APPENDIX D.3

100-N GROUNDWATER
(RC-GW-2, RIVER CORRIDOR)
EVALUATION UNIT SUMMARY TEMPLATE

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PART I. EXECUTIVE SUMMARY

EU LOCATION

100 Industrial Area

RELATED EUS

Other Groundwater Projects

PRIMARY CONTAMINANTS, CONTAMINATED MEDIA AND WASTES

The primary contaminants of the 100-NR Interest Area (IA), which is related to the 100-NR-2 Operable Unit (OU), includes strontium-90 (Sr-90), nitrate (NO3), diesel as total petroleum hydrocarbon (TPH-diesel), hexavalent chromium (Cr-VI), and tritium (H-3). Contaminated media includes a vadose zone comprised of sand and gravel of the Hanford formation portion of the Ringold Formation unit E. An unconfined aquifer also possesses contaminants within the sand and gravel from the Ringold and Hanford formations. This unconfined aquifer is highly transmissive due to the open framework gravelly sediment, resulting in high flow velocities. The Ringold upper mud unit (RUM) forms the base of the unconfined aquifer. (DOE/RL-2016-09, Rev. 0)

BRIEF NARRATIVE DESCRIPTION:

The 100-NR groundwater area is adjacent to the Columbia River and encompasses the 100-N Area. Groundwater contamination in 100-NR is primarily associated with wastes produced by the N reactor (a dual-purpose reactor that produced plutonium for defense and steam for electrical power generation) and associated processes. Strontium-90 and TPH-diesel are being remediated under a Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) interim action (EPA/ROD/R10-99/112 as amended). Under this interim ROD, a permeable reactive barrier is in place along the shoreline to reduce the amount of strontium-90 migrating from groundwater into the Columbia River. A draft Remedial Investigation (RI)/Feasibility Study (FS) report was submitted by U.S. DOE to the lead regulatory agency in 2013 for review. The draft RI/FS has not yet been finalized because the comment resolution process continued during 2015. The RI/FS report will be used to support future cleanup decisions specified in a Proposed Plan and ROD. (DOE/RL-2016-09, Rev. 0)

SUMMARY TABLES OF RISKS AND POTENTIAL IMPACTS TO RECEPTORS

Table D.3-1 provides a summary of nuclear and industrial safety related risks to humans and impacts to important physical Hanford site resources.

Human Health

A Facility Worker is deemed to be an individual located anywhere within the physical boundaries of the 100-NR area; a Co-located Person (CP) is an individual located 100 meters from the physical boundaries of the BC Cribs and Trenches areas; and Public is an individual located at the closest point on the Hanford Site boundary not subject to DOE access control. The nuclear-related risks to humans are based on unmitigated (unprotected or controlled conditions) dose exposures expressed in a range of from Not Discernible (ND) to High. The estimated mitigated exposure that takes engineered and administrative controls and protections into consideration, is shown in parentheses.

Groundwater and Columbia River

Direct impacts to groundwater resources and the Columbia River have been rated based on available information for the current status and estimates for future time periods. These impacts are also expressed in a range of from Not Discernible (ND) to Very High.

Ecological Resources

The risk ratings are based on the degree of physical disruption (and potential additional exposure to contaminants) in the current status and as a potential result of remediation options.

Cultural Resources[1]

No risk ratings are provided for Cultural Resources. The Table identifies the three overlapping Cultural Resource landscapes that have been evaluated: Native American (approximately 10,000 years ago to the present); Pre-Hanford Era (1805 to 1943) and Manhattan/Cold War Era (1943 to 1990); and provides initial information on whether an impact (both direct and indirect) is KNOWN (presence of cultural resources established), UNKNOWN (uncertainty about presence of cultural resources), or NONE (no cultural resources present) based on written or oral documentation gathered on the entire EU and buffer area. Direct impacts include but are not limited to physical destruction (all or part) or alteration such as diminished integrity. Indirect impacts include but are not limited to the introduction of visual, atmospheric, or audible elements that diminish the cultural resource's significant historic features. Impacts to Cultural Resources as a result of proposed future cleanup activities will be evaluated in depth under Section 106 of the National Historic Preservation Act (16 USC 470, et. seq.) during the planning for remedial action.

[1] References throughout this Evaluation Unit Summary Template supporting analyses related to Ecological Resources and/or Cultural Resources may be found in Appendices J and K, respectively. Refer to the specific EU when searching for the reference.

Table D.3-1 Risk Rating Summary (for Human Health, unmitigated nuclear safety basis indicated, mitigated basis indicated in parentheses (e.g., "Very High" (Low)).

Population or Resource		Evaluation Time Period	
		Active Cleanup (to 2064)	
		Current Condition:	**From Cleanup Actions:**
Human Health	Facility Worker	Low (Low)	Low (Low)
	Co-located Person	Low (Low)	Low (Low)
	Public	Not Discernible (Not Discernible)	Not Discernible (Not Discernible)
Environmental	Groundwater (No Vadose Zone)	A&B: Medium (Sr-90) All: Medium (Sr-90, NO3)	A&B: Medium (Sr-90)[(b)] All: Medium (Sr-90, NO3)[(b)]
	Columbia River (No Vadose Zone)	A&B: Medium (Sr-90, benthic, riparian) All: Medium (Sr-90, benthic, riparian)	A&B: Medium (Sr-90, benthic, riparian) [(b)] All: Medium (Sr-90, benthic, riparian) [(b)]
	Ecological Resources[(a)]	Low to Moderate	Very High
Social	Cultural Resources[(a)]	**Native American:** Direct: Known Indirect: Known **Historic Pre-Hanford:** Direct: Known Indirect: Known **Manhattan/Cold War:** Direct: Known Indirect: Known	**Native American:** Direct: Known Indirect: Known **Historic Pre-Hanford:** Direct: Known Indirect: Known **Manhattan/Cold War:** Direct: Known Indirect: Known

a. For both Ecological and Cultural Resources see Appendices J and K, respectively, for a complete description of Ecological Field Assessments and literature review for Cultural Resources. Ecological ratings are described in Table 4-11 of the Final Report.

b. The final remedy has not been selected and thus the times needed to reach cleanup levels are not known. After cleanup levels are achieved, then these ratings would be *Not Discernible*.

SUPPORT FOR RISK AND IMPACT RATINGS FOR EACH POPULATION OR RESOURCE

Human Health

Current

Human health risk from exposure to groundwater was evaluated through risk calculations and comparison to federal and state drinking water or cleanup standards. The approach 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. Groundwater concentrations were also compared to existing federal and state drinking water or cleanup standards. Current interim remediation activities for the 100-NR groundwater IA involve (i) Sampling and

monitoring for strontium-90, nitrate, total petroleum hydrocarbon-diesel (TPH-D), hexavalent chromium (CR-VI), total chromium (Cr), and tritium; (ii) Pump and treat for removal of strontium-90 contaminated groundwater; (iii) Use of an apatite barrier to retard and/or cease the migration of strontium-90 contaminated groundwater into the Columbia River; (iv) Remove/dispose for radioactive, inorganic, burn pit, and surface solid groups to a depth of 4.6 m; (v) Remove/ex-situ bioremediation/dispose for TPH-D with near-surface contamination to a depth of 4.6 m or the bottom of the engineering structure, whichever is deeper; (vi) In-situ bioremediation for TPH-D with deep contamination below 4.6m; and (vii) Institutional controls (ICs). As such, impacts from potential remediation approaches will vary depending on the activity (U.S. DOE, 2000).

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

The range of cleanup activities for the 100-NR groundwater IA is significant. As such, impacts from potential remediation approaches will vary depending on the activity: RTD, monitoring/sampling, pump and treat, in-situ bioremediation, and IC. The threat to the Facility Worker is thus described as low to medium risk (Low for monitoring, sampling, and IC; Medium for RTD, in-situ bioremediation, and appetite barrier).

Unmitigated Risk: Facility Worker – Low to Medium; CP – Low to Medium; Public – Low to ND.

Mitigation: The Department of Energy and contractor site-specific safety and health planning that includes work control, fire protection, training, occupational safety and industrial hygiene, emergency preparedness and response, and management and organization—which are fully integrated with nuclear safety and radiological protection—have proven to be effective in reducing industrial accidents at the Hanford site to well below that in private industry. Further, the safety and health program must effectively ensure that ongoing task-specific hazard analyses are conducted so that the selection of appropriate PPE can be made and modified as conditions warrant. Task-specific hazard analyses must lead to the development of written work planning documents and standard operating procedures (SOPs) [DOE uses the term work planning documents in addition to procedures] that specify the controls necessary to safely perform each task, to include continuous employee exposure monitoring. Last, ICs will be used to control access to residual contaminants in soil and groundwater as long as they exceed the cleanup levels (CULs).

Mitigated Risk: Facility Worker – Low; CP – Low; Public – ND.

Environmental – Groundwater

Evaluation of the threats to groundwater as a protected resource from saturated zone contamination utilized the groundwater evaluation framework procedure outlined in Chapter 6 of the Methodology Report (CRESP 2015). The results of this analysis are described briefly below and in additional detail in Part VI and Table D.3-3.

Current

The groundwater plumes (strontium-90, nitrate, TPH-D, CR-VI, total chromium (Cr), and tritium) associated with 100-NR are described in Part V. As shown in Table D.3-3 in Part VI, the saturated zone (SZ) groundwater threat metric (GTM) values for the Group A and B primary contaminants translate to Low to Medium ratings for the RC-GW-2 EU. Thus the overall rating for groundwater impacts from current plumes is Medium.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

Selected interim remediation activities involve a number of remedial approaches, each with ICs. As such, impacts from the selected remediation approach will vary little from the current conditions risk assessment during active remediation until cleanup levels are reduced below WQSs. Once below WQS, the overall rating for groundwater impacts would be assessed *Not Discernible (ND)*.

Environmental – Columbia River

Current

Plumes associated with the RC-GW-2 EU currently intersect the Columbia River, which translate to *Not Discernible* to *Medium* ratings for all evaluation periods.

The rating threat evaluation to the benthic ecology for strontium-90, a Group B PC, is *Medium* due to the high maximum groundwater concentration to BCG ratio (48.7) and relatively moderate length of impacted shoreline (670 m). Benthic threat ratings for Cr-VI, a Group B PC, is *Low* due to the moderate maximum groundwater concentration to BCG ratio (12) and current lack of impacted shoreline. The rating *Ratio* for nitrate, a Group C PC, is 9.8, and an impacted shoreline of 80 m, garnering a rating of *Low*.

The rating threat evaluation to the riparian ecology for strontium-90 is *Medium* due to the high Ratio, but slightly elevated riparian impact area of 0.59 hectares. The rating *Ratio* for Cr-VI is 12, and a riparian impact area of none hectares, garnering a rating of *Low*. The rating *Ratio* for nitrate, a Group C PC, is 9.8, and a riparian impact area of 0.081 hectares, garnering a rating of *Low*.

The large dilution effect of the Columbia River results in a rating of *Not Discernible* for the free-flowing ecology for all evaluation periods.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

Use of (i) sampling and monitoring; (ii) pump and treat (iii) Use of an apatite barrier for strontium-90; (iv) remove/dispose for radioactive, inorganic, burn pit, and surface solid groups to a depth of 4.6 m; (v) remove/ex-situ bioremediation/dispose for TPH-D; (vi) in-situ bioremediation for TPH-D with deep contamination; and (vii) institutional controls (ICs) suggests that the selected remediation approaches will vary significantly, but that the current conditions risk assessment for groundwater during active remediation is likely to remain unchanged from current conditions until cleanup levels are reduced below WQSs (U.S. DOE, 2000). Once below WQS, the overall rating for groundwater impacts will be assessed *Not Discernible (ND)*. Further, because the selected remediation activities may result in hazardous substances remaining on-site above levels that allow for unlimited use, a review will be conducted to ensure that the remedies continue to provide adequate protection of human health and the environment within five years after the commencement of the interim remedial actions (U.S. DOE 2000).

Ecological Resources

Current

There are areas where groundwater plumes intersect the riparian vegetation. Potential for contaminant uptake by terrestrial vegetation. Sensitive animals and bird species use region and may be at risk.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

Remediation activities in the shoreline will need to be monitored to evaluate resources and seasonal use of shoreline.

Cultural Resources

Current

Entire shoreline area is extremely culturally sensitive based on prehistoric, ethno-historic, and historic land use in the area. Upland areas where characterization and monitoring activities take place may be culturally sensitive regions as well. Traditional cultural places are known to be located in the vicinity as well as National Register eligible archaeological sites associated with all 3 landscapes.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

Entire shoreline area is extremely culturally sensitive based on prehistoric, ethno-historic, and historic land use in the area. Upland areas where characterization and monitoring activities take place may be culturally sensitive regions as well. Traditional cultural places are known to be located in the vicinity as well as National Register eligible archaeological sites associated with all 3 landscapes.

Considerations for timing of the cleanup actions

Near-Term, Post-Cleanup Risks and Potential Impacts

Permanent direct and indirect effects are possible due to the high sensitivity of area.

PART II. ADMINISTRATIVE INFORMATION

OU AND/OR TSDF DESIGNATION(S)

100-NR-2

COMMON NAME(S) FOR EU

RC-GW-2 in 100-NR

KEY WORDS

100 Area, RC-GW-2, 100-NR-2, Soils, Sediments, River Corridor

REGULATORY STATUS

Regulatory basis

Contaminants strontium-90 and TPH-diesel are being remediated under a CERCLA interim action (EPA/ROD/R10-99/112 as amended). Groundwater is being monitored at four waste sites to meet requirements of RCRA and WAC-173-303.

Applicable regulatory documentation

- Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) interim action (EPA/ROD/R10-99/112 as amended).
- Resource Conservation and Recovery Act of 1976 (RCRA).
- Chapter WAC-173-303 Dangerous Waste Regulations, State of Washington Department of Ecology, 30 June 2009.

EU Designation: RC-GW-2 (100-NR-2)

Applicable Consent Decree or TPA milestones:

There is one TPA milestone for the 100-NR-2 Groundwater OU: M-016-110-T03. DOE shall take actions necessary to contain the Strontium-90 groundwater plume at the 100-NR-2 Operable Unit such that the default ambient water quality standard (8 pCi/L) for strontium-90 is achieved in the hyporheic zone and river water column. The original target data of 12/31/2016 was deleted in 2016 for this milestone.

RISK REVIEW EVALUATION INFORMATION

Completed: Revised 20 February 2017

Evaluated by: E. LeBoeuf, K. G. Brown, H. Turner

Ratings/Impacts Reviewed by: D. Kosson, M. Gochfeld, J. Salisbury, A. Bunn

PART III. SUMMARY DESCRIPTION

CURRENT LAND USE

DOE Hanford industrial site area.

DESIGNATED FUTURE LAND USE

The Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS) (CLUP ROD) identifies the 100-NR-2 OU, which is related to the 100-NR IA, within the geographic area of the Columbia River Corridor. The remediation and restoration efforts in the Columbia River Corridor are expected to return the lands to undeveloped, natural conditions over the next 75 years, although restrictions on certain activities may continue to be required to prevent the mobilization of contaminants, the most likely example of which is the restriction of activities that discharge water to the soil or involve excavating below 4.6 m. (U.S. DOE 2003)

PRIMARY EU SOURCE COMPONENTS

Legacy Source Sites

Not Applicable.

High-Level Waste Tanks and Ancillary Equipment

Not Applicable.

Groundwater Plumes

The 100-N Area is located adjacent to the Columbia River. The contaminants of concern include strontium-90, nitrate, TPH-D, Cr-VI, chromium (total), and tritium. Specific groundwater plume details are extracted from the Hanford Site Groundwater Monitoring Report for 2015 (DOE/RL-2016-09-32, Rev. 0).

- The primary source of the strontium-90 contamination in 100-NR was liquid waste disposal to the 116-N-1 and 116-N-3 waste sites. The size and shape of the strontium-90 plume changes very little from year to year, except near the apatite permeable reactive barrier. The plume extends from beneath the 116-N-1 and 116-N-3 waste sites to the Columbia River at concentrations exceeding the drinking water standard (DWS) (8 pCi/L). The highest concentration portion of the strontium-90 groundwater plume (i.e., the area with concentrations exceeding 800 pCi/L) primarily underlies the 116-N-1 Trench and the 116-N-3 Crib. The highest concentration is found beneath, and inferred downgradient of, 116-N-1. The lateral distribution of the groundwater plume with concentrations between 8 and 80 pCi/L is found peripheral to the highest concentration in a distribution consistent with historical radial flow away from the two trenches and elongated toward the river.
    - Maximum concentrations: 13,600 pCi/L versus a Cleanup Level of 8 pCi/L.
    - Areal extent of the plume: 0.64 km^2.
    - Shoreline impact: 670 m.
    - Riparian area: 0.59 hectares.
- Tritium concentrations were elevated in 2015 at an aquifer tube cluster. The increasing tritium concentrations did not fluctuate with river stage, suggesting that a pulse of tritium was moving through this area. Tritium sources are likely the same as discussed for strontium-90. The increases in concentration are likely a result of the recent deep excavation and the addition of

dust suppression water at waste sites between the reactor and the river. Three new wells are planned in 2016 to evaluate the source of this contamination. Tritium concentrations exceeded the DWS (20,000 pCi/L) in well 199-N-186 in 2015 (the maximum value was 20,800 pCi/L) and have been detected above the DWS since the well was installed in 2011. The well was drilled through the 116-N-1 Crib in 2011, and concentrations have declined since that time. The 116-N-1 waste site was a source of tritium contamination in 100-NR groundwater. This was the only monitoring well in 100-NR with tritium concentrations above the DWS in 2015.

- Maximum concentrations: 876,000 pCi/L versus a Cleanup Level of 20,000 pCi/L.
- Areal extent of the plume: Not calculated.
- Shoreline impact: Not calculated.
- Riparian area: 0.056 hectares.

- Nitrate exceeds 45 mg/L in groundwater beneath the 116-N-1 and 116-N-3 waste sites and the 100-N Reactor area to the southwest. The highest concentration detected in 2015 was 308 mg/L in well 199-N-67 downgradient of the 116-N-1 crib. The 116-N-1 and 116-N-3 waste sites are implicated as the primary source of nitrate based on the persistent groundwater plume beneath them. Nitrate concentrations were relatively low during disposal operations at the 116-N-1 and 116-N-3 sites. The highest nitrate concentrations were detected following remediation activities at these two sites from 2000 to 2006, which included excavation, application of dust suppression water and soil fixatives, and backfill. Increases in nitrate concentrations in 2015 may be due to delayed drainage from the deep vadose zone caused by dust suppression during waste site remediation several years ago.
  - Maximum concentrations: 308 mg/L versus a Cleanup Level of 45 mg/L.
  - Areal extent of the plume: 0.55 km^2.
  - Shoreline impact: 80 m.
  - Riparian area: 0.081 hectares.
- The primary source of the TPH-diesel groundwater contamination is a 1966 diesel fuel spill. A small, relatively narrow groundwater plume extends downgradient from the spill location to the river. The highest groundwater concentration in 2015 was 6,400 µg/L, (in well 199-N-346), a substantial decrease from 18,000 µg/L in this well in 2014. The overall plume reduction in concentration in 2012 and 2015 is attributed primarily to the bioventing pilot test conducted by Washington Closure Hanford in 2010 and 2011 for remediation of diesel in the deep vadose zone at UPR-100-N-17. Some natural biodegradation of diesel occurs in groundwater, as shown by the anomalously low nitrate groundwater concentrations in this area. In 2015, a maximum concentration of 800 µg/L was detected in aquifer tube N116mArray-0A, a decrease from 2,200 µg/L in 2014.
  - Maximum concentrations: 6.4 mg/L versus a Cleanup Level of 0.5 mg/L.
  - Areal extent of the plume: 0.02 km^2.
  - Shoreline impact: 55 m.
  - Riparian area: 0.04 hectares.
- Sodium dichromate was used in N Reactor operations only from 1964 to 1972, and in lesser amounts than in the other 100 Area reactors because of the design of the N Reactor cooling system and the use of corrosion-resistant metals in the fuel and facility. Although chromium was present in the effluent discharged to the 116-N-1 waste site, it was never detected in samples of the effluent. Given the mobility and nonsorbing nature of chromium in solution, the high continuous discharge rates and high temperatures while chromium was being delivered to the 116-N-1 waste site, and the fact that liquid discharges to 116-N-1 continued for another 10 years after use of sodium dichromate had ceased, the mobile portion of chromium was

thoroughly flushed from the vadose zone and into the unconfined aquifer. Because a groundwater mound was present, the diluted effluent spread radially, with some portion reaching the Columbia River by the end of the N Reactor operational period. Only hexavalent chromium values are provided for 2015.

- Maximum concentrations:
  - Cr-VI: 120 µg/L versus a Cleanup Level of 10 µg/L.
- Areal extent of the plume:
  - Cr-VI: 0.49 km^2.
- Shoreline impact:
  - Cr-VI: none.
- Riparian area:
  - Cr-VI: none

Operating Facilities

Not Applicable

LOCATION AND LAYOUT MAPS

A series of maps are used to illustrate the location of the components within the RC-GW-2 EU relative to the Hanford Site. Figure D.3-1 shows the relationship among the various Evaluation Units studied in the Interim Report and the Hanford Site. Figure D.3-2 illustrates the extent of groundwater contamination in the River Corridor. Figure D.3-3 shows a detailed view of the groundwater plumes in and near the 100-NR Interest Area (IA) and RC-GW-1 EU.

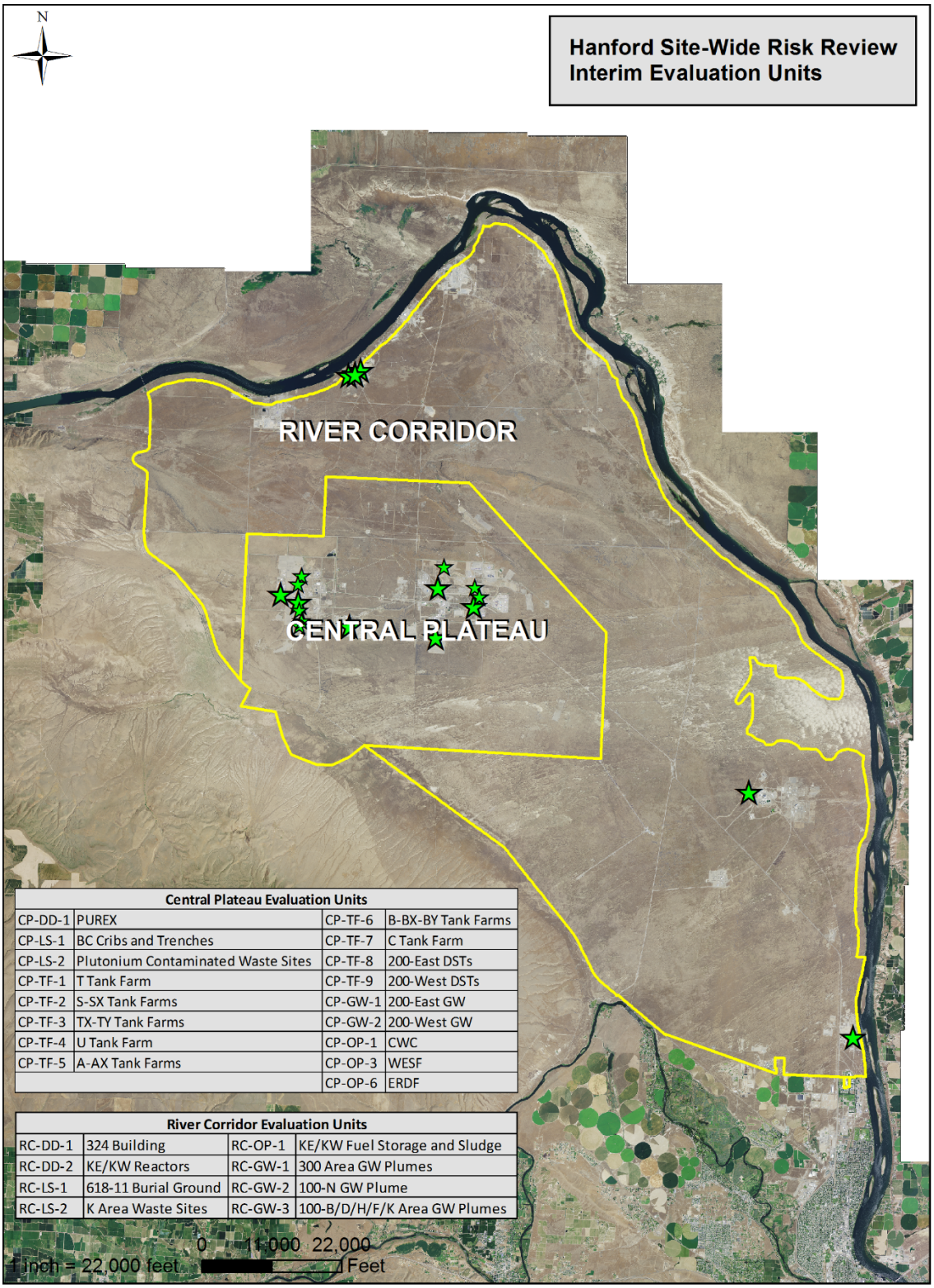

Figure D.3-1. Location of the Evaluation Units in Relation to the Hanford Site.

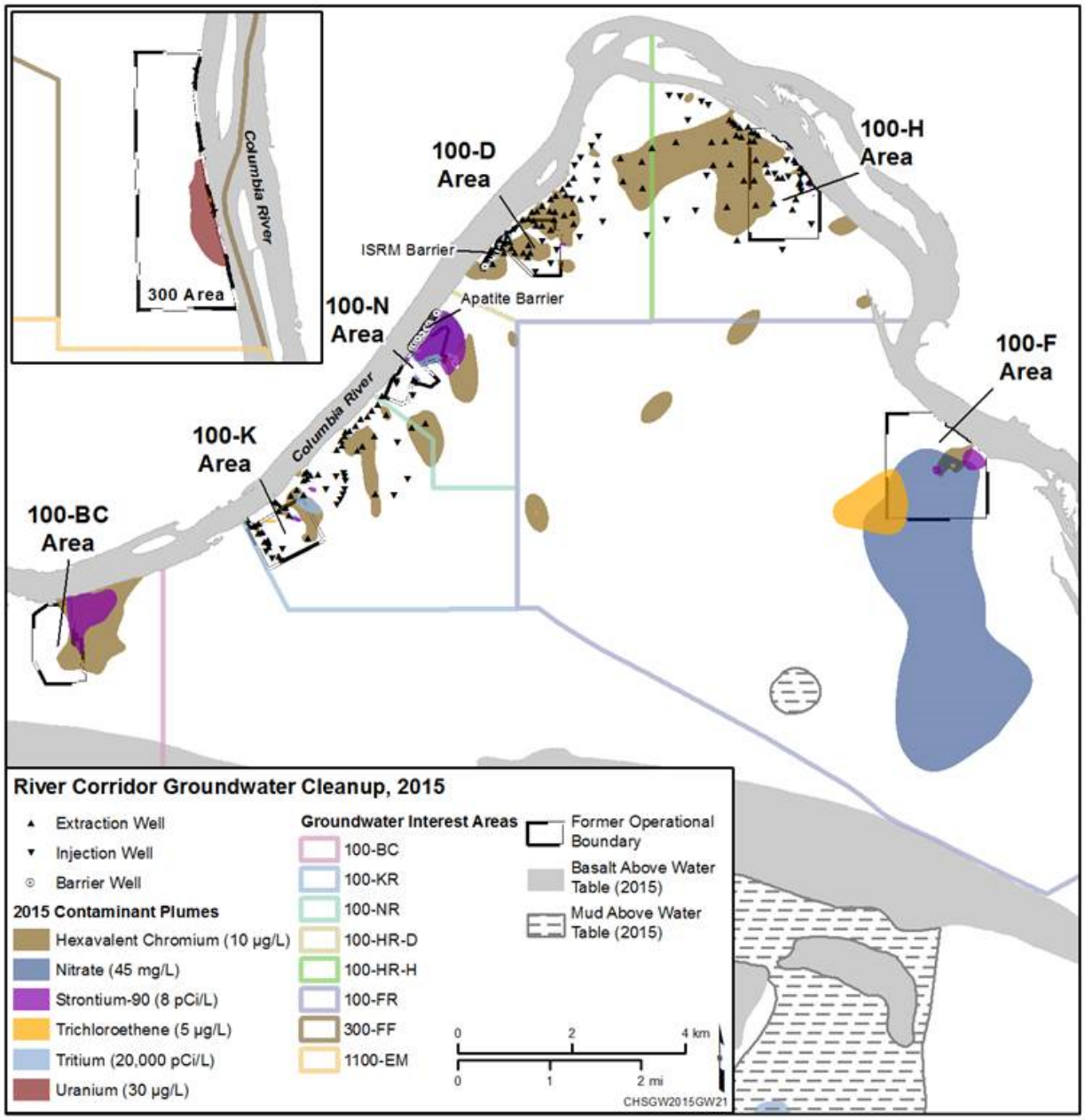

Figure D.3-2. Groundwater Contamination in the River Corridor in 2015 (DOE/RL-2016-09, Rev. 0)

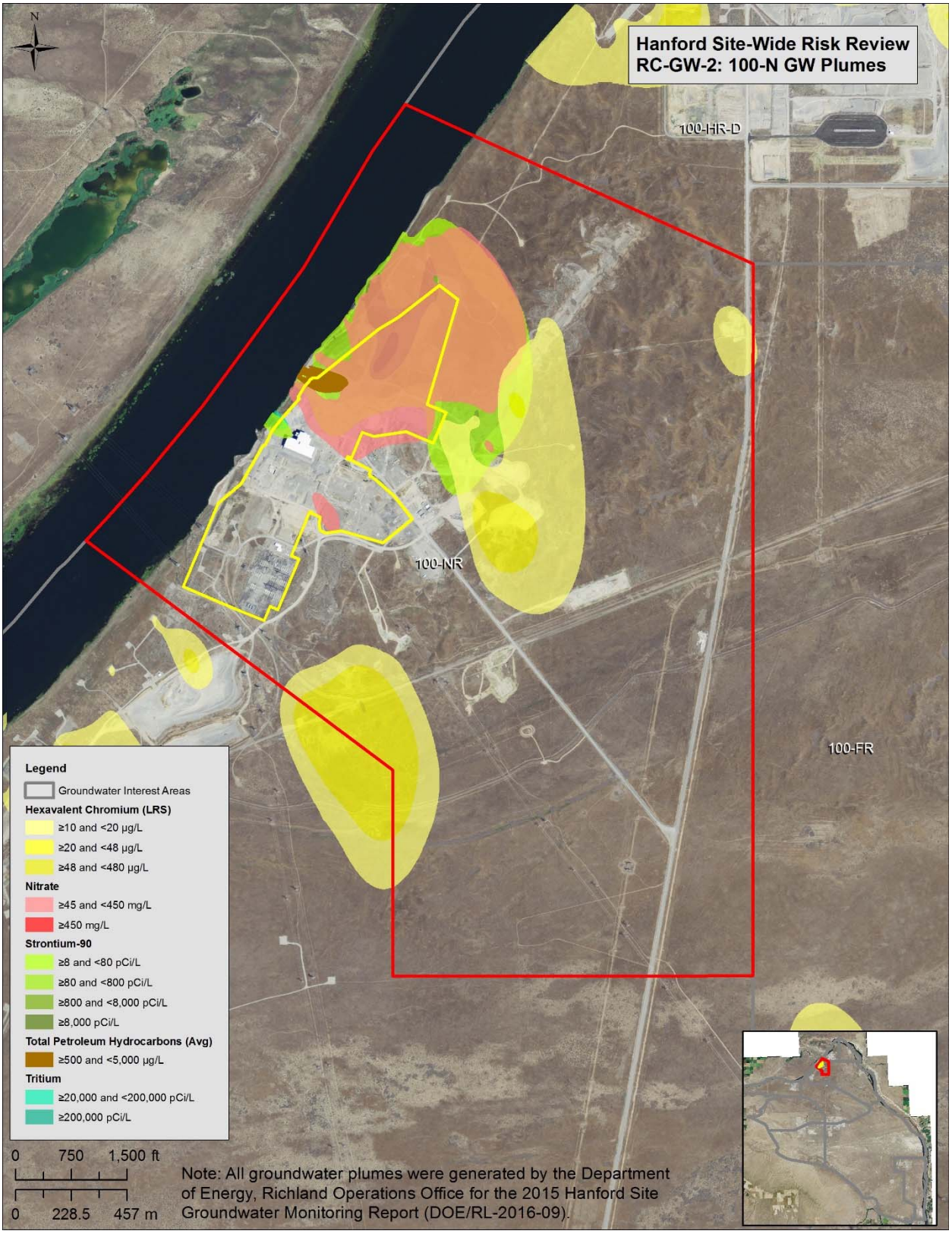

Figure D.3-3. Groundwater Plumes near the 100-NR Interest Area in 2015

PART IV. UNIT DESCRIPTION AND HISTORY

EU FORMER/CURRENT USE(S)

The 100-N Area includes two Operable Units (OUs). The 100-NR-1 OU encompasses approximately 405 hectares (1,000 acres), while the 100-NR-2 OU includes contaminated groundwater beneath and in proximity to the 100-NR-1 OU. The 100-NR Interest Area, upon which this Review is based, is related to and encompasses most of the 100-NR-2 OU, with the exception of an area to the southwest along the Columbia River. DOE has defined informal groundwater interest areas, which include the groundwater OUs and the intervening regions, to provide scheduling, data review, and data interpretation for the entire Site (DOE/RL-2016-09, Rev. 0, pages 1-4 to 1-5). A separate interim action ROD, *Interim Remedial Action Record of Decision for the 100-NR-1 Operable Unit of the Hanford 100-N Area, Hanford Site*, addresses all contaminated soil, structures, and pipelines associated with the 116-N-1 and 116-N-3 liquid waste disposal facilities (LWDFs). Cooling water from 100-N Area reactor operations was initially discharged to two LWDFs. When Strontium-90 was detected at the shoreline in 1985, the cooling water was diverted to the a third LWDF, which was located farther inland (DOE/RL-95-111, *Corrective Measures Study for the 100-NR-1 and 100-NR-2 Operable Units*). The discharges to the LWDFs contained radioactive waste products, as well as corrosive liquids, metals-laden wastes, and other laboratory chemicals as identified in the RCRA Part A permit (DOE/RL-88-21, 2004, *Hanford Facility Dangerous Waste Part A Permit Application*, Rev. 37). While the reactor was in operation, large volumes (3,785 L [1,000 gal.] per minute) of cooling water were discharged (DOE/RL-95-111) to the soil through the 116-N-1 LWDF (between 1963 and 1983) and the 116 N-3 LWDF (between 1983 and 1991). The liquids percolated through the soil column where they were subsequently transported by groundwater toward the Columbia River. The LWDFs are known to be the primary source of Strontium-90 contamination present in the 100-NR-2 OU. (U.S. EPA SEP 2010). Current use of the site is as an active remediation site.

LEGACY SOURCE SITES

Not Applicable

HIGH-LEVEL WASTE TANKS

Not Applicable

GROUNDWATER PLUMES

Please See Above

D&D OF INACTIVE FACILITIES

Not Applicable

OPERATING FACILITIES

Not Applicable

ECOLOGICAL RESOURCES SETTING

The potential for terrestrial ecological receptors to interact directly with any of the groundwater plumes is expected to be limited to those areas where the depth to groundwater is very shallow (<15 ft from the

soil surface). On the Hanford Site, this condition is unlikely except where groundwater approaches the surface near the Columbia River. Where groundwater plumes intercept and enter the river, there may be mixing of river and groundwater at shallower depths (river bank storage), and plant roots and burrowing animals in the riparian zone could potentially access portions of the groundwater plume.

For purposes of this assessment, areas were delineated where the mapped riparian zone along the river shoreline intersects the estimated contours for the groundwater plumes. Riparian areas along the river shoreline are considered priority habitats that are classified as level 4 biological resources. The delineated area and acreage for the intersection of the riparian zone for separate contaminant plumes within each groundwater evaluation unit are provided in Table D.3-2 and indicate the extent of biological resources that could potentially be affected by the groundwater plumes. For the groundwater evaluation units, there are approximately 109.5 acres of riparian habitat along the river shoreline that where contaminated groundwater could affect the ecological resources.

Table D.3-2. Areal Extent (Acres) of Riparian Zone Intersected by 2015 Groundwater Plumes Within Each Groundwater Interest Area.

Evaluation Unit Groundwater Interest Area COPC	Reference Value	RC-GW-3 100-BC	RC-GW-3 100-KR	RC-GW-2 100-NR	RC-GW-3 100-HR-D	RC-GW-3 100-HR-H	CP-GW-1 200-PO	RC-GW-1 300-FF	Total Area
Carbon-14	2,000 pCi/L[a]	-	-	-	-	-		-	-
Cyanide	200 µg/L[a]	-	-	-	-	-	-	-	-
Chromium	10 µg/L[b]	8.62	1.57	-	2.80	30.30	-	-	43.29
Carbon Tetrachloride	5 µg/L[a]	-	-	-	-	-	-	-	-
Iodine-129	1 pCi/L[a]	-	-	-	-	-	-	-	-
Nitrate	45 mg/L[a]	-	-	0.20	-	-	-	0.79	1.00
Strontium-90	8 pCi/L[a]	2.34	-	1.46	-	-	-	-	3.80
Technetium-99	900 pCi/L[a]	-	-	-	-	-	-	-	-
Trichloroethylene	5 µg/L[c]	-	-	-	-	-	-	-	-
TPH-D	500 µg/L[c]	-	-	0.10	-	-	-	-	0.10
Tritium	20,000 pCi/L[a]	-	-	0.14	-	-	18.28	-	18.42
Uranium	30 µg/L[a]	-	-	-	-	-	-	6.38	6.38
Total Extent of Plumes[d]	-	8.82	1.57	1.70	2.80	30.30	18.28	7.17	70.64
Total Riparian Area[e]	-	491.51	78.06	11.39	329.74	463.00	357.48	212.30	2664.66

a EPA Drinking Water Standard

b Criteria for chronic exposure in fresh water, WAC 173-201A-240. "Water Quality Standards for Surface Waters of the State of Washington," "Toxic Substances," Table 240(3)

c Washington State Department of Ecology, "Method A Cleanup Levels for Groundwater," from "Model Toxics Control Act Cleanup Regulation Chapter 173-340 WAC", Table 720-1

d. The Total Extent of Plumes for a given Interest Area is not equal the sum of individual COPC plume areas because some plumes overlap; i.e., the total represents the combined 2-dimensional extent of individual COPC plumes.

e. The Total Riparian Area is the based on the areal extent of mapped riparian vegetation along the Benton County shoreline of the Hanford Site. The total riparian area listed (2664.66 ac) includes riparian area within 100-FR (721.2 ac), which is part of the Hanford Reach but is not listed in other parts of the table because there is no plume intersection with the riparian zone.

CULTURAL RESOURCES SETTING

The potential for cultural resources in the area of the groundwater plumes is high and likely to affect the Native American, Historic Pre-Hanford, and Manhattan Project/Cold War landscapes. As discussed in RC-LS-2, K Area Waste Sites EU, there are documented cultural resources along the shoreline for all the

landscapes. A literature review of the setting for the groundwater EUs has not been completed. Current remedial actions for groundwater plumes have included evaluation of Section 106 of the National Historic Preservation Act. Future activities will also include Section 106 evaluations.

Consultation with Hanford Tribes (Confederated Bands of the Yakama Nation, Wanapum, Confederated Tribes of the Umatilla Indian Reservation, and the Nez Perce) and other groups who may have an interest in the areas (e.g. East Benton Historical Society, Prosser Cemetery Association, Franklin County Historical Society, the Reach, and the B-Reactor Museum Association) will be completed. Consultation with Hanford Tribes will be necessary to provide input on indirect effects to both recorded and potential unrecorded TCPs in the area and other cultural resource issues of concern.

PART V. WASTE AND CONTAMINATION INVENTORY

The method described in Chapter 6 of the Methodology Report (CRESP 2015) was used to approximate saturated zone inventories for the 100-NR primary contaminants[2].

CONTAMINATION WITHIN PRIMARY EU SOURCE COMPONENTS

Legacy Source Sites

Not Applicable.

High Level Waste Tanks and Ancillary Equipment

Not Applicable.

Vadose Zone Contamination

Please see related EUs for specific details on the vadose zone contamination and potential impacts.

Groundwater Plumes

The estimated inventory for the saturated zone contamination is provided in Table D.3-3 where the process is outlined in Chapter 6 of the Methodology Report (CRESP 2015). For the groundwater plumes described in the 100-NR IA (DOE/RL-2016-09, Rev. 0), inventories are estimated as follows: [3]

- Strontium-90 – The maximum measured concentration in 2015 was 13,600 pCi/L, the 95% upper confidence limit (UCL) on the log-transformed groundwater and aquifer tube (AT) data from HEIS (http://ehs.hanford.gov/eda/) was 323 pCi/L. The areal extent of the plume is 0.64 km^2. The plume pore volume is estimated to be 1.15×10^6 m^3, the plume inventory (pore water) is estimated to be 0.372 Ci.
- TPH-Diesel – The maximum measured concentration in 2015 was 6.40 mg/L, the 95% UCL on the log-transformed groundwater and aquifer tube (AT) data from HEIS

[2] See Appendix D.1 *Overview of Groundwater Evaluation Units And The Rating Process* for changes to the methodology.

[3] As indicated in Table D.3-3, plume depths are not known for the 100-NR-2 OU primary contaminants. As indicated in the Methodology Report (CRESP 2015), in this case, the minimum of the value from the Hanford 200-UP-1 OU Interim ROD (EPA 2012) or the unconfined aquifer thickness is used. The unconfined aquifer thickness used (~10 m) is Ringold Unit E (DOE/RL-2016-09, Rev. 0; Last 2006, pp. 4.5-4.6). Furthermore, use of the unconfined aquifer thickness likely results in very large uncertainties in the pore volume and related estimates.

(http://ehs.hanford.gov/eda/) was 2 mg/L. The plume pore volume is estimated to be 3.6×10^4 m^3, and the plume inventory (pore water) is estimated to be 72.1 kg.

- Nitrate – The maximum measured concentration in 2015 was 308 mg/L, the 95% UCL on the log-transformed groundwater and aquifer tube (AT) data from HEIS (http://ehs.hanford.gov/eda/) was 79.6 mg/L. The plume pore volume is estimated to be 0.99×10^6 m^3, and the plume inventory (pore water) is estimated to be 7.88×10^4 kg.
- Cr-VI – The maximum measured concentration in 2015 was 120 μg/L, the 95% UCL on the log-transformed groundwater and AT data from HEIS (http://ehs.hanford.gov/eda/) was 46.8 μg/L. The plume pore volume is estimated to be 0.882×10^6 m^3, and the plume inventory (pore water) is estimated to be 41.3 kg.
- Tritium – The maximum measured concentration in 2013 was 8.76×10^5 pCi/L, the 95% UCL on the log-transformed groundwater and AT data from HEIS (http://ehs.hanford.gov/eda/) was 4.86×10^5 pCi/L. The plume inventory (pore water) is not estimated because no plume area was available.

As illustrated in Table D.3-3, the saturated zone (SZ) GTM values for the Group A and B primary contaminants are 4.13 for Mm^3 and 46.6 Mm^3 for Cr-VI (*Low* rating) and strontium-90 (*Medium* rating), respectively. The plume areas for the Group C contaminants (TPH-diesel and nitrate) translate to *Low Medium* ratings, respectively. Tritium is not rated because no plume area was available.

It is unlikely that additional PCs might contaminant the groundwater in the 100-NR IA in the future. Remediation activities should not increase contaminant migration into groundwater. Scenarios where this is possible, albeit unlikely, include increased infiltration of water into the subsurface due to a broken water pipe or other significant water addition event such as could occur for dust suppression. Neither of which is associated with any planned remediation activities or ICs.

Columbia River

Contaminant plumes of strontium-90, TPH-diesel, nitrate, chromium (total and CR-VI), and tritium all are in contact or close proximity of the Columbia River, and thus have already or are expected to migrate to the Columbia River within 10 years or less. As such, the evaluation in Chapter 6 of the Methodology Report (CRESP 2015) based on *current impacts* to benthic and riparian ecology will be used as a function of the ratio (*Ratio*) of the maximum groundwater concentration to the biota concentration guide (BCG) or ambient water quality criterion (AWQC). For radionuclides, the BCG consistent with DOE Technical Standard DOE-STD-1153-2002[4] is used. For chemical PCs, the AWQC from the Columbia River Component Risk Assessment (CRCRA) (DOE/RL-2010-117, Rev. 0) Volume I: Screening Level Ecological Risk Assessment are used (where the Tier II Screening Risk Values are used when the AWQC is unavailable, which is also consistent with the CRCRA).

As illustrated in Table D.3-4, the overall evaluation of groundwater as a pathway to the Columbia River is assessed as *Medium* for strontium-90 (Group B), *Low* for Cr-VI (Group A), *Low* for nitrate, and *Not Discernible* for tritium (Group C).

Results of the Threat Evaluation to the Benthic Ecology

The rating threat evaluation to the benthic ecology (Table D.3-4) for Cr-VI, (Group A) is *Low* due to the moderate maximum groundwater concentration to BCG ratio (12.0) and current lack of impacted

[4] The values used are taken from RESRAD BIOTA (https://web.evs.anl.gov/resrad/home2/biota.cfm), which is consistent with DOE Technical Standard DOE-STD-1153-2002 and the Columbia River Component Risk Assessment (DOE/RL-2010-117, Rev. 0) Volume I: Screening Level Ecological Risk Assessment.

shoreline. Benthic threat ratings for strontium-90 (Group B) is *Medium* due to the high maximum groundwater concentration to BCG ratio (48.7) and relatively moderate length of impacted shoreline (670 m). Benthic threat ratings for nitrate (Group C) is *Low* due to moderate high maximum groundwater concentration to BCG ratio (9.8).

Results of the Threat Evaluation to the Riparian Zone Ecology

The rating threat evaluation to the riparian ecology (Table D.3-4) for strontium-90 (Group B) is *Medium* due to the high Ratio, but slightly high riparian impact area of 0.59 hectares. The rating *Ratio* for Cr-VI is 12.0, and no riparian impact area, garnering a rating of *Low*. The rating *Ratio* for nitrate (Group C) is 9.8, and no riparian impact area, garnering a rating of *Low*.

Threats to the Columbia River Free-flowing Ecology

The threat determination process for the free-flowing River ecology was evaluated in a manner similar to that described above for benthic receptors (Chapter 6, Methodology Report). However, because of the large dilution effect of the Columbia River on the contamination from the seeps and groundwater upwellings[5], the differences from EU to EU were not found distinguishing and the potential for groundwater contaminant discharges from Hanford to achieve concentrations above relevant thresholds is very remote.

Facilities for D&D

Not Applicable.

Operating Facilities

Not Applicable.

[5] "Groundwater is a potential pathway for contaminants to enter the Columbia River. Groundwater flows into the river from springs located above the water line and through areas of upwelling in the river bed. Hydrologists estimate that groundwater currently flows from the Hanford unconfined aquifer to the Columbia River at a rate of ~ 0.000012 cubic meters per second (Section 4.1 of PNNL-13674). For comparison, the average flow of the Columbia River is ~3,400 cubic meters per second (DOE/RL-2016-09, Rev. 0)." This represents a dilution effect of more than eight orders of magnitude (a dilution factor of greater than 100 million).

Table D.3-3. Summary of the Evaluation of Threats to Groundwater as a Protected Resource from Saturated Zone (SZ) Contamination associated with RC-GW-2 (100-NR).

IA	PC	Grp	WQS[a]	Area (km^2)[b]	Thick-ness (m)[c]	Pore Vol. (Mm^3)	Max GW Conc	95th % GW UCL	Porosity[d]	K_d (mL/g)[d]	ρ (kg/L)[d]	R	SZ Total M^{SZ} (kg or Ci)	SZ GTM (Mm^3)	SZ Rating[e]
100-NR	Sr-90	B	8 pCi/L	0.64	10	1.15	13600 pCi/L	323 pCi/L	0.18	22	1.84	226	3.72E-01	4.66E+01	Medium*
	TPH-D	C	0.5 mg/L	0.02	10	0.036	6.40 mg/L	2.00 mg/L	0.18	0	1.84	1	7.21E+01	---	Low*
	NO3	C	45 mg/L	0.55	10	0.99	308 mg/L	79.6 mg/L	0.18	0	1.84	1	7.88E+04	---	Medium
	Cr-VI	A	10 µg/L	0.49	10	0.882	120 µg/L	46.8 µg/L	0.18	0	1.84	1	4.13E+01	4.13E+00	Low
	H-3	C	20000 pCi/L	N/C	10	---	876000 pCi/L	486000 pCi/L	0.18	0	1.84	1	---	---	---

a. The Water Quality Standard (WQS) is typically the drinking water standard (DWS). The exceptions are TPH-diesel (TPH-D) where the cleanup value (0.5 mg/L or 500 µg/L from WAC 173-340-720(3)(b) Table 720-1) is used and hexavalent chromium (Cr-VI) where the surface water standard is used.

b. Plume area (DOE/RL-2016-09, Rev. 0).

c. As described in Chapter 6 of the Methodology Report (CRESP 2015), for those areas outside of the 200-UP IA, the minimum of the value from the Hanford 200-UP-1 OU Interim ROD (EPA 2012) or the unconfined aquifer thickness is used. The unconfined aquifer thickness used (~10 m) is Ringold Unit E (DOE/RL-2016-09, Rev. 0; Last 2006, pp. 4.5-4.6). Furthermore, use of the unconfined aquifer thickness likely results in very large uncertainties in the pore volume and related estimates.

d. Parameters obtained from the analysis provided in Attachment 6-1 to Methodology Report (CRESP 2015).

e. Groundwater Threat Metric rating based on Table 6-3, Methodology Report. After pump-and-treat (Interim Action) was found to be insufficient, an apatite permeable reactive barrier was installed (2006-2011) to enhance attenuation of Sr-90 in groundwater moving toward the Columbia River. TPH-diesel free product is being removed from groundwater in one well (199-N-18), and Washington Closure Hanford conducted a bioventing pilot test (2010-2011) for remediation of diesel in the deep vadose zone (DOE/RL-2016-09, Rev. 0).

Table D.3-4. Summary of the Evaluation of Groundwater as Pathway to the Columbia River associated with RC-GW-2 (100-NR-2)

OU	PC	Grp	WQS[a]	BCG or AWQC[b]	Max GW Conc	95th % GW UCL	Max GW Conc / BCG or WQS	95th % GW UCL / BCG or WQS	Shoreline Impact (m)[c]	Riparian Area (ha)[d]	Benthic rating[e]	Riparian rating[e]	Overall rating[e]
100-NR-2	Sr-90	B	8 pCi/L	279 pCi/L	13600 pCi/L	323 pCi/L	4.87E+01	1.16E+00	6.70E+02	5.91E-01	Medium	Medium	Medium
	TPH-D	C	0.5 mg/L	Undefined	6.40 mg/L	2.00 mg/L	---	---	6.00E+01	4.05E-02	---	---	---
	NO3	C	45 mg/L	7.10 mg/L	308 mg/L	79.6 mg/L	9.80E+00	2.53E+00	8.00E+01	8.09E-02	Low	Low	Low
	Cr-VI	A	10 µg/L	10 µg/L	120 µg/L	46.8 µg/L	1.20E+01	4.68E+00	0.00E+00	---	Low	Low	Low
	H-3	C	20000 pCi/L	2.65E+08 pCi/L	876000 pCi/L	486000 pCi/L	3.31E-03	1.83E-03	N/C	5.67E-02	---	---	ND

a. The Water Quality Standard (WQS) is typically the drinking water standard (DWS). The exceptions are TPH-diesel (TPH-D) where the cleanup value (0.5 mg/L or 500 µg/L from WAC 173-340-720(3)(b) Table 720-1) is used and hexavalent chromium (Cr-VI) where the surface water standard is used.

b. Biota Concentration Guide (BCG) from RESRAD-BIOTA v1.8 (consistent with DOE Technical Standard DOE-STD-1153-2002) for radionuclides. For chemicals, either the Ambient Water Quality Criterion (AWQC) (Table 6-1 in DOE/RL-2010-117, Rev. 0) or Tier II Screening Concentration Value (SVC) (http://rais.ornl.gov/documents/tm96r2.pdf) is used when AQWC not available. No threshold is available for TPH-diesel, which constitutes a gap in the analysis of potential threats to the Columbia River.

c. Shoreline impact from 2015 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-09, Rev. 0). Excludes tritium and nitrate in plumes associated with the 200-PO groundwater interest area (Appendix G.1).

d. The intersection area between the groundwater plume and the riparian zone was provided by PNNL based on the 2015 Hanford Site Groundwater Monitoring Report (DOE/RL-2016-09, Rev. 0).

e. Benthic and riparian zone ratings based on Figure 6-11 in the Methodology Report (CRESP 2015). The Group C ratings (for nitrate and tritium) are ND because R1 ≤ 1. The free-flowing ratings are all ND. The overall rating is the maximum rating.

PART VI. POTENTIAL RISK/IMPACT PATHWAYS AND EVENTS

CURRENT CONCEPTUAL MODEL

The vadose zone in 100-NR is 0 to 23 meters thick and is composed of gravels and sands of the Hanford formation and upper Ringold Formation unit E (Table D.3-4). The unconfined aquifer is approximately 6.5 to 14 meters thick. When the Columbia River stage is high, the water table can rise into the Hanford formation in wells near the shoreline. The Ringold upper mud unit (RUM) forms the base of the unconfined aquifer. Groundwater in 100-NR generally flows northwest toward the Columbia River. Groundwater flow was influenced in 2015 by groundwater extraction and injection for the KX Pump and Treat (P&T) remediation system located in the southwest portion of 100-NR. A small groundwater mound surrounding KX injection wells 199-K-159, 199-K-160, and 199-K-164 creates local radial flow. The seasonally high river stage normally observed in May through July did not occur in 2015 because of low snowpack in the mountains. During a normal year, changing river stage can influence groundwater elevations over 1 km (0.6 mi) inland from the river. (DOE/RL-2016-09, Rev. 0)

Fluctuations in river stage, caused by dam operations, and seasonal variations have the same general impact on flow direction, hydraulic gradients, and groundwater levels throughout the 100-N Area. Contamination associated with 100·NR-I waste sites ranges from surface contamination, such as at the 128·N-I Burn Pit or the 100-N-47 Military Site, to very deep contamination, probably reaching groundwater (18 to 23 m) for most of the 100-N Area). Approximate depth to groundwater near the 116-N-1 Crib is 19 m and near the 116-N-3 Crib it is 22 m. (U.S. DOE 2000)

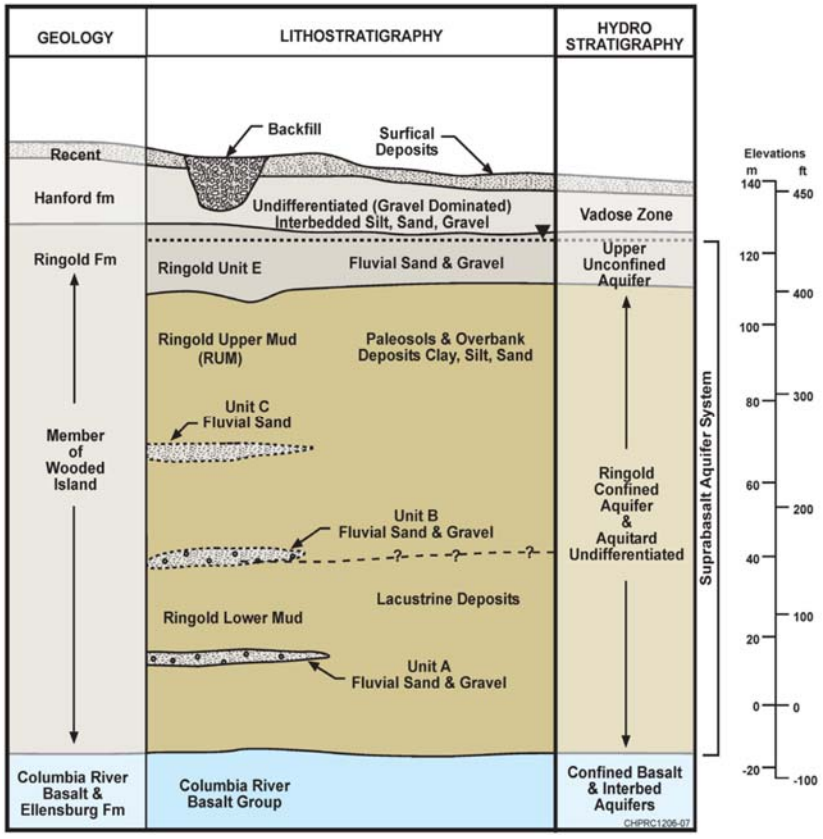

Figure D.3-4. 100-NR Area Geology Profile (after EPA et al., 2013).

POPULATIONS AND RESOURCES CURRENTLY AT RISK OR POTENTIALLY IMPACTED

Facility Worker

Only workers at risk or impacted would be working on the active remediation activities, to include monitoring and sampling.

Co-Located Person (CP)

Workers typically are not directly exposed to the contaminated groundwaters because they are located below grade beneath soil covers.

Public

The contamination remains underground, except where there is active RTD remediation activities and where the contaminated groundwater intersects the Columbia River.

Groundwater

Evaluation of the threats to groundwater as a protected resource from saturated zone contamination utilized the groundwater evaluation framework procedure outlined in Chapter 6 of the Methodology Report (CRESP 2015). The results of this analysis are described below and summarized in Table D.3-3.

Current

For strontium-90, TPH-diesel, nitrate, Cr-VI, chromium (total), and tritium, the measured maximum groundwater concentrations currently exceed the water quality standard (WQS) in each instance. Further, contaminants are grouped based on their relative mobility and persistence, with Group A possessing both high mobility and high persistence (e.g., Cr-VI), followed by Group B (e.g., Chromium (total), Strontium-90), Group C (e.g., tritium, nitrate, TPH-diesel), and Group D (e.g., Cs-137). From Table D.3-3, Cr-VI is categorized as a Group A primary contaminant (PC); strontium-90 is categorized as Group B PCs; while tritium and nitrate are categorized as Group C PCs. For Group A and Group B PCs, the groundwater threat metric (GTM) is used to evaluate the groundwater threat and represents the maximum volume of water that could be contaminated by the inventory of a primary contaminant from a source if it was found in the saturated zone at the WQS and in equilibrium with the soil/sediment. Note that the GTM accounts only for (i) source inventory; (ii) partitioning with the surrounding subsurface; and (iii) the WQS. The GTM reflects a snapshot in time (assuming no loss by decay/degradation or dispersion, etc.) and does not account for differences in contaminant mobility or bulk groundwater flow. For Group C PCs, the threat is evaluated in terms of contaminant plume area.

Based on a GTM (units of 1E6 m^3 or Mm^3) of 46.6 Mm^3 for strontium-90, the threat rating was evaluated as *Medium*. For Cr-VI, the threat rating was evaluated as *Low* due to the low GTM of 4.13 Mm^3 and plume area of 0.49 km^2. For TPH-diesel, and nitrate, the contaminant plume areas were 0.02 km^2, and 0.55 km^2, respectively, reflecting *Low*, and *Medium* groundwater ratings, respectively. Tritium was not rated because a plume area was not available.

Risks and Potential Impacts from Selected or Potential Cleanup Approaches

Interim actions are being conducted for strontium-90 and TPH-diesel contamination in 100-NR-2, including constructing a permeable reactive barrier to sequester strontium-90 and removal of petroleum hydrocarbons (free product) if observed in a monitoring well (DOE/RL-2016-09, Rev. 0). The final Record of Decision is anticipated in 2017. Thus the time required to reach selected cleanup levels

will be dependent upon the final remedy selection (and is thus unknown)[6]. As such, impacts from the selected remediation approach are assumed to vary little from the current conditions during active remediation until cleanup levels are reduced below cleanup levels. Once below WQS, the overall rating for groundwater impacts would be assessed *Not Discernible (ND)*.

Columbia River

As described in Part V (Table D.3-4), plumes associated with the RC-GW-2 EU currently intersect the Columbia River, which translate to *Not Discernible* to *Medium* ratings.

The rating threat evaluation to the benthic ecology for Cr-VI (Group A) is *Low* due to the moderate maximum groundwater concentration to AWQC ratio (12.0) and current lack of impacted shoreline. Benthic threat ratings for strontium-90 (Group B) is *Medium* due to the high maximum groundwater concentration to BCG ratio (48.7) and relatively moderate length of impacted shoreline (670 m)[7]. No AWQC or SVC exists for TPH-diesel so no threat rating was evaluated (representing an analysis gap); however, if the cleanup level were to be used, then the TPH-diesel (Group C) would have a *Low* rating.

The rating threat evaluation to the riparian ecology for strontium-90 is *Medium* due to the high Ratio, but slightly high riparian impact area of 0.59 hectares[7]. The rating *Ratio* for Cr-VI is 12.0, and no riparian impact area, garnering a rating of *Low*. The rating *Ratio* for nitrate, a Group C PC, is 9.8, and a riparian impact area of 0.081 hectares, garnering a rating of *Low*.

The large dilution effect of the Columbia River results in a rating of *Not Discernible* for the free-flowing ecology for all evaluation periods.

Ecological Resources

For the four groundwater evaluation units with plumes that are estimated to intersect the Columbia River, there are approximately 70.64 acres of riparian habitat and resources along the river shoreline that could potentially be affected.

Remediation actions taken to reduce the contaminated groundwater plumes may have indirect effects on terrestrial ecological resources. Subsurface remediation actions such as pump and treat activities or development of subsurface chemical barriers to contaminant transport may indirectly affect ecological resources through several mechanisms:

- Injection and pumping wells might alter the hydrology in the vadose zone, and change soil water availability for plants.
- Injection of barrier constituents might alter soil chemistry and nutrient availability depending on rate or distance of migration of those constituents and whether the constituents interact with soils within the rooting zone

[6] Performance monitoring wells for the central (original) segment of the barrier show an overall reduction in strontium-90 concentrations following the apatite injections in 2008. In 2015, strontium-90 concentrations remained considerably lower in the wells monitored along the central segment of the barrier than before the injections began in 2006. A strontium-90 reduction of 90 percent occurred in only one of the four downriver barrier segment monitoring wells in 2015. Ongoing monitoring will help determine the continued effectiveness of the apatite barrier and support decisions regarding future apatite treatments and need for reinjection. (DOE/RL-2016-09, Rev. 0).

[7] For reasons given in the previous section, the benthic and riparian ratings for strontium-90 will be maintained as *Medium* for the Active Cleanup period and modified to *Low* for the Near-term, Post-Cleanup period.

- Well pad and road construction may disturb the surface, degrade available habitat, and impact ecological resources/receptors
- Pedestrian and vehicle traffic during construction, maintenance, monitoring, and decommission of subsurface barrier systems may degrade habitats, disturb wildlife and affect animal behavior, and introduce exotic plant species.

Use of plants to accomplish phytoremediation would incur both direct and indirect effects to ecological receptors within the area of the EU used for treatment. Direct effects include surface disturbance and habitat removal associated with preparation and planting of the phytoremediation species to be used. As with subsurface treatment activities, pedestrian and vehicle traffic during construction, maintenance, monitoring, and decommission may degrade habitats, disturb wildlife and affect animal behavior, and introduce exotic plant species.

Cultural Resources

The potential for cultural resources in the area of the groundwater plumes is high and likely to affect the Native American, Historic Pre-Hanford, and Manhattan Project/Cold War landscapes. A literature review of the setting for the groundwater EUs has not been completed. Current remedial actions for groundwater plumes have included evaluation of Section 106 of the National Historic Preservation Act. Future activities will also include Section 106 evaluations.

CLEANUP APPROACHES AND END-STATE CONCEPTUAL MODEL

The Interim Record of Decision (ROD) (U.S. DOE, 2000) for the 100-NR-2 OU was signed on 29 September 1999. The Selected interim remedial actions are intended to ensure that contaminants present at these waste sites will not adversely impact existing groundwater quality beneath the sites or beneficial uses of the Columbia River. The future land use for the 100-NR Area has not been determined; however, the selected remedial actions are intended to not preclude any future land use (other than for the Columbia River shoreline site): Remedial action objectives and cleanup standards will be re-evaluated if future land use and groundwater use determinations are inconsistent with the selected remedy (U.S. DOE, 2000). Specific ICs and remedial actions follow below as provided by the Interim ROD (U.S. DOE 2000).

Institutional Controls

- U.S. DOE will continue to use a badging program and control access to the sites associated with this ROD for the duration of the interim action. Visitors (i.e., persons not employed on the Hanford Site who are granted access for discussions on project related matters, employment interviews, or tours) entering any of the sites associated with this ROD are required to be escorted at all times.
- DOE will utilize the on-site excavation permit process to control well dril1ing and excavation of soil within the 100 Area OUs to prohibit any drilling or excavation except as approved by Ecology.
- DOE will maintain existing signs prohibiting public access to the shoreline site. .
- DOE will provide notification to Ecology upon discovery of any trespass incidents.
- Trespass incidents will be reported to the County Sheriff's Office for investigation and evaluation for possible prosecution.
- DOE will take the necessary precautions to add access restriction language to any land transfer, sale, or lease of property that the U.S. Government considers appropriate while institutional

controls arc compu1sory, and Ecology will have to approve any access restrictions prior to transfer, sale, or lease.
- Until final remedy selection, DOE shall not delete or terminate any institutional control requirement established in this ROD unless Ecology has provided written concurrence on the deletion or termination.
- DOE will evaluate the implementation and effectiveness of ICs on an annual basis. DOE shall submit a report to Ecology by 31 July of each year summarizing the results of the evaluation for the preceding calendar year. At a minimum, the report shall contain an evaluation of whether or not the OU IC requirements continue to be me, a description of any deficiencies discovered, and what measures have been taken to correct problems.

Remove/Dispose for Radioactive, Inorganic, Burn Pit, and Surface Solid Groups
- Remove contaminated soil, structures, debris, and pipelines to a depth of 4.6 m below surrounding grade or to the bottom of the engineering structure, whichever is deeper.
- Treat these wastes as required to meet ERDF compliance criteria.
- Dispose of soil, structures, debris, and pipelines at ERDF.
- Backfill excavated areas with clean material, grade, and re-vegetate the areas.
- Maintain ICs as described above for this group.

Remove/Ex-Situ Bioremediation/Dispose for Petroleum Waste Group with Near-Surface Contamination
- Remove contaminated media (soil debris) down to a depth of 4.6 m below surrounding grade or the bottom of the engineering structure, whichever is deeper. The depth of removal may be adjusted if field conditions warrant and Ecology approves.
- Remove contaminated media (soil/debris) below 4.6 m as necessary if field conditions warrant and Ecology approves.
- Ex-Situ bioremediate contaminated media within the 100-N boundary.
- Dispose of residual contaminated media, if required, to an Ecology approved facility.
- Collect and dispose of leachate to the Effluent Treatment Facility (ETF) or as approved by Ecology.
- Backfill excavated areas with clean material, grade, and re-vegetate the areas.
- Maintain ICs as described above for this group.

In-Situ Bioremediation for Petroleum Waste Group with Deep Contamination
- In-Situ bioremediation of contaminated media below 4.6 m of surrounding grade, bottom of' engineering structure, or at the stopping point of *Ex Situ* bioremediation, whichever is greater.
- Install necessary injection wells and infrastructure.
- Maintain groundwater monitoring wells to monitor bioremediation and impacts to groundwater.
- Grade and re-vegetate the areas.
- Maintain ICs as described above for this group until remediation is complete.

CONTAMINANT INVENTORY REMAINING AT THE CONCLUSION OF PLANNED ACTIVE CLEANUP PERIOD

The Interim Action ROD provides a decision framework to evaluate leaving contamination in place at a limited number of sites, specifically where contamination is located at depths greater than 4.6 m. The decision to leave contamination wastes in place at such sites will be a site-specific determination made during remedial design and remedial action activities that will balance the extent of remediation with

protection of human health and the environment, disturbance of ecological and cultural resources, worker health and safety, remediation costs, operation and maintenance costs, and radioactive decay of short-lived radionuclides (half-lives less than 30.2 years). The application of the balancing factors criteria and the process for determining the extent of remediation at deep sites will be made by the U.S. EPA and Ecology. Any decision to leave waste in place will occur after the public has been asked to comment on the proposal to leave waste in place. (U.S. DOE, 2000)

Current and anticipated water use in the 100-N Area derives from municipal water from the city of Richland. There are no current plans to start using 100-NR-2 groundwater as drinking water when drinking water standards (DWSs) are met. The expected timeframes to attain the WQSs in 100-NR-2 groundwater are dependent upon final remedial actions (U.S. DOE, 2000).

RISKS AND POTENTIAL IMPACTS ASSOCIATED WITH CLEANUP

Ecological Resources

Personnel, cars, trucks, heavy equipment and drill rigs, as well as heavy, wide hoses, on roads through non-target areas or remediation site carry seeds or propagules on tires, injure or kill vegetation or animals, make paths, cause greater compaction of soil, displace animals and disrupt behavior/reproductive success. Also seeds and propagules can be dispersed from soil from truck or blowing from heavy equipment. Often permanent or long-term compaction can result in the destruction of soil invertebrates. Compaction can decrease plant growth in those areas, decrease abundance and diversity of soil invertebrates, and prevent fossorial snakes or mammals from using the area. Compaction of soils may permanently destroy areas of the site with intense activity. Construction of new buildings can cause permanent destruction of plants and animals, and of the on-site ecosystem larger than the footprint of the building. Effects will radiate from the building, and post-remediation effects depend on the degree of use (e.g., personnel and truck traffic, type of truck traffic and heavy equipment activity). During remediation, radionuclides or other contaminants could be released or spilled on the surface, and depending upon the type and quantity, could have adverse effects on the plants and animals on site.

Cultural Resources

Personnel, truck, heavy equipment, and drill rigs may have direct impact on cultural resources in the riparian areas and in upland areas where there is soil/ground or alteration to the landscape. Assuming heavy equipment locations, new roads and staging areas have been cleared for cultural resources, then it is assumed adverse effects would have been resolved and/or mitigated. If heavy equipment and drilling locations and staging areas have not been cleared, this could result in artifact breakage and scattering, compaction and disturbance to the soil surface and immediate subsurface, thereby compromising stratigraphic integrity of an archaeological site. TCPs may be directly affected if personnel are on roads located on TCP and if personnel are unaware of cultural resource sensitivity, appropriate behaviors and protocols. For traffic on roads located on TCP, direct effects include visual, auditory and vibrational alterations to landscape/setting. Heavy equipment and drilling may cause direct effects to TCPs including destruction of culturally important plants, physical attributes of the TCP and introduction of noise and vibrations also altering the setting. These actions may interfere with traditional uses of TCP. The use of heavy, wide hoses could have direct effects to archaeological resources including artifact scattering or breakage as well as disturbance of surface sediments, if the areas have not been previously cleared. Construction of staging areas and other containment systems, and/or soil removal activities are assumed to have been cleared for cultural resources and any adverse effects would be resolved and/or

mitigated. If staging areas and other containment system locations have not been reviewed for cultural resources this could result in compaction and disturbance to the soil surface and throughout the subsurface leading to permanent adverse effects to the surface and subsurface integrity of an archaeological site by destroying the stratigraphic relationships of the soil, archaeological artifacts and features as well as all proximal information associated with archaeological artifacts and features. Construction of staging areas and other containment systems, and/or soil removal activities can have direct effects to TCPs including destroying physical attributes of TCP, destruction of culturally important plants, alteration of the setting and introduction of noise and vibrations also altering the setting. These actions may interfere with traditional uses of TCP. In some instances, the waste site is considered an archaeological site and/or pockets of undisturbed soils and potentially intact archaeological material are present. In these instances, effects could include preservation of artifacts in-situ if any information had already been gleaned from archeological site testing prior to capping. Otherwise, containment systems could result in compaction and compression of artifacts by destroying the stratigraphic relationships of the soil, archaeological artifacts and features as well as all proximal information associated with archaeological artifacts and features. Direct effects to TCPs include permanent alteration of physical setting and design of TCP, permanent viewshed impacts and possibly permanent interference with traditional use of TCP. Revegetation activities may cause direct effects to TCPs including physical alteration to or restoration of TCP depending on how the area is recontoured and what plants are selected for revegetation. Contamination remaining in situ may have direct effects including permanent physical alteration of TCP, and lead to permanent intrusion in long-term use and access to TCP.

Indirect effects from personnel, truck, heavy equipment, and drill rigs may lead to the introduction of invasive plant species or removal of culturally important plants that alters the landscape/setting for roads located within the viewshed and noise-scape of TCP. New roads alter the viewshed or noise-scape. Presence of vehicles may result in visual, auditory and vibrational alterations to landscape/setting. Remediation actions may lead to visual alteration of landscape/setting. Introduction of noise alters landscape/setting. Introduction of equipment and buildings may interfere with traditional uses of TCP. During remediation activities, indirect effects could result in temporary auditory, visual and vibrational effects. Revegetation could lead to indirect effects from visual alterations to setting depending on how the area is recontoured and what plants are selected for revegetation. Remaining contamination could lead to indirect effects from permanent intrusion, which could limit the use and access to TCP.

POPULATIONS AND RESOURCES AT RISK OR POTENTIALLY IMPACTED DURING OR AS A CONSEQUENCE OF CLEANUP ACTIONS

Workers (directly involved)

Please see above.

Co-located Person (CP)

Please see above.

Public

Please see above.

Groundwater

Please see above. As described in Part V, the final remedy has not been selected and future conditions are assumed to vary little from current conditions (until cleanup levels are achieved). Ratings for the primary contaminants would be *Not Discernible* when cleanup levels are achieved.

Columbia River

Please see above. As described in Part V, the final remedy has not been selected and future conditions are assumed to vary little from current conditions (until cleanup levels are achieved). Ratings for the primary contaminants would be *Not Discernible* when cleanup levels are achieved.

Ecological Resources

Personnel, car, pick-up truck, truck traffic as well as heavy equipment, drill rigs, and new facilities in the non-target and remediated areas will likely lead to permanent effects in areas of heavy equipment use, drill rigs and construction areas. Effects on the ecological resources are likely to include exotic/alien species, differences in native species structure, and soil invertebrate changes in areas of high activity (compaction). During remediation, radionuclides or other contaminants released or spilled on the surface could have long-term effects if the contamination remained, and plants did not recolonize or thrive. Such disruptions could affect the associated animal and plant communities.

Cultural Resources

Personnel, truck, heavy equipment, and drill rigs may have direct impact on cultural resources in the riparian areas and in upland areas where there is soil/ground or alteration to the landscape. Assuming heavy equipment locations, new roads and staging areas have been cleared for cultural resources, then it is assumed adverse effects would have been resolved and/or mitigated. If heavy equipment and drilling locations and staging areas have not been cleared, this could result in artifact breakage and scattering, compaction and disturbance to the soil surface and immediate subsurface, thereby compromising stratigraphic integrity of an archaeological site. TCPs may be directly affected if personnel are on roads located on TCP and if personnel are unaware of cultural resource sensitivity, appropriate behaviors and protocols. For traffic on roads located on TCP, direct effects include visual, auditory and vibrational alterations to landscape/setting. Heavy equipment and drilling may cause direct effects to TCPs including destruction of culturally important plants, physical attributes of the TCP and introduction of noise and vibrations also altering the setting. These actions may interfere with traditional uses of TCP. The use of heavy, wide hoses could have direct effects to archaeological resources including artifact scattering or breakage as well as disturbance of surface sediments, if the areas have not been previously cleared. Construction of staging areas and other containment systems, and/or soil removal activities are assumed to have been cleared for cultural resources and any adverse effects would be resolved and/or mitigated. If staging areas and other containment system locations have not been reviewed for cultural resources this could result in compaction and disturbance to the soil surface and throughout the subsurface leading to permanent adverse effects to the surface and subsurface integrity of an archaeological site by destroying the stratigraphic relationships of the soil, archaeological artifacts and features as well as all proximal information associated with archaeological artifacts and features. Construction of staging areas and other containment systems, and/or soil removal activities can have direct effects to TCPs including destroying physical attributes of TCP, destruction of culturally important plants, alteration of the setting and introduction of noise and vibrations also altering the setting. These actions may interfere with traditional uses of TCP. In some instances, the waste site is considered an archaeological site and/or pockets of undisturbed soils and potentially intact archaeological material are present. In these instances, effects could include preservation of artifacts in-situ if any information had already been gleaned from archeological site testing prior to capping. Otherwise, containment systems could result in compaction and compression of artifacts by destroying the stratigraphic relationships of the soil, archaeological artifacts and features as well as all proximal information associated with archaeological artifacts and features. Direct effects to TCPs include permanent alteration of physical setting and design of TCP, permanent viewshed impacts and possibly permanent interference with traditional use of TCP. Revegetation activities may cause direct effects to TCPs including physical

alteration to or restoration of TCP depending on how the area is recontoured and what plants are selected for revegetation. Contamination remaining in situ may have direct effects including permanent physical alteration of TCP, and lead to permanent intrusion in long-term use and access to TCP.

Indirect effects from personnel, truck, heavy equipment, and drill rigs may lead to the introduction of invasive plant species or removal of culturally important plants that alters the landscape/setting for roads located within the viewshed and noise-scape of TCP. New roads alter the viewshed or noise-scape. Presence of vehicles may result in visual, auditory and vibrational alterations to landscape/setting. Remediation actions may lead to visual alteration of landscape/setting. Introduction of noise alters landscape/setting. Introduction of equipment and buildings may interfere with traditional uses of TCP. During remediation activities, indirect effects could result in temporary auditory, visual and vibrational effects. Revegetation could lead to indirect effects from visual alterations to setting depending on how the area is recontoured and what plants are selected for revegetation. Remaining contamination could lead to indirect effects from permanent intrusion, which could limit the use and access to TCP

ADDITIONAL RISKS AND POTENTIAL IMPACTS IF CLEANUP IS DELAYED

Please see above.

NEAR-TERM, POST-CLEANUP STATUS, RISKS AND POTENTIAL IMPACTS

Please see above.

POPULATIONS AND RESOURCES AT RISK OR POTENTIALLY IMPACTED AFTER CLEANUP ACTIONS (FROM RESIDUAL CONTAMINANT INVENTORY OR LONG-TERM ACTIVITIES)

Table D.3-5. Populations and Resources at Risk or Potential Impacted After Cleanup Actions.

Population or Resource		Risk/Impact Rating	Comments
Human	Facility Worker	Low	Only workers at risk or impacted would be working on the active remediation activities, to include monitoring and sampling.
	Co-located Person	Not Discernible	Workers are not directly exposed to the contaminated groundwaters because they are located below grade beneath a soil cover. Further, strontium-90 is expected to be below AWQS after cleanup actions.
	Public	Not Discernible	The contamination remains underground, except where the contaminated groundwater intersects the Columbia River.
Environmental	Groundwater	Group A&B: Medium (Sr-90) All: Medium (Sr-90, NO3)	Based on a GTM (units of 1E6 m^3 or Mm^3) of 46.6 Mm^3 for Sr-90, the threat rating was evaluated as *Medium*. For Cr-VI, the threat rating was evaluated as *Low* due to the low GTM of 4.13 Mm^3. For nitrate, plume area was 0.55 km^2 a *Medium* rating. Plume area for tritium was not available Conditions assumed to vary little from current until cleanup levels are achieved.
	Columbia River	A&B: Medium (Sr-90, benthic, riparian) All: Medium (Sr-90, benthic, riparian)	The rating threat evaluation to the benthic ecology for Cr-VI (Group A) is *Low* due to the moderate maximum groundwater concentration to AWQC ratio (12.0) and current lack of impacted shoreline. Benthic threat ratings for Sr-90 (Group B) is *Medium* due to the high maximum groundwater concentration to BCG ratio (48.7) and relatively moderate length of impacted shoreline (670 m). Conditions assumed to vary little from current until cleanup levels are achieved. The rating threat evaluation to the riparian ecology for strontium-90 is *Medium* due to the high Ratio, but slightly high riparian impact area of 0.59

Population or Resource		Risk/Impact Rating	Comments
			hectares. The rating *Ratio* for Cr-VI is 12.0, and no riparian impact area, garnering a rating of *Low*. The ratings for nitrate and TPH-diesel (Group C) are *Not Discernible*. These are not altered. Conditions assumed to vary little from current until cleanup levels are achieved. The large dilution effect of the Columbia River results in a rating of *Not Discernible* for the free-flowing ecology for all evaluation periods.
	Ecological Resources[(a)]	Low	Contamination remaining in areas for monitored natural attenuation may still result in uptake in biota, but is not likely to cause an effect to the biota. Continued long-term monitoring activities may disrupt riparian and terrestrial habitats. Re-vegetation in EU will result in additional level 3 resources, and potentially creation of level 4 resources potentially at risk because of disturbance, especially from invasive species.
Social	Cultural Resources[(a)]	**Native American:** Direct: Known Indirect: Known **Historic Pre-Hanford:** Direct: Known Indirect: Known **Manhattan/Cold War**: Direct: Unknown Indirect: Unknown	Permanent direct and indirect effects are possible due to high sensitivity of area.

a. For both Ecological and Cultural Resources see Appendices J and K, respectively, for a complete description of Ecological Field Assessments and literature review for Cultural Resources. Ecological ratings are described in Table 4-11 of the Final Report.

LONG-TERM, POST-CLEANUP STATUS – INVENTORIES AND RISKS AND POTENTIAL IMPACT PATHWAYS

The National Contingency Plan (NCP) (40 CFR 300) establishes an expectation to "return useable ground waters to their beneficial uses wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site" ("Remedial Investigation/Feasibility Study and Selection of Remedy" [40 CFR 300.430(a)(1)(iii)(F)]). Washington state regulations contain a similar expectation. Given the nature of the groundwater in 100-NR, potential beneficial groundwater uses include drinking water, irrigation, and industrial uses. Drinking water use includes other domestic uses such as bathing and cooking. (EPA et al., 2013)

PART VII. SUPPLEMENTAL INFORMATION AND CONSIDERATIONS

The 100-NR Area needs to remain under DOE control to maintain institutional control for all remediation activities until all soil and groundwater contaminants reach CULs, to include areas outside 100-NR which have the potential to also contaminant groundwater in this area.

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