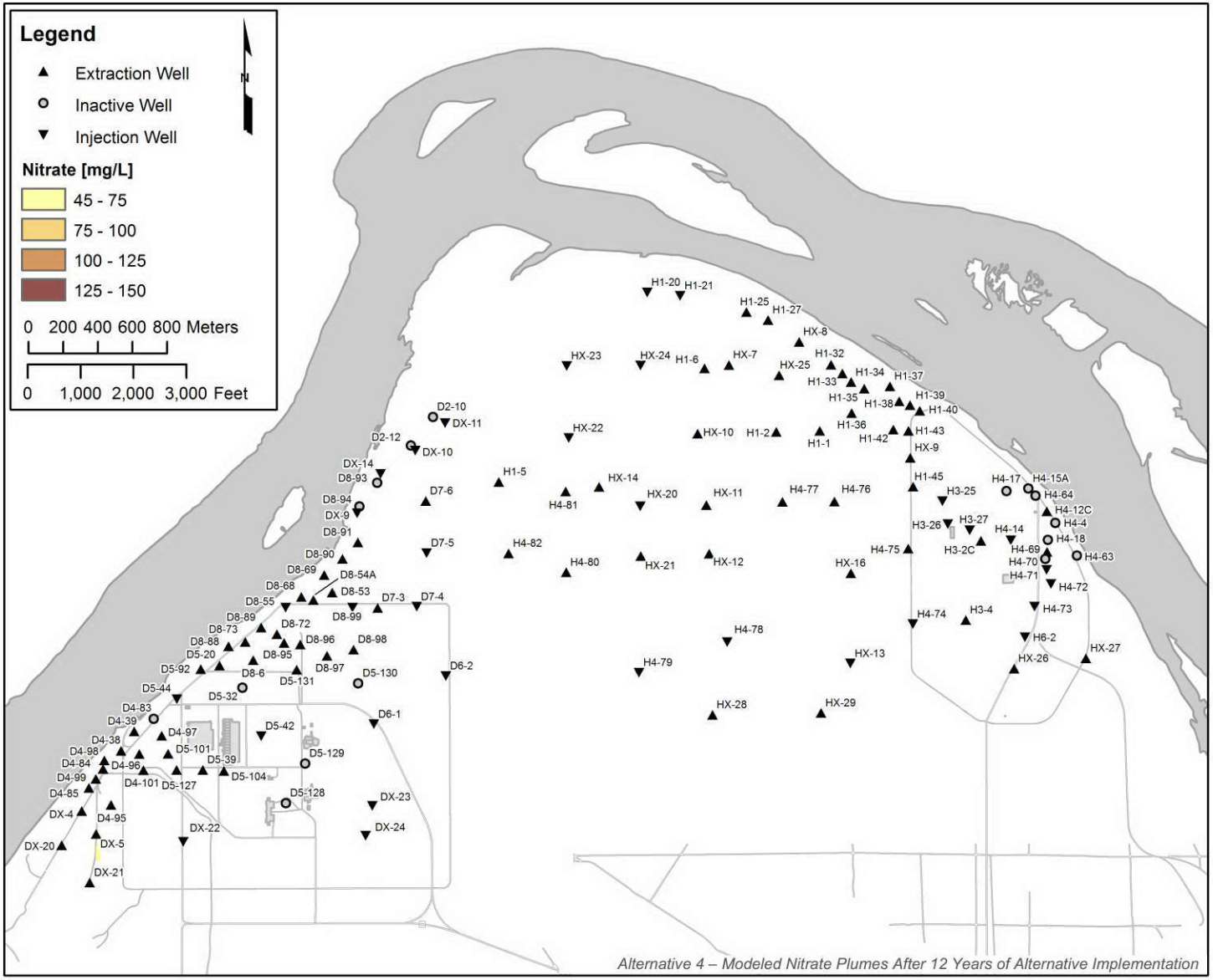


Figure 9-17c. Alternative 4—Modeled Nitrate Plume after 12 Years

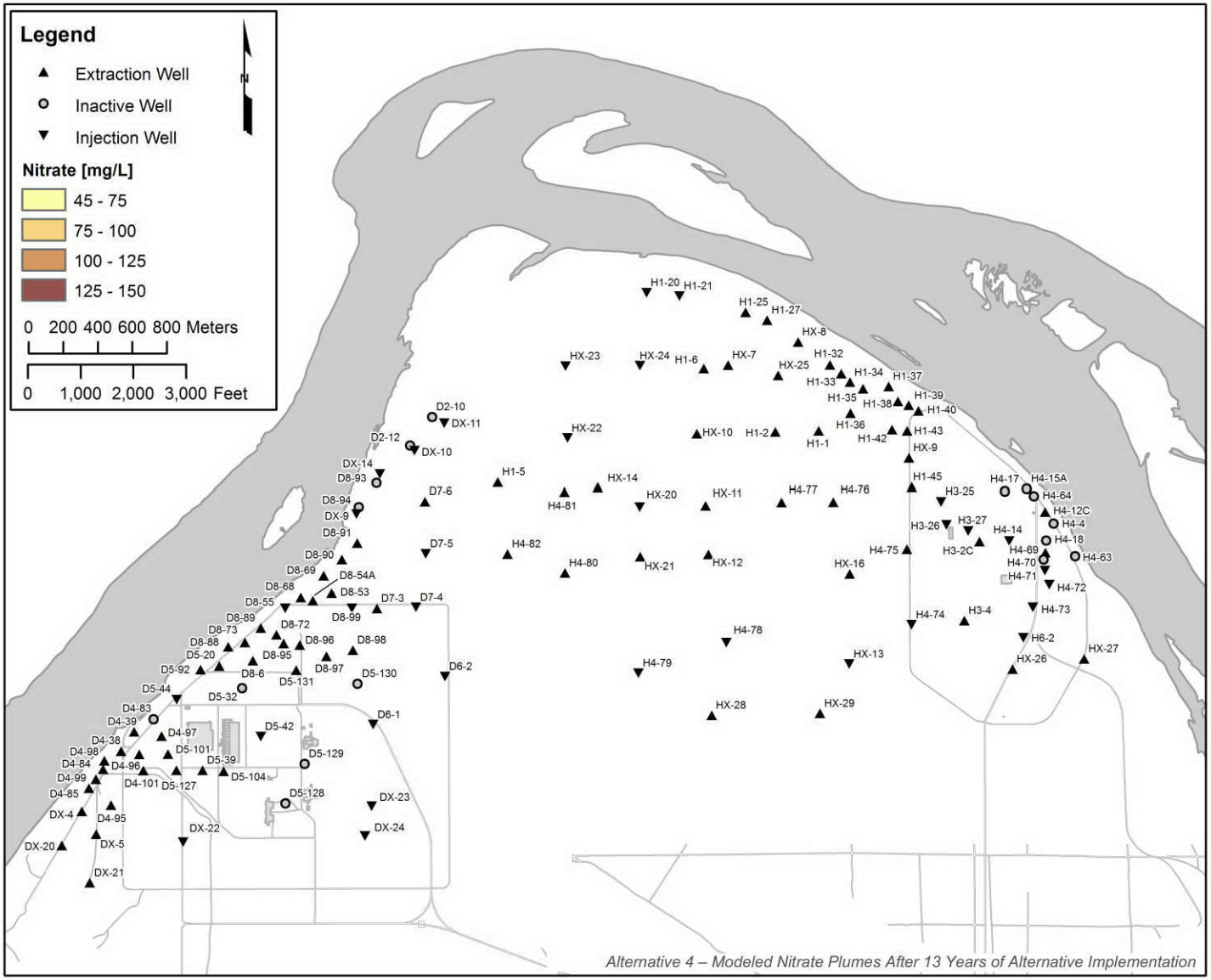


Figure 9-17d. Alternative 4—Modeled Nitrate Plume after 13 Years

Strontium-90 has low solubility and mobility in groundwater. Modelling (Appendix F) indicates that small pockets of strontium-90 contamination will remain in the aquifer above cleanup levels following pump-and-treat system shut down. The remedy for strontium-90 following active remediation is MNA through radioactive decay. Remaining strontium-90 contamination will attenuate to cleanup levels through radiological decay in 17 years after Cr(VI) remediation (i.e., 56 years after implementation of the Alternative 4 remedy). Strontium-90 plume depictions after 3, 18, 48, and 56 years of operating under this alternative are provided in Figure 9-18 (a-d).

Uranium is identified as a localized contaminant associated with the 183-H Solar Evaporation Basin, and is within the capture zone of the pump-and-treat system. Uranium concentrations have been attenuating in wells downgradient, which have concentrations decreasing overall (Section 4.5.4). If uranium is detected following completion of Cr(VI) remediation and the shutdown of the pump-and-treat system, the localized uranium contamination will continue to be managed through dispersion and diffusion by normal groundwater flow. Effectiveness of continued natural attenuation will be monitored through performance monitoring sampling. Uranium cleanup is not modeled since the concentrations were identified in a single well and have since decreased to below the DWS.

9.3 Remedial Alternative Screening Evaluation

As discussed in EPA guidance (*The Feasibility Study: Development and Screening of Remedial Action Alternatives* [OSWER Directive 9355.3-01FS3]), screening of alternatives is not a required step because only three alternatives are being evaluated. Consequently, they are all carried into the detailed evaluation in Chapter 10.

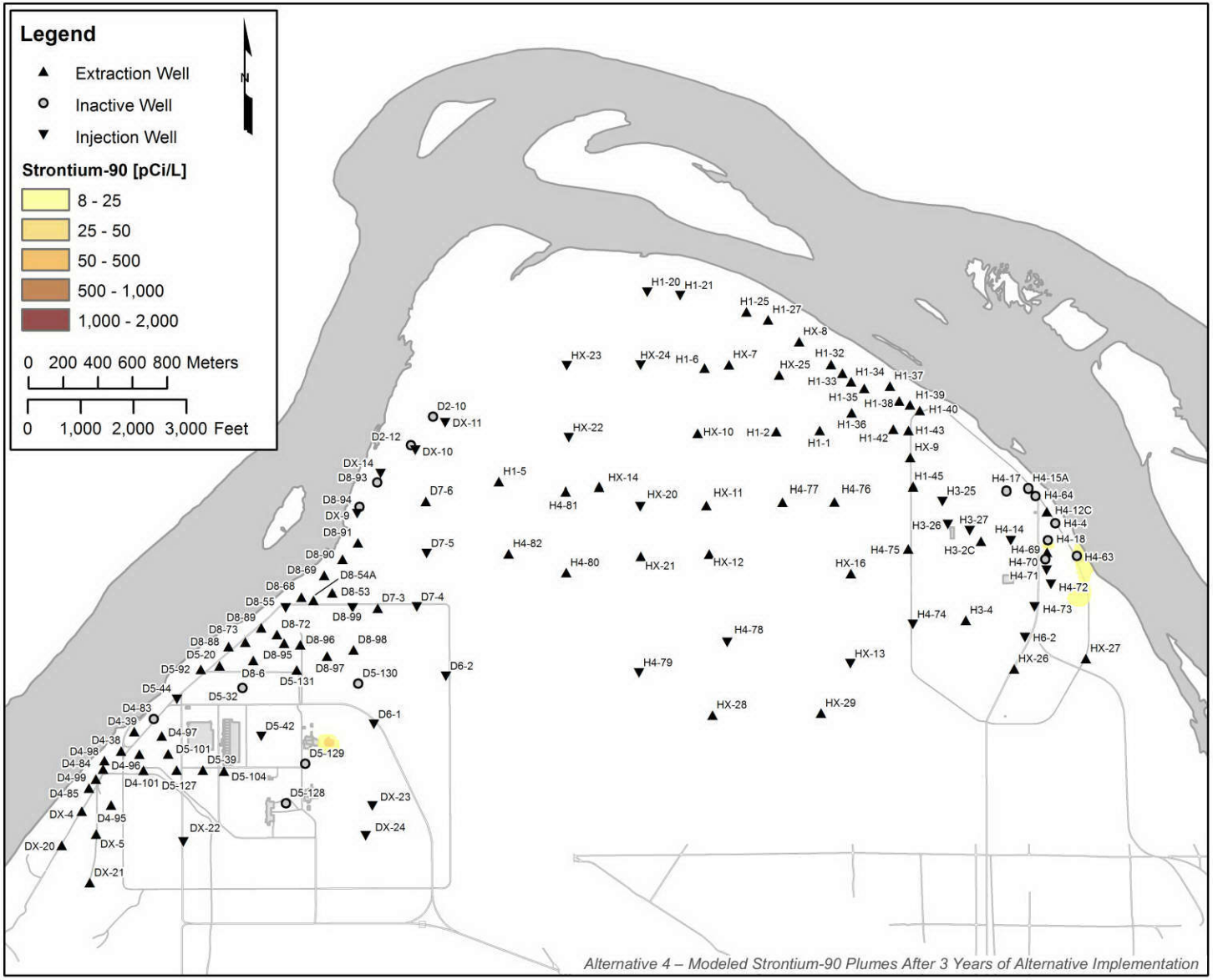


Figure 9-18a. Alternative 4—Modeled Strontium-90 Plume after 3 Years

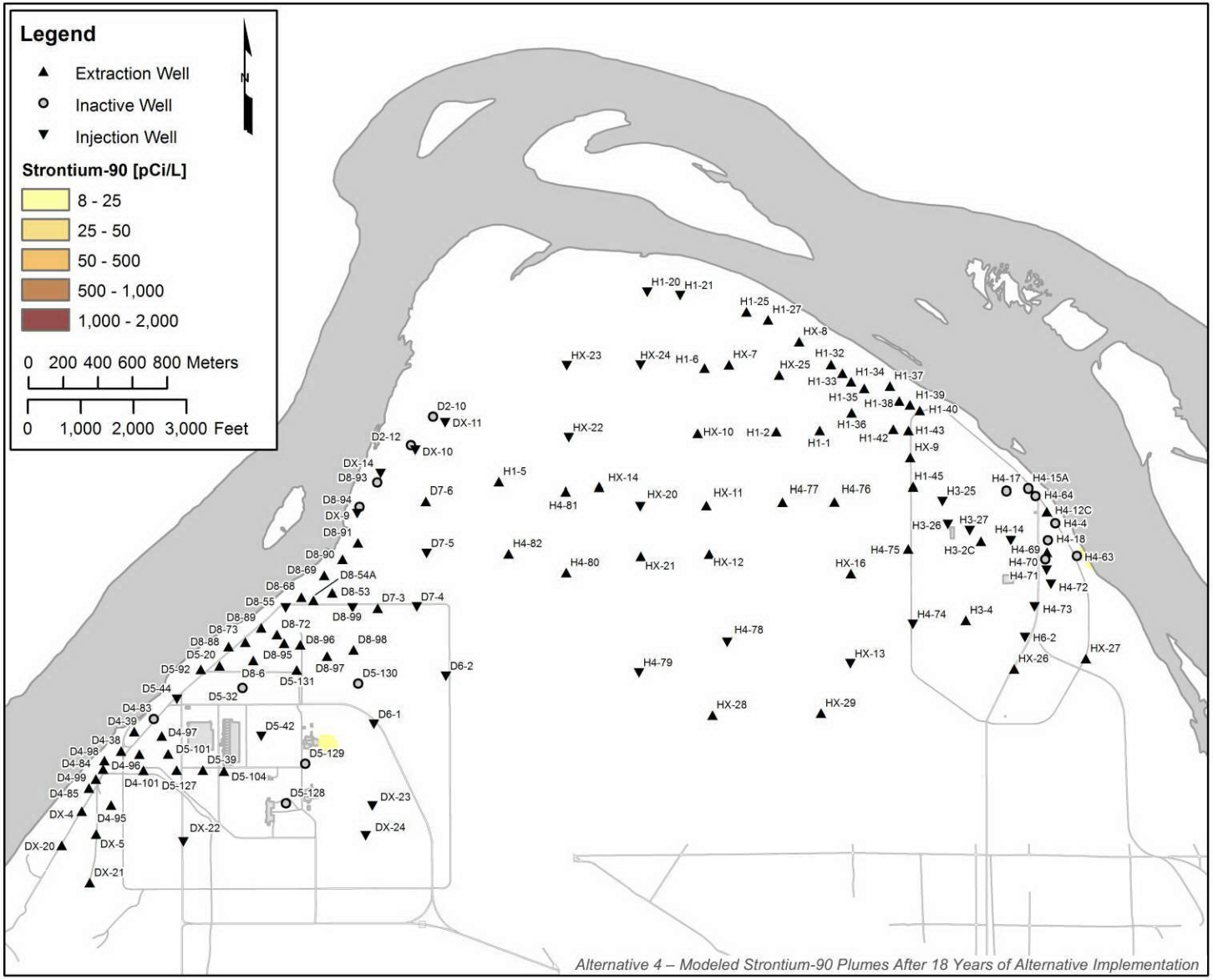


Figure 9-18b. Alternative 4—Modeled Strontium-90 Plume after 18 Years

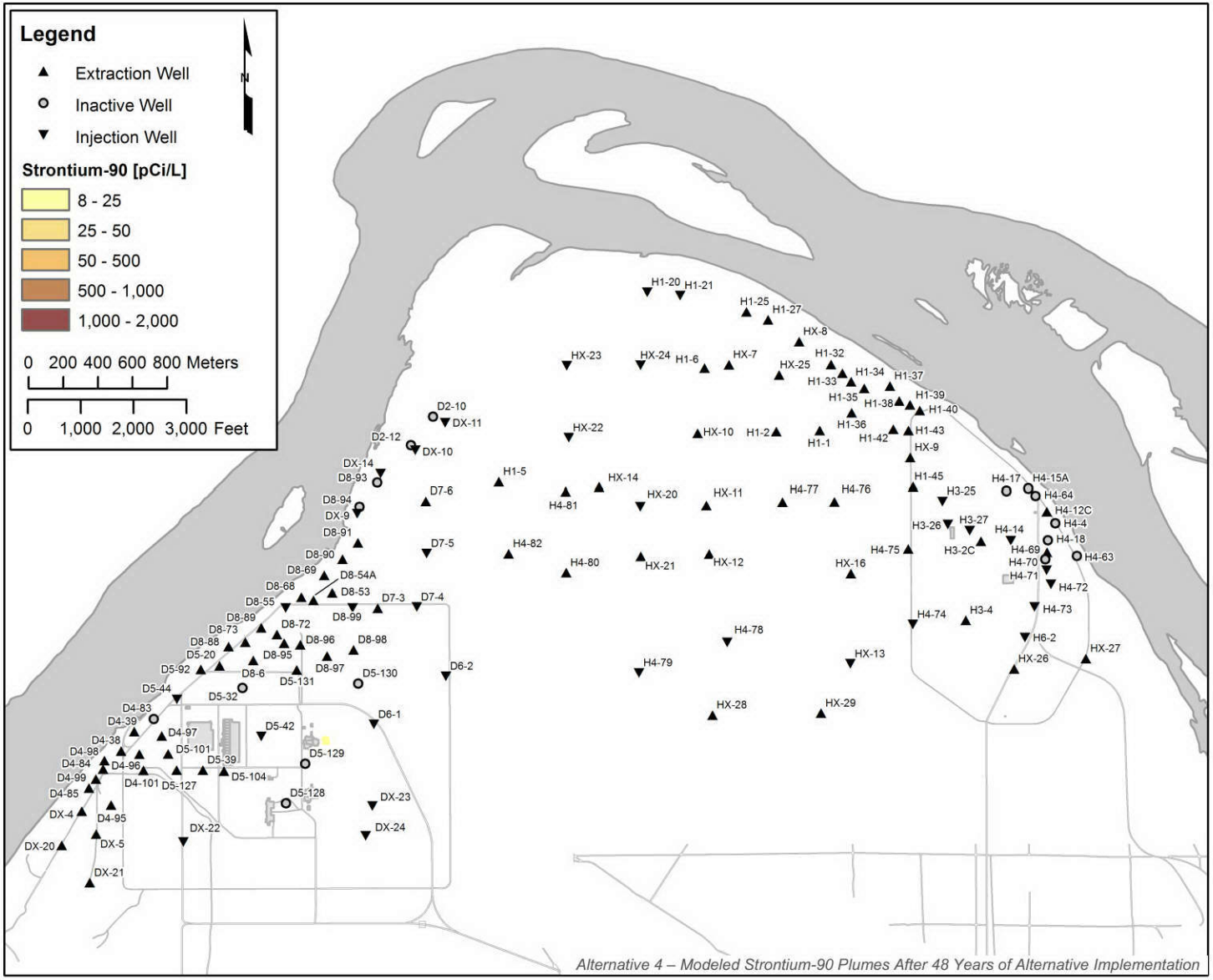


Figure 9-18c. Alternative 4—Modeled Strontium-90 Plume after 48 Years

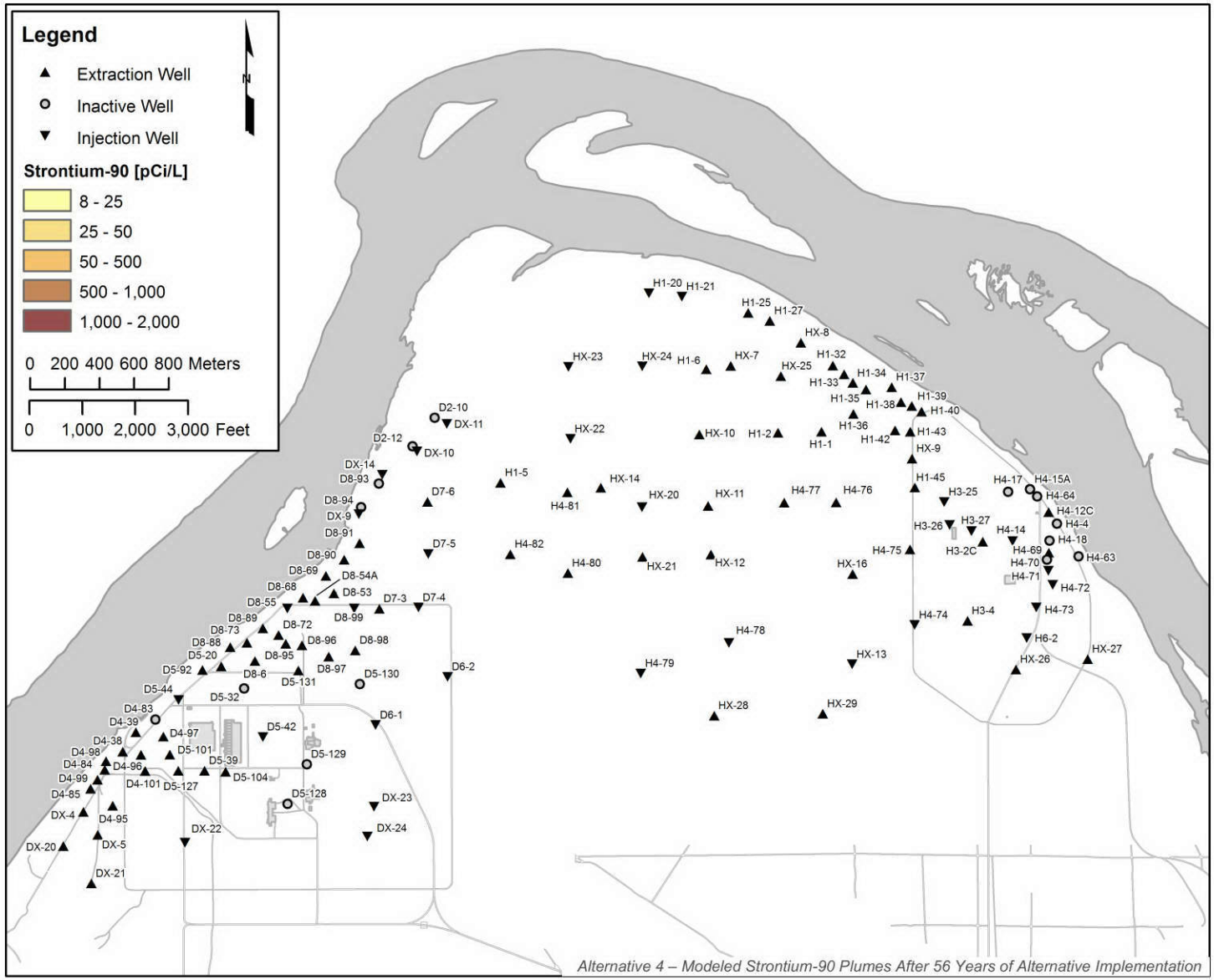


Figure 9-18d. Alternative 4—Modeled Strontium-90 Plume after 56 Years

10 Detailed Analysis of Alternatives

This chapter provides a detailed analysis of the remedial alternatives developed for waste sites and groundwater at 100-D/H. This analysis follows the development of alternatives presented in Chapter 9 and precedes the Proposed Plan, which includes the identification of a preferred alternative.

This chapter evaluates the remedial alternatives defined in Chapter 9 for 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 alternatives is evaluated individually and comparatively against the CERCLA criteria in Sections 10.2 and 10.3, respectively. The remaining two 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, the Tri-Parties will select a final remedial action alternative for 100-D/H that will lead to a ROD.

Highlights

- Alternative 1 (No Action [as required by the NCP]) does not meet threshold criteria for all sites.
- Alternative 2 (RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater) meets threshold criteria, performs well for long-term effectiveness, and short-term effectiveness, and moderately for reduction of toxicity, mobility, or volume (TMV), and implementability. The NPV cost for this alternative is $334 million.
- Alternative 3 (RTD and Void-Fill Grouting of Waste Sites and Increased Capacity Pump-and-Treat for Groundwater) meets threshold criteria, performs well for short-term effectiveness, long-term effectiveness, and implementability, and moderately for reduction of TMV. The NPV cost for this alternative is $375 million.
- Alternative 4 (RTD for Waste Sites and Pump-and-Treat for Groundwater) meets threshold criteria, performs well for long-term effectiveness and implementability, and moderately for short-term effectiveness and reduction of TMV. The NPV cost for this alternative is $433 million.

10.1 Description of CERCLA Evaluation Criteria

This section describes the nine CERCLA evaluation criteria upon which the detailed and comparative evaluations are based. The nine criteria 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 suggests be used 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 the performance of each alternative to the others, 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 ("Degree of Cleanup" [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 HHE.
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 effectiveness of alternatives in maintaining protection of HHE after response objectives have been met.
Reduction of 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 HHE 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 and 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.

ARAR = applicable or relevant and appropriate requirement
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
HHE = human health and the environment
O&M = operations and maintenance
TMV = toxicity, mobility, or volume
* These criteria are not assessed in this report.

The five "balancing criteria" represent technical considerations upon which the detailed analysis is primarily based. These criteria include long-term effectiveness and permanence; reduction of 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 provides the best combination of primary balancing attributes.

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 public and stakeholder comments on the Proposed Plan. Community and State Acceptance are not addressed in the FS. Based on information from public participation, the Tri-Parties 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 each alternative achieves and maintains short term and long term protection from unacceptable risks posed by contaminants. Alternatives are protective by eliminating, reducing, or controlling exposure through 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 ARARs

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 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

Long-term effectiveness and permanence are criteria that evaluate the anticipated ability of an alternative to maintain reliable protection of HHE for the duration of time that risk is above allowable levels. 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. 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

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 remedial design/remedial action (RD/RA) work plan, and the interim remedial action report; 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

- 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 of these costs 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 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 perform the remedial 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" (Appendix C) of the "Guidelines and Discount Rates for Benefit-Cost Analysis of Federal Programs" (OMB Circular No. A-94, revised December 2011). This version of the appendix is valid for calendar year 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 DOE's *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-D/H Vadose Zone and Groundwater RI/FS* (ECE-100HR311-00004) and *100-DH Cost Estimate Scoping Forms for Feasibility Study Alternative Costing* (ECF-100DR1-12-0022) in Appendix J.

The estimated costs for maintaining the site-wide 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, controls for excavating soil, accessing and using groundwater, and irrigation restrictions are also provided. These costs were assembled and, where appropriate, a 50 percent adjustment was made to represent CERCLA cleanup as a portion of the current Hanford Site mission. The TPA (Ecology et al., 1989a) currently identifies 22 CERCLA RODs, so each ROD would be allocated an equal portion of the CERCLA programmatic ICs costs.

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, such as site access, would be likewise reduced.

The total non-discounted cost for the ICs for 150 years is estimated to be $563 million for the Hanford Site (about $26 million per ROD). The total discounted cost for the ICs at Hanford is estimated at $221 million (about $10 million per ROD).

The total non-discounted cost for the 5-year reviews for 150 years is estimated to be $14 million (about $630,000 per ROD). The total discounted cost for the 5-year reviews for 150 years is estimated to be $4 million (about $190,000 per ROD).

The costs for maintaining programmatic ICs and the 5-year reviews conducted as oversight for the CERCLA actions on the Hanford Site are the same for each alternative (except No Action) and are included with the cost estimates. Detailed cost estimates for programmatic ICs and 5-year reviews are included in Appendix J.

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 below indicate the expected performance of each alternative relative to the CERCLA criteria:

◉ = Performs very well against the criterion with minimal disadvantages or uncertainties

○ = Performs moderately well against the criterion but with some disadvantages or uncertainties

● = Performs poorly against the criterion and may have significant disadvantages or uncertainties

10.2.1 Alternative 1—No Action Alternative

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 remediation action alternatives and is retained throughout the FS process. As presented in Chapter 9, to evaluate the required No Action Alternative, all site remedial activities and interim actions (with the possible exception of backfilling any open excavations that are not safe) will be discontinued in December 2012, including ceasing operation of pump-and-treat systems and additional monitoring. Preliminary design details and cost estimates are not prepared for Alternative 1.

The individual analysis of this alternative is presented in Table 10-2. Given that No Action fails the threshold criteria established in NCP ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(f)]), information regarding the performance of this alternative with respect to the balancing criteria is not included.

Table 10-2. Individual Criteria Evaluation for Alternative 1—No Action

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	-	***Not expected to be protective of HHE*** • RAOs will not be achieved • Allows unmonitored migration of contaminated groundwater to the Columbia River • Potential for exposure to human and ecological receptors and potential of contaminants to leach to groundwater may remain at the waste sites
Compliance with ARARs	-	***Is not compliant*** • Since there is no action, ARARs for waste sites will not be met • DWS and State surface water quality standard ARARs may not be achieved in a reasonable time since cessation of remedial actions allows for further migration of groundwater contaminants and exposure to groundwater

Table 10-2. Individual Criteria Evaluation for Alternative 1—No Action

Criterion	Rating	Detailed Analysis
Long-term Effectiveness and Permanence	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation on balancing criteria is not provided.
Reduction of TMV through Treatment	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation on balancing criteria is not provided.
Short-term Effectiveness	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation on balancing criteria is not provided.
Implementability	N/A	Alternative 1 fails threshold criteria. Therefore, an evaluation of balancing criteria is not provided.
Cost	N/A	A cost estimate for Alternative 1 is not provided because no action is proposed.

ARAR = applicable or relevant and appropriate requirement
DWS = drinking water standard
HHE = human health and the environment
N/A = not applicable
RAO = remedial action objective

10.2.2 Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

The remedial strategy for Alternative 2 relies on optimizing the risk reduction and cost by using a mixture of RTD, void-fill grouting, MNA and ICs, and groundwater pump-and-treat. For remediated waste sites that are evaluated in the FS because of PRG exceedances, this alternative builds off the interim actions previously completed. For waste sites, the actions include the following:

- RTD for removal of contamination to clean up levels for waste sites (47 waste sites), including demolition of structures (e.g., buildings)
- RTD and void-fill grouting at 100-H-36
- Capping of pipe ends to provide containment of contamination in pipelines associated with waste site 100-D-50:2
- MNA and ICs to mitigate exposure at waste sites 116-DR-9, 100-D-25, and 116-D-8 until radiological contaminants (cesium-137, strontium-90, and technetium-99) decay to less than residential RBSLs in the year 2035

For groundwater, the actions include optimization of the pump-and-treat system with biological injection for treatment of Cr(VI). The optimized pump-and-treat system would operate for 25 years following implementation of the remedial alternative. The groundwater model results for this alternative predict Cr(VI) plumes will be remediated to meet the 48 µg/L DWS cleanup levels throughout the aquifer in 11 years. The groundwater treatment systems will continue operating for another 14 years to meet the 10 µg/L State surface water quality standard cleanup level at the river for groundwater flowing into the river. Based on current operational data, the groundwater treatment system effluent is expected to remain below cleanup levels for Cr(VI).

Evaluation of Potential Hydraulic Capture and Plume Recovery from the Ringold Upper Mud (RUM) in the 100-HR-3 Operable Unit (OU) (ECF-100HR3-12-0025 in Appendix F) evaluated use of extraction wells to capture the contamination plume in the RUM. Sensitivity analysis was performed to evaluate bounding cases for flow through the aquifer, leakage from the overlying unit, and flow from the Columbia River. Based on this evaluation a four extraction well configuration is included in the remedial alternatives to remediate Cr(VI) contamination in the RUM water-bearing unit.

Remedial process optimization activities will be conducted throughout the operational period to assess remedial action performance. Groundwater simulations are used to modify extraction/injection well fields and locations for bioremediation for remediation of remaining contamination. Groundwater actions include MNA and ICs for strontium-90 contamination.

Nitrate, strontium-90, and total chromium contaminated groundwater plumes are within the treatment footprint for the Cr(VI) plume and will be co-extracted by the extraction well network used for the Cr(VI) plume remediation. Based on operational data from the currently operating pump-and-treat facilities and groundwater simulation modeling results, the groundwater treatment system effluent has not and is not expected to exceed MCLs for co-extracted nitrate, strontium-90, or total chromium, so no treatment is proposed for these groundwater COCs. However, if, through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated (and the associated CERCLA documentation developed) for the respective COCs before discharge.

Groundwater model simulation for this alternative indicates that nitrate contamination is remediated to cleanup levels within the Cr(VI) remediation period. Small pockets of strontium-90 contamination remain in the aquifer following completion of the Cr(VI); however, remaining strontium-90 contamination will attenuate to cleanup levels through radiological decay in 31 years after Cr(VI) remediation (i.e., 56 years after implementation of the Alternative 2 remedy). Groundwater monitoring will confirm effectiveness of MNA (described in Section 9.2.2.3) for strontium-90 and determine the effect of pump-and-treat on the persistence of strontium-90, nitrate, and uranium within the aquifer over time.

The Cr(VI) pump-and-treat system also includes extraction wells in the area where uranium has been historically detected near the 183-H Solar Evaporation Basin. Operational data indicate the uranium concentration in the HX pump-and-treat influent and effluent is less than the DWS, as are the current groundwater conditions. The localized uranium contamination, as detected, will be further reduced by dispersion and diffusion created through co-extraction and injection. Any residual uranium contamination in the groundwater following cessation of the pump-and-treat system will continue to be addressed through dispersion and diffusion by normal groundwater flow as discussed in Section 9.2.2.3.

Table 9-6 and Figure 9-7 provide additional information on this alternative. Appendix J, Table J-3, presents a summary of the remedial components, areas, and volumes that were assumed for each waste site in development of cost estimates.

Table 10-3 presents the individual analysis of Alternative 2 with respect to the seven CERCLA criteria. Alternative 2 is considered to pass the threshold criteria, since the actions as part of this alternative achieve RAOs and ARARs. Alternative 2 provides long-term effectiveness and permanence, and short-term effectiveness. Alternative 2 is expected to achieve reduction in TMV because it incorporates active treatment of groundwater and waste sites. However, contaminated soil removal by RTD is not considered treatment, so reduction by TMV was reduced to moderately effective. Alternative 2 is expected to be moderately implementable.

Table 10-3. Individual Criteria Evaluation for Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	O	***Protective of HHE*** • This alternative incorporates previous interim action remedies (i.e., soil RTD and groundwater extraction) that have been demonstrated to be effective, plus additional techniques to optimize remedial design. • Monitoring can track progress and achievement of RAOs. • RTD mitigates risk to human and ecological receptors and soil-to-groundwater/surface water risks encountered at the site through physical removal of contaminated soil. • Pump-and-treat provides for hydraulic containment to limit potential further migration of groundwater contaminants and treatment to remediate the Cr(VI) plume. Biological injection enhances the remediation of the Cr(VI) plume. Other COCs (total chromium, strontium-90 and nitrate) will be co-extracted with groundwater extracted for Cr(VI) treatment, where the concentration of strontium-90 and nitrate in the combined effluent will be less than their respective MCLs. Following the cessation of active treatment for Cr(VI), MNA will be the sole mechanism to achieve cleanup levels for strontium-90. • The pump-and-treat enhanced with biological injection is projected to achieve risk standards in a period of about 56 years in the 100-D Area, 30 years in the 100-H Area, and 25 years in the Horn area. • Institutional controls prevent exposure to affected soil and groundwater.
Compliance with ARARs	O	***Compliant*** • Remedial action/systems are designed to meet ARARs. • DWS and State surface water quality standard ARARs for Cr(VI) are projected to be achieved in approximately 11 and 25 years of operation, respectively.
Long-term Effectiveness and Permanence	O	***Expected to have long-term effectiveness and permanence*** *Factors for this alternative performing very well against the long-term effectiveness and permanence criterion:* • RTD, void-fill grouting, containment by capping the ends of pipelines, MNA and institutional controls, hydraulic containment, pump-and-treat, and biological injections achieve RAOs. • RTD using conventional equipment is reliable and practiced extensively at Hanford. ERDF disposal is effective and reliable. • Adequacy and reliability of pump-and-treat operations are proven at Hanford. • Groundwater biological treatment (bioinjection) provides additional treatment as pump-and-treat efficiency decreases with decreasing Cr(VI) concentration. • This alternative remediates soil site and groundwater COCs to PRG levels established to achieve the RAOs. Residual risks following cleanup to PRG levels will meet the 10^{-4} to 10^{-6} ELCR for radiological and carcinogenic COCs and will be less than or equal to an HI value of 1.0 for hazardous substances. • Long-term effectiveness and permanence will be evaluated in CERCLA 5-year review process. *Factors that may provide some disadvantages or uncertainty to long-term effectiveness and permanence:* • Requires long-term enforcement of institutional controls to mitigate risk. • Cr(VI) treatment systems will operate beyond their design life to achieve cleanup and may require major system renovations or replacement.

Table 10-3. Individual Criteria Evaluation for Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

Criterion	Rating	Detailed Analysis
Reduction of TMV by Treatment	○	***Expected to have moderate reduction of TMV by treatment*** *Factors for this alternative performing moderately well against the reduction of TMV by treatment criterion:* • Significant mass of Cr(VI) will be removed through pump-and-treat where ion exchange treatment removes Cr(VI) from the groundwater. When the ion exchange resin capacity is reached, the resin will be changed out with fresh resin. Removal of Cr(VI) is not reversible since the spent resin loaded with Cr(VI) will be disposed as solid waste at ERDF or another EPA-approved disposal facility. • Other reduction of TMV by treatment is achieved through biological reduction (bioinjection) converting Cr(VI) to less toxic Cr(III). The re-oxidation of Cr(III) compounds to Cr(VI) is not anticipated to be a significant issue after bioremediation is completed as identified in the bioremediation technology descriptions in Appendix I. • Void-fill grouting reduces leaching (mobility) of contamination from the vadose zone to groundwater through containment of contaminated media. • Capping of ends of the 100-D-50:2 waste site pipelines provides containment of contaminated media (scale within the pipelines) to reduce direct contact human health risks. • Removed soil is treated at ERDF, if needed
		Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment: • Design testing of biological injections is needed to fully develop the design parameters for these technologies, since they have not been applied full-scale at Hanford. • Contaminated soil removal by RTD is not considered treatment. RTD is the primary remediation technology implemented for most of the waste sites, and for this reason, this alternative performs moderately for this criterion.
Short-term Effectiveness	●	***Expected to have short-term effectiveness*** *Factors for this alternative performing very well against the short-term effectiveness criterion:* • No adverse risks to the community from implementation of active treatment options because of the remote location and implementation of institutional controls. • Risks to workers from implementation of active treatment actions are minimized through a health and safety plan and proper PPE. • Nominal short-term risks to workers during installation of groundwater extraction and conveyance piping, system O&M activities, and monitoring. Risks are minimized through a health and safety plan and PPE. • Cr(VI) DWS and State surface water quality standard ARARs are achieved within 11 and 25 years of remedy implementation, respectively. *Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:* • 56 years to achieve RAOs for strontium-90 in the unconfined aquifer. • Negative environmental impacts may include: – Generation of GHG from use of excavation equipment and disposal to ERDF; production and delivery of biological reagents (may mobilize other metal but will be captured and treated in pump-and-treat); well installation,

Table 10-3. Individual Criteria Evaluation for Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

Criterion	Rating	Detailed Analysis
		development, and injection activities; and operation of pump-and-treat system – Waste generation from disposal of contaminated soil and spent ion exchange resin – Large amounts of backfill will be required; borrow material may have significant environmental impacts
Implementability	○	***Expected to be moderately implementable*** *Factors for this alternative performing moderately well against the implementability criterion:* • Conventional equipment and vendors for implementation of treatment options (RTD, void-fill grouting, pump-and-treat, and biological injections) are readily available. • RTD of waste sites have been implemented and proven through interim actions at Hanford. • ERDF for waste disposal is proven, reliable, and accessible. • Grout void-fill being implemented at the Hanford U Plant facility as part of the ROD selected remedy. Grout pours to fill voids in facility structures, larger than those identified for the 100-H-36 waste site at 100-H, have been successfully performed.
		• Pump-and-treat construction and operations have been implemented through interim actions, and the ability to construct and operate is proven at Hanford. • Radioactive decay is a confirmed attenuating process for strontium-90, which exhibits a sufficiently short radioactive half-life (29.1 years). • Institutional controls have been approved and implemented, and are reliable/effective at Hanford. *Factors that may provide some disadvantages or uncertainty to implementability:* Design testing required for biological reducing zone parameters for design of in situ bioremediation treatment of groundwater.

Cost (in Millions)[a]		
Waste Site Treatment	Capital	$56.2
	Annual O&M	$25.7
	Total Periodic[b]	$0.8
	Total Nondiscounted	$82.7
	Net Present Value	$66.7
Groundwater Treatment	Capital	$33.3
	Total O&M	$173.1
	Total Periodic[b]	$143.6
	Total Nondiscounted	$349.9
	Net Present Value	$267.2

Table 10-3. Individual Criteria Evaluation for Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater

Criterion	Rating	Detailed Analysis
Total Nondiscounted Cost of Alternative		$432.6
Total Net Present Value (Discounted) of Alternative		$333.9

a. Order-of-magnitude cost estimates and support information are presented in Appendix J. Costs for institutional controls are included under the costs for waste site treatment.

b. Periodic costs include O&M and/or construction activities, including costs to replace an installed remedy or components of an installed remedy, and services that are not included in initial capital costs or annual O&M costs. Periodic costs may be one-time costs or costs that recur at intervals over the life of the remedy.

ARAR	= applicable or relevant and appropriate requirement	MCL	= maximum contaminant level
COC	= contaminant of concern	MNA	= monitored natural attenuation
Cr(III)	= trivalent chromium	O&M	= operations and maintenance
Cr(VI)	= hexavalent chromium	PPE	= personal protective equipment
DWS	= drinking water standard	PRG	= preliminary remediation goal
ELCR	= excess lifetime cancer risk	RAO	= remedial action objective
ERDF	= environmental restoration disposal facility	ROD	= record of decision
GHG	= greenhouse gas	RTD	= removal, treatment, and disposal
HHE	= human health and the environment	TMV	= toxicity, mobility, or volume

10.2.3 Alternative 3—RTD and Void-Fill Grouting of Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

The remedial strategy for Alternative 3 relies on optimizing the risk reduction and cost by using a mixture of RTD, void-fill grouting, and MNA and ICs for waste site contamination to achieve the RAOs, as well as expanded pump-and-treat with increased treatment capacity for groundwater. For remediated waste sites that are evaluated in the FS because of PRG exceedances, this alternative builds off the interim actions previously completed. The remedial action will include the following:

- RTD for removal of contaminants to clean-up levels for waste sites (47 waste sites), including demolition of structures (e.g., buildings), when necessary
- RTD and void-fill grouting at 100-H-36
- Capping of pipe ends to provide containment of contamination in pipelines associated with waste site 100-D-50:2
- MNA and ICs to mitigate exposure at waste sites 116-DR-9, 100-D-25, and 116-D-8 until radiological contaminants (cesium-137, strontium-90, and technetium-99) decay to less than residential RBSLs in the year 2035

For groundwater, Cr(VI) will be treated with an expanded pump-and-treat with increased treatment capacity for a period of about 12 years following implementation of the remedial alternative for treatment of Cr(VI). The groundwater model results for this alternative, which are considered estimates for comparison purposes, predict Cr(VI) plumes will be remediated to meet the 48 µg/L DWS cleanup levels throughout the aquifer in 6 years. The groundwater treatment systems will continue operating for another

6 years to meet the 10 µg/L State surface water quality standard cleanup level at the river for groundwater flowing into the river. The groundwater treatment system effluent has not and is not expected to exceed MCLs for Cr(VI).

Evaluation of Potential Hydraulic Capture and Plume Recovery from the Ringold Upper Mud (RUM) in the 100-HR-3 Operable Unit (OU) (ECF-100HR3-12-0025 in Appendix F) evaluated use of extraction wells to capture the contamination plume in the RUM. Sensitivity analysis was performed to evaluate bounding cases for flow through the aquifer, leakage from the overlying unit, and flow from the Columbia River. Based on this evaluation a four extraction well configuration is included in the remedial alternatives to remediate Cr(VI) contamination in the RUM water-bearing unit.

Remedial process optimization activities will be conducted throughout the operational period to assess remedial action performance. Groundwater actions include MNA and ICs for strontium-90 contamination.

Nitrate, strontium-90, and total chromium contaminated groundwater plumes are within the treatment footprint for the Cr(VI) plume and will be co-extracted by the extraction well network used for the Cr(VI) plume remediation. Based on operational data from the currently operating pump-and-treat facilities and groundwater simulation modeling results, the groundwater treatment system effluent has not and is not expected to exceed MCLs for co-extracted nitrate, strontium-90, or total chromium, so no treatment is proposed for these groundwater COCs. However, if, through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated for the respective COCs before discharge.

Groundwater model simulation for this alternative indicates that nitrate contamination is remediated to cleanup levels within the Cr(VI) remediation period. Small pockets of strontium-90 contamination remain in the aquifer following completion of the Cr(VI), however, remaining strontium-90 contamination will attenuate to cleanup levels through radiological decay in 32 years after Cr(VI) remediation (i.e., 44 years after implementation of the Alternative 3 remedy). Groundwater monitoring will confirm effectiveness of MNA for strontium-90 and determine the effect of pump-and-treat on the persistence of strontium-90 and nitrate within the aquifer over time.

The Cr(VI) pump-and-treat system includes extraction wells in the area where uranium has been historically detected near the 183-H Solar Evaporation Basin. Operational data indicate the uranium concentrations in the HX pump-and-treat influent and effluent is less than the DWS, as are the current groundwater conditions. The localized uranium contamination, as detected, will be further reduced by dispersion and diffusion created through co-extraction and injection. Any residual uranium contamination in the groundwater following cessation of the pump-and-treat system will continue to be addressed through dispersion and diffusion by normal groundwater flow as discussed in Section 9.2.2.3.

Table 9-8 and Figure 9-11 provide additional information on this alternative. Appendix J, Table J-3, presents a summary of the remedial components, areas, and volumes that were assumed for each waste site in development of cost estimates.

Table 10-4 presents the individual analysis of Alternative 3 with respect to the seven CERCLA criteria. Alternative 3 was considered to pass the threshold criteria, since the actions as part of this alternative achieve RAOs and ARARs. Alternative 3 is considered to have good long-term effectiveness and permanence, short-term effectiveness, and reduction of TMV through RTD and void-fill grouting of contaminated soil and pump-and-treat for groundwater. However, contaminated soil removal by RTD is not considered treatment, so reduction by TMV was reduced to moderately effective. Alternative 3 is expected to be implementable.

Table 10-4. Individual Criteria Evaluation for Alternative 3—RTD and Void-Fill Grouting of Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	O	***Protective of human health and the environment*** • This alternative incorporates previous interim action remedies (i.e., soil RTD and groundwater treatment) that have been demonstrated to be effective. • Monitoring can track progress and achievement of RAOs. • RTD mitigates risks to human and ecological receptors and soil-to-groundwater/surface water risks encountered at the site through physical removal of contaminated soil. • Pump-and-treat remediates the Cr(VI) plumes. Other COCs (strontium-90, and nitrate) will be co-extracted with groundwater extracted for Cr(VI) treatment, where the concentration of strontium-90 and nitrate in the combined effluent will be less than their respective MCLs. Following the cessation of active treatment for Cr(VI), MNA will be the sole mechanism to achieve cleanup levels for strontium-90. • The enhanced pump-and-treat achieves risk standards for groundwater within a period projected to be approximately 44 years of implementation at the 100-D Area, 28 years at the H Areas, and 12 years in the Horn area. • Institutional controls prevent exposure to affected soil and groundwater.
Compliance with ARARs	O	***Compliant*** • Remedial action/systems meet ARARs. • DWS and State surface water quality standard ARARs for Cr(VI) are projected to be achieved in approximately 6 and 12 years of operation, respectively.
Long-term Effectiveness and Permanence	O	***Expected to have long-term effectiveness and permanence*** *Factors expected to perform very well against the long-term effectiveness and permanence criterion:* • RTD, void-fill grouting, containment (by capping of ends of pipelines), MNA and institutional controls, hydraulic containment, and pump-and-treat achieve RAOs. • RTD using conventional equipment is reliable and practiced extensively at Hanford. ERDF disposal is effective and reliable. • Adequacy and reliability of pump-and-treat are proven at Hanford. • Monitoring and verification sampling, and long-term groundwater monitoring track progress toward achieving RAOs. • This alternative remediates soil site and groundwater COCs to PRG levels established to achieve the RAOs. Residual risks following cleanup to PRG levels will meet the 10^{-4} to 10^{-6} ELCR for radiological and carcinogenic COCs and will be less than or equal to an HI value of 1.0 for hazardous substances. • Long-term effectiveness and permanence will be evaluated in the CERCLA 5-year review process. *Factors that may provide some disadvantages or uncertainty to long-term effectiveness and permanence:* • Requires long-term enforcement of institutional controls to mitigate risk.

Table 10-4. Individual Criteria Evaluation for Alternative 3—RTD and Void-Fill Grouting of Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Criterion	Rating	Detailed Analysis
Reduction of TMV by Treatment	○	***Expected to have moderate reduction of TMV by treatment*** *Factors expected to perform moderately well against the reduction of TMV by treatment criterion:* • Significant mass of Cr(VI) will be removed through pump-and-treat where ion exchange treatment removes Cr(VI) from the groundwater. When the ion exchange resin capacity is reached, the resin will be changed out with fresh resin. Removal of Cr(VI) is not reversible since the spent resin loaded with Cr(VI) will be disposed as solid waste at ERDF or another EPA-approved disposal facility. • Void-fill grouting reduces leaching (mobility) of contamination from the vadose zone to groundwater through containment of contaminated media. • Capping of ends of the 100-D-50:2 waste site pipelines provides containment of contaminated media (scale within the pipelines) to reduce direct contact human health risks. • Removed soil is treated at ERDF, if needed *Factors that may provide some disadvantage or uncertainty to the reduction of TMV by treatment:* Contaminated soil removal by RTD is not considered treatment. RTD is the primary remediation technology implemented for most of the waste sites; for this reason, this alternative performs moderately for this criterion.
Short-term Effectiveness	●	***Expected to have short-term effectiveness*** *Factors expected to perform very well against the short-term effectiveness criterion:* • No effects to the community associated with implementation of institutional controls. No adverse risks to the community from implementation of active treatment options because of the site's remote location. • Risks to workers from implementation of active treatment actions are minimized through an HSP and proper PPE. • Nominal short-term risks to workers during installation of groundwater extraction and conveyance piping, system O&M activities, and monitoring. Risks are minimized through HSP and PPE. • Cr(VI) DWS and State surface water quality standard ARARs are achieved within 6 years and 12 years of remedy implementation, respectively. *Factors that may provide some disadvantages or uncertainty to short-term effectiveness* • Negative environmental impacts may include the following: – Generation of GHG from use of excavation equipment and disposal to ERDF, operation of pump-and-treat system – Waste generation from disposal of contaminated soil and spent ion exchange resin – Energy consumption from process equipment • Large amounts of backfill will be required; borrow material may have significant environmental impacts
Implementability	●	***Expected to have Implementability*** *Factors considered for implementability* • Limited technical challenges are associated with implementation of this alternative. • Institutional controls have been approved and implemented, and are reliable/effective at Hanford.

Table 10-4. Individual Criteria Evaluation for Alternative 3—RTD and Void-Fill Grouting of Waste Sites and Increased Capacity Pump-and-Treat for Groundwater

Criterion	Rating	Detailed Analysis
		• Conventional equipment and vendors for implementation of active treatment options (RTD, and pump-and-treat) are readily available. • ERDF is proven, reliable, and accessible. • Grout void-fill being implemented at the Hanford U Plant facility as part of the ROD selected remedy. Grout pours to fill voids in facility structures, larger than those identified for the 100-H-36 waste site at 100-H, have been successfully performed. • Pump-and-treat construction and operations have been previously approved and the ability to construct and operate is proven at Hanford. • Radioactive decay is a confirmed attenuating process for strontium-90, which exhibits a sufficiently short radioactive half-life (29.1 years). *Factors considered for low implementability:* Installation of the large number of new pump-and-treat wells may present logistics problems with waste site excavation.

Cost (in Millions)[a]		
Waste Site Treatment	Capital	$56.2
	Annual O&M	$25.7
	Total Periodic[b]	$0.8
	Total Nondiscounted	$82.7
	Net Present Value	$66.7
Groundwater Treatment	Capital	$131.9
	Total O&M	$93.6
	Total Periodic[b]	$113.5
	Total Nondiscounted	$339.0
	Net Present Value	$308.4
Total Nondiscounted Cost of Alternative		$421.7
Total Net Present Value (Discounted) of Alternative		$375.1

a. Order-of-magnitude cost estimates and support information are presented in Appendix J.

b. Periodic costs include O&M and/or construction activities, including costs to replace an installed remedy or components of an installed remedy, and services that are not included in initial capital costs or annual O&M costs. Periodic costs may be one-time costs or costs that recur at intervals over the life of the remedy.

ARAR = applicable or relevant and appropriate requirement
COC = contaminant of concern
Cr(III) = trivalent chromium
Cr(VI) = hexavalent chromium
DWS = drinking water standard
ELCR = excess lifetime cancer risk
ERDF = environmental restoration disposal facility
GHG = greenhouse gas
HHE = human health and the environment
HSP = health and safety plan
MCL = maximum contaminant level
MNA = monitored natural attenuation
O&M = operations and maintenance
PPE = personal protective equipment
PRG = preliminary remediation goal
RAO = remedial action objective
ROD = record of decision
RTD = removal, treatment, and disposal
TMV = toxicity, mobility, or volume

10.2.4 Alternative 4—RTD for Waste Sites and Pump-and-Treat for Groundwater

Remedial action under Alternative 4 relies on RTD for waste site contamination, to achieve the RAOs with the greatest degree of certainty, and groundwater pump-and-treat. For remediated waste sites that are evaluated in the FS because of PRG exceedances, this alternative builds off the interim actions previously completed. For waste sites, the actions include RTD for removal of contamination to clean-up levels for waste sites (52 waste sites), including demolition of structures (e.g., buildings).

For groundwater, the actions include optimization of the pump-and-treat for treatment of Cr(VI). The optimized pump-and-treat system would operate for 39 years following implementation of the remedial alternative. The groundwater model results for this alternative, which are considered estimates for comparison purposes, predict Cr(VI) plumes will be remediated to meet the 48 µg/L DWS cleanup levels throughout the aquifer in 11 years. The groundwater treatment systems will continue operating for another 28 years to meet the 10 µg/L State surface water quality standard cleanup level at the river for groundwater flowing into the river. The groundwater treatment system effluent has not and is not expected to exceed MCLs for Cr(VI).

Evaluation of Potential Hydraulic Capture and Plume Recovery from the Ringold Upper Mud (RUM) in the 100-HR-3 Operable Unit (OU) (ECF-100HR3-12-0025 in Appendix F) evaluated use of extraction wells to capture the contamination plume in the RUM. Sensitivity analysis was performed to evaluate bounding cases for flow through the aquifer, leakage from the overlying unit, and flow from the Columbia River. Based on this evaluation a four extraction well configuration is included in the remedial alternatives to remediate Cr(VI) contamination in the RUM water-bearing unit.

Remedial process optimization activities will be conducted throughout the operational period to assess remedial action performance. Groundwater modeling simulations are used to support design optimization. Actual performance data are used to update model parameters to reduce model uncertainty. Groundwater simulations are used to modify extraction/injection well field and locations for remediation of remaining contamination. Groundwater actions include MNA and ICs for strontium-90 contamination.

Nitrate, strontium-90, and total chromium contaminated groundwater plumes are within the treatment footprint for the Cr(VI) plume and will be co-extracted by the extraction well network used for the Cr(VI) plume remediation. Based on operational data from the currently operating pump-and-treat facilities and groundwater simulation modeling results, the groundwater treatment system effluent has not and is not expected to exceed MCLs for co-extracted nitrate, strontium-90, or total chromium, so no treatment is proposed for these groundwater COCs. However, if, through normal operation of the groundwater treatment system, concentrations of co-extracted COCs exceed MCLs in the effluent, specific treatment would be evaluated for the respective COCs before reinjection or other approved discharge. Groundwater model simulation for this alternative indicates that nitrate contamination is remediated to cleanup levels within the Cr(VI) remediation period. Small pockets of strontium-90 contamination remain in the aquifer following completion of the Cr(VI), however, remaining strontium-90 contamination will attenuate to cleanup levels through radiological decay in 17 years after Cr(VI) remediation (i.e., 56 years after implementation of the Alternative 4 remedy). Groundwater monitoring will confirm effectiveness of MNA for strontium-90 and determine the effect of pump-and-treat on the persistence of strontium-90 and nitrate within the aquifer over time.

The Cr(VI) pump-and-treat system includes extraction wells in the area where uranium has been historically detected near the 183-H Solar Evaporation Basin. Operational data indicate the uranium concentration in the HX pump-and-treat influent and effluent is less than the DWS, as are the current groundwater conditions. The localized uranium contamination, as detected, will be further reduced by dispersion and diffusion created through co-extraction and injection. Any residual uranium contamination

in the groundwater following cessation of the pump-and-treat system will continue to be managed through dispersion and diffusion by normal groundwater flow as discussed in Section 9.2.2.3.

Table 9-10 and Figure 9-15 provide additional information on this alternative. Appendix J, Table J-3, presents a summary of the remedial components, areas, and volumes that were assumed for each waste site in development of cost estimates.

Table 10-5 presents the individual analysis of Alternative 4 with respect to the seven CERCLA criteria. Alternative 4 was considered to pass the threshold criteria, since the actions as part of this alternative achieve RAOs and ARARs. Alternative 4 is expected to have long-term effectiveness and permanence. Alternative 4 is expected to achieve reduction in TMV because it incorporates active treatment of groundwater and waste sites. However, contaminated soil removal by RTD is not considered treatment, so reduction by TMV was reduced to moderately effective. Short-term effectiveness is expected to be moderate since the Cr(VI) State surface water quality standard is achieved following 39 years of remedy implementation. Alternative 4 is expected to be implementable.

Table 10-5. Individual Criteria Evaluation for Alternative 4— RTD for Waste Sites and Pump-and-Treat for Groundwater

Criterion	Rating	Detailed Analysis
Overall Protection of Human Health and the Environment	○	***Protective of human health and the environment*** • This alternative incorporates previous interim action remedies (i.e., soil RTD and groundwater extraction) that have been demonstrated to be effective, plus additional techniques to optimize remedial design. • Monitoring can track progress and achievement of RAOs. • RTD mitigates risk to human and ecological receptors and soil-to-groundwater/surface water risks encountered at the site through physical removal of contaminated soil. • Pump-and-treat remediates the Cr(VI) plumes. Other COCs (strontium-90, and nitrate) will be co-extracted with groundwater extracted for Cr(VI) treatment, where the concentration of strontium-90 and nitrate in the combined effluent will be less than their respective MCLs. Following the cessation of active treatment for Cr(VI), MNA will be the sole mechanism to achieve cleanup levels for strontium-90. • Pump-and-treat is projected to achieve risk standards in a period of about 56 years in the 100-D Area, 26 years in the 100-H Area, and 39 years in the Horn area. • Institutional controls prevent exposure to affected soil and groundwater.
Compliance with ARARs	○	***Compliant*** • Remedial action/systems are designed to meet ARARs. • DWS and State surface water quality standard ARARs for Cr(VI) are projected be achieved in approximately 11 and 39 years of operation, respectively.
Long-term Effectiveness and Permanence	○	***Expected to have long-term effectiveness and permanence*** *Factors expected to perform very well against the long-term effectiveness and permanence criterion:* • RTD, hydraulic containment, and pump-and-treat achieve RAOs. • RTD using conventional equipment is reliable and practiced extensively at Hanford. ERDF disposal is effective and reliable. • Adequacy and reliability of pump-and-treat operations are proven at Hanford.

Table 10-5. Individual Criteria Evaluation for Alternative 4— RTD for Waste Sites and Pump-and-Treat for Groundwater

Criterion	Rating	Detailed Analysis
		• This alternative remediates soil site and groundwater COCs to PRG levels established to achieve the RAOs. Residual risks following cleanup to PRG levels will meet the 10^{-4} to 10^{-6} ELCR for radiological and carcinogenic COCs and will be less than or equal to an HI value of 1.0 for hazardous substances. • Long-term effectiveness and permanence will be evaluated in the CERCLA 5-year review process. *Factors that may provide some disadvantages or uncertainty to long-term effectiveness and permanence:* • Requires long-term enforcement of institutional controls to mitigate risk. • Cr(VI) treatment systems will operate for 39 years to achieve the State surface water quality standard and may require major system renovations or replacement.
Reduction of TMV by Treatment	○	***Expected to have moderate reduction of TMV by treatment*** *Factors expected to perform moderately well against the reduction of TMV by treatment criterion:* • Significant mass of Cr(VI) will be removed through pump-and-treat where ion exchange treatment removes Cr(VI) from the groundwater. When the ion exchange resin capacity is reached, the resin will be changed out with fresh resin. Removal of Cr(VI) is not reversible since the spent resin loaded with Cr(VI) will be disposed as solid waste at ERDF or another EPA-approved disposal facility. • Removed soil is treated at ERDF, if needed *Factors that may provide some disadvantages or uncertainty to the reduction of TMV by treatment:* • Contaminated soil removal by RTD is not considered treatment. RTD is the primary remediation technology implemented for most of the waste sites; for this reason, this alternative performs moderately for this criterion.
Short-term Effectiveness	○	***Expected to have moderate short-term effectiveness*** *Factors expected to perform moderately well against the short-term effectiveness criterion:* • No adverse risks to the community from implementation of active treatment options because of the remote location and implementation of institutional controls. • Risks to workers from implementation of active treatment actions are minimized through an HSP and proper PPE. • Nominal short-term risks to workers during installation of groundwater extraction and conveyance piping, system O&M activities and monitoring. Risks are minimized through HSP and PPE. • Cr(VI) DWS and State surface water quality standard ARARs are achieved within 11 and 39 years of remedy implementation, respectively. *Factors that may provide some disadvantages or uncertainty to the short-term effectiveness:* • 56 years to achieve RAOs for strontium-90 in the unconfined aquifer. • Negative environmental impacts may include: - Generation of GHG from use of excavation equipment and disposal to ERDF; well installation, development; and operation of

Table 10-5. Individual Criteria Evaluation for Alternative 4— RTD for Waste Sites and Pump-and-Treat for Groundwater

Criterion	Rating	Detailed Analysis
		pump-and-treat system. - Waste generation from disposal of contaminated soil and spent ion exchange resin. • Large amounts of backfill will be required; borrow material may have significant environmental impacts.
Implementability		***Expected to be implementable*** *Factors expected to perform very well against the implementability criterion:* • Conventional equipment and vendors for implementation of active treatment options (RTD, pump-and-treat) are readily available. • RTD of waste sites have been implemented and proven through interim actions at Hanford. • ERDF is proven, reliable, and accessible. • Pump-and-treat construction and operations have been implemented through interim actions, and the ability to construct and operate is proven at Hanford. • Radioactive decay is a confirmed attenuating process for strontium-90, which exhibits a sufficiently short radioactive half-life (29.1 years). • Institutional controls have been approved and implemented, and are reliable/effective at Hanford.

Cost (in Millions)[a]		
Waste Site Treatment	Capital	$68.0
	Annual O&M	$25.6
	Total Periodic[b]	$0.6
	Total Nondiscounted	$94.2
	Net Present Value	$78.3
Groundwater Treatment	Capital	$40.7
	Total O&M	$232.7
	Total Periodic[b]	$251.5
	Total Nondiscounted	$524.9
	Net Present Value	$355.1
Total Nondiscounted Cost of Alternative		$619.1
Total Net Present Value (Discounted) of Alternative		$433.4

Notes:

a. Order-of-magnitude cost estimates and support information are presented in Appendix J. Costs for institutional controls are included under the costs for waste site treatment.

b. Periodic costs include O&M and/or construction activities, including costs to replace an installed remedy or components of an installed remedy, and services that are not included in initial capital costs or annual O&M costs. Periodic costs may be one-time costs or costs that recur at intervals over the life of the remedy.

Table 10-5. Individual Criteria Evaluation for Alternative 4— RTD for Waste Sites and Pump-and-Treat for Groundwater

Criterion	Rating	Detailed Analysis

ARAR	= applicable or relevant and appropriate requirement	MCL	= maximum contaminant level
COC	= contaminant of concern	MNA	= monitored natural attenuation
Cr(III)	= trivalent chromium	O&M	= operations and maintenance
Cr(VI)	= hexavalent chromium	PPE	= personal protective equipment
DWS	= drinking water standard	PRG	= preliminary remediation goal
ELCR	= excess lifetime cancer risk	RAO	= remedial action objective
ERDF	= environmental restoration disposal facility	ROD	= record of decision
GHG	= greenhouse gas	RTD	= removal, treatment, and disposal
HHE	= human health and the environment	TMV	= toxicity, mobility, or volume
HSP	= health and safety plan		

10.3 Comparative Analysis of Remedial Alternatives

The comparative analysis of the proposed alternatives assists in identifying advantages and disadvantages of each alternative relative to the others to identify key tradeoffs that should be noted in the decision-making process. The previous sections presented individual evaluations for each alternative. The remedial alternatives proposed for contaminated soil and groundwater at 100-D/H are compared in Table 10-6, and the analysis follows.

Table 10-6. Comparative Analysis of Alternatives

Criterion	Alternative 1 —No Action Alternative	Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater	Alternative 3—RTD and Void-Fill Grouting of Waste Sites and Increased Capacity Pump-and-Treat for Groundwater	Alternative 4—RTD for Waste Sites and Pump-and-Treat for Groundwater
	Rating	Rating	Rating	Rating
Overall Protection of HHE	No	Yes	Yes	Yes
Compliance with ARARs	No	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 10-6. Comparative Analysis of Alternatives

Criterion	Alternative 1 —No Action Alternative	Alternative 2—RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater	Alternative 3—RTD and Void-Fill Grouting of Waste Sites and Increased Capacity Pump-and-Treat for Groundwater	Alternative 4—RTD for Waste Sites and Pump-and-Treat for Groundwater
	Rating	Rating	Rating	Rating
Implementability	N/A	★☆☆	★★☆	★★★
Net Present Value of Alternative (Discounted)*	N/A	$334 million	$375 million	$433 million

Note: The comparative evaluation metrics are defined as follows:

★☆☆ = Expected to perform less well with more disadvantages or uncertainty when compared to the other alternatives.

★★☆ = Expected to perform moderately well with some disadvantages or uncertainties when compared to the other alternatives.

★★★ = Expected to perform best with less disadvantages or uncertainties when compared to the other alternatives.

ARAR = applicable or relevant and appropriate requirement
N/A = not applicable
HHE = human health and the environment
RTD = removal, treatment, and disposal
* Detailed cost estimates are presented in Appendix J.

The remedial alternatives for the vadose zone propose RTD for the waste sites. Alternatives 2 and 3 propose void filling with grout for waste site 100-H-36, containment by capping pipe ends and ICs for waste site 100-D-50:2, and MNA and ICs for waste sites 100-DR-9, 100-D-25, and 116-D-8. Alternative 3 proposes an expanded pump-and-treat system for remediation of groundwater contamination. Alternatives 2 and 4 use the capacity of the existing pump-and-treat systems, and Alternative 2 includes biological treatment through bioinjection to treat groundwater. Groundwater remediation to achieve RAOs for Alternatives 2 and 4 is projected to take longer than Alternative 3, with Alternative 4 taking longer than Alternative 2. Remedy performance time frames for Alternatives 2, 3, and 4 are based on successful source area remedial action.

10.3.1 Overall Protection of Human Health and the Environment

Alternative 1 is not protective of HHE because RAOs and ARARs are not achieved in a reasonable period.

Alternatives 2, 3, and 4 will achieve the RAOs and meet this threshold criterion. Proposed actions for groundwater are projected to achieve cleanup criteria for Cr(VI) within 25, 12, and 39 years from the start of alternative implementation for Alternatives 2, 3, and 4, respectively. Cleanup levels for all groundwater COCs are projected to be achieved within 56, 44, and 56 years for Alternatives 2, 3, and 4, respectively. For affected waste sites, treatment alternatives such as RTD and void-fill grouting effectively control or prevent significant risks. Unacceptable risks are also prevented or controlled through implementation of ICs, as needed.

10.3.2 Compliance with ARARs

Alternative 1 will not comply with soil cleanup requirements or groundwater chemical-specific ARARs because of the potential for plume migration to the river. Since Alternative 1 does not comply with

ARARs and is not protective of HHE (the two threshold criteria), it was not evaluated for the balancing criteria.

Alternatives 2, 3, and 4 comply with ARARs and meet this threshold criterion. Remedial actions and treatment systems proposed under these alternatives would be designed to meet ARARs. For groundwater, proposed remedies will achieve DWS and State surface water quality standard ARARs in a reasonable time frame.

10.3.3 Long-Term Effectiveness and Permanence

Alternatives 2, 3, and 4 are all expected to provide good long-term effectiveness and permanence. Proposed actions for groundwater are projected to achieve cleanup criteria for Cr(VI) within 25, 12, and 39 years from the start of alternative implementation for Alternatives 2, 3, and 4, respectively. With projected pump-and-treat facility design life of 25 years, systems would need major renovations under Alternative 2 and Alternative 4, which use existing systems that have been in place since 2010.

The alternatives remediate soil site and groundwater COCs to PRG levels established to achieve the RAOs. Residual risks following cleanup to PRG levels will meet the 10^{-4} to 10^{-6} ELCR for radiological and carcinogenic COCs and will be less than or equal to an HI value of 1.0 for hazardous substances.

For waste sites, Alternatives 2, 3, and 4 use RTD and disposal at ERDF to remove contamination, which are demonstrated to be adequate, effective, and reliable at the Hanford Site. Alternatives 2 and 3 also use void-fill grouting of waste site 100-H-36, containment by capping pipe ends, and ICs for waste site 100-D-50:2, and MNA and ICs for waste sites 100-DR-9, 100-D-25, and 116-D-8. Alternative 4 remediates these sites with RTD and disposal at ERDF.

Pump-and-treat is used in Alternatives 2, 3, and 4 for treatment of groundwater. The adequacy and reliability of pump-and-treat is demonstrated at the Hanford Site through the interim actions. Alternative 3 remediates groundwater using expanded pump-and-treat. Alternative 2 uses pump-and-treat enhanced with biological treatment. Alternative 3 provides an expanded pump-and-treat system to address the uncertainties identified in the CSM described in Section 4.9 associated with locations where groundwater monitoring indicates potential residual contamination in the vadose zone that may contribute to groundwater contamination. Alternative 3 enables more flexibility for more responsive system adjustments through the RPO because of the expanded well field and increased system capacity.

Alternatives 2, 3, and 4 will achieve DWSs and State surface water quality standard ARARs in a reasonable time. The adequacy and reliability of ICs is proven at Hanford.

Alternatives 2, 3, and 4 propose implementation of monitoring and include the CERCLA 5-year review process, which would evaluate effectiveness of the proposed actions and track progress towards achievement of RAOs.

10.3.4 Reduction of Toxicity Mobility or Volume through Treatment

Alternatives 2 and 3 are evaluated to perform moderately well for reduction of TMV and better than Alternative 4. RTD is the primary technology implemented for Alternatives 2, 3, and 4 for remediation of waste sites. Contaminated soil removal by RTD is not considered treatment. Alternative 4 implements RTD exclusively for remediation of waste sites and, therefore, provides the least reduction in TMV by treatment among the alternatives.

Void-fill grouting in Alternatives 2 and 3 provide for treatment of 4,550 m^3 (160,600 ft^3) of contaminated soil/debris.

For groundwater, Alternatives 2, 3, and 4 provide substantial reduction of TMV through pump-and-treat and MNA/ICs. Under Alternative 2, reduction of TMV is also achieved through treatment via biological reduction (bioinjection).

10.3.5 Short-Term Effectiveness

Alternatives 2, 3, and 4 are compared primarily against the time for the alternative to achieve RAOs. Alternative 3 achieves RAOs sooner than Alternative 2 and Alternative 4. Alternative 4 takes longer to achieve RAOs than both Alternative 2 and Alternative 3. The time to achieve RAOs following remedy implementation by meeting the State surface water quality standard for Cr(VI) in the unconfined aquifer is 12, 25, and 39 years, respectively, for Alternatives 3, 2, and 4.

The alternatives all protect the community and workers during remedial actions. Potential effects to the community and workers from implementing any actions onsite would be controlled and mitigated through effective health and safety plans (HSP) and adequate PPE.

Effects on the environment for all alternatives result from waste site areas exposed to the environment with machinery-generated dust, generation of remediation process waste, and GHG emissions (from excavation equipment and transportation of material to ERDF). All alternatives will have some negative environmental impacts as follows:

- Ecological disturbances and generation of GHG from use of excavation equipment and disposal to ERDF, installation of well pads and construction and operation of pump-and-treat system
- Waste generation from disposal of contaminated soil and spent ion exchange resin
- Energy consumption from process equipment
- Potential cultural resource effects

10.3.6 Implementability

Alternative 4 uses proven technologies that are currently being implemented for interim remedial actions (i.e., RTD and pump-and-treat) and is considered to have the best implementability compared to the other alternatives.

Alternatives 2 and 3 implement other technologies for waste site treatment (e.g., void-fill grouting) that will likely require additional testing of grout material during remedial design. Alternative 2 also implements biological treatment that will likely require design testing to establish biological reducing zone parameters for design of in situ bioremediation treatment of groundwater.

Although biological treatment proposed in Alternative 2 has been proven, the additional design testing leads to comparatively lower implementability compared to the other alternatives.

10.3.7 Cost

Estimated design, construction, O&M, and decommissioning costs were developed for Alternatives 2, 3, and 4. The total estimated net present value is $334 million for Alternative 2, $375 million for Alternative 3, and $433 million for Alternative 4. The higher cost estimate for Alternative 4 is mainly due to the longer operational period of the pump-and-treat system.

The cost estimate for Alternative 3 includes new facility construction to provide identified increased pump-and-treat capacity. The RD/RAWP will determine if new facilities are needed or if modifications to existing pump-and-treat facilities will provide needed capacity.

Details regarding cost estimates for Alternatives 2, 3, and 4 are provided in Appendix J. These cost estimates have been prepared to meet the -30 to +50 percent range of accuracy recommended in the CERCLA RI/FS Guidance (EPA/540/G-89/004). No capital or O&M costs are associated with Alternative 1.

Overall, Alternative 2 has the lowest cost estimate.

10.4 NEPA Values

This section addresses the incorporation of NEPA values into CERCLA documents. As a matter of DOE policy, DOE has adopted DOE O 451.1B, *National Environmental Policy Act Compliance Program*, at 5.a.(13), which directs DOE field offices to "Incorporate NEPA values, such as analysis of cumulative, off-site, ecological, and socioeconomic impacts, *to the extent practicable*, in DOE documents prepared under the Comprehensive Environmental Response, Compensation, and Liability Act." In a July 11, 2002 policy memorandum from the DOE Office of NEPA Policy and Compliance, it states:

> "Under DOE's CERCLA/NEPA Policy, established in 1994, DOE relies on the CERCLA process for review of actions to be taken under CERCLA, i.e., no separate NEPA document or NEPA process is ordinarily required. In conducting the CERCLA process, DOE addresses NEPA values (such as analysis of cumulative, off-site, ecological, and socioeconomic impacts) to the extent practicable and includes a brief discussion of impacts in CERCLA documents or other site environmental documents as appropriate."

Effectively applying NEPA values is reflected in the manner in which the CERCLA response action complies with ARARs. For example, applicable aspects of the *National Historic Preservation Act of 1966*, and the *Native American Grave Protection and Repatriation Act of 1990* are implemented through the Hanford Cultural Resources Management Plan (DOE/RL-98-10). The *Endangered Species Act of 1973* and the *Migratory Bird Treaty Act of 1918* are implemented through the Hanford Site Biological Resources Management Plan (DOE/RL-96-32).

Alternatives for remediation of contamination at 100-D/H are presented in Chapters 9 and 10, and include:

- Alternative 1 (No Action [as required by the NCP])
- Alternative 2 (RTD and Void-Fill Grouting for Waste Sites and Pump-and-Treat with Biological Treatment for Groundwater)
- Alternative 3 (RTD and Void-Fill Grouting of Waste Sites and Increased Capacity Pump-and-Treat for Groundwater)
- Alternative 4 (RTD for Waste Sites and Pump-and-Treat for Groundwater)

The No Action Alternative would not mitigate the environmental impacts from contaminated waste sites and groundwater. All other alternatives mitigate the environmental impacts associated with affected waste sites and groundwater within the scope of the 100-D/H RI/FS.

Consideration of NEPA values associated with remediation is based on the information presented in this RI/FS, including the area and site characteristics (Chapters 1, 2, and 3), COPCs and ARARs (Chapter 8), and identification and analysis of remedial actions (Chapters 9 and 10). The principle 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 Alternatives 2, 3, or 4 would be a positive contribution to cumulative environmental effects at the Hanford Site. Where RTD is part of the selected remedial action, DOE expects that the primary facility to receive contaminated soil will be the ERDF. NEPA values for ERDF operation were addressed in *NEPA Roadmap for the Environmental Restoration Disposal Facility Regulatory Package* (DOE/RL-94-41), *Remedial Investigation and Feasibility Study Report for the Environmental Restoration Disposal Facility* (DOE/RL-93-99), and the ROD, as amended (most recently *Amendment to the Record of Decision for the USDOE Hanford Environmental Restoration Disposal Facility* [EPA et al., 2007]).

DOE has included the combined effects anticipated from ongoing CERCLA/TPA (Ecology et al., 1989a) response actions and a Hanford Site groundwater analysis as part of the cumulative impact analysis in *Final Tank Closure and Waste Management Environmental Impact Statement for the Hanford Site, Richland, Washington* (DOE/EIS-0391). In addition, the impacts of borrow materials used during remediation was analyzed in *Expansion of Borrow Areas on the Hanford Site* (DOE/EA-1934). 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 10-7.

10.5 Coordination of Interim and Final CERCLA Remedial Activities

A feature of each alternative 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.

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 remedial action goals established under the interim action RODs have been met. This information will be essential to implementing final action RODs.

There are many buildings and structures in the 100 Area. The buildings and structures are evaluated for removal, usually using a CERCLA removal action. Once these structures are demolished and decommissioned under CERCLA non-time-critical removal actions, samples of the residual soil may be collected for analysis. If the analytical results indicate the area is contaminated, the area is considered a potential waste site. The area is then evaluated, and a remedy is selected in accordance with the interim action ROD.

The sequence and timing of the remedial action to be conducted at the 100-D/H Area OUs under the ROD associated with this RI/FS will be specified in an RD/RAWP written by DOE. The RD/RAWP will be submitted to Ecology within 6 months after ROD approval. In-progress interim action remediation for these OUs shall use the cleanup levels selected in the ROD immediately upon its issuance. All other aspects of the interim actions for these OUs shall continue to be performed in accordance with the existing RD/RAWP. When the new RD/RAWP is approved, that document will direct future remedial action and will replace all interim action RD/RAWP requirements.

Table 10-7. 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 aforementioned Alternatives; they would involve transport of contaminated soil moved from a waste site(s) to ERDF. Lesser effects would result from backfilling, including transportation of borrow material, revegetation, and monitoring activities. Transportation effects to ERDF 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). Transportation effects associated with a waste site under Alternatives 2, 3, and 4 are similar, though Alternative 2 and Alternative 3 effects are somewhat smaller than for Alternative 4, given the smaller volume of soil to be excavated and transported to ERDF. The discussion of cumulative effects provides a perspective of transportation to ERDF.
Water Quality	Considers potential water quality concerns associated with the groundwater below the site and the Columbia River.	All alternatives include source area remediation and implement pump-and-treat to restore groundwater to beneficial uses. Contaminants would be removed from groundwater in all alternatives, which would be expected to cause a net positive effect in water quality both for groundwater below the site and for the Columbia River.
Air Quality	Considers potential air quality concerns associated with emissions generated during the proposed action.	Airborne releases associated with Alternatives 2, 3, and 4 could occur because of dust generation during excavation. Any potential of airborne release of contaminants during alternative 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. Alternative 4 is expected to have a slightly greater extent of these emissions since the larger quantity of soil would be excavated and transported. As applicable, vehicular and equipment emissions would be controlled and mitigated in compliance with the substantive standards for air quality protection that apply to the Hanford Site.

Table 10-7. NEPA Values Evaluation

NEPA Values	Description	Evaluation*
Ecological, Cultural, and Historic 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 installation of groundwater wells and excavation of contaminated soil. Such effects would be mitigated in accordance with the *Hanford Site Biological Resources Management Plan* (DOE/RL-96-32) and *Biological Resources Mitigation Strategy* (DOE/RL-96-88), and applicable standards of all relevant biological species protection regulations. Effects to cultural and historic resources 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 cultural and historic resources and address any other relevant concerns.
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 create 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.
Environmental Justice	Considers if 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 are no effects associated with proposed activities associated with 100-D/H 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.
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], *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.

Table 10-7. NEPA Values Evaluation

NEPA Values	Description	Evaluation*
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. (When a resource [e.g., energy minerals, water] or wetlands is used or destroyed and cannot be replaced within a reasonable amount of time, its use is considered irreversible.)	Materials that would be used to backfill waste sites could be taken from the surrounding area to contour the backfill to match the surrounding area. Borrow materials were addressed in *Expansion of Borrow Areas on the Hanford Site* (DOE/EA-1934). For Alternatives 2, 3, and 4, normal usage of resources during construction activities, such as fuel and water, would be irreversibly used. Potential effects would be expected to be greater for Alternative 4, because of the slightly larger 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.
Cumulative Impacts (Direct and Indirect)	Considers if 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-D/H 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 material threat to human health and the environment, that threat would be mitigated. The net anticipated effect would 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, like ERDF. Backfill of the remediated waste sites to natural contour and revegetation to the shrub steppe habitat would also provide a positive contribution to cumulative environmental impacts. Contaminated soil removed under any alternative would meet the ERDF waste acceptable criteria as described in *Environmental Restoration Disposal Facility Waste Acceptance Criteria* (WCH-191). Wastes generated during implementation of the proposed alternatives would be manageable within the capacities of existing facilities. For perspective, current ERDF capacity is roughly 3 million tons. 100-D/H generated 396,000 tons of waste in CY 2011 and 224,00 tons in CY 2012. Radiological contamination is expected to be minimal. Radiological contamination from 100-D/H waste included approximately 21,000 Ci in CY 2011 and approximately 9,500 Ci in CY 2012.

ARAR = applicable or relevant and appropriate requirement
COC = contaminant of concern
CY = calendar year
DOE = U.S. Department of Energy
ERDF = Environmental Restoration Disposal Facility
NEPA = *National Environmental Policy Act of 1969*
RTD = removal, treatment, and disposal
* Includes the evaluation for each alternative.

10.6 CERCLA and RCRA Corrective Action and TSD Unit Closure

In the TPA (Ecology et al., 1989a), DOE, EPA, and Ecology intend to integrate DOE's CERCLA response obligations and RCRA corrective action obligations which relate to the release(s) of hazardous substances, hazardous wastes, pollutants and contaminants covered by the TPA. 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 applies to the performance of both CERCLA remedial action and RCRA corrective action.
- Article XXIII acknowledges the potential for overlap between CERCLA and RCRA cleanup.
- Article XXIV specifies the approach for regulatory oversight.

Section 5.4 of the TPA Action Plan (Ecology et al., 1989b) describes the rationale for placing units in either a RCRA-CERCLA or a CERCLA past practice category for corrective action. Two key objectives are that "all past-practice units within an OU will be designated as either RCRA-CERCLA past practice units or CERCLA past practice units" and that "the past practice process selected for each operable unit shall 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 the RCRA Hanford Facility Permit (*Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste* [WA7890008967]), Condition II.Y.2.a, which provides that "Ecology accepts work under the HFFACO, as amended, and under the CERCLA program, as satisfying corrective action requirements to the extent provided for in, and subject to the reservations and requirements of, Permit Conditions II.Y.2.a.i through II.Y.2.a.iv." (Ecology et al., 1989a).

The 183-H Solar Evaporation Basins are currently in post-closure care. Groundwater monitoring will continue under current RCRA permit requirements until permit modifications are approved and implemented.

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