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DOE/RL-2012-68
Draft A

# Proposed Plan for Remediation of the 100-NR-1 and 100-NR-2 Operable Units

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

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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**APPROVED**
*By Shauna Adams at 7:04 am, Jun 18, 2013*

Release Approval Date

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River Corridor Remediation at the Department of Energy Hanford Site—EPA Region 10

# Proposed Plan for Remediation of the 100-NR-1 and 100-NR-2 Operable Units

DOE/RL-2012-68, Draft A
June 2013

U.S. Department of Energy,
Richland Operations Office
U.S. Environmental Protection Agency
Washington State Department of Ecology

**Public Comment Period TBD**

*How You Can Participate:*

***Read*** this Proposed Plan and review documents in the Administrative Record.

***Comment*** on this Proposed Plan by mail or e-mail on or before TBD.

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***See*** page 70 for more information about public involvement and contact information.

**Figure 1. 100-N Area Location within the Hanford Site**

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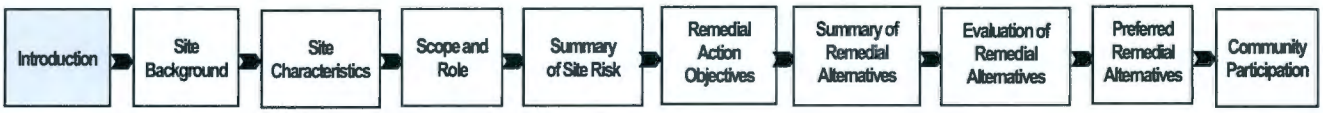
The U.S. Department of Energy (DOE), the Washington State Department of Ecology (Ecology), and the U.S. Environmental Protection Agency (EPA) invite the public and Tribal Nations to comment on this ***Proposed Plan***[1] for cleanup of one soil ***operable unit (OU)*** and one ***groundwater*** OU in the 100-N Area of the Hanford Site located near Richland, Washington (Figure 1). DOE has completed its investigation of these ***waste sites*** and groundwater through its comprehensive ***remedial investigation (RI)/feasibility study (FS)*** process. The RI/FS concluded that without ***remedial action***, some contaminants in these OUs would exceed acceptable risk levels to human health and the environment (HHE). This Proposed Plan identifies cleanup for contaminated soil and ***debris*** in 136 waste sites in the 100-NR-1 OU and cleanup for groundwater in the 100-NR-2 OU, which comprise the 100-N Area portion of the 100 Area ***National Priorities List*** (NPL) site. DOE is issuing this Proposed Plan to summarize and seek public and Tribal Nations input on the cleanup alternatives considered and on the ***preferred alternative*** proposed for implementation.

[1] Important technical and administrative terms are used throughout this Proposed Plan. When these terms are first used, they appear in ***bold italics***. Explanations of these terms are provided in the Glossary at the end of this Proposed Plan.

Input from the Tribal Nations and the public on this Proposed Plan will help Ecology and EPA, working in cooperation with DOE, select the final remedy. Ecology is the lead regulatory agency for the 100-N Area OUs that are the subject of this Proposed Plan, and EPA is the non-lead regulatory agency. The RI/FS documents and the preliminary determination leading up to the ***Record of Decision (ROD)*** will be the responsibility of DOE and Ecology. The remedial action selected may differ from the preferred alternative presented in this Proposed Plan based on comments received during the public comment period.

Comments on this Proposed Plan will be accepted during the 30-day public comment period (see sidebar on the left of page 1). Following consideration of Tribal Nations and public input on the cleanup alternatives presented in this Proposed Plan, a ROD identifying the alternative selected for implementation will be prepared jointly by EPA and Ecology, working in cooperation with DOE. The ROD will include a ***responsiveness summary*** that will present the comments received, and DOE and Ecology's responses to those comments. The responsiveness summary will also identify where comments resulted in a change to the preferred alternative.

The following graphic is included before each new section to indicate where the new section fits within the Proposed Plan:




## Introduction

DOE, the lead agency responsible for conducting the RI/FS and implementing the selected cleanup alternative, is issuing this Proposed Plan to fulfill the public participation requirements under Section 117(a) ("Public Participation," "Proposed Plan") of the ***Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)*** (commonly known as "Superfund") and Section 300.430(f)(2) ("Remedial Investigation/Feasibility Study and Selection of Remedy") of the "***National Oil and Hazardous Substances Pollution Contingency Plan***" (commonly known as the "National Contingency Plan," or NCP) (40 ***Code of Federal Regulations [CFR]*** 300). CERCLA establishes the federal authority for conducting cleanup at Superfund sites, and the NCP includes requirements and expectations for cleanup.

In 1989, the Hanford Site's 100 Area was placed on the CERCLA NPL (NCP, 40 CFR 300, Appendix B). Also in 1989, DOE, EPA, and Ecology (known as the ***Tri-Parties***) entered into the *Hanford Federal Facility Agreement and Consent Order* ***(Tri-Party Agreement)*** (Ecology et al., 1989), which governs cleanup of the Hanford Site. To enhance implementation of the Site's CERCLA cleanup, the Tri-Parties divided the overall cleanup into discrete OUs, which under CERCLA are logical groupings of facilities, waste sites, or environmental media (e.g., soil, groundwater, and surface water) for decision-making and management purposes.

DOE has completed an investigation of the 100-NR-1 and the 100-NR-2 OUs (found in DOE/RL-2012-15, *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units* [hereafter called the 100-N RI/FS report]) and prepared this Proposed Plan. This investigation evaluated the entire 100-N Area for the release of chemicals and ***radionuclides***. The process is described in the 100-N RI/FS report (Appendix L of DOE/RL-2012-15). Contamination within the 100-NR-1 OU was associated with 136 waste sites, which were included in the *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-99/112, hereafter called the 100-N interim action ROD) and the *Interim Remedial Action Record of Decision for the 100-NR-1 Operable Unit, Hanford Site, Benton County, Washington* (EPA/ROD/R10-00/120, hereafter called the 100-NR-1 interim action ROD).

This Proposed Plan presents a preferred alternative and the other alternatives that were considered for the final remedy for all 136 waste sites. Of the 98 waste sites recommended for additional remedial actions, 89 will have already been remediated under the interim action RODs. Once the final remedy is selected, it will be incorporated into a ROD that would replace the 100-N and 100-NR-1 interim action RODs.

Contamination within 100-NR-2 OU groundwater has resulted from liquid wastes discharged to waste sites in the 100-NR-1 OU or unintentionally released to the subsurface. The contaminated groundwater was included in the 100-N interim action ROD (EPA/ROD/R10-99/112). This Proposed Plan presents a preferred alternative and the other alternatives that were considered for the final remedy for the contaminated groundwater.

The 100-N RI/FS report (DOE/RL-2012-15) and other supporting information used to develop and evaluate cleanup alternatives are available in the ***Administrative Record***, which can be viewed at the various information repositories identified in the "Community Participation" section of this Proposed Plan. The 100-N RI/FS report (DOE/RL-2012-15) concluded that without remedial action, contaminants in waste sites and the groundwater would present an unacceptable level of risk to HHE.

## Remedial Alternatives

As described in later sections of this Proposed Plan and in detail in the 100-N RI/FS report (Chapter 9 of DOE/RL-2012-15), five ***remedial alternatives*** were developed to provide integrated waste site and groundwater remediation. The remedial technologies included in the five alternatives were selected based on identification and detailed screening of a broad array of potential technologies (Chapter 8 of DOE/RL-2012-15).

Several technologies, including ***monitored natural attenuation (MNA)***, were evaluated for remediation of strontium-90 contamination in the groundwater upgradient of the near-shore area. However, no technologies were identified that could achieve the ***drinking water standard (DWS)*** in a reasonable time frame (typically identified as within 100 years). Therefore, Alternatives 2 through 5 require a ***technical impracticability (TI) waiver*** of this ***applicable or relevant and appropriate requirement (ARAR)*** for strontium-90 in groundwater in order to meet the CERCLA threshold criteria of overall protection of HHE and compliance with ARARs. A detailed discussion of the TI waiver is provided in Appendix O of the 100-N RI/FS report (DOE/RL-2012-15).

Based on the detailed and comparative evaluation performed in the FS (Chapter 10 of DOE/RL-2012-15), Alternative 3 is the preferred alternative and addresses risks posed by the soil and groundwater contamination to HHE. The five remedial alternatives are as follows:

- ***Alternative 1 — No Action:*** Under the No Action alternative, no remedial action would be taken to address potential threats to HHE, and all ongoing soil and groundwater interim actions would be discontinued. The NCP (40 CFR 300.430[e][6]) requires consideration of a No Action alternative.

- ***Alternative 2 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs:*** Alternative 2 uses ***removal, treatment, and disposal (RTD)*** to excavate contaminated soil and debris from waste sites; an apatite ***permeable reactive barrier (PRB)*** to enhance attenuation of strontium-90 in the ***vadose zone*** and groundwater near the shore of the Columbia River; a TI waiver for strontium-90 in the groundwater upgradient of the apatite PRB; bioventing for total petroleum hydrocarbon-diesel (TPH-D)-contaminated soil in the deep vadose zone; MNA for TPH-D in groundwater; and groundwater monitoring for strontium-90, TPH-D, ethylbenzene, chromium, hexavalent chromium (Cr[VI]), nitrate, and ***contaminants of potential concern (COPCs)***. ***Institutional controls (ICs)***

are identified for specific waste sites and groundwater areas as required to protect HHE until cleanup levels are achieved.

- ***Alternative 3 (Preferred Alternative) — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs:*** Alternative 3 uses RTD to excavate contaminated soil and debris from waste sites; an apatite PRB to enhance attenuation of strontium-90 in the vadose zone and groundwater near the shore of the Columbia River; a TI waiver for strontium-90 in the groundwater upgradient of the apatite PRB; bioventing for TPH-D-contaminated soil in the deep vadose zone; biosparging for TPH-D-contaminated groundwater; and groundwater monitoring for strontium-90, TPH-D, ethylbenzene, chromium, Cr(VI), nitrate, and COPCs. ICs are identified for specific waste sites and groundwater areas as required to protect HHE.

- ***Alternative 4 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs:*** Alternative 4 uses RTD to excavate contaminated soil and debris from waste sites; an apatite PRB to enhance attenuation of strontium-90 in the vadose zone and groundwater near the shore of the Columbia River; a TI waiver for strontium-90 in the groundwater upgradient of the apatite PRB; bioventing for TPH-D-contaminated soil in the deep vadose zone; biosparging for TPH-D-contaminated groundwater; carbon (organic) substrate injections for in situ biological treatment of nitrate in groundwater; and groundwater monitoring for strontium-90, TPH-D, ethylbenzene, chromium, Cr(VI), nitrate, and COPCs. ICs are identified for specific waste sites and groundwater areas as required to protect HHE.

- ***Alternative 5 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90; Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs:*** Alternative 5 uses RTD to excavate contaminated soil and debris from waste sites; an apatite PRB to enhance attenuation of strontium-90 in the vadose zone and groundwater near the shore of the Columbia River; apatite injections to enhance attenuation of strontium-90 in groundwater in the area upgradient of the apatite PRB; a TI waiver for strontium-90 in the groundwater upgradient of the apatite PRB; bioventing for TPH-D-contaminated soil in the deep vadose zone; biosparging for TPH-D-contaminated groundwater; carbon (organic) substrate injections for in situ biological treatment of nitrate in groundwater; and groundwater monitoring for strontium-90, TPH-D, ethylbenzene, chromium, Cr(VI), nitrate, and COPCs. ICs are identified for specific waste sites and groundwater areas as required to protect HHE.

### Preferred Alternative

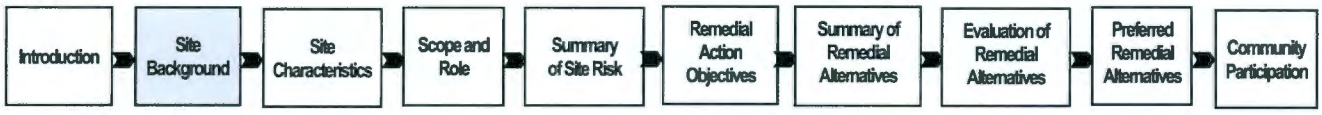
Based on the results of the detailed and comparative evaluation in the 100-N RI/FS report (Sections 10.2 and 10.3 of DOE/RL-2012-15), the preferred alternative is Alternative 3 (RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90; Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs).

This alternative meets the statutory requirements under CERCLA and the NCP (40 CFR 300) to select remedies that are protective of HHE and comply with ARARs (or justify a waiver), are cost effective, and use permanent solutions and alternative treatment technologies to the maximum extent practicable. In addition, Alternative 3 satisfies the statutory preference for remedies using treatment that permanently and significantly reduces the toxicity, mobility, or volume of hazardous wastes as a principal element and the statutory bias against offsite disposal of untreated wastes. Alternative 3 proposes a TI waiver from the ARAR to achieve the DWS for strontium-90 in the upland groundwater in a reasonable time frame.

## Proposed Plan Organization

The subsequent sections of this Proposed Plan include the following:

- **Site Background:** Facts about the site contamination, investigations, interim remedial actions, and previous public participation.
- **Site Characteristics:** Description of land and groundwater use, physical features affecting remedy selection, and the ***nature and extent of contamination*** at waste sites and in groundwater.
- **Scope and Role:** How the waste site and groundwater remedial actions fit into the overall Hanford Site cleanup strategy; descriptions of prior and planned cleanup actions.
- **Summary of Site Risks:** Identifies the ***contaminants of concern (COCs)***, results of the ***baseline risk assessment***, and land and groundwater use assumptions.
- ***Remedial Action Objectives (RAOs)*:** Description of what the proposed Hanford Site cleanup is expected to accomplish.
- **Summary of Remedial Alternatives:** Identification of the options for attaining the identified RAOs.
- **Evaluation of Remedial Alternatives:** Comparison of the remedial options using CERCLA criteria.
- **Preferred Remedial Alternative:** Explanation of the rationale for selecting the preferred alternative.
- **Community Participation:** Information on how the Tribal Nations and public can provide input to the remedy selection process.




# Site Background

The Hanford Site is a 1,517 $km^2$ (586 $mi^2$) federally owned property located within the semiarid, shrub-steppe Pasco Basin of the Columbia Plateau in south-central Washington State. Past nuclear material production and processing at the Hanford Site released hazardous substances to the environment, resulting in areas of contaminated soil and groundwater that pose a risk to HHE. To facilitate cleanup, the Hanford Site has been divided into the following major components: the River Corridor, the Central Plateau (Inner and Outer Areas), Groundwater, and Tank Waste. The River Corridor (Figure 2) includes 570 $km^2$ (220 $mi^2$) of land that borders the Columbia River and has been divided into six geographic areas. These six areas were identified to define portions of the River Corridor that align with historical operations (e.g., uranium fuel rod preparation or reactor operations).

The section of the Columbia River next to the Hanford Site is within the Hanford Reach, a non-tidal, free-flowing section of the river. The Hanford Reach extends from the upstream Priest Rapids Dam to the downstream slack waters of Lake Wallula, created by McNary Dam. In 2000, Presidential Proclamation 7319 (*Establishment of the Hanford Reach National Monument*), under authority of the *American Antiquities Act of 1906*, set aside approximately half of the Hanford Site for preservation as the Hanford Reach National Monument (HRNM), including lands in the River Corridor within about 0.4 km (0.25 mi) of the river (Figure 2).

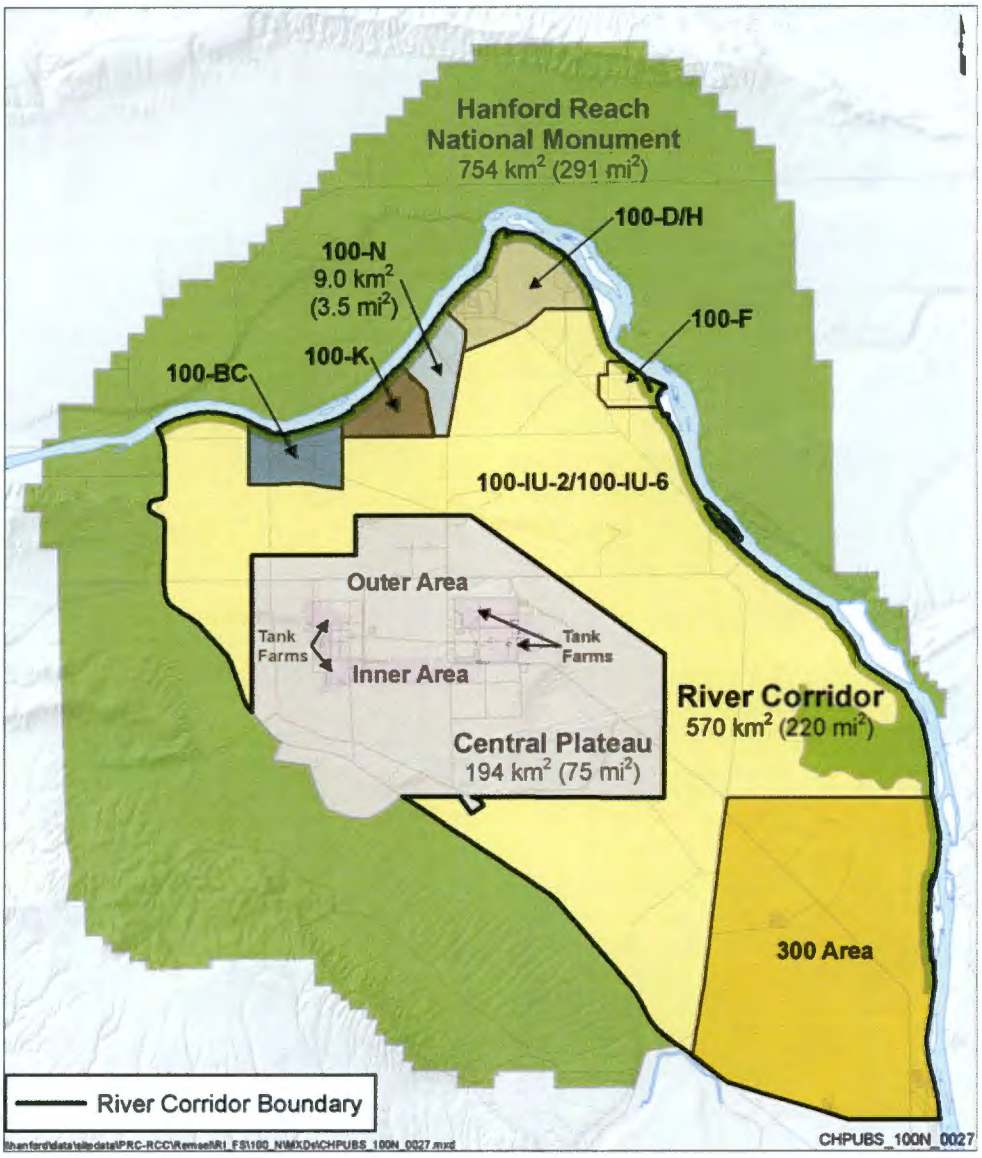



**Figure 2. Hanford Site**

The 100-N Area encompasses approximately 9.0 km$^2$ (3.5 mi$^2$) adjacent to the Columbia River in the northwest portion of the Hanford Site. Operations in the 100-N Area began in 1964 following construction of the N Reactor, the last of the nine Hanford Site plutonium-production reactors constructed between 1943 and 1964 (Figure 3).

Among the Hanford Site's plutonium-production reactors, the design of N Reactor was unique. The N Reactor was a dual-purpose reactor that produced plutonium for defense purposes and steam for public/commercial electrical power generation by the adjoining Hanford Generating Plant (HGP). A major design change from the other eight Hanford production reactors was introduced to support this dual-purpose mission. The once-through cooling water design of previous Hanford reactors was replaced with a closed-loop, recirculation design for the primary cooling water system. The primary loop provided cooling for the N Reactor fuel elements and thermal shields. Heat exchangers (steam generators) in the primary cooling water loop transferred energy to a secondary steam/water cooling system. The secondary cooling loop transferred the excess heat to the HGP steam

generators to generate electricity for commercial use. The N Reactor reached full operating power in 1964; the 800-megawatt HGP began producing electricity in 1966. The reactor continued to operate, producing plutonium and electricity, until it was shut down in 1986.

**Figure 3. N Reactor Complex During Construction (1962)**

Operation of the N Reactor and associated facilities generated radioactive liquid wastes. Normal operation of the N Reactor primary coolant system resulted in bleed-off and leakage wastes, which were discharged to the 116-N-1 and 116-N-3 Cribs and Trenches. Approximately every 3 to 5 years, the reactor primary coolant loop was decontaminated to remove the activation and fission products that had built up as residue in the piping. The spent decontamination solution was routed from the primary coolant loop to the 116-N-2 (1310-N) chemical waste storage tank, where it was neutralized and sent to the 200 Areas for disposal in underground tanks. Final decontamination rinses were pumped through the primary cooling system and discharged to the 116-N-1 and/or 116-N-3 Cribs and Trenches. The secondary coolant system was a closed-loop system with a relatively small bleed-off that was discharged to the 116-N-1 and 116-N-3 Cribs and Trenches. Additional details on radioactive liquid waste are provided in the 100-N RI/FS report (Section 1.3.2.3 of DOE/RL-2012-15).

Untreated Columbia River water was used to cool the secondary cooling loop water for N Reactor in a single-pass mode. The effluent was discharged to the Columbia River through the 100-N-77 pipeline from the 1908-N outfall. Untreated Columbia River water was also used to cool the HGP turbine condensate. This effluent was discharged to the Columbia River through the 100-N-80 pipeline from the 1908-NE outfall. Both river discharges were permitted through the National Pollutant Discharge Elimination System authorized by the *Clean Water Act of 1972*.

Approximately 98 percent of the heat from N Reactor was transferred to the secondary cooling loop in the 109-N Heat Exchange Building. The balance of the heat was transferred to the ancillary cooling water systems for the graphite moderator block, the concrete thermal and biological shields, the horizontal control rods, and the fuel storage basin. Most of the ancillary cooling water systems included secondary heat exchangers cooled by

circulating untreated Columbia River water. As a result, nearly all of the thermal energy not used to produce steam for electrical generation was disposed to the Columbia River through a permitted wastewater discharge.

From 1963 to 1972, sodium dichromate was added to the once-through ancillary cooling water system used to cool the horizontal control rods. The primary function of the sodium dichromate was to provide corrosion protection for aluminum parts. The design of N Reactor required approximately 100 times less sodium dichromate for corrosion control compared to that required at the first eight single-pass reactors in the 100 Areas. The ancillary cooling water, containing low concentrations of sodium dichromate, was discharged to the 116-N-1 Crib and Trench.

In 1972, the once-through ancillary cooling water system was converted to a recirculation process, and sodium dichromate was replaced with hydrazine in the cooling water for corrosion control. Approximately 79.5 billion L (21 billion gal) of chromium-free water were flushed through the 116-N-1 Crib in the 10 plus years following cessation of sodium dichromate use. Given the high solubility of Cr(VI) and its low affinity to sorb to sediments (i.e., high mobility), it was likely flushed from the vadose zone and the unconfined aquifer during this time.

From 1963 until 1984, the spent fuel storage basin was cooled using a single-pass ancillary cooling water system. Irradiated fuel was discharged from N Reactor to the spent fuel basin and stored in the water-filled basin for about 180 days to allow radioactive decay of short-lived fission products before transfer for reprocessing. In 1984, a recirculating cooling water treatment system was installed to cool, filter, and recycle the fuel storage basin water. The recirculating cooling water treatment system provided a 90 percent reduction in the amount of strontium-90 discharged.

The fission products from ruptured irradiated fuel were purged from the fuel storage basin to the 116-N-1 Crib and Trench from 1963 to 1985, and to the 116-N-3 Crib and Trench from 1985 to 1991. Essentially all of the strontium-90 and cesium-137 that was discharged to the 116-N-1 and 116-N-3 Cribs and Trenches was from the fuel storage basin cooling and purgewater.

Operations at N Reactor required large supplies of untreated Columbia River water for cooling and to produce filtered water and demineralized water for use in the N Reactor systems. Water treatment chemicals were used to produce filtered water and demineralized water. Liquid effluents associated with these activities were nonradioactive. Nonradioactive liquids were discharged to percolation sites, septic drain systems, and water treatment ponds. Additional details on nonradioactive liquid wastes are provided in the 100-N RI/FS report (Section 1.3.2.4 of DOE/RL-2012-15).

Fuel oil and diesel were used to produce emergency electric power and steam. The 166-N Tank Farm stored Number 6 fuel oil in one large aboveground storage tank and Number 2 diesel fuel in four aboveground storage tanks. The fuel was used in boilers and generators that provided steam and emergency electrical power for the N Reactor emergency cooling system. The diesel fuel was used to ignite the fuel oil and to power emergency generators and pumps.

A major spill (302,833 L [80,000 gal]) of diesel fuel occurred in 1966 when a 10 cm (4 in.) diameter pipeline corroded and developed a leak (unplanned release [UPR]-100-N-17) near the western side of the 166-N Tank Farm. The diesel fuel flowed overland toward the river, draining through the soil to the groundwater, eventually reaching the Columbia River. A trench (100-N-65) was excavated along the riverbank to intercept the diesel fuel before it could reach the river. Diesel fuel captured in the trench was burned periodically through 1967 (DOE-RL-90-22, *RCRA Facility Investigation/Corrective Measures Study Work Plan for the 100-NR-1 Operable Unit, Hanford Site, Richland, Washington*), and remediation of residue from this release continues

today (WCH-490, *UPR-100-N-17: Bioventing Pilot Plant Performance Report*). Other (smaller) petroleum releases have also occurred at the 100-N Area (Table 1-4 of the 100-N RI/FS report [DOE/RL-2012-15]).

Solid waste consisted of radioactive spacers and various other contaminated items associated with reactor operations. There are no permanent solid waste burial grounds in the 100-N Area (WHC-MR-0521, *The Plutonium Production Story at the Hanford Site: Processes and Facilities History*). The burial grounds in the 100-BC, 100-K, and 100-D Areas were used to dispose of contaminated solid wastes generated at the 100-N Area. Additional detail on the solid waste is provided in the 100-N RI/FS report (Section 1.3.2.5 of DOE/RL-2012-15).

## Investigations and Testing

In 1991, the Tri-Parties developed the *Hanford Past-Practice Strategy* (DOE/RL-91-40) to prioritize CERCLA investigations and identify early actions to address waste sites and groundwater contamination that may pose a near-term impact to public health and the environment. Protection of the Columbia River by taking action in the River Corridor was a central objective of the strategy. Strontium-90 contamination in the 100-N Area became the focus of early decisions and actions.

In the 1990s, RIs and ***limited field investigations*** were initiated for the 100-NR-1 and 100-NR-2 OUs (DOE/RL-93-80, *Limited Field Investigation Report for the 100-NR-1 Operable Unit Abatement Assessment*; DOE/RL-93-81, *Limited Field Investigation Report for the 100-NR-2 Operable Unit: Hanford Site, Richland, Washington*; and DOE/RL-96-11, *1301-N and 1325-N Liquid Waste Disposal Facilities Limited Field Investigation Report*). These investigations were an initial step in characterizing the nature and extent of contamination in the waste sites and associated vadose zone that received radioactive liquid effluent discharges. A comprehensive summary of previous 100-N Area investigations is included in the 100-N RI/FS report (Section 1.3.4 and Appendix N of DOE/RL-2012-15). The results of these investigations are also presented in the 100-N RI/FS report (Chapter 4 and Appendix D of DOE/RL-2012-15). These early investigations led to the selection of actions to remediate source and groundwater contamination within the 100-NR-1 and 100-NR-2 OUs under an expedited response action and two interim action RODs (described in the "Previous Cleanup Actions" section of this Proposed Plan).

In 1998, the DOE Richland Operations Office (DOE-RL) requested that the Innovative Treatment and Remediation Demonstration (ITRD) Program provide technical assistance to evaluate innovative technologies to address strontium-90 contamination in the vadose zone and groundwater at the 100-N Area. The ITRD Program formed and coordinated the Technical Advisory Group (TAG) with technology experts and participants from government, industry, and regulatory agencies. The strength of the ITRD process rested in its review and identification of approximately 40 technologies relevant to strontium-90 remediation. Based on the results of additional site characterization that the TAG deemed necessary to further evaluate these technologies, the TAG retained five technologies for further consideration: a clinoptilolite permeable barrier, a sheet pile/cryogenic impermeable barrier, MNA, phytoremediation, and soil flushing. The ITRD process is described in more detail in the 100-N RI/FS report (Sections 1.3.5 and 8.3.1 of DOE/RL-2012-15).

By 2003, installation of a sheet pile wall had been attempted and found to be unfeasible, and the TAG had determined that soil flushing was not a feasible option. Interest in strontium stabilization using phosphate injection (chemical injection) was renewed based on reports of successful bench testing at Sandia National Laboratory. In December 2004, DOE and Ecology agreed to test this technology and consider it for full-scale application in the FS. Following extensive study and laboratory testing (described in Chapter 1 of the 100-N RI/FS report [DOE/RL-2012-15]), pilot testing began with the injection of apatite-forming chemicals into the aquifer through vertical wells along the bank of the Columbia River. The test area, approximately 91 m (300 ft) long, encompassed the highest strontium-90 concentrations observed at the shoreline.

Throughout 2006 and 2007, a low-concentration, apatite-forming solution was injected into shallow groundwater, followed by a high-concentration injection in 2008. The low-concentration injections were designed to provide a small amount of treatment capacity, thus stabilizing the strontium-90 residing within the treatment zone. In theory, this approach would act to minimize strontium-90 mobilization during subsequent high-concentration injections. However, based on the results and experience from these injections, a high-concentration amendment solution was formulated to maximize apatite formation within the targeted treatment zone while minimizing the short-term increases in strontium-90 concentration associated with injection of high ionic-strength solutions. The apatite barrier was extended in 2011 to 274 m (900 ft) using this modified formulation (Section 8.3.1 of the 100-N RI/FS report [DOE/RL-2012-15]).

Strontium-90 sequestration using this technology occurs by injecting a calcium-citrate-phosphate solution into the aquifer. After the solution is injected, biodegradation of the citrate results in apatite (a calcium phosphate mineral [$Ca_5(PO_4)_3(OH)$]) precipitation. The strontium-90 (and strontium) ions in groundwater substitute for calcium ions through cation exchange and eventually become trapped as part of the mineral matrix during apatite crystallization.

In 2010, an amendment to the 100-N interim action ROD required that the apatite PRB be extended to a total length of approximately 762 m (2,500 ft) in the aquifer. Prior to full-scale expansion, two studies were conducted to optimize the apatite PRB technology (described in Section 8.3.2 of the 100-N RI/FS report [DOE/RL-2012-15]). The injection wells to extend the length of the ***preliminary remediation goal (PRG)*** to 762 m (2,500 ft) were installed in 2011 as part of the barrier extension design optimization study, but these wells have not yet been injected with the calcium-citrate-phosphate solution.

In 2007 and 2008, a treatability test was conducted to determine the suitability of phytoextraction for treatment of strontium-90 in soil and groundwater in the 100-N Area. Phytoextraction is a managed remediation technology in which plants are used to extract or bind soil contaminants. The results of the testing and an evaluation of the advantages and disadvantages of phytoextraction are provided in the 100-N RI/FS report (Section 8.5.3.1 of DOE/RL-2012-15). The potential benefits of implementing phytoextraction at the 100-N Area do not compensate for the significant risks associated with this technology, and phytoextraction was not considered further in the FS.

The RI for the 100-N Area was conducted in accordance with the *Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan* (DOE/RL-2008-46), which contains the planning elements common to all of the Hanford Site 100 Area source and groundwater OUs, and the *Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan, Addendum 5: 100-NR-1 and 100-NR-2 Operable Units* (DOE/RL-2008-46-ADD5 [hereafter called the 100-N work plan]), which is specific to the 100-N Area. In addition, the RI was conducted in accordance with the *Sampling and Analysis Plan for the 100-NR-1 and 100-NR-2 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-42). These work plans and the sampling and analysis plan were developed and approved by Ecology to assist in reaching final decisions for the OUs within the 100 Area NPL site (40 CFR 300, Appendix B).

The RI combined the results of previous studies, monitoring, and remediation with vadose zone and groundwater data collected under the 100-N work plan (DOE/RL-2008-46-ADD5). The RI field activities included drilling and sampling vadose zone boreholes; installing and sampling groundwater monitoring wells; sampling pore water, surface water, and sediment to investigate groundwater upwelling in to the Columbia River; and collecting and analyzing groundwater samples to define the nature and extent of contamination and to support the risk assessment. The boreholes and wells were drilled and sampled in 2011. The results of the RI are provided in the 100-N RI/FS report (DOE/RL-2012-15).

## Previous Cleanup Actions

A total of 238 facilities were used or constructed in the 100-N Area to support operations. As of December 2012, 215 of the 238 facilities have been demolished or removed, 8 facilities are awaiting decommissioning and demolition, and 15 facilities are currently in use (Table 1-7 of the 100-N RI/FS report [DOE/RL-2012-15]) (Figure 4). Until the structures located over a source site are removed, soil remediation cannot be completed. Therefore, the facilities (including associated contaminated pipelines) have been undergoing removal to clear the way for the remedial work that focuses on underlying soil contamination.

**Figure 4. Aerial Photograph of the N Reactor Complex (October 2012)**

Remediation of the waste sites in the 100-NR-1 OU began in 1999 under the authority provided by the 100-N interim action ROD, 100-NR-1 interim action ROD, and the *Resource Conservation and Recovery Act of 1976* (RCRA) closure and monitoring plans. In accordance with the interim action RODs, each excavation has soil sampling and modeling conducted (if needed) to assess the potential impact to human health, groundwater, and the Columbia River from residual contamination. Remediation consists of RTD of contaminated soil, debris, and waste material; backfill with clean material and recontouring to provide a natural grade; followed by revegetation with native plants. Remediation follows the observational approach, including the use of radiological field screening data, in-process samples, and direct visual observation.

Liquid discharges to the 116-N-1 (1301-N) and 116-N-3 (1325-N) Cribs and Trenches were the major sources of groundwater contamination in the 100-NR-2 OU. Between 2000 and 2005, approximately 474,000 metric tons (522,000 tons) of contaminated soil were removed during remediation of these two sites (Figures 1-18 and 1-19 in the 100-N RI/FS report [DOE/RL-2012-15]). As of December 2012, interim remediation had been completed for 30 of the 138 waste sites in the 100-NR-1 OU. As of June 2012, approximately 660,000 metric tons (725,000 tons) of contaminated soil and debris had been removed from 100-N Area waste sites. Additional details on the 100-NR-1 OU waste site remediation are provided in the 100-N RI/FS report (Sections 1.3.2.6 and 1.3.5.2 of DOE/RL-2012-15).

In September 1995, an expedited response action using ***pump-and-treat*** technology to address strontium-90 groundwater contamination was implemented along the Columbia River shoreline upgradient of N Springs ("Action Memorandum: N-Springs Expedited Response Action Cleanup Plan, U.S. Department of Energy Hanford Site, Richland, WA" [Ecology and EPA, 1994]). The pump-and-treat system, originally designed to have a minimum combined extraction pumping rate of 190 L/min (50 gal/min) with a 10-year operational life, was upgraded to operate at 227 L/min (60 gal/min) beginning in December 1996.

The pump-and-treat extraction wells were located along the entire length of the 116-N-1 (1301-N) Trench, between the trench and the river, to reduce the flux of strontium-90 to the Columbia River. At the optimized pumping rate of 227 L/min (60 gal/min), the system was removing approximately 0.2 Ci of strontium-90 each year, which was approximately 10 times less than the amount removed each year by radioactive decay. Strontium-90 data collected at the river's edge also showed that the strontium-90 plume was not changing significantly since implementation of the system, and that strontium-90 concentrations had not decreased. However, operation of the system provided hydraulic containment of the plume, with a 96 percent reduction in net groundwater flux of strontium-90 toward the river by 1998. From September 1996 through March 2006, the 100-N pump-and-treat system treated more than 1.1 billion L (305 million gal) of groundwater and removed approximately 1.8 Ci of strontium-90 from the aquifer in the 100-NR-2 OU. Additional details on the 100-N pump-and-treat system are provided in the 100-N RI/FS report (Sections 1.3.5.3 and 8.4.3.1 of DOE/RL-2012-15).

The TPH-D plume in groundwater is centered on well 199-N-18 (Figure 1-10 in the 100-N RI/FS report [DOE/RL-2012-15]). In compliance with the 100-N interim action ROD (EPA/ROD/R10-99/112), over 10 kg (22 lb) of diesel (as free product) were removed from groundwater in this well between 2003 and 2011 (Table 1-10 in the 100-N RI/FS report [DOE/RL-2012-15]).

To address the deep TPH-D contamination, the 100-N interim action ROD (EPA/ROD/R10-99/112) prescribed in situ bioremediation. A system of injection wells would supply oxygen to the TPH-D-contaminated soils at the depth where remediation would take place. In preparation for this technology, a bioventing pilot plant operational test was conducted at the UPR-100-N-17 (166-N diesel oil supply line leak) waste site between February 2010 and May 2011. Based on the results of the bioventing treatability test, a full-scale bioventing system was implemented in December 2012 (Section 8.3.4 of the 100-N RI/FS report [DOE/RL-2012-15]).

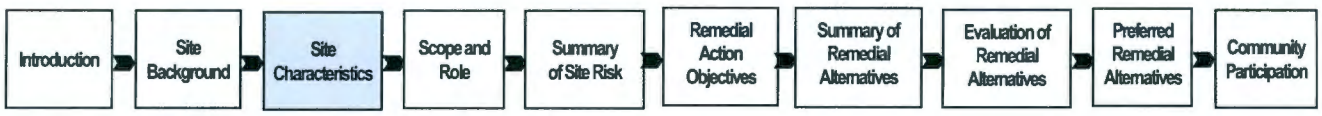
## Previous Public Participation

The *Hanford Public Involvement Plan* (Ecology et al., 2012) outlines ways that the public can become involved in Hanford Site cleanup decision making and summarizes information about government and public organizations involved with Hanford Site issues, including the state of Oregon and the Hanford Advisory Board (a federally chartered advisory board comprised of representatives of diverse stakeholders concerned with Hanford Site cleanup). Historical input and advice from all parties relative to the 100-NR-1 and 100-NR- OUs were reviewed in the development of this Proposed Plan.

The Tri-Parties conducted formal public involvement during the previous decision processes for soil and groundwater cleanup in the 100-NR-1 and 100-NR-2 OUs, as well as for ***deactivation and decommissioning*** of buildings in the 100-N Area. A list of the relevant prior decision documents can be found in the "Scope and Role" section of this Proposed Plan.

### Previous Tribal Nation Participation

The Hanford Site is located on land ceded to the United States under separate treaties with the Confederated Tribes and Bands of the Yakama Nation and the Confederated Tribes of the Umatilla Indian Reservation (CTUIR). The Nez Perce Tribe also secured rights on what is now the Hanford Site in its separate treaty. In addition, DOE consults with the Wanapum Band of Indians, who had historically resided on Hanford lands. During preparation of this Proposed Plan, DOE and Ecology invited the Tribes to formal consultation on this proposed cleanup action. In addition to these formal activities, DOE and Ecology have worked with Tribal staff during the RI/FS process.




## Site Characteristics

The following discussion provides information on 100-N surface features, current land and groundwater uses, the contamination release conceptual model, and groundwater contaminant plumes.

### Site Features and Land and Groundwater Use

Major facilities and roads in the 100-N Area are shown on Figure 5. The 105-N Reactor building is in interim safe storage (ISS) until the final remediation decision is implemented. The Bonneville Power Administration substation is active and is expected to remain active for many years.

The 100-N Area is being used for waste management, environmental monitoring, waste site remediation, and conservation and restoration activities. This segment of the river adjacent to the 100-N Area is used for a variety of recreational activities.

Many communities downstream of the Hanford Site draw water from the Columbia River for all or part of their domestic water supply. The City of Richland's water uptake is the closest to the Hanford Site. The City of Richland provides an annual drinking water report to comply with the *Safe Drinking Water Act of 1974*. Contaminants released from Hanford Site operations have not caused an exceedance of legally safe drinking water levels at the city's intake.

### Physical Features Impacting Remedy Selection

The topography of the reactor area in the 100-N Area is relatively flat, with elevations increasing from approximately 140 to 165 m (459 to 541 ft) above mean sea level inland from the Columbia River. The area has been disturbed and graded extensively since reactor construction began in 1959 and continues through present-day waste site remediation activities that restore natural contours. The elevation at the river shore is approximately 120 m (390 ft) above mean sea level. From the riverbank, the topography rises up a relatively narrow and terraced, steep (greater than 30 percent) slope onto the broad, slightly undulating plain where the reactor and ancillary facilities are located.

The localized relief on the surrounding terrain is the result of catastrophic flooding associated with Pleistocene glaciation (DOE/RL-93-81), and it is characterized by a series of rolling low hills and mounds known as Mooli Mooli ("Little Stacked Hills") (DOE/RL-2009-54, *Proposed Plan for Amendment of 100-NR-1/NR-2 Interim Action Record of Decision*). Several geologic terraces and levees are located along both sides of the river channel adjacent to the 100-N Area. Based on geological and archeological studies of the terraces (Section 3.1 of the 100-N RI/FS report [DOE/RL-2012-15]), the Columbia River has occupied the same channel, from the

100-BC Area to the 100-D Area, for at least the past 8,000 years (BHI-01628, *Final Report for Interim Stabilization of 211-U and 211-UA Contamination Areas*; and WCH-46, *Late Pleistocene- and Holocene-Age Columbia River Sediments and Bedforms; Hanford Reach Area, Washington, Part 2 – Geologic Atlas Series*). The Columbia River channel is stable and should not change during decay of strontium-90 in the shoreline sediment adjacent to the channel.

Figure 6 shows the stratigraphy and hydrogeologic units for the 100-N Area. The ***vadose zone*** at 100-N is 0 to 23 m (0 to 77 ft) thick, and it thins to the northwest adjacent to the Columbia River. The geologic units found in the vadose zone within the 100-N Area include recent deposits near the surface (i.e., silt and sand and backfill) underlain by the gravel-dominated sequence of the Hanford formation and the upper portion of the Ringold Formation unit E (Figure 6). Additional details about the vadose zone are provided in the 100-N RI/FS report (Section 3.5 of DOE/RL-2012-15).

**Figure 5. 100-N Area Features**

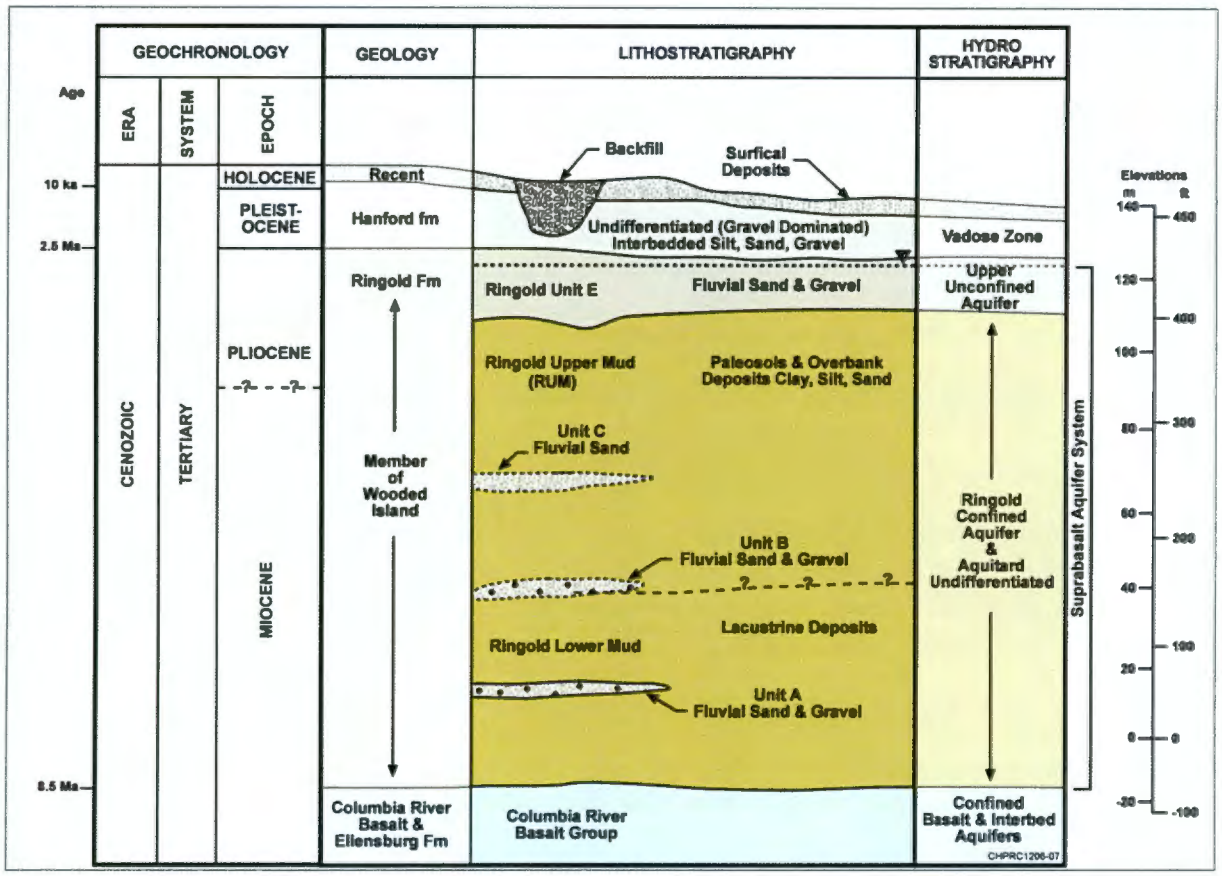



**Figure 6. Stratigraphy ad Hydrogeologic Units of the 100-N Area**

The contact between the Hanford formation and the Ringold unit E is important because the saturated hydraulic conductivity for the gravel-dominated sequence of the Hanford formation is one to two orders of magnitude higher than the more compacted and locally cemented Ringold unit E. Since hydraulic conductivity varies with the formation, different groundwater-level responses may occur where channels scoured into the Ringold Formation are now filled with Hanford formation sediment. These buried channels can potentially become preferential pathways for contaminated groundwater during high river stages.

The complicating aspect of the release of contaminants from the vadose zone in the 100-N Area is the seasonal and diurnal fluctuations of the Columbia River. High river stage can cause the water table to temporarily rise into vadose zone sediments that contain higher concentrations of contaminants. The subsequent lowering of the river stage and water table may carry remobilized contaminants to the aquifer. Additionally, the diurnal and seasonal water table fluctuations may cause chemistry changes within this periodically rewetted zone (PRZ) that affect the release of contaminants from the vadose zone. This interaction between the river, aquifer, and vadose zone may result in a continuing source of contaminants to the groundwater and is considered part of the conceptual basis for the deeper than expected occurrence of relatively immobile (i.e., high distribution coefficient) analytes.

The water table is encountered within the upper Ringold unit E and forms the top of the unconfined aquifer. The unconfined aquifer at 100-N occurs entirely within the Ringold unit E (sands and gravels), except during very high river stages adjacent to the river where the lowest Hanford formation sediment (the PRZ) becomes saturated. The Ringold upper mud (aquitard) underlies the entire area; is a thick, low-transmissivity unit; and

forms the base of the unconfined aquifer. The unconfined aquifer ranges in thickness from approximately 6.5 to 14 m (21 to 46 ft).

The net groundwater flow beneath the 100-N Area is northwest toward the Columbia River from upgradient inland to the southeast. Groundwater discharges to the river primarily below the low water line and above the Ringold upper mud surface contact. When the river stage is low, the overall groundwater flow direction is northwest toward the river. However, when the river stage is high, the overall groundwater flow direction is southeast away from the river because the ***hydraulic gradients*** change direction in response to river stage. This interaction with the river not only affects groundwater flow patterns, but it also affects contaminant transport rates, groundwater geochemistry, contaminant concentrations, and ***attenuation rates***.

From the 1960s through the 1980s, effluent discharged to the liquid waste disposal facilities (LWDFs) created groundwater mounds that influenced groundwater flow and the distribution of contaminants. While groundwater mounds existed, the water table was raised through the Ringold Formation to approximately the lower Hanford formation in some parts of 100-N. At that time, groundwater discharged to the Columbia River through a series of riverbank springs (known as N Springs) occurring in the hill slope above the Columbia River that roughly correlated to the exposure of the Hanford formation/Ringold Formation contact (UNI-3866, *Characterization of Radionuclide Concentrations of the N-Springs Along the Columbia River Shoreline*). The groundwater mounds in the 100-N Area dissipated rapidly in the early 1990s after liquid effluent disposal ceased.

In 2010, the 100-K Area pump-and-treat operations began to influence the groundwater flow patterns in the southwestern portion of the 100-N Area. The water table elevation has been modified artificially by groundwater injection and extraction pumping. A groundwater mound at least 1 m (3.3 ft) high creates the potential for radial flow in the southernmost part of the 100-N Area.

Daily and seasonal changes in Columbia River stage are controlled by the Priest Rapids Dam, located upstream of the Hanford Site. During spring, the river level rises because snowmelt runoff is allowed to flow through the dam. During these periods of high river stage, river water flows into the aquifer along the Hanford Reach, causing the water table to rise throughout the 100 Area. High river stages can be more than 3 m (10 ft) higher than low river stages. River stage may fluctuate several feet over short time intervals (i.e., hours to days) based on Priest Rapids Dam operations (DOE/RL-96-84, *Remedial Design and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units' Interim Action*). Changing river stage influences groundwater elevations at least 1.7 km (1.1 mi) inland from the river (Section 3.6.1 of the 100-N RI/FS report [DOE/RL-2012-15]).

Groundwater in the unconfined aquifer discharges to the Columbia River via upwelling through the riverbed and riverbank seeps. The rate of discharge from the Hanford Site aquifer is very low compared to the flow of the river. Because the river stage regularly fluctuates up and down, the flow beneath the shoreline is back and forth, with river water intruding into the unconfined aquifer and mixing with groundwater. When the river stage drops to a low elevation, localized riverbank seeps may occur (sometimes masked beneath riprap). With the overall lowering of the water table caused by cessation of effluent discharges in 1991, the riverbank springs known as N Springs have disappeared.

### Waste Site Contamination

The liquid waste discharged to the 100-NR-1 OU waste sites primarily contained nitrate, radionuclides, metals, anions, and organic chemicals. Most of the mobile contaminants (e.g., nitrate and Cr[VI], which was used early in the process) have migrated through the vadose zone to the groundwater.

The 116-N-1 and 116-N-3 Cribs and Trenches were the primary source of strontium-90 contamination in the subsurface of the 100-N Area. Contamination in the shallow vadose zone at these sites was removed during implementation of the RTD interim remedy. Because strontium-90 sorbs strongly to sediment grains, the majority of the strontium-90 remaining in the subsurface in the 100-N Area is in the vadose zone. The lateral extent of the residual strontium-90 in the vadose zone is similar to the lateral extent of the strontium-90 groundwater plume.

At the 116-N-1 and 116-N-3 waste sites, strontium-90 contamination remaining below the depth of the interim remedial action excavation generally decreases with depth. Soil sampling was conducted in the 116-N-1 Crib, 116-N-1 Trench, and 116-N-3 Crib in 2011 as part of the RI. In the cribs and trenches, strontium-90 was detected through the vadose zone and into groundwater, but the highest concentrations of strontium-90 were detected at mid-depth in the vadose zone (in the Hanford formation). Downgradient of the 116-N-1 Crib and Trench, the highest concentrations of strontium-90 detected in 2011 were near the water table. Detailed results of the characterization sampling conducted at these sites are provided in the 100-N RI/FS report (Sections 4.3.2 and 4.3.3 of DOE/RL-2012-15).

When the water table rises, residual strontium-90 sorbed to sediment in the deep vadose zone is released to groundwater, and concentrations in the groundwater increase. When the water table decreases, strontium-90 resorbs to sediment, and concentrations in the groundwater decrease. Annual concentration peaks in groundwater are correlated with periods when the water table was higher and saturated the lower vadose zone (Ringold Formation) containing residual strontium-90 contamination.

Several diesel and fuel oil spills occurred in the vicinity of the 166-N oil storage facilities; the largest was a 302,800 L (80,000 gal) diesel fuel spill in 1966 (UPR-100-N-17). The fuel oil flowed over land toward the river, drained through the soil to the groundwater, and eventually reached the Columbia River. A trench (100-N-65) was excavated along the riverbank to intercept the oil before it could enter the river. Oil captured in the trench was burned periodically through 1967.

Soil samples were collected in the area of the 166-N oil storage facility in 2011 as part of the RI. Elevated concentrations of TPH-D range and TPH-gasoline range were detected in samples collected near the water table. These contaminants are consistent with residual contamination from historical spills of diesel and fuel oil in this region. Detailed results of characterization sampling are provided in the 100-N RI/FS report (Section 4.3.4 of DOE/RL-2012-15).

Seven wells were installed in the vicinity of UPR-100-N-17 in 2009 to support the bioremediation pilot study for the TPH-D contamination in the vadose zone. Field data collected during borehole installation showed that all seven wells had elevated TPH-D concentrations in the deep vadose zone and extended to the water table. Data from these wells indicate that the contamination in the vadose zone is generally located above the TPH-D groundwater plume, with the highest concentrations mirroring those in the groundwater. Results of the bioventing characterization sampling are provided in the 100-N RI/FS report (Table 9-1 and Section 9.2.2 of DOE/RL-2012-15).

Ecology and DOE-RL have agreed to a process to create a discovery site (shallow petroleum-only releases [SPOR]) (100-N-106) to address recent unanticipated discoveries of petroleum contamination at the 100-N Area. Sites are included in the SPOR waste site if soil stains and/or elevated TPH or polyaromatic hydrocarbons are discovered during remediation where petroleum contamination was not initially a concern (i.e., it was not identified as a potential contaminant for the waste site). Only shallow RTD sites (0 to 4.6 m [0 to 15 ft] below ground surface [bgs] excavation) are included in the SPOR waste site. If petroleum contamination is found deeper than >4.6 m (>15 ft) bgs, further discussions between Ecology and DOE-RL will identify site dispositions (e.g., bioventing, soil removal, or other options).

Figure 7 shows the locations of the waste sites in the 100-NR-1 OU that have been remediated under interim action RODs. Figure 8 shows the location of the sites that remain to be remediated.

In addition to the waste sites in the 100-NR-1 OU, the 100-N interim action ROD (EPA/ROD/R10-99/112) presented an additional site, the "shoreline site," as requiring remediation. The shoreline site was defined as a single, unique waste site containing the N Springs (riverbank seeps) along the eastern shore of the Columbia River, as well as associated contaminated soil from strontium-90-contaminated groundwater discharge from the 1301-N and 1325-N Cribs and diesel-fuel-contaminated soil from waste site 100-N-65 (DOE/RL-95-111, *Corrective Measures Study for the 100-NR-1 and 100-NR-2 Operable Units*). The shoreline site is approximately 840 m (2,772 ft) long and 22 m (73 ft) wide. The lateral boundaries are generally defined as the river's edge at the low river stage (115 m [378 ft] above mean sea level), and the river's edge during a 300-year flood event (estimated at 123 m [402 ft] above mean sea level). The N Springs are the result of groundwater discharge from the unconfined aquifer flowing under the 100-N Area, and from the release (at certain times of the year) of Columbia River water held in bank storage. A riprap cover consisting of large boulders was placed over the N Springs seeps in 1984 to minimize the accessibility of the seeps to both human and fauna contact.

## Groundwater Contamination

Groundwater contaminants at levels that exceed the DWS, federal or state water quality standards, or calculated cleanup levels per the ***Model Toxics Control Act (MTCA)*** (*Washington Administrative Code* [WAC] 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards") in the 100-NR-2 OU are strontium-90, TPH-D, and associated ethylbenzene, nitrate, chromium, and Cr(VI). Contaminant concentrations are declining in groundwater through natural processes of degradation, radioactive decay, and dispersion.

***Strontium-90.*** The extent of the strontium-90 plume in 2011 is shown on Figure 9. The area of the strontium-90 plume that exceeds the 8 ***picocurie (pCi)***/L DWS is approximately 0.58 $km^2$ (143 ac). The plume had nearly the same areal extent and shape in 2011 as it did in 1996, before startup of 100-N pump-and-treat operations. The highest groundwater concentrations are still found at the water table beneath the 116-N-1 and 116-N-3 sites, where large volumes of liquid waste containing strontium-90 were discharged and where most of the strontium-90 was initially sorbed. Because strontium-90 strongly sorbs to sediment, the strontium-90 concentrations decrease both laterally and vertically away from these source areas (i.e., no significant dispersion in the decades since source disposal ended). The strontium-90 contamination occurs primarily in the uppermost portion of the unconfined aquifer and in the PRZ, the interval affected by water table vertical fluctuations.

***Nitrate.*** The extent of the 2011 nitrate plume is shown on Figure 10. The area of the nitrate plume that exceeds the 45 mg/L DWS is approximately 0.58 $km^2$ (143 ac). The highest concentrations are found beneath the 116-N-1 Crib and Trench, decreasing away from these source sites. The nitrate contamination appears to be uniformly dispersed through the unconfined aquifer. The nitrate groundwater plume is commingled with the strontium-90 groundwater plume (Figure 11).

***TPH-D and Ethylbenzene.*** The extent of the TPH-D plume is shown on Figure 12. The area of the TPH-D plume is approximately 0.01 $km^2$ (2.5 ac) and it is centered on well 199-N-18, with detections of TPH-D found in seven other nearby wells. The size of the plume will continue to decrease because of ongoing remediation and natural dispersion and migration in groundwater. The TPH-D primarily occurs at the water table and decreases to undetectable levels with depth into the unconfined aquifer. Residual concentrations of TPH-D greater than 200 µg/L detected deeper in the unconfined aquifer appear to be of limited extent. The TPH-D contaminant plume remains within the same historical flow path from the 166-N Tank Farm leak source to the Columbia River.

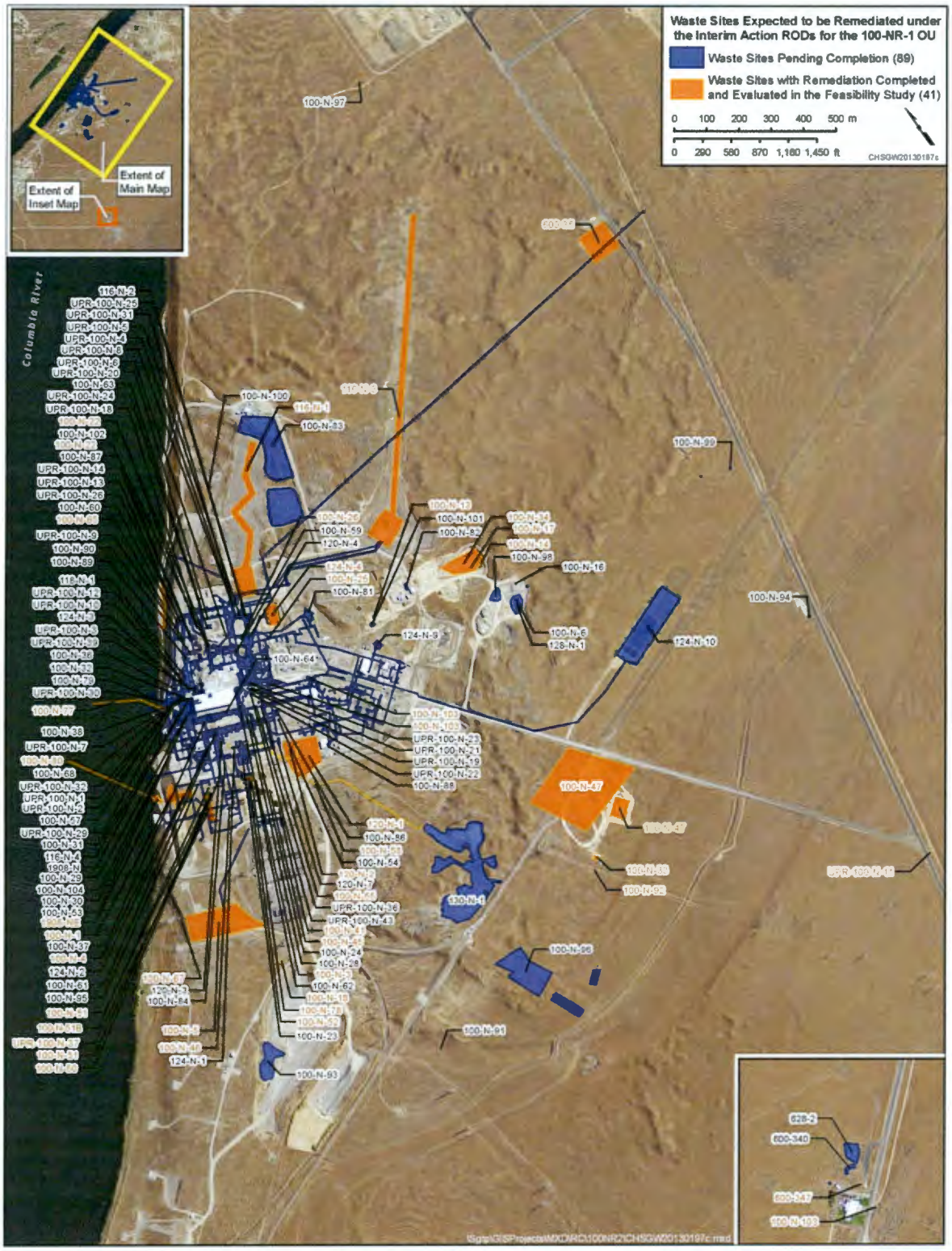



Figure 7. Waste Sites Expected to be Remediated under the Interim Action RODs for the 100-NR-1 OU (Not Included in the FS Cost Estimate)

**Figure 8. Waste Sites Expected to be Remediated under the ROD for the 100-NR-1 OU (Included in the FS Cost Estimate)**

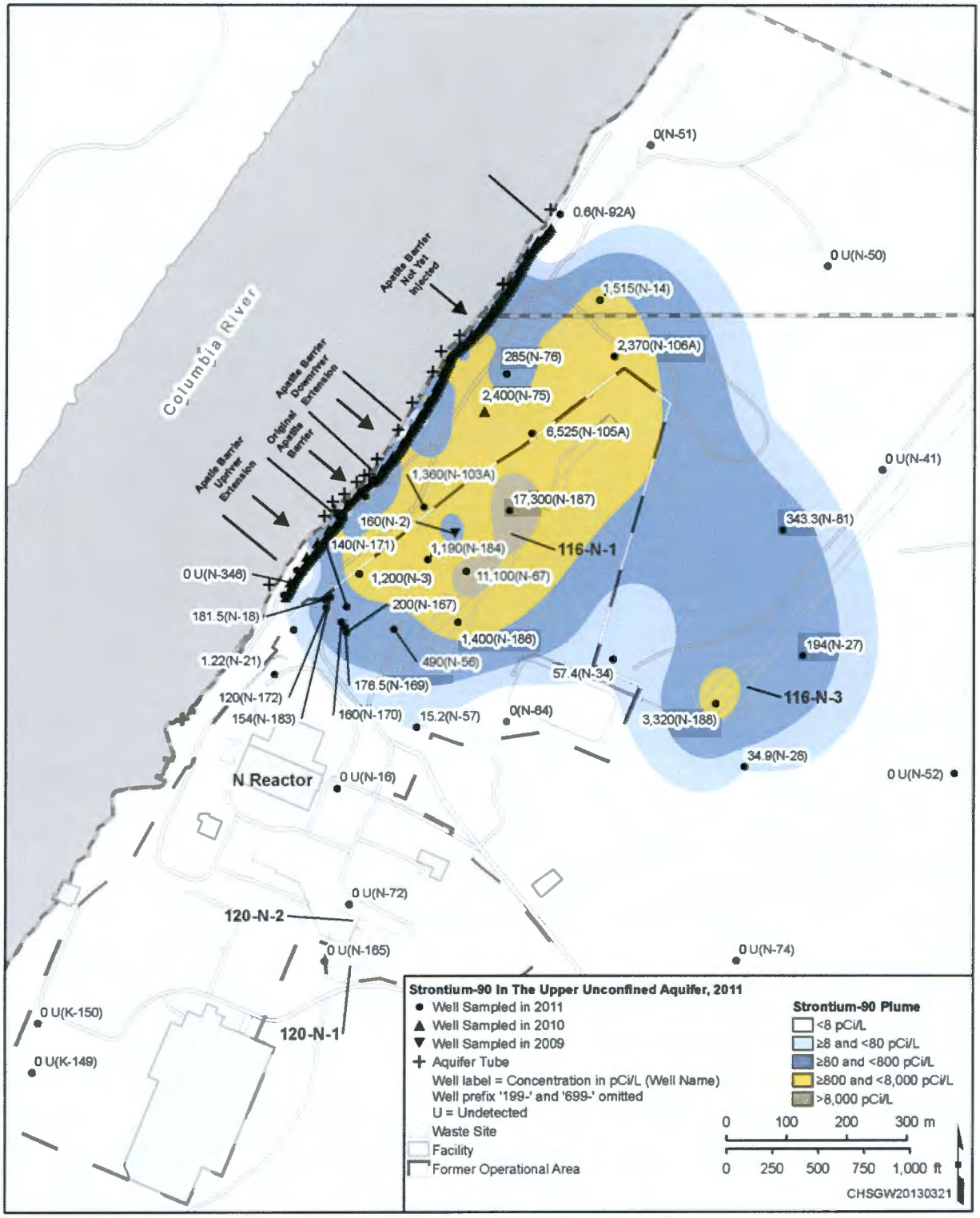



Figure 9. 100-NR-2 OU Strontium-90 Groundwater Plume, 2011

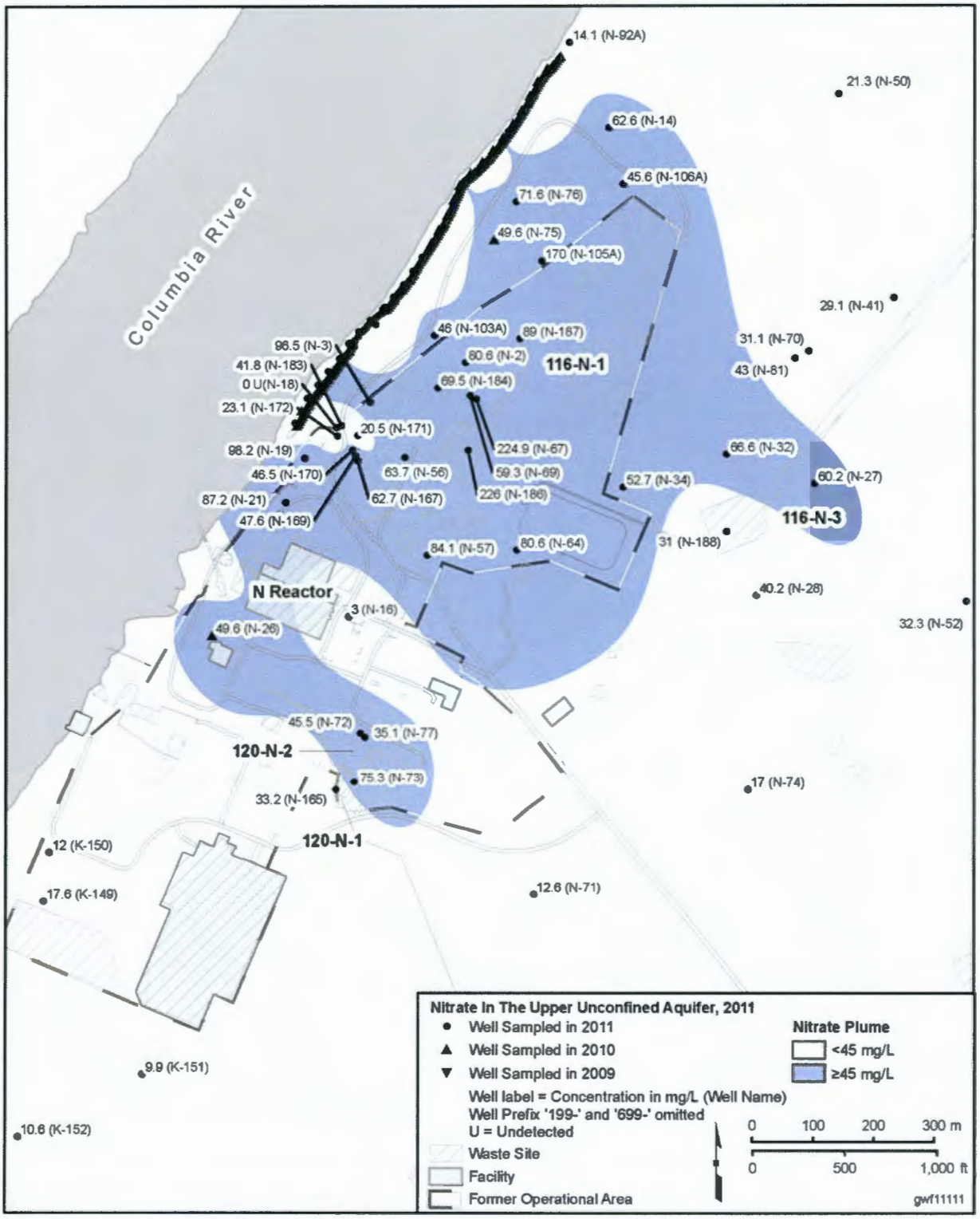



**Figure 10. 100-NR-2 OU Nitrate Groundwater Plume, 2011**

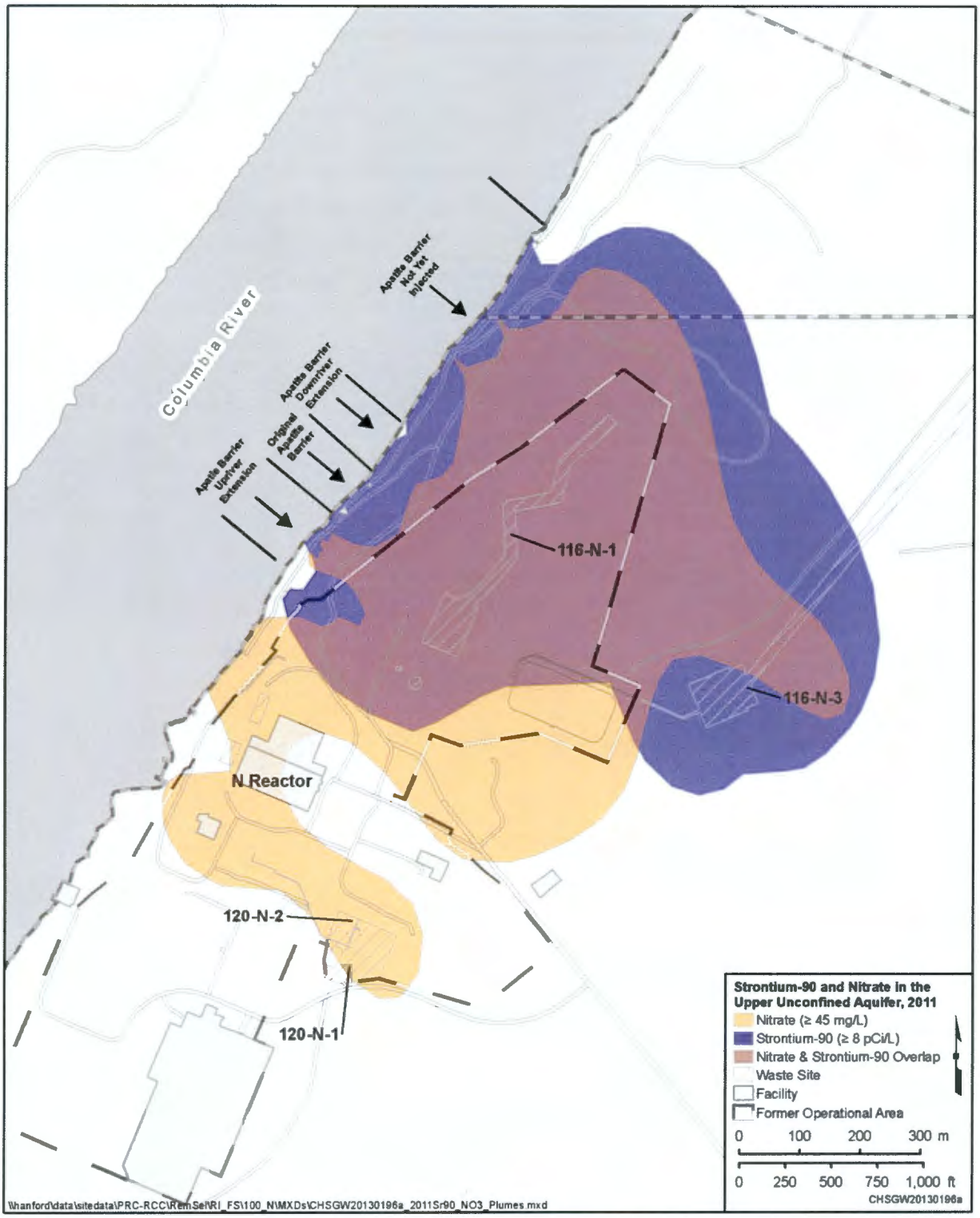



**Figure 11. 100-NR-2 OU Commingled Strontium-90 and Nitrate Groundwater Plumes, 2011**

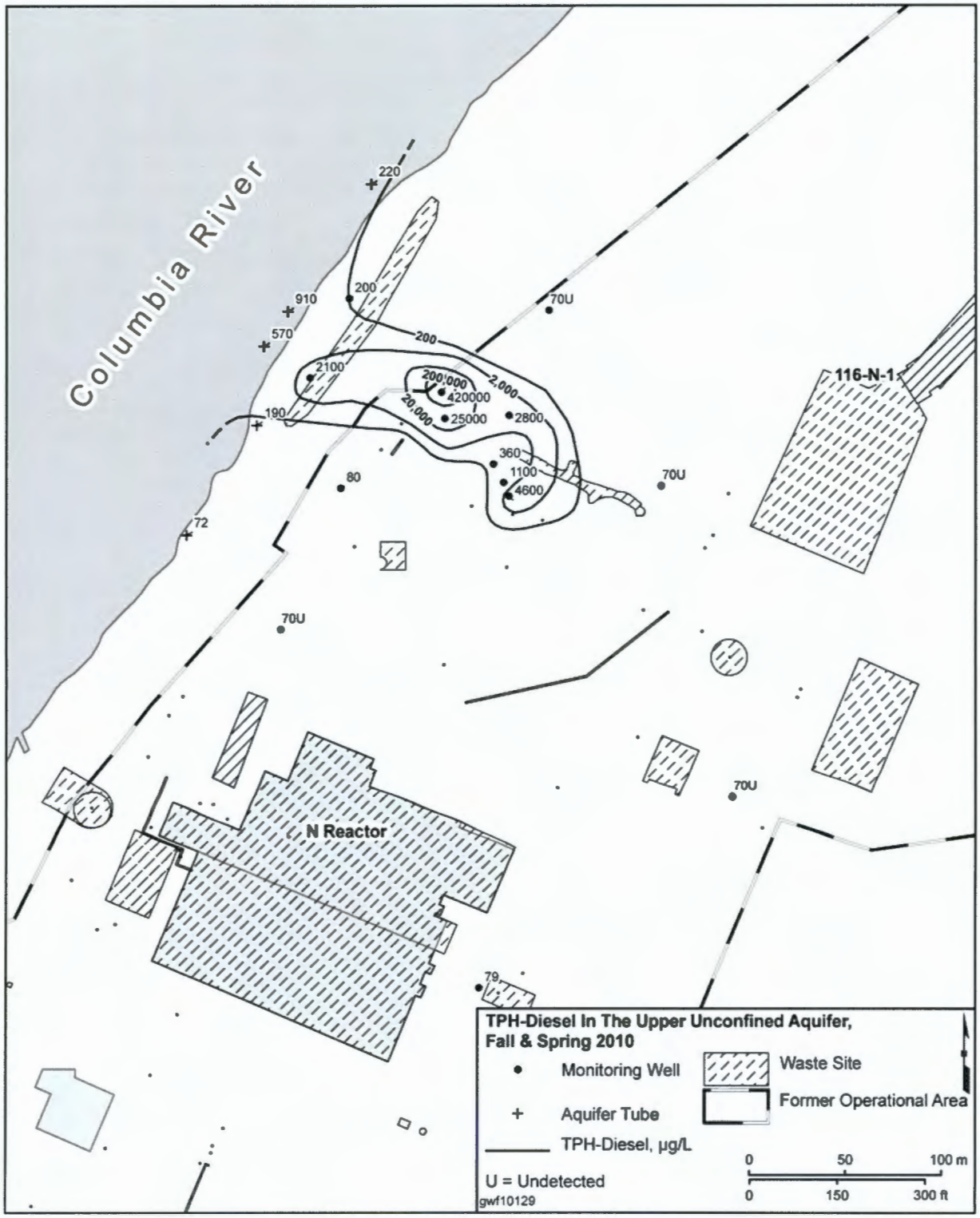



Figure 12. 100-NR-2 OU TPH-D Groundwater Plume, 2010

Ethylbenzene was detected at concentrations greater than 5 µg/L in only two samples, both from well 199-N-18, which is located in the TPH-D plume. Ethylbenzene is often associated with crude oil and other petroleum products, including TPH-D.

***Chromium and Cr(VI).*** Chromium concentrations that exceed the 100 µg/L DWS from 100-N Area waste sites are detected only in well 199-N-80, a confined zone monitoring well downgradient of the 116-N-1 site. This isolated, anomalous occurrence is thought to result from a combination of corrosion of the chromium stainless-steel well screen and completion of the screen in the Ringold upper mud, which is a tight zone that does not allow water to move freely.

Elevated concentrations of chromium and Cr(VI) occur in the southwest portion of the 100-N Area. The source of this contamination is chromium-contaminated liquid waste that was disposed to the 100-K-2 Trench and migrated to groundwater in the 100-KR-4 Groundwater OU. The Cr(VI) contamination in the 100-KR-4 OU migrated inland while the 100-K-2 Trench was in use and a groundwater mound was present. A portion of the plume has migrated northward into the 100-NR-2 OU.

### *Impacts to the Columbia River*

The discharge of groundwater to the Columbia River via seeps and upwelling to the riverbed provides a means for transporting 100-NR-2 OU groundwater contaminants to the Columbia River. The greatest contaminant flux to the river and highest concentrations at exposure locations along the river bank and river bottom occur during periods of low river stage when the aquifer is discharging to the river. During this time, the hydraulic gradient toward the river is greatest and mixing between river water and groundwater is minimal.

Riverbed sampling tubes, a shoreline aquifer tube, and near-river monitoring wells were installed along the 100-N shoreline in 2007 to evaluate the nature and extent of strontium-90 contamination along the shoreline (Section 1.3.4 of the 100-N RI/FS report [DOE/RL-2012-15]). The sampling results showed that the strontium-90 plume extended approximately 400 m (1,310 ft) laterally along the river shoreline. The vertical extent of the plume was limited to elevations of 113 m (371 ft) and higher.

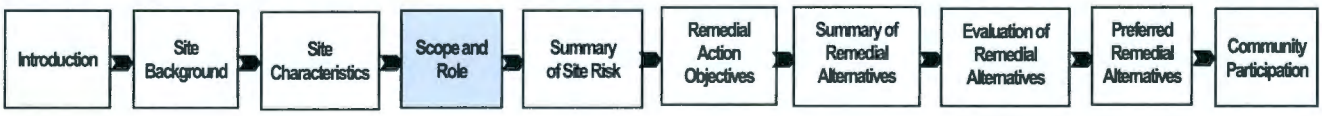
Pore water, river water, and aquifer tube sampling was conducted in 2010 along the 100-N shoreline of the Columbia River to characterize groundwater upwelling (Section 4.5.1 of the 100-N RI/FS report [DOE/RL-2012-15]). The data provide an assessment of the nature and extent of past releases of 100-N Area contaminants to the Columbia River. Results of the sampling program indicated that Cr(VI), uranium, and strontium-90 in the surface water samples were all at nondetect levels; none of the surface water sample values exceeded the DWS in the water column in the river. Co-located pore water sample results for Cr(VI) were all nondetects, with the exception of 26 µg/L detected just upriver from the original apatite barrier well network. Strontium-90 concentrations ranged from 8 to 55 pCi/L in the co-located pore water samples, with the maximum found near the 1908-N outfall. Tritium concentrations detected in the pore water (1,100 to 12,000 pCi/L) were below the DWS.

Supplemental pore water sampling was conducted in 2010 along a near-shore transect across the 1908-N outfall and spillway where strontium-90 was detected in the earlier sampling, and near the upriver end of the original apatite PRB where Cr(VI) was previously detected. The highest concentration of strontium-90 was detected at the upriver end of the apatite original barrier (100 pCi/L). Strontium-90 was also detected at the 1908-N outfall (18 pCi/L). Construction of the outfall likely created a preferential pathway for contaminated effluent or groundwater to migrate to the Columbia River at this location. Cr(VI) was not detected in these supplemental pore water samples.

### Principal Threat Wastes

The NCP (40 CFR 300.430[a][l][iii][A]) establishes an expectation that treatment will be used to address the principal threats posed by a site wherever practicable. Principal threat wastes are those source materials considered highly toxic or highly mobile that generally cannot be reliably contained or would present a significant risk to public health or the environment should exposure occur. Contaminated groundwater is generally not considered to be source material. Where the toxicity and mobility of source material combine to pose a potential human health ***excess lifetime cancer risk (ELCR)*** greater than one in a thousand ($1\times10^{-3}$), treatment alternatives should be identified (*A Guide to Principal Threat and Low Level Threat Wastes* [EPA, 1991]). The waste sites in the 100-NR-1 OU do not contain principal threat waste. The fuel was removed from N Reactor in 1989 and transferred to the 100-K fuel storage basins. The sludge in the 100-N fuel storage basin was removed in 1998, treated, and disposed at the ***Environmental Restoration Disposal Facility (ERDF)***.

The principal threat waste in the 100-N Area consists of the N Reactor core. The reactor core will be addressed by a ***CERCLA removal action*** following ISS, independent of the ROD associated with this Proposed Plan. The removal action will remove and manage all of the remaining principal threat waste in the 100-N Area. Therefore, the alternatives presented in this Proposed Plan do not contain provisions for managing or treating principal threat waste.




## Scope and Role

The Tri-Party Agreement (Ecology et al., 1989) is a comprehensive cleanup and compliance agreement for the Hanford Site. DOE's overall proposed strategy for cleaning up the Hanford Site is identified in *Hanford Site Cleanup Completion Framework* (DOE/RL-2009-10), which is a planning document that provides a context for DOE's proposed cleanup approach. One of the principal components of the framework is cleanup of contamination in the River Corridor, which includes a contiguous area that extends from the 100 and 300 Areas to the Central Plateau boundaries (Figure 2). Cleanup in the River Corridor is being conducted on an OU-specific basis under CERCLA. For sites in the River Corridor, final remedial actions are expected to protect HHE, restore groundwater to DWSs, and protect aquatic life in the Columbia River by achieving ***ambient water quality criteria (AWQC)*** and state water quality standards at groundwater discharge points to the river. Current cleanup activities are intended to remove contamination close to the Columbia River and shrink the Hanford Site footprint to the 194 $km^2$ (75 $mi^2$) Central Plateau, including a final waste management area (Inner Area) that is anticipated to be less than 26 $km^2$ (10 $mi^2$).

The N Reactor and the Bonneville Power Administration substation (currently active) shown on Figure 5 are not within the scope of this Proposed Plan. The chromium groundwater contamination emanating from the 100-K Area will be addressed by the 100-KR-4 OU.

### Previous or Planned Cleanup Decisions

Figure 13 presents a chronology of key 100-N Area OU documents that have been prepared and activities that have been implemented since the Hanford Site was added to the NPL (40 CFR 300, Appendix B). The CERCLA decisions made for the 100-N Area OUs are listed below. The ROD that will be issued after the comment period on this Proposed Plan will address waste sites and groundwater contamination. Following the comment period, EPA, in cooperation with DOE, will issue a ROD selecting the final remedy for implementation that will supersede the existing interim action RODs.

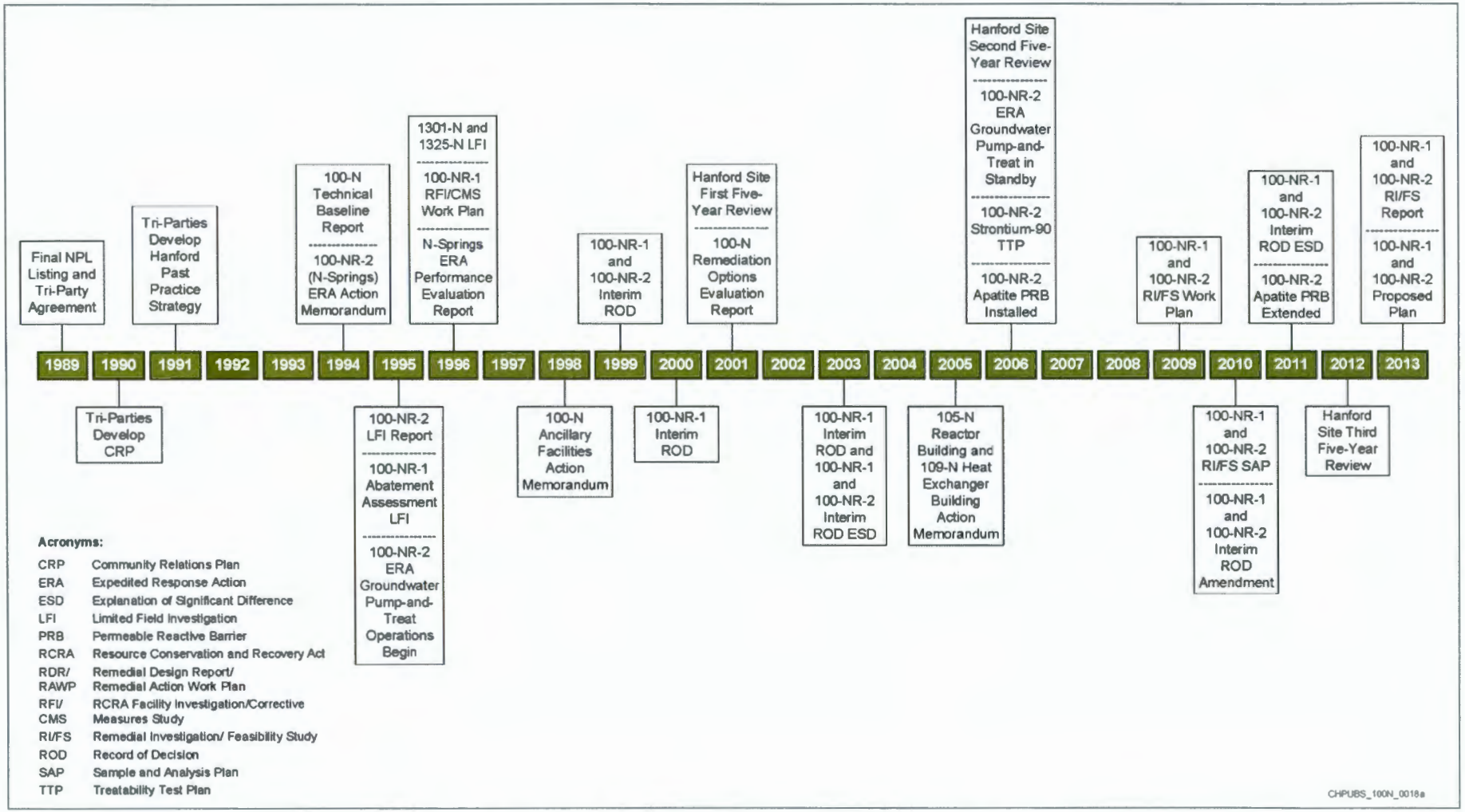



**Figure 13. 100-NR-1 and 100-NR-2 OU Investigation and Remediation Timeline**

***Interim Action RODs.*** The 100-N interim action ROD was issued in 1999 for contaminated waste sites in the 100-NR-1 OU and contaminated groundwater in the 100-NR-2 OU. The 100-NR-1 interim action ROD was issued in 2000 for two treatment, storage, and disposal (TSD) units and an associated waste site in the 100-NR-1 OU. The interim action RODs and associated modifications are listed below:

- **1999:** *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-99/112)
  - **2003:** *Explanation of Significant Difference for the 100-NR-1 Operable Unit Treatment, Storage, and Disposal Interim Action Record of Decision and 100-NR-1/100-NR-2 Operable Unit Interim Action Record of Decision, Hanford Site, Benton County, Washington* (EPA/ESD/R10-03/605)
  - **2010:** *U.S. Department of Energy 100-NR-1 and NR-2 Operable Units Hanford Site – 100 Area Benton County, Washington Amended Record of Decision, Decision Summary and Responsiveness Summary* (EPA et al., 2010)
  - **2011**: *Explanation of Significant Differences for the 100-NR-1 and 100-NR-2 Operable Units Interim Remedial Action Record of Decision, Hanford Site, Benton County, Washington* (EPA et al., 2011)
- **2000:** *Interim Remedial Action Record of Decision for the 100-NR-1 Operable Unit, Hanford Site, Benton County, Washington* (EPA/ROD/R10-00/120)
  - **2003:** *Explanation of Significant Differences for the 100-NR-1 Operable Unit Treatment, Storage, and Disposal Interim Action Record of Decision and 100-NR-1/100-NR-2 Operable Unit Interim Action Record of Decision, Hanford Site, Benton County, Washington* (EPA/ESD/R10-03/605)

***Transition from Interim to Final Action.*** Remedial activities performed prior to the signing of the final action ROD will be conducted under the authority and requirements of the interim action RODs. There will be a period of time between when the final action ROD is approved and when the required ***remedial design report/remedial action work plan (RDR/RAWP)*** is prepared and issued. In order for these remedial actions performed during this period of time to be consistent with the final action remedy selection, the current interim action RDR/RAWPs will be modified using the Tri-Party Agreement (Ecology et al., 1989) change notice process to include the final cleanup levels specified in the final action ROD when it is issued.

***Removal Action Memoranda (Facilities).*** The following action memoranda addressed facility decommissioning and removal:

- **1998:** "100 N Area Ancillary Facilities Action Memorandum" (Wilson, 1999)
- **2005:** "105-N Reactor Building and 109-N Heat-Exchanger Building Action Memorandum" (Wilson, 2005)
- **2010:** *Action Memorandum for General Hanford Site Decommissioning Activities* (DOE/RL-2010-22)

***Removal Action Memorandum/Expedited Response Action Memorandum (Groundwater).*** The following action memorandum was issued in 1994 to address strontium-90 groundwater contamination at N Springs:

- **1994:** "Action Memorandum: N-Springs Expedited Response Action Cleanup Plan, U.S. Department of Energy Hanford Site, Richland, WA" (Ecology and EPA, 1994)

### *Five-Year Review Reports*

CERCLA and the NCP (40 CFR 300) require that remedial actions resulting in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure be reviewed at least every 5 years after initiation of the selected remedial action to ensure that HHE are being protected by the remedial action being implemented. Three 5-year reviews have been completed for the Hanford Site:

- **2001:** *USDOE Hanford Site Five Year Review Report* (EPA, 2001)
- **2006:** *The Second CERCLA Five-Year Review Report for the Hanford Site* (DOE/RL-2006-20)
- **2012:** *Hanford Site Third CERCLA Five-Year Review Report* (DOE/RL-2011-56)

In the first 5-year review, EPA concluded that the 1999 100-N interim action ROD requirement of reducing the flux of strontium-90 to the Columbia River relative to natural decay was not being met. To address this issue, DOE investigated alternative remedial action technologies for the removal, mass reduction, or attenuation of strontium-90 from the 100-NR-2 OU aquifer sediments, and to further reduce the net flux of strontium-90 to the Columbia River. DOE documented this investigation in *Hanford 100-N Area Remediation Options Evaluation Summary Report* (TAG, 2001) in November 2001. The report presented five possible 100-NR-2 OU aquifer remediation scenarios and suggested that additional detailed evaluations of these alternatives needed to be conducted before a remedial action could be recommended. Additional details are provided in the 100-N RI/FS report (Section 1.3.7.1 of DOE/RL-2012-15).

In the second 5-year review, EPA concluded that three of the 1999 interim action ROD requirements were not being met. To address these issues, DOE took the following steps:

- Implement the treatability test plan for a PRB using apatite sequestration as described in *Strontium-90 Treatability Test Plan for 100-NR-2 Groundwater Operable Unit* (DOE/RL-2005-96) and issue a treatability test report.
- Perform additional data collection to support risk assessment, provide Ecology with previously collected data, and coordinate with River Corridor sampling efforts to collect additional pore water data from new and existing aquifer tubes along the 100-NR-2 OU shoreline in order to assess water quality impacts.

Implementation of the treatability test plan resulted in the installation of an apatite PRB in the saturated zone along a 91 m (300 ft) long stretch of shoreline where strontium-90 concentrations were the highest. DOE conducted pore water sampling along the 100-N Area shoreline to assess water quality impacts. This sampling was coordinated with annual groundwater monitoring; the River Corridor Baseline Risk Assessment (DOE/RL-2007-21, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* and *Volume II: Human Health Risk Assessment* [hereafter called the RCBRA]); and DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*) documented in the RCBRA and *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment* and *Columbia River Component Risk Assessment, Volume II: Baseline Human Health Risk Assessment* (DOE/RL-2010-117, hereafter called the CRC]). Additional details are provided in the 100-N RI/FS report (Section 1.3.7.2 of DOE/RL-2012-15).

No issues for the 100-N Area were identified in the third 5-year review (DOE/RL-2011-56).

***RCRA TSD Units, Closure/Post-Closure.*** Closure activities for the following two RCRA TSD units in the 100-N Area were performed in 2002 under the 2000 100-NR-1 interim action ROD (EPA/ROD/R10-00-120):

- 116-N-1 (1301-N) LWDF
- 116-N-3 (1325-N) LDWF

RCRA closure activities were completed and certified in 2003 (via a letter from DOE-RL to Ecology, "Certification of Closure for the 1324-N Surface Impoundment and 1324-NA Percolation Pond" [Hebdon, 2003]), for the following two RCRA TSD units in the 100-N Area:

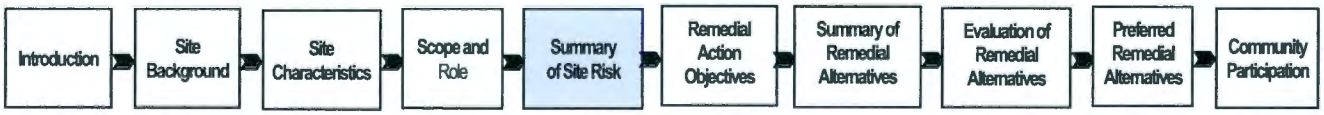
- 120-N-1 (1324-NA) percolation pond
- 120-N-2 (1324-N) surface impoundment

These two TSD units did not become CERCLA sites in the 100-NR-1 interim action ROD (EPA/ROD/R10-00/120) because of the lack of soil contamination, as reported in *100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan* (DOE/RL-96-39).

Post-closure groundwater monitoring required by RCRA for all four TSD units in the 100-N Area is conducted in accordance with *100-NR-1 Treatment, Storage, and Disposal Units Corrective Measures Study/Closure Plan* (DOE/RL-96-39), which is incorporated into the *Hanford Facility Resource Conservation and Recovery Act Permit, Dangerous Waste Portion, Revision 8C, for the Treatment, Storage, and Disposal of Dangerous Waste* (WA7890008967). The 120-N-1 and 120-N-2 units are monitored as a single site because of their proximity and similar waste types.

***Reactor.*** In the 1993 "Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington (58 FR 48509, hereafter called the NEPA Reactor ROD), DOE decided on ISS of these eight reactors followed by decommissioning.

Although the N Reactor was not included in the NEPA Reactor ROD (58 FR 48509), the same ISS process was completed for the N Reactor in September 2012 as part of CERCLA removal action (Wilson, 2005). The NEPA Reactor ROD did not include the N Reactor because at the time that the environmental impact statement was prepared (March 1989), the N Reactor was in standby mode for the possible production of plutonium and of steam to generate electricity. DOE will address the eventual disposition of the N Reactor through the NEPA process in a manner similar to that for the other eight surplus reactors. If contaminated soil is identified beneath the N Reactor (100-N-66), the soil will be remediated in accordance with the cleanup requirements identified in the CERCLA ROD associated with this Proposed Plan.




## Summary of Site Risk

A baseline risk assessment is required under the NCP to characterize current and potential threats to HHE and to provide information for use in the development and evaluation of remedial alternatives. The RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) were conducted to (1) characterize current and potential future risks to HHE, (2) establish a basis for remedial actions, and (3) support final cleanup decisions in the River Corridor. The RCBRA evaluated soil, sediment, and water located in riparian and near-shore areas and consists of a human health risk assessment (HHRA) (DOE/RL-2007-21, Volume II) and an ecological risk assessment (ERA) (DOE/RL-2007-21, Volume I). The CRC provides a comprehensive HHRA

(DOE/RL-2010-117, Volume II) and a screening-level ERA (DOE/RL-2010-117, Volume I). The intent of the CRC HHRA (DOE/RL-2010-117, Volume II) was to complete the assessment of the "bank-to-bank" Hanford Reach and downstream areas (i.e., Lake Wallula) of the Columbia River, characterizing risk in areas of the River Corridor not previously addressed under the RCBRA (DOE/RL-2007-21). The results of the RCBRA (DOE/RL-2007-21) and the CRC (DOE/RL-2010-117), which address potential risks from Hanford Site releases to the Columbia River, are summarized in the 100-N RI/FS report (Chapters 6 and 7 of DOE/RL-2012-15).

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

### Land and Groundwater Use Assumptions

Land use in the River Corridor is currently controlled by DOE and the U.S. Fish and Wildlife Service (USFWS). The DOE and the USFWS jointly manage this federally owned land to protect natural and cultural resources while cleanup activities are being conducted. Such management is consistent with the *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (CLUP) (DOE/EIS-0222-F) and the *Supplement Analysis, Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE/EIS-0222-SA-01) for the site. This joint management also reflects the requirements of the USFWS management plan (*Hanford Reach National Monument, Final Comprehensive Conservation Plan and Environmental Impact Statement, Adams, Benton, Grant and Franklin Counties, Washington* [USFWS, 2008]) for the HRNM. Both DOE and the USFWS expect that this joint management of the Hanford Site will continue for many years into the future and that the property will remain under federal ownership.

In 1999, DOE issued the CLUP (DOE/EIS-0222-F) and the corresponding "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)" (64 FR 61615). Additional evaluation on land use was later performed, and DOE issued the supplement analysis (DOE/EIS-0222-SA-01) in 2008. DOE included participation from federal agencies; Tribal governments; and state, county, and local governments during preparation of the CLUP (DOE/EIS-0222-F). The land in the 100 Areas was designated in the NEPA Reactor ROD (58 FR 48509) as preservation and conservation (mining).

"Establishment of the Hanford Reach National Monument" (65 FR 37253) established the HRNM within the boundaries of the Hanford Site (Figure 2). *Establishment of the Hanford Reach National Monument* (Presidential Proclamation 7319) mandates preservation of the natural and cultural resources within the HRNM. Preservation is generally a more restrictive land use than what DOE has designated in the CLUP.

In consideration of these land-use decisions and associated Tribal and public input, DOE and Ecology propose a cleanup strategy supporting residential exposures. The decision to use cleanup levels based on residential exposure scenarios is more restrictive than the previous land-use decisions and minimizes future ICs and long-term monitoring.

The NCP (40 CFR 300) establishes an expectation to "return useable ground waters to their beneficial uses wherever practicable, within a time frame that is reasonable given the particular circumstances of the site" (40 CFR 300.430[a][1][iii][F]). The Tri-Parties' goal for Hanford Site groundwater is to attain those regulatory goals by returning groundwater to its beneficial use as a potential future drinking water source.

Groundwater from the 100-NR-2 OU is currently contaminated above DWSs, and withdrawal of this contaminated groundwater for uses other than remediation and monitoring is prohibited via the *Sitewide Institutional Controls Plan for Hanford CERCLA Response Actions and RCRA Corrective Actions* (DOE/RL-2001-41). In areas where groundwater has been known to seep along the river shoreline, riprap has been emplaced to prevent exposure. Groundwater in the risk evaluation was evaluated assuming potential future use for drinking water and other domestic activities. Contaminant concentrations were also compared to aquatic criteria because groundwater discharges to the Columbia River via riverbank seeps and upwelling through the river bottom.

### Current and Future Exposure Scenarios

Based on current land use and existing ICs, there are no complete exposure pathways for risk to human health at this time. Potential risk to site workers is managed through health and safety programs.

For purposes of assessing future potential risk, various human exposure scenarios were evaluated in the RCBRA (DOE/RL-2007-21), the CRC (DOE/RL-2010-117, Volume II), and the baseline HHRA in the 100-N RI/FS report (Section 6.2.3 of DOE/RL-2012-15). The 100-N RI/FS report (Section 6.2 of DOE/RL-2012-15) includes human health estimates for residential, resident national monument worker, and casual recreational user scenarios. For the purpose of establishing cleanup levels, Ecology and DOE have agreed to use the residential scenario.

***Residential Scenario.*** The residential scenario for chemicals is Washington State's MTCA (WAC 173-340) for unrestricted use. The residential exposure scenario for radionuclides is based on a 30-year residential exposure. Each of these scenarios is described below.

For assessing risks from chemicals in soil, the MTCA Standard Method B (WAC 173-340-740, "Unrestricted Land Use Soil Cleanup Standards") levels are used. For direct contact, these levels are based on exposure of a child through incidental soil ingestion. For the inhalation pathway, the MTCA Standard Method B air levels are based on exposure of adults and children from inhalation of vapors and dust in ambient air. Calculations for the soil PRGs are described in the 100-N RI/FS report (Section 8.1.4 of DOE/RL-2012-15).

For assessing risks from radionuclides in soil, the residential scenario assumes that exposure to soil within the top 4.6 m (15 ft) occurs over a 30-year period. A residence is established on the waste site and the resident receives exposure from direct contact with the soil from the remediated waste site and through the food chain. This includes potential exposure through external radiation, incidental soil ingestion, and inhalation of ambient dust particulates. The food chain pathway includes exposure from consumption of fruits and vegetables grown in a backyard garden and consumption of meat (beef and poultry) and milk from livestock raised in a pasture. Uptake of contamination into crops and livestock is assumed to occur from contamination present in soil. Contaminants in soil are transported through the soil column, into the underlying groundwater, and to a hypothetical downgradient well located at the waste site boundary that is used for drinking water consumption, irrigation of crops and watering of livestock, and consumption of fish raised in a pond of water from the downgradient well. An additional evaluation was performed for groundwater if the only exposure was through use of groundwater as a drinking water source.

### Groundwater

Groundwater contamination within the 100-NR-2 OU was evaluated using two different methods. Concentrations of chemicals and radionuclides that were measured over the last 5 years were compared to federal and state DWSs. In addition, chemicals were compared to MTCA Method B groundwater cleanup levels.

These are the standards and cleanup values established to protect human health. Groundwater COPCs were identified when a concentration was greater than the DWS or MTCA Method B groundwater cleanup levels.

An additional evaluation calculated human health ELCRs and hazards using EPA's residential drinking water exposure scenario. This scenario assumes that the groundwater is used as a tap water source for a 30-year period. Potential routes of exposure include ingestion, dermal contact, and inhalation of volatiles during household activities. ***Exposure point concentrations (EPCs)*** were used to calculate ELCRs and noncancer hazards. COPCs were identified when ELCRs and noncancer hazards were greater than thresholds established by EPA and Ecology.

### Contaminant Fate and Transport Modeling

Contaminant fate and transport modeling was performed to simulate and predict the movement of strontium-90, nitrate, and TPH-D. This modeling is described in Chapter 5 and additional detail is provided in Appendix F of the 100-N RI/FS report (DOE/RL-2012-15).

For strontium-90, the model predictions indicate a long-term declining trend in strontium-90 concentrations in groundwater. With no additional remedial actions, the strontium-90 concentration is predicted to take approximately 225 years (starting in 2012) to drop below the federal ***maximum contaminant level (MCL)*** of 8 pCi/L. The estimated time for strontium-90 to decline below the MCL is based on the 90$^{th}$ percentile concentration from the groundwater plume. Along the river shoreline, the strontium-90 concentration is predicted to take approximately 125 years to fall below the MCL and 9 years for strontium-90 concentrations to fall below the aquatic benchmark of 278 pCi/L (Appendix M of the 100-N RI/FS report [DOE/RL-2012-15).

Contaminant fate and transport modeling was also performed for nitrate and TPH-D. Under the No Action alternative, nitrate concentrations in the inland groundwater and at the river shoreline are predicted to take 50 years and 39 years, respectively, to drop below the MCL of 45,000 µg/L. Transport modeling for TPH-D assumes that the residual contamination in the vadose zone is a continuous, unlimited source. Because of this assumption, the TPH-D concentrations throughout the plume fail to decrease below the regulatory cleanup level of 500 µg/L. However, the TPH-D concentrations along the river shoreline do not currently, and are not predicted to, exceed the regulatory cleanup level.

### Human Health Soil Risks

A total of 33 interim remediated waste sites with closeout verification data from the shallow vadose zone (0 to 4.6 m [0 to 15 ft] bgs) were evaluated in the risk assessment presented in Chapter 6 of the 100-N RI/FS report (DOE/RL-2012-15). For radionuclides, all interim remediated waste sites report an ELCR less than $1\times10^{-4}$ based on the residential exposure scenario. For chemicals, all interim remediated waste sites report an ELCR less than the MTCA (WAC 173-340-708[5], "Human Health Risk Assessment Procedures") total risk threshold or $1\times10^{-5}$ and a ***hazard index (HI)*** less than one for the residential scenario.

Of the 33 interim remediated waste sites, two waste sites (116-N-1 and 116-N-3) have closeout verification data from the deep vadose zone (greater than 4.6 m [15 ft] bgs). Even though the contamination at these two waste sites is deep, the sites were evaluated in the risk assessment to identify where potential exposure to residual contamination could occur through deep excavation activities. These two waste sites report an ELCR greater than $1\times10^{-4}$ for the deep vadose zone contamination based on the residential exposure scenario. Radionuclides associated with historical waste disposal contribute to the majority of the ELCR and include americium-241, cesium-137, cobalt-60, europium-154, nickel-63, plutonium-239/240, and strontium-90.

In addition to the residential risk estimates, the 100-N RI/FS report (Section 6.3 of DOE/RL-2012-15) also includes an evaluation of the human health risk for the resident national monument worker and the casual

recreational user exposure scenarios. These exposure scenarios result in a lower risk than the residential exposure scenario. Tribal exposure scenarios were evaluated in the RCBRA (DOE/RL-2007-21, Volume II) and are summarized in Section 6.1 of the 100-N RI/FS report (DOE/RL-2012-15). The estimated risk from the Tribal exposure scenarios are higher than the estimated risk for the residential exposure scenario.

The 33 interim remediated waste sites with closeout verification data were also evaluated as potential sources for groundwater and surface water contamination in Chapter 5 of the 100-N RI/FS report (DOE/RL-2012-15). Two of these waste sites reported residual strontium-90 contamination that exceeds the soil PRG for protection of groundwater. These two waste sites are the 116-N-1 Crib and Trench and the 116-N-3 Trench. No other soil contaminants were identified that would cause an unacceptable risk to groundwater.

### Groundwater Risks

Groundwater was evaluated as a potential drinking water source through a comparison of the EPC for each contaminant against federal and state DWSs and Washington State's groundwater cleanup levels. To facilitate evaluation, groundwater within the 100-NR-2 OU was separated into four geographic areas. Three of the geographic areas are based on existing groundwater plumes and include the chromium plume located upgradient from the 100-NR-2 OU, the diesel plume located near the former fuel tank farm, and the apatite PRB plume located along the Columbia River shoreline. Contaminated groundwater downgradient from the apatite PRB was not evaluated in the risk assessment because the analytical results are influenced by the injection of phosphate solutions used for construction of the barrier (see Section 4.4 of the 100-N RI/FS report [DOE/RL-2012-15]). The fourth geographic area includes everything within the 100-NR-2 OU footprint that is located outside the three known plume areas.

A total of six monitoring wells are completed in the unconfined aquifer within the chromium plume area, and these wells were evaluated in the risk assessment. Although these wells reside within the 100-NR-2 OU, they are located upgradient and reflect contamination that has migrated from the 100-KR-4 OU. This contamination is being actively remediated via a pump-and-treat groundwater extraction network under the 100-KR-4 OU. Chromium concentration was identified above the AWQC, and Cr(VI) concentrations were identified above Washington State's water quality level.

A total of four monitoring wells are completed in the unconfined aquifer within the diesel plume area, and these wells were evaluated in the risk assessment. Groundwater in this area contains strontium-90 and nitrate concentrations greater than the DWS of 8 pCi/L and 45,000 µg/L, respectively. In addition, TPH-D, TPH-gasoline, ethylbenzene, and cobalt concentrations are greater than Washington State's groundwater cleanup levels; and cadmium and chromium concentrations are greater than the AWQC. Groundwater measured in near-river wells will need to meet the DWS and AWQC; however, groundwater located further inland will only need to meet the DWS. The elevated metals concentrations within the diesel plume area are caused by the reducing conditions created by the anaerobic microbial decomposition of the petroleum hydrocarbons through the natural biodegradation processes. The elevated metals concentrations will return to background levels once the diesel plume is remediated.

A total of 45 monitoring wells are completed in the unconfined aquifer within the 100-N Area, and these wells were evaluated in the risk assessment. Groundwater in this area contains strontium-90 and nitrate concentrations greater than the DWS of 8 pCi/L and 45,000 µg/L, respectively. Tritium was also detected in a single sample from well 199—186 at concentrations above the DWS of 20,000 pCi/L. A subsequent sample collected from this well was not above the DWS. Well 199-N-186 was recently installed as part of the RI and has been sampled twice.

### Ecological Risks at Upland Areas

The RCBRA (DOE/RL-2007-21, Volume I) and the 100-N RI/FS report (Chapter 7 of DOE/RL-2012-15) evaluated ecological risks at the 100-N interim remediated waste sites with upland habitats for potential ecological risks. The 100-N RI/FS used information from the RCBRA and from other sources to evaluate the risk to populations and communities of ecological receptors, and it was concluded that there was no ecological risk at remediated waste sites within the 100-NR-1 OU. The ecological risk evaluations determined that the interim remedial actions that achieved the cleanup levels identified in the interim RODs (EPA/ROD/R10-99/112 and EPA/ROD/R10-00/120) to protect human health were also protective of ecological receptors. Once human health cleanup levels are achieved, residual contamination would not be sufficient to adversely impact populations and communities of ecological receptors.

### Ecological Risks at Riparian and Near-Shore Areas

The RCBRA (DOE/RL-2007-21, Volume I), the CRC (DOE/RL-2010-117, Volume I), and the 100-N RI/FS report (Section 7.5 of DOE/RL-2012-15) evaluated ecological risks present in the riparian, near-shore, and river areas adjacent to the 100-N Area. The 100-N RI/FS used information from these risk assessments and from other sources to evaluate risk to populations and communities of ecological receptors. The 100-N RI/FS evaluated contaminants present in these environments and pathways where Hanford Site operations may have released contaminants to the riparian, near-shore, and river environments. The evaluation included releases or potential releases of radionuclides, metals, and nitrate into the Columbia River from groundwater. The 100-N RI/FS concluded that there were no contaminants of ecological concern and, therefore, no ecological risk from Hanford Site operations that were at levels that warranted remedial action.

### Contaminants of Potential Concern

The COPCs (Table 1) include radionuclides, metals, inorganic anions, TPHs, polyaromatic hydrocarbons, and polychlorinated biphenyls. These COPCs were identified based on the history of operations in the 100-NR-1 OU and analysis of environmental samples. The list of COPCs is applicable to all of the waste sites (including the waste sites that have been or will be remediated under the interim ROD (EPA/ROD/R10-99/112) and groundwater. For the six waste sites remaining to be remediated, the COPCs are identified and listed in the 100-N RI/FS report (Section 8.1.1 [Table 8-1] of DOE/RL-2012-15)

The COCs are based on the COPCs and include radionuclides and chemicals that pose an unacceptable threat to human health or the environment and, therefore, need to be addressed by a remedial action. COCs are typically contaminants that exceed an acceptable risk level or a federal or state standard.

The soil COCs (Table 1) for the 100-NR-1 OU are based on an evaluation of closeout verification soil data for interim remediated waste sites and soil samples collected for the 100-N RI/FS. The vadose zone COCs for the 100-NR-1 OU are identified in Chapters 5, 6, and 7 of the 100-N RI/FS report (DOE/RL-2012-15).

The groundwater COCs (Table 1) were identified through an evaluation of groundwater contaminant concentrations and include strontium-90, nitrate, total chromium and Cr(VI), TPH-D, and ethylbenzene. Additional contaminants were identified as groundwater COPCs and include antimony, cadmium, cobalt, copper, and TPH-gasoline.

**Table 1. Summary of Soil and Groundwater COCs**

| Radionuclides | Metals | Inorganic Anions |
|---|---|---|
| Americium-241 | Aluminum | Nitrate (as nitrogen)[b] |
| Carbon-14 | Antimony[a] | **Polyaromatic Hydrocarbons** |
| Cesium-137 | Arsenic | Acenaphthene |
| Curium-243 | Barium | Anthracene |
| Cobalt-60 | Beryllium | Benzo(a)anthracene |
| Europium-152 | Boron | Benzo(a)pyrene |
| Europium-154 | Cadmium[a] | Benzo(b)fluoranthene |
| Europium-155 | Chromium (hexavalent)[b] | Dibenz(a,h)anthracene |
| Iodine-129 | Chromium (total)[b] | Fluoranthene |
| Neptunium-237 | Cobalt[a] | Fluorene |
| Nickel-63 | Copper[a] | Indeno(1,2,3-cd)pyrene |
| Niobium-94 | Lead[a] | Naphthalene |
| Plutonium-238 | Lithium | Phenanthrene |
| Plutonium-239/240 | Manganese | Pyrene |
| Silver-108m | Mercury | |
| Strontium-90[b] | Molybdenum | **Total Petroleum Hydrocarbons** |
| Technetium-99 | Nickel | TPH (gasoline range)[a] |
| Tritium (H-3) | Selenium | TPH (diesel range)[b] |
| Uranium-233/234 | Silver | **Volatile Organic Compounds** |
| Uranium-235 | Thallium[a] | Ethylbenzene[b] |
| Uranium-238 | Vanadium | Trichloroethene |
| | Zinc | |
| **Polychlorinated Biphenyl Aroclors** | | |
| Aroclor 1016 | Aroclor 1242 | Aroclor 1260 |
| Aroclor 1221 | Aroclor 1248 | |
| Aroclor 1232 | Aroclor 1254 | |

Source: Table 8-1 and Table 8-5 of *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units* (DOE/RL-2012-15).

a. Identifies a groundwater contaminant of potential concern.

b. Identifies a groundwater contaminant of concern.

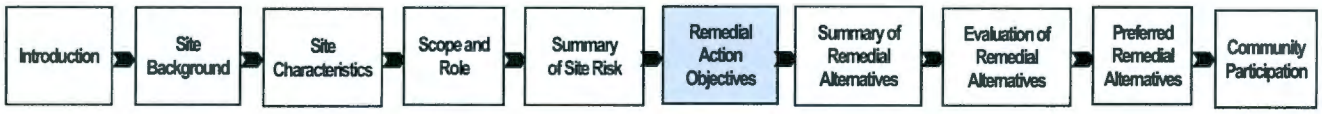
## Need for Action

A total of 33 interim remediated waste sites with closeout verification data were evaluated in the 100-N RI/FS report (DOE/RL-2012-15). These remedial actions have been successful in achieving the risk-based cleanup goals, as evaluated in the 100-N RI/FS report. While currently presenting no complete exposure pathway, certain waste sites with deep vadose zone contamination have been identified for ICs to prevent exposure.

Waste sites that have not been remediated were evaluated and determined to pose an unacceptable risk to HHE from direct exposure. Some of the waste sites are potential sources for groundwater contamination, providing the basis for remedial action.

Based on the results of the groundwater risk evaluation, concentrations of strontium-90, nitrate, total chromium and Cr(VI), TPH-D, and ethylbenzene are present at levels that provide the basis for remedial action.

It is DOE's and Ecology's current judgment that the preferred alternative identified in this Proposed Plan, or one of the other active measures considered in this Proposed Plan, is necessary to protect public health or welfare, or the environment, from actual or threatened releases of hazardous substances, pollutants, and contaminants into the environment that may present an imminent and substantial endangerment to public health or welfare.




## Remedial Action Objectives

The RAOs describe what a proposed remedial action is expected to accomplish. The RAOs generally include information on the media, COCs, potential exposure pathways, and remediation goals. The RAOs for the 100-NR-1 and 100-NR-2 OUs are 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 exposure to surface water containing contaminant concentrations above federal and state standards and risk-based thresholds.
- **RAO #3:** Prevent unacceptable risk from contaminants migrating and/or leaching through soil that will result in groundwater concentrations exceeding 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 MTCA Method 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 and to structures and debris contaminated with radiological constituents.
  - Prevent exposure to radiological constituents at concentrations at or above a dose rate limit that causes an ELCR threshold of $1\times10^{-6}$ to $1\times10^{-4}$ above background for the rural residential exposure scenario.
  - Protect ecological receptors based on a dose rate limit of 0.1 rad/day for terrestrial wildlife populations, which is a "to-be-considered" criterion.

### Preliminary Remediation Goals

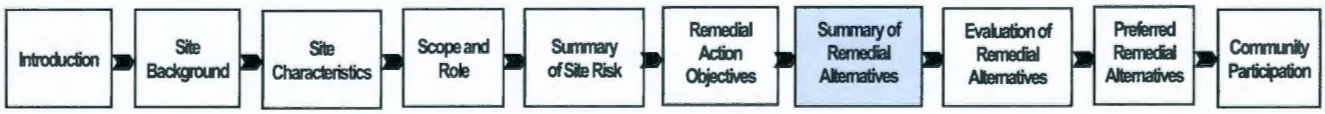
The PRGs provide the basis for cleanup levels in the ROD. PRGs are based on the RAOs and establish acceptable exposure levels for specific contaminants based on the media (e.g., soil or groundwater) and exposure scenario (e.g., residential activities). The PRGs developed in the RI/FS are proposed as cleanup levels for all alternatives in the ROD and are presented in Tables A-1 and A-2.

Soil PRGs for direct contact human health and for ecological receptors were developed using standard approaches, consistent with state and federal guidance. Direct contact PRGs for nonradionuclides are based on

risk calculations provided in Washington State's MTCA procedures using either health hazard thresholds or 1 in 1,000,000 ECLR. Direct contact PRGs for radionuclides are calculated based on radionuclide dose (15 mrem/year) and on ECLR (1 in 10,000 risk). For each radionuclide, the lower of the dose or risk-based calculations is proposed for cleanup.

Soil PRGs for groundwater and surface water protection were also developed based on current state and federal guidance and, consistent with guidance, incorporated site-specific data from the 100-N Area. For the 100-N Area, soil PRGs are presented based on native vegetation and irrigation recharge scenarios. The irrigation recharge scenario (Section 5.4.1 in the 100-N RI/FS report [DOE/RL-2012-15]) is used to identify the potential for groundwater and surface water contamination to occur from waste sites due to higher groundwater recharge rates associated with irrigation of crops. This irrigation recharge scenario was used to develop the irrigation PRGs. A native vegetation recharge scenario is used to identify the potential for groundwater and surface water contamination to occur from waste sites due to infiltration rates associated with conservation (non-irrigation). This native vegetation recharge scenario was used to develop the non-irrigation PRGs. In instances where soil concentrations exceed the irrigation PRGs but achieve the non-irrigation PRGs, an IC will be applied to the waste site to restrict irrigation rather than to continue excavation. Thus, both the irrigation PRGs and the non-irrigation PRGs, with an IC to restrict irrigation, are protective of HHE.

PRGs are calculated for single contaminants. During the cleanup verification process for individual waste sites, cleanup levels will be adjusted to account for waste site-specific residual contamination information. For sites with multiple residual contaminants, risks from individual contaminants will be added and evaluated to ensure that the waste site meets total risk limits specified in CERCLA, the NCP, and MTCA. When a groundwater protection level is exceeded, site-specific information will be evaluated to determine if remediation has achieved the RAOs.




## Summary of Remedial Alternatives

Remedial alternatives were developed in the 100-N RI/FS report (Chapter 9 of DOE/RL-2012-15) to encompass the waste sites with unacceptable risk and the groundwater plumes. The alternatives include a range of technology groupings that were selected from a detailed technology screening process that is described in Chapter 8 and Appendix I of the 100-N RI/FS report. The technology screening process considered the results of waste site remediation and groundwater treatment programs that have been ongoing at Hanford Site River Corridor OUs for over a decade.

The estimated times for strontium-90, nitrate, and TPH-D in groundwater to achieve the DWSs are based on numerical fate and transport modeling (Section 5.8 and Appendix F of the 100-N RI/FS report [DOE/RL-2012-15]). Uncertainty is expected in the modeling results due to local variations in vadose zone and/or aquifer material properties, uncertainty in estimating contaminant concentration and distribution, uncertainty in contaminant transport parameters, and uncertainties based on the numerical implementation within the model. The estimated times provided in this Proposed Plan are based on when the 90$^{th}$ percentile concentration declines below the DWS. The 100-N RI/FS report also includes the estimated times to achieve cleanup based on the predicted mean and maximum concentrations, which are considered to bracket the range of uncertainty in the results.

Although the FS evaluated several technologies to remediate the strontium-90 contamination in the upland groundwater, no technologies were identified that could achieve the DWS of 8 pCi/L in a reasonable time frame.

Therefore, Alternatives 2 through 5 require a TI waiver of the groundwater ARAR in order to meet the CERCLA threshold criteria of "overall protection of HHE and compliance with ARARs." A detailed discussion of the TI waiver is provided in Appendix O of the 100-N RI/FS report (DOE/RL-2012-15).

For Alternatives 2 through 5, the estimated time to achieve the strontium-90 DWS at the river shore downgradient of the apatite PRB is 110 years based on the 90$^{th}$ percentile concentration. The estimated times based on the mean and maximum concentrations are 65 and 151 years, respectively. Because the estimated time to achieve the strontium-90 DWS downgradient from the apatite PRB is close to, and quite possibly less than, 100 years, a TI waiver is not proposed for the strontium-90 in this portion of the aquifer.

The five remedial alternatives that were evaluated in the 100-N RI/FS report (DOE/RL-2012-15), along with the TI waiver for the strontium-90 contamination in the upland aquifer, include the following:

- **Alternative 1:** No Action
- **Alternative 2:** RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs
- **Alternative 3 (Preferred Alternative):** RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs
- **Alternative 4:** RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs
- **Alternative 5:** RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

The components of the remedial alternatives are summarized in Table 2.

The RI/FS evaluated 136 waste sites in the 100-NR-1 OU. Of these waste sites, 38 were identified as requiring no further action. Two of the waste sites recommended for no further action are associated with river effluent pipelines (100-N-77 and 100-N-80), which are discussed in the 100-N RI/FS report (Chapters 6 and 7 of DOE/RL-2012-15). The remaining 98 waste sites are included in the remedial alternatives.

**Table 2. Components of Remedial Alternatives**

| Remedial Alternative* | Vadose Zone | | | Groundwater | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | RTD at Waste Sites | ICs | Bioventing for TPH-D | MNA for TPH-D | Groundwater Monitoring | Removal of Free Product TPH-D | Biosparging for TPH-D | Apatite PRB for Near-Shore Strontium-90 | Technical Impracticability Waiver for Upland Strontium-90 | In Situ Bioremediation for Nitrate | Apatite Injections for Upland Strontium-90 |
| 1 | N | N | N | N | N | N | N | N | N | N | N |
| 2 | Y | Y | Y | Y | Y | Y | N | Y | Y | N | N |
| 3 | Y | Y | Y | N | Y | Y | Y | Y | Y | N | N |
| 4 | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | N |
| 5 | Y | Y | Y | N | Y | Y | Y | Y | Y | Y | Y |

Note: "N" indicates no, not included as a component of the remedial alternative; "Y" indicates yes, included as a component of the remedial alternative.

* The remedial alternatives are as follows:

Alternative 1: No Action

Alternative 2: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs

Alternative :3 RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs

Alternative 4: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

Alternative 5: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

IC = institutional control
MNA = monitored natural attenuation
PRB = permeable reactive barrier
RTD = removal, treatment, and disposal
TPH-D = total petroleum hydrocarbon-diesel

### Alternative 1 — No Action

***Estimated capital cost:*** *$0 million*

***Estimated O&M cost:*** *$0 million*

***Estimated present value (discounted):*** *$0 million*

***Estimated time to achieve RAOs at river boundary:*** *125 years for strontium-90, 39 years for nitrate, and 0 years for TPH-D*

***Estimated time to achieve RAOs at upland area:*** *225 years for strontium-90, 50 years for nitrate, and 300 years for TPH-D*

Consideration of a No Action alternative is a requirement of the NCP (40 CFR 300.430[e][6]) and is included to provide a baseline for comparison against the other alternatives. Under the No Action alternative, no active remedial action would be taken to address potential threats to HHE posed by the COCs present. All ongoing actions would cease, including ICs and monitoring. No further remedial action will be performed for the residual contamination associated with the 100-NR-1 OU waste sites. The existing 270 m (900 ft) long apatite PRB installed between 2006 and 2011 would remain in place in the aquifer. Groundwater restoration for the 100-NR-2 OU would only occur through natural processes.

***Time to Achieve RAOs.*** Groundwater model simulations indicate that if the No Action alternative is implemented, it will take approximately 9 years for strontium-90 concentrations along the river to decline below the aquatic benchmark of 278 pCi/L. Groundwater model simulations indicate that it will take 125 years for strontium-90 concentrations at the river shore to fall below the DWS of 8 pCi/L. It is estimated that it will take 225 years for strontium-90 concentrations throughout the plume to decline below the DWS of 8 pCi/L; approximately 50 years for the nitrate concentrations throughout the plume to fall below the DWS of 45,000 µg/L; and 300 years for the TPH-D concentrations throughout the plume to fall below the groundwater cleanup level of 500 µg/L.

The model simulations also indicate that under the No Action alternative, with the existing 270 m (900 ft) long apatite PRB in place, approximately 0.077 Ci of strontium-90 will enter the river over the next 300 years (Section 5.8.2.2 of the 100-N RI/FS report [DOE/RL-2012-15]). Under the No Action alternative, which includes no previously installed remedial component for nitrate, approximately 110,000 kg (242,508 lb) of nitrate are predicted to enter the river (Section 5.8.3.2 of the 100-N RI/FS report [DOE/RL-2012-15]).

### Alternative 2 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs

***Estimated capital cost:*** *$42.6 million*

***Estimated O&M cost:*** *$80.1 million*

***Estimated present value (discounted):*** *$91.3 million*

***Estimated time to achieve RAOs at river boundary:*** *110 years for strontium-90, 39 years for nitrate, and 0 years for TPH-D*

***Estimated time to achieve RAOs at upland area:*** *225 years for strontium-90, 50 years for nitrate, and 32 years for TPH-D*

Alternative 2 uses RTD to excavate contaminated soil and debris from waste sites; an apatite PRB to enhance attenuation of strontium-90 in the vadose zone and groundwater near the shore of the Columbia River; a TI waiver for strontium-90 in groundwater upgradient of the apatite PRB; bioventing for in situ treatment of TPH-D-contaminated soil in the deep vadose zone; MNA for TPH-D in groundwater; groundwater monitoring for strontium-90, nitrate, TPH-D, ethylbenzene, chromium, Cr(VI), and COPCs; and ICs for waste left in place.

Alternative 2 builds on the interim actions already accomplished and completes DOE's commitments in the 100-N interim action ROD (EPA/ROD/R10-99/112) using cleanup levels based on the PRGs developed in the 100-N RI/FS report (Section 6.2.3 of DOE/RL-2012-15). With the exception of MNA for TPH-D, the components in Alternative 2 are common to Alternatives 3, 4, and 5. The remedial technologies for

Alternative 2 are shown on Figure 14. The areas for implementation of the remedial technologies for Alternative 2 are shown on Figure 15. The remedial components of Alternative 2 are described below.

***RTD at Waste Sites.*** The RTD component of the 1999 100-N interim action ROD (EPA/ROD/R10-99/112, as amended in 2010), and the 2000 100-NR-1 interim action ROD (EPA/ROD/R10-00/120) is proposed to be replaced by the RTD component in Alternatives 2 through 5. The RTD component in Alternatives 2 through 5 incorporates the interim action ROD requirements to (1) RTD the soil as deep as 4.6 m (15 ft) in waste sites to protect human health and ecological receptors from direct exposure to contaminants; (2) remove engineered structures; and (3) RTD the soil below 4.6 m (15 ft) in waste sites to protect groundwater quality and Columbia River water quality (or to meet soil contamination concentrations demonstrated to be effective, based onsite conditions). Contaminated soil and debris will be removed, treated (as necessary to meet waste acceptance criteria), and disposed at the ERDF (which is considered onsite) or at another EPA-approved disposal facility. The waste sites will be backfilled with clean material and recontoured, followed by revegetation with native plants.

Culturally sensitive sites may be identified during design or implementation of an RTD remedy. For waste sites in culturally sensitive areas where mitigation activities to protect resources would be inadequate, DOE and EPA will work with the Tribal Nations to identify an alternative remediation strategy. Depending on the change, this alternative remediation strategy would be implemented through an explanation of significant differences or a ROD amendment.

***Apatite PRB for Near-Shore Strontium-90.*** A 760 m (2,500 ft) long PRB for in situ immobilization of strontium-90 in groundwater will be installed along the shoreline. The 270 m (900 ft) long section of the PRB, consisting of 64 wells that have been injected with apatite, is complete. The additional 98 injection wells to complete the 760 m (2,500 ft) long PRB have been installed but have not been injected with apatite. Under this alternative, these aqueous injections will be performed after the ROD is signed. Within approximately 5 years of completion of all first-round apatite injections, one additional round of apatite injections will be performed at a subset of injection well locations where a 90 percent reduction in strontium-90 concentrations has not been achieved.

A 305 m (1,000 ft) long PRB for in situ immobilization of strontium-90 in the vadose zone will be installed along the portion of the shoreline where the 270 m (900 ft) long section of the apatite PRB for groundwater was installed. The vadose zone apatite PRB will target the PRZ that provides a continuing source of strontium-90 contamination to groundwater. Emplacement of the barrier will be accomplished by jet injection of apatite during drilling of approximately 305 borings to a depth of 4.6 to 6.1 m (15 to 20 ft) bgs.

The total mass of strontium-90 entering the river is estimated to be 0.05 Ci for Alternative 2. Apatite may be added to groundwater or to the vadose zone at locations outside of the apatite PRB as needed to address locally elevated areas of strontium-90 contamination.

As part of the installation and completion of the apatite barrier for strontium-90 in groundwater, the pump-and-treat system will be decommissioned.

**Alternative 2: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs**

### Overview

Alternative 2 incorporates the remedy components identified in the interim action ROD (EPA/ROD/R10-99/112) for the 100-NR-1 OU and 100-NR-2 OU.

#### Waste Sites

For waste sites that have not undergone interim actions, the actions will vary depending on the nature and extent of contamination and may include one or more of the following:

- RTD of the waste sites to protect human health and groundwater.
- Aerobic bioremediation of TPH via bioventing in deep vadose zone.
- Institutional controls.

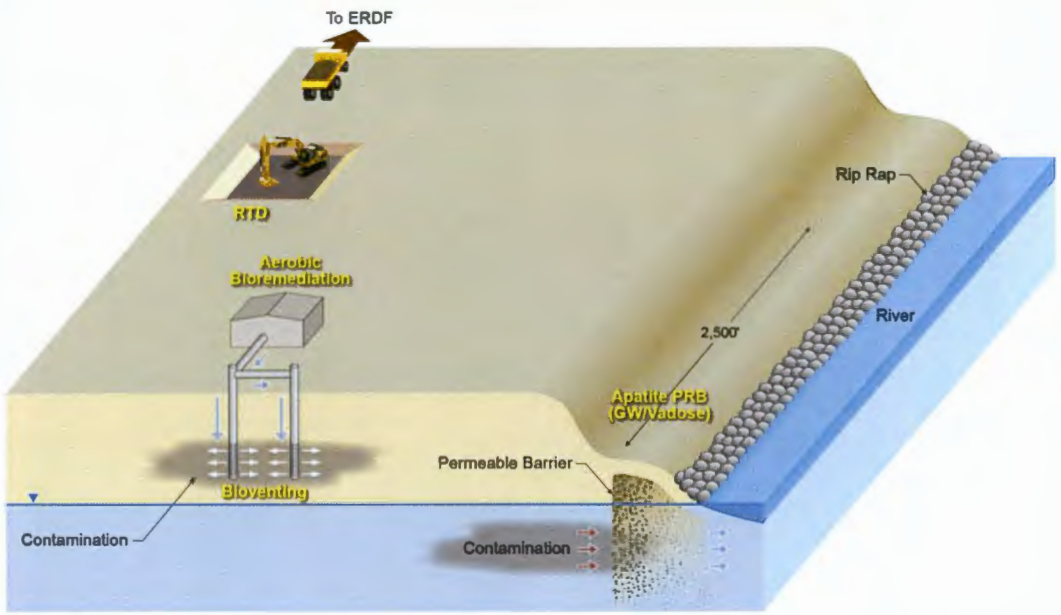
#### Groundwater

For groundwater, the actions include MNA, monitoring, and institutional controls. The scope of the actions includes:

- Decommissioning of the pump-and-treat system at 100-N.
- Replacement of well 199-N-16 with two monitoring wells.
- Expansion of the apatite permeable reactive barrier (PRB) for Strontium-90 to 2,500 feet near the shoreline.
- Technical Impracticability waiver for Strontium-90 upgradient of the apatite PRB.
- Installation of 305 m (1,000 ft) apatite barrier to enhance attenuation of Strontium-90 in vadose zone.
- MNA, groundwater monitoring, and ICs, as appropriate.

Note: Backfill materials (to fill the excavated waste site) will be determined in the Remedial Design/Remedial Action Work Plan. Excess materials from ERDF construction will be considered for use as waste site backfill material to minimize natural near-site damages.

### Conceptual Schematic




### Cost

| | Waste Site Treatment | Groundwater Treatment | TOTAL |
|---|---|---|---|
| Total Present Value of Alternative (Discounted) | $ 22,317,000 | $ 68,976,000 | $ 91,293,000 |

*Note. Waste site treatment costs include the costs for institutional controls.*

Source: EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington.*

**Figure 14. Alternative 2 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs**

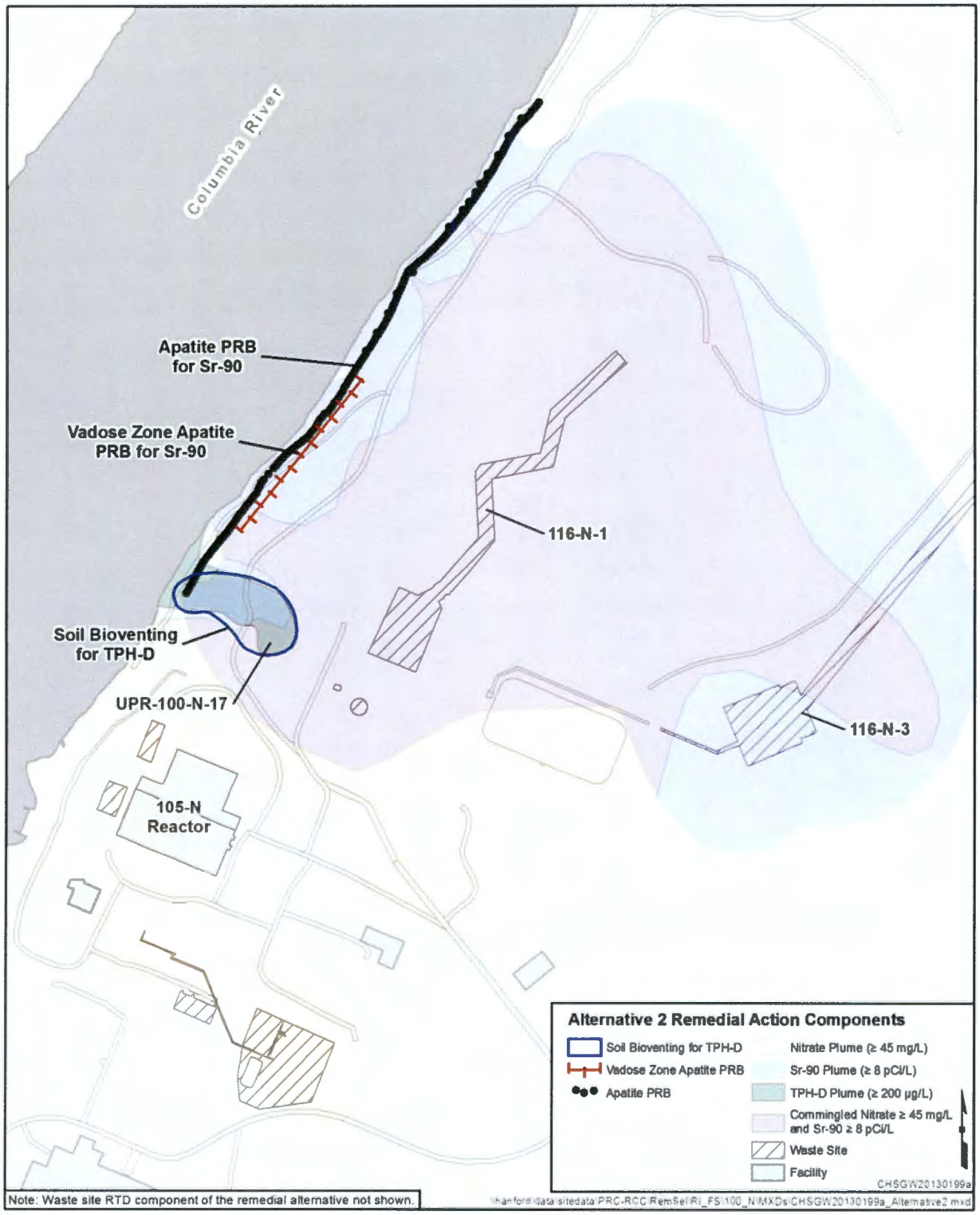



**Figure 15. Areas for Implementation of Remedial Components of Alternative 2**

***TI Waiver for Upland Strontium-90.*** The groundwater ARAR for strontium-90 (i.e., 8 pCi/L DWS) is being waived because the available technologies are not capable of restoring groundwater to its beneficial use within a reasonable time frame. The groundwater ARAR waiver will be applied within the proposed TI zone, which has been defined as the plume area within the 100-NR-2 OU where groundwater concentrations in the unconfined aquifer exceed the DWS of 8 pCi/L and are intersected by the apatite barrier along the Columbia River shoreline. The shoreline area on the river side (i.e., northwest) of the apatite barrier is not included in the TI zone. The vertical extent of the TI zone within the unconfined aquifer is defined at the top by the high water level and at the bottom by the Ringold upper mud.

To minimize offsite migration of strontium-90 to the river, the apatite PRB will be maintained until strontium-90 concentrations downgradient from the PRB are below the DWS. In addition, groundwater monitoring will be conducted while the ARAR waiver is in place to monitor strontium-90 concentrations in the TI zone as the plume naturally decays. ICs will be implemented within the TI zone to prevent groundwater withdrawal, irrigation, or excavation without approval of the Tri-Parties.

***Bioventing for TPH-D in Vadose Zone.*** The bioventing technology is used for in situ remediation of TPH-D-contaminated soil at depths greater than 4.6 m (15 ft). Oxygen is introduced into the deep vadose zone to promote microbial activity, thus enhancing hydrocarbon degradation. To prepare for implementation of this technology, a 6-month bioventing pilot plant operational test was conducted at the UPR-100-N-17 (166-N diesel oil supply line leak) waste site (WCH-490). Seven bioremediation wells were completed between January and March 2009, and pilot testing conducted between February 2010 and May 2011 included a respirometry test, an air injection (radius of influence test), and a 6-month operational test period. The results of the pilot study are provided in the 100-N RI/FS report (Section 9.2.3.1 of DOE/RL-2012-15).

The data from the bioventing pilot test were used to support the design of full-scale bioventing system implemented in December 2012. Because installation and startup of the bioventing system has been completed prior to the ROD associated with this Proposed Plan, only the ***operations and maintenance (O&M)*** costs for this technology are included in the FS cost estimate (Appendix K of the 100-N RI/FS report [DOE/RL-2012-15]).

***MNA for TPH-D in Groundwater.*** MNA relies on natural processes within the aquifer to achieve reductions in the toxicity, mobility, volume, concentration, and/or bioavailability of contaminants. These natural processes include physical, chemical, and biological transformations that occur without human intervention. TPH-D contamination will be removed from the deep vadose zone and will no longer provide a source of groundwater contamination. TPH in groundwater is then expected to attenuate by dispersal and biodegradation. MNA will be used to monitor and confirm that the TPH-D concentrations in groundwater decline as expected. MNA for TPH-D in groundwater is a component of Alternative 2.

***TPH-D Free Product Removal from Groundwater.*** Passive remedial action to remove free product from well 199-N-18 has continued since 2003 in accordance with the 100-N interim action ROD (EPA/ROD/R10-99/112). Passive remediation is conducted using a polymer "smart sponge" that selectively absorbs petroleum products from the surface of the water within the well. The sponges are weighed prior to placement in the well and again after removal (approximately 2 months later). The weight difference between the two measurements is the amount of product, or TPH-D, removed. TPH-D as free product has been observed only at wells 199-N-18 and 199-N-17 (which was decommissioned in 2002).

***Groundwater Monitoring.*** Groundwater monitoring will be performed to evaluate the effectiveness of the selected alternative to attain the cleanup levels. The monitoring will be for groundwater COCs (strontium-90, nitrate, TPH-D, ethylbenzene, chromium, and Cr[VI]) and will follow state and federal guidance for evaluating

achievement of ROD requirements. Groundwater monitoring for chromium and Cr(VI) will be coordinated with groundwater remediation for these contaminants addressed in the 100-KR-4 OU.

Groundwater monitoring will also be performed for groundwater COPCs (antimony, cadmium, cobalt, copper, lead, thallium, and TPH-gasoline range). A groundwater monitoring plan will be part of the RDR/RAWP prepared for the final remedy selected.

***Institutional Controls.*** ICs are defined and discussed in more detail in the 100-N RI/FS report (Sections 8.3.4, 8.3.5, and 9.2.2.1 of DOE/RL-2012-15). ICs are mechanisms to control uses of land, facilities, and environmental media and to prevent unacceptable HHE exposure to residual contaminants that could pose risks above levels deemed protective. ICs generally include nonengineered restrictions on activities and access to land, groundwater, surface water, waste sites, waste disposal areas, and other areas or media that may contain hazardous substances to minimize the potential for human exposure to the substances. Common types of ICs include procedural restrictions for access, warning notices, permits, easements, deed notifications, leases and contracts, and land-use controls. Examples include the following:

- Controlling excavation in areas where contamination remains below 4.6 m (15 ft) bgs that exceed residential direct contact PRGs
- Preventing irrigation over or near waste sites that represent a potential groundwater or surface water protection risk

Alternatives 2 through 5 require ICs during the period before completion of the remedial action and following remedial action implementation where ICs are required to protect human health (DOE/RL-2001-41). Interim actions have been completed at three waste sites where concentrations of radionuclide COCs in the vadose zone below a depth of 4.6 m (15 ft) are greater than human health PRGs. Although the exposure pathway is incomplete, DOE will place excavation restrictions on these sites to control possible exposure. Table 3 identifies the waste sites where ICs are proposed.

Alternatives 2 through 5 also require ICs to prevent exposure to elevated strontium-90 soil contamination at the shoreline site and apatite PRB. The riprap will be maintained along the Columbia River shoreline at the former N Springs location to prevent exposure to elevated strontium-90 soil contamination.

For groundwater, DOE will restrict well drilling and groundwater use in accordance with IC requirements until the RAOs are achieved. Groundwater use on the Hanford Site is generally restricted, except for limited research purposes and for monitoring and treatment, as approved by the EPA or Ecology. Groundwater use is also controlled through excavation permits and the land-use process.

***Time to Achieve RAOs.*** Groundwater model simulations indicate that it will take 9 years for strontium-90 concentrations at the river shore to fall below the aquatic benchmark of 278 pCi/L. This estimate is the same as the estimate for Alternative 1 (No Action) because the single apatite injection in Alternative 2 does not enhance attenuation of the strontium-90 in the bank storage sediments located downgradient from the barrier.

Groundwater model simulations indicate that it will take 110 years for strontium-90 concentrations at the river shore to fall below the DWS of 8 pCi/L. The cleanup time for strontium-90 at the river shore in Alterative 2 was reduced relative to Alternative 1 (No Action) because the completed, full length of the apatite PRB component of Alternative 2 immobilized additional strontium-90.

**Table 3. Specific ICs for 100-NR-1 OU Waste Sites**

| Risk Driver | Alternatives 2 through 5 ICs | IC Expiration Year |
|---|---|---|
| Waste sites with groundwater/surface water protection risk if irrigation was applied | Prohibit irrigation:<br>• 100-N-65<br>• 116-N-1<br>• 116-N-3 | For Alternatives 2, 3, and 4, ICs required until 2240. For Alternative 5, ICs required until 2176. |
| Waste sites with deep (greater than 4.6 m [15 ft] bgs) radiological contamination exceeding human health direct contact PRG levels | Excavation restrictions:<br>• 100-N-65<br>• 116-N-1<br>• 116-N-3 | For Alternatives 2, 3, and 4, ICs required until 2240. For Alternative 5, ICs required until 2176. |
| Waste sites with shallow contamination exceeding HHE PRG levels | Prohibit access until remediated:<br>• 2607-FSM<br>• 600-339<br>• 600-348 | ICs required until 2025 (fire station decommissioned in 2020). |

Source: Table 9-4 in *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units* (DOE/RL-2012-15).

bgs = below ground surface

HHE = human health and the environment

IC = institutional control

PRG = preliminary remediation goal

Groundwater model simulations indicate that it will take 225 years for strontium-90 concentrations throughout the plume to fall below the DWS of 8 pCi/L and 50 years for nitrate concentrations throughout the plume to fall below the DWS of 45,000 µg/L. These estimates are the same as the estimates for Alternative 1 (No Action).

For Alternative 2, the source term for TPH-D was removed from the groundwater model to simulate the effect of bioventing. Groundwater model simulations indicate that it will take approximately 32 years for the TPH-D concentrations throughout the plume to fall below the groundwater cleanup level of 500 µg/L. The cleanup time for TPH-D in Alternative 2 was reduced relative to Alternative 1 because the bioventing component removed the TPH-D source from the vadose zone.

Under Alternative 2, with the installation of the 760 m (2,500 ft) long apatite PRB and a single apatite injection into groundwater, approximately 0.05 Ci of strontium-90 are predicted to enter the river over the next 300 years (Section 10.3.4 of DOE/RL-2012-15). Installation of the 760 m (2,500 ft) apatite PRB in Alternative 2 reduces the strontium-90 flux to the river by 35 percent compared to Alternative 1 (No Action).

Because Alternative 2 includes no remedial component for nitrate, the flux of nitrate to the river under Alternative 2 is the same as it would be under Alternative 1 (No Action).

### Alternative 3 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs (Preferred Alternative)

***Estimated capital cost:*** *$45.8million*

***Estimated O&M cost:*** *$81.1 million*

***Estimated present value (discounted):*** *$12.96 million*

***Estimated time to achieve RAOs at river boundary:*** *110 years for strontium-90, 39 years for nitrate, and 0 years for TPH-D*

***Estimated time to achieve RAOs at upland area:*** *225 years for strontium90, 50 years for nitrate, and 3 years for TPH-D*

Alternative 3 uses RTD to excavate contaminated soil and debris from waste sites; an apatite PRB to enhance attenuation of strontium-90 in the vadose zone and groundwater near the shore of the Columbia River; a TI waiver for strontium-90 in groundwater upgradient of the apatite PRB; bioventing for TPH-D-contaminated soil in the deep vadose zone; biosparging for TPH-D-contaminated groundwater; groundwater monitoring for strontium-90, nitrate, TPH-D, ethylbenzene, chromium, Cr(VI), and COPCs; and ICs for waste left in place.

The remedial action components in Alternative 3 include all those in Alternative 2 plus biosparging (in situ bioremediation) of TPH-D in groundwater. The remedial technologies for Alternative 3 are shown on Figure 16. The areas for implementation of the remedial technologies for Alternative 3 are shown on Figure 17. The remedial components of Alternative 3 are described below.

***Biosparging for TPH-D.*** Biosparging of groundwater is similar to bioventing of the vadose zone because both technologies inject oxygen (in air) into the contaminated region to stimulate biological activity. Biosparging treats TPH-D contamination in the groundwater, aquifer materials, and the capillary fringe. The effectiveness of biosparging depends primarily on three factors: (1) environmental conditions conducive to biological growth of TPH-D-degrading microorganisms, (2) the intrinsic permeability and homogeneity of the soil, and (3) the biodegradability of the petroleum constituents. The success of the bioventing pilot test for vadose zone soil indicates that aerobic bioremediation of TPH-D-impacted groundwater and aquifer sediment is a viable remediation technology. Biosparging will target the TPH-D plume where concentrations are consistently above the groundwater cleanup level of 500 µg/L. Additional information on the use of biosparging to treat petroleum contamination in 100-NR-2 OU groundwater is provided in the 100-N RI/FS report (Section 9.2.4.2 of DOE/RL-2012-15).

***Time to Achieve RAOs.*** Groundwater model simulations indicate that it will take 9 years for strontium-90 concentrations at the river shore to fall below the aquatic benchmark of 278 pCi/L and 110 years for strontium-90 concentrations at the river shore to fall below the DWS of 8 pCi/L. Groundwater model simulations for the entire strontium-90 and nitrate plumes indicate that it will take 225 years for strontium-90 concentrations to fall below the DWS of 8 pCi/L and 50 years for nitrate concentrations to fall below the DWS of 45,000 µg/L. These estimates are the same as the estimates for Alternative 2.

For Alternative 3, the source term for TPH-D was removed from the groundwater model to simulate the effect of biosparging. Groundwater model simulations indicate that it will take 3 years for TPH-D concentrations throughout the plume to fall below the groundwater cleanup level of 500 µg/L. The cleanup time for TPH-D in Alternative 3 was reduced relative to Alternative 2 because the biosparging component of Alternative 3 removed the TPH-D from the groundwater.

## Alternative 3: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs

### Overview

Alternative 3 incorporates the remedy components identified in the interim action ROD (EPA/ROD/R10-99/112) for the 100-NR-1 OU and 100-NR-2 OU.

#### Waste Sites

For waste sites that have not undergone interim actions, the actions will vary depending on the nature and extent of contamination and may include one or more of the following:

- RTD of the waste sites to protect human health and groundwater.
- Aerobic bioremediation of TPH via bioventing in deep vadose zone.
- Institutional controls.

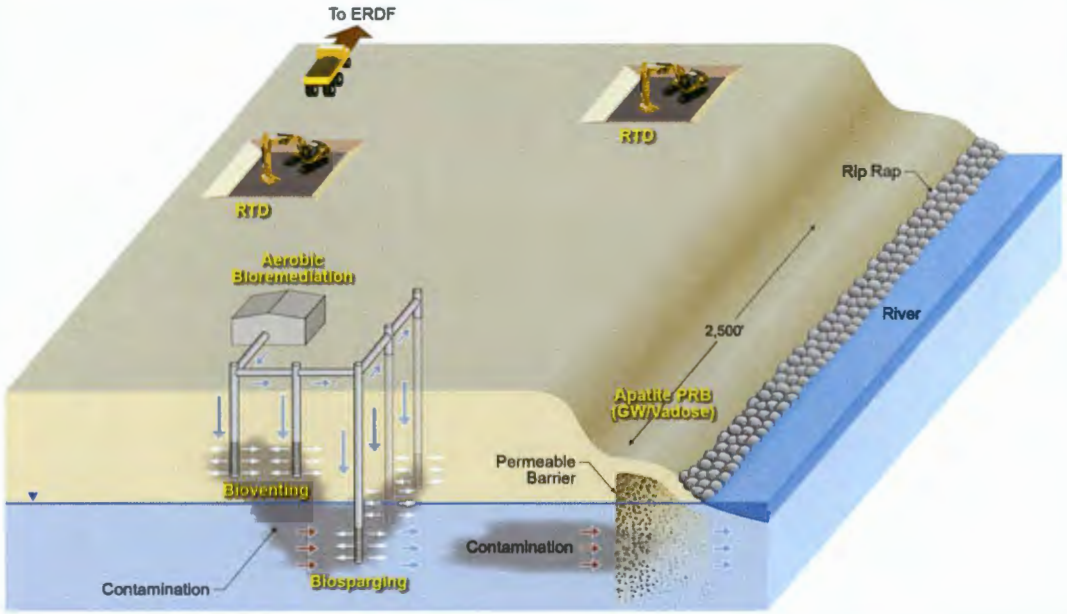
#### Groundwater

For groundwater, the actions include MNA, monitoring, and institutional controls. The scope of the actions includes:

- Decommissioning of the pump-and-treat system at 100-N.
- Replacement of well 199-N-16 with two monitoring wells.
- Expansion of the apatite permeable reactive barrier (PRB) for Strontium-90 to 2,500 feet near the shoreline.
- Technical Impracticability waiver for Strontium-90 upgradient of the apatite PRB.
- Installation of 305 m (1,000 ft) apatite barrier to enhance attenuation of Strontium-90 in vadose zone.
- MNA, groundwater monitoring, and ICs, as appropriate.
- Injection of air into the saturated zone to enhance aerobic bioremediation of TPH in groundwater (biosparging).

Note: Backfill materials (to fill the excavated waste site) will be determined in the Remedial Design/Remedial Action Work Plan. Excess materials from ERDF construction will be considered for use as waste site backfill material to minimize natural near-site damages.

### Conceptual Schematic




### Cost

| | Waste Site Treatment | Groundwater Treatment | TOTAL |
|---|---|---|---|
| Total Present Value of Alternative (Discounted) | $ 22,317,000 | $ 71,532,000 | $ 93,849,000 |

*Note: Waste site treatment costs include the costs for institutional controls*

Source: EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington.*

**Figure 16. Alternative 3 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs**

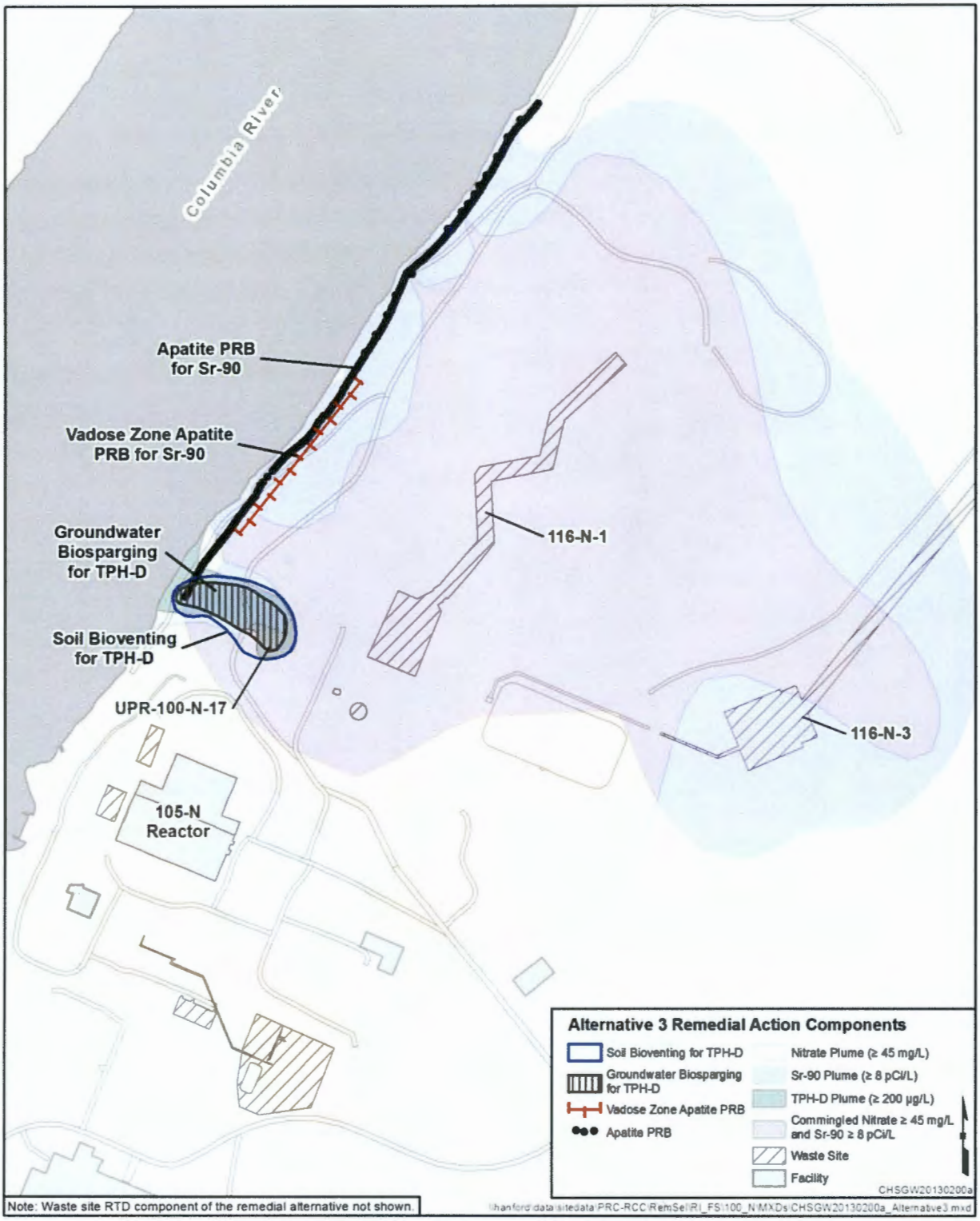



**Figure 17. Areas for Implementation of Remedial Components of Alternative 3**

Under Alternative 3, with the installation of the 760 m (2,500 ft) long apatite PRB and a single apatite injection into groundwater, approximately 0.05 Ci of strontium-90 are predicted to enter the river over the next 300 years (Section 10.3.4 of the 100-N RI/FS report [DOE/RL-2012-15]). Installation of the 760 m (2,500 ft) apatite PRB in Alternative 3 reduces the strontium-90 flux to the river by 35 percent compared to Alternative 1 (No Action).

Because Alternative 3 includes no remedial component for nitrate, the flux of nitrate to the river under Alternative 3 is the same as it would be under Alternative 1 (No Action) or Alternative 2.

### Alternative 4 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

***Estimated capital cost:*** *$56.1 million*

***Estimated O&M cost:*** *$86.8 million*

***Estimated present value (discounted):*** *$142.9 million*

***Estimated time to achieve RAOs at river boundary:*** *110 years for strontium-90, 10 years for nitrate, and 0 years for TPH-D*

***Estimated time to achieve RAOs at upland area:*** *225 years for strontium-90, 20 years for nitrate, and 3 years for TPH-D*

Alternative 4 uses RTD to excavate contaminated soil and debris from waste sites; an apatite PRB to enhance attenuation of strontium-90 in the vadose zone and groundwater near the shore of the Columbia River; a TI waiver for strontium-90 in groundwater upgradient of the apatite PRB, bioventing for TPH-D-contaminated soil in the deep vadose zone; biosparging for TPH-D-contaminated groundwater; carbon (organic) substrate injections for in situ biological treatment for nitrate in groundwater; groundwater monitoring for strontium-90, nitrate, TPH-D, ethylbenzene, chromium, Cr(VI), and COPCs; and ICs for waste left in place.

The remedial action components in Alternative 4 include all those in Alternative 3 plus in situ bioremediation for nitrate in groundwater. The remedial technologies for Alternative 4 are shown on Figure 18. The areas for implementation of the remedial technologies for Alternative 4 are shown on Figure 19. The remedial components for Alternative 4 are described below.

***In Situ Biological Treatment for Nitrate.*** In situ biological reduction of nitrate, or denitrification, is a bioremediation technology that removes nitrate in groundwater by converting the nitrate to nitrogen gas. In the absence of oxygen, denitrifying bacteria will use nitrate as an electron acceptor, converting it to nitrogen gas through a series of intermediate gaseous nitrogen oxide products. In the presence of carbon, aerobic bacteria will multiply rapidly (assuming that other conditions are not limiting) and will quickly deplete the oxygen present. As oxygen is depleted, denitrifying bacteria begin to use the carbon substrate to support their growth as they reduce nitrate. This bioremediation technology uses the injection of a carbon substrate (electron donor) to first create an anoxic environment and then to promote denitrification.

A treatability test was conducted at the 100-D Area to evaluate the effect of introducing different carbon (organic) substrates on the removal of chromium, nitrate, and dissolved oxygen from groundwater through anaerobic reduction (PNNL-16424, *Treatability Test Plan for an In Situ Biostimulation Reducing Barrier*). Two different substrates, molasses and emulsified vegetable oil, were chosen for the study. Molasses is a soluble (miscible) substrate that is relatively easy to distribute over a large areal extent, is inexpensive, and is expected to have moderate longevity. Emulsified vegetable oil is an immiscible substrate that can be distributed over a reasonable areal extent at a moderate cost, but it is expected to have increased longevity over molasses. This test confirms the potential for using carbon (organic) substrates to promote denitrification in Hanford Site groundwater (PNNL-18784, *Hanford 100-D Area Biostimulation Treatability Test Results*).

**Alternative 4: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment**

### Overview

Alternative 4 incorporates the remedy components identified in the interim action ROD (EPA/ROD/R10-99/112) for the 100-NR-1 OU and 100-NR-2 OU.

#### Waste Sites

For waste sites that have not undergone interim actions, the actions will vary depending on the nature and extent of contamination and may include one or more of the following:

- RTD of the waste sites to protect human health and groundwater.
- Aerobic bioremediation of TPH via bioventing in deep vadose zone.
- Institutional controls.

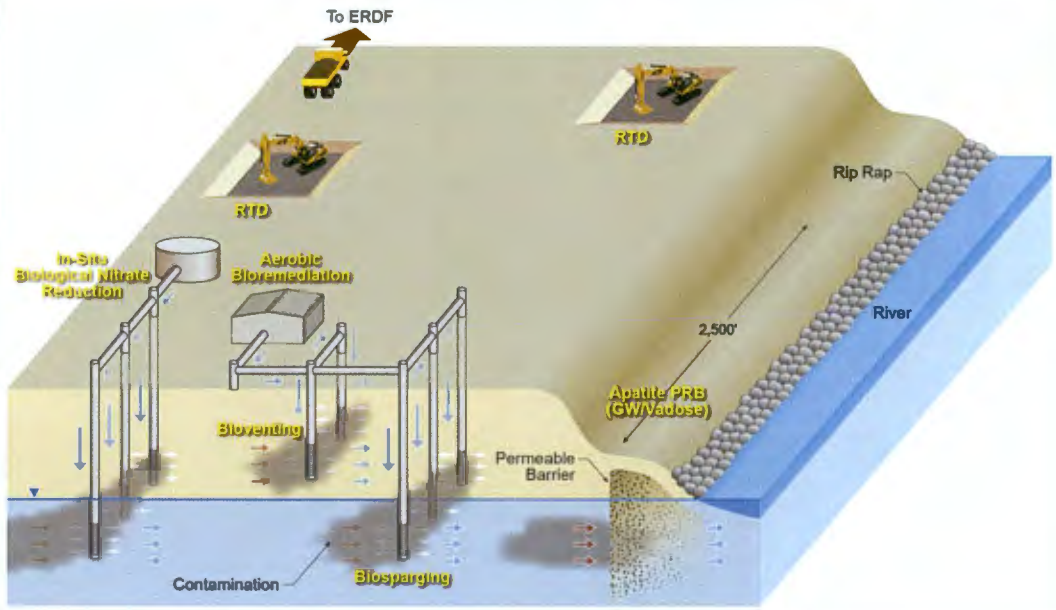
#### Groundwater

For groundwater, the actions include MNA, monitoring, and institutional controls. The scope of the actions includes:

- Decommissioning of the pump-and-treat system at 100-N.
- Replacement of well 199-N-16 with two monitoring wells.
- Expansion of the apatite permeable reactive barrier (PRB) for Strontium-90 to 2,500 feet near the shoreline.
- Technical Impracticability waiver for Strontium-90 upgradient of the apatite PRB.
- Installation of 305 m (1,000 ft) apatite barrier to enhance attenuation of Strontium-90 in vadose zone.
- MNA, groundwater monitoring, and ICs, as appropriate.
- Injection of air into the saturated zone to enhance aerobic bioremediation of TPH in groundwater (biosparging).
- Injection of a carbon substrate to the saturated zone to enhance anoxic biological reduction of nitrate in situ.

Note: Backfill materials (to fill the excavated waste site) will be determined in the Remedial Design/Remedial Action Work Plan. Excess materials from ERDF construction will be considered for use as waste site backfill material to minimize natural near-site damages.

### Conceptual Schematic




### Cost

| | Waste Site Treatment | Groundwater Treatment | TOTAL |
|---|---|---|---|
| Total Present Value of Alternative (Discounted) | $ 22,317,000 | $ 86,953,000 | $ 109,270,000 |

*Note Waste site treatment costs include the costs for institutional controls*

Source: EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington.*

**Figure 18. Alternative 4 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs**

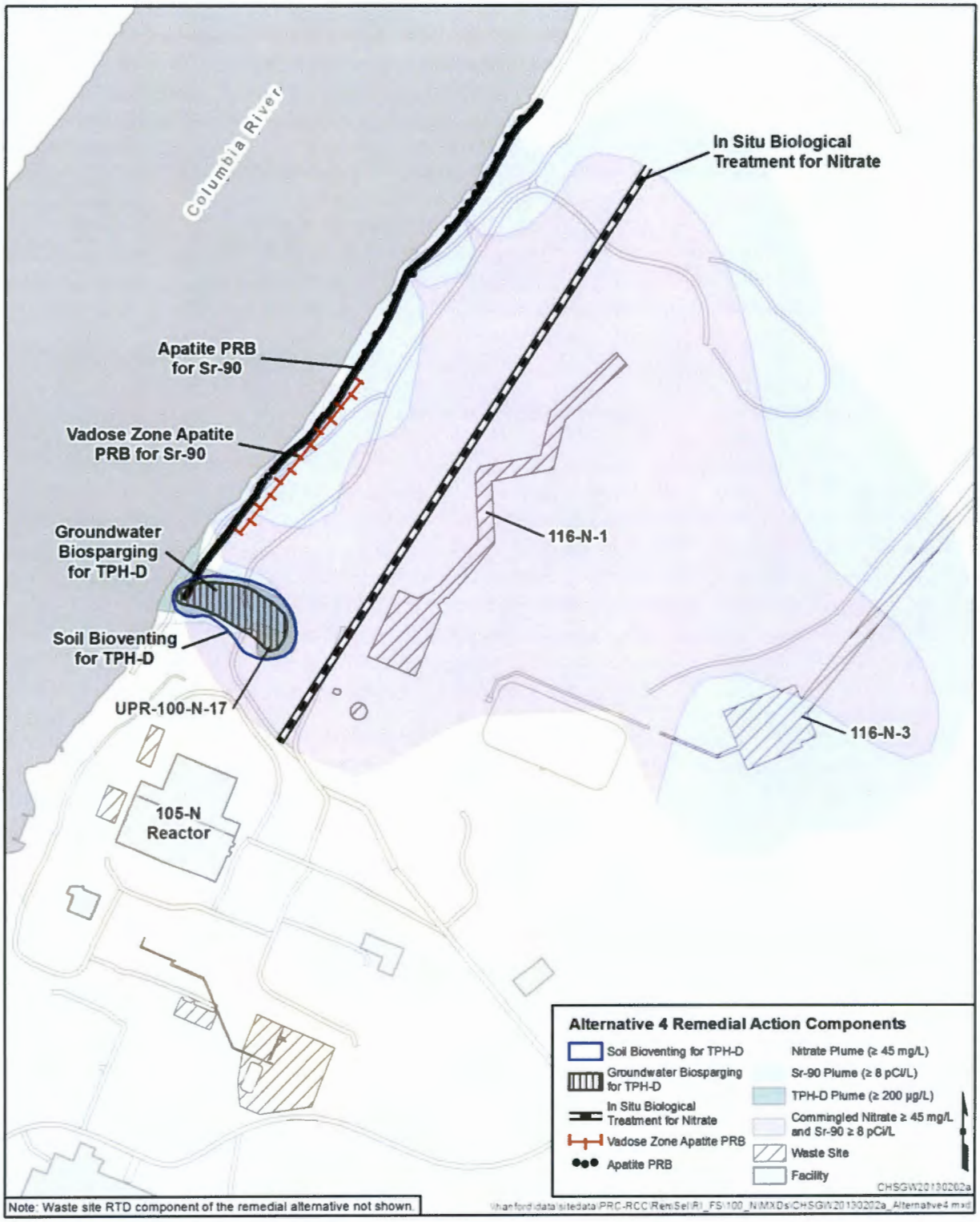



**Figure 19. Areas for Implementation of Remedial Components of Alternative 4**

In situ bioremediation of nitrate will target the plume in the vicinity of the 116-N-1 waste site, where groundwater concentrations are consistently above the PRG of 45 mg/L. A row of injection wells will be installed across the plume to form a barrier parallel to the river, upgradient of and parallel to the apatite PRB. The injection depth will be between 23 and 26 m (75 and 85 ft) bgs. Pilot testing will be performed prior to design to determine the radius of influence of the injections and the degradation rates of nitrate and the carbon (organic) substrate. Additional information on the use of in situ bioremediation to treat nitrate in 100-NR-2 OU groundwater is provided in the 100-N RI/FS report (Section 9.2.4.1 of DOE/RL-2012-15).

The strontium-90 and nitrate groundwater plumes are commingled in the 100-NR-2 OU. Enhancing microbial growth in the aquifer has the potential for biofouling in the apatite PRB injection wells or the saturated zone. While it is unlikely that biofilm buildup will clog the aquifer, it is possible that biofilm will develop within the downgradient apatite barrier, potentially impacting strontium-90 adsorption and apatite PRB performance.

Water quality will be negatively impacted by introducing organic substrate and promoting microbial activity to treat the nitrate. The resulting decreases in dissolved oxygen, oxidation-reduction potential, and pH cause a release of metals from the sediment to groundwater, which may then discharge the metals to the river.

***Time to Achieve RAOs.*** Groundwater model simulations indicate that it will take 9 years for strontium-90 concentrations at the river shore to fall below the aquatic benchmark of 278 pCi/L and 110 years for strontium-90 concentrations at the river shore to fall below the DWS of 8 pCi/L. The groundwater model simulations for strontium-90 and TPH-D concentrations throughout the plume for Alternative 4 are the same as those for Alternative 3. For Alternative 4, the groundwater model simulated the installation of a denitrification zone in the interior of the nitrate groundwater plume. Groundwater model simulations indicate that it will take 20 years for the nitrate concentrations throughout the plume to fall below the DWS of 45,000 µg/L. The cleanup time for nitrate in Alternative 4 was reduced relative to Alternative 3 because the in situ biological treatment component of Alternative 4 accelerated the removal of nitrate from the groundwater.

Because Alternative 4 includes a remedial component for nitrate, the flux of nitrate to the river under Alternative 4 is predicted to be 44,000 kg (97,000 lb) over the next 300 years (Appendix F of the 100-N RI/FS report [DOE/RL-2012-15]). Implementation of in situ bioremediation of nitrate in Alternative 4 reduces the projected nitrate flux to the river by 60 percent compared to no treatment of nitrate in Alternatives 1 (No Action) through 4.

### Alternative 5 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

***Estimated capital cost:*** *$222.4 million*

***Estimated O&M cost:*** *$94.6 million*

***Estimated present value (discounted):*** *$317.0 million*

***Estimated time to achieve RAOs at river boundary:*** *110 years for strontium-90, 10 years for nitrate, and 0 years for TPH-D*

***Estimated time to achieve RAOs at upland area:*** *161 years for strontium-90, 20 years for nitrate, and 3 years for TPH-D*

Alternative 5 uses RTD to excavate contaminated soil and debris from waste sites; an apatite PRB to enhance attenuation of strontium-90 in the vadose zone and groundwater near the shore of the Columbia River; treatment using apatite injections and a TI waiver for the strontium-90 in groundwater upgradient of the apatite PRB; bioventing for TPH-D-contaminated soil in the deep vadose zone; biosparging for TPH-D-contaminated groundwater; carbon (organic) substrate injections for in situ biological treatment of nitrate in groundwater; groundwater monitoring for strontium-90, nitrate, TPH-D, ethylbenzene, chromium, Cr(VI), and COPCs; and ICs for waste left in place.

The remedial action components in Alternative 5 include all those in Alternative 4 plus apatite injections for treatment of strontium-90 in upgradient groundwater. The remedial technologies for Alternative 5 are shown on Figure 20. The areas for implementation of the remedial technologies for Alternative 5 are shown on Figure 21.

***Apatite Treatment for Upland Strontium-90.*** Apatite will be injected into the saturated zone in upland areas where strontium-90 groundwater concentrations exceed 800 pCi/L. This upland area of strontium-90 contamination is approximately 162,000 $m^2$ (40 ac). Apatite to immobilize the strontium-90 in this upland area would be injected throughout the aquifer using an approach similar to that used for the calcium-citrate-phosphate injections for the apatite PRB. To ensure adequate coverage, more than 800 injection wells, 15.4 m (50 ft) apart, would be installed throughout the plume. The injection depth will be below the water table at depths ranging between 23 and 27 m (75 and 90 ft) bgs. Additional information on the use of apatite injections to treat strontium-90 in the upland groundwater is provided in the 100-N RI/FS report (Section 9.2.5.1 of DOE/RL-2012-15).

The strontium-90 and nitrate groundwater plumes are commingled in the 100-NR-2 OU. Alternative 5 includes components for apatite treatment for upland strontium-90 and for in situ biological treatment for upland nitrate. The effect of injecting both the apatite solution and the organic substrate into the groundwater in the same area may have unintended consequences that impact one or both treatment processes and result in a release of contaminants to the Columbia River.

The apatite-forming solution has a high ionic strength that causes a short-term release of strontium-90 and other trace metals normally sorbed to sediment by strong ionic bonds. Following the injections for the apatite PRB expansion in 2011, aluminum, chloride, chromium, cobalt, copper, iron, lead, manganese, nickel, silver, strontium, and zinc exceeded their associated drinking water or water quality levels in some of the wells within the apatite treatment zone, with concentrations returning to pre-treatment levels within a year. The upland aquifer covers a much larger area and contains significantly higher strontium-90 concentrations than the shoreline treatment area. Injections of apatite-forming solution in the upland area are likely to release a proportionally larger and more concentrated slug of strontium-90 and trace metals that will be driven toward the apatite PRB by the large injection volumes. The apatite barrier, designed to remove strontium-90 at current flow rates, would be overwhelmed by the large flux, and the majority of the strontium-90 and trace metals would be flushed to the river. This scenario may be moderated by a rigorous engineering design, but the risk that this remedy may result in a significant release of strontium-90 and other trace metals to the river will remain.

***Time to Achieve RAOs.*** Groundwater model simulations indicate that it will take 9 years for strontium-90 concentrations at the river shore to fall below the aquatic benchmark of 278 pCi/L and 110 years for strontium-90 concentrations at the river shore to fall below the DWS of 8 pCi/L. The groundwater model simulations for nitrate and TPH-D concentrations throughout the plume for Alternative 5 are the same as those for Alternative 4. For Alternative 5, the groundwater model simulated the immobilization of strontium-90 in upland groundwater where concentrations exceed 800 pCi/L. Groundwater model simulations indicate that it will take 161 years for strontium-90 concentrations in the upland area to fall below the DWS of 8 pCi/L. Treating individual strontium-90 upland groundwater hot spots (e.g., where concentrations exceed 8,000 pCi/L) will not effectively reduce the time to achieve the DWS, based on the estimated time to achieve the DWS if the entire upland strontium-90 plume (exceeding 800 pCi/L) is treated. The cleanup time for strontium-90 in the upland area in Alternative 5 was reduced relative to Alternative 4 because the apatite injections immobilized the strontium-90. The cleanup time for strontium-90 at the river boundary and the flux of strontium-90 to the river in Alternative 5 were not reduced relative to Alternative 4 because strontium-90, which has a relatively high distribution coefficient, would radioactively decay before it migrated from the upland area to the river.

**Alternative 5: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment**

### Overview

Alternative 5 incorporates the remedy components identified in the interim action ROD (EPA/ROD/R10-99/112) for the 100-NR-1 OU and 100-NR-2 OU.

#### Waste Sites

For waste sites that have not undergone interim actions, the actions will vary depending on the nature and extent of contamination and may include one or more of the following:

- RTD of the waste sites to protect human health and groundwater.
- Aerobic bioremediation of TPH via bioventing in deep vadose zone.
- Institutional controls.

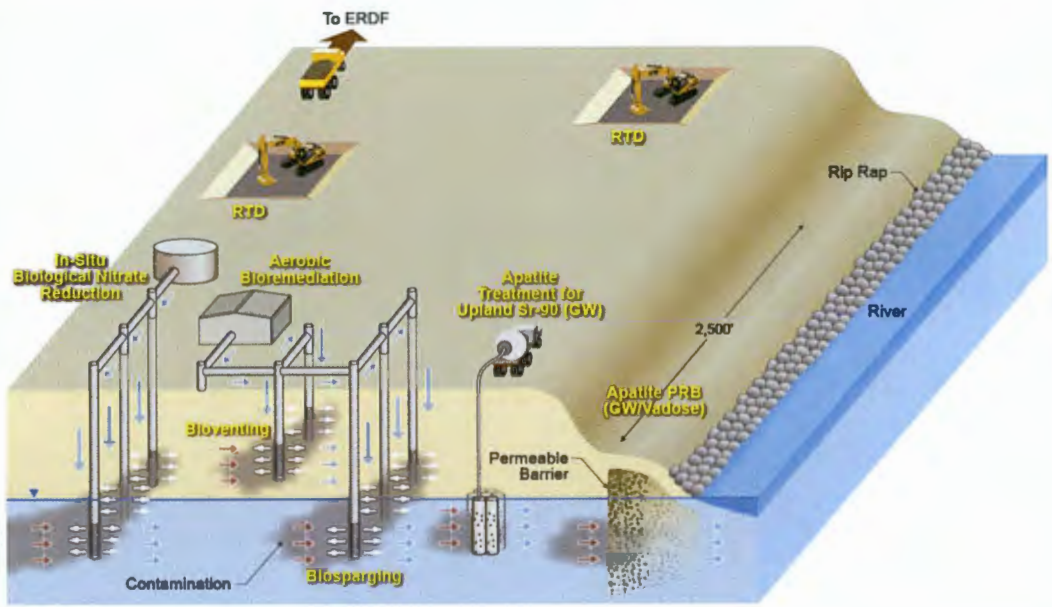
#### Groundwater

For groundwater, the actions include MNA, monitoring, and institutional controls. The scope of the actions includes:

- Decommissioning of the pump-and-treat system at 100-N.
- Replacement of well 199-N-16 with two monitoring wells.
- Expansion of the apatite permeable reactive barrier (PRB) for Strontium-90 to 2,500 feet near the shoreline.
- Technical Impracticability waiver for Strontium-90 upgradient of the apatite PRB.
- Installation of 305 m (1,000 ft) apatite barrier to enhance attenuation of Strontium-90 in vadose zone.
- MNA, groundwater monitoring, and ICs, as appropriate.
- Injection of air into the saturated zone to enhance aerobic bioremediation of TPH in groundwater.
- Injection of a carbon substrate to enhance anoxic biological reduction of nitrate in situ.
- Treatment of Strontium-90 in the saturated zone through injection of an apatite-forming solution in areas of elevated Strontium-90 concentrations (>800 pCi/L) upgradient of the apatite PRB.

Note: Backfill materials (to fill the excavated waste site) will be determined in the Remedial Design/Remedial Action Work Plan. Excess materials from ERDF construction will be considered for use as waste site backfill material to minimize natural near-site damages.

### Conceptual Schematic




### Cost

| | Waste Site Treatment | Groundwater Treatment | TOTAL |
|---|---|---|---|
| Total Present Value of Alternative (Discounted) | $ 22,317,000 | $ 262,533,000 | $ 284,850,000 |

*Note. Waste site treatment costs include the costs for institutional controls*

Source: EPA/ROD/R10-99/112, *Interim Remedial Action Record of Decision for the 100-NR-1 and 100-NR-2 Operable Units, Hanford Site, Benton County, Washington.*

**Figure 20. Alternative 5 — RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs**

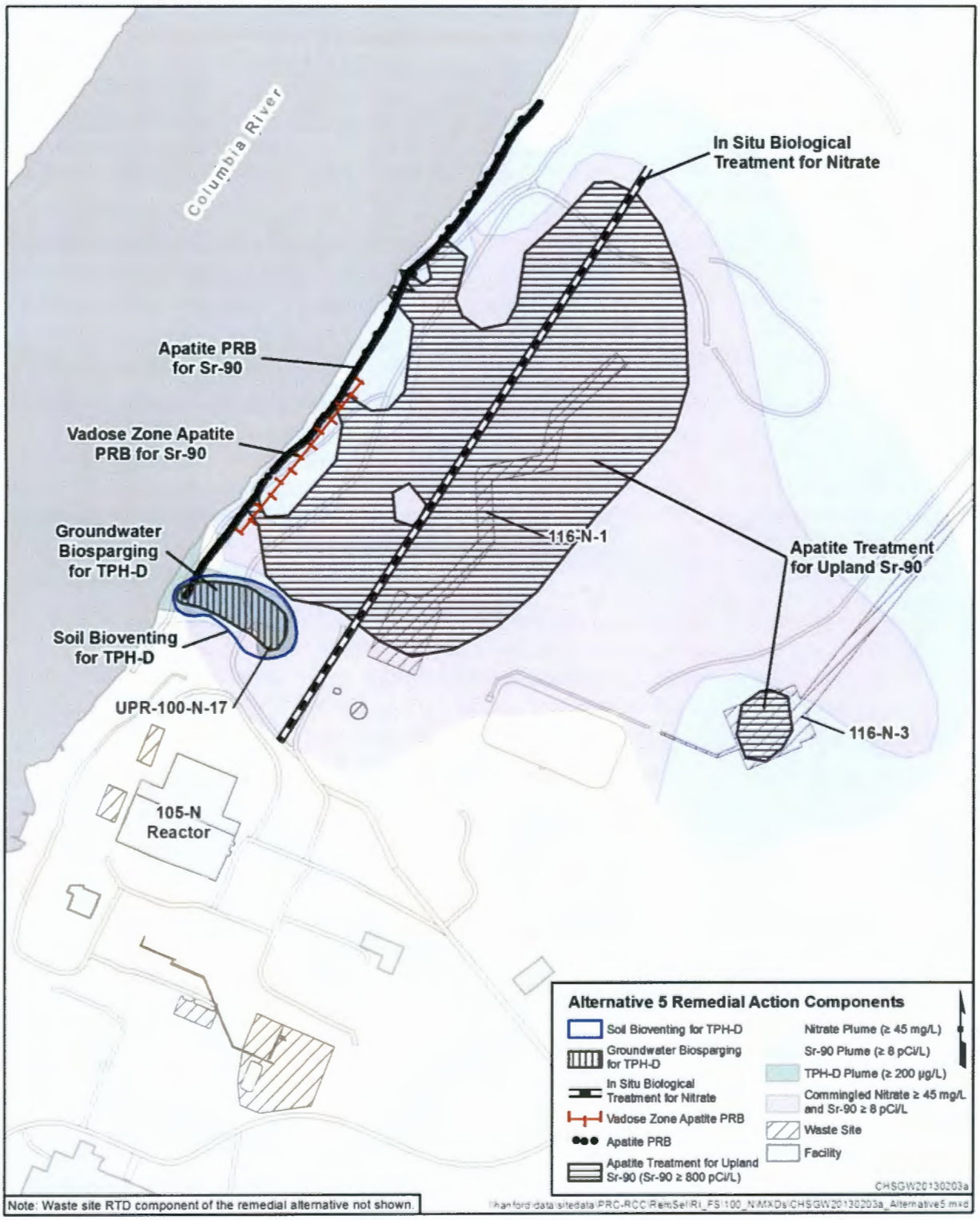
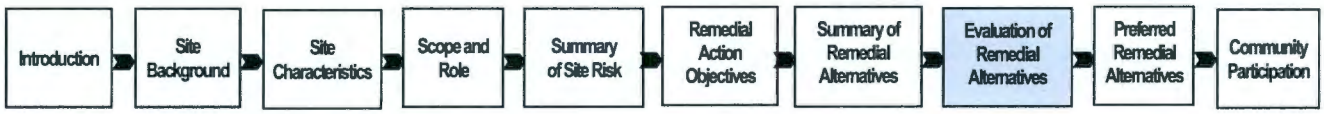



Figure 21. Areas for Implementation of Remedial Components of Alternative 5

Because Alternatives 4 and 5 include in situ bioremediation as the remedial component for nitrate, the flux of nitrate to the river under Alternative 5 is the same as it would be under Alternative 4.




## Evaluation of Remedial Alternatives

As part of the FS, DOE and Ecology evaluated each remedial alternative against CERCLA threshold and balancing criteria described in the NCP (40 CFR 300.430[e][9]). Following this evaluation, a comparative analysis was performed to assess the overall performance of each alternative relative to the others. Figure 22 presents the nine CERCLA evaluation criteria. The nine criteria are categorized into three groups: threshold criteria, balancing criteria, and modifying criteria.

A remedial alternative must satisfy the two threshold criteria of overall protection of HHE and compliance with ARARs to be considered viable. The five balancing criteria allow for a comparison of major tradeoffs among the alternatives. The ability of a preferred alternative to meet the modifying criteria (state and community acceptance) will be evaluated after the review and comment period for Tribal Nations and the public, which is initiated with this Proposed Plan. After completion of the formal public comment period, the Tri-Parties will consider the comments received before issuing a ROD. The modifying criteria are important considerations in the final evaluation of remedial alternatives.

The following sections describe the comparative analysis of alternatives that was used to identify the preferred alternative. The comparative analysis focuses on remediation of strontium-90, nitrate, and TPH-D in the deep vadose zone and groundwater because the remedial alternatives differ only in their approaches for these three contaminants. A more detailed comparative analysis can be found in the 100-N RI/FS report (Section 10.3 of DOE/RL-2012-15). The comparative analysis is summarized in Table 4.

### Threshold Criteria

#### *Overall Protection of Human Health and the Environment*

Alternative 1 (No Action) does not achieve the RAOs and does not meet the threshold criterion for protection of HHE for waste sites and groundwater (Table 10-2 of the 100-N RI/FS [DOE/RL-2012-15]).

To achieve all RAOs and meet the threshold criterion for the protection of HHE in a reasonable time frame for waste sites and groundwater, Alternatives 2 through 5 require that the groundwater ARAR for strontium-90 be waived within the upland area (Tables 10-3 through 10-6 in the 100-N RI/FS [DOE/RL-2012-15]). ICs will be required to protect HHE until RAOs are achieved. The estimated time frames to achieve RAOs for strontium-90, nitrate, and TPH-D after the remedial actions have been completed are provided for each alternative in Table 4.

#### *Compliance with Applicable or Relevant and Appropriate Requirements*

The ARAR identification process is based on CERCLA, the NCP (40 CFR 300), and guidance. The lead and non-lead agencies are to identify requirements applicable or relevant and appropriate to the release or remedial action at a CERCLA site (NCP [40 CFR 300.400(g)], "General"). The 100-N RI/FS report (Section 8.1.2 of DOE/RL-2012-15) provides a detailed discussion on how the ARARs evaluation process is conducted through the remedial action process in accordance with the NCP (40 CFR 300.430[f][1][ii][B][2]). All of the federal and Washington State ARARs that are pertinent to these remedial actions are identified in the 100-N RI/FS report (Table 8-2 of DOE/RL-2012-152). The ARARs will be finalized as part of the ROD.

# CERCLA Evaluation Criteria

## THRESHOLD CRITERIA

**Threshold criteria mean that only those remedial alternatives that provide adequate protection of human health and the environment and comply with ARARs are eligible for selection:**

1. **Overall Protection of Human Health and the Environment** is the primary objective of the remedial action and determines whether an alternative provides adequate overall protection of human health and the environment. This criterion must be met for all remedial actions.

2. **Compliance with Applicable or Relevant and Appropriate Requirements** addresses whether an alternative meets federal and state statutes or provides grounds for a waiver. This criterion must be met for a remedial alternative to be eligible for consideration.

## BALANCING CRITERIA

**Balancing criteria help describe technical and cost trade-offs among the various remedial alternatives:**

3. **Long-Term Effectiveness and Permanence** refers to the ability of a remedy to protect human health and the environment over time, after remedial action objectives have been met.

4. **Reduction of Toxicity, Mobility, or Volume through Treatment** means the alternative is evaluated for its ability to reduce the toxicity, mobility, and volume of the hazards at a site.

5. **Short-Term Effectiveness** refers to an evaluation of the speed with which the remedy can be successful and also takes into consideration any adverse impacts on human health and the environment that may result during the construction and implementation phase of the remedial action.

6. **Implementability** refers to the technical and administrative feasibility of a remedial action, including the availability of materials and services needed to implement the selection.

7. **Cost** refers to an evaluation of the costs of each alternative.

## MODIFYING CRITERIA

**Modifying criteria can only be considered after public comment is received on the proposed remedy:**

8. **State Acceptance** indicates whether the state concurs with, opposes, or has no comment on the proposed remedial action.

9. **Community Acceptance** assesses the public response to the proposed remedial action. Although public comment is an important part of the decision-making process, EPA is required by law to balance community concerns with the above criteria.

Figure 22. CERCLA Evaluation Criteria

**Table 4. Summary of Comparative Analysis of Alternatives**

| CERCLA Criterion | Remedial Alternative | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | Rating | Rating | Rating | Rating | Rating |
| **Threshold Criteria** | | | | | |
| Protection of human health/environment | No | Yes | Yes | Yes | Yes |
| Compliance with ARARs | No | Yes[a] | Yes[a] | Yes[a] | Yes[a] |
| **Balancing Criteria** | | | | | |
| Long-term effectiveness and permanence | Not evaluated | ★★☆ | ★★☆ | ★★☆ | ★★☆ |
| Reduction of toxicity, mobility, or volume through treatment | Not evaluated | ★☆☆ | ★★☆ | ★★★ | ★★★ |
| Short-term effectiveness and time to achieve RAOs[a] | Not evaluated | ★★☆ | ★★★ | ★☆☆ | ☆☆☆ |
| Implementability | Not evaluated | ★★★ | ★★★ | ★★☆ | ★☆☆ |
| Estimated time to achieve RAOs for strontium-90 in groundwater in the river boundary (years) | 125 | 110 | 110 | 110 | 110 |
| Estimated time to achieve RAOs for strontium-90 in groundwater in the upland area (years) | 225 | 225 | 225 | 225 | 161 |
| Estimated time to achieve RAOs for nitrate in groundwater in the upland area (years) | 50 | 50 | 50 | 20 | 20 |
| Estimated time to achieve RAOs for TPH-D in groundwater in the upland area (years) | 300 | 32 | 3 | 3 | 3 |
| **Cost (millions):[c]** | | | | | |
| • Waste site treatment | $0 | $22.3 | $22.3 | $22.3 | $22.3 |
| • Groundwater | $0 | $69.0 | $71.5 | $87.0 | $262.5 |
| Total cost (millions) | $0 | 91.3[b] | $93.8[b] | $109.3[b] | $284.9[b] |

Source: Table 10-9 in *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units* (DOE/RL-2012-15).

a. Based on approval of a TI waiver from the following ARAR for strontium-90 in groundwater; "Maximum Contaminant Levels for Radionuclides" (40 CFR 141.66) under the *Safe Drinking Water Act of 1974*.

b. Total cost includes $10 million for programmatic ICs and $0.2 million for 5-year reviews.

c. These cost estimates represent the total present value (discounted), prepared to meet the -30 to +50 percent range of accuracy recommended in *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA/540/G-89/004).

Notes: Although the remedial alternatives developed for evaluation do not have specific provisions for sustainable elements, those values can be incorporated during the remedial design phase.

**Table 4. Summary of Comparative Analysis of Alternatives**

| CERCLA Criterion | Remedial Alternative | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| | Rating | Rating | Rating | Rating | Rating |

The comparative evaluation metrics are defined as follows:

☆☆☆ = Expected to perform less well with significant disadvantages and uncertainties when compared with other alternatives.

★☆☆ = 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 fewer disadvantages or uncertainties when compared to the other alternatives.

**Alternatives:**

Alternative 1: No Action

Alternative 2: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs

Alternative 3: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs

Alternative 4: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

Alternative 5: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

ARAR = applicable or relevant and appropriate requirement
CERCLA = *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
IC = institutional control
MNA = monitored natural attenuation
PRB = permeable reactive barrier
RAO = remedial action objective
RTD = removal, treatment, and disposal
TI = technical implementability
TPH-D = total petroleum hydrocarbon

***Potential Chemical-Specific ARARs.*** Some of the key potential chemical-specific ARARs for this remedial action are the substantive (non-administrative) elements of the federal and state regulations that implement the DWSs under the *Safe Drinking Water Act of 1974* (40 CFR 141, "National Primary Drinking Water Regulations") and Model Toxics Control Act, "Groundwater Cleanup Standards" [WAC 173-340-720[4][b][iii][A] and [B]), and for health protection (WAC 173-340-720[7][b])].

Because the federal DWSs and specific groundwater cleanup sections of Washington State's MTCA (WAC 173-340) are potential ARARs, the remedial alternatives were developed to achieve ARARs, if technically possible, for each identified COC so groundwater present in the 100-NR-2 OU could be used as a future drinking water source.

***Potential Location-Specific ARARs.*** Potential location-specific ARARs identified for the 100-NR-1 and 100-NR-2 OUs include those that protect cultural, historical, and Native American sites and artifacts under the *Native American Graves Protection and Repatriation Act of 1990*, *Archaeological and Historic Preservation Act of 1974*, *National Historic Preservation Act of 1966*, and those that protect listed endangered and threatened species or their critical habitat under the *Endangered Species Act of 1973*. The *Migratory Bird Treaty Act of 1918* is a potential location-specific ARAR.

***Potential Action-Specific ARARs.*** Potential action-specific ARARs relate to waste management activities; solid and dangerous waste regulations under WAC 173-303, "Dangerous Waste Regulations," and WAC 173-350, "Solid Waste Handling Standards"; and radioactive waste management under *Atomic Energy Act of 1954* regulations. The other major category of potential action-specific ARARs concerns standards for controlling air emissions to the environment in WAC 246-247, "Radiation Protection Air Emissions," and WAC 173-480, "Ambient Air Quality Standards and Emission Limits for Radionuclides."

Alternative 1 (No Action) will not meet ARARs for waste sites and the vadose zone and will not meet ARARs for groundwater within a reasonable time. Because Alternative 1 will not be protective of HHE and does not comply with ARARs (the two CERCLA threshold criteria), it was not evaluated for performance with respect to the CERCLA balancing criteria.

Alternatives 2 through 5 will comply with ARARs for waste sites and the vadose zone. No waivers from ARARs are required for Alternatives 2 through 5 for soil remedial actions.

Alternatives 2 through 5 will achieve compliance with ARARs for groundwater within a reasonable time frame for protection of HHE for all contaminants except strontium-90. The ARAR that will not be achieved within a reasonable time is the "Maximum Contaminant Levels for Radionuclides" (40 CFR 141.66) under the *Safe Drinking Water Act of 1974* for strontium-90 in the groundwater that may be used for drinking water supply.

The NCP requires that usable groundwater be returned to beneficial uses wherever practicable within a time frame that is reasonable given the particular circumstances of the site (40 CFR 300.430[a][1][iii][F]). For groundwater remedial actions, strontium-90 concentrations within groundwater in the upland area (i.e., upgradient of the apatite PRB) are not expected to decline below the DWS (8 pCi/L) in less than 100 years under any of the remedial alternatives. Because achievement of the DWS for strontium-90 in the upland area in fewer than 100 years is technically impracticable, a waiver from this ARAR is proposed.

Given that empirical evidence and predictive modeling have demonstrated that strontium-90 contamination in the upland area will not be cleaned up in a reasonable time frame, DOE prepared a TI waiver evaluation in accordance with *Guidance for Evaluating the Technical Impracticability of Ground-Water Restoration Interim Final* (EPA, 1993). The TI waiver evaluation for this ARAR for strontium-90 is provided in the 100-N RI/FS report (Appendix O of DOE/RL-2012-15).

There is no aquatic water concentration standard for strontium-90. The biota concentration guide for strontium-90 is 278 pCi/L. This aquatic concentration benchmark will be achieved in 9 years for all alternatives. No other waivers from ARARs are required for Alternatives 2 through 5 for groundwater remedial actions.

As the lead agency, Ecology will request that EPA invoke a TI waiver of the DWS for strontium-90 in the ROD associated with this Proposed Plan. In accordance with CERCLA and the NCP (40 CFR 300), the explanation for the proposed ARAR waiver is provided in this Proposed Plan to allow the Tribal Nations and the public an opportunity to comment on the waiver (NCP, 40 CFR 300.430[f][2][iv] and 40 CFR 300.500 through 300.515). EPA will respond to any significant federal agency, state, Tribal Nation, or public comments concerning the use of ARAR waivers.

With the waiver from the DWS ARAR for strontium-90, Alternatives 2 through 5 will comply with ARARs for groundwater. Because Alternatives 2 through 5 will be protective of HHE and will comply with ARARs (the two CERCLA threshold criteria), they were evaluated for performance with respect to the CERCLA balancing criteria.

## Balancing Criteria

### *Long-Term Effectiveness and Permanence*

The criterion of long-term effectiveness and permanence is used to compare the ability of the remedial alternatives to maintain protection of HHE after the RAOs have been met. Factors that are considered include whether (1) the remedy will degrade over time, (2) the remedy relies on natural processes that do not require human intervention, and (3) the remedy has a high degree of certainty in performance to meet and maintain RAOs.

All of the alternatives include an apatite PRB component for reducing strontium-90 flux to the Columbia River. Alternative 5 is the only alternative that also includes a component of apatite treatment for the strontium-90 in the upland area (upgradient of the apatite PRB). After the apatite has been injected, the apatite PRB and upland treatment zone rely on natural processes for enhanced attenuation of strontium-90. As previously noted in the "Physical Features Impacting Remedy Selection" section of this Proposed Plan, the Columbia River from the 100-BC Area to the 100-D Area has occupied the same channel for at least the past 8,000 years. Because the Columbia River channel is stable, it should not change during decay of strontium-90 in the shoreline sediment adjacent to the channel. In addition, this segment of the Columbia River shoreline is within the HRNM, which is unlikely to be developed. Immobilization of the strontium-90 while it naturally decays makes this a permanent and effective remedy.

All alternatives include a bioventing component for deep TPH-D in the vadose zone. After oxygen (in air) has been injected to stimulate natural aerobic biodegradation, bioventing relies on natural processes to biodegrade the TPH-D in situ to carbon dioxide and water. Biodegradation is a permanent and irreversible process.

Alternatives 3, 4, and 5 include a biosparging component for treatment of the TPH-D in groundwater, whereas Alternative 2 does not include a component to treat the TPH-D in groundwater. After oxygen has been injected to stimulate natural aerobic biodegradation, biosparging (e.g., bioventing) relies on natural processes to biodegrade the TPH-D in groundwater to carbon dioxide and water and is a permanent, irreversible, and effective remedy.

Alternatives 4 and 5 include an in situ biological treatment component to accelerate biodegradation by native microorganisms of nitrate in groundwater to nitrogen gas. Alternatives 2 and 3 do not include injection of organic substrate to accelerate the in situ biodegradation of nitrate; however, nitrate in groundwater will continue to biodegrade naturally. Under all alternatives, the biodegradation (accelerated or natural) of nitrate in groundwater is permanent and irreversible.

Under all alternatives, ICs will be required to protect HHE until RAOs are met. Because of the length of time expected for strontium-90 in groundwater to meet RAOs, ICs will be needed for an extended period. Although long-term permanence evaluates the remedy following attainment of RAOs, the need for long-term ICs is not typically a permanent solution.

Alternatives 2 through 5 all perform well with respect to long-term effectiveness and permanence, as shown in Table 4.

### *Reduction of Toxicity, Mobility, or Volume through Treatment*

The criterion of reduction of toxicity, mobility, or volume through treatment is used to compare the anticipated performance of specific treatment technology components of the remedial alternatives. Each of Alternatives 2 through 5 includes at least one of the following four in situ treatment components:

- The mobility of strontium-90 in the vadose zone and groundwater is reduced through in situ treatment using apatite. The mineral apatite forms in the subsurface following injections of calcium-citrate-phosphate solutions. The apatite immobilizes strontium-90 by incorporating the strontium cation in the mineral structure as a substitution for the calcium cation.

- The toxicity, mobility, or volume of TPH-D in the deep vadose zone is reduced through in situ treatment using bioventing. An aerobic environment is enhanced following injection of oxygen (in air) at low flow rates through vertical wells. The oxygen stimulates natural, in situ aerobic biodegradation of the TPH-D in the deep vadose zone to carbon dioxide and water.

- The toxicity, mobility, or volume of TPH-D in the groundwater is reduced through in situ treatment using biosparging. Oxygen (in air) is sparged through the groundwater and stimulates natural, in situ biodegradation of the TPH-D in the groundwater to carbon dioxide and water.

- The toxicity, mobility, or volume of nitrogen in the groundwater is reduced through in situ biological treatment. An organic substrate (e.g., vegetable oil ) is injected into the groundwater to accelerate the natural, in situ biodegradation of the nitrate in the groundwater to nitrogen gas.

***Strontium-90 in the Vadose Zone and Groundwater.*** The apatite PRB component of Alternatives 2 through 5 reduces mobility of strontium-90 in the vadose zone and groundwater near the river. Installation of the apatite PRB into groundwater is predicted to crystallize the mineral apatite in 13.6 percent of the pore volume. The apatite treatment component of Alternative 5 immobilizes strontium-90 in groundwater in the upland area (upgradient of the apatite PRB).

Approximately 0.25 Ci of strontium-90 would have been released to the river if the apatite PRB (completed in 2011) had not been installed, based on extrapolation of 2006 data (Section 10.3.4 of the 100-N RI/FS report [DOE/RL-2012-15]). The numerical model predicts a cumulative discharge to the river of 0.077 Ci of strontium-90 (a 66 percent decrease) with the completed 270 m (900 ft) long apatite barrier, and a cumulative discharge of 0.05 Ci strontium-90 (an 80 percent decrease) with the installation of the 760 m (2,500 ft) long apatite PRB in Alternatives 2 through 5.

Treatment of the 162,000 $m^2$ (40 ac) upland area in Alternative 5 does not reduce the mass of strontium-90 discharged to the river. This is because the high distribution coefficient of strontium-90 retards the migration of strontium-90, and strontium-90 in the upland area decays before it reaches the river.

The mobility of the majority (80 percent) of the strontium-90 mass that would have entered the river is reduced by installation of the 760 m (2,500 ft) long apatite PRB in Alternatives 2 through 5. Alternative 5 ranks slightly higher in treatment of strontium-90 using apatite because it includes the upland area component.

***TPH-D in Groundwater.*** Alternatives 3 through 5 all rank higher than Alternative 2 for reduction of toxicity, mobility, or volume through treatment of TPH-D in the groundwater because each of these alternatives includes the biosparging component. Because Alternative 2 does not include a component for TPH-D in groundwater, it rates poorly on this criterion for TPH-D in groundwater.

***Nitrate in Groundwater.*** Alternatives 4 and 5 rank higher than Alternatives 2 and 3 for reduction of toxicity, mobility, or volume through treatment of nitrate in the groundwater because these alternatives all include in situ biological treatment component. Because Alternatives 2 and 3 include no component for accelerating in situ treatment of nitrate in groundwater, they rate lower on this criterion for nitrate in the groundwater.

***Summary.*** Alternatives 4 and 5 rank highest for reduction of toxicity, mobility, or volume through treatment because they include the biosparging components for TPH-D and the in situ biological treatment component for nitrate. Alternative 5 ranks slightly higher than Alternative 4 because it includes apatite treatment for strontium-90 in the upland area.

Alternative 3 ranks higher than Alternative 2 because it includes the biosparging component for TPH-D in groundwater.

### *Short-Term Effectiveness*

The criterion of short-term effectiveness is used to compare the ability of the remedial alternatives to maintain protection of HHE during construction and implementation of the remedy until the RAOs have been met. Factors that are considered include (1) the speed with which the remedy can be successful, and (2) any adverse impacts on HHE during the construction and implementation phase of the remedial action.

The FS in the 100-N RI/FS report (Table 10-11 in DOE/RL-2012-15) compares the expected time frames to achieve groundwater PRGs based on the model results presented in Chapters 5 and 9 of the 100-N RI/FS report (DOE/RL-2012-15). The expected length of time to reach PRGs for strontium-90 in groundwater is approximately the same for all alternatives (225 years for Alternatives 2 through 4, and 161 years for Alternative 5) and is therefore not a useful discriminator for comparing short-term effectiveness. The length of time to reach groundwater cleanup levels for TPH-D in groundwater is shorter for Alternatives 3 through 5 (3 years) than for Alternative 2 (32 years) because Alternatives 3 through 5 include the biosparging component. The length of time to reach PRGs for nitrate in groundwater is shorter for Alternatives 4 and 5 (20 years) than for Alternatives 2 and 3 (50 years) because Alternatives 4 and 5 include in situ biological treatment to accelerate biodegradation of nitrate. However, the majority of the nitrate plume occurs within the strontium-90 plume; therefore, this reduction in time to reach the PRGs for nitrate does not reduce the time to reach the PRGs for all COCs in groundwater.

Implementation of the apatite PRB in all alternatives has the potential for short-term releases of strontium-90 and trace metals to the river during injection of the calcium-citrate-phosphate solution, which may displace some of the metals bound to the sediments.

Implementation of in situ biological treatment for nitrate in Alternatives 4 and 5 also has the potential to cause significant adverse impacts to HHE. Injection of large quantities of organic substrate and the development of the anoxic environment needed to treat the nitrate plume will mobilize metals from sediment to groundwater and may result in a significant release of trace metals to the river. Enhancing microbial growth in the aquifer to treat the nitrate plume has the potential for developing biofilms within the downgradient apatite barrier, potentially impacting strontium-90 adsorption and apatite PRB performance.

There is no environmental benefit for remediating the nitrate in the groundwater because the groundwater cannot be used for drinking water until the strontium-90 has decayed. While the mass of nitrate entering the river from 100-NR-2 OU groundwater is approximately 7 kg/day (15 lb/day), it represents approximately 0.25 percent of the 2,700 kg/day (6,000 lb/day) that entered the Columbia River on average during a 4-month period in 1980 from five waste ways (WA-36-1010, *Irrigation Return Flow Quality, South Columbia Basin Irrigation District May-August 1980*). Fifteen irrigation waste ways return irrigation water back to the river between the Interstate 90 bridge at Vantage, Washington (upstream of the 100-NR-2 OU) and the Oregon state line (downstream of the 100-NR-2 OU).

Implementation of the component for apatite treatment for upland strontium-90 in Alternative 5 also has the potential to cause significant adverse impacts on HHE. The apatite treatment will require installation of over

800 injection wells to a depth of 27 m (90 ft) throughout 162,000 $m^2$ (40 ac). The high-concentration calcium-citrate-phosphate solution that will be injected into each of the wells to form the apatite in the subsurface will be diluted with over 400 million L (105 million gal) of river water, all of which must be contained, transported, and injected into the wells. Massive injections of the calcium phosphate solution are likely to release a concentrated slug of strontium-90 and trace metals that will be driven toward the PRB by the large injection volumes, with the majority likely to be flushed through the PRB to the river. The drilling and the chemical and river water transportation required by Alternative 5 will also generate greenhouse gases.

Alternative 5 includes the component for apatite treatment for upland strontium-90 and the component for in situ biological treatment for upland nitrate. The effect of injecting both the apatite solution and the organic substrate into the groundwater in the same area may have unintended consequences that impact one or both treatment processes and result in release of contaminants to the river. The uncertainty regarding whether the implementation of these two components has the potential to cause significant adverse impacts on HHE results in a lower ranking of Alternative 5 for short-term effectiveness.

Alternative 3 rates highest for the criterion of short-term effectiveness because it includes biosparging to reduce the time to reach PRGs for TPH-D in groundwater and it minimizes adverse impacts to HHE. Although Alternative 2 does not include the biosparging component, it rates second highest because it also minimizes adverse impacts to HHE. Alternative 4 includes the biosparging component but rates lower because of its potential for adverse impacts to HHE associated with the in situ treatment for nitrate. Alternative 5 includes the biosparging component but rates the lowest among the alternatives because of its potential for adverse impacts to HHE associated with the in situ treatment for nitrate and strontium-90 in the upland area.

### *Implementability*

The criterion of implementability is used to compare the technical and administrative feasibility of the remedial alternatives. Factors that are considered include the availability of materials and services needed to implement the remedy components.

Alternatives 2 and 3 rate highest for implementability. Both alternatives include the apatite PRB component for strontium-90. The injection wells for the apatite PRB are already in place. Both alternatives include the bioventing component for TPH-D in the deep vadose zone. Bioventing for TPH-D has been successfully pilot tested at the location of the TPH-D contamination. Based on test results, the bioventing technology has been successfully implemented as part of the 100-N interim action ROD. The biosparging component in Alternative 3 for TPH-D in groundwater is a proven technology that deploys conventional equipment for which vendors are readily available. Retention of metals in soil is favored by oxidizing conditions, a positive side effect from biosparging.

Alternatives 4 and 5 are less implementable than Alternatives 2 or 3 because they include the component for in situ biological treatment of nitrate. Introducing organic substrate to promote anaerobic conditions will decrease pH and release metals from the sediment to groundwater. Implementation of injections to minimize the potential to mobilize contaminants to the river is technically challenging. Phased implementation may be required to develop design parameters to mitigate the uncertainty associated with this component.

Alternative 5 is rated the least implementable because it includes the component for apatite treatment for strontium-90 in the upland area. Implementation of apatite treatment throughout the 162,000 $m^2$ (40 ac) area will require additional services to install more than 800 injection wells to a depth of at least 27 m (90 ft) and to obtain, prepare, contain, transport, and inject a large quantity of apatite solutions. Implementation of apatite injections that minimize the potential to mobilize contaminants to the river is technically challenging, as is the co-treatment of nitrate and apatite in the upland area using different compounds with potential interferences.

Additionally, part of the area identified for apatite injections overlaps a previously undisturbed area within the Mooli Mooli, which is a culturally significant area, potentially posing implementability challenges.

### *Cost*

Estimated design, construction, O&M, and decommissioning costs were developed for each alternative. The O&M costs were estimated based on an alternative-specific remedial time frame from 150 to 225 years. The estimated net present value costs are provided in Table 5.

**Table 5. Summary of Costs for Remedial Alternatives**

| Remedial Alternative | Capital Cost | Annual Operations and Maintenance Cost* | Total Present Value (Discounted) |
|---|---|---|---|
| 1 | $0 | $0 | $0 |
| 2 | $42,591,000 | $80,100,000 | $122,691,000 |
| 3 | $45,793,000 | $81,062,000 | $126,855,000 |
| 4 | $56,091,000 | $86,825,000 | $142,916,000 |
| 5 | $222,412,000 | $94,604,000 | $317,016,000 |

* Includes both total annual cost and total periodic cost.

**Alternatives:**

Alternative 1: No Action

Alternative 2: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium--90, Bioventing for TPH-D in Vadose Zone, MNA for TPH-D in Groundwater, Groundwater Monitoring, and ICs

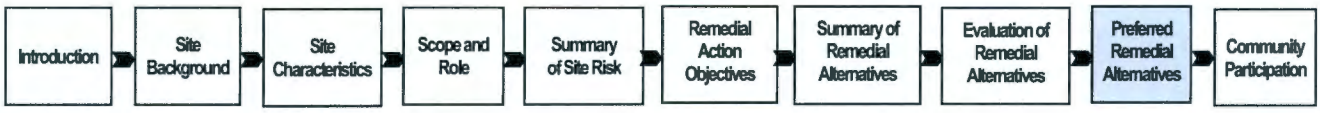
Alternative 3: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs

Alternative 4: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

Alternative 5: RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, Apatite Treatment and TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, In Situ Biological Treatment for Nitrate, Groundwater Monitoring, and ICs

### *Modifying Criteria*

In the final balancing of tradeoffs between alternatives upon which the final remedy selection is based, modifying criteria and balancing criteria are both important.




## Preferred Remedial Alternative

Alternative 3 (RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs) is the preferred alternative. This alternative is recommended because it achieves a substantial risk reduction through RTD of waste sites; enhanced attenuation of strontium-90 in groundwater near the river shore for river protection; a TI waiver for strontium-90 in the groundwater upgradient of the apatite PRB; in situ treatment of TPH-D sources in the deep vadose zone and groundwater; and safe management of residual contamination through ICs.

Table 6 lists all of the waste sites in the 100-NR-1 OU and indicates how each would be specifically addressed under the preferred alternative.

**Table 6. Waste Sites included in the Preferred Alternative**

| Technology/Approach | Waste Sites |
|---|---|
| No additional action (waste sites that do not pose an unacceptable risk and do not require additional action): 38 waste sites | 100-N-1, 100-N-103, 100-N-13, 100-N-14, 100-N-17, 100-N-18, 100-N-22, 100-N-25, 100-N-26, 100-N-3, 100-N-33, 100-N-34, 100-N-4, 100-N-41, 100-N-45, 100-N-46, 100-N-47, 100-N-5, 100-N-50, 100-N-51, 100-N-51B, 100-N-52, 100-N-55, 100-N-58, 100-N-67, 100-N-77, 100-N-78, 100-N-80, 100-N-92, 120-N-1, 120-N-2, 124-N-4, 1908-NE, 600-347, 600-35, UPR-100-N-11, UPR-100-N-37, and UPR-100-N-42 |
| Institutional controls (waste sites that require institutional controls to prevent irrigation and excavation): 3 waste sites | 100-N-65, 116-N-1, and 116-N-3 |
| Removal, treatment, and disposal: 95 waste sites | 100-N-100, 100-N-101, 100-N-102, 100-N-104, 100-N-106*, 100-N-16, 100-N-23, 100-N-24, 100-N-28, 100-N-29, 100-N-30, 100-N-31, 100-N-32, 100-N-36, 100-N-37, 100-N-38, 100-N-53, 100-N-54, 100-N-57, 100-N-59, 100-N-6, 100-N-60, 100-N-61, 100-N-62, 100-N-63, 100-N-64, 100-N-68, 100-N-79, 100-N-81, 100-N-82, 100-N-83, 100-N-84, 100-N-85*, 100-N-86, 100-N-87, 100-N-88, 100-N-89, 100-N-90, 100-N-91, 100-N-93, 100-N-94, 100-N-95, 100-N-96, 100-N-97, 100-N-98, 100-N-99, 116-N-2, 116-N-4, 118-N-1, 120-N-3, 120-N-4, 120-N-7, 124-N-1, 124-N-10, 124-N-2, 124-N-3, 124-N-9, 128-N-1, 130-N-1, 1908-N, 2607-FSM*, 600-339*, 600-340, 600-348*, 628-2, UPR-100-N-1, UPR-100-N-10, UPR-100-N-12, UPR-100-N-13, UPR-100-N-14, UPR-100-N-17*, UPR-100-N-18, UPR-100-N-19, UPR-100-N-2, UPR-100-N-20, UPR-100-N-21, UPR-100-N-22, UPR-100-N-23, UPR-100-N-24, UPR-100-N-25, UPR-100-N-26, UPR-100-N-29, UPR-100-N-3, UPR-100-N-30, UPR-100-N-31, UPR-100-N-32, UPR-100-N-36, UPR-100-N-39, UPR-100-N-4, UPR-100-N-43, UPR-100-N-5, UPR-100-N-6, UPR-100-N-7, UPR-100-N-8, and UPR-100-N-9 |
| **Total waste sites: 136** | |

Source: Section 8.2.1.1 in *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units* (DOE/RL-2012-15).

* These six waste sites are to be remediated using RTD under the ROD for the 100-NR-1 OU and, therefore, are included in the cost estimate in the feasibility study for the remedial alternative (Section 10.2 of DOE/RL-2012-15). The other 89 waste sites identified for RTD are pending completion of remediation under the interim action RODs for the 100-NR-1 OU and are not included in the cost estimate in the feasibility study for the remedial alternative.

OU = operable unit
ROD = Record of Decision
RTD = removal, treatment, and disposal
UPR = unplanned release

Alternative 3 will permanently reduce the toxicity, mobility, or volume through treatment of the highest contaminant mass of strontium-90 in the vadose zone and groundwater. Although Alternatives 4 and 5 will also reduce the toxicity, mobility, and volume through treatment of nitrate, achievement of RAOs for all COCs in groundwater is controlled by remediation of the strontium-90. Alternative 3 will not remediate the nitrate in groundwater because the groundwater cannot be used for drinking water until the strontium-90 has decayed. Alternative 3 also is expected to perform very well in short-term effectiveness and implementability. Alternative 3 performs equally well as Alternatives 2, 4, and 5 with respect to long-term effectiveness and permanence.

Based on information currently available, DOE and Ecology recommend Alternative 3, "RTD at Waste Sites, Apatite PRB for Near-Shore Strontium-90, TI Waiver for Upland Strontium-90, Bioventing and Biosparging for TPH-D, Groundwater Monitoring, and ICs," as the preferred alternative (Table 4).

DOE and Ecology believe that Alternative 3 meets the threshold criteria and provides the best balance of tradeoffs compared with Alternatives 2, 4, and 5 with respect to the balancing and modifying criteria. DOE and Ecology expect Alternative 3 to satisfy the following statutory requirements of CERCLA Section 121(b):

- Protect HHE
- Comply with ARARs (or qualify for an ARAR waiver)
- Be cost effective
- Use permanent solutions and alternative treatment technologies or resource recovery technologies to the maximum extent practicable
- Satisfy the preference for treatment as a principal element

The recommendation of Alternative 3 as the preferred alternative may change in response to comments received on this Proposed Plan.

## National Environmental Policy Act Values

***National Environmental Policy Act of 1969 (NEPA)*** values are incorporated into DOE's CERCLA documentation (*National Environmental Policy Act Compliance Program* [DOE O 451.1B, Chg. 2]). NEPA values include (but are not limited to) consideration of the cumulative, ecological, cultural, historical, and socioeconomic impacts of the proposed remedial alternative. NEPA values were incorporated into the FSs, and the conclusions will be included in the CERCLA ROD. For the remedies evaluated in this Proposed Plan, environmental impacts include temporary short-term disturbance (e.g., increased traffic, noise levels, and fugitive dust) within limited areas. DOE expects minimal, if any, long-term impacts to air quality, natural resources and historical resources; transportation; socioeconomic values; or environmental justice.

## Community Participation

Public input is a key element in DOE's decision-making process. The Tribal Nations and the public are encouraged to read and provide comments on any of the alternatives presented in this proposed plan, including the preferred alternative. The Administrative Record for this proposed remedial action decision is available for review at the repository locations listed to the right.

The comment period for this Proposed Plan extends from MM DD, 2013, through MM DD, 2013. Comments on the preferred alternative, other alternatives, or any element of this Proposed Plan or support information will be accepted through MM DD, 2013. Please send comments to either of these people:

Mail: Tifany Nguyen
U.S. Department of Energy
Richland Operations Office
P.O. Box 550, A7-75
Richland, WA 99352
Email: 100FIUPP@RL.gov

Mail:
Washington State Department of Ecology
Port of Benton Blvd.
Richland, WA 99354
Email:

To request a meeting in your area, please contact Tifany Nguyen (phone ###) no later than MM DD, 2013. After the public comment period, DOE and Ecology will consider the comments regarding this Proposed Plan and the information gathered during the comment period.

### Hanford Public Information Repository Locations

**Administrative Record and Public Information Repository:**
2440 Stevens Center Place
Room 1101, Richland, WA
Phone: (509) 376-2530
Website: http://www2.hanford.gov/arpir/

**Portland**
Portland State University
Branford P. Millar Library
1875 SW Park Avenue, Portland, OR
Phone: (503) 725-4542
Map: http://www.pdx.edu/map.html

**Seattle**
University of Washington
Suzallo Library, Government Publications Department
P.O. Box 352900, Seattle, WA 98195
Phone: (206) 543-5597
Map: http://tinyurl.com/m8ebj

**Richland**
Washington State University, Tri-Cities
Consolidated Information Center
Room 101-L, 2770 University Drive
Richland, WA
Phone: (509) 375-3308
Map: http://reading-room.labworks.org/Directions.aspx

**Spokane**
Gonzaga University Foley Center Library
East 502 Boone Ave., Spokane, WA 99258
Phone: (509) 313-6110
Map: http://tinyurl.com/2c6bpm

**Table A-1. Summary of 100-N Proposed Soil Cleanup Levels for Protection of Human Health and Soil Concentrations Protective of Groundwater and Surface Water Based on Soil Screening Levels and PRGs**

| COC | Hanford Site Background Concentration[a] | Proposed Direct Contact Human Health Cleanup Levels (≤4.6 m [15 ft] bgs) | | Proposed Groundwater and Surface Water Protection Cleanup Levels (Ground Surface to Water Table)[e,f] | |
|---|---|---|---|---|---|
| | | PRG | Exposure Driver | No Irrigation | Irrigation |
| Americium-241 | -- | 32 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Carbon-14 | -- | 8.7 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Cesium-137 | 1.1 | 4.4 | Direct contact residential scenario | See footnote g | See footnote g |
| Cobalt-60 | 0.0084 | 1.4 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Curium-243 | -- | 22 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Europium-152 | -- | 3.3 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Europium-154 | 0.033 | 3.0 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Europium-155 | 0.054 | 125 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Iodine-129 | -- | 0.076 | Direct contact residential scenario | See footnote g | 0.14 |
| Neptunium-237 | -- | 2.4 | Residential RAG (DOE/RL-96-17) | See footnote g | 5,400 |
| Nickel-63 | -- | 608 | Direct contact residential scenario | See footnote g | See footnote g |
| Niobium-94 | -- | 1.4 | Direct contact residential scenario | See footnote g | See footnote g |
| Plutonium-238 | 0.0038 | 39 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Plutonium-239/240 | 0.025 | 35 | Residential RAG (DOE/RL-96-17) | See footnote g | See footnote g |
| Strontium-90 | 0.18 | 2.3 | Direct contact residential scenario | See footnote g | See footnote g |
| Technetium-99 | -- | 1.5 | Direct contact residential scenario | 15 | 5.9 |
| Tritium | -- | 459 | Residential RAG (DOE/RL-96-17) | 516 | 316 |
| Uranium-233/234 | 1.1 | 1.1 | Residential RAG (DOE/RL-96-17) | See footnote h | See footnote h |

**Table A-1. Summary of 100-N Proposed Soil Cleanup Levels for Protection of Human Health and Soil Concentrations Protective of Groundwater and Surface Water Based on Soil Screening Levels and PRGs**

| COC | Hanford Site Background Concentration[a] | Proposed Direct Contact Human Health Cleanup Levels (≤4.6 m [15 ft] bgs) | | Proposed Groundwater and Surface Water Protection Cleanup Levels (Ground Surface to Water Table)[e,f] | |
|---|---|---|---|---|---|
| | | PRG | Exposure Driver | No Irrigation | Irrigation |
| Uranium-235 | 0.11 | 0.61 | Residential RAG DOE/RL-96-17 | See footnote h | See footnote h |
| Uranium-238 | 1.1 | 1.1 | Residential RAG DOE/RL-96-17 | See footnote h | See footnote h |
| Antimony | 0.13 | 32 | Direct contact, MTCA Method B | See footnote g | 2.9/2.7 |
| Arsenic | 6.5 | 20[b] | WAC 173-340-900, Table 740-1, Method A | See footnote g | See footnote g |
| Barium | 132 | 16,000 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Beryllium | 1.5 | 160 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Boron | 3.9 | 16,000 | Direct contact, MTCA Method B | See footnotes g and i | 1,154[i] |
| Cadmium | 0.56 | 40 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Chromium | 19 | 120,000 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Cobalt | 16 | 24 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Copper | 22 | 3,200 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Cr(VI) | -- | 240 | Direct contact, MTCA Method B | 2.0[j] | 2.0[j] |
| Lead | 10.2 | 250 | WAC 173-340-900, Table 740-1, Method A | See footnote g | See footnote g |
| Lithium | 13 | 160 | Direct contact, MTCA Method B | 1,154[i] | See footnotes g and i |
| Manganese | 512 | 11,200 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Mercury | 0.013 | 24 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Molybdenum | 0.47 | 400 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Nickel | 19 | 1,600 | Direct contact, MTCA Method B | See footnote g | See footnote g |

**Table A-1. Summary of 100-N Proposed Soil Cleanup Levels for Protection of Human Health and Soil Concentrations Protective of Groundwater and Surface Water Based on Soil Screening Levels and PRGs**

| COC | Hanford Site Background Concentration[a] | Proposed Direct Contact Human Health Cleanup Levels (≤4.6 m [15 ft] bgs) | | Proposed Groundwater and Surface Water Protection Cleanup Levels (Ground Surface to Water Table)[e,f] | |
|---|---|---|---|---|---|
| | | PRG | Exposure Driver | No Irrigation | Irrigation |
| Selenium | 0.78 | 400 | Direct contact, MTCA Method B | See footnote g | 34/3.4 |
| Silver | 0.17 | 400 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Strontium | -- | 48,000 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Tin | -- | 48,000 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Uranium | 3.2 | 240 | Direct contact, MTCA Method B | See footnote g | 8.1/211 |
| Vanadium | 85 | 400 | Direct contact, MTCA Method B | See footnotes g and i | See footnotes g and i |
| Zinc | 68 | 24,000 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Chloride | 100 | See footnote c | -- | 4,246/3,906 | 1,642/1,510 |
| Cyanide | -- | 1,600 | Direct contact, MTCA Method B | See footnote g | 1,806/47 |
| Fluoride | 2.8 | 4,800 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Nitrate | 52 | 568,000 | Direct contact, MTCA Method B | 764 | 295 |
| Nitrite | -- | 24,000 | Direct contact, MTCA Method B | 56[i] | 22[i] |
| Sulfate | 237 | See footnote c | -- | 4,246[i] | 1,642[i] |
| Aroclor 1016 | -- | 5.6 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Aroclor 1221 | -- | 0.50 | Direct contact, MTCA Method B | See footnote g | 0.53/0.017 |
| Aroclor 1232 | -- | 0.50 | Direct contact, MTCA Method B | See footnote g | 0.53/0.017 |
| Aroclor 1242 | -- | 0.50 | Direct contact, MTCA Method B | See footnote g | See footnote g |

**Table A-1. Summary of 100-N Proposed Soil Cleanup Levels for Protection of Human Health and Soil Concentrations Protective of Groundwater and Surface Water Based on Soil Screening Levels and PRGs**

| COC | Hanford Site Background Concentration[a] | Proposed Direct Contact Human Health Cleanup Levels (≤4.6 m [15 ft] bgs) | | Proposed Groundwater and Surface Water Protection Cleanup Levels (Ground Surface to Water Table)[e,f] | |
|---|---|---|---|---|---|
| | | PRG | Exposure Driver | No Irrigation | Irrigation |
| Aroclor 1248 | -- | 0.50 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Aroclor 1254 | -- | 0.50 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Aroclor 1260 | -- | 0.50 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Acenaphthene | -- | 4,800 | Direct contact, MTCA Method B | See footnote g | 914/612 |
| Acenaphthylene | -- | See footnote c | -- | See footnote g | See footnote i |
| Anthracene | -- | 24,000 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Benzo(a)anthracene | -- | 1.4 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Benzo(a)pyrene | -- | 0.14 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Benzo(b)fluoranthene | -- | 1.4 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Benzo(ghi)perylene | -- | See footnote c | -- | See footnote g | See footnote g |
| Benzo(k)fluoranthene | -- | 1.4 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Chrysene | -- | 14 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Dibenz[a,h]anthracene | -- | 1.4 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Fluoranthene | -- | 3,200 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Fluorene | -- | 3,200 | Direct contact, MTCA Method B | See footnote g | 1,233/2,119 |
| Indeno(1,2,3-cd)pyrene | -- | 1.4 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Naphthalene | -- | 1.4 | Inhalation, MTCA Method B | See footnote g | 25/757 |
| Phenanthrene | -- | See footnote c | -- | See footnote i | See footnote i |

**Table A-1. Summary of 100-N Proposed Soil Cleanup Levels for Protection of Human Health and Soil Concentrations Protective of Groundwater and Surface Water Based on Soil Screening Levels and PRGs**

| COC | Hanford Site Background Concentration[a] | Proposed Direct Contact Human Health Cleanup Levels (≤4.6 m [15 ft] bgs) | | Proposed Groundwater and Surface Water Protection Cleanup Levels (Ground Surface to Water Table)[e,f] | |
|---|---|---|---|---|---|
| | | PRG | Exposure Driver | No Irrigation | Irrigation |
| Pyrene | -- | 2,400 | Direct contact, MTCA Method B | See footnote g | See footnote g |
| Ethylbenzene | -- | 2.3 | Inhalation, MTCA Method B | 0.49/2.0 | 0.13/0.51 |
| Trichloroethene | -- | 0.17 | Inhalation, MTCA Method B | 0.027/0.14 | 0.0091/0.046 |
| TPH–diesel range | -- | 2,000[d] | WAC 173-340-900, Table 747-5 Method A | 2,000[d,i] | 2,000[d,i] |
| TPH–motor oil (high boiling) | -- | 2,000[d] | WAC 173-340-900, Table 747-5, Method A | 2,000[d,i] | 2,000[d,i] |

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 Data 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. Arsenic PRG is compared to the WAC 173-340-900, "Model Toxics Control Act—Cleanup," "Tables," Table 740-1, "Method A, Soil Cleanup Level for Unrestricted Land Use."

c. A direct contact PRG is not calculated because a toxicity value is not available for this analyte.

d. The PRG for TPH is a default level obtained from WAC 173-340-900, Table 747-5, "Residual Saturation Screening Levels for TPH."

e. PRGs are provided for the protection of groundwater and surface water based on site-specific data and specific parameters, including natural recharge rates (i.e., no irrigation) and a rural residential exposure scenario that includes irrigation. PRGs based on the irrigation scenario are proposed for use in the ROD. Both irrigation PRG and the non-irrigation PRG with an institutional control to restrict irrigation are protective of human health and the environment. In instances where verification sampling exceeds irrigated PRGs but achieves non-irrigated PRGs, the Tri-Parties may elect to apply institutional controls to ensure protectiveness rather than continuing excavation.

f. Should site-specific data during remediation indicate that the PRG is not representative of site conditions, additional protectiveness evaluations may occur.

g. The SSL or PRG value for groundwater or surface water protection is considered nonrepresentative because there is no breakthrough of the analyte simulated within 1,000 years for the majority of the soil columns (breakthrough is defined as concentrations above 1E-04 µg/L, or 1E-04 pCi/L).

h. The 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, exposure point concentrations are compared to the total uranium SSL. When only isotopic uranium results (pCi/g) are available, uranium is addressed by converting the isotopic uranium from activity-based (pCi/g) to mass-based (µg/kg) concentrations and summing to provide a mass-based total uranium exposure point concentration (identified as Total_U_Isotopes), as described in ECF-100NR1-12-0041, *Computation of Exposure Point Concentrations for the 100-NR-1 Source Operable Unit*. The Total_U_Isotopes exposure point concentration is then compared to the total uranium SSL.

i. A groundwater 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.

j. Hexavalent chromium proposed cleanup level is set to the interim RAG of 2.0 mg/kg (DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*).

**Table A-1. Summary of 100-N Proposed Soil Cleanup Levels for Protection of Human Health and Soil Concentrations Protective of Groundwater and Surface Water Based on Soil Screening Levels and PRGs**

| COC | Hanford Site Background Concentration[a] | Proposed Direct Contact Human Health Cleanup Levels (≤4.6 m [15 ft] bgs) | | Proposed Groundwater and Surface Water Protection Cleanup Levels (Ground Surface to Water Table)[e,f] | |
|---|---|---|---|---|---|
| | | PRG | Exposure Driver | No Irrigation | Irrigation |

k. The PRG for TPH is a default screening level obtained from WAC 173-340-900, Table 747-5, "Residual Saturation Screening Levels for TPH."

bgs = below ground surface
CAS = Chemical Abstract Services
COC = contaminant of concern
Cr(VI) = hexavalent chromium
MCL = maximum contaminant level
MTCA = "Model Toxics Control Act—Cleanup" (WAC 173-340)
PRG = preliminary remediation goal
RAG = remedial action goal
SSL = soil screening level
TPH = total petroleum hydrocarbon

**Table A-2. Proposed Cleanup Levels for 100-NR-2 Groundwater and Surface Water Based on PRGs**

| COC | Units | 90th Percentile EPC | DWS | BCG | WAC 173-340 | | WAC 173-340-900 | AWQC | | WAC 173-201A | 40 CFR 131 Water Quality Standard | | Proposed Groundwater Cleanup Level[a] | Proposed Surface Water Cleanup Level[a] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Freshwater | | | | | | |
| | | | | | Noncarcinogens at HQ = 1 | Carcinogens at 1 × 10-5 Risk Level | | CMC (acute) | CCC (chronic) | CCC (chronic) | CMC (acute) | CCC (chronic) | | |
| Strontium-90 | pCi/L | 1,650 | 8 | 278 | -- | -- | -- | -- | -- | -- | -- | -- | 8 | 278[c] |
| Chromium | µg/L | 80 | 100 | -- | 24,000 | -- | -- | 570 | 65 | 156 | 550 | 180 | 100 | 65[c] |
| Cr(VI) | µg/L | 81 | See footnote b | -- | 48 | -- | -- | 16 | 11 | 10 | 15 | 10 | 10[c] | 10[c] |
| Ethylbenzene | µg/L | 9.4 | 700 | -- | 4 | 40 | -- | -- | -- | -- | -- | -- | 4 | -- |
| TPH-diesel | µg/L | 420,000 | See footnote b | -- | -- | -- | 500 | -- | -- | -- | -- | -- | 500 | -- |
| Nitrate[d] | µg/L | 71,900 | 45,000 | -- | 113,600 | -- | -- | -- | -- | -- | -- | -- | 45,000 | -- |

Sources: 40 CFR 131, "Water Quality Standards"; WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington"; and WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Groundwater Cleanup Standards"; WAC 173-340-900, "Model Toxics Control Act—Cleanup," "Tables."

Note: DWS from 40 CFR 141, "National Primary Drinking Water Regulations."

a. For chemicals, the final cleanup levels achieved at the conclusion of the remedial action will correspond to a cumulative excess lifetime cancer risk less than $1 \times 10^{-5}$ and hazard index of less than one.

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

c. The aquatic protection standard applies to groundwater where it discharges to the surface water.

d. Nitrate may be expressed as nitrate-nitrogen ($NO_3$-N) or as nitrate ($NO_3$). The DWSs for $NO_3$-N and $NO_3$ are 10,000 and 45,000 µg/L, respectively.

AWQC = ambient water quality criteria
BCG = background concentration guideline
CCC = criterion continuous concentration
CMC = critical maximum concentration
COC = contaminant of concern
Cr(VI) = hexavalent chromium
DWS = drinking water standard
EPC = exposure point concentration
***HQ*** = ***hazard quotient***
TPH = total petroleum hydrocarbon

1

## Acronym List

| | |
|---|---|
| ARAR | applicable or relevant and appropriate requirement |
| AWQC | ambient water quality criteria |
| BCG | background concentration guide |
| bgs | below ground surface |
| CAS | Chemical Abstract Services |
| CCC | criterion continuous concentration |
| CERCLA | *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* |
| CMC | critical maximum concentration |
| CFR | *Code of Federal Regulations* |
| COC | contaminant of concern |
| COPC | contaminant of potential concern |
| CRC | Columbia River Component |
| Cr(VI) | hexavalent chromium |
| CTUIR | Confederated Tribes of the Umatilla Indian Reservation |
| DOE | U.S. Department of Energy |
| DOE-RL | U.S. Department of Energy, Richland Operations Office |
| DWS | drinking water standard |
| Ecology | Washington State Department of Ecology |
| ELCR | excess lifetime cancer risk |
| EPA | U.S. Environmental Protection Agency |
| EPC | exposure point concentration |
| ERA | ecological risk assessment |
| ERDF | Environmental Restoration Disposal Facility |
| FS | feasibility study |
| HGP | Hanford Generating Plant |
| HHE | human health and the environment |
| HHRA | human health risk assessment |
| HI | hazard index |
| HRNM | Hanford Reach National Monument |

| | |
|---|---|
| HQ | hazard quotient |
| IC | institutional control |
| ISS | interim safe storage |
| ITRD | Innovative Treatment and Remediation Demonstration |
| LWDF | liquid waste disposal facility |
| MCL | maximum contaminant level |
| MNA | monitored natural attenuation |
| MTCA | *Model Toxics Control Act—Cleanup* (WAC 173-340) |
| NCP | National Contingency Plan ("National Oil and Hazardous Substances Pollution Contingency Plan" [40 CFR 300]) |
| NEPA | *National Environmental Policy Act of 1969* |
| NPL | National Priorities List (40 CFR 300, Appendix B) |
| O&M | operations and maintenance |
| OU | operable unit |
| PRB | permeable reactive barrier |
| PRG | preliminary remediation goal |
| PRZ | periodically rewetted zone |
| RAG | remedial action goal |
| RAO | remedial action objective |
| RCBRA | River Corridor Baseline Risk Assessment |
| RCRA | *Resource Conservation and Recovery Act of 1976* |
| RDR/RAWP | remedial design report/remedial action work plan |
| RI | remedial investigation |
| ROD | Record of Decision |
| RTD | removal, treatment, and disposal |
| SPOR | shallow petroleum-only releases |
| SSL | soil screening level |
| TAG | Technical Advisory Group |
| TI | technical impracticability |
| TPH | total petroleum hydrocarbon |

| | |
|---|---|
| TPH-D | total petroleum hydrocarbon-diesel |
| Tri-Party Agreement | *Hanford Federal Facility Agreement and Consent Order* |
| TSD | treatment, storage, and disposal |
| UPR | unplanned release |
| USFWS | U.S. Fish and Wildlife Service |
| WAC | *Washington Administrative Code* |

## Glossary

**Administrative Record:** The collection of information, including reports, public comments, and correspondence, that contains the documents that form the basis for selection of a response action. A list of locations where the Administrative Record is available appears in the "Community Participation" section of this Proposed Plan.

**Ambient water quality criteria (AWQC):** As defined by EPA, the suggested maximum allowable concentration of a chemical in surface water for the protection of human health.

**Applicable or relevant and appropriate requirements (ARARs):** "Applicable requirements" mean those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site. Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable. "Relevant and appropriate requirements" mean that those cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate.

**Attenuation rate:** The rate at which concentrations of a contaminant decrease because of natural processes such as radioactive decay, oxidation/reduction, biodegradation, and/or sorption.

**Baseline risk assessment:** A study that identifies and evaluates the contaminants present at a site and assesses the current and potential threats to human health and the environment if no remedial action is taken at the site. This assessment is also used to determine the need, or basis, for action.

**CERCLA removal action:** The cleanup or removal of released hazardous substances from the environment. This includes such actions as may be necessary in the event of the threat of release of hazardous substances into the environment; such actions as may be necessary to monitor, assess, and evaluate the release or threat of release of hazardous substances; the disposal of removed material; or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release (NCP [40 CFR 300.5], "Definitions").

***Code of Federal Regulations* (CFR):** The CFR is the codification of the general and permanent rules published in the *Federal Register* by the executive departments and agencies of the federal government. It is divided into 50 titles that represent broad areas subject to federal regulation. Each volume of the CFR is updated once each calendar year and is issued on a quarterly basis.

***Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA):** Also known as the *Superfund Act*, CERCLA is the federal law that establishes a program to identify, evaluate, and remediate, as appropriate, sites where hazardous substances, pollutants, or contaminants have been released (e.g., leaked, spilled, or dumped) to the environment or where there is a substantial threat of such a release.

**Contaminant of concern (COC):** Radionuclides and chemicals that exceed risk threshold values in the baseline risk assessment.

**Contaminant of potential concern (COPC):** COPCs are hazardous substances that have been found, or are likely to be present, in waste sites or groundwater operable units that could potentially represent risks to human health and the environment. The effects are dependent upon the amount of the contaminant present, the toxicity of the contaminant, and how the contaminant is contacted. COPCs are evaluated to develop a list of contaminants that should be considered for remediation and to screen out contaminants that are unlikely to be a threat to human health or the environment.

**Debris:** Building or construction material that has been demolished.

**Drinking water standard (DWS):** The maximum allowable concentration of a chemical or radionuclide constituent in drinking water that is protective of human health. The DWSs, described in 40 CFR 141 ("National Primary Drinking Water Regulations"), are also known as maximum contaminant levels.

**Environmental Restoration Disposal Facility (ERDF):** Hanford's onsite state and federally approved disposal facility for most hazardous (radioactive and nonradioactive) waste and contaminated environmental media generated under a CERCLA response action.

**Excess lifetime cancer risk (ELCR):** Potential carcinogenic effects that are characterized by estimating the probability of cancer incidence in a population of individuals for a specific lifetime from projected intakes (and exposures) and chemical-specific dose-response data (i.e., slope factors).

**Exposure point concentration (EPC):** An EPC is a conservative estimate of the average chemical concentration in an exposure medium.

**Groundwater:** Water in a saturated zone or geologic stratum beneath the land surface or beneath a surface water body.

**Hazard index (HI):** The sum of hazard quotients for substances that affect the same target organ or organ system.

**Hazard quotient (HQ):** The ratio of the potential exposure to the substance and the level at which no adverse effects are expected.

**Hydraulic gradient:** The slope of the water table along a groundwater flow path.

**Institutional control (IC):** Nonengineered instruments such as administrative or legal measures to protect human health and the environment from exposure to contamination. ICs are maintained until requirements are met for safe, unrestricted land use.

**Limited field investigation:** The collection of limited additional site data that is sufficient to support a decision on conducting an ecological risk assessment or interim remedial measure.

**Maximum contaminant level (MCL):** The maximum concentration of a contaminant allowed in water delivered to public drinking water systems.

**Model Toxics Control Act (MTCA):** MTCA (RCW 70.105D, "Hazardous Waste Cleanup--Model Toxics Control Act") provides state standards that set cleanup regulations for protection of human health and the environment. The standards and requirements established to implement the MTCA are published in WAC 173-340.

**Monitored natural attenuation (MNA):** A decrease in the concentration of a contaminant due to natural processes such as radioactive decay, oxidation-reduction, biodegradation, and/or sorption. Monitoring is

conducted to determine if the attenuation is occurring as predicted or if additional cleanup activities are warranted.

***National Environmental Policy Act of 1969* (NEPA):** NEPA is a United States environmental law that requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions and reasonable alternatives to those actions. Federal agencies conducting CERCLA actions may rely on the CERCLA process for environmental reviews that are functionally equivalent and are not required to engage in a separate NEPA analysis such as preparation of environmental assessments and environmental impact statements (40 CFR 1500, "Purpose, Policy, and Mandate"; "National Environmental Policy Act Policy Statement" [O'Leary, 1994).

***National Oil and Hazardous Substances Pollution Contingency Plan* (NCP):** The first NCP was developed and published in 1968 to address potential spills in United States waters. Following the passage of Superfund legislation in 1980, the NCP was expanded to include the regulations covering releases of hazardous substances or pollutants or contaminants. In 1994, the NCP was revised to mirror the oil spill provisions of the *Oil Pollution Act of 1990.*

**National Priorities List (NPL):** The list, compiled by EPA pursuant to CERCLA Section 105 ("National Contingency Plan"), of uncontrolled hazardous substance releases in the United States that are priorities for long-term remedial evaluation and response.

**Nature and extent of contamination:** Characteristics of contamination at a site including concentrations and degree of migration in the environment.

**Operable unit (OU):** Logical groupings of facilities, waste sites, or environmental media (e.g., soil, groundwater, and surface water) for decision-making and management purposes. The primary criteria for placing a site into an OU include geographic proximity, similarity of waste characteristics and site type, and the possibility for economies of scale.

**Operations and maintenance (O&M):** Long-term remedial action operations, maintenance, and institutional controls.

**Picocurie (pCi):** A unit of radioactivity equivalent to $1.0\times10^{-12}$ curies or 0.037 disintegrations per second.

**Permeable reactive barrier (PRB):** Cost-effective technology for in situ groundwater remediation that allows contaminated groundwater to pass through it, thereby removing or reducing contamination via (1) sorption and precipitation, (2) chemical reaction, or (3) reactions involving biological mechanisms.

**Preferred alternative:** The remedial action proposed after an evaluation of a range of viable alternatives. The preferred alternative must meet ARARs and be protective of human health and the environment.

**Preliminary remediation goal (PRG):** An ARAR-specified or risk-based concentration for a contaminant that is protective of human health and the environment for a specified exposure pathway. PRGs are established during the feasibility study, based on scientific information, and are used as a target for remedial cleanup levels. Alternatives are developed and evaluated based on how well they meet PRGs. Final cleanup levels are set in the ROD and are used during the remediation of a site.

**Proposed Plan:** A plan that briefly describes the remedial alternatives analyzed, proposes a preferred remedial action alternative, and summarizes the information relied upon to select the preferred alternative. The plan provides the public with an opportunity to comment on the preferred alternative, as well as the other alternatives under consideration.

**Pump-and-treat:** A technology that extracts contaminated groundwater and treats contaminants with an assortment of specific technologies to meet cleanup levels.

**Radionuclide:** An unstable atom that emits excess energy (decays) in the form of radioactivity (rays or particles). Depending on the type and amount of decay, prolonged exposure may be harmful.

**Record of Decision (ROD):** A ROD is a legally binding public document that identifies the selected remedy for an operable unit and the rationale behind the selection.

**Remedial action:** Actions consistent with a permanent remedy taken instead of, or in addition to, removal action in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so they do not migrate to cause substantial danger to present or future public health or welfare or the environment.

**Remedial action objective (RAO):** An RAO is a medium-specific (e.g., soil) or operable unit-specific goal for protecting human health and the environment that specifies the contaminant(s) of concern, the exposure route(s), and the receptor(s).

**Remedial alternative:** General or specific actions that are evaluated to determine the extent to which they can eliminate or minimize threats posed to human health and the environment because of a release or threatened release of a hazardous substance into the environment, comply with environmental laws and regulations, and meet other selection criteria.

**Remedial design report/remedial action work plan (RDR/RAWP):** The RDR/RAWP is the work plan produced based on the specifications described in the ROD. It is the phase at a Superfund site cleanup where the technical specifications for cleanup remedies and technologies are designed.

**Remedial investigation (RI)/feasibility study (FS):** The RI/FS process, as outlined in this Proposed Plan, represents the methodology that the Superfund program has established for characterizing the nature and extent of releases or threats of releases of hazardous substances, of risks posed thereby, and for evaluating potential remedial alternatives.

**Removal, treatment, and disposal (RTD):** A cleanup method where soil and debris are excavated in such a way that no contaminants above the approved remedial action goals or concentration for direct exposure and groundwater protection remain at the site. Excavated material is treated (as necessary) and sent to an onsite or offsite engineered facility for disposal.

**Responsiveness summary:** The responsiveness summary is made available with the ROD and contains the public comments received on the proposed plan and the Tri-Parties' responses.

**Technical impracticability (TI) waiver:** A waiver of ARARs allowed by CERCLA when the restoration of groundwater to its beneficial use within a reasonable time frame is not practicable. A TI evaluation that conforms to EPA TI waiver guidance must be prepared to justify the waiver.

**Tri-Parties:** Three agencies composed of the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the Washington State Department of Ecology (Ecology).

**Tri-Party Agreement:** DOE, EPA, and Ecology signed the *Hanford Federal Facility Agreement and Consent Order*, or Tri-Party Agreement, on May 15, 1989. The Tri-Party Agreement, as updated and modified through formal change control, is a comprehensive cleanup and compliance agreement for achieving compliance with the CERCLA remedial action provisions and with RCRA treatment, storage, and disposal unit regulations and corrective action provisions. More specifically, the Tri-Party Agreement (1) defines and prioritizes CERCLA

and RCRA cleanup commitments, (2) establishes responsibilities, (3) provides a basis for budgeting, and (4) reflects a concerted goal of achieving full regulatory compliance and remediation, with enforceable milestones.

**Vadose zone:** The vadose zone is the unsaturated soil column between the land surface and the groundwater.

**Waste sites:** Waste sites are contaminated or potentially contaminated sites from past operations. Contamination may be contained in environmental media (e.g., soil, groundwater) or in manmade structures or solid waste (e.g., debris).

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