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# Remedial Investigation Report for the 200-PO-1 Groundwater Operable Unit

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# Executive Summary

The U.S. Department of Energy (DOE) has completed a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[1] remedial investigation (RI) of the 200-PO-1 Groundwater Operable Unit (OU) within the 200 Area National Priorities List (NPL) Site located in Washington State at the DOE Hanford Site. The purpose for conducting the RI was to collect additional data to refine the nature and extent, to assess the fate and transport, and to evaluate potential risks to human health and the environment (HHE) from 200-PO-1 Groundwater OU contaminants. The information collected during the RI also will support the development of the feasibility study (FS) for the 200-PO-1 Groundwater OU. The 200-PO-1 Groundwater OU (Figure ES-1) is the largest of the groundwater OUs on the Hanford Site and extends south/southeast from the 200 East Area across the Hanford Site to the Columbia River.

The observed groundwater contamination in the 200-PO-1 Groundwater OU has resulted largely from the liquid wastes generated by the Plutonium-Uranium Extraction (PUREX) Plant and B Plant that were discharged to surface ponds (e.g., B Pond), cribs (e.g., PUREX cribs), and trenches and then allowed to infiltrate into the soil column. Unplanned releases (UPRs) of liquid wastes also occurred within the OU and were generally associated with leaks, spills, or overfill of tanks, above ground and below ground pipelines, and other conveyance and storage facilities.

The scope of the RI did not include investigation and characterization of the contaminant sources and associated residual vadose zone contamination. The evaluation of these sources of contamination to the 200-PO-1 Groundwater OU will be completed in a separate source OU RI/FS process and addressed as discrete CERCLA OUs with their own accompanying record of decision (ROD). The source OU RODs will include provisions to define and incorporate future groundwater protection requirements into remedial actions aimed at preventing further degradation of the groundwater beneath the Hanford Site. Chapter 1 provides additional detail on the integration of source and groundwater OU decision strategies.

[1] *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*, 42 USC 9601, et seq. Available at: http://uscode.house.gov/download/pls/42C103.txt.

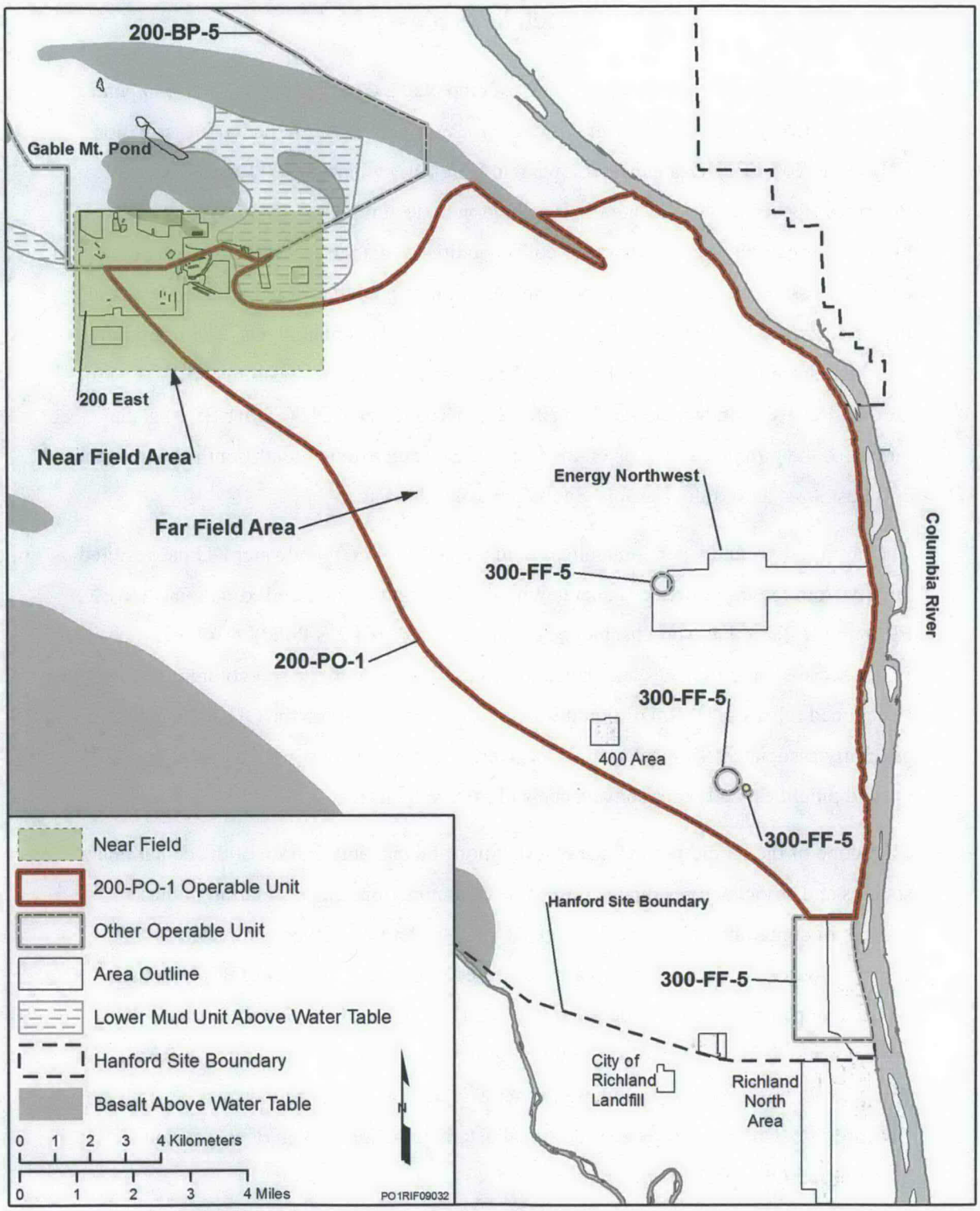



**Figure ES-1. Location of the 200-PO-1 Groundwater Operable Unit as Defined by the 2000 pCi/L Tritium Plume in DOE/RL-2007-31**

To organize the characterization of the 200-PO-1 groundwater, the network of groundwater monitoring wells was segregated into Near Field and Far Field regions. The Near Field region includes the southern portion of the 200 East Area where the contamination originated and the highest contaminant concentrations have been detected. The Far Field region, consisting of the broad geographic area extending between the 200 East Area and the Columbia River, is located downgradient from the plume sources where contaminant concentrations have dispersed over time.

The following primary objectives were identified for the Near Field and Far Field investigations:

- Collect additional characterization data for groundwater contaminants to further refine the nature and extent of groundwater contamination.
- Acquire geophysical data to estimate vertical and lateral extent of geologic features to refine the conceptual site model (CSM).
- Confirm or refine the understanding of preferred groundwater contaminant flow pathways needed to refine the conceptual exposure model (CEM) and complete the baseline risk assessment (BRA).

The RI monitoring focused on the contaminants that were found to exceed identified federal and Washington State statutory and risk-based groundwater cleanup standards. Tritium, nitrate, and iodine-129 are associated with the most extensive groundwater plumes within this OU. The contaminant plumes of strontium-90, uranium, and technetium-99 are found in more localized areas. Figure ES-2 illustrates the distribution of groundwater contaminants in the 200-PO-1 Groundwater OU; Chapter 4 provides additional information on the nature and extent of the contaminant plumes.

Concentrations of tritium and iodine-129 within the primary plume generally have declined in the Far Field area. These declining concentrations are due to natural attenuation as a result of radioactive decay and dispersion, a cessation of liquid disposal operations, and a decreasing source of contaminants that resulted from the termination of PUREX Plant and B Plant operations. A smaller, but distinct tritium plume originates at the 618-11 Burial Ground near the Energy Northwest Complex as associated with the 300-FF-5 Groundwater OU. This plume and a small uranium plume that originates near the 618-10 Burial Ground in the Far Field region are the subject of the 300-FF-5 Groundwater OU RI and are not included in this report.

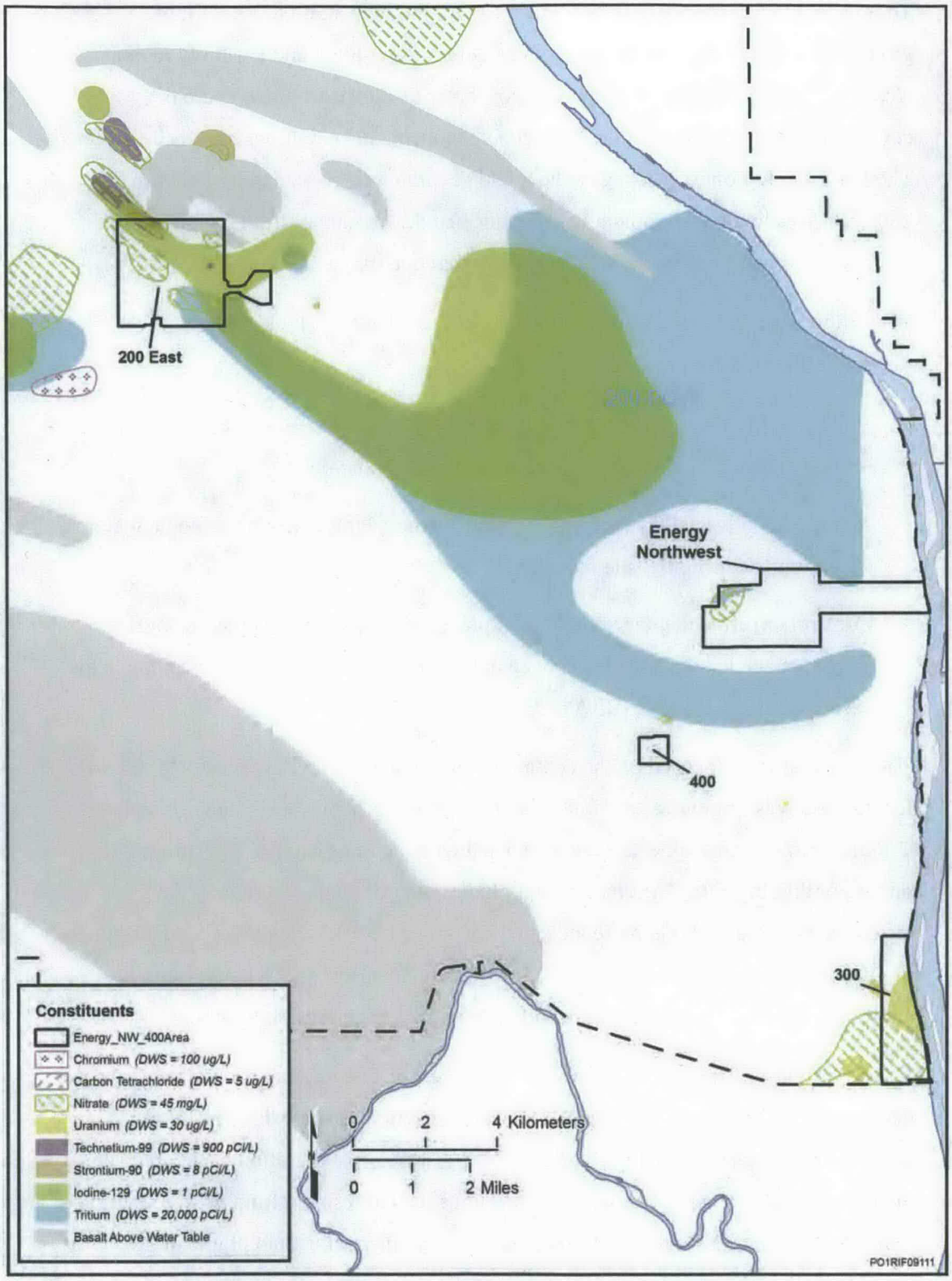



**Figure ES-2. 200-PO-1 Groundwater Operable Unit Constituent Contaminant Distribution Based on 2008 Annual Report, DOE/RL-2008-66**

In the Near Field Area, the extent of the strontium-90 and uranium plumes is very small as a result of relatively low to moderate mobility of the contaminants in the aquifer. Prior to 2003, groundwater sampling in the area of the PUREX cribs and WMA A-AX returned technetium-99 results up to a maximum concentration of 600 pCi/L. Since 2004, increasing technetium-99 concentrations have been detected with concentration in one well exceeding the 900 pCi/L drinking water standard in 2006. In this area, there is a local source and an upgradient source for technetium-99 coming into WMA A-AX from the northwest.

In the Far Field Area, tetrachloroethene, trichloroethene (TCE), and carbon tetrachloride have been detected in the vicinity of the Solid Waste Landfill (SWL) and Nonradioactive Dangerous Waste Landfill (NRDWL), which are being addressed through RCRA corrective action and final closure. Groundwater monitoring in the SWL and NRDWL wells since the early 1990s had shown decreasing trends in tetrachloroethene and TCE concentrations. Recently, tetrachloroethene has shown a trend upwards while TCE concentrations continue to decline.

Computer simulation of the fate and transport of 200-PO-1 groundwater contamination was used to estimate future impacts of current groundwater contamination in both the Near Field and Far Field regions. This simulation does not consider effects of continuing vadose zone contribution to be addressed by overlying source OUs. The fate and transport simulation for the Near Field contaminants included the following results:

- The iodine-129 plume, beginning with an initial maximum concentration of less than 10 pCi/L persists over the simulated time frame (i.e., 1,000 years) due to moderate retardation and long half-life. At the end of the simulation, the maximum calculated iodine-129 concentration at all locations is less than 0.3 pCi/L.
- The technetium-99 plume, increases initially from about 53 pCi/L at five years to about 218 pCi/L at ten years and then gradually decreases to about 15 pCi/L.
- The tritium plume decreases from a maximum concentration of about 513,000 pCi/L to about 5,700 pCi/L after fifty years.
- The nitrate plume concentration declines gradually from a maximum of about 100,000 μg/L to about 3,500 μg/L within 300 years.

- The TCE plume concentration declines from a maximum of about 0.5 μg/L to less than 0.04 μg/L within 100 years.
- The strontium-90 plume concentration, declines from a maximum of 80 pCi/L to less than 0.02 pCi/L within 100 years.
- The uranium plume concentration declines from a maximum of 34 μg/L to less than 3 μg/L within 500 years.

The results of the transport model demonstrate that peak concentrations of contaminants which currently exist in the Far Field region (e.g., tritium, iodine-129, and nitrate) generally decline over time and distance. Peak concentrations for COPCs that have not arrived in the Far Field region (e.g. uranium, technetium-99, strontium-90, tetrachloroethene, TCE, and carbon tetrachloride) are predicted to remain lower than those at the upstream boundary, suggesting decreasing risk. The Near Field and Far Field fate and transport activities are discussed in Chapter 5 of this report.

A CEM also was developed for the 200-PO-1 Groundwater OU. The CEM identifies potentially complete human and ecological exposure pathways in the Near Field, Far Field, and river exposure areas. Potential human receptors, including Native American subsistence users, are assumed to be hypothetical future domestic groundwater users. Ecological receptors are limited to aquatic organisms in the Columbia River that may be exposed to contaminants in groundwater that discharges into the river. The following potential exposure routes were identified:

- Ingestion of contaminated water by drinking or from food preparation
- Inhalation of contaminant vapors during showering or other household activities
- Dermal contact exposure to contaminant in groundwater
- External radiation exposure from radioactive contaminants in groundwater

In addition, the following potential exposure route was identified for the Near Field and river exposure areas:

- Consumption of fish from the affected portion of the river

Chapter 6 describes the BRA that was conducted to evaluate current and potential future risks to hypothetical human and ecological receptors. Table ES-1 provides the results of the BRAs for each of the Near Field, Far Field, and river exposure areas. This table identifies the standards that are exceeded under current and estimated future groundwater conditions, as well as a summary of the quantified risk results that would be encountered should no remedial action be taken. Based on the information provided in the modeling and results of the BRA, it is appropriate to proceed with the FS for the 200-PO-1 Groundwater OU.

**Table ES-1. Summary of Groundwater Conditions in the 200-PO-1 Operable Unit that Exceed Standards and Present a Basis for Feasibility Study**

| Exposure Area | Final COPC | Groundwater Standard[a] | Current Exceedance[b] | Year Maximum Projected Concentration Achieves Groundwater Standard |
|---|---|---|---|---|
| Near Field | Iodine-129 | 1 pCi/L | Yes | 2709 |
| Near Field | Technetium-99 | 900 pCi/L | Yes | 2034 |
| Near Field | Strontium-90 | 8 pCi/L | No | 2034 |
| Near Field | Tritium | 20,000 pCi/L | Yes | 2059 |
| Near Field | Trichloroethene | 0.49 µg/L | Yes | 2059 |
| Near Field | Nitrate | 45,000 µg/L/25,600 µg/L | Yes | 2309/2509 |
| Near Field | Uranium | 30 µg/L | No | 2209 |
| Far Field | Iodine-129 | 1 pCi/L | Yes | 2709 |
| Far Field | Tritium | 20,000 pCi/L | Yes | 2084 |
| Far Field | Carbon tetrachloride | 0.34 µg/L | Yes | 2034 |
| Far Field | Tetrachloroethene | 0.081 µg/L | Yes | 2059[c] |
| Far Field | Trichloroethene | 0.49 µg/L | Yes | 2059[d] |
| Far Field | Nitrate | 45,000 µg/L/25,600 µg/L | Yes | 2309/2509 |
| River | Tritium | 20,000 pCi/L | Yes | 2084 |
| River | Nitrate | 45,000 µg/L/25,600 µg/L | Yes | 2309/2509 |

Notes:

a. Standard Exceeded:

MCL = Maximum contaminant level established by the *Safe Drinking Water Act of 1974* groundwater cleanup

Standard = WAC 173-340-720

b. Current Exceedance:

**Table ES-1. Summary of Groundwater Conditions in the 200-PO-1 Operable Unit that Exceed Standards and Present a Basis for Feasibility Study**

Yes = Calculated groundwater exposure point concentration[2] currently exceeds the applicable standard(s).

No = Calculated groundwater exposure point concentration does not currently exceed the MCL, WAC 173-340-708 risk threshold of 1 x 10-5 for multiple hazardous substances or the upper National Contingency Plan (NCP) threshold of $1 \times 10^{-4}$, or a noncancer hazard index of 1.

c. Represents the year that the $10^{-6}$ risk level is achieved.

d. Represents the year that the MCL of 5 µg/L is achieved.

*Safe Drinking Water Act of 1974*, 42 USC 300, et seq.

WAC 173-340-708, "Model Toxics Control Act—Cleanup," "Human Health Risk Assessment Procedures," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-708.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Ground Water Cleanup Standards," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-720.

COPC = contaminant of potential concern

[2] The exposure point concentration is the 90th percentile value for each COPC calculated from the current groundwater data set.

# Contents

**1 Introduction ..... 1-1**
1.1 Purpose, Scope, and Objectives of Report ..... 1-1
1.1.1 Purpose ..... 1-1
1.1.2 Scope ..... 1-1
1.1.3 Objectives ..... 1-5
1.2 Site Background ..... 1-6
1.2.1 Site Description ..... 1-6
1.2.2 Site History ..... 1-13
1.2.3 Previous Investigations ..... 1-15
1.2.4 Regulatory Basis and History ..... 1-16
1.2.5 Current Land Use, Demography, and Future Land Use ..... 1-17
**2 Study Area Investigation ..... 2-1**
2.1 Historical Review ..... 2-1
2.2 Remedial Investigation Field Characterization Activities ..... 2-4
2.2.1 Near Field Investigation ..... 2-4
2.2.2 Far Field Investigations ..... 2-11
2.3 Soil and Vadose Zone Investigations ..... 2-17
2.3.1 Geological and Geophysical Data Compilation ..... 2-17
2.4 Groundwater Chemistry Data Compilation ..... 2-45
2.4.1 COPC Sampling ..... 2-47
2.4.2 Quality Assurance/Data Quality Assessment ..... 2-47
**3 Physical Characteristics of the Study Area ..... 3-1**
3.1 Surface Features ..... 3-1
3.2 Meteorology ..... 3-4
3.2.1 Wind ..... 3-4
3.2.2 Temperature and Humidity ..... 3-4
3.2.3 Precipitation ..... 3-6
3.2.4 Fog and Visibility ..... 3-6
3.2.5 Severe Weather ..... 3-6
3.3 Surface Water Hydrology ..... 3-6
3.3.1 Water Quality of the Columbia River ..... 3-8
3.3.2 Yakima River ..... 3-9
3.3.3 Springs and Streams ..... 3-9
3.3.4 Columbia Riverbank Springs ..... 3-9
3.3.5 Runoff and Net Infiltration ..... 3-10
3.3.6 Flooding ..... 3-10

3.3.7 Non-Riverine Surface Water ..... 3-11
3.4 Geology ..... 3-12
3.4.1 General Geologic Setting of the Operable Unit ..... 3-12
3.4.2 200-PO-1 Groundwater Operable Unit Near Field Suprabasalt Geology ..... 3-13
3.4.3 200-PO-1 Groundwater OU Far Field Suprabasalt Geology ..... 3-18
3.5 Soils ..... 3-23
3.6 Hydrogeology ..... 3-27
3.6.1 Summary of Aquifer Systems in the 200-PO-1 Groundwater Operable Unit ..... 3-27
3.6.2 200-PO-1 Groundwater Operable Unit Hydrostratigraphy ..... 3-27
3.6.3 Basalt and Interbed Aquifers ..... 3-28
3.6.4 Suprabasalt Aquifer System ..... 3-28
3.6.5 Aquifer Intercommunication ..... 3-30
3.6.6 Effects of Site Geology on Groundwater and Plume Movement and Behavior ..... 3-37
3.6.7 Conceptual Site Model ..... 3-58
3.6.8 Geochemistry ..... 3-85
3.6.9 Groundwater Recharge ..... 3-88
3.6.10 Groundwater Velocity and Travel Time ..... 3-92
3.6.11 Groundwater/Surface Water Interactions ..... 3-93
3.6.12 Summary of Aquifer Properties ..... 3-99
3.7 Water Use ..... 3-99
3.7.1 Surface Water Use in the Vicinity of the 200-PO-1 Groundwater OU ..... 3-101
3.8 Ecology ..... 3-101
**4 Nature and Extent of Contamination ..... 4-1**
4.1 Background Concentrations ..... 4-8
4.2 Operable Unit Contaminants ..... 4-12
4.2.1 Tritium ..... 4-12
4.2.2 Nitrate ..... 4-19
4.2.3 Iodine-129 ..... 4-24
4.2.4 Strontium-90 ..... 4-28
4.2.5 Technetium-99 ..... 4-28
4.2.6 Uranium ..... 4-32
4.2.7 Minor COPCs Volatile Organic Compounds (Tetrachloroethene, Trichloroethene, and Carbon Tetrachloride) ..... 4-32
4.3 200-PO-1 RI/FS Work Plan Well Sampling Results ..... 4-38
4.3.1 Results from Remedial Investigation Work Plan Appendix A, Table A3.2-2, Groundwater Sampling ..... 4-39
4.3.2 Groundwater Sampling Results from Exploratory Boreholes ..... 4-40

**5 Contaminant Fate and Transport and Conceptual Exposure Model ..... 5-1**
5.1 Groundwater Modeling Process ..... 5-2
5.1.1 Contaminants of Potential Concern Characteristics ..... 5-2
5.1.2 Contaminant Mobility Discussion ..... 5-2
5.1.3 Fate and Transport Models and Approach to Simulations ..... 5-5
5.1.4 Central Plateau Near Field Hydrogeologic Conceptual Site Model Development ..... 5-7
5.2 Groundwater Impacts ..... 5-12
5.2.1 Simulation of Contaminant Migration in the 200-PO-1 Near Field Environment ..... 5-12
5.2.2 Simulation of Contaminant Migration in the 200-PO-1 Far Field Environment ..... 5-43
5.2.3 Uncertainty in Simulated Future Conditions ..... 5-65
5.3 Conceptual Exposure Model ..... 5-65
5.3.1 Current and Reasonably Anticipated Future Land Use ..... 5-65
5.3.2 Groundwater Beneficial Use ..... 5-67
5.3.3 Surface Water Beneficial Use ..... 5-68
5.3.4 200-PO-1 Groundwater Operable Unit Exposure Areas ..... 5-68
5.3.5 Conceptual Exposure Model for Human Health and the Environment ..... 5-73
**6 Baseline Risk Assessment ..... 6-1**
6.1 Selection of Contaminants of Potential Concern ..... 6-3
6.1.1 Data Used to Select Contaminants of Potential Concern ..... 6-3
6.1.2 Identification of Action Levels ..... 6-4
6.1.3 Process Used to Select Initial Contaminants of Potential Concern ..... 6-6
6.1.4 Process Used to Select Final Contaminants of Potential Concern ..... 6-8
6.1.5 Exposure Point Concentrations ..... 6-10
6.2 Summary of Final Groundwater COPCs ..... 6-12
6.2.1 Exposure Assessment ..... 6-12
6.2.2 Toxicity Assessment ..... 6-13
6.2.3 Risk Characterization ..... 6-16
6.2.4 Uncertainties in Risk Assessment ..... 6-41
6.3 Ecological Risk ..... 6-49
6.4 Summary of the Native America Risk Assessments ..... 6-49
6.5 Summary of the CTUIR Risk Assessment ..... 6-50
6.5.1 Use of Groundwater as a Potential Drinking Water Source ..... 6-50
6.5.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use ..... 6-52
6.6 Summary of the Yakama Nation Risk Assessment ..... 6-55
6.6.1 Use of Groundwater as a Potential Drinking Water Source ..... 6-55
6.6.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use ..... 6-57

6.7 Summary of the EPA Tap Water Equations ..... 6-60
6.7.1 Use of Groundwater as a Potential Drinking Water Source ..... 6-60
6.8 Comparison of Native American and EPA Tap Water Results Risk Estimates ..... 6-62
**7 Summary and Conclusions ..... 7-1**
7.1 Summary ..... 7-1
7.2 Conclusions ..... 7-5
**8 References ..... 8-1**

## Appendices

**A Plate Maps ..... A-i**
**B Annotated Biliography ..... B-i**
**C Historical Water Table Maps ..... C-i**
**D Hydrogeologic Cross Sections for 200-PO-1 Groundwater Operable Unit ..... D-i**

# Figures

Figure 1-1. Location of the Hanford Site ..... 1-2
Figure 1-2. Location of the 200-PO-1 Groundwater Operable Unit ..... 1-3
Figure 1-3. The CERCLA Process ..... 1-4
Figure 1-4. 200 East Area Source Sites Overlying 200-PO-1 Groundwater OU ..... 1-7
Figure 1-5. Inferred Regional Groundwater Elevation Contours Beneath the Hanford Site (PNNL-18427) ..... 1-11
Figure 2-1. 200-PO-1 Groundwater Operable Unit Near Field Monitoring Wells (2008 Annual Report ..... 2-6
Figure 2-2. 200-PO-1 Groundwater Operable Unit Far Field Monitoring Wells Sampled Per DOE/RL-2003-04 (2008 Annual Report) and Additional Wells Sampled from DOE/RL-2007-31 ..... 2-7
Figure 2-3. Locations of Wells (A 2, A 4, and A 5) in the PUREX Area to be Opportunistically Sampled for 200-PO-1 Groundwater Operable Unit Analytes (DOE/RL-2007-31) ..... 2-13
Figure 2-4. Location of Well A 30 in the PUREX Area to be Opportunistically Sampled for 200-PO-1 Groundwater Operable Unit Analytes (DOE/RL-2007-31) ..... 2-14
Figure 2-5. Aquifer Tubes in the 200-PO-1 Groundwater Operable Unit ..... 2-18
Figure 2-6. Aquifer Tube Location Along the Columbia River ..... 2-19
Figure 2-7. 200-PO-1 Operable Unit Aquifer Tube Installation ..... 2-19
Figure 2-8. 200-PO-1 Groundwater Sampling of Existing Wells ..... 2-20
Figure 2-9. 200-PO-1 Groundwater Sample Collection ..... 2-20
Figure 2-10. 200-PO-1 Fugro® Airborne Electromagnetic and Magnetic Surveys ..... 2-23
Figure 2-11. 200-PO-1 Heli-GEOTEM® Derived Electrical Resistivity Along Profile J-J' ..... 2-27
Figure 2-12. 200-PO-1 RESOLVE® Derived Electrical Resistivity Along Profile J-J' ..... 2-28
Figure 2-13. 200-PO-1 RESOLVE® Derived Electrical Resistivity, 32 m Depth ..... 2-29
Figure 2-14. 200-PO-1 Residual Magnetic Survey Results ..... 2-31
Figure 2-15. 200-PO-1 200 East Area Seismic Reflection Surveys (FY 2008) ..... 2-35
Figure 2-16. 200-PO-1 Seismic Reflection Surveys (FY 1979-1980 and FY 2008) ..... 2-36
Figure 2-17. 200-PO-1 Interpretation of 7th Street Seismic Reflection Profile ..... 2-37
Figure 2-18. 200-PO-1 Interpretation of BWIP FY79-02 Seismic Reflection Profile ..... 2-38
Figure 2-19. 200-PO-1 Check Shot Surveys ..... 2-39
Figure 2-20. 200-PO-1 Check Shot Survey: Well 299-E34-07 – Geology Correlation ..... 2-41
Figure 2-21. 200-PO-1 Check Shot Surveys, Geologic Units And Seismic Section Correlation ..... 2-42
Figure 2-22. 200-PO-1 Advanced Borehole Logging Truck ..... 2-43
Figure 2-23. 200-PO-1 Well 299-E17-3 Hydrogeology Summary Log Composite Lithology ..... 2-44
Figure 3-1. Generalized Structural Geologic Map of the Pasco Basin ..... 3-2
Figure 3-2. 200-PO-1 Groundwater Operable Unit Topography ..... 3-3
Figure 3-3. Hanford Site Meteorological Monitoring Network Location Map ..... 3-5

Figure 3-4. Surface Water Features of the Hanford Site ..... 3-7
Figure 3-5. Generalized Hydrostratigraphy of the Hanford Site ..... 3-14
Figure 3-6. Hydrostratigraphy near the Columbia River (300 Area) ..... 3-15
Figure 3-7. Near Field Hydrogeology Depicting Truncation of Ringold Units onto Uplifted Basalt ..... 3-16
Figure 3-8. Near Field Hydrogeology Conceptual Relationships – Multiple Migrating Channels ..... 3-17
Figure 3-9. Clastic Dike in the Hanford Formation ..... 3-19
Figure 3-10. Near Field Pleistocene Paleo-Erosional Surface Topography ..... 3-20
Figure 3-11. Cross-Section Location Map, 200-PO-1 Groundwater Operable Unit ..... 3-21
Figure 3-12. Far Field Hydrogeology Section O-O' ..... 3-25
Figure 3-13. Far Field Hydrogeology Section F-F' ..... 3-26
Figure 3-14. Potentiometric Surface Map of the Basalt Confined Aquifer ..... 3-29
Figure 3-15. Suprabasalt Aquifer Thickness, 200-PO-1 Groundwater OU Interest Area ..... 3-31
Figure 3-16. Potentiometric Surface Map of the Lower Suprabasalt Confined Aquifer ..... 3-32
Figure 3-17. Hydraulic Head Comparisons Between Confined and Unconfined Wells Within the Near Field ..... 3-33
Figure 3-18. Hydraulic Head Variations - Suprabasalt Unconfined and Basalt Confined Aquifers - Far Field ..... 3-34
Figure 3-19. Central Plateau Contaminant Conceptual Model, 200-PO-1 Groundwater OU Current Conditions (2008) ..... 3-35
Figure 3-20. Liquid Effluent Disposal Activities Across the Hanford Site ..... 3-38
Figure 3-21. Pre-Hanford Distribution of Hydrogeologic Units at the Water Table ..... 3-39
Figure 3-22. Distribution of Hydrogeologic Units at the Water Table During Hanford Operations ..... 3-40
Figure 3-23. Variability in Hydraulic Conductivities Within the Suprabasalt Aquifer (Well 399-1-23) ..... 3-41
Figure 3-24. Far Field Hanford/Ringold Contact Relationships Within the Suprabasalt Aquifer ..... 3-43
Figure 3-25. Far Field Hydrogeology Section P-P' ..... 3-44
Figure 3-26. Far Field Hydrogeology Section J-J' ..... 3-45
Figure 3-27. Example of Hanford/Ringold Contact Structure Map Near Columbia River (300 Area) ..... 3-48
Figure 3-28. Near Field Hydrogeology Showing May Junction Fault ..... 3-49
Figure 3-29. 200 East Area Groundwater Flow Patterns (2008) ..... 3-51
Figure 3-30. Groundwater Contaminant Plumes Source Area to Columbia River (2008) ..... 3-53
Figure 3-31. Representative Historical Groundwater Elevations in 200 East Area ..... 3-54
Figure 3-32. Primary Contaminant Flow Path Within the Upper Unconfined Aquifer as Illustrated by the Evolution of Observed Tritium Plume in Groundwater ..... 3-55
Figure 3-33. Hydrogeology Relative to Contaminant Flow Paths ..... 3-56
Figure 3-34. Core Sample Showing Hanford Formation Gravel ..... 3-57

Figure 3-35. Core Sample Showing Hanford-Ringold Contact ..... 3-57
Figure 3-36. Core Sample Showing Ringold-LMU Contact ..... 3-58
Figure 3-37. Near Field Conceptual Site Model Aquifer Recharge Beneath B-Pond (During Historical Period of Discharge) and the Treated Effluent Disposal Facility ..... 3-59
Figure 3-38. Unconfined and Confined Aquifer Head Comparisons (2008) ..... 3-61
Figure 3-39. Near Field Source Area Identifying Liquid Effluent Disposal, Cribs, Ponds, and Ditches ..... 3-63
Figure 3-40. Near Field Conceptual Site Model ..... 3-67
Figure 3-41. Waste Sites Within the Far Field ..... 3-68
Figure 3-42. Example Vertical Contaminant Distribution in Suprabasalt Aquifer System Well near the Columbia River (399-3-18) ..... 3-71
Figure 3-43. Far Field Hydrogeologic Cross-Section H-H' ..... 3-72
Figure 3-44. Contaminant Conceptual Site Model for Far Field ..... 3-75
Figure 3-45. Groundwater Flow of the Hyporheic Zone ..... 3-77
Figure 3-46. Generalized Groundwater Flow During Low River Stage ..... 3-78
Figure 3-47. View of 300 Area Hypothetical Groundwater Flow into the Columbia River ..... 3-79
Figure 3-48. Footprint of Potential Contaminated Groundwater Impact (Upwelling) within HSU 1 Intersected Portions of the Columbia River in the Vicinity of the 300 Area ..... 3-81
Figure 3-49. Shoreline Variations in Uranium Concentrations (Dashed Line is Hanford/Ringold Contact) ..... 3-82
Figure 3-50. Southeastern Tritium Plume Extent (PO-1 OU) Along the 300 Area Shoreline ..... 3-83
Figure 3-51. 300 Area Columbia Riverbed Transect Sampling Locations ..... 3-84
Figure 3-52. Riverbed Tritium Concentrations – 300 Area and Vernita Bridge (2008) ..... 3-85
Figure 3-53. Rivershore (Aquifer Tube) and Aquifer (Monitoring Well) Network Near the Hanford Town Site 200-PO-1 Groundwater Operable Unit ..... 3-86
Figure 3-54. Selected Results for Depth Discrete Water Sampling in the Suprabasalt Aquifer from Well 399-3-18 ..... 3-87
Figure 3-55. Depth to Groundwater (Vadose Zone) in the 200-PO-1 Groundwater Operable Unit ..... 3-89
Figure 3-56. Liquid Effluent Disposal Activities to B-Pond and the Treated Effluent Disposal Facility ..... 3-90
Figure 3-57. Water Table Map of the Hanford Site (June 1993) ..... 3-91
Figure 3-58. Inferred Pre-Hanford Site Operations Water Table Map ..... 3-94
Figure 3-59. Groundwater Flow Path and Velocity Estimation Based on Peak Tritium Contaminant Arrival Time ..... 3-95
Figure 3-60. Contaminant Preferential Flow Path at the Hanford Town Site ..... 3-97
Figure 3-61. Vertical Contaminant Uranium Concentrations Along the 300 Area Shoreline ..... 3-98
Figure 3-62. Aquifer Tube Distribution near the Hanford Town Site ..... 3-98
Figure 3-63. Hydraulic Conductivity Values Derived from Well Pump Tests ..... 3-100
Figure 4-1. Far Field Wells ..... 4-2

Figure 4-2. Location of Additional Wells for Characterization Sampling ..... 4-7
Figure 4-3. Tritium Plume 2008 ..... 4-14
Figure 4-4. Tritium Plume in the Near Field near the Sources of Tritium Groundwater Contamination ..... 4-15
Figure 4-5. Tritium Groundwater Plume in 1980 and 2004 ..... 4-16
Figure 4-6. Tritium Concentrations at Well 699-24-33 Located near NRDWL ..... 4-17
Figure 4-7. Tritium Concentrations at Well 699-20-20 in the 600 Area ..... 4-18
Figure 4-8. Tritium Concentrations at Well 699-37-E4 near the Columbia River ..... 4-18
Figure 4-9. Tritium Concentrations in Wells at PUREX Cribs ..... 4-19
Figure 4-10. Nitrate Concentrations in the 200-PO-1 OU Near Field, Upper Part of Unconfined Aquifer (Average FY 2007 and FY 2008 Concentrations) ..... 4-21
Figure 4-11. Nitrate Concentrations in the 200-PO-1 OU Far Field, Upper Part of Unconfined Aquifer (Average FY 2007 and FY 2008 Concentrations) ..... 4-22
Figure 4-12. Nitrate Groundwater Plume in 1980 and 2004 ..... 4-23
Figure 4-13. Nitrate Concentrations in Well 299-E24-16 near the 216-A-10 Crib ..... 4-24
Figure 4-14. Iodine-129 Plume ..... 4-25
Figure 4-15. Iodine-129 Concentrations in Well 299-E17-14 at the 216-A-36B Crib ..... 4-26
Figure 4-16. Iodine-129 Plume in 1994 and 2004 Showing Slight Reduction in Overall Area and Reduction in Area of the Portion Greater than 5 pCi/L ..... 4-27
Figure 4-17. Strontium-90 Concentrations at Well 299-E17-14 near the 216-A-36B Crib ..... 4-29
Figure 4-18. Technetium-99 Concentrations at Well 299-E24-33 and Well 299-E25-93 at WMA A-AX ..... 4-30
Figure 4-19. Technetium-99 Plume Map of the WMA C and WMA A-AX in the 200 East Area ..... 4-31
Figure 4-20. Gross Alpha Concentrations in Well 299-E17-14 ..... 4-33
Figure 4-21. Uranium Concentrations in Well 299-E17-14 and Well 299-E24-16 at the PUREX Cribs ..... 4-34
Figure 4-22. Uranium Plume near the PUREX Cribs ..... 4-35
Figure 4-23. Tetrachloroethene Concentrations in Two Wells at the Solid Waste Landfill ..... 4-36
Figure 4-24. Trichloroethene Concentrations at Two Wells at the Solid Waste Landfill ..... 4-37
Figure 4-25. Carbon Tetrachloride Concentrations at Well 699-26-33 at the Nonradioactive Dangerous Waste Landfill ..... 4-38
Figure 5-1. Plan View of Central Plateau Groundwater Model Domain Boundary and Cross-Section Locations ..... 5-8
Figure 5-2. Location and Extent of the Pipe Pathways for Transport Calculations in the Far Field Portion of the 200-PO-1 Groundwater Operable Unit and Their Location Relative to the Central Plateau Modflow Model Domain and Inferred Groundwater Tritium Plume Location ..... 5-9
Figure 5-3. Selected Points of Calculation for Illustration of Future COPC Concentration Trends in the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain ..... 5-14

Figure 5-4. Iodine-129 Plume at Selected Times for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain ..... 5-19
Figure 5-5. Technetium-99 Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain ..... 5-23
Figure 5-6. Tritium Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain ..... 5-27
Figure 5-7. Nitrate Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain ..... 5-31
Figure 5-8. Trichloroethene Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain ..... 5-33
Figure 5-9. Strontium-90 Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain ..... 5-37
Figure 5-10. Uranium Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain ..... 5-41
Figure 5-11. Spatial Discretization of the Pipe Pathways Along with the Saturated Thickness Variation in the Unconfined Aquifer ..... 5-43
Figure 5-12. Predicted Concentration of Tritium in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway ..... 5-57
Figure 5-13. Predicted Concentration of Iodine-129 in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway ..... 5-58
Figure 5-14. Predicted Concentration of Technetium-99 in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway ..... 5-59
Figure 5-15. Predicted Concentration of Nitrate in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway ..... 5-60
Figure 5-16. Predicted Concentration of Uranium in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway ..... 5-61
Figure 5-17. Predicted Concentration of Tetrachloroethene in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway ..... 5-62
Figure 5-18. Predicted Concentration of Trichloroethene in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway ..... 5-63
Figure 5-19. Predicted Concentration of Carbon Tetrachloride in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway ..... 5-64
Figure 5-20. Monitoring Wells in the 200-PO-1 Groundwater Operable Unit ..... 5-70
Figure 5-21. Conceptual Exposure Model for Potential Human and Ecological Receptors in the 200-PO-1 Groundwater Operable Unit ..... 5-75
Figure 6-1. Analytical Data Processing for COPC Selection Process ..... 6-5
Figure 6-2. Initial COPC Identification ..... 6-7

Figure 6-3. Final COPC Identification ..... 6-9
Figure 6-4. Final COPC Verification ..... 6-11
Figure 7-1. Major Groundwater Plumes in the Hanford Central Plateau ..... 7-2

# Tables

Table 1-1. Decision Structure and Operable Units for the Inner and Outer Areas ..... 1-9
Table 1-2. Groundwater Plume Areas ..... 1-13
Table 1-3. Major Sources of Wastewater Discharge to the 200-PO-1 Groundwater Operable Unit ..... 1-14
Table 1-4. Current and Potential Future Land Use ..... 1-18
Table 2-1. Contaminants of Potential Concern in the 200-PO-1 Groundwater OU ..... 2-3
Table 2-2. Status Summary of 200-PO-1 Remedial Investigation Characterization Activities ..... 2-9
Table 2-3. 200-PO-1 Groundwater Monitoring Wells in the Near Field Area ..... 2-15
Table 2-4. 200-PO-1 Groundwater Monitoring Wells in the Far Field Area ..... 2-16
Table 2-5. Geophysical Logging Tool, Technology, and Corresponding Measured Properties ..... 2-43
Table 2-6. Remedial Investigation Work Plan Opportunistic Well Status ..... 2-45
Table 2-7. Samples by Field Activity ..... 2-46
Table 3-1. Hydraulic Conductivity Results for Well 399-1-23 ..... 3-41
Table 3-2. Estimated Groundwater Velocity in the 200-PO-1 Groundwater Operable Unit Unconfined Aquifer, Based on Arrival of Tritium Concentration Peaks ..... 3-92
Table 3-3. List of Endangered, Threatened, Sensitive, and Candidate Species Occurring or Potentially Occurring in the 200-PO-1 Area on the Hanford Site (PNNL-18427) ..... 3-103
Table 3-4. List of Endangered, Threatened, Sensitive, and Candidate Species Affected by Discharges to the Columbia River in the 200-PO-1 Area on the Hanford Site (PNNL-18427) ..... 3-106
Table 4-1. Contaminants and Analytical Methods ..... 4-3
Table 4-2. Waste Sites Above the 200-PO-1 Groundwater Operable Unit ..... 4-5
Table 4-3. Detected Groundwater Constituents in the 43 Wells Selected for Site Characterization in FY 2008 ..... 4-9
Table 5-1. Physical Characteristics of Selected Contaminants of Potential Concern ..... 5-3
Table 5-2. Contaminant Distribution Coefficients for Contaminants of Potential Concern in Fate and Transport Modeling ..... 5-4
Table 5-3. Maximum Near Field Concentration of Iodine-129 (pCi/L) for Selected Points of Calculation at Selected Timesteps ..... 5-17
Table 5-4. Maximum Near Field Concentration of Technetium-99 (pCi/L) for Selected Points of Calculation at Selected Timesteps ..... 5-21
Table 5-5. Maximum Near Field Concentration of Tritium (pCi/L) for Selected Points of Calculation at Selected Timesteps ..... 5-25
Table 5-6. Maximum Near Field Concentration of Nitrate (μg/L) for Selected Points of Calculation at Selected Timesteps ..... 5-29
Table 5-7. Maximum Near Field Concentration of Trichloroethene (μg/L) for Selected Points of Calculation at Selected Timesteps ..... 5-35

Table 5-8. Maximum Concentration of Strontium-90 (pCi/L) for Selected Points of Calculation at Selected Timesteps ..... 5-36

Table 5-9. Maximum Near Field Concentration of Uranium (µg/L) for Selected Points of Calculation at Selected Timesteps ..... 5-39

Table 5-10. Pipe Pathway Property Details ..... 5-44

Table 5-11. Predicted Far Field Concentration of Tritium (pCi/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration ..... 5-47

Table 5-12. Predicted Far Field Concentration of Iodine-129 (pCi/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration ..... 5-49

Table 5-13. Predicted Far Field Concentration of Technetium-99 (pCi/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration ..... 5-50

Table 5-14. Predicted Far Field Concentration of Nitrate (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration ..... 5-51

Table 5-15. Predicted Far Field Concentration of Uranium (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration ..... 5-52

Table 5-16. Predicted Far Field Concentration of Tetrachloroethene (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration ..... 5-53

Table 5-17. Predicted Far Field Concentration of Trichloroethene (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration ..... 5-54

Table 5-18. Predicted Far Field Concentration of Carbon Tetrachloride (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration ..... 5-55

Table 5-19. Summary of 200-PO-1 Groundwater Monitoring Wells in the Near Field Exposure Area ..... 5-71

Table 5-20. Summary of 200-PO-1 Groundwater Monitoring Wells in the Far Field Exposure Area ..... 5-72

Table 5-21. Summary of 200-PO-1 Groundwater Monitoring Wells in the River Exposure Area ..... 5-73

Table 6-1. Summary of Groundwater COPCs Selected for Final COPC Evaluation ..... 6-8

Table 6-2. Summary of Final Groundwater COPCs Identified for the 200-PO-1 Operable Unit ..... 6-12

Table 6-3. Summary of Near Field 90th Percentile Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels ..... 6-20

Table 6-4. Summary of Near Field 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions ..... 6-21

Table 6-5. Summary of Near Field 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Non-Cancer Hazard Index ..... 6-22

Table 6-6. Summary of Far Field 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173-340-720 Groundwater Cleanup Levels ..... 6-23

Table 6-7. Summary of Far Field 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions ..... 6-23

Table 6-8. Summary of Far Field 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Non-Cancer Hazard Index ..... 6-24

Table 6-9. Summary of River Area 90th Percentile Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels ..... 6-25

Table 6-10. Summary of River Area 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions ..... 6-26

Table 6-11. Summary of River Area 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Non-Cancer Hazard Index ..... 6-27

Table 6-12. Near Field Monitoring Wells Selected for Calculating Future Groundwater Concentrations ..... 6-28

Table 6-13. Far Field Monitoring Wells Selected for Calculating Future Groundwater Concentrations ..... 6-30

Table 6-14. Summary of Near Field 90th Percentile and Maximum Projected Future Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels ..... 6-33

Table 6-15. Summary of Far Field 90th Percentile and Maximum Projected Future Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels ..... 6-36

Table 6-16. Summary of Near Field Maximum Projected Future Groundwater Concentrations and Associated Sum of Fractions ..... 6-39

Table 6-17. Summary of Near Field Maximum Projected Future Groundwater Concentrations and Associated Cancer Risk and Non-Cancer Hazard Index ..... 6-39

Table 6-18. Summary of Far Field Maximum Projected Future Groundwater Concentrations Associated Sum of Fractions ..... 6-40

Table 6-19. Summary of Far Field 90th Percentile Future Groundwater Concentrations Associated Cancer Risk and Non-Cancer Hazard Index ..... 6-40

Table 6-20. Comparison of Aquifer Tube and Monitoring Well Results ..... 6-44

Table 6-21. Percentile Concentrations and Summary Statistics ..... 6-46

Table 6-22. Maximum Contaminant Levels and ELCRs for Final COPCs ..... 6-48

Table 6-23. Confederated Tribes of the Umatilla Indian Reservation Exposure Scenario – Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source ..... 6-50

Table 6-24. CTUIR Exposure Scenario – Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge ..... 6-53

Table 6-25. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source ..... 6-55

Table 6-26. Yakama Nation Exposure Scenario – Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge ..... 6-58

Table 6-27. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations ..... 6-60

Table 6-28. Comparison of Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations ..... 6-65

Table 7-1. Summary of Final Groundwater COPCs ..... 7-3

Table 7-2. Summary of Groundwater Conditions in the 200-PO-1 Operable Unit that Exceed Standards and Present a Basis for Feasibility Study ..... 7-3

# Terms

| | |
|---|---|
| AAMSR | aggregate area management study report |
| AEA | alpha energy analysis |
| ALE | Arid Lands Ecology |
| ARAR | applicable or relevant and appropriate requirement |
| AS | alpha spectroscopy |
| AWQC | ambient water quality criteria |
| BCG | biota concentration guide |
| bgs | below ground surface |
| BRA | baseline risk assessment |
| BWIP | Basalt Waste Isolation Project |
| CalEPA | California Environmental Protection Agency |
| CAS | Chemical Abstract System |
| CCC | criteria continuous concentration |
| CCU | Cold Creek Unit |
| CEM | conceptual exposure model |
| CERCLA | *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* |
| CLARC | *Cleanup Levels and Risk Calculations (Under the Model Toxics Control Act Cleanup Regulation)* |
| CMC | criteria maximum concentration |
| CMS | *(RCRA) Corrective Measures Study* |
| COC | contaminant of concern |
| COPC | contaminant of potential concern |
| CSM | conceptual site model |
| CTUIR | Confederated Tribes of the Umatilla Indian Reservation |
| DOE | U.S. Department of Energy |
| DOH | (Washington State) Department of Health |
| DQA | data quality assessment |
| DQO | data quality objective |

| | |
|---|---|
| DST | double-shell tank |
| DTB | depth to bottom |
| DTW | depth to water |
| DWS | drinking water standards |
| Ecology | Washington State Department of Ecology |
| EIS | environmental impact statement |
| ELCR | excess lifetime cancer risk |
| EPA | U.S. Environmental Protection Agency |
| EPC | exposure point concentration |
| ERDF | Environmental Restoration Disposal Facility |
| FFTF | Fast Flux Test Facility |
| FS | feasibility study |
| FY | fiscal year |
| GEA | gamma energy analysis |
| GPC | gas proportional counting |
| HCP EIS | *Hanford Comprehensive Land Use Plan Environmental Impact Statement* |
| HEAST | Health Effects Assessment Summary Table |
| HEIS | Hanford Environmental Information System |
| HFFACO | Hanford Federal Facility Agreement and Consent Order |
| HGA | HydroGeo Analyst (database) |
| HHE | human health and the environment |
| HI | hazard index |
| HMS | Hanford Meteorology Station |
| HQ | hazard quotient |
| HSU | hydrostratigraphic unit |
| IC | institutional control |
| IDF | Integrated Disposal Facility |
| IRIS | Integrated Risk Information System |
| Kd | distribution coefficient |
| LIGO | Laser Interferometer Gravitational Wave Observatory |

| | |
|---|---|
| LMU | lower mud unit |
| LPU | low permeability unit |
| LSC | liquid scintillation counting |
| MCL | maximum contaminant level |
| MCLG | maximum contaminant level goal |
| MRDL | maximum residual disinfectant level |
| MTCA | (Washington State) Model Toxics Control Act |
| MW | molecular weight |
| N/A | not applicable |
| NCEA | National Center for Environmental Assessment |
| NCP | National Contingency Plan |
| NDWAC | National Drinking Water Advisory Council |
| NEPA | *National Environmental Policy Act of 1969* |
| NJDEP | New Jersey Department of Environmental Protection |
| NPDWR | national primary drinking water regulations |
| NPL | National Priorities List |
| NRDWL | Nonradioactive Dangerous Waste Landfill |
| OEHHA | Office of Environmental Health Hazard Assessment |
| OU | operable unit |
| PMG | pre-Missoula gravel |
| PPRTV | provision peer reviewed toxicity value |
| PRG | preliminary remediation goal |
| PSPL | Puget Sound Power and Light |
| PUREX | Plutonium-Uranium Extraction (Plant) |
| QA | quality assurance |
| QC | quality control |
| RAIS | *Risk Assessment Information System* |
| RAO | remedial action objective |
| RCBRA | River Corridor Baseline Risk Assessment |
| RCRA | *Resource Conservation and Recovery Act of 1976* |

| | |
|---|---|
| REDOX | Reduction-Oxidation |
| RfD | oral reference dose |
| RFI | *RCRA Facility Investigation* (Report) |
| RI | remedial investigation |
| RME | reasonable maximum exposure |
| ROD | record of decision |
| SALDS | state-approved land disposal site |
| SAP | sampling and analysis plan |
| SDWA | Safe Drinking Water Act |
| SFO | oral slope factor |
| SST | single-shell tank |
| SVOC | semi-volatile organic compound |
| SWL | Solid Waste Landfill |
| TEDF | Treated Effluent Disposal Facility |
| Tri-Party Agreement | *Hanford Federal Facility Agreement and Consent Order* |
| TSD | treatment, storage, and disposal |
| UCL | upper confidence limit |
| UPR | unplanned release |
| USACE | U.S. Army Corps of Engineers |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| VOC | volatile organic compound |
| WAC | *Washington Administrative Code* |
| WDFW | Washington Department of Fish and Wildlife |
| WIDS | Waste Information Data System |
| WMA | Waste Management Area |
| WPPSS | Washington Public Power Supply System |
| WRIA | Water Resource Inventory Area |

# 1 Introduction

This remedial investigation (RI) report presents the observations and findings developed through the RI process performed at the 200-PO-1 Groundwater Operable Unit (OU), located within the U.S. Department of Energy's (DOE's) Hanford Site in Washington State (Figure 1-1 and Figure 1-2). The RI report follows an outline based on guidance developed by the U.S. Environmental Protection Agency (EPA) for conducting an RI (EPA/540/G-89/004, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*). The feasibility study (FS) for this OU will be completed at a later date in conjunction with the FS for the adjacent 200-BP-5 Groundwater OU. The results of the 200-PO-1 Groundwater OU RI have identified groundwater conditions exceeding action levels that require further evaluation in the FS. Contributing source (surface soil and vadose zone) information and its effects on groundwater will be presented as separate source area OU RIs using the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) process (Figure 1-3).

When conducting the CERCLA process, it is DOE policy to address values and concerns that otherwise might be considered under the *National Environmental Policy Act of 1969* (NEPA). NEPA values, such as analysis of cumulative, offsite, ecological, and socioeconomic impacts, are considered, to the extent practicable, as part of the site analysis and alternatives screening process presented in the FS.

## 1.1 Purpose, Scope, and Objectives of Report

The purpose and scope of the 200-PO-1 Groundwater OU RI report, defined in DOE/RL-2007-31, *Remedial Investigation/Feasibility Study Work Plan for the 200-PO-1 Groundwater Operable Unit*, are summarized in the following sections.

### 1.1.1 Purpose

The purpose of this RI report is to describe the approach for and results of the RI activities for the 200-PO-1 Groundwater OU, which were designed to establish the source, nature, and extent of contamination in the groundwater at this location. This information provides the basis for developing a baseline risk assessment (BRA), presented in Chapter 6, which describes the potential for adverse effects to human health and the environment (HHE), if no action is performed at this site. This work supports Ecology et al., 1989, *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) milestone (M-015-73).

### 1.1.2 Scope

The scope of the RI report applies to the nature and extent of contaminants of potential concern (COPCs) in the groundwater system underlying the portion of the Hanford Site identified as the 200-PO-1 Groundwater OU (Figure 1-2).

The 200-PO-1 OU RI report summarizes investigations of contaminants in the saturated zone originating from the 200 East Area and extending to the Columbia River. The investigations of groundwater contaminants originating from waste sites located in the 300 Area (e.g., 316-4, 618-10 and 618-11 Burial Grounds, and 300 Area Industrial Complex) and 100 Area River Corridor are being addressed under separate project work plans. Waste sites overlying the 300-FF-5 groundwater OU (Figure 1-2) will be addressed in the 300 Area Remedial Investigation (DOE/RL 2009-30, *300 Area Decision Unit Remedial Investigation/Feasibility Study Work Plan*).

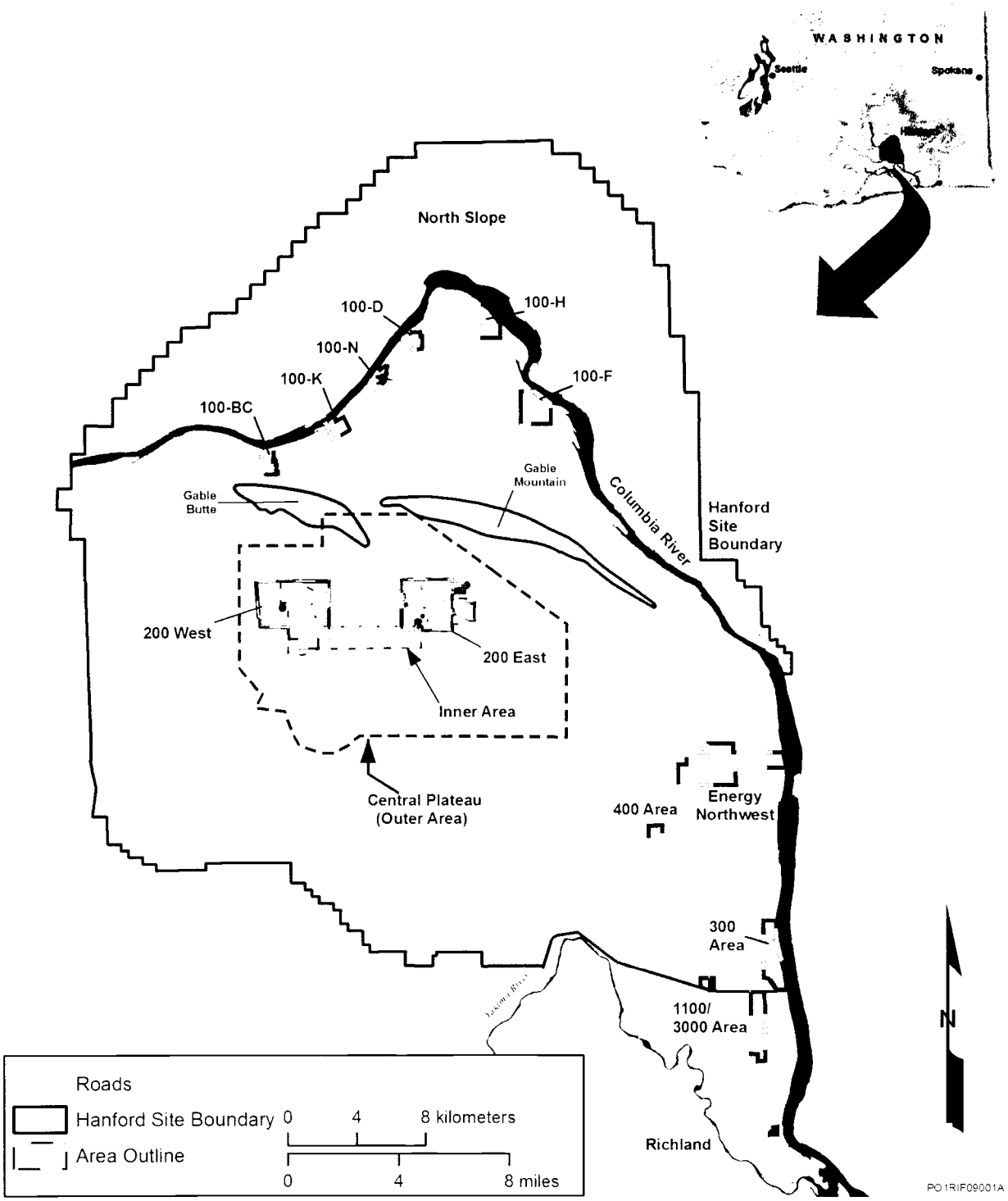



**Figure 1-1. Location of the Hanford Site**

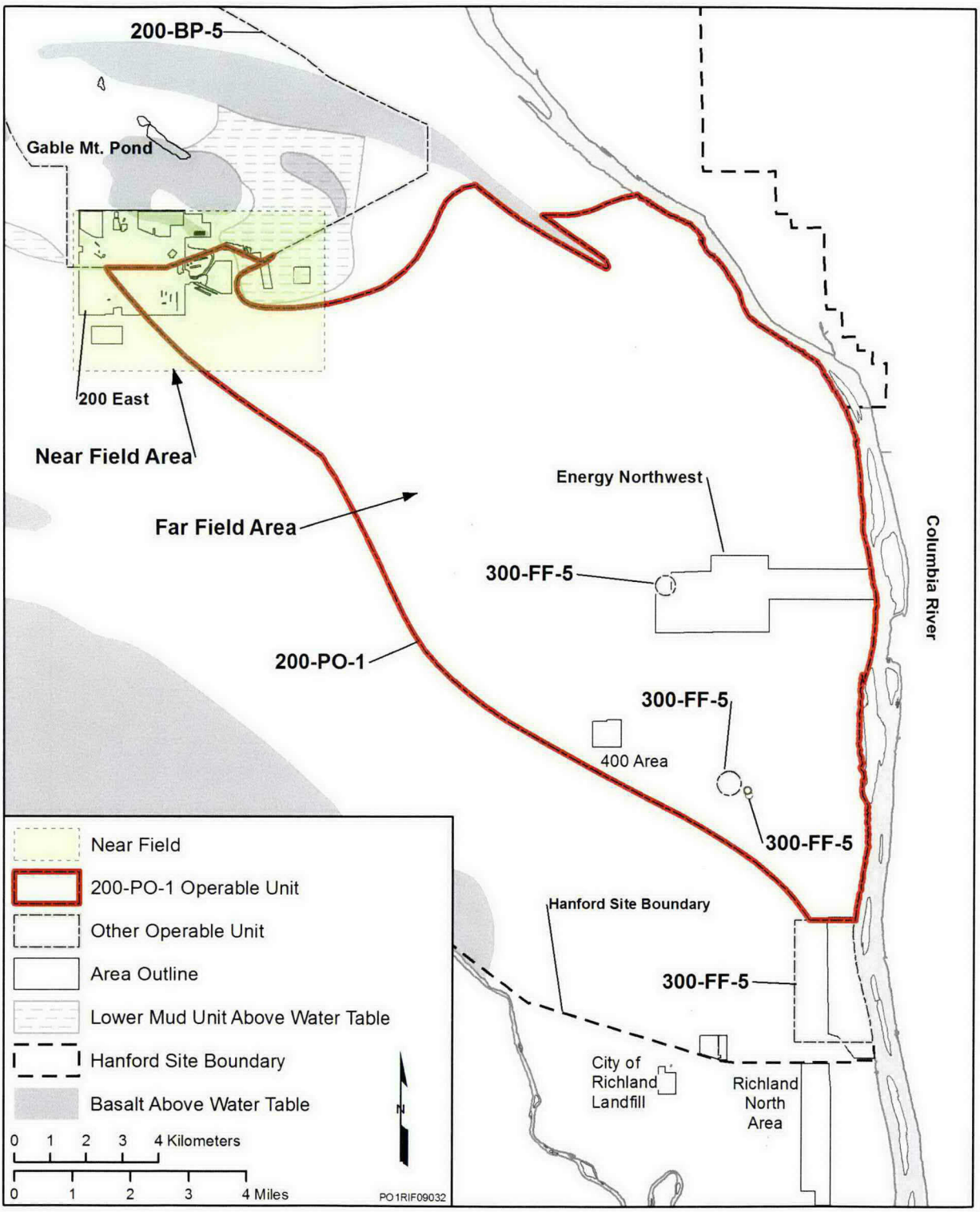
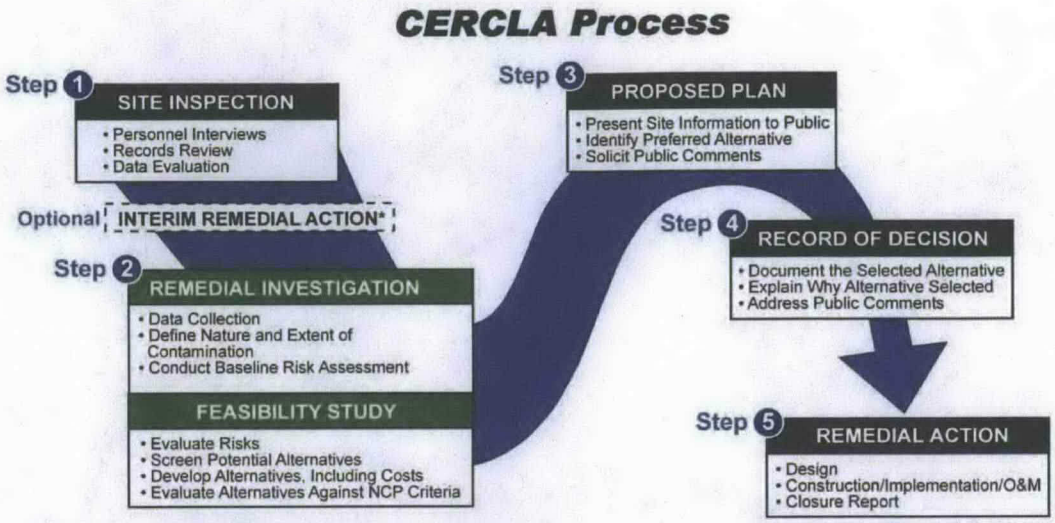



**Figure 1-2. Location of the 200-PO-1 Groundwater Operable Unit**




*Interim Remedial Action normally occurs after Site Inspection, but could occur at any point in the process when a concern has been identified.

**Step 1. Site Inspection.** "Site inspection" includes interviewing site personnel regarding the history of the site, reviewing waste disposal records, and evaluating existing data.

**Step 2. The Remedial Investigation/Feasibility Study.** The topic of the combined segments are:
**Remedial Investigation.** "Remedial Investigation" consists of conducting an environmental study to identify the nature and extent of contamination and performing a preliminary evaluation of the risk posed to human health and the environment.

**Feasibility Study.** The "Feasibility study" includes the details of a remedial alternatives evaluation, which includes a complete risk assessment of current conditions and an evaluation of the potential risk reduction presented for each of the remedial alternatives that are considered.

**Step 3. Proposed Plan.** The "Proposed Plan" (this document) is based on previous field investigations and reports that are completed in the first three steps of the CERCLA process described above. The Proposed Plan summarizes the remedial alternative evaluations and presents the preferred alternative recommended in the FS to the public for comments.

**Step 4. Record of Decision.** The "Record of Decision" (ROD) formally documents the cleanup alternative that was selected after the Tri-Parties reviewed and responded to public comments on the Proposed Plan.

**Step 5. Remedial Action.** "Remedial action" consists of the actual cleanup activities being performed. When cleanup is completed a final report is written that describes the remedial actions implemented, the result of the actions, and the conclusion of the CERCLA process.

CHPRC0902-16

**Figure 1-3. The CERCLA Process**

Historical and ongoing waste operations contributing to the OU and/or conditions related to residual vadose zone contamination are discussed in this report to provide context and historical perspective but are not the subject of this study. As appropriate, the reader is provided with citations to the relevant documents describing these related investigations and remedial activities.

This scope includes the following components:

- Data are confined to the measurements and observations of the RI conducted under the auspices of DOE/RL-2007-31. A description of the work conducted under the RI is included, along with the results of the data quality assessment (DQA) of the analytical results generated under the work plan, with an understanding of site conditions based on integration of the new RI information with existing historical information.
- A BRA, in Chapter 6, presents an evaluation of potential effects on HHE. Human health impacts are assessed through consideration of hypothetical exposure of human receptors to OU contaminants in groundwater via a drinking water pathway, and comparison of site conditions to action levels based on established drinking water standards (DWS) or other identified preliminary remediation goals (PRGs). Ecological receptors are evaluated through consideration of a hypothetical exposure to contaminated groundwater entering the Columbia River at the aquifer discharge boundary adjacent to the Columbia River. The baseline conditions were developed from groundwater sampling and analysis results collected during the preceding five years.
- Discussion of the relationship of the CERCLA remedial action(s) with *Resource Conservation and Recovery Act of 1976* (RCRA) corrective action for regulated waste units within the OU boundary is included.

### 1.1.3 Objectives

The overall objectives of the RI report are to describe groundwater contamination conditions in the OU and determine the need for an FS. To this end, the report has the following discrete objectives:

- Provide a sufficient quantity of information to answer the principal study questions related to contamination conditions within the OU, as described in SGW-34011, *Data Quality Objectives Summary Report Supporting the 200-PO-1 Groundwater Operable Unit*, and DOE/RL-2007-31.
- Present the results of the RI measurements and observations in an informative manner that describes the conditions observed within the OU and provides a clear technical basis for assessing risk, along with a basis for evaluation of remedial alternatives.
- Present a clear analysis of risks to HHE posed by contamination conditions within the OU, including which site conditions present unacceptable levels of risk and, therefore, define a basis for evaluating potential remedial actions.
- Define uncertainties associated with the nature and extent of contamination and how this uncertainty may affect the determination of risk, as well as the efficacy of remedial alternatives.
- Provide conclusions regarding an apparent basis for remedial action, describe those conditions posing unacceptable risk, describe projections of changes in conditions over time that may affect the apparent risk, and identify locations that may require evaluation in an FS.

## 1.2 Site Background

The site background section presents the physical location of the 200-PO-1 Groundwater OU, along with a description of the site, the processes that contributed to site contamination, and the activities that have provided insights into the nature and extent of site contamination. This section also considers the regulatory basis for activities at the site, as well as the current and future land use activities that provide a context for remedial actions.

### 1.2.1 Site Description

The 200-PO-1 Groundwater OU is located beneath the 200 East Area and extends to the south/southeast of the 200 East Area across the Hanford Site (Figure 1-2). The OU extends east to the Columbia River, south to the 300-FF-5 Groundwater OU, and north to the 200-BP-5 Groundwater OU. Figure 1-4 shows the source sites in the 200 East Area that overlie the 200-PO-1 Groundwater OU; remediation of these sites through separate CERCLA activities will address the waste sources that contributed to the contamination in the 200-PO-1 Groundwater OU. The RI for 200-PO-1 Groundwater OU does not address contaminant contributions from waste sources or vadose zone contamination.

Consistent with the Tri-Party Agreement; DOE/RL-2007-20, *Hanford Integrated Groundwater and Vadose Zone Management Plan*; and DOE/RL-2009-81, *Central Plateau Cleanup Completion Strategy*, the remediation of waste sites and impacted vadose zone soils overlying the four Central Plateau groundwater OUs will be addressed as discrete CERCLA OUs with their own accompanying record of decision (ROD). The 200-PO-1 Groundwater OU addresses the contamination already present in the aquifer, within the OU.

The waste site RODs will include provisions to define and incorporate future groundwater protection requirements into the remedial action objectives (RAOs) and cleanup levels for the waste sites, aimed at preventing unacceptable further degradation of the groundwater beneath the Central Plateau.

In April 2010, a Tentative Agreement was reached between the Tri-Party Agencies to define the new CERCLA decision structure accompanying the Central Plateau strategy, consistent with the division of decision making between the groundwater OUs and the waste site OUs noted above. Under DOE/RL-2009-81, two major geographic areas for waste site remediation are defined:

- The Inner Area (Figure 1-1) covers approximately 10 square miles in the middle of the Central Plateau, where the bulk of the chemical processing and waste management activities occurred. The Inner Area is envisioned to be the smallest practical final cleanup footprint where waste management and containment of residual contamination will occur.

- The Outer Area (Figure 1-1) is greater than 65 square miles and includes much of the open area on the Central Plateau. Limited processing activity occurred in the Outer Area, and cleanup objectives for the Outer Area waste sites will be comparable to the 100 Area River Corridor waste sites.

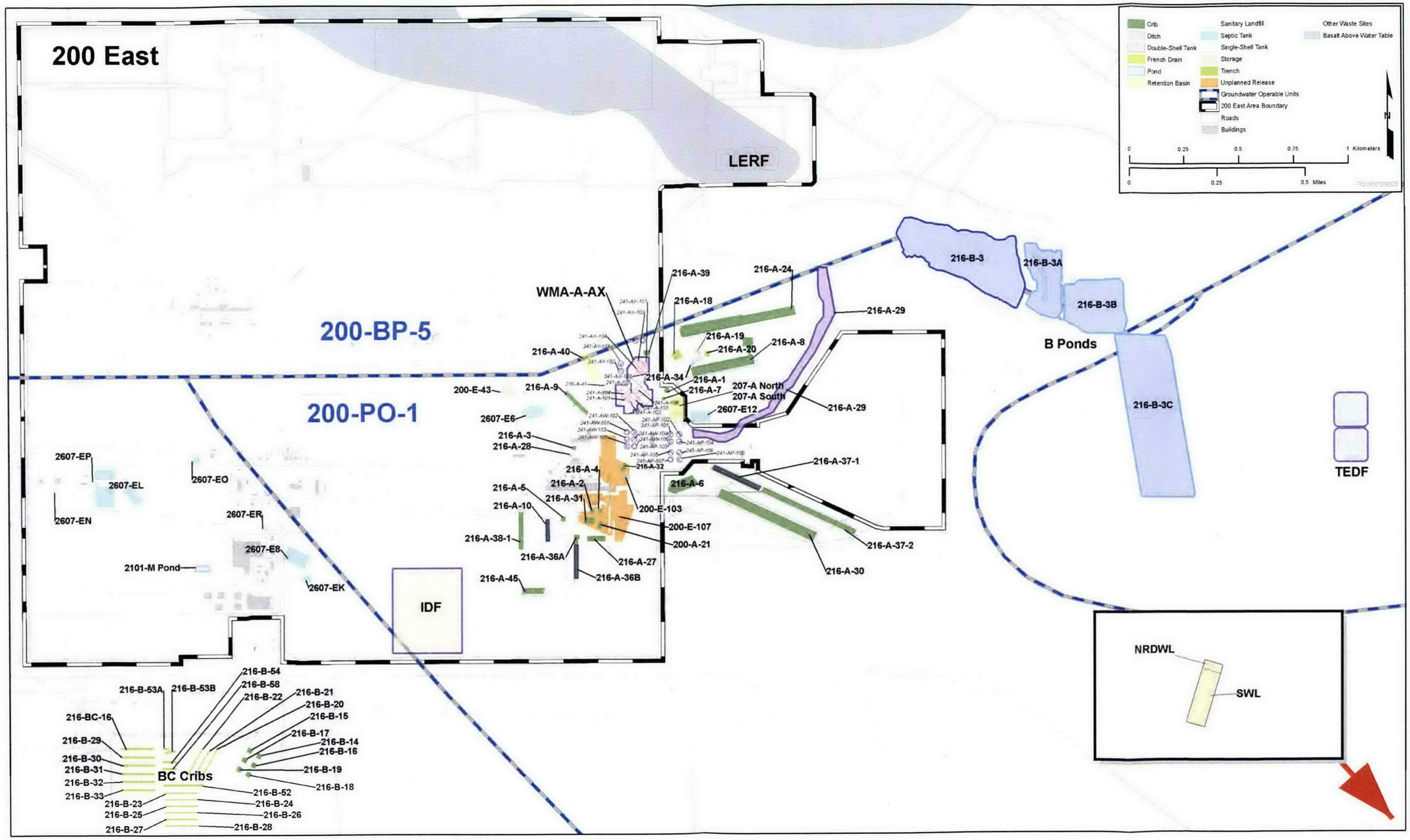



Figure 1-4. 200 East Area Source Sites Overlying 200-PO-1 Groundwater OU

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Along with the Inner and Outer Areas, the Tentative Agreement also recognizes groundwater remediation. As acknowledged in the DOE/RL-2002-59, *Hanford Site Groundwater Strategy: Protection, Monitoring, and Remediation*, and DOE/RL-2007-20, and then reaffirmed in the 200-ZP-1 Final ROD (EPA et al., 2008), DOE's goal is to restore Central Plateau groundwater to its beneficial uses, unless restoration is determined to be technically impracticable. This includes the groundwater underlying both the Inner and Outer Areas.

Under the Tentative Agreement, the new decision structure and accompanying OUs for the Inner and Outer Areas and groundwater remediation are defined in Table 1-1.

**Table 1-1. Decision Structure and Operable Units for the Inner and Outer Areas**

| Decision Structure/Operable Unit | Scope and Focus |
|---|---|
| 200 West Groundwater | Contaminated groundwater associated with the 200-ZP-1 and 200-UP-1 operable units. |
| 200 East Groundwater | Contaminated groundwater associated with the 200-PO-1 and 200-BP-5 operable units. |
| 200-PW-1/3/6 and 200-CW-5 | Key plutonium bearing waste sites in the Inner Area. |
| 200 West Inner Area | Majority of the waste sites in 200 West. |
| 200 East Inner Area/Pipelines | Majority of the waste sites in 200 East. Includes the majority of pipelines across the Inner Area (200 East and West). |
| Deep Vadose Zone | Key waste sites in the Inner Area representing significant deep vadose zone contamination. Many sites are associated with the Central Plateau's tank farms. |
| 200-SW-2 (burial grounds) | The Central Plateau's landfills. |
| B Plant Canyon and Associated Waste Sites | One of the four remaining canyon decisions. (U Plant canyon decision made in 2005.) |
| PUREX Canyon and Associated Waste Sites | One of the four remaining canyon decisions. |
| REDOX Canyon and Associated Waste Sites | One of the four remaining canyon decisions. |
| T Plant Canyon and Associated Waste Sites | One of the four remaining canyon decisions. |
| Outer Area | Waste sites within the approximately 65 square mile Outer Area. |

Notes:
PUREX = Plutonium-Uranium Extraction (Plant)
REDOX = Reduction-Oxidation

As can be seen from this decision structure, the 200-PO-1 Groundwater OU RI will serve as a foundation document to support the new 200 East Groundwater OU proposed in the Tentative Agreement. The Tentative Agreement and accompanying proposed Tri-Party Agreement revisions will become final at the conclusion of the public comment period commencing on April 26, 2010 and concluding in June 2010.

The western boundary of the OU is defined by the perimeter of the plume as it extends from sources in the 200 East Area, as described in Tri-Party Agreement change number M-13-95-01. The boundaries of the OU may change as additional information is developed for the site and a remedy is selected.

Groundwater in the uppermost unconfined aquifer of the 200-PO-1 Groundwater OU generally flows southeasterly toward the Columbia River. In the northern portion of the 200 East Area (200-BP-5 OU), the unconfined aquifer flows northwest toward Gable Mountain and south/southeast to 200-PO-1 (Figure 1-5). As groundwater within the 200-PO-1 Groundwater OU migrates east (downgradient), off the Central Plateau, its flow path is less constrained by uplifted basalt and other low permeability material (Ringold Lower Mud). Subsequently, the aquifer covers a much broader region, allowing groundwater to fan outward and flow northeast, east, and southeast as it approaches the Columbia River.

In order to distinguish between groundwater contamination that is clearly associated with specific waste disposal activities originating in the 200 East Area and the more regionally dispersed contamination that has a less specific origin, the groundwater monitoring system has been segregated into Near Field and Far Field wells. Wells located in or adjacent to the 200 East Area, near the major sources for groundwater contamination, are in the Near Field area; wells located in the 600 Area to the east and southeast are considered Far Field wells. Appendix A includes two plate maps illustrating the well locations and contaminant plumes for the Near Field (Plate 1) and Far Field (Plate 2).

Tritium, nitrate, and iodine-129 are associated with the most extensive groundwater plumes within this OU, resulting primarily from the two periods of Plutonium-Uranium Extraction (PUREX) Plant operation. COPCs in more localized areas include strontium-90 near the 216-A-36B Crib (a PUREX Crib) and technetium-99 in Waste Management Area (WMA) A-AX (Figure 1-4). Table 1-2 provides the estimated extent of groundwater plume areas that exceed primary drinking water standards (DWS). Plumes are illustrated on Plate 1 and Plate 2 (Appendix A).

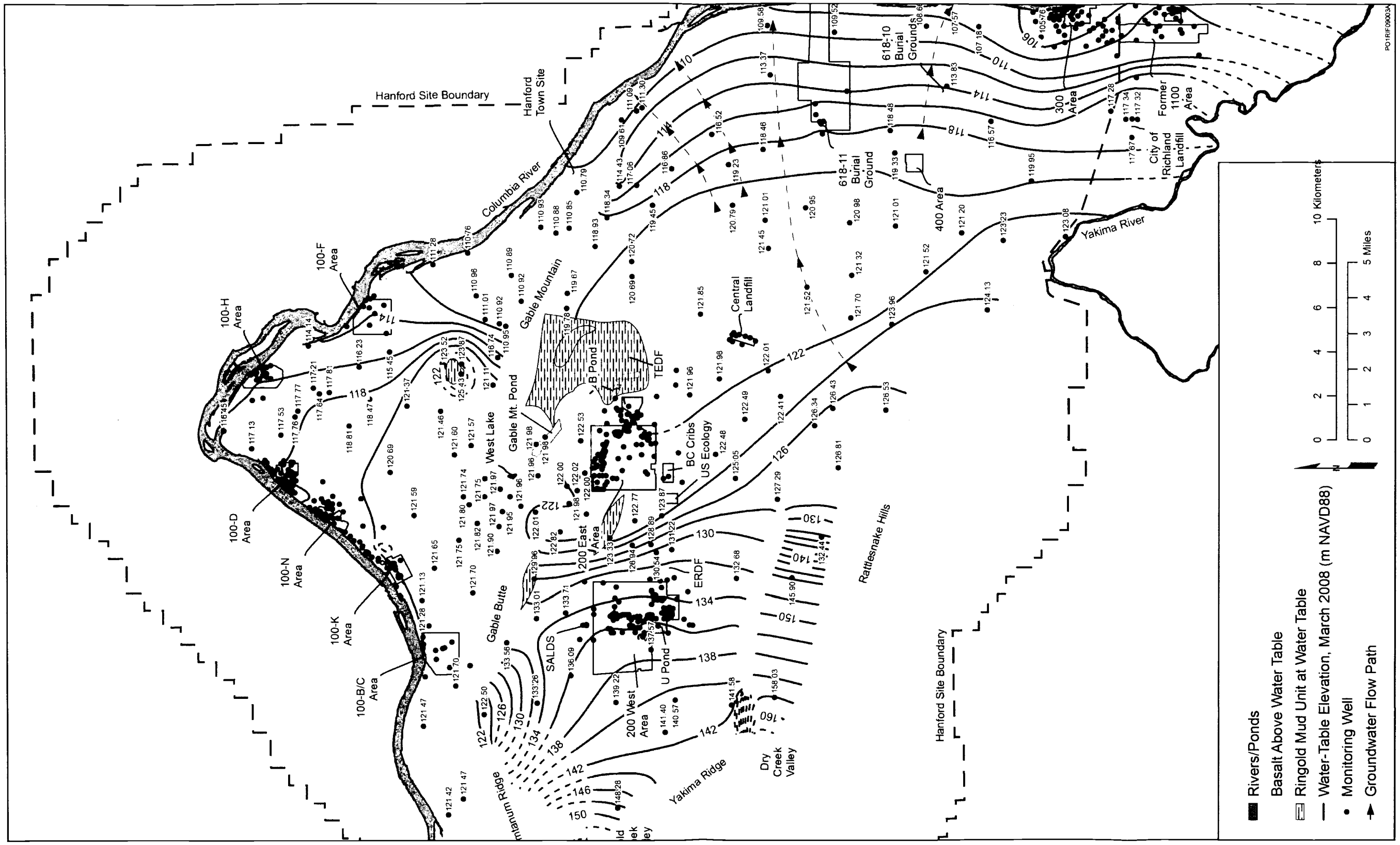


Figure 1-5. Inferred Regional Groundwater Elevation Contours Beneath the Hanford Site (PNNL-18427)

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**Table 1-2. Groundwater Plume Areas**

| Contaminant | Primary DWS Concentration | Plume Area in $km^2$ |
|---|---|---|
| Iodine-129 | >1 pCi/L | 53.80 |
| Nitrate | >45 mg/L | 0.66 |
| Strontium-90 | >8 pCi/L | 0.01 |
| Technetium-99 | >900 pCi/L | <0.01 |
| Tritium | >20,000 pCi/L | 117.48 |
| Uranium | >30 µg/L | 0.09 |

### 1.2.2 Site History

Liquid waste discharge to ground has been a practice in the 200 Area since the inception of plutonium processing activities on the Hanford Site. Liquids from the PUREX Plant, B Plant, and U Plant operations were disposed to the soil column at locations overlying the 200-PO-1 Groundwater OU and contributed to groundwater contamination. Waste streams included steam condensate, process cooling water, chemical sewer waste, and acid fractionator condensate (DOE/RL-95-100, *RCRA Facility Investigation Report for the 200-PO-1 Operable Unit*) (RFI Report). Waste considered to be uncontaminated, such as cooling water condensate, was disposed to open trenches and ponds, and later flushed with fresh water. Radiologically contaminated process waste was disposed to cribs and trenches. High-level radioactive wastes derived from reprocessing of reactor fuel were directed to underground tanks. Some of the tanks have been associated with unplanned releases (UPRs) to the soil column. By June 1995, per Tri-Party Agreement milestone M-017-10, all liquid waste disposal to ground was terminated. Currently, only the Treated Effluent Disposal Facility (TEDF) disposal points remain active within the 200-PO-1 Groundwater OU.

Waste sites in the 200 Area initially were grouped geographically. In 1993, various aggregate area management study reports (AAMSRs) provided significant characterization information that supported the preparation of the RFI Report for the 200-PO-1 OU (DOE/RL-95-100, Rev. 1) and DOE-RL-96-66, Rev. 1, *RCRA Corrective Measures Study for the 200-PO-1 Operable Unit* (CMS) (Section 1.2.4). The AAMSRs describe the general site conditions (geology, hydrology, ecology, and meteorology), the major facilities within each aggregate area, as well as information on the processes and operational history for the more significant facilities. The reports list waste disposal activities and the types of waste that were generated, along with quantities of waste disposed to waste management units. The AAMSRs include a preliminary conceptual site model (CSM) that summarizes the understanding of the aggregate area with respect to the types and the extent of contamination, and the relevant exposure pathways and receptors.

The following AAMSRs contribute to an understanding of conditions at the 200-PO-1 Groundwater OU:

- **200 East Groundwater** – DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*, summarizes information about groundwater contaminants beneath the 200 East Area. The document describes radiological and non-radiological contaminant plumes.

- **PUREX Plant** – DOE/RL-92-04, *PUREX Source Aggregate Area Management Study Report*, discusses processes and waste streams from the PUREX operations. Lower-activity radioactive waste was disposed to cribs, trenches, and French drains; highly radioactive waste was diverted to the tank farms. "Uncontaminated" wastes were allowed to infiltrate through ponds and open ditches.

- **B Plant** – DOE/RL-92-05, *B Plant Source Aggregate Area Management Study Report*, describes the separations process at this facility. Process wastes were managed as at PUREX, in single-shell tanks (SSTs), and to cribs, trenches, reverse wells, and open ponds. Process cooling water and steam condensate was sent to the B Pond. Significant groundwater mounding below the B Pond has receded since discharges were halted in 1985.

- **U Plant** – Aqueous waste from the U Plant in the 200 West Area was transported through underground pipelines and disposed to cribs and trenches in the 200 East Area, including the 216-B/C Cribs complex. More information is available in DOE/RL-91-52, *U Plant Source Aggregate Area Management Study Report*.

The waste sites located within the OU footprint that potentially contributed contaminants to the 200-PO-1 Groundwater OU groundwater include cribs, French drains, and various ponds, trenches, and ditches (Figure 1-4). Table 1-3 summarizes the waste volumes provided in the AAMSR for the major sources that historically contributed to groundwater contamination in the 200-PO-1 Groundwater OU. These numbers do not account for spills, tank leaks, or other UPRs of wastewaters through pipelines, diversion boxes, or other sources that have not been quantified. The evaluation of extensive vadose zone contamination will be conducted as part of the Central Plateau source unit investigations to assess future impacts to groundwater.

**Table 1-3. Major Sources of Wastewater Discharge to the 200-PO-1 Groundwater Operable Unit**

| Major Source | Discharge Volume | Cribs and Drains | Ponds, Trenches, and Ditches | Reverse Wells |
|---|---|---|---|---|
| PUREX Aggregate Area | Liters | 18,680,664,420 | 13,895,312 | — |
| | Gallons | 4,934,909,459 | 3,670,753 | — |
| B Plant Aggregate Area | Liters | 2,360,847,000 | 703,664,236,100 | 66,210,000 |
| | Gallons | 623,669,797 | 185,888,425,420 | 17,490,886 |

Notes:

Volumes were compiled from values provided in DOE/RL-92-19, *200 East Groundwater Aggregate Area Management Study Report*.

PUREX = Plutonium-Uranium Extraction (Plant)

In 1996, waste sites overlying the various 200 Area Groundwater OUs were re-grouped into source OUs that continue to be investigated. In 1998, DOE/RL-98-28, *200 Areas Remedial Investigation/Feasibility Study Implementation Plan - Environmental Restoration Program*, was developed to outline a framework for implementing source investigation activities in the 200 Area. These source investigations are not within the scope of the 200-PO-1 Groundwater OU investigation, but provide valuable data regarding contaminants that impact the site groundwater.

The annotated bibliography describes more than 100 documents that provide background information regarding the processes that contributed to the contamination at the 200-PO-1 Groundwater OU, as well as various activities that have been conducted to provide a better understanding of conditions at this site (Appendix B).

### 1.2.3 Previous Investigations

The 200-PO-1 Groundwater OU originally was defined as a combined source and groundwater OU. In June 1993, the OU was re-designated as a groundwater only OU in order to implement recommendations from the PUREX and B Plant AAMSRs (DOE/RL-92-04 and DOE/RL-92-05), and the 200 East Groundwater AAMSR (DOE/RL-92-19). Washington State Department of Ecology (Ecology) was designated the lead regulatory agency for the 200-PO-1 Groundwater OU in 1993, and it was agreed that groundwater OUs would be addressed as CERCLA past practice units. Although groundwater remediation within the 200-PO-1 Groundwater OU is to be performed under CERCLA, there is ongoing RCRA monitoring associated with specific regulated waste units as well.

In 1994, the Columbia River and Hanford Groundwater change packages were issued to implement the selection of three remedial strategy documents for submittal in lieu of OU work plans under Tri-Party Agreement milestone series M-013:

- Hanford Federal Facility Agreement and Consent Order (HFFACO) Change Control Form, Change Number M-13-94-03 (May 1995), provided for the implementation of the 1994 Refocusing Negotiations and modified M-013 milestones for completion of the 200 Area National Priorities List (NPL) pre-ROD. This change package established the M-013-10 milestone to (1) submit the 200-PO-1 Groundwater OU RFI/CMS Work Plan by October 31, 1995, (2) change the 200-PO-1 Groundwater OU unit category from CERCLA past practice to "RCRA past practice," and (3) keep Ecology as the designated lead regulatory agency.

- In July 1995, HFFACO Change Control Number M-13-95-01 deleted the M-013-10 milestone to "Submit the 200-PO-1 Groundwater OU RFI/CMS Work Plan" and established three new M-015 milestones, which were completed as scheduled. The three parties agreed that sufficient information was available to proceed with (1) submitting a RCRA RFI by December 1995 (M-015-25), (2) submitting a 200-PO-1 CMS by July 31, 1996 (M-015-25A), and (3) submitting a 200-PO-1 Permit Modification by August 30, 1996 (M-015-25B).

- In February 2002, an M-013 milestone change provided for the submittal of 200 Area EPA RI/FS work plans to complete the investigation of past practice units. In November 2006, the Tri-Parties (Ecology, DOE, and EPA) developed milestone M-013-10A for the preparation of the 200-PO-1 Groundwater OU RI/FS work plan to be completed by September 30, 2007. DOE/RL-2007-31 fulfilled Milestone M-013-10A; Rev. 0 was issued on January 24, 2008 and approved on February 6, 2008.

This RI report includes a discussion of the RI activities that were performed in 2008 under CERCLA; the rationale for these studies is described in detail in Section 4 of DOE/RL-2007-31. This section provides a brief discussion of the RFI/CMS studies performed as part of the RCRA hazardous waste compliance activities for regulated waste sites within the 200-PO-1 Groundwater OU. Section 3 of DOE/RL-2007-31 provides additional information regarding previous studies of the 200-PO-1 Groundwater OU.

Groundwater monitoring at the 200-PO-1 Groundwater OU is conducted under three major programs: CERCLA, the Washington State Hazardous Waste Management Act for treatment, storage, and disposal (TSD) and RCRA past practice facilities, and the federal *Atomic Energy Act of 1954*. These programs accomplish the following general objectives:

- Determine groundwater quality baseline conditions.

- Characterize hydrogeologic and geochemical trends in the natural groundwater system resulting from historical Hanford Site operations.

- Assess existing and emerging groundwater quality problems and impacts to the aquifer system.
- Support analyses such as groundwater flow and contaminant fate and transport modeling.

As a consequence, an assortment of site characterization and monitoring programs have been developed for individual waste sites, as well as for the various groupings of sites, to assess contamination and remediation in the 200 Area. Analytical results are maintained in the Hanford Environmental Information System (HEIS) and Waste Information Data System (WIDS) databases, as well as the documents that are referenced throughout this report.

The RCRA Groundwater Monitoring Program monitors active and inactive hazardous waste TSD units at the Hanford Site that are governed by RCRA regulations. Groundwater monitoring wells installed under the RCRA program must meet the requirements set forth in *Washington Administrative Code* (WAC) 173-160, "Minimum Standards for Construction and Maintenance of Wells," through WAC 173-162, "Regulation and Licensing of Well Contractors and Operators," and current, relevant RCRA regulations. The 200-PO-1 Groundwater OU contains six RCRA sites with groundwater monitoring requirements:

1. Integrated Disposal Facility (IDF)
2. PUREX Cribs (includes 216-A-10, 216-A-36B, and 216-A-37-1 Cribs)
3. SSTs WMA A-AX
4. 216-A-29 Ditch
5. 216-B-3 Pond Facility
6. Nonradioactive Dangerous Waste Landfill (NRDWL)

The 200-PO-1 Groundwater OU also includes the Solid Waste Landfill (SWL), regulated by Ecology under WAC 173-304, "Minimum Functional Standards for Solid Waste Handling," the 200 Area TEDF (monitored under state waste discharge permit ST 4502), and three 400 Area water supply wells monitored for the *Atomic Energy Act of 1954*.

### 1.2.4 Regulatory Basis and History

DOE/RL-2007-31 did not address compliance issues for RCRA TSD operating units within the 200-PO-1 Groundwater OU. The operating RCRA sites will be evaluated for impact to groundwater in the 200-PO-1 Groundwater OU in accordance with the current regulatory strategy (DOE/RL-2009-81) outlined in Section 1.2.1. Previous regulatory reports provide an overview of the RCRA facilities associated with the 200-PO-1 Groundwater OU:

- RFI Report for the 200-PO-1 Groundwater OU
  - The RFI Report for the 200-PO-1 Groundwater OU (DOE/RL-95-100, Rev. 1) was prepared in support of the RFI/CMS process. The RFI report summarizes information that was presented in the 200 East Groundwater and PUREX AAMSRs (DOE/RL-92-19 and DOE/RL-92-04). The report addresses particular COPCs for each waste site within the 200-PO-1 Groundwater OU, as well as the potential for contaminants from these waste sites to impact groundwater. The RFI conveys that the groundwater was impacted by operations at the PUREX and B Plants in the 200 East Area, and disposal of waste from the U Plant (200 West Area) to the BC Cribs and Trenches.

- RCRA CMS for the 200-PO-1 Groundwater OU
  - The *RCRA Corrective Measures Study for the 200-PO-1 Operable Unit* (DOE/RL-96-66, Rev. 1) was prepared to support the RFI/CMS process for the 200-PO-1 Groundwater OU. Two remedial actions were evaluated for the iodine-129 and tritium plumes: (1) no action, and (2) institutional controls (ICs). There was no further evaluation of the nitrate plume because the majority of the plume was at concentrations below the maximum contaminant level (MCL). IC was the remedial action chosen for both iodine-129 and tritium. The CMS recommended no human contact with contaminated groundwater until contaminant concentrations are reduced through natural attenuation. This report predicted that the concentrations of iodine-129 and tritium would be at or below levels of concern within 50 years.

Tri-Party Agreement Change Notice, TPA-CN-2-253, *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: DOE/RL-2007-31 Rev 0, Remedial Investigation/Feasibility Study Work Plan for the 200-PO-1 Operable Unit* (January 15, 2009), documents concurrence among the parties that adequate RI data are available for DOE to develop and evaluate remedial alternatives necessary to make remedial action decisions. If supplemental investigation efforts are needed, they will be conducted through the post-ROD decision change process, as provided for in EPA/540/R-98/031, *A Guide to Preparing Superfund Proposed Plans, Records of Decision, and Other Remedy Selection Decision Documents* (OSWER 9200.1-23P). The ROD approach includes the preparation of RI/FS documentation that will rely on the existing 200-PO-1 Groundwater OU RFI/CMS documentation and incorporate updated information. The RI/FS documentation will provide the data required to support the 200-PO-1 Groundwater OU Proposed Plan and ROD process.

### 1.2.5 Current Land Use, Demography, and Future Land Use

Under CERCLA and the National Contingency Plan (NCP), a groundwater remedy must: (1) be protective of HHE, and (2) meet ARARs (or satisfy criteria for an ARAR to be waived). This concept is of central importance to the development of the groundwater remedy for the 200-PO-1 Groundwater OU. These requirements are clarified in Fields, 1997a, *Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA* (OSWER Directive 9200.4-23).

#### *1.2.5.1 Current Land Use*

The NCP indicates that EPA expects a remedy to return groundwater to beneficial use whenever practicable, within a reasonable timeframe. Federal decisions for groundwater cleanup generally defer to state determinations of current and future groundwater uses, as described in EPA/540/G-88/003, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*, and Fields, 1997b, *The Role of CSGWPPs in EPA Remediation Programs* (OSWER Directive 9283.1-09). Washington State has determined that the 200-PO-1 Groundwater OU groundwater meets the state's potable groundwater definition, and the highest beneficial use for the groundwater is as a potential source of domestic drinking water.

The general objectives for groundwater cleanup are consistent with the intended use of the land above the groundwater. Through the 1990s, DOE worked with other agencies and stakeholders, including the National Park Service, Tribal Nations, Washington and Oregon, local county and city governments, economic and business development interests, environmental groups, and agricultural interests, to define land use goals and develop future land use plans for the Hanford Site. The results of this effort culminated in DOE/EIS-0222-F and associated 64 FR 61615, "Record of Decision: Hanford Comprehensive

Land-Use Plan Environmental Impact Statement (HCP EIS)," both issued in 1999. An amendment to the HCP EIS ROD clarifying the plan's implementing procedures was issued in September 2008.

#### 1.2.5.2 Demography

There are no residences on the Hanford Site. The nearest inhabited residences are farm homes on land located 21 km (13 mi) north of the 200-PO-1 OU. There are approximately 411,000 people living within an 80 km (50 mi) radius of the 200 Areas Plateau. The primary population centers are the cities of Richland, Kennewick, and Pasco, located southeast of the Hanford Site, Prosser to the south, Sunnyside to the southwest, and Benton City to the south.

Additional information to support this section may be found in PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*, DOE/EIS-0222-F, and the *Hanford Reach National Monument Comprehensive Conservation Plan and Environmental Impact Statement* (USFWS, 2008).

#### 1.2.5.3 Future Land Use

The Central Plateau (Inner Area) is designated, as an industrial area for future land use, to be used for activities such as TSD of hazardous, dangerous, radioactive, and non-radioactive wastes.

The areas outside the Central Plateau are designated conservation (mining), which includes management and protection of archeological, cultural, ecological, and natural resources. Management would allow recreational use (e.g., hiking, biking, hunting, and bird watching) of the surface areas, but include restrictions against intrusive human activities. Subsurface activities would be restricted to preclude contact with or disturbance of contaminated soils. These activities could occur around, but not on, the waste sites.

The current and potential future land use designations for the Near Field, Far Field, and River Corridor regions are presented in Table 1-4.

**Table 1-4. Current and Potential Future Land Use**

| Zone Boundary | Current Land Use | Potential Future Land Use |
|---|---|---|
| Near Field | Industrial | Industrial-Exclusive. |
| Far Field | Industrial for the next 150 years or other negotiated time | Conservation (mining) reserved for management and protection of archeological, cultural, ecological, and natural resources. |
| River Corridor | Industrial (no groundwater use) for the next 150 years | High and low intensity recreation, and conservation (mining) reserved for management and protection of archeological, cultural, ecological, and natural resources. Must be consistent with the River Corridor land use risk assessment. |

Notes:

Derived from: 64 FR 61615, "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)."

Industrial-exclusive land use would preserve DOE control of the continuing remediation activities and would use the existing, compatible infrastructure required to support activities such as dangerous waste, radioactive waste, and mixed waste TSD facilities. The HCP EIS anticipates mining only for materials needed to build surface barriers as part of remedial actions, and that mining would be precluded from contaminated areas. Conservation would require active management practices to enhance or maintain the existing resources and to minimize or eliminate undesirable or non-native species.

The reasonably anticipated future land use for the industrial use zone is continued industrial (exclusive) activities. Eventually, portions of this area may be used for non-DOE-related industrial uses. Groundwater beneath the Central Plateau in the Near Field Area currently is contaminated and is not withdrawn for beneficial uses. Groundwater is withdrawn in the Far Field Area for industrial use and treated for potable use as discussed in Section 3.7. The HCP EIS indicates that contamination in the groundwater would restrict use (DOE/EIS-0222-F).

Completion of all cleanup activities within this OU is expected by 2050, and active ICs are assumed following the termination of operations. ICs are expected to be maintained until the contamination is no longer hazardous to HHE.

Additional details of anticipated land use of the area encompassed by the 200-PO-1 Groundwater OU are provided in SGW-34011 and DOE/RL-2007-31.

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# 2 Study Area Investigation

The 200-PO-1 Groundwater OU RI included a review of historical information and RI field activities conducted in accordance with the work plan (DOE/RL-2007-31) and presented in the following sections.

## 2.1 Historical Review

The soils, geology, and groundwater at the 200-PO-1 Groundwater OU have undergone extensive site investigations in recent years. The following discussion presents a summary of the most recent activities that contribute to an understanding of conditions at this site.

In 2002/2003, the data quality objective (DQO) process for groundwater monitoring on the Central Plateau was presented in CP-15329, *Data Quality Objectives Summary Report for Establishing a RCRA/ CERCLA/AEA Integrated 200 West and 200 East Area Groundwater Monitoring Network.* This process was conducted to assess the groundwater monitoring well networks for the 200 West Area and 200 East Area and to develop an integrated groundwater monitoring system encompassing the various regulatory needs. The regulatory programs that oversee activities within the 200-PO-1 Groundwater OU have the following complementary, but not identical, purposes:

- The CERCLA remediation performance monitoring program provides a routine and ongoing assessment of the effectiveness of groundwater remediation activities.
- The RCRA detection program (40 CFR 264.99, "Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities," "Compliance Monitoring Program") identifies whether TSD units are impacting groundwater quality and defines the rate and extent of detected contaminant migration.
- DOE also conducts monitoring to meet the requirements of the AEA and DOE O 450.1A, *Environmental Protection Program.* The site wide surveillance monitoring program determines baseline conditions of groundwater quality and quantity; characterizes and defines hydrogeologic, physical, and chemical trends in the groundwater system; and provides data to support decisions concerning land disposal practices and the management and protection of groundwater resources.

The DQO process determined the groundwater constituents, sampling frequencies, and water table measurements were adequate to meet data collection and regulatory requirements for the various programs. Subsequently, DOE/RL-2003-04, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* (a monitoring sampling and analysis plan [SAP]), provided the approach for ongoing groundwater monitoring for this OU.

SGW-34011 provides the foundation for the 200-PO-1 Groundwater OU RI/FS work plan and characterization SAP. Based on previously collected data, the DQO team performed a formal evaluation to develop a list of COPCs in the groundwater of the 200-PO-1 Groundwater OU. The COPC list was developed in two steps as follows:

**Step 1** – Existing documents listed in Appendix B were examined to prepare a comprehensive list of radionuclides and hazardous chemicals disposed from or used in processes at facilities potentially contributing to the 200-PO-1 Groundwater OU.

**Step 2** The HEIS database was queried for data from 189 wells, for the time period of 1986-2006 (20 years), located within the 200-PO-1 Groundwater OU to evaluate analytical results for the 339 potential contaminants discovered in step one and an additional 257 potential contaminants for which analytical data are recorded in the HEIS database. From a total of 596 COPCs, DOE identified PRGs for 235 COPCs. A total of 179 COPCs of the 235 had no detects that exceeded PRGs. These 179 COPCSs were not retained for further evaluation. Of the remaining 56 COPCs with PRGs, 12 were excluded due to questionable initial analytical results and chemical properties; subsequent analyses for these constituents consistently had results below the PRGs. The query yielded a list of 44 COPCs in the following two categories:

- Groundwater contaminants with concentrations greater than state and/or federal MCLs
- Potential contaminants that had no analytical data available therefore, could not be excluded

Screening values, when available, were extracted for all constituents from the following sources:

- The *Cleanup Levels and Risk Calculations* (CLARC) database (Ecology, 2009) for carcinogen and non-carcinogen values.
- Primary and secondary MCLs from 40 CFR 141, "National Primary Drinking Water Regulations" and 40 CFR 143, "National Secondary Drinking Water Regulations."
- PRGs defined in DOE/RL-96-17, *Remedial Design Report/Remedial Action Work Plan for the 100 Area.*
- Background levels from DOE/RL-92-23, *Hanford Site Groundwater Background.* If the reported natural groundwater background value was higher than any PRG available, the background value was used.

Table 2-1 presents the retained list of 44 COPCs within the 200-PO-1 Groundwater OU. Section 4.2 of the RI Work Plan (DOE/RL-2007-31) includes the details of the COPC selection process.

**Table 2-1. Contaminants of Potential Concern in the 200-PO-1 Groundwater OU**

| Metals | Semi-Volatile Organic Compounds |
|---|---|
| Antimony | 2,4-Dinitrophenol |
| Arsenic | Bis(2-ethylhexyl) phthalate |
| Cadmium | Nitrobenzene[a] |
| Chromium | Pentachlorophenol |
| Lead | **Radiological** |
| Manganese | Gross alpha[b] |
| Nickel | Iodine-129 |
| Thallium | Neptunium-237[c] |
| Uranium | Protactinium-231[c] |
| Vanadium | Selenium-79[c] |
| Zinc | Strontium-90 |
| **Volatile Organic Compounds** | Technetium-99 |
| 1,1,2,2-Tetrachloroethane | Tritium |
| 1,2-Dichloroethane | Uranium-234 |
| 1,4-Dioxane[a] | Uranium-238 |
| Benzene | **Pesticides** |
| Bromodichloromethane | Dieldrin |
| Carbon tetrachloride | Dimethoate |
| Dibromochloromethane | Heptachlor |
| Hexane[c] | Heptachlor epoxide |
| Methylene chloride | **Ions** |
| Tetrachloroethene | Fluoride |
| Trichloroethene | Nitrate |
| Vinyl chloride | Nitrite |

Notes:

Contaminants were identified in DOE/RL-2007-31, *Remedial Investigation/Feasibility Study Work Plan for the 200-PO-1 Groundwater Operable Unit.*

a. Constituents are not found in historical process documents, but are found in samples from the 200-PO-1 Groundwater OU.

b. Survey parameter.

c. Constituents are found in historical process documents that have a potential to contribute to dose and have long half lives, or, in the case of hexane, regulatory limits set due to EPA listing as a possible carcinogen; these COPCs have not been previously analyzed in the 200-PO-1 Groundwater OU.

## 2.2 Remedial Investigation Field Characterization Activities

The shapes and contaminant concentrations of groundwater plumes within the 200-PO-1 Groundwater OU have changed over time as a result of changes in groundwater flow direction, source-term variability, and a decrease in the discharge of other waste streams (e.g., cooling water). Two SAPs provide the scope of sampling and analysis activities conducted to monitor these changes and support the 200-PO-1 Groundwater OU final decisions:

- DOE/RL-2003-04, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*, provides the basis for routine monitoring and analyses of COPCs. The monitoring SAP was approved in 2005 to provide groundwater data necessary to track the extent and concentration of contaminant plumes and to develop a CSM. Monitoring results from this SAP are reported annually in the Hanford Site Annual Groundwater Monitoring Report. The 2008 Near Field well locations are illustrated in Figure 2-1, and Far Field well locations are shown in Figure 2-2 (A).
- DOE/RL-2007-31, Appendix A, *Sampling and Analysis Plan for Remedial Investigation and Characterization of the 200-PO-1 Groundwater Operable Unit*, was prepared to provide further definition of conditions within the 200-PO-1 Groundwater OU. Data acquisition was designed to complement the monitoring SAP and yield new information regarding groundwater flow direction and rates, preferential pathways for contaminant migration, and contaminant mass transport. Appendix A and the RI/FS work plan describe the collection of "opportunistic" samples from wells that are drilled in other OUs, from which 200-PO-1 Groundwater OU task leads will collect samples to acquire supplemental data. Figure 2-2 (B) illustrates the additional Near Field and Far Field wells sampled to support this SAP.

The data collected from sampling and analysis activities defined in DOE/RL-2003-04 and DOE/RL-2007-31 were combined to form the RI data set. Although focused on gathering information from 200-PO-1 Groundwater OU wells, the characterization SAP (DOE/RL-2007-31), which can be found in the RI/FS Work Plan, identified activities that were to be conducted in FY 2008 to support characterization of conditions at this site. Table 2-2 presents a list of these activities and their status.

A total of 177 wells were selected for assessment based on criteria identified during the DQO process for the 200-PO-1 Groundwater OU. In addition, 11 aquifer tube stations (ten new and one replacement) were installed at locations along the River Corridor. An aquifer tube station consists of a set of three tubes emplaced vertically at different depths in one well casing. Each tube was to be sampled for the 44 COPCs listed in Table 2-1; however, it was not possible to collect samples from all three tubes at each location. Forty-three wells scheduled for decommissioning also were identified in the work plan SAP (DOE/RL-2007-31, Appendix A, Table A3-3) for sampling prior to decommissioning, as these were able to have a groundwater sample obtained. This activity has been completed, and information generated from the ongoing sampling of candidate wells for decommissioning will be included in future groundwater annual reports and used, as appropriate, in future decision making activities (e.g., included in data considered as part of the FS).
The analytes chosen for analyses to support the 200-PO-1 Groundwater OU RI in the Near Field and Far Field investigations are comprised of two categories:

- Routine monitoring analytes, which are included in Table 2.1 and Table 2.2 of DOE/RL-2003-04.
- The list of 44 analytes, identified in Table 2-1, which consist of COPCs derived from the evaluation process presented in the work plan (DOE/RL-2007-31) and previously described.

### 2.2.1 Near Field Investigation

The 200-PO-1 OU Near Field wells are located within, and adjacent to, the 200 East Industrial Area on the Central Plateau (Figure 2-1). The primary objectives for the Near Field investigation were to collect

additional characterization data for groundwater contaminants, acquire geophysical data to estimate vertical and lateral extent of geologic features, and refine or confirm preferred groundwater contaminant pathways. In addition, a detailed evaluation of existing monitoring data was conducted to determine preliminary fate and transport of analytes in the 200-PO-1 Groundwater OU. Data were gathered in order to define the depth of contaminants in the aquifer more accurately and the stratigraphy of sediments to determine the extent of known plumes, flow direction, and well deviations and to refine depth to water measurements.

Groundwater grab samples were collected at waste sites from borings that intercept the water table within the 200-PO-1 Groundwater OU and were analyzed for the 44 COPCs. The purpose of these samples is to more accurately define the nature and extent of contamination, and movement of contaminants deep in the aquifer. Geophysical seismic data also were collected to provide useful information for future fate and transport modeling and to help locate preferential pathways for contaminant movement.

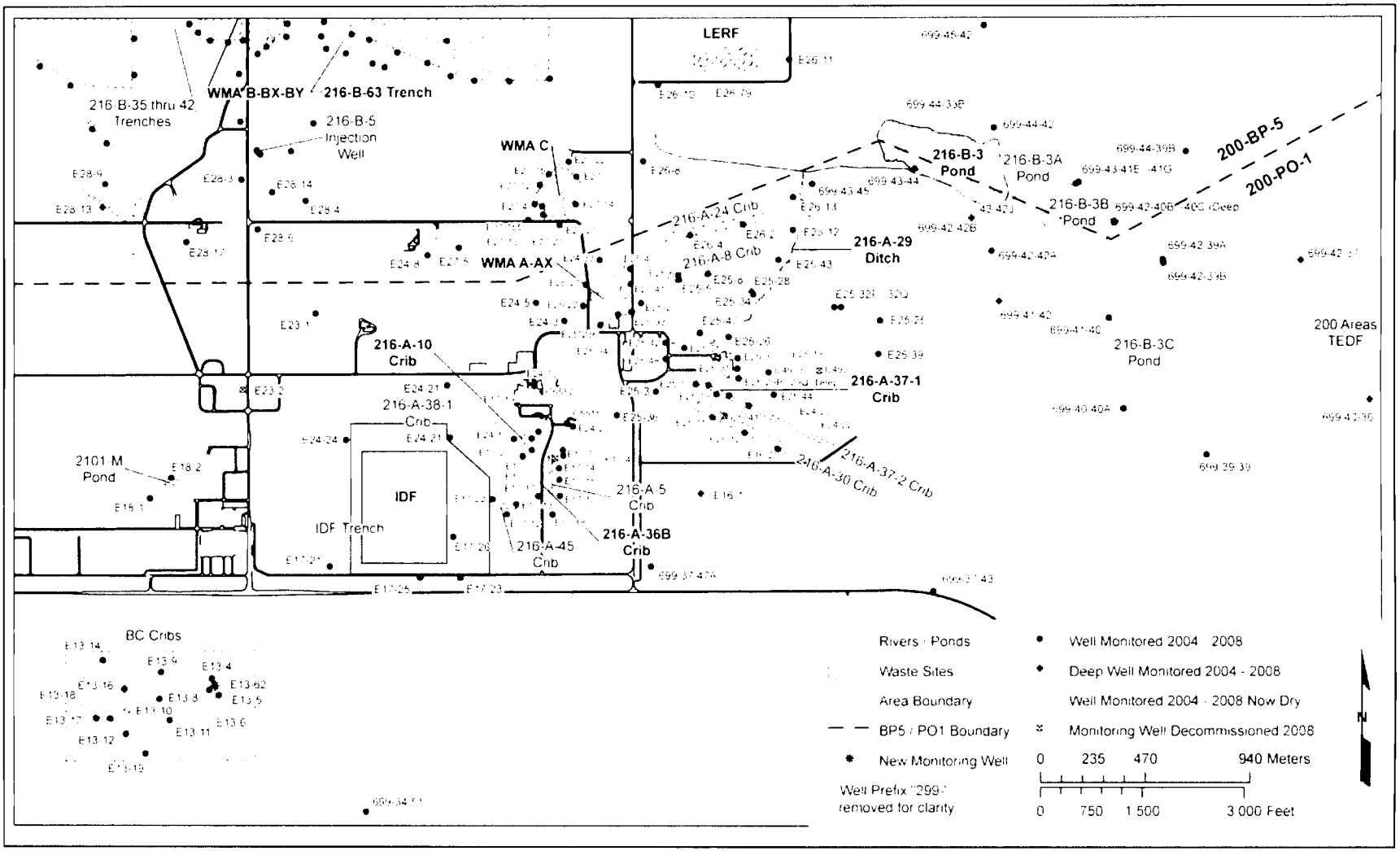


**Figure 2-1. 200-PO-1 Groundwater Operable Unit Near Field Monitoring Wells (2008 Annual Report)**

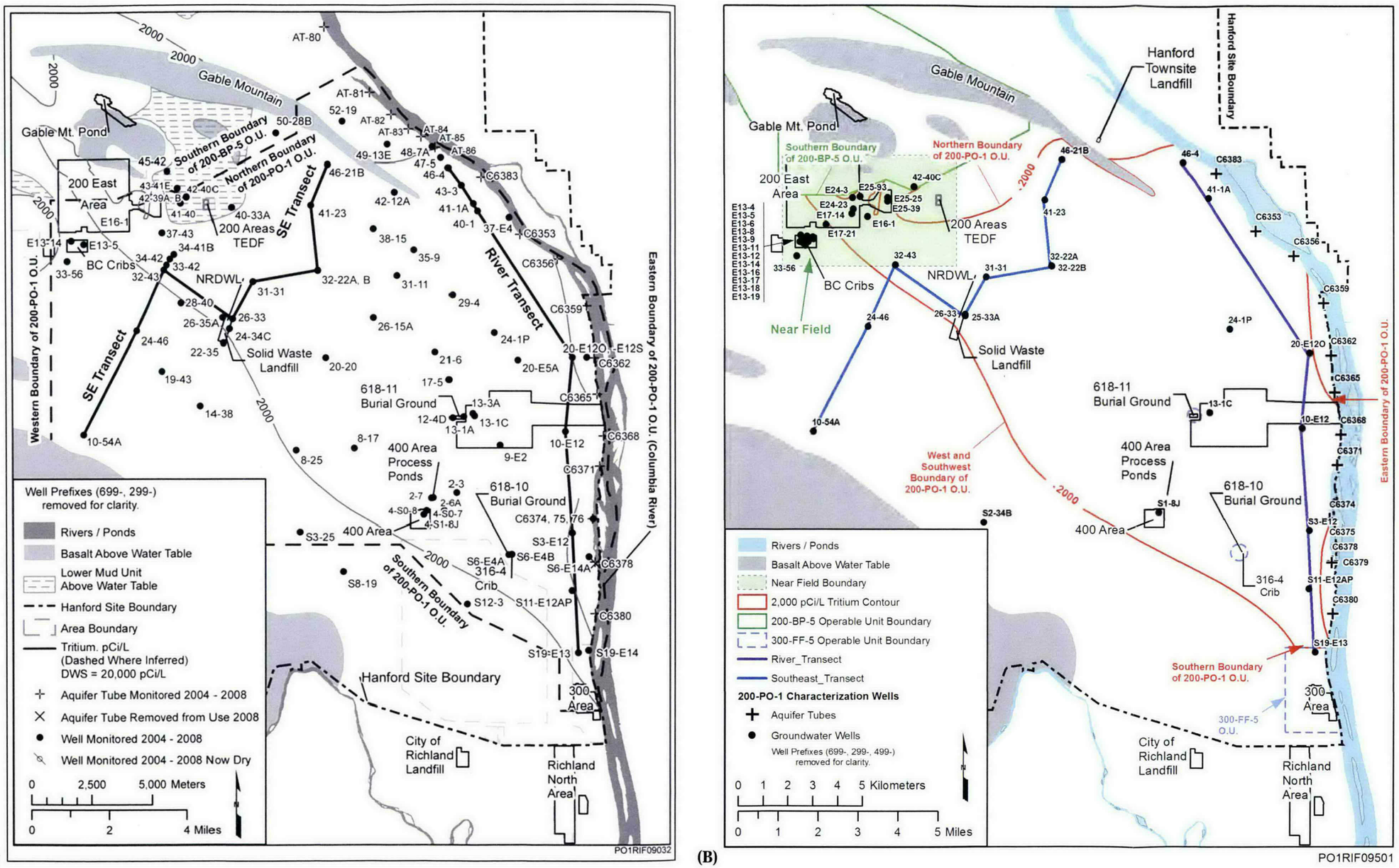


**Figure 2-2. 200-PO-1 Groundwater Operable Unit Far Field Monitoring Wells Sampled Per DOE/RL-2003-04 (2008 Annual Report) and Additional Wells Sampled from DOE/RL-2007-31**

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**Table 2-2. Status Summary of 200-PO-1 Remedial Investigation Characterization Activities**

| Task | Requirement (DOE/RL-2007-31, Table 5-1) Work Plan Section | Status |
|---|---|---|
| **Task A. Ongoing Characterization Groundwater Sampling** | | |
| A-1. Sampling of existing monitoring wells for 2 years | • Routine monitoring SAP (DOE/RL-2003-04, Rev. 1 as amended) Table 2-1 and Table 2-2 | FY 2008 – 161 wells sampled (Characterization & Monitoring) (Annual Report); FY 2009 – TBD |
| A-2. Sampling of characterization wells for 2 years | • Characterization SAP (DOE/RL-2007-31), Tables A3-2 as available for sampling; 43 wells, 44 analytes | Tables 2-3 and 2-4 Characterization wells identified with asterisks, 41 of 43 wells sampled in FY 2008 |
| A-3. Opportunistic sampling | • BC cribs soil site boreholes (A, C, and E) | Table 2-6 – FY 2008 – 1 out of 3 drilled to groundwater and sampled |
| | • PUREX (A-2, A-5, and A-30) | Table 2-6 – FY 2008 - 3 out of 3 sampled/1 additional well made into a groundwater monitoring well (A-4 crib) |
| A-4. Aquifer tube location | • Sample existing PO-1 aquifer tubes | Table 2-6 – FY 2008 - 5 sample results reported in FY 2008 Annual Report |
| | • Install and sample 10 new aquifer tubes (Work Plan Section 4.3.2.6 and SAP Section A.1.4.5) | Table 2-6 – FY 2008 10 new plus 1 replacement tube installed and sampled FY 2008 Annual Report |
| **Task B. Groundwater Monitoring** | • Conduct groundwater monitoring activities per routine monitoring SAP (DOE/RL-2003-04) and Work Plan Section 4.1.1 | FY 2008 161 sampled (Annual Report), as noted in Task A |
| **Task C. Assess Contaminant Transport Model** | • Refine the type of analyses and modeling needed, as well as appropriate inputs (Work Plan Section 5.4) | Presented recommendations for appropriate analysis and modeling to Tri-Parties for discussion prior to implementation (August 2009) |
| **Task D. Summarize Existing Geologic Information** | • Compile information on existing geologic information (Work Plan Section 4.1.2): | |
| | – Prepare table of existing documentation | Appendix B, Annotated Bibliography |
| | – Revise/update cross-sections | ECF-200PO1-09-2074 |
| | – Revise suprabasalt study to include new well and tops information | Geohydrologic updates to formation tops database updated where needed for fate and transport model and as developed from interpretation of top basalt reflectors on vintage and FY 2008 acquired seismic reflection data |
| **Task E. Compile and Summarize Available Inventory Data for Contributing Waste Sites** | • Historic contaminant research (Work Plan Section 4.2) and SAP Appendix A Section A1.2 Source Waste Sites | RI Report includes references (Table 3-2) and Work Plan Section 3.2 to source operable unit documents along with summary table of source information. Appendix B Annotated Bibliography |
| **Task F. Determine Geophysical Methods for Characterization** | • Geophysical data will be acquired (Work Plan Section 4.3.2) | Methods were determined and field work was performed in FY 2008; analysis of results is summarized in RI Section 2.3.1 and SGW-42313 |
| **Task G. Determine Additional Characterization Needs to Support Modeling** | • Work Plan Section 5.4 | Deferred to the RD/RA Work Plan for modeling necessary to support the remedial decision |
| **Task H. Begin Groundwater Analysis and Modeling** | • Input values gathered during characterization activities, from other field studies, and published literature (Work Plan Section 5.4: | |
| | – Compile and evaluate data | Data compiled, evaluated, and summarized in this RI Report |
| | – Identify currently impacted groundwater | Chapter 4, Nature and Extent of Contamination |
| | – Interpret historic flow direction and rates | Chapter 4, Nature and Extent of Contamination |
| | – Assess likely future flow directions and rates | Work in progress |
| | – Evaluate likely future contaminant migration | Work in progress |

**Table 2-2. Status Summary of 200-PO-1 Remedial Investigation Characterization Activities**

| Task | Requirement (DOE/RL-2007-31, Table 5-1) Work Plan Section | Status |
|---|---|---|
| **Task I. Summarize Data and Perform Baseline Risk Assessment** | • Develop Conceptual Site Model (Work Plan Section 5.5 and Section 6.1) | Physical Model provided in Chapter 3, Exposure Model in Chapter 5, additional hydrogeology CSM provided in PNNL-12261 and previously in DOE/RL-95-100 |
| | • Identify Exposure pathways (Work Plan Section 6.1) | Chapter 5 |
| | • Establish cumulative risk using reasonable maximum exposure, toxicity values, current and future use risks, uncertainty (Work Plan Section 6.0) | Risk evaluation is provided in Section 6.0. COPC selection is described in Section 6.1, exposure assessment is in Section 6.2.1, toxicity assessment (including sources of toxicity values) is in Section 6.2.2, the protectiveness and risk evaluation (including cumulative effects) is presented in the Section 6.2.3 (risk characterization), and the uncertainty assessment is presented in Section 6.2.4 |
| | • Identify exposed populations (Work Plan Section 6.1) | A description of the conceptual exposure model is provided in Section 5.3; this section provides a description of current and future land use, groundwater and surface water beneficial use, and potentially complete receptors (exposed populations) and exposure pathways |
| | • Establish ecological risk (Work Plan Section 6.1) | The potential for ecological exposure and risks to aquatic receptors is evaluated concurrently with human health risk in Section 5.3.5 |
| **Task J. Establish Remedial Alternatives and Perform the Alternative Screening Process** | • Develop applicable or relevant and appropriate requirements (Work Plan Section 6.0) | Draft ARARs; Table prepared and provided to regulators July 2009 |
| | • Develop general remedial action objectives (Work Plan Section 6.0) | To be developed in FS – Chapter 7 provides RAO key elements |
| | • Develop remedial alternatives (Work Plan Section 6.0) | To be provided in FS – Preliminary alternatives were presented in DOE/RL-2007-31, Section 6.4, and previously in DOE/RL-96-66, Section 6.1 |
| | • Screen remedial alternatives (Work Plan Section 6.0) | To be provided in FS – Previously screened in DOE/RL-96-66, Section 6.1 |
| | • Conduct a detailed analysis of alternatives (Work Plan Section 6.0) | To be provided in FS – Previously screened in DOE/RL-96-66, Section 6.1 |
| **Task K. Produce the RI and Generate the FS** | • Prepare an RI and FS as identified in Work Plan Section 5.5 and Section 6.0 | Work in progress |

Notes:
DOE/RL-95-100, *RCRA Facility Investigation Report for the 200-PO-1 Operable Unit*
DOE/RL-96-66, *RCRA Corrective Measure Study for the 200-PO-1 Operable Unit*
DOE/RL-2003-04, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*
DOE/RL-2007-31, *Remedial Investigation/Feasibility Study Work Plan for the 200-PO-1 Groundwater Operable Unit*
ECF-200PO1-09-2074, *200-PO-1 Groundwater Operable Unit Remedial Investigation Report – Geologic Cross Sections*
PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*
ARARs = applicable or relevant and appropriate requirement
COPC = contaminant of potential concern
CSM = conceptual site model
FS = feasibility study
FY = fiscal year
PUREX = Plutonium-Uranium Extraction (Plant)
RAO = remedial action objective
RD/RA = remedial design/remedial action
RI = remedial investigation
SAP = sampling and analysis plan
TBD = to be determined

#### 2.2.1.1 PUREX

Vadose zone Well 299-E24-23 was drilled adjacent to the 216-A-4 Crib within the PUREX Area (Figure 2-3). To assess whether COPCs migrated deep into the vadose zone in an area known for high contamination, this well was deepened to the upper unconfined aquifer and sampled for the full 44 COPCs (Table 2-1). Sediments were sampled for geochemical and geotechnical parameters required for modeling and remedial alternatives evaluation.

Three source OU boreholes were drilled to the water table in the 216-A-2 (C5515), 216-A-5 (C5301), and 216-A-30 (C5941) Cribs (Figure 2-3 and Figure 2-4). Groundwater from these wells was sampled and analyzed for the constituents presented in DOE/RL-2007-31, Appendix A, Table A3-2.

Alkalinity and ammonium (RCRA constituents) were added to the COPCs for all wells chosen for sampling within the PUREX area. The data from these wells were evaluated as part of the characterization in the vicinity of the PUREX cribs.

In order to provide better characterization of the key geologic and hydrogeologic properties of the vadose and saturated zones, a special geophysical logging campaign using innovative logging tools was performed by Schlumberger™ in Well 299-E17-3, south of the PUREX Plant. One well (299-E17-3) in the PUREX cribs area was selected as a test well for conducting advanced geophysical logging in steel cased holes using instrumentation adapted from tools used extensively in the petroleum industry. The emphasis of the measurements was to determine porosity, water/moisture content, water saturation, matrix geochemistry and lithologic composition, concentration of cobalt and cesium contamination, and hydraulic conductivity and permeability more accurately. Results of the innovative technology (Section 2.3) provide data to support the physical conceptual model and are detailed in SGW-42929, *Advanced Geophysics (Vendor Report)*.

#### 2.2.1.2 BC Cribs and Trenches Area

Twelve wells (Table 2-3) in the BC Cribs and Trenches Area were sampled for the monitoring SAP constituents. The analytical results were reviewed to determine whether additional groundwater wells are needed. One new well (299-E13-62) in the BC Crib and Trenches Area, shown in Figure 2-1, was sampled for the list of 44 analytes presented in Table 2-1.

### 2.2.2 Far Field Investigations

The Far Field is defined as east and southeast of the 200-PO-1 OU Near Field area, and to the west of the Columbia River, including the B Ponds, NRDWL, SWL, 400 Area wells, Southeast Transect wells, and River Transect and River Corridor wells (Table 2-4). Far Field wells (Figure 2-2) were sampled to collect data on groundwater contaminants, acquire geophysical data to estimate vertical and lateral extent of contamination in the aquifer, and refine or confirm preferred contaminant pathways.

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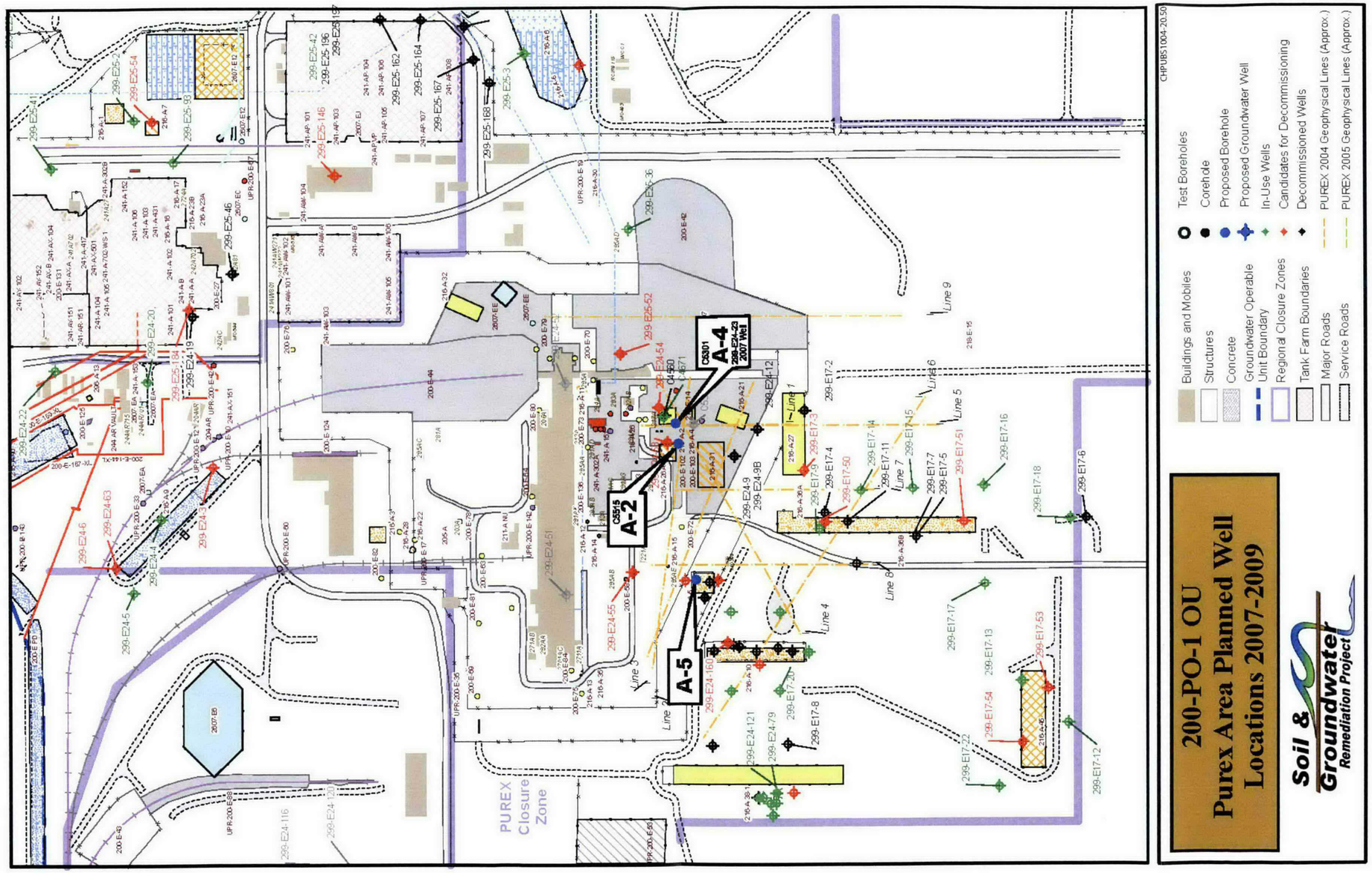


Figure 2-3. Locations of Wells (A 2, A 4, and A 5) in the PUREX Area to be Opportunistically Sampled for 200-PO-1 Groundwater Operable Unit Analytes (DOE/RL-2007-31)

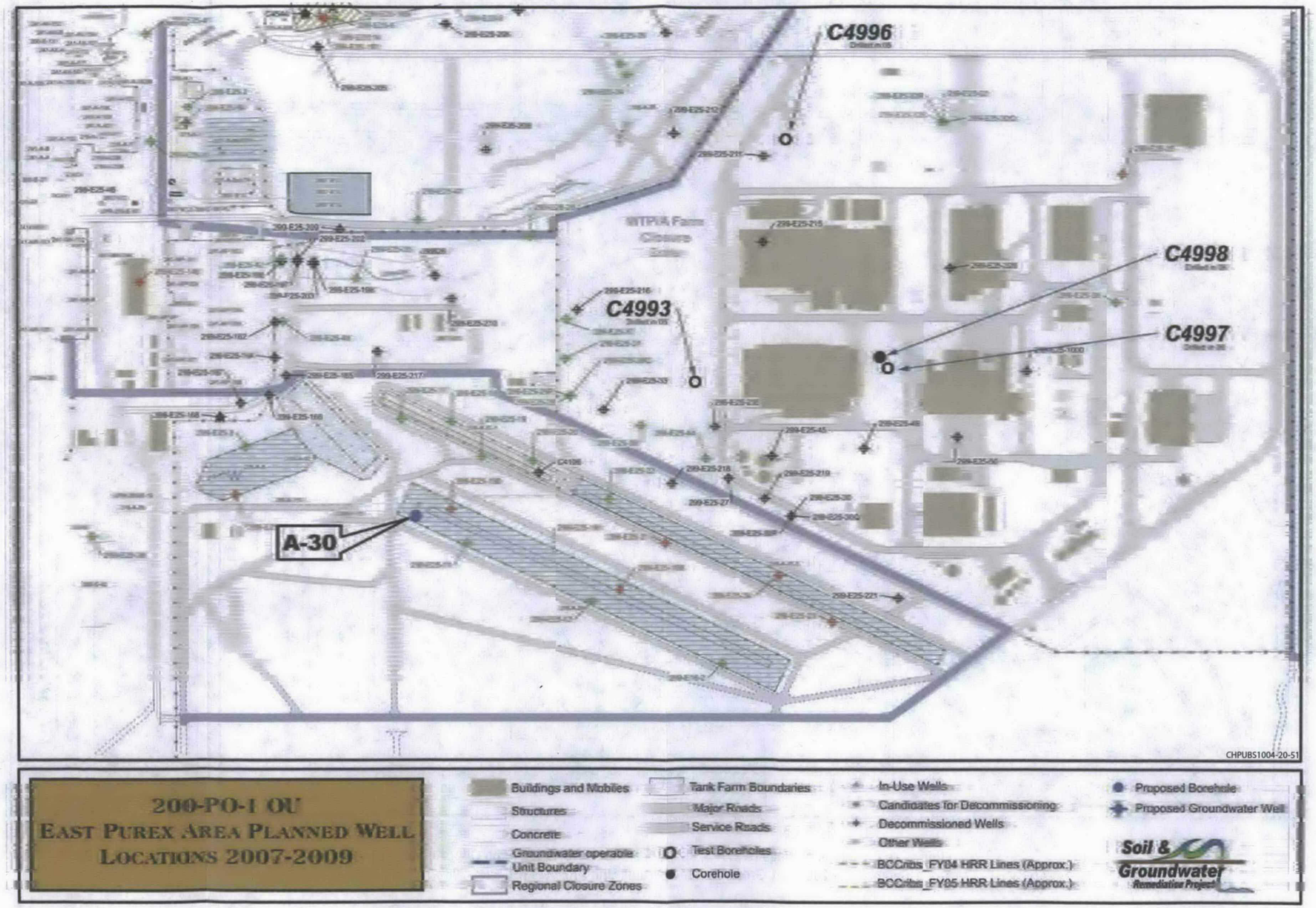


Figure 2-4. Location of Well A 30 in the PUREX Area to be Opportunistically Sampled for 200-PO-1 Groundwater Operable Unit Analytes (DOE/RL-2007-31)

**Table 2-3. 200-PO-1 Groundwater Monitoring Wells in the Near Field Area**

| Wells Identified in Near Field General | | | |
|---|---|---|---|
| 299-E16-2 | 299-E24-18 | 299-E25-29P | 299-E25-43 |
| 299-E17-1 | 299-E24-20 | 299-E25-29Q | 299-E25-47 |
| 299-E17-12 | 299-E24-22 | 299-E25-236 | 299-E25-6 |
| 299-E17-13 | 299-E24-23* | 299-E25-3 | 299-E25-93* |
| 299-E17-14* | 299-E24-33 | 299-E25-32P | 299-E25-94 |
| 299-E17-16 | 299-E24-5 | 299-E25-32Q | 299-E26-4 |
| 299-E17-18 | 299-E25-17 | 299-E25-34 | 699-37-47A |
| 299-E17-19 | 299-E25-18 | 299-E25-35 | 699-39-39 |
| 299-E17-23 | 299-E25-19 | 299-E25-36 | 699-41-42 |
| 299-E17-25 | 299-E25-2 | 299-E25-37 | 699-42-40A |
| 299-E18-1 | 299-E25-20 | 299-E25-40 | 699-42-42B |
| 299-E23-1 | 299-E25-22 | 299-E25-41 | 699-43-45 |
| 299-E24-16 | 299-E25-28 | 299-E25-42 | 699-44-39B |
| 299-E17-21* | 299-E24-3* | 299-E25-25* | 299-E25-39* |
| **Wells Identified in BC Cribs** | | | |
| 299-E13-5* | 299-E13-9* | 299-E13-16* | 299-E13-18* |
| 299-E13-6* | 299-E13-12* | 299-E13-17* | 299-E13-19* |
| 299-E13-8* | 299-E13-14* | 299-E13-4* | 299-E13-11* |

Notes:

* Well is also a characterization well (Table A3-2 of SAP, DOE/RL-2007-31, Appendix A).

**Table 2-4. 200-PO-1 Groundwater Monitoring Wells in the Far Field Area**

| | | | | | |
|---|---|---|---|---|---|
| **Wells Identified in Southeast Transect** | | | | | |
| 699-24-46* | 699-26-33 | 699-31-31 | 699-32-22A* | 699-32-43* | 699-41-23* |
| **Wells Identified in River Transect** | | | | | |
| 699-20-E12O* | 699-41-1A* | 699-46-4* | 699-S3-E12* | 699-S19-E13* | |
| **Wells Identified in Basalt Confined Aquifer** | | | | | |
| 699-13-1C* | 699-24-1P* | 699-32-22B* | 699-42-40C* | 699-S2-34B* | 699-S11-E12AP* |
| **Wells Identified in Far Field General** | | | | | |
| 499-S0-8 | 499-S1-8J* | 699-12-4D | 699-13-1A | 699-13-3A | 699-14-38 |
| 699-19-43 | 699-20-20 | 699-20-E12S | 699-20-E5A | 699-21-6 | 699-2-3 |
| 699-24-34C | 699-26-15A | 699-26-35A | 699-2-6A | 699-2-7 | 699-28-40 |
| 699-31-11 | 699-33-56* | 699-34-41B | 699-34-42 | 699-35-9 | 699-37-43 |
| 699-38-15 | 699-40-1 | 699-40-33A | 699-40-36 | 699-41-40 | 699-42-12A |
| 699-42-39B | 699-43-3 | 699-45-42 | 699-47-5 | 699-48-7A | 699-49-13E |
| 699-52-19 | 699-8-17 | 699-8-25 | 699-9-E2 | 699-S12-3 | 699-S19-E14 |
| 699-S6-E14A | 699-S8-19 | 699-25-33A* | 699-26-33* | 699-31-31* | |

Notes:

* Well is also a characterization well (Table A3-2 of SAP, DOE/RL-2007-31, Appendix A).

#### 2.2.2.1 *River Transect Wells*

The River Transect is positioned along the Columbia River at the eastern edge of the Hanford Site to monitor contaminant transport into the Columbia River. Five existing River Transect wells (Figure 2-2) were chosen for sampling and analysis to evaluate 44 COPCs annually. These analyses supported evaluation of the extent of contamination adjacent to the Columbia River for the purposes of risk assessment.

#### 2.2.2.2 *Southeast Transect Wells*

The Southeast Transect is located to the south and east of the 200 East Area and detects contamination moving into the southern and eastern parts of the Hanford Site from the 200-UP-1 Groundwater OU to the 200-PO-1 Groundwater OU. Nine existing wells were chosen along the Southeast Transect to analyze all 44 COPCs annually (Figure 2-2).

#### 2.2.2.3 Aquifer Tubes

Five existing aquifer tubes stations in the vicinity of the Hanford town site were sampled. Eleven (ten new and one replacement) aquifer tube stations were installed along the river (Figure 2-5). Each station was designed to include three vertical tubes with a monitoring point placed within the upper, middle, and lower portions of the groundwater/river interface (Figure 2-6 and Figure 2-7). Completed station installations, however, included only the shallow, or upper, monitoring point at nine of the ten new stations. Rock formations at those locations prevented installation of the deeper monitoring points at all except planned station AT-8, where two points were installed (C6378 and C6379). The purpose of the aquifer tubes is to acquire contaminant data within a geographic area that had not been characterized as needed for risk assessment.

## 2.3 Soil and Vadose Zone Investigations

The 200-PO-1 Groundwater OU is specifically a groundwater OU, and this RI focuses on characterization of groundwater conditions (Figure 2-8 and Figure 2-9). Some RI activities, however, included geophysical measurement techniques that provided information on geological features from ground surface to the underlying bedrock in support of developing the 200-PO-1 physical model.

### 2.3.1 Geological and Geophysical Data Compilation

The complete catalog of available geological formation contacts information was used to populate a database in HydroGeo Analyst (HGA), a data management system that includes subsurface characterization, mapping, and three-dimensional visualization. The following summary reports include compilations of geological data:

- ECF-200PO1-09-2074, *200-PO-1 Groundwater Operable Unit Remedial Investigation Report – Geologic Cross Sections*
- ECF-200PO1-09-2015, *200-PO-1 Groundwater Operable Unit Remedial Investigation Report – Groundwater Quality Analysis to Support Contaminat Fate and Transport Modeling*

Geophysical surveys were conducted during FY 2008 to test whether airborne electromagnetic (EM) and state-of-art seismic reflection profiling could provide technical information to refine both the Near Field and Far Field physical models. Objectives of the geophysical surveys focused on mapping the following subsurface characteristics:

- Top of the basalt
- Location and orientation of faulting
- Areas of preferred flow pathways, such as high permeability channels eroded or deposited into the older sediments across the area

Geophysical information was augmented using seismic reflection data previously collected under the Basalt Waste Isolation Project (BWIP) during FYs 1979 and 1980. BWIP seismic sections were scanned, digitized (converted back to digital seismic data) and re-interpreted in order to aid physical model refinement. Information used to constrain the seismic interpretation consisted of check shot seismic surveys conducted between FY 2006 and FY 2009, as well as existing borehole velocity scans (FYs 1979 and 1980), which were used to tie known geologic information with seismic reflectors. Known geologic information from boreholes adjacent to seismic profiles and within the Airborne EM survey area was also used to constrain the geophysical interpretations.

These data were analyzed in FY 2009 to support the identification of possible preferential groundwater flow paths from the 200 East Area to the Columbia River. Results from these investigations are provided in SGW-42313, *Geophysical Investigations: 200-PO-1 Groundwater Operable Unit.*

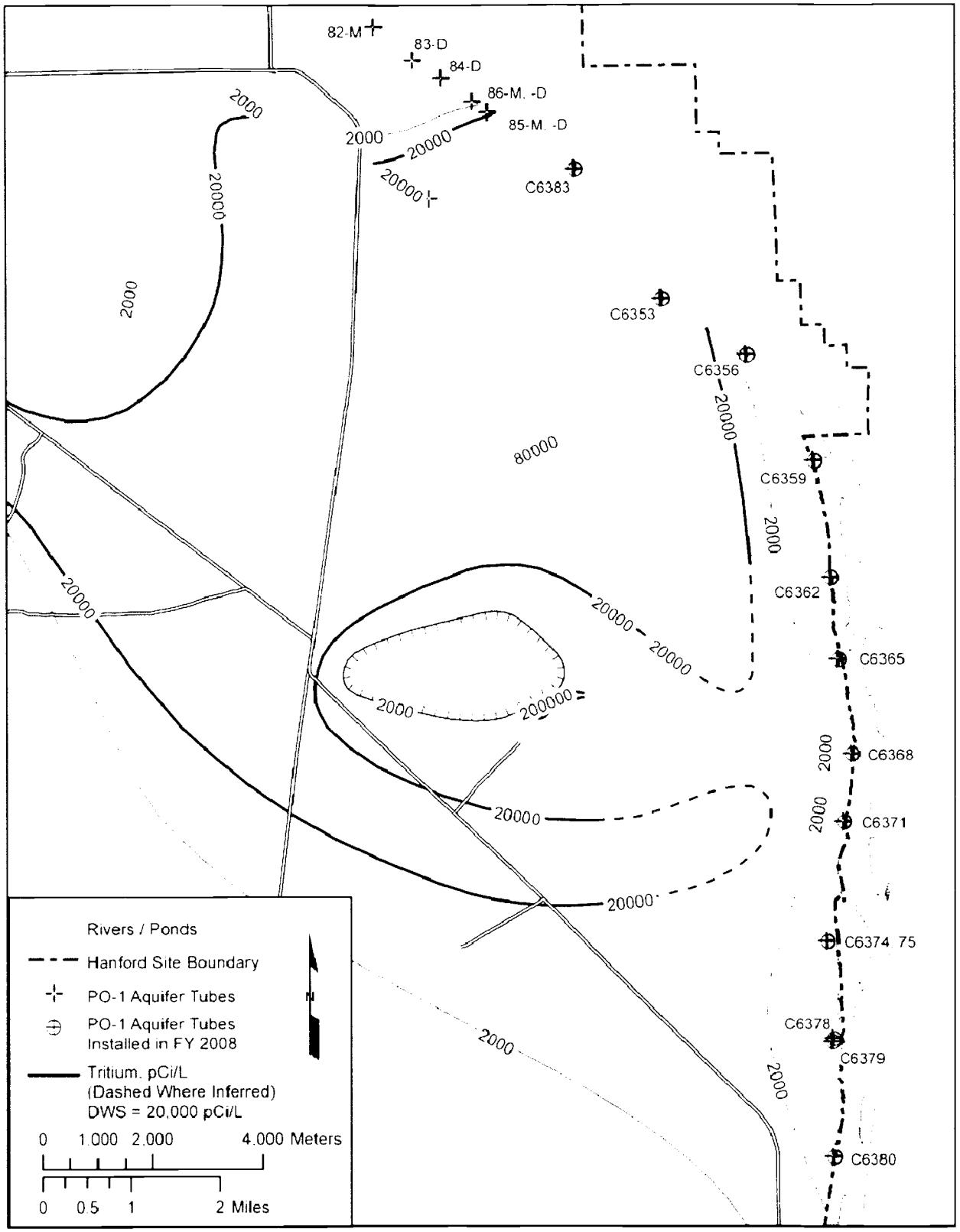


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**Figure 2-5. Aquifer Tubes in the 200-PO-1 Groundwater Operable Unit**

Figure 2-6. Aquifer Tube Location Along the Columbia River

Figure 2-7. 200-PO-1 Operable Unit Aquifer Tube Installation

Figure 2-8. 200-PO-1 Groundwater Sampling of Existing Wells

Figure 2-9. 200-PO-1 Groundwater Sample Collection

#### 2.3.1.1 Airborne Geophysics

Airborne electromagnetic (EM) and magnetic data were acquired by Fugro® Air Services during FY 2008 in the 200-PO-1 Groundwater OU (Figure 2-10). Both the Heli-GEOTEM-II® time domain system and RESOLVE® frequency domain systems were used to map subsurface variations in electrical resistivity along north-south oriented profiles with the presumption of intersection east-west oriented features. A vendor report of the airborne electromagnetic survey is provided in SGW-39674, *Airborne Electromagnetic Survey Report, 200-PO-1 Groundwater Operable Unit, 600 Area, Hanford Site.*

Heli-GEOTEM® surveys were acquired along north-south profiles spaced at approximate 400 m (1,312.3 ft) E-W intervals and covered an area of approximately 336 $km^2$ (130 $mi^2$). RESOLVE® surveys covered an area of approximately 90 $km^2$ (35 $mi^2$) within a corridor paralleling the Columbia River and using a profile spacing of 200 m (656.2 ft); the seven easternmost profiles were collected at a spacing of 100 m (328.1 ft). Total field magnetic data was acquired contemporaneously with the EM surveys using a cesium vapor magnetometer.

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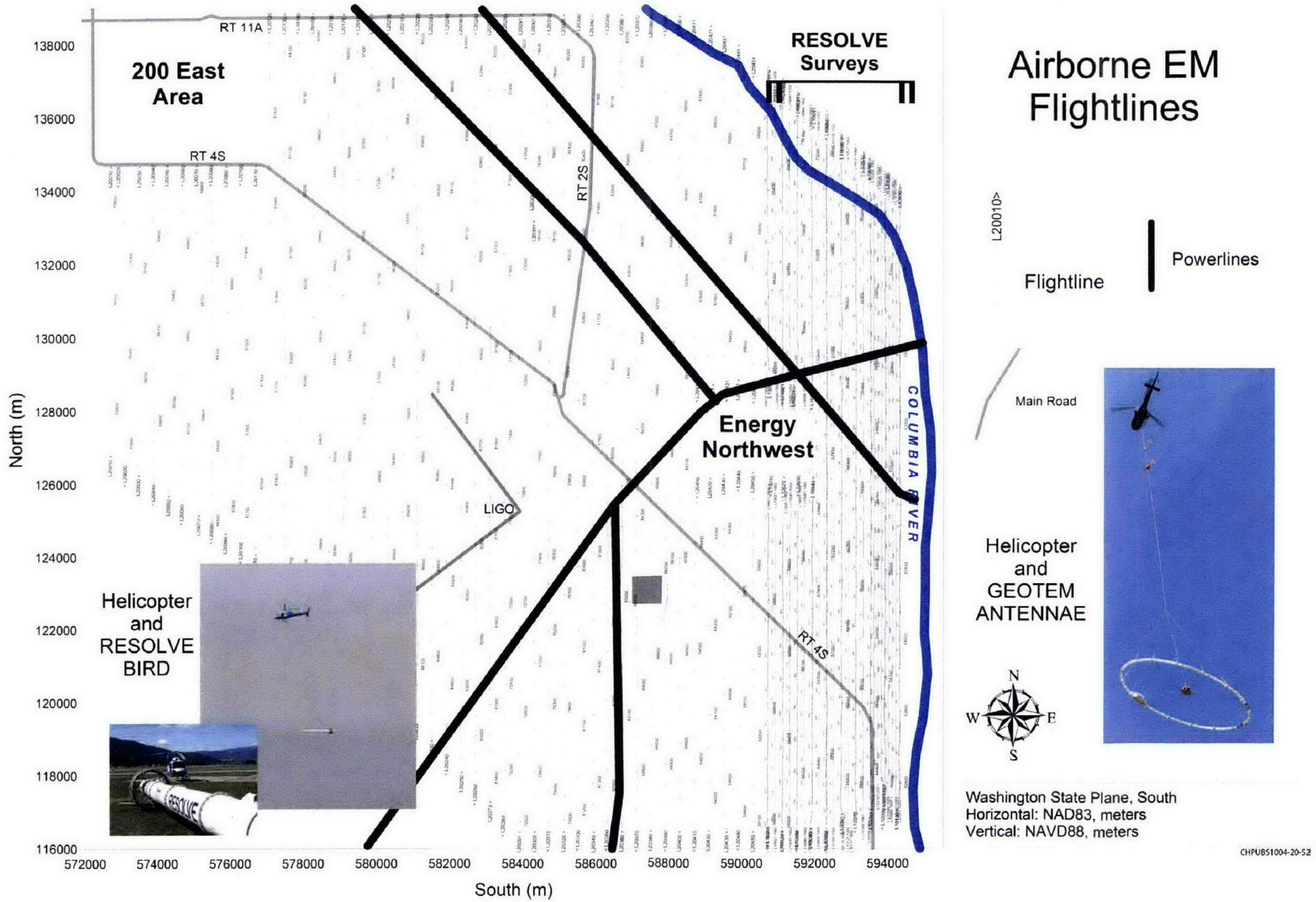


Figure 2-10. 200-PO-1 Fugro® Airborne Electromagnetic and Magnetic Surveys

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A simple modeling algorithm was initially used to convert the Heli-GEOTEM® data into apparent depth and apparent resistivity cross-sections, termed Resistivity-Depth-Images by Fugro®. Follow on correlations with existing geologic information indicated that a more rigorous modeling method should be used, and Fugro® performed geophysical inversion of the Heli-GEOTEM® data using a proprietary five-layer algorithm along three of the geologic profiles – G-G', H-H', and J-J'. Total resulting depth of investigation post inversion ranged from 60 to 150 m (196.9 to 492.1 ft), with greater penetration occurring where higher electrical resistivity is indicated in the subsurface. RESOLVE® data were processed using a pseudo-layered half-space model which allowed the determination of apparent resistivity at depths of 2, 12, 22, 32, 42, and 52 m (6.6, 39.4, 72.2, 105, 137.8, and 170.6 ft) below ground surface (bgs).

Examples of the airborne EM survey results along the J-J' geologic profile are shown in Figure 2-11 and Figure 2-12. Results are presented in units of electrical-resistivity (ohm-m) with zones of higher resistivity marked by blue colors and lower resistivity by red colors. Both EM surveys detail lateral and vertical changes in electrical resistivity that are currently interpreted to represent changes in grain size, and where coarser grained intervals are associated with zones of higher resistivity. The Heli-GEOTEM® survey (Figure 2-11) details a broad zone of high resistivity (>300 ohm-m) centered at profile coordinate 17,500, which likely represents a zone of coarser grained units. Zones of lower resistivity are broadly consistent with finer grained intervals within the Ringold units. As modeled, there is currently a poor correlation with the basalt surface.

RESOLVE® data (Figure 2-12) are compiled from short segments of flight lines adjacent to the J-J' profile, which results in apparent faults where the splices abut (this is most evident north of Well 699-20-E12 where the J-J' transect crosses multiple flight lines on a NW direction). Geo-electrical layering is apparent in the southern half of the RESOLVE® section, where three layers are indicated by changes from low resistivity (40-100 ohm-m) to intermediate resistivity (125-170 ohm-m) to low resist again (20-100 ohm-m). The upper layer is coincident with the Hanford sediments and primarily above water table. The intermediate and basal low resistivities occur within the Ringold E Unit and are likely indicating increases in fine content.

RESOLVE® survey results for the calculated 32 m bgs depth slice are compared against the shape of the tritium plume in Figure 2-13. The shape of the eastern most 2,000 pCi/l tritium contour is weakly consistent with a subtle west-to-east increase in electrical conductivity (decrease in resistivity) on the 12, 32, and 42 m depth slices. This may correspond to an increase in finer grained sediments, which would serve to retard eastward groundwater migration in this area. The tritium plume is mapped towards the Columbia River in the southern quarter of the survey area. This coincides with a moderate increase in electrical resistivity from north to south along the River Corridor. The north-to-south increase in resistivity is presumed to correspond with an increase in coarser sediments in the vicinity of the tritium plume.

Magnetic survey results are shown in Figure 2-14 and are compared to the currently understood basalt topography. Relative magnetic highs are color coded toward pink colors and relative lows toward blue colors. Magnetic data correlate well with the top-of-basalt structure within the survey area. The southeast buried Gable Mountain structure is coincident with a southeast trending magnetic lineament. Uplift of the Central Plateau correlates with an increase in magnetic intensity from east to west across the May Junction Fault. The eastern extension of the Yakima Ridge appears to correlate with a magnetic high trending from the western edge of the surveyed area.

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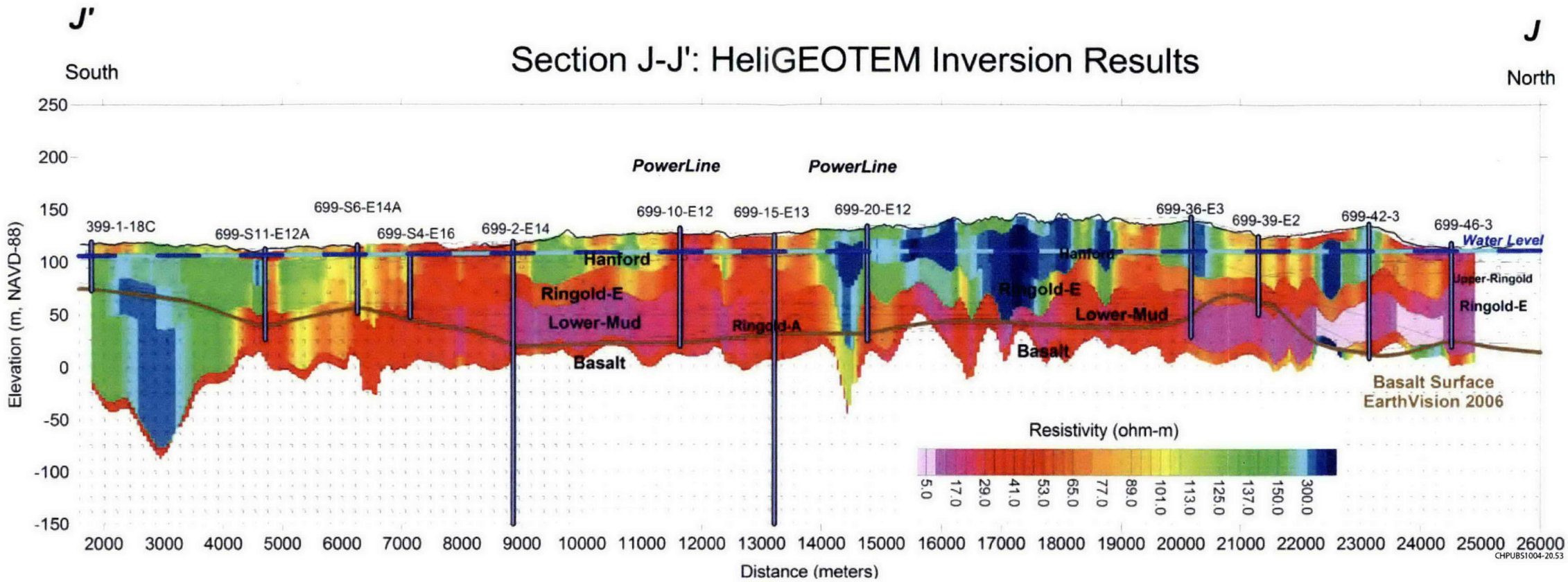


Figure 2-11. 200-PO-1 Heli-GEOTEM® Derived Electrical Resistivity Along Profile J-J'

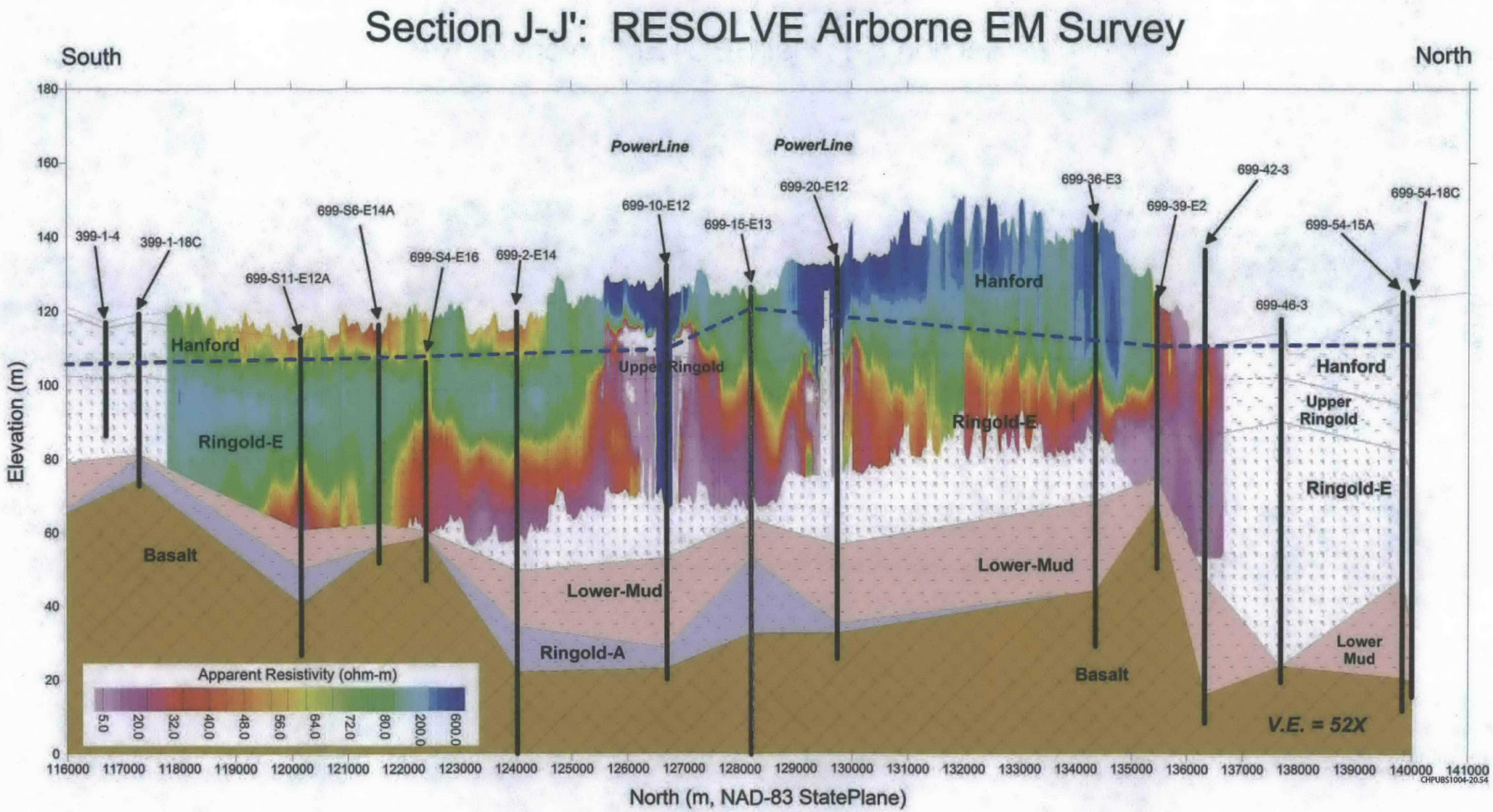


Figure 2-12. 200-PO-1 RESOLVE® Derived Electrical Resistivity Along Profile J-J'

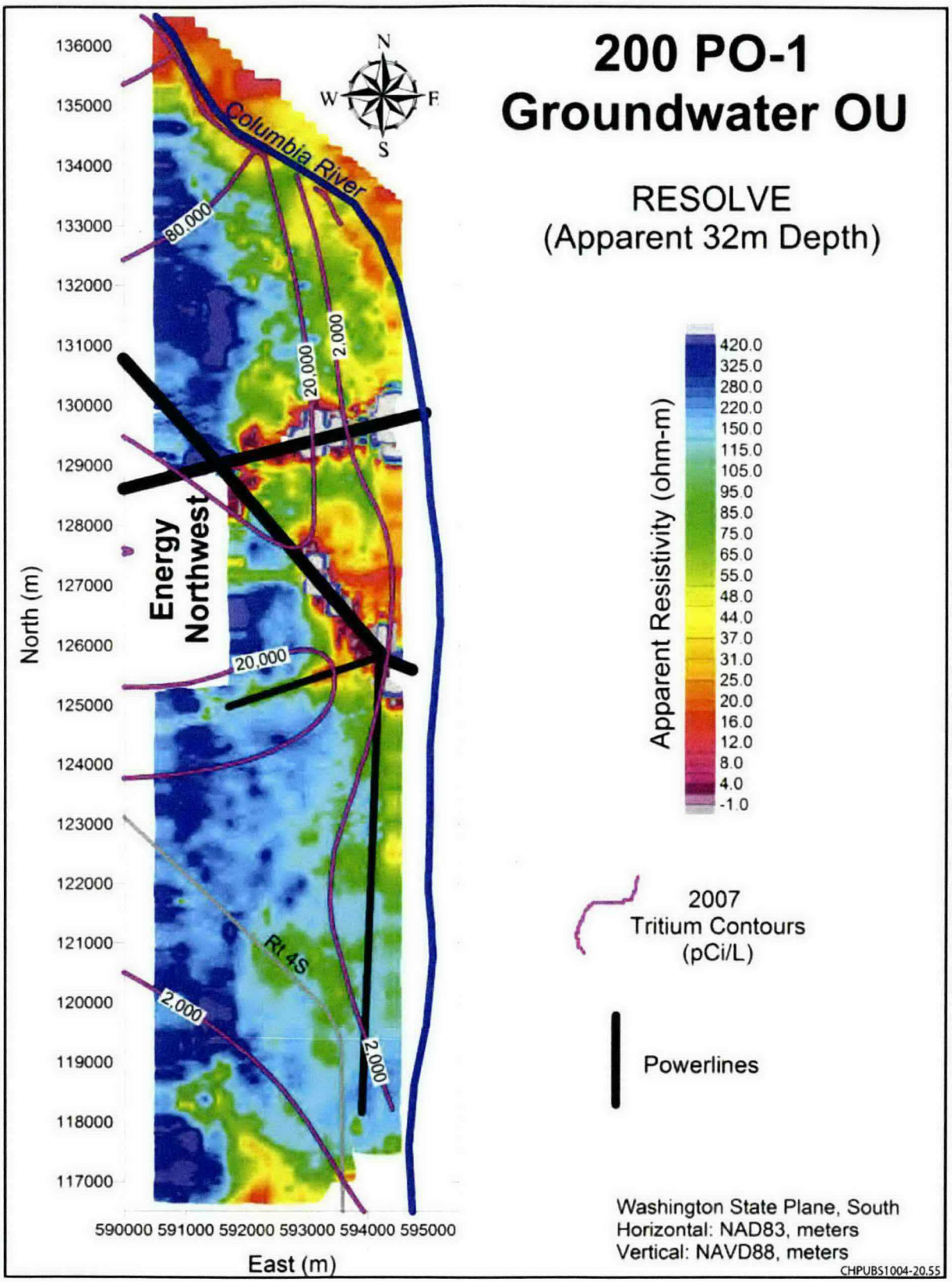


**Figure 2-13. 200-PO-1 RESOLVE® Derived Electrical Resistivity, 32 m Depth**

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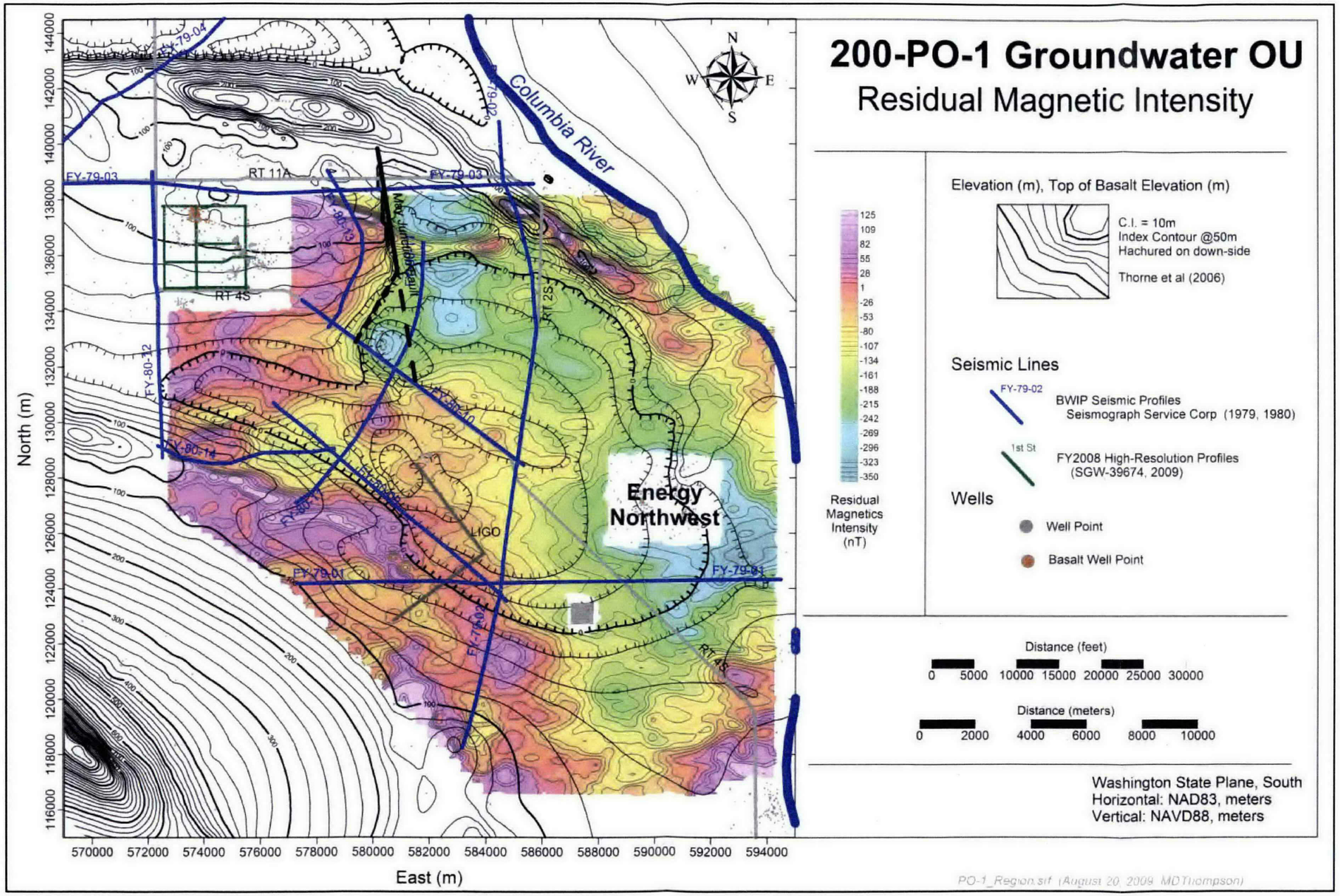


Figure 2-14. 200-PO-1 Residual Magnetic Survey Results

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#### 2.3.1.2 Seismic Reflection Survey

A total of 24 km (15 mi) of seismic reflection surveys were collected during FY 2008 by Bay Geophysical, Inc. in the 200 East Area. (Figure 2-15). The design criteria for these surveys included imaging subsurface acoustic interfaces, between 22.8 m to 304. 8 m (75 ft to 1,000 ft) bgs, primarily to image the top of the basalt (Figure 2-12). SGW-39675, *Reflection Seismic Survey Report, 200 East Area, Hanford Site – Fiscal Year 2008*, provides data acquisition details; interpreted data results are presented in SGW-42313. An additional 80 km (50 mi) of existing seismic reflection data that cross through the 200-PO-1 Groundwater OU (Figure 2-16) were re-interpreted during FY 2009. Known geologic information from nearby wells was used to constrain the interpretations.

Seismic reflection data acquired during FY 2008 in the 200 East Area was able to map top-of-basalt, identify two north-south oriented channel cuts in the bedrock surface, and image intra-basalt fractured zones. Though supra-basalt sedimentary facies of the Hanford and Ringold Formations were poorly imaged with the processing used, correlation with borehole-derived geologic tops using check shot velocity information suggests that H2 and H3 Hanford sub-units are mappable with seismic reflection. Results for the 7$^{th}$ Street Profile are shown in Figure 2-17 where an approximately 100 m (328 ft) wide channel in the basalt surface is imaged, as well as subtle changes in seismic character that likely correlate with the H1-H2 and H2-H3 interfaces.

Reinterpretation of the BWIP seismic reflection data indicated the potential for mapping Ringold sub-units as well as the top of basalt. Ringold sub-unit identification was based on correlating check shot velocity and borehole geologic tops with reflectors. The BWIP seismic data set also identified numerous structural features (anticlines, sedimentary basins, reverse/normal faulting) that are used to refine conceptual site models. Figure 2-18 shows the re-interpretation for the northern half of BWIP profile FY79-02 (see Figure 2-16). The seismic section images a topographic high in the subcropping basalt surface that correlates with the southern extent of the Gable Mt structure. Anticlinal features south of this basalt high also are imaged. South to north changes in supra-basalt sediment reflector character likely correlate with changes within the Ringold units. For example, the strongly reflective Ringold sequence under Well 699-26-15C (station 720) contrasts with that under Well 699-33-14 (station 580) where the Ringold Lower Mud Unit is not present.

#### 2.3.1.3 Check Shot Surveys

Check shot surveys provide time-depth correlation information to aid in interpreting seismic reflection profiles by associating geologic units with specific seismic reflectors or characteristics. Available check shot information includes data from ten wells collected during FY 2008 and FY 2009, four check surveys for the Waste Treatment Plant design (FY 2006), and three borehole velocity surveys (1979) conducted contemporaneously with the BWIP seismic data collection (see Figure 2-19). Check shot surveys are used to obtain an in situ measure of compressional wave seismic velocity for sediment and rock in the vicinity of the well point, and to provide the seismic wave travel time to geologic horizons of interest. The collected travel time information provides a direct tie between subsurface geology and reflecting horizons identified by the seismic reflection surveys. Report SGW-39676, *Check Shot Survey Summary Report, 200 East Area, Hanford Site – Fiscal Year 2008*, provides more detail on the check shot survey method as applied at Hanford.

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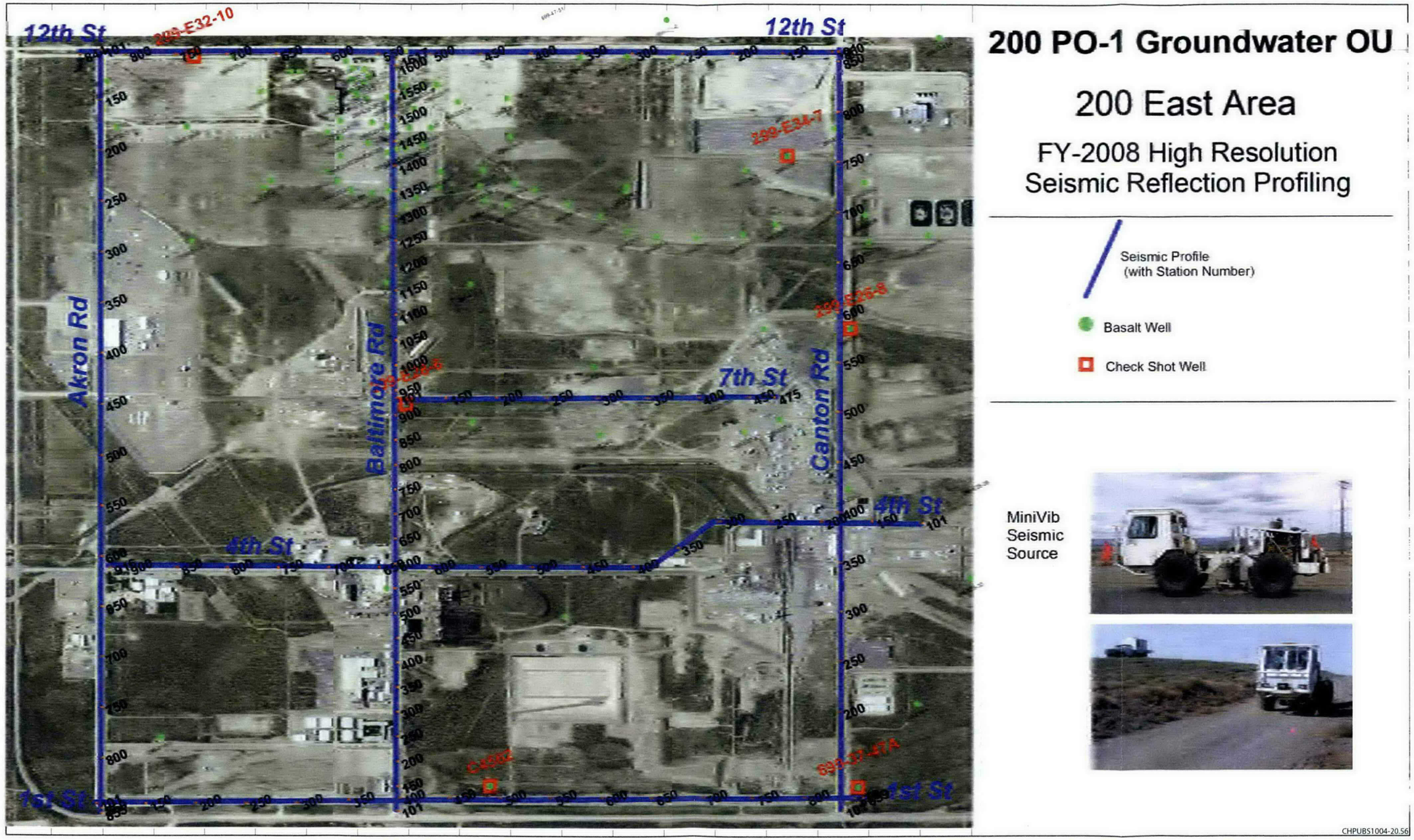


Figure 2-15. 200-PO-1 200 East Area Seismic Reflection Surveys (FY 2008)

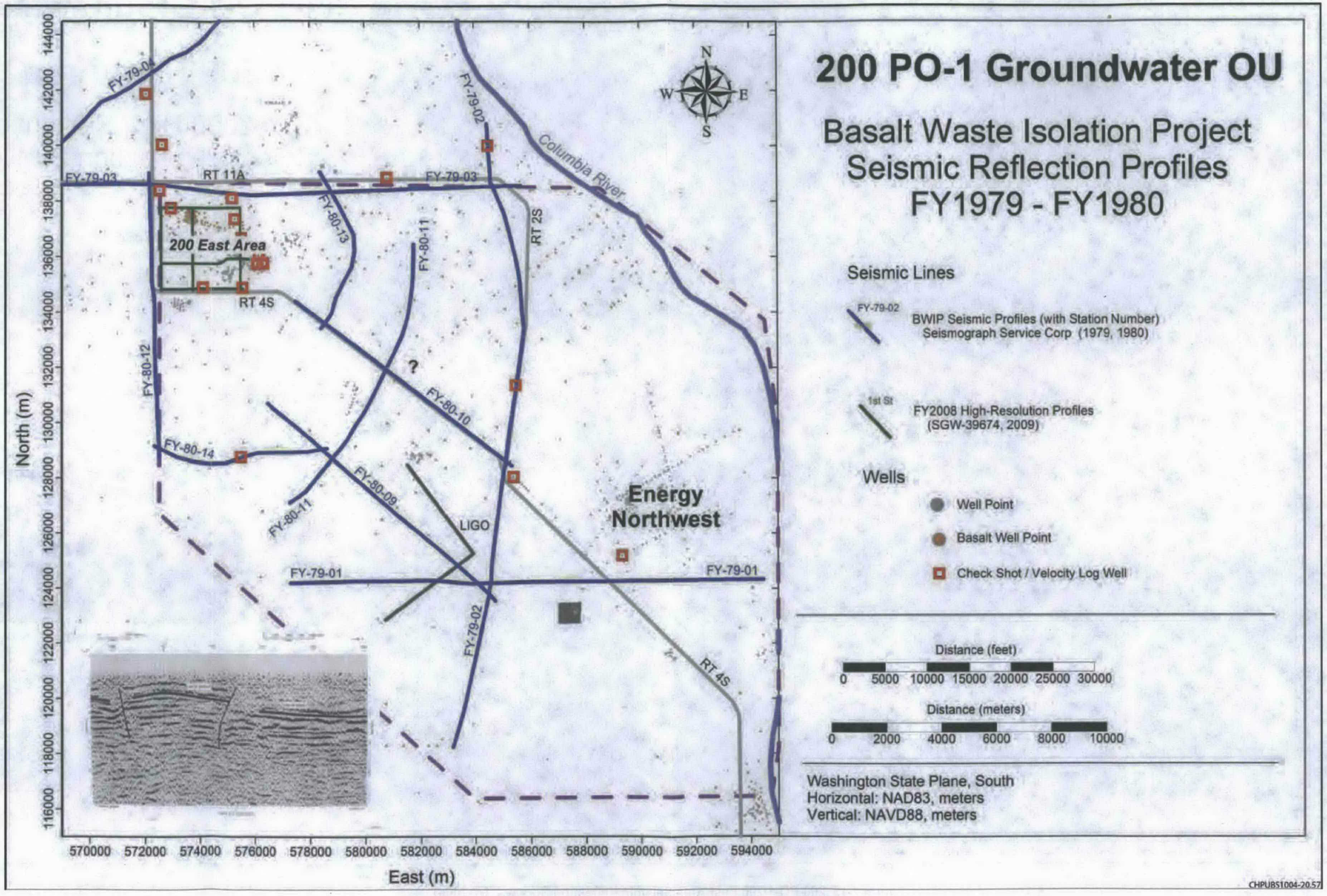


Figure 2-16. 200-PO-1 Seismic Reflection Surveys (FY 1979-1980 and FY 2008)

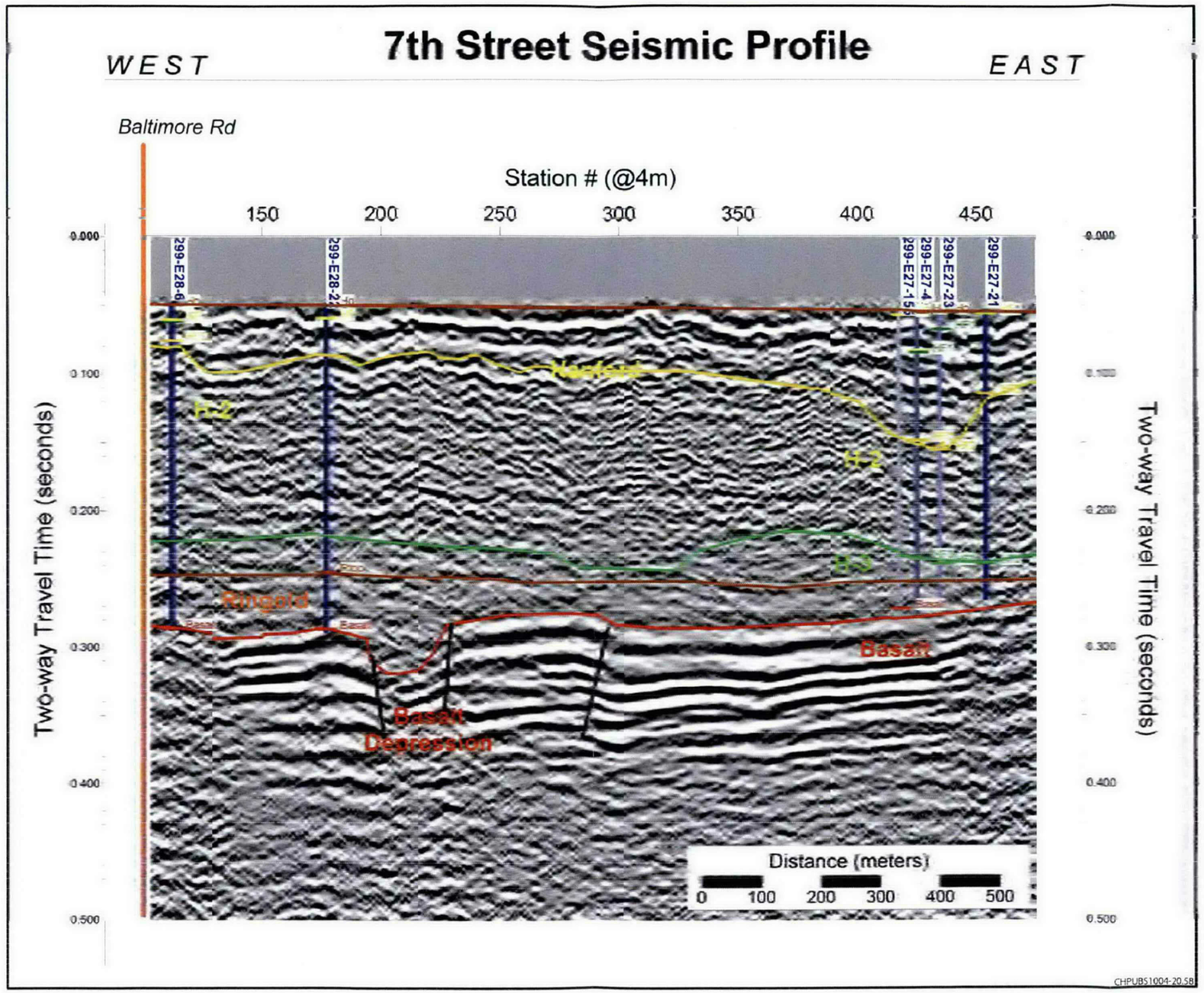


Figure 2-17. 200-PO-1 Interpretation of 7th Street Seismic Reflection Profile

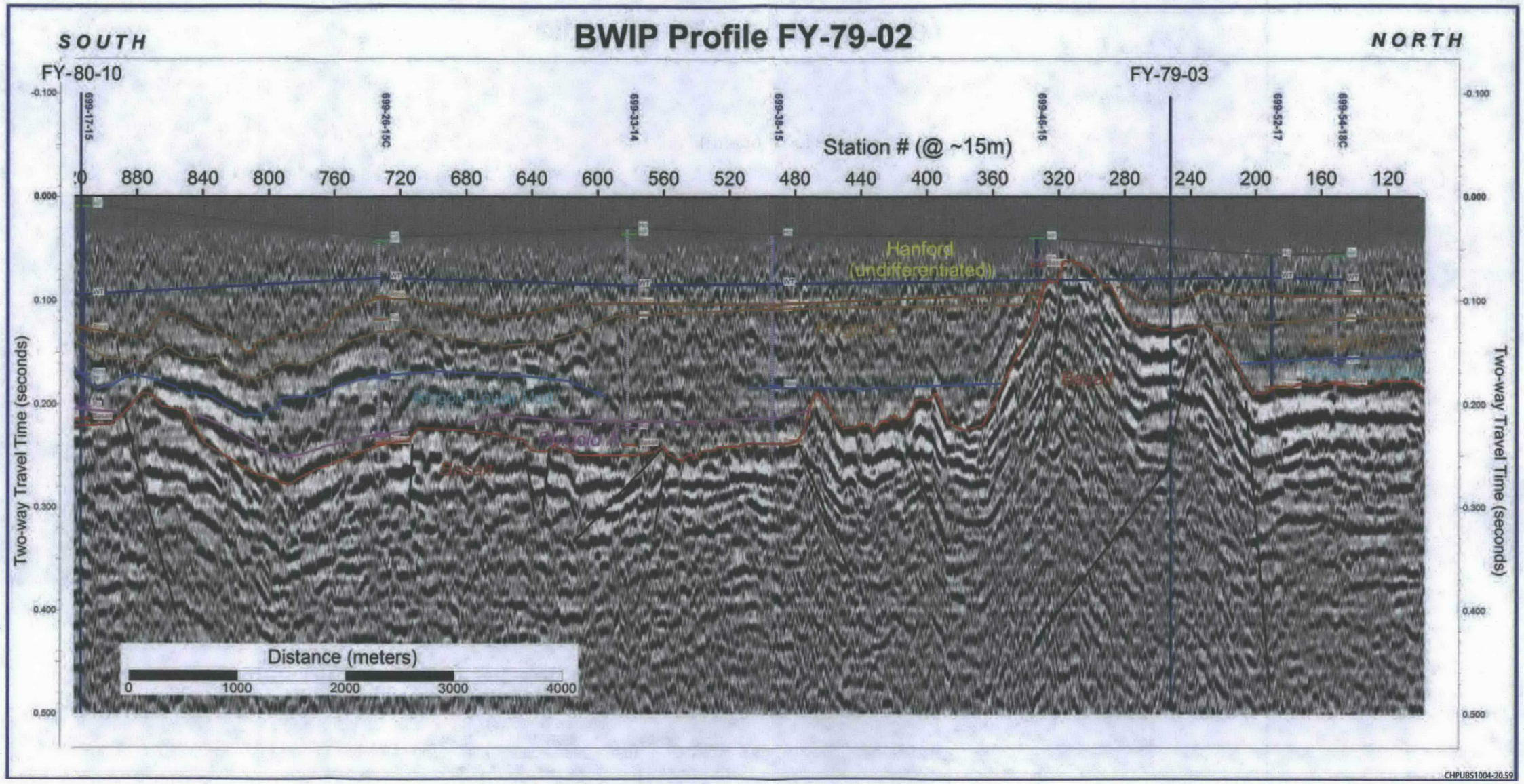


Figure 2-18. 200-PO-1 Interpretation of BWIP FY79-02 Seismic Reflection Profile

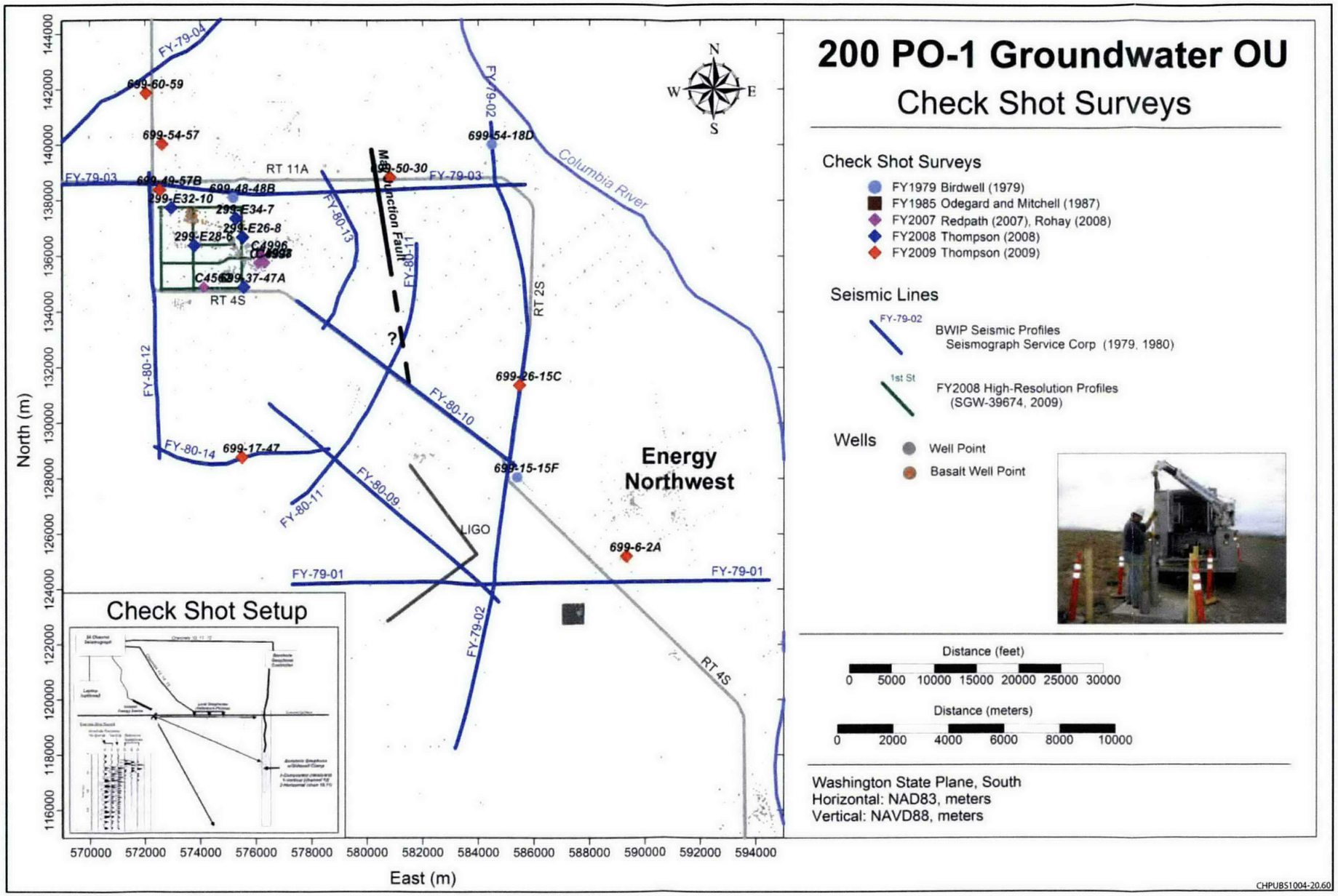


Figure 2-19. 200-PO-1 Check Shot Surveys

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Figure 2-20 shows check shot results for Well 299-E34-7, which is located in the northeast part of the 200 East Area. The left-most plot shows one-way seismic travel time with depth, and the right-most plot illustrates the resulting seismic interval velocities calculated from changes in slope on the time-depth plot. Figure 2-20 also shows the geologic units, driller's description and the gamma-log acquired for the well. Check shot information indicates that the H1-H3 interface should occur at a one-way travel time of approximately 0.041 seconds, which equates to a seismic section two-way travel time of 0.082 seconds. Thus, reflectors in the vicinity of this two-way travel time likely correspond to the subtle increase in velocity indicated by the check shot results.

Figure 2-21 shows examples of how geologic information is correlated with seismic sections for short segments of two of the FY 2008 seismic profiles and BWIP Profile FY 79-02. For all three cases, the basalt surface is represented by strong reflectors that correlate with a sharp increase in interval velocity (from 914.4 m/s to 1,981.2 m/s [3,000 ft/s to 6,500 ft/s] to over 3,048 m/s [10,000 ft/s] for the basalt). For the FY 2008 seismic data, subtle changes in interval velocity within the sedimentary column is loosely correlated with changes in seismic character and tied to Hanford Fm subunits. Time-depth information from Well 699-26-15C tie Ringold Units with relatively strong reflectors that occur above the basalt surface.

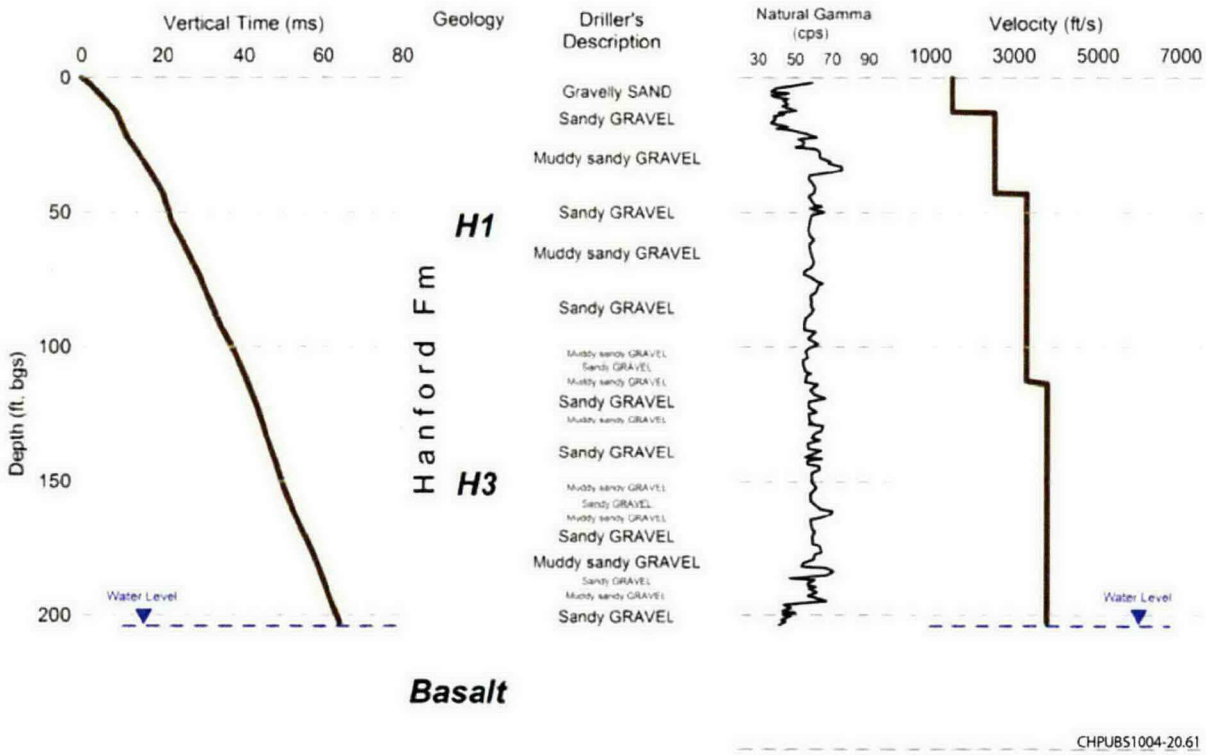



**Figure 2-20. 200-PO-1 Check Shot Survey: Well 299-E34-07 – Geology Correlation**

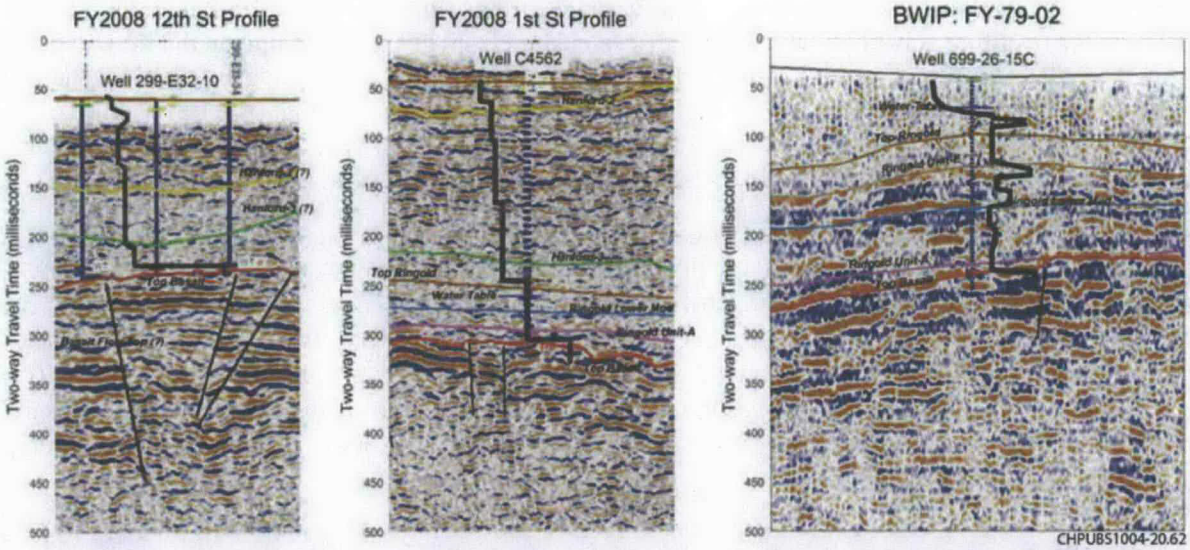



**Figure 2-21. 200-PO-1 Check Shot Surveys, Geologic Units And Seismic Section Correlation**

### *2.3.1.4 Advanced Borehole Logging*

Geophysical logging was conducted by Schlumberger™ Water Services in Well 299-E17-3 to evaluate the application of advanced geophysical logging measurements in Hanford Site cased monitoring wells for quantitative evaluation of key geologic and hydrogeologic properties of the vadose and saturated zones. The evaluation focused on determining porosity, formation bulk resistivity, water/moisture content, water saturation, matrix geochemistry and lithologic composition, concentration of cesium and cobalt contamination, and hydraulic conductivity and permeability. These objectives were accomplished by completing the following measurements, nearly continuously, along the length of the well:

- Non-source multi-detector epithermal neutron porosity, providing saturated and vadose zone volumetric water/moisture content
- Non-source pulsed neutron capture multi-detector gamma activation (sensitive to water and air-filled porosity and lithology)
- Non-source neutron induced gamma ray spectroscopy, providing bulk concentrations of a number of important mineral-forming elements
- Spectral passive gamma ray, including potassium, thorium, uranium, cesium, and cobalt isotope concentrations
- Direct current cased hole electrical resistivity stations (sensitive to water and clay content)

Well 299-E17-3 is located within the 200 East Area, south of the PUREX (Figure 2-3), on the Central Plateau. Table 2-5 describes the logging tools used and the petrophysical properties that are measured. The logging measurements were acquired from a total depth of 121 m (398 ft) below the top of wellhead (primary reference point) to near surface (Figure 2-22 and Figure 2-23).

**Table 2-5. Geophysical Logging Tool, Technology, and Corresponding Measured Properties**

| Tool | Technology | Properties Measured |
|---|---|---|
| Accelerator Porosity Sonde | Non-source epithermal neutron porosity and neutron capture cross-section | Water/moisture content, lithologic variations (particularly clay/silt content) |
| Cased Hole Formation Resistivity | Direct current relative bulk resistivity station measurements thru steel casing | Formation bulk resistivity (sensitive to water/moisture content and lithologic variations) |
| Reservoir Saturation Tool – Sigma Mode | Non-source pulsed neutron capture multi-detector gamma activation | Water and air-filled porosity, water saturation |
| Reservoir Saturation Tool – Spectroscopy Mode | Non-source pulsed neutron induced gamma ray spectroscopy | Formation matrix elemental geochemistry (used to derive lithology and mineralogy) |
| Hostile Natural Gamma Spectroscopy and Gamma Ray | Passive multi-detector passive gamma ray spectroscopy and gross gamma | Naturally occurring potassium, thorium, and uranium concentrations for matrix geochemistry, lithology, and mineralogy; cesium and cobalt concentrations |

**Figure 2-22. 200-PO-1 Advanced Borehole Logging Truck**

NOTE: Photo contains trademark name of Schlumberger Limited Corporation, New York, New York.

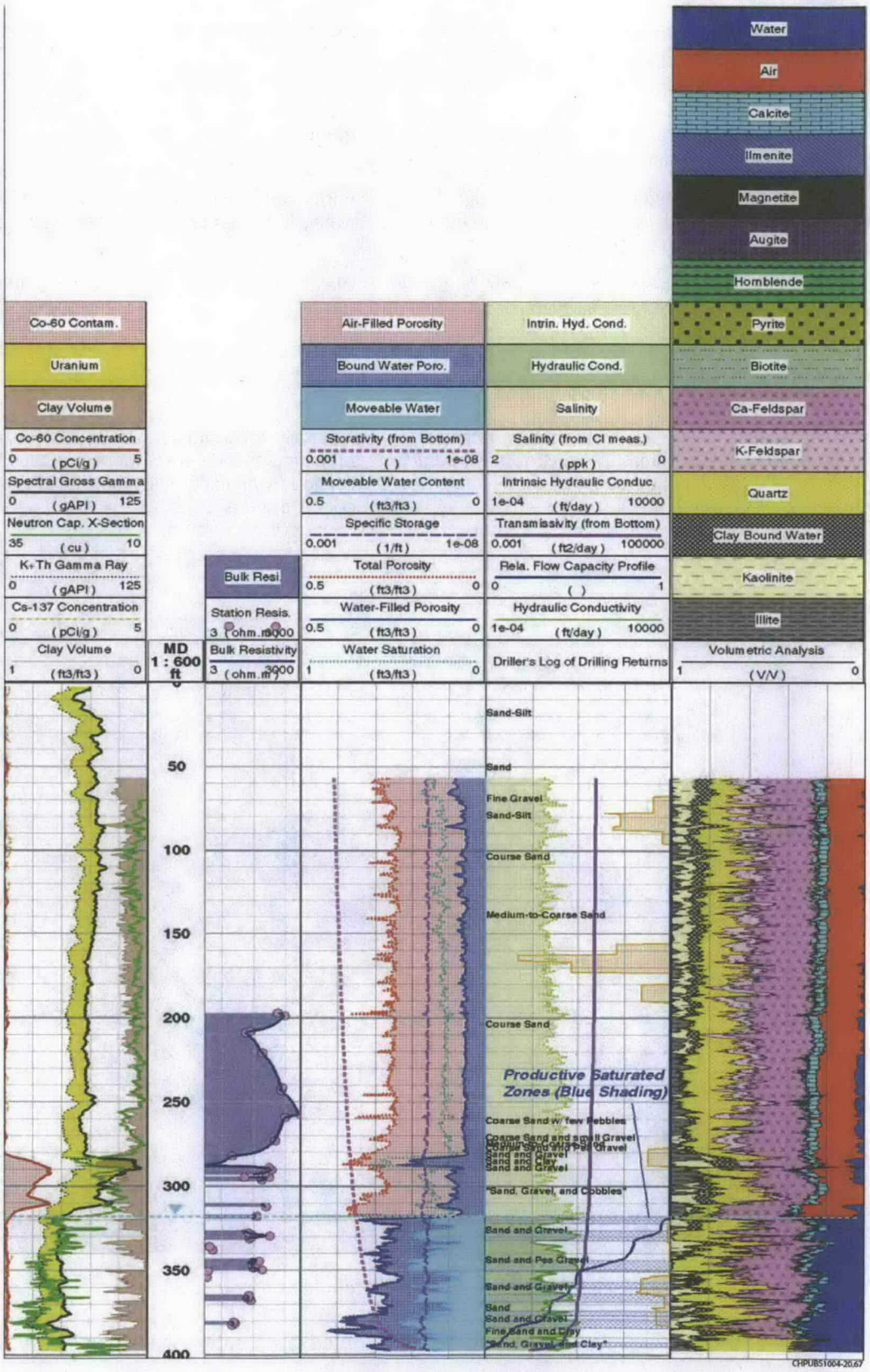



**Figure 2-23. 200-PO-1 Well 299-E17-3 Hydrogeology Summary Log Composite Lithology**

The logging report, including the integrated and reprocessed log data, is available in SGW-42929 and provides quantitative property estimates that appear consistent for all applicable measurements, as well as estimates of properties that otherwise could not be reliably estimated from the single measurements alone (e.g., total porosity inclusive of all water and air present, water saturation, hydraulic conductivity, and lithology).

Overall, the geophysical log measurements from Well 299-E17-3 provide good quality results (as determined from log quality control [QC] logs) that are consistent with each other across the logged interval and within the range of values expected for the geologic environment. However, the possible effect on the geophysical logs of a water or air-filled annulus between the casing/screen and the borehole wall (voids behind the casing and the telescoping inner screen) is difficult to quantify and correct. Logging conditions were very difficult and unsuccessful for the cased hole resistivity measurement tool. More detail is provided in SGW-42929.

## 2.4 Groundwater Chemistry Data Compilation

Over the period from January 2004 through March 2009, groundwater samples were collected from 175 wells identified to support the 200-PO-1 Groundwater OU evaluation. These include both Near Field and Far Field wells, routine wells, characterization wells, and aquifer tubes. In addition, samples were collected from opportunistic wells (Table 2-6) associated with source OUs where data could be provided that might support the analysis of conditions at the 200-PO-1 Groundwater OU.

**Table 2-6. Remedial Investigation Work Plan Opportunistic Well Status**

| Activity | Area | Well Identification[a] | Status |
|---|---|---|---|
| Sampling and Analysis of Opportunistic Wells[b] | PUREX | A-2<br>C5515 | C5515 exploratory borehole drilled near the 216-A-2 Crib. Groundwater grab sample was collected 9/6/2007, consistent with Table A3-2 of Work Plan/SAP (DOE/RL-2007-31). |
| | | A-4<br>299-E24-23 | Well 299-E24-23 exploratory borehole drilled near the 216-A-4 Crib was completed as a groundwater well and was sampled 4/10/2007, consistent with Table A3-2 of Work Plan/SAP (DOE/RL-2007-31). |
| | | A-5<br>C6552 | C6552 exploratory borehole drilled near the 216-A-5 Crib. Groundwater grab sample collected 9/2/2008, consistent with Table A3-2 of the Work Plan/SAP (DOE/RL-2007-31). |
| | | A-30<br>C5941 | C5941 exploratory borehole drilled near the 216-A-30 Crib. Groundwater grab sample was collected 4/23/2008, consistent with Table A3-2 of the Work Plan/SAP (DOE/RL-2007-31). |
| | | 299-E23-2 | Sample was collected 6/25/2007 prior to well decommissioning, per Table A3-3 of SAP (DOE/RL-2007-31, Appendix A). |
| | | 299-E17-14 | Sampled quarterly, meeting requirements of Table A3-2 of SAP (DOE/RL-2007-31, Appendix A). |

**Table 2-6. Remedial Investigation Work Plan Opportunistic Well Status**

| Activity | Area | Well Identification[a] | Status |
|---|---|---|---|
| | BC Cribs | C5923<br>299-E13-62 | Borehole completed and developed into groundwater sampling well. Sampled on 7/15/2008. |
| Installation Sampling and Analysis of Planned Aquifer Tubes | River Corridor | Three aquifer tubes at each of 10 locations | New aquifer tubes were installed at 11 locations, although fewer than three tubes were installed at most locations. Samples were collected from 16 tube locations in September and October of 2008, which includes 5 pre-existing aquifer tube locations. |

Notes:

DOE/RL-2007-31, *Remedial Investigation/Feasibility Study Work Plan for the 200 PO 1 Groundwater Operable Unit.*

a. Preliminary well identification is presented (e.g., A-2). When boreholes are completed, a borehole number (C5515) is added and, as wells are physically established, formal well names (e.g., 299-E24-23) are added.

b. Opportunistic wells are wells located within the 200-PO-1 Groundwater OU and proposed by other projects that offer an opportunity for supplemental data gathering.

PUREX = Plutonium-Uranium Extraction (Plant or process)

SAP = sampling and analysis plan

Table 2-7 presents a summary of the samples that were collected and evaluated for the various wells in the Near Field and Far Field and along the river shore to support the characterization activities described in the work plan. In addition, a groundwater geochemical evaluation utilizing Stiff and Piper diagrams was conducted and summarized in ECF-200-PO-1-09-2015.

**Table 2-7. Samples by Field Activity**

| | Near Field | Far Field | River Shoreline | Totals |
|---|---|---|---|---|
| Wells identified | 67 | 98 | 12 | 177 |
| Wells sampled | 65 | 98 | 12 | 175 |
| Samples per SAP requirements | 503 | 988 | 272 | 1,763 |
| Samples collected | 141 | 488 | 136 | 765 |
| Inorganic results per SAP requirements | 89 | 214 | 48 | 351 |
| Inorganic results collected | 31 | 107 | 24 | 162 |
| Organic results per SAP requirements | 163 | 524 | 146 | 833 |
| Organic results collected | 38 | 262 | 73 | 373 |
| Rad results per SAP requirements | 133 | 250 | 78 | 461 |
| Rad results collected | 37 | 119 | 39 | 195 |

Notes:

SAP = sampling and analysis plan

Ecology previously requested summaries of the resulting data by analyte group (e.g., metals and volatiles). A separate output, therefore, was generated to address this request; the detailed evaluation is available electronically upon request. Four questions from Ecology were addressed with the new data:

1. Were data obtained for the 44 COPCs listed in Table 4-5 of the Work Plan?
   - Data were obtained for all 44 of the COPCs for all wells sampled and any new aquifer tubes. Therefore, the data gathered are complete.
2. Were data for the analyte groups requested by Ecology collected as outlined in the Work Plan/SAP Tables A3-2 and A3-3?
   - Data were obtained for all analyte groups for all wells that could be sampled and any new aquifer tubes. Therefore, the data gathered are complete.
3. Did any of the new maximum detections for analytes lead to potential new COPCs?
   - No new potential COPCs were identified. A maximum detection of 6 µg/L for beryllium in Well 299-E17-14 occurred in 1989 and was associated with a less than 5 µg/L non-detect duplicate result. All previous and subsequent beryllium results for this well have been below 5 µg/L. Beryllium was not added as a potential COPC.
4. Did the maximum detection in the new data for the existing 44 COPCs exceed the previous maximums?
   - For the 44 COPCs, only one analyte had a maximum detection above the previous maximum. This occurred in Well C5515 near the A-2 Crib in PUREX for 1,1,2,2-Tetrachloroethane. The previous maximum for this analyte for all of the well data as of November 1, 2006, was 2 µg/L, and the new maximum in C5515 is 18 µg/L. This value is qualified as "estimated" and is associated with a duplicate result of non-detect at an MDC of 0.14 µg/L.

### 2.4.1 COPC Sampling

Of the 44 COPCs sampled, tritium, nitrate, and iodine-129 are the contaminants with the most spatially extensive groundwater plumes. Other COPCs associated with more localized plumes include strontium-90, technetium-99, and uranium. Details on the nature and extent of the COPCs are presented in Chapter 4.

### 2.4.2 Quality Assurance/Data Quality Assessment

A formal DQA (SGW-41557, *200-PO-1 Groundwater Operable Unit Data Quality Assessment*) was performed on the 200-PO-1 Groundwater OU data to accomplish the following objectives:

- Evaluate the quality of the data collected to support the RI/FS activities for the 200-PO-1 Groundwater OU against quality criteria found in the 200-PO-1 Characterization SAP.
- Ensure that the data are of sufficient pedigree to provide an appropriate description of site conditions.
- Specifically assess the usability of the data set for 200-PO-1 RI/FS-related activities, including risk assessment and remedial alternative evaluation.

A total of 29,447 distinct analytical results, obtained from the analysis of groundwater collected from 175 200-PO-1 target wells, were included in this DQA, including Near Field, Far Field, and Near River wells. Sample results were limited to those generated from January 1, 2004 through March 21, 2009. A list of the 177 wells is included as Attachment A to SGW-41557. Two wells, 299-E 3, and 299-E25-236, were not sampled during the five-year period.

All analytical data were evaluated in accordance with EPA guidance (EPA/240/B-06/002, 2006, *Data Quality Assessment: A Reviewer's Guide* and EPA/240/B-06/003, 2006, *Data Quality Assessment: Statistical Methods for Practitioners*) to ensure that the quality assurance (QA) objectives of the project were achieved. The following data were evaluated:

- Formal validation of 5 percent of a randomly selected segment of the data
- Supplemental data, including review of the specified data set to determine the degree to which detection limit requirements were achieved and completeness of data set; development and evaluation of data trend charts to evaluate the data set for trend, outliers, and anomalies; and evaluation of the annual groundwater monitoring reports to assess comparability of the laboratories and support the assessment of the adequacy of the sampling plan design and completeness
- Field QC sample data
- Laboratory QC data

#### 2.4.2.1 Data Quality Summary

The overall conclusion of this DQA is that the data are of the right type and of sufficient quality and quantity to support the three objectives identified above. The analytical data are acceptable for decision making purposes and for calculating the required statistical values.

Detection limits, precision, accuracy, and completeness were assessed against project criteria to determine if any analytical results should be rejected as a result of QA/QC deficiencies. No data were rejected through the validation process. All minor deficiencies identified through the laboratory analysis and validation process have resulted in data qualifiers in HEIS. The quality of the data generally met all applicable expectations. There were two exceptions to this general statement:

- The number of field transfer blanks to support volatiles did not meet the requirements of the work plan. Nevertheless, the trip blank analyses that were performed showed that contamination was acceptably low or absent.
- The detection limit for antimony (60 µg/L) exceeded the PRG of 6.4 µg/L. However, if the practical quantitation limit (PQL) for a COPC is above the PRG, state regulations allow the PQL to become the de facto PRG for that COPC. The PQL for antimony is (60 µg/L). This may impact the ability of the modelers to establish risks associated with antimony. Although, future data may provide lower reporting limits.

# 3 Physical Characteristics of the Study Area

The Hanford Site is located in the Columbia Basin of the Pacific Northwest. The Columbia Basin is an intermontane basin between the Cascade Range and the Rocky Mountains, and forms the northern part of the Columbia Plateau physiographic province and the Columbia River flood basalt province. Most of the geologic features visible in the Columbia Basin developed during the last 18 million years of the Cenozoic Era, but events as far back as the late Precambrian (2.3 billion years ago) have had significant influence on the geologic history of the area.

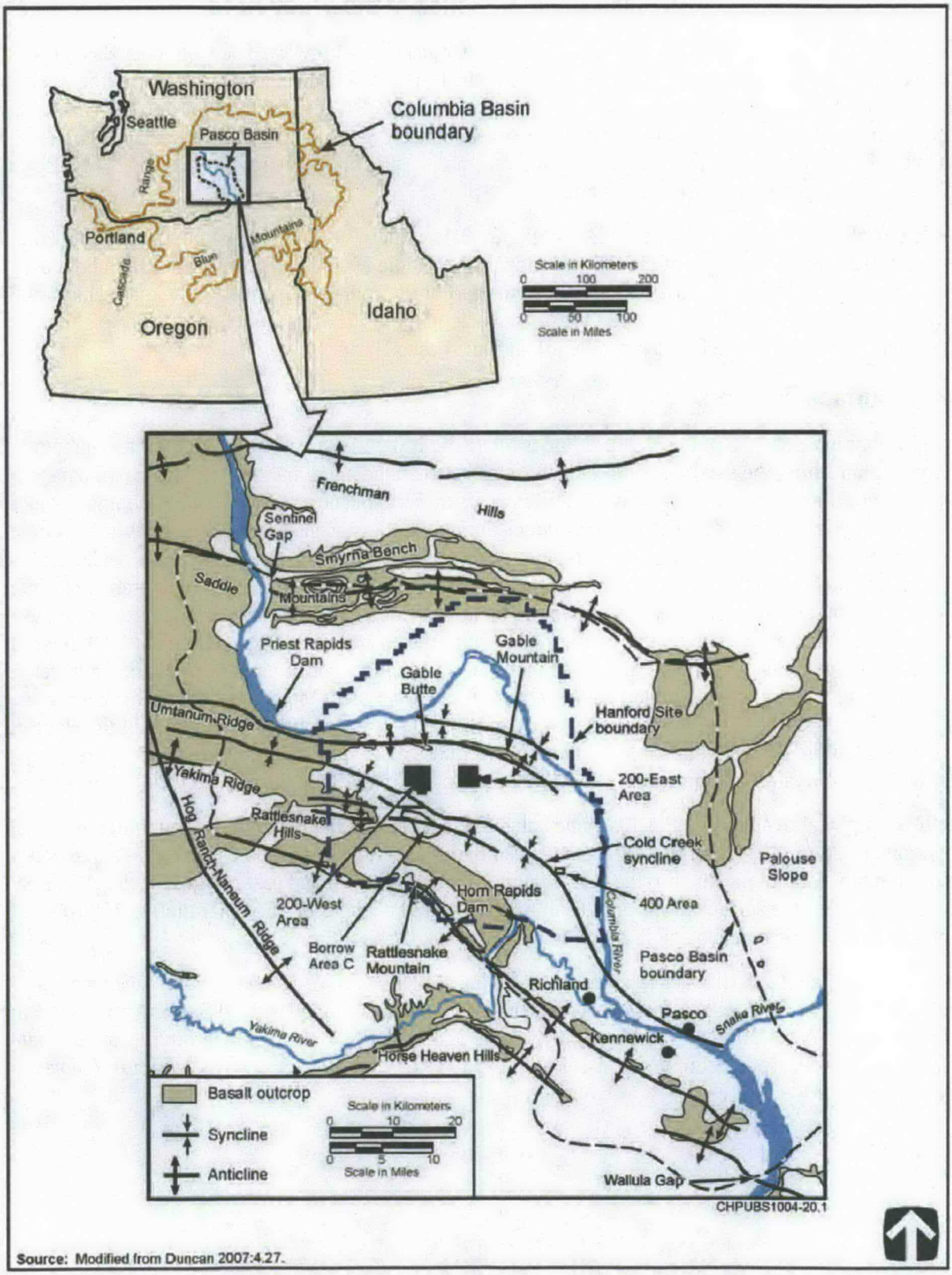
The Hanford Site lies within the Pasco Basin (Figure 3-1), which is a smaller basin in the Yakima Fold Belt along the western margin of the Palouse Slope. The Saddle Mountains form the northern boundary of the Pasco Basin, while Rattlesnake Mountain forms part of the southern boundary. The main Hanford Site WMAs, located in the 200 East and 200 West Areas, lie in the Cold Creek syncline between Yakima Ridge and Umtanum Ridge in the central portion of the Pasco Basin.

## 3.1 Surface Features

The physiographic setting of the Hanford Site is relatively low-relief, resulting from river and stream sedimentation filling the synclinal valleys and basins between the anticlinal ridges. Surface topography has been modified within the past several million years by Pleistocene era cataclysmic flooding, Holocene eolian activity, and landslides. Cataclysmic floods during the Pleistocene eroded sediments and scoured basalt bedrock, forming "scabland" topography visible north of the Pasco Basin, and large scale erosional channels visible within the Central Plateau at the Hanford Site (Figure 3-2). In addition, branching flood channels, giant current ripples, ice rafted erratics, and giant flood bars are among the landforms created by the floods and readily seen on the Hanford Site. Since the end of the Pleistocene (about 10,000 years ago), prevailing winds have locally reworked the flood sediments, depositing dune sands in the lower elevations and windblown silt around the margins of the Pasco Basin. Most sand dunes have been stabilized by vegetation. Active dunes exist north of the 300 Area near the eastern border of the Hanford Site in the Hanford Reach National Monument. Some dunes elsewhere on the Hanford Site were temporarily reactivated by removal of vegetation resulting from the June through July 2000 range fire.

The topography above the 200-PO-1 Groundwater OU is relatively flat to gently rolling, ranging from an elevation of 223 m (730 ft) on the 200 Area Plateau in the west, to 117 m (385 ft) elevation at the dune fields along the Columbia River to the east (Figure 3-2). On the north and east margins of the 200 Area Plateau, however, the surface drops off steeply with elevation changes of 15 to 30 m (50 to 100 ft) coming off of the Pleistocene age flood created Cold Creek bar.

The Hanford Site NEPA Characterization report (PNNL-6415, *Hanford Site National Environmental Policy Act (NEPA) Characterization*) describes the major features of the Hanford Site environment. Much of the following description of the site setting is excerpted from PNNL-6415. Meterorology and climate descriptions are excerpted from PNNL-6415 and PNNL-18427, *Hanford Site Environmental Report for Calendar Year 2008.*




Source: Modified from Duncan 2007:4.27.

**Figure 3-1. Generalized Structural Geologic Map of the Pasco Basin**

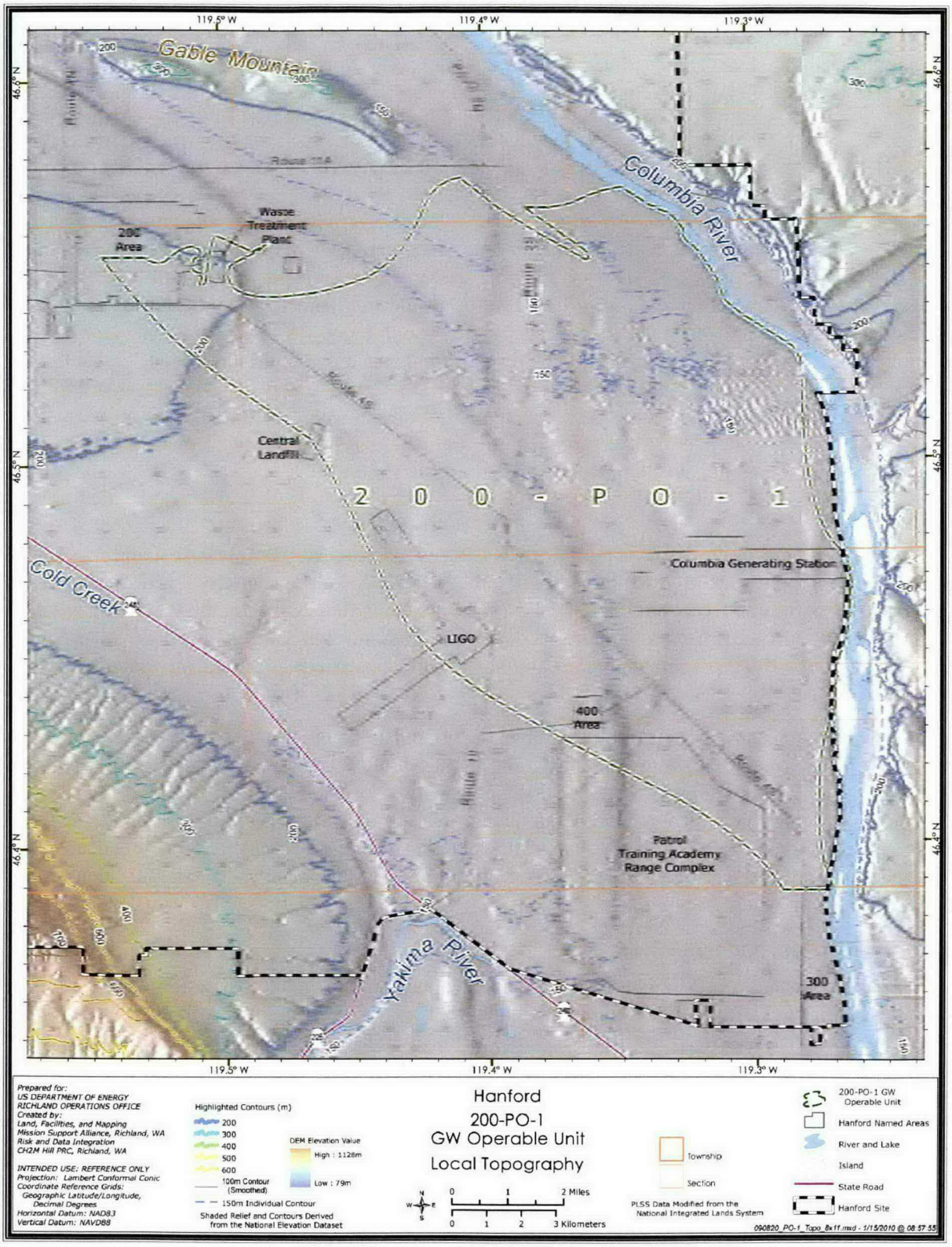



**Figure 3-2. 200-PO-1 Groundwater Operable Unit Topography**

## 3.2 Meteorology

The Pacific Ocean moderates temperatures throughout the Pacific Northwest, and the Cascade Range generates a rain shadow that limits rain and snowfall in the eastern half of Washington State. The Cascade Range also serves as a source of cold air drainage, which has a considerable effect on the wind regime at the Hanford Site. The mountain ranges to the north and east of the region shield the area from the severe winter storms and frigid air masses that move south across Canada.

Climatological data for the Hanford Site are compiled at the Hanford Meteorology Station (HMS), which is located on the Central Plateau, just outside the northeast corner of the 200 West Area and about 4 km (3 mi) west of the 200 East Area. Data from the HMS capture the general climatic conditions for the region and describe the specific climate of the Hanford Site Central Plateau. Meteorological measurements have been made at the HMS since late 1944. Before the HMS was established, local meteorological observations were made at the old Hanford town site (1912 through late 1943) and in Richland (1943-1944). To characterize meteorological differences accurately across the Hanford Site, the HMS operates a network that currently contains 30 monitoring stations (Figure 3-3). Data are collected and processed at each station, and information is transmitted to the HMS every 15 minutes. This monitoring network has been in full operation since the early 1980s.

### 3.2.1 Wind

The prevailing surface winds on the Hanford Site Central Plateau are from the northwest and occur most frequently during the winter and summer. Winds from the southwest also occur frequently on the Central Plateau. In the southeastern portion of the Hanford Site (including the 300 Area), the prevailing wind direction near the surface is from the southwest during most months; winds from the northwest are much less common. In the 100 Area and along the Columbia River, local winds are strongly influenced by the topography near the river (PNNL-6415).

Monthly average wind speeds 15.2 m (50 ft) above the ground are lower during the winter months, averaging 2.7 to 3.1 m/s (6 to 7 mph), and faster during the spring and summer, averaging 3.6 to 4.0 m/s (8 to 9 mph). The fastest wind speeds at the HMS are usually associated with flow from the southwest; however, the summertime drainage winds from the northwest frequently exceed speeds of 13 m/s (30 mph). The maximum speed of the drainage winds (and their frequency of occurrence) tends to decrease moving toward the southeast across the Hanford Site. Surface features have less influence on winds aloft than on winds near the surface.

### 3.2.2 Temperature and Humidity

Based on data collected from 1946 through 2008, the average monthly temperatures at the HMS range from a low of -0.2°C (31.3°F) in December to a high of 24.6°C (76.3°F) in July. Daily maximum temperatures at the HMS vary from an average of 2°C (35°F) in late December and early January to 36°C (96°F) in late July. On average, 52 days during the summer months have maximum temperatures greater than or equal to 32°C (90°F) and 12 days with maximum temperatures greater than or equal to 38°C (100°F). The largest number of consecutive days on record with maximum daily temperatures greater than or equal to 32°C (90°F) is 32 days. The record maximum temperature, 45°C (113°F), occurred at the HMS on July 23, 2006, July 13, 2002, and August 4, 1961.

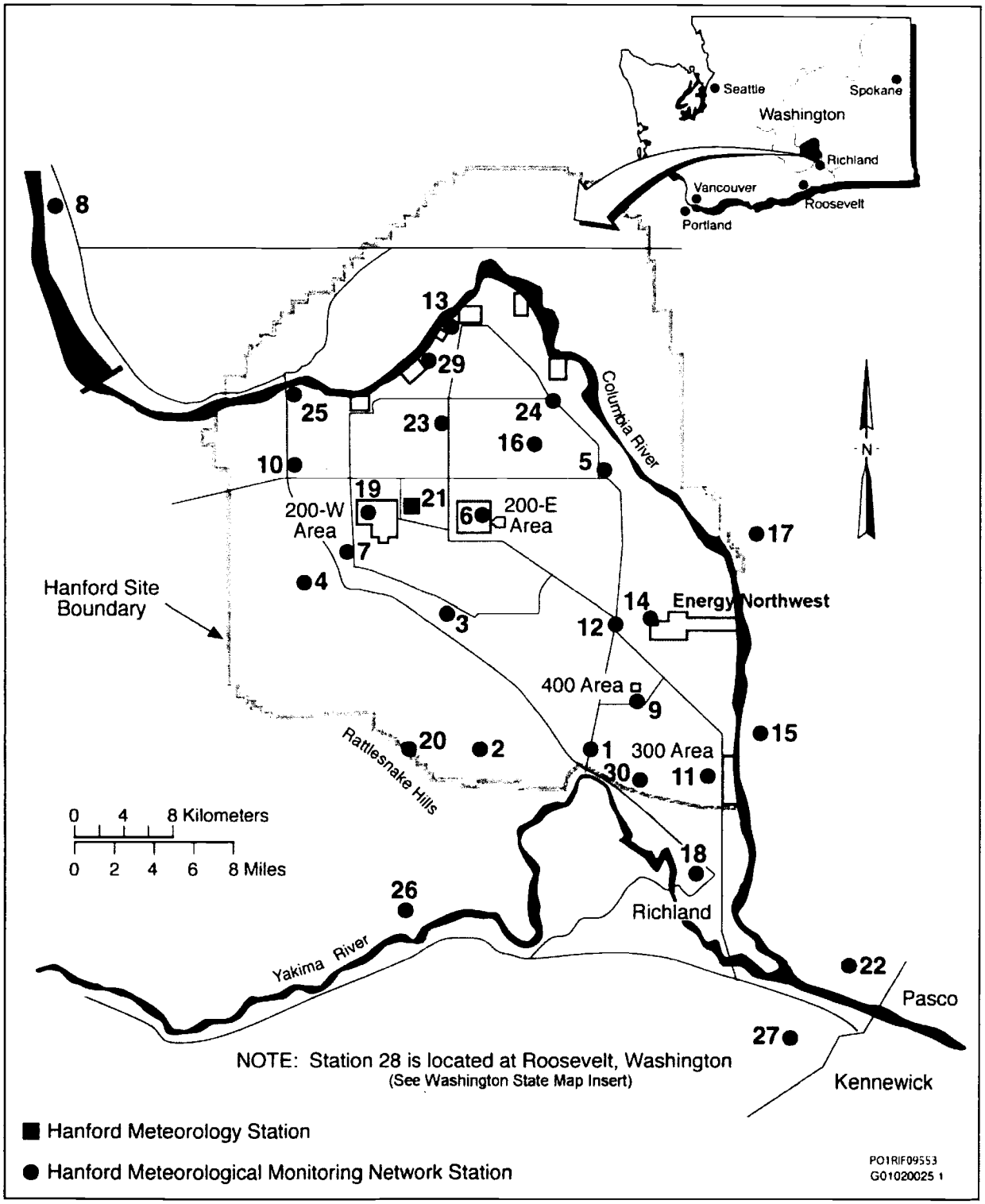



**Figure 3-3. Hanford Site Meteorological Monitoring Network Location Map**

From mid-November through early March, the average daily minimum temperature is below freezing; the daily minimum in late December and early January is -6°C (21°F). On average, the daily minimum temperature of less than or equal to -18°C (approximately 0°F) occurs only three days per year; however, only about one winter in two experiences such low temperatures. The record minimum temperature was –30.6°C (–23.1°F) in February 1950. The normal annual relative humidity at the HMS is 54 percent. It is highest during the winter months, averaging about 76 percent, and lowest during the summer, averaging about 36 percent.

### 3.2.3 Precipitation

Normal annual precipitation at the HMS is 17.7 cm (6.98 in.). Most precipitation occurs during the late autumn and winter, with more than half of the annual amount occurring from November through February. The wettest year on record, 1995, received 31 cm (12.31 in.) of precipitation; the driest, 1976, received 7.6 cm (2.99 in.). The snowiest winter on record, 1992-1993, received 142.5 cm (56.1 in.) of snow. Snowfall accounts for about 38 percent of all precipitation from December through February.

### 3.2.4 Fog and Visibility

Fog has been recorded during every month of the year at the HMS; however, 89 percent of the occurrences are from November through February. The average number of days per year with fog (visibility less than or equal to 9.6 km [6 mi]) is 48, while those with dense fog (visibility less than or equal to 0.4 km [0.25 mi]) number 25. Other phenomena causing restrictions to visibility (i.e., visibility less than 9.6 km [6 mi]) include dust, blowing dust, and smoke from field burning and naturally occurring fire in the region.

### 3.2.5 Severe Weather

Nationwide concerns about severe weather usually center on hurricanes, tornadoes, and thunderstorms. Fortunately, Washington does not experience hurricanes; tornadoes are infrequent and generally small in the northwestern portion of the United States. In the counties closest to the Hanford Site, only 24 tornadoes have been recorded from 1950 through November 2004. Of these, 17 tornadoes had maximum wind speeds estimated to be in the range of 18 to 32 m/s (40 to 72 mph), four had maximum wind speeds in the range of 33 to 50 m/s (73 to 112 mph), and three had maximum wind speeds in the range of 51 to 71 m/s (113 to 157 mph). No deaths or substantial property damage (in excess of $50,000) were associated with any of these tornadoes. The estimated probability of a tornado striking a point on the Hanford Site is $9.6 \times 10^{-6}$/yr (Ramsdell and Andrews, *Tornado Climatology of the Contiguous United States*).

The average occurrence of thunderstorms in the vicinity of the HMS is 10 per year. These thunderstorms are most frequent during the summer; however, they have occurred in every month. High-speed winds at the Hanford Site are more commonly associated with strong cold frontal passages. In rare cases, intense low-pressure systems can generate winds of near hurricane force.

## 3.3 Surface Water Hydrology

Naturally occurring surface water at the Hanford Site (Figure 3-4) includes the Columbia River, springs, and ponds. Intermittent surface streams, such as Cold Creek, may also contain water after large precipitation or snowmelt events. In addition, the Yakima River flows along a short section of the southern boundary of the Hanford Site, and surface water is associated with irrigation east and north of the Site.

Except for the Columbia River estuary, the only unimpounded stretch of the river in the United States is the Hanford Reach, which extends from Priest Rapids Dam downstream approximately 82 km (51 mi) to the northern extent of Lake Wallula, above Richland. The Hanford Reach of the Columbia River was recently incorporated into the land area established as the Hanford Reach National Monument.

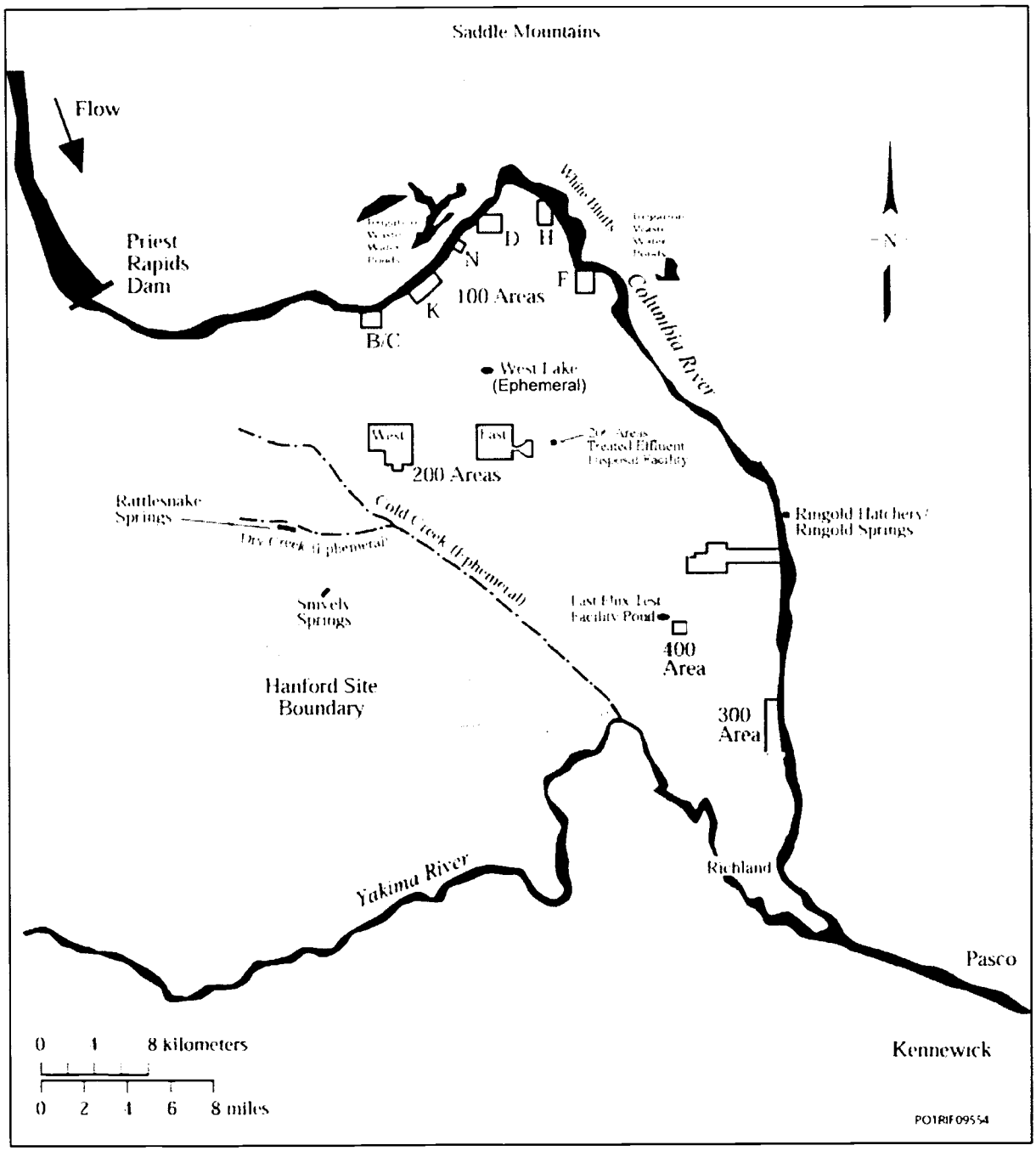



**Figure 3-4. Surface Water Features of the Hanford Site**

River flow through the Hanford Reach fluctuates significantly and is controlled primarily by operations at upstream storage dams (i.e., Grand Coulee in the United States, and Mica and Keenleyside in Canada). Flows in the Hanford Reach are directly affected by releases from Priest Rapids Dam; however, Priest Rapids operates as a run-of-the-river dam rather than a storage dam. Flows are controlled to generate power and promote salmon egg and embryo survival.

The annual average flow of the Columbia River downstream of Priest Rapids Dam is approximately 3,400 $m^3$ (120,000 $ft^3$) per second (WA-94-1). In 2008, the Columbia River had below normal flows; the average daily flow rate downstream of Priest Rapids Dam was 3,069 $m^3$ (108,400 $ft^3$) per second (PNNL-18427). The peak monthly average flow rate occurred during June (6,197 $m^3$ [218,800 $ft^3$] per second). The lowest monthly average flow rate occurred during September (1,826 $m^3$ [64,480 $ft^3$] per second), based on mean daily flows. Daily average flow rates varied from 1,130 to 7,467 $m^3$ (39,900 to 263,700 $ft^3$) per second during 2008. As a result of fluctuation in discharges, the depth of the river varies significantly over time. The river stage (water-surface level) may change along the Hanford Reach by up to 3 m (10 ft) within a few hours. Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately one-half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (PNL-8580) and the relative distance of each area from Priest Rapids Dam. The width of the river varies from approximately 300 to 1,000 m (980 to 3,300 ft) as it passes through the Hanford Site.

No naturally occurring bodies of water are located within the borders of the 200-PO-1 Groundwater OU. As a result of the arid climate and rapidly draining surface sediment, no surface drainage pattern has developed throughout the majority of the 200-PO-1 Groundwater OU. The 200 East Area is not in a designated floodplain, and calculations of probable maximum floods for the Columbia River indicate that the 200 East Area is not expected to be inundated under maximum flood conditions (RHO-BWI-C-120/PNL-4219, *Flood Risk Analysis of Cold Creek near the Hanford Site*).

### 3.3.1 Water Quality of the Columbia River

The water quality of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, has been designated as Class A, Excellent (WAC 173-201A, "Water Quality Standards for Surface Waters of the State of Washington") by Washington State. Class A waters are suitable for all uses, including raw drinking water, recreation, and wildlife habitat. State and federal DWS apply to the Columbia River.

In 2008, Columbia River water samples were collected from fixed-location monitoring stations at Priest Rapids Dam and in Richland, Washington, and from cross-river transects and near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site (within the 200-PO-1 Groundwater OU), 300 Area, and Richland. Columbia River water sample data show a statistical increase in concentrations of tritium, nitrate, uranium, and iodine-129 between samples taken upriver of the Hanford Site at the Vernita Bridge and below (downriver) the Hanford Site at the Richland Pump House (PNNL-18427). These constituents are known to be entering the river from contaminated groundwater beneath the Hanford Site.

Transect measurements for tritium showed higher concentrations near the shoreline relative to mid-river for samples from the 100-N Area and the Richland Pump House. The highest tritium concentration measured during 2005 in water samples from cross-river transects was 95 ± 9.5 pCi/L (3.5 ± 0.35 Bq/L), which was detected along the shoreline at the Richland Pump House (PNNL-18427). For comparison, the DWS for tritium in groundwater is 20,000 pCi/L. The highest total uranium concentration (1.5 ± 0.23 pCi/L [0.056 ± 0.0085 Bq/L]) was measured for the Richland transect at the southern boundary of the 300 Area on the Benton County shoreline (PNNL-18427).

### 3.3.2 Yakima River

The Yakima River follows a portion of the southwestern boundary of the Hanford Site and has much lower flows than the Columbia River. The average flow, based on 70 years of daily flow records, is about 100 $m^3/s$ (3,530 $ft^3/s$), with an average monthly maximum of 497 $m^3/s$ (17,550 $ft^3/s$) and minimum of 4.6 $m^3/s$ (165 $ft^3/s$). Average daily flow during 2006 was 100 $m^3/s$ (3,530 $ft^3/s$) (USGS, 2007, *USGS Water Data for the Nation*).

The Yakima River system drains surface runoff from approximately one-third of the Hanford Site. Groundwater is expected to flow from the Yakima River into the aquifer underlying the Hanford Site rather than from the aquifer into the river because, based on well water level measurements, the elevation of the river surface is higher than the adjacent water table (PNL-10195, *Three-Dimensional Conceptual Model for the Hanford Site Unconfined Aquifer System: FY 1994 Status Report*). Therefore, groundwater contaminants from the Hanford Site do not reach the Yakima River.

### 3.3.3 Springs and Streams

Springs are found on the slopes of the Rattlesnake Hills (Figure 3-4) along the western edge of the Hanford Site (DOE/RW-0164, *Consultation Draft Site Characterization Plan: Reference Repository Location, Hanford Site, Washington*). An alkaline spring is located at the east end of Umtanum Ridge (TNC, 1998, *Biodiversity Inventory and Analysis of the Hanford Site, 1997 Annual Report*). Rattlesnake Springs and Snively Springs form small surface streams. Water discharged from Rattlesnake Springs flows in Dry Creek for about 3 km (1.6 mi) before disappearing into the ground. Cold Creek and its tributary, Dry Creek, are ephemeral streams within the Yakima River drainage system in the southwestern portion of the Hanford Site. These streams drain areas to the west of the Hanford Site and cross the southwestern part of the Hanford Site toward the Yakima River. When surface flow occurs, it infiltrates rapidly and disappears into the surface sediments in the western part of the Hanford Site. The quality of water in these springs and streams varies depending on the source; they are upgradient of Hanford waste sites and groundwater contamination plumes.

### 3.3.4 Columbia Riverbank Springs

During the early 1980s, researchers identified 115 springs along the Benton County shoreline of the Hanford Reach (PNL-5289, *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River*). Seepage occurs both below the river surface and on the exposed riverbank, particularly at low river stage. Riverbank springs flow intermittently, apparently influenced primarily by changes in river level. In many areas, water flows from the river into the aquifer at high river stage and then returns to the river at low river stage. This "bank storage" phenomenon has been modeled numerically for the 100-H Area. In areas of contaminated groundwater, riverbank springs are also generally contaminated. However, the concentrations in seeping water along the riverbank may be lower than groundwater, because of the mixing between river water and the contaminated aquifer attributed by the fluctuating bank storage phenomenon.

Contamination historically has been detected in near-shore samples downstream from riverbank springs (PNNL-18427). Riverbank springs are monitored for radionuclides at the 100 Area, the Hanford town site (within the 200-PO-1 Groundwater OU), and the 300 Area. Detected radionuclides include strontium-90, technetium-99, iodine-129, U-234, U-235, U-238, and tritium. Other site-related contaminants detected in riverbank springs include arsenic, chromium, chloride, fluoride, nitrate, and sulfate.

Tritium concentrations in riverbank springs vary widely with location. The highest tritium concentration detected in riverbank springs within the 200-PO-1 Groundwater OU during 2005 was 39,000 ± 2,800 pCi/L [1,400 ± 100 Bq/L]) at the Hanford town site (PNNL-15892). During 2000 to 2004, the highest iodine-129 concentration of 0.25 pCi/L (0.0093 Bq/L) was also found in a Hanford town site spring.

### 3.3.5 Runoff and Net Infiltration

Total precipitation over the Pasco Basin is estimated as $9 \times 10^8$ $m^3$ ($3.2 \times 10^{10}$ $ft^3$) annually (DOE/RW-0164). Precipitation varies both spatially and temporally with higher amounts generally falling at higher elevations. Mean annual runoff from the Pasco Basin is estimated at $3.1 \times 10^7$ $m^3$/yr ($1.1 \times 10^9$ $ft^3$/yr), or approximately three percent of the total precipitation (DOE/RW-0164). Most of the remaining precipitation is lost through evapotranspiration; however, a portion of the precipitation that infiltrates the soil eventually recharges the groundwater flow system. The amount of recharge varies spatially based primarily on soil texture and vegetation (PNL-10285, *Estimated Recharge Rates at the Hanford Site*; Gee et al., "Variations in Recharge at the Hanford Site"). Natural recharge also varies temporally with the majority occurring in the winter and spring. Some evidence exists that the most significant recharge events are associated with rapid melting of relatively large snowpacks, which may only occur a few times in a decade (PNNL-14744, *Recharge Data Package for the 2005 Integrated Disposal Facility Performance Assessment*). Estimates of manmade (artificial) recharge to the area are discussed in Section 3.6.9.

### 3.3.6 Flooding

Although large Columbia River floods have occurred in the past (DOE/EIS-0113, Vols. 1-3, *Final Environmental Impact Statement: Disposal of Hanford Defense High-Level, Transuranic and Tank Wastes, Hanford Site Richland, Washington*), the likelihood of recurrence of large-scale flooding has been reduced by the construction of several flood control/water storage dams upstream of the Hanford Site. Major floods on the Columbia River are typically the result of rapid melting of the winter snowpack over a wide area augmented by above-normal precipitation. The exceptionally high runoff during the spring of 1996 resulted in a maximum discharge of nearly 11,750 $m^3$/s (415,000 $ft^3$/s) according to the U.S. Geological Survey (USGS) *Water Data for that Nation* (USGS, 2007).

The probable maximum flood for the Columbia River downstream of Priest Rapids Dam has been calculated to be 40,000 $m^3$/s (1.4 million $ft^3$/s) and is greater than the 500-year flood. This flood would inundate parts of the 100 Area adjacent to the Columbia River, but the central portion of the Hanford Site would remain unaffected (DOE/RW-0070, *Environmental Assessment: Reference Repository Location, Hanford Site, Washington*, Vols. I - III). The U.S. Army Corps of Engineers (USACE), 1989, *Water Control Manual for McNary Lock and Dam, Columbia River, Oregon and Washington* has derived the Standard Project Flood with both regulated and unregulated peak discharges given for the Columbia River downstream of Priest Rapids Dam. The regulated Standard Project Flood for this part of the river is given as 15,200 $m^3$/s (37,000 $ft^3$/s) and the 100-year regulated flood as 12,400 $m^3$/s (440,000 $ft^3$/s) (DOE/RL-97-56, *Hanford Site Manhattan Project and Cold War Era Historic District Treatment Plan*). Impacts to the Hanford Site are negligible and would be less than the probable maximum flood.

USACE evaluated a number of scenarios on the effects of failures of Grand Coulee Dam, assuming flow conditions of 11,000 $m^3$/s (400,000 $ft^3$/s). The discharge or flood wave resulting from an instantaneous 50 percent breach at the outfall of the Grand Coulee Dam was determined to be 600,000 $m^3$/s (21 million $ft^3$/s). In addition to the areas inundated by the probable maximum flood, the remainder of the 100 Area, 300 Area, and nearly all of Richland would be flooded (DOE/RW-0070; RLO-76-4, *Evaluation of Impact of Potential Flooding Criteria on the Hanford Project*). The 50 percent scenario was believed

to represent the largest realistically conceivable flow resulting from either a natural or human-induced breach (DOE/RW-0070). It was also assumed that a scenario such as the 50 percent breach would occur only as the result of direct explosive detonation, and not because of a natural event such as an earthquake, and that even a 50 percent breach under these conditions would indicate an emergency situation in which there might be other overriding major concerns.

Fewer than 20 major floods have occurred on the Yakima River since 1862 (DOE/RW-0070). The most severe occurred during November 1906, December 1933, May 1948, and February 1996; discharge magnitudes at Kiona, Washington, were 1,870 $m^3/s$ (66,000 $ft^3/s$), 1,900 $m^3/s$ (67,000 $ft^3/s$), 1,050 $m^3/s$ (37,000 $ft^3/s$), and 1,300 $m^3/s$ (45,900 $ft^3/s$), respectively. The average flow of the Yakima River is 104 $m^3/s$ (3,665 $ft^3/s$), and the average monthly maximum is 490 $m^3/s$ (17,500 $ft^3/s$). The recurrence intervals for the 1933 and 1948 floods are estimated at 170 and 33 years, respectively. The development of irrigation reservoirs within the Yakima River Basin has considerably reduced the flood potential of the river. The southern border of the Hanford Site could be susceptible to a 100-year flood on the Yakima River.

During 1980, a flood risk analysis of Cold Creek was conducted as part of the characterization of a basaltic geologic repository for high-level radioactive waste. In lieu of 100- and 500-year floodplain studies, a probable maximum flood evaluation was performed based on a large rainfall or combined rainfall/snowmelt event in the Cold Creek and Dry Creek watershed (RHO-BWI-C-120/PNL-4219). The probable maximum flood discharge rate for the lower Cold Creek Valley was 2,265 $m^3/s$ (80,000 $ft^3/s$) compared to 564 $m^3/s$ (19,900 $ft^3/s$) for the 100-year flood. Modeling indicated that State Route 240 along the Hanford Site's southwestern and western areas would not be usable.

### 3.3.7 Non-Riverine Surface Water

Active ponds on the Hanford Site include West Lake and the 200 Area TEDF disposal ponds. West Lake is north of the 200 East Area within the 200-BP-5 groundwater OU and is a natural feature recharged from groundwater (ARH-CD-775, *Geohydrologic Study of the West Lake Basin*; PNL-7662, *An Evaluation of the Chemical, Radiological, and Ecological Conditions of West Lake on the Hanford Site*). West Lake (Figure 3-4) has not received direct effluent discharges from Hanford Site facilities; rather, its existence is caused by the intersection of the elevated water table with the land surface in a topographically low area. Water levels of West Lake fluctuate with water table elevation, which is influenced by wastewater discharge in the 200 Area. The water level and size of the lake have been decreasing over the past several years because of reduced wastewater discharge.

TEDF is east of the 200 East Area within the 200-BP-5 Groundwater OU and consists of two disposal ponds. These ponds are each 0.02 $km^2$ (0.008 $mi^2$) in size and receive industrial wastewater permitted in accordance with Ecology's State Waste Discharge Permit Program (WAC 173-216, "State Waste Discharge Permit Program"). The wastewater evaporates into the air or percolates into the ground from the disposal ponds.

Several naturally occurring vernal ponds are located within the 200-BP-5 Groundwater OU near Gable Mountain and Gable Butte (TNC, 1998). The formation of these ponds in any particular year depends on the amount and temporal distribution of precipitation and snowmelt events. The vernal ponds range in size from about 400 $ft^2$ to 15000 $ft^2$ (.01 to .34 acres) and were found in three clusters. Approximately ten were documented at the eastern end of Umtanum Ridge, seven were observed in the central part of Gable Butte, and three were found at the eastern end of Gable Mountain.

## 3.4 Geology

The subsurface geology forms the framework that affects the locations of aquifers and the release and movement of contaminants. The physiographic setting, stratigraphy, and geologic structure of the 200-PO-1 Groundwater OU are described in this section. Hydrostratigraphic cross-sections and descriptions of unconsolidated sediments and basalt bedrock are included to describe the nature of the aquifers and illustrate the lateral continuity and/or variations that occur across the 200-PO-1 Groundwater OU. The discussion of the geology in these sections is divided into two parts: Near Field and Far Field (Figure 1-2). This discussion presents the relative geology of each region, including the transition from the Near Field into the Far Field portion of the OU.

The geology of the Hanford Site has been extensively characterized as a result of various past investigation activities. These activities have included the siting of nuclear reactors (Washington Public Power Supply System [WPPSS], 1981, *Final Safety Analysis Report*; Puget Sound Power and Light [PSPL], 1982, *Preliminary Safety Analysis for Skagit/Hanford Nuclear Project*), site characterization efforts of the Basalt Waste Isolation Project (BWIP) (DOE/RW-0164), and support for waste management operations (DOE/EIS-0113) and the recent environmental restoration activities. Geologic and geophysical investigations within the 200-PO-1 Groundwater OU have included regional and Hanford Site surface mapping, borehole/well sediment logging, field and laboratory sediment classification (DOE/RL-95-100), surface and borehole geophysical studies (including radiological borehole logging and various seismic, magnetic, and gravity surveys), and in situ and laboratory hydrogeologic properties testing.

### 3.4.1 General Geologic Setting of the Operable Unit

The 200-PO-1 Groundwater OU is located in the central part of the Pasco Basin. Figure 3-1 presents a generalized structural geologic map of the Pasco Basin, showing the broad structural and topographic basin that was formed by deformation of thick sequences of tholeiitic flood basalts, intercalated sediments of the Ellensburg Formation, and overlying suprabasalt sediments.

Previous studies containing geologic interpretations and related maps and cross-sections pertaining to the 200-PO-1 Groundwater OU include the 200 East AAMSR (DOE/RL-92-19) and the 200-PO-1 RFI (DOE/RL-95-100), which included cross-sections from BHI-00184, *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington*, and provided the basis for the Far Field characterization in this RI. The updated hydrogeology is based on the revised hydrogeology of the 200 East Area (PNNL-12261, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington*) published in 2000. This RI supplements the 1997 and 2002 reports by adding new well information and associated interpretations on the cross-sections and geologic summary provided in Section 3.4.

The basalt flows of the Columbia River Basalt Group were deposited during Miocene time from source vents in southeastern Washington, northern Oregon, and western Idaho. Beneath the 200-PO-1 Groundwater OU, the youngest and uppermost basalts present are members of the Saddle Mountains Basalt Formation (RHO-BWI-ST-4, *Geologic Studies of the Columbia Plateau: A Status Report*). The Saddle Mountains Basalt is divided into the Ice Harbor, Elephant Mountain, Pomona, Esquatzel, Asotin, Wilbur Creek, and Umatilla Members. The Elephant Mountain Member is the uppermost basalt unit and is approximately 35-m (115-ft) thick beneath most of the Hanford Site, except in the vicinity of the 300 Area where the overlying Ice Harbor Member is present and forms the top of the Saddle Mountains Basalt. The Rattlesnake Ridge interbed of the Ellensburg Formation is present between the Elephant Mountain Member and the underlying Pomona Member and comprises the uppermost basalt confined aquifer beneath most of the 200-PO-1 Groundwater OU.

In the central portion of the Pasco Basin, the interbed ranges from 1.5 to 15 m (5 to 50 ft) in thickness and is composed of clayey basalt conglomerates, fluvial floodplain deposits, and ash tuffs and tuffites (RHO-RE-ST-12P, *An Assessment of Aquifer Intercommunication in the B-Pond-Gable Mountain Pond Area of the Hanford Site*).

Unconsolidated and partly consolidated sediments of the Miocene through Holocene (approximately 8.5 million years to the present) ages overlie the basalts (DOE/RL-95-100). The 200-PO-1 Groundwater OU is most concerned with the suprabasalt sedimentary units because these sediments contain the uppermost unconfined aquifer system within the region. The geologic units are generally continuous within the thicker portion of the basin located in the center of the OU. Figure 3-5 presents a generalized hydrogeologic column of the Hanford Site, including the Near Field and Far Field regions of the 200-PO-1 Groundwater OU. Along the eastern margin near the Columbia River, some strata are not present and the entire sequence thins on the uplifted basalt. Figure 3-6 shows the relative hydrogeologic column for the river area (e.g., near the 300 Area) of the 200-PO-1 Groundwater OU, where several hydrogeologic units identified in the central and western portions of the OU are not present.

The geology of the suprabasalt sediments is well defined in the 200 East Area and NRDWL/SWL (200-PO-1 Groundwater OU Near Field region) due to characterization data obtained from many closely spaced wells. A lesser degree of confidence exists in the Far Field region east of the 200 Area and NRDWL/SWL, and north of the 300 Area due to the wide spacing, age, and shallow (partially penetrating) depths of most boreholes. The suprabasalt sediments beneath the 200-PO-1 Groundwater OU are dominated by extensive fluvial and lacustrine deposits, assigned to the Miocene to Pliocene Age Ringold Formation (Fm), which are deposited on top of the basalt surface. The Ringold Fm is overlain in some areas by the Cold Creek unit (CCU), formerly the pre-Missoula [PMG] gravel, which is overlain with coarse-grained Pleistocene Age paleo-flood deposits of the Hanford formation (fm).

The suprabasalt sedimentary sequence ranges up to 215 m (700 ft) thick in the center of the basin and contains the uppermost unconfined aquifer, which controls groundwater contaminant migration beneath the 200-PO-1 Groundwater OU.

### 3.4.2 200-PO-1 Groundwater Operable Unit Near Field Suprabasalt Geology

Within the 200-PO-1 Groundwater OU Near Field region, many boreholes are available to support mapping key suprabasalt sedimentary geologic units (e.g., Figure 1-5). The Ringold Fm comprises the oldest sediment and the primary sequence of the suprabasalt aquifer system. The Ringold Fm is composed of fluvially deposited, gravel-dominated units designated as Unit A, Unit B/D, Unit C, and Unit E (from oldest to youngest). These high-energy deposits may be intercalated with fine-grained lacustrine and/or overbank deposits that are designated as the lower mud unit (LMU) and the upper Ringold unit. Within the 200 East Area (Near Field), four units, from oldest to youngest, are present: the fluvial gravel Unit A, LMU, fluvial gravel Unit E, and upper Ringold unit. These geologic units are designated as hydrostratigraphic intervals (hydrostratigraphic unit [HSU]) 9, HSU 8, HSU 5, and HSU 4, respectively (Figure 3-5). A detailed lithologic description of these units can be found in PNNL-12261.

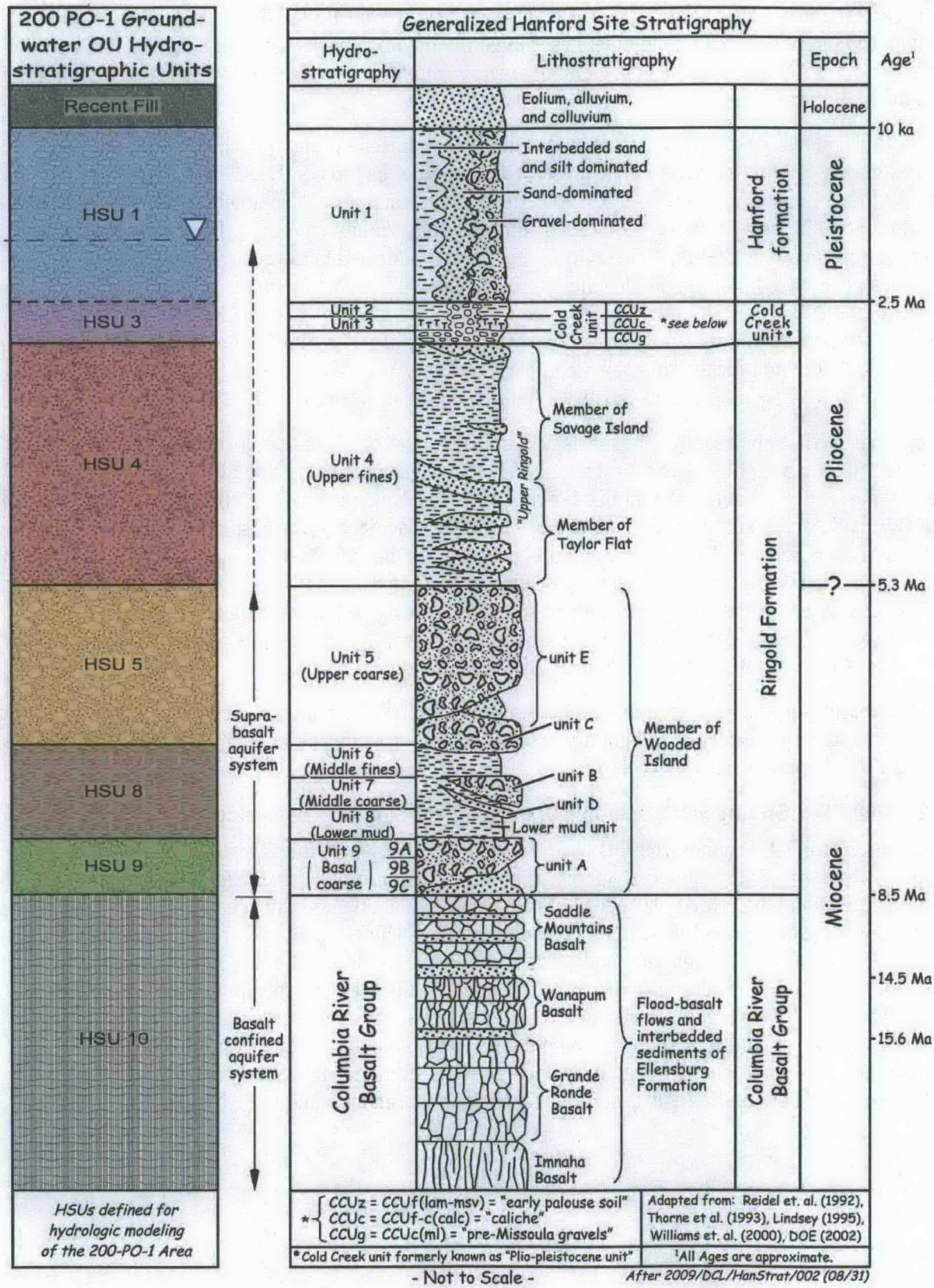
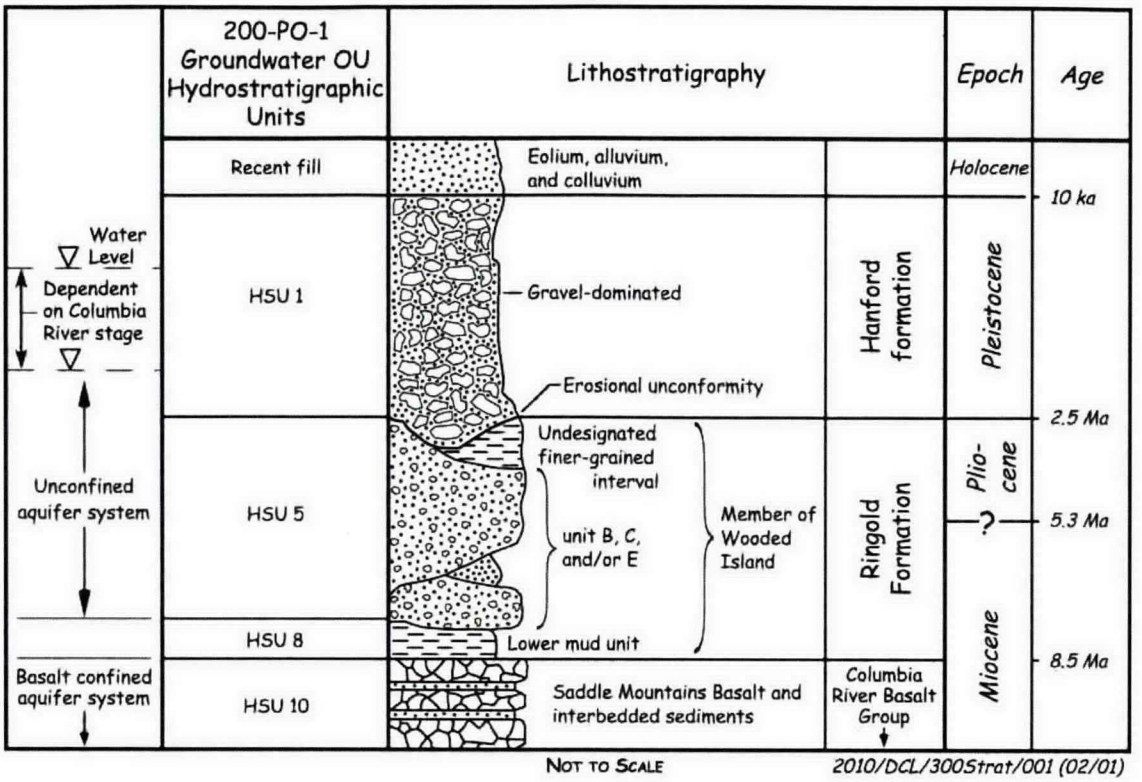



**Figure 3-5. Generalized Hydrostratigraphy of the Hanford Site**




Modified for 300 Area after Reidel et al. (1992), Thorne et al. (1993), Lindsey (1995), Williams et al. (2000), DOE-RL (2002)

**Figure 3-6. Hydrostratigraphy near the Columbia River (300 Area)**

Ringold fluvial gravel Unit A (HSU 9) directly overlies the Elephant Mountain Basalt and displays a relatively flat surface that dips southerly toward the axis of the Cold Creek syncline. Unit A is not present in the northern portion of the 200 East Area, probably due to structural uplift that created depositional thinning and/or paleo-flood removal (erosion) across this area (Figure 3-7). Unit A (HSU 9) ranges in thickness from over 30 m (100 ft) south of 200 East Area to zero at the truncation boundary within 200 East Area. This northern boundary is approximate and is identified as the erosional limit of the post-Ringold fluvial incision from Pleistocene Age cataclysmic flooding that traversed the uplifted anticlinal areas. For the Near Field region, cross-sections (Figure 3-7 and Figure 3-8) depict the stratigraphy and general structural and erosional relationships of the Ringold Fm and overlying Hanford fm sediment.

The Ringold Fm LMU is a relatively thick, low-permeability fine-grained sequence of overbank, paleosol, and lacustrine silt and clay with minor sand and gravel. Where the LMU (HSU 8) occurs below the water table, it forms a confining unit within the suprabasalt aquifer system, separating the lower saturated Ringold Fm Unit A (HSU 9) from the overlying saturated Ringold Fm Unit E (HSU 5). Where the LMU is at or above the water table, it creates a relative aquitard, i.e., a 'no-flow' groundwater boundary. The uppermost unconfined aquifer is contained within the geologic units overlying the LMU (i.e., Ringold Fm Unit E and saturated Hanford fm or Cold Creek sediments), where present, or the top of basalt where the LMU is missing. The LMU sequence thickens and dips southeast into the syncline, similar to the underlying Ringold Unit A. Like Unit A, the LMU is absent through much of the northern portion of the 200 East Area. The LMU ranges from 0 m (0 ft) to more than 33 m (110 ft) thick.

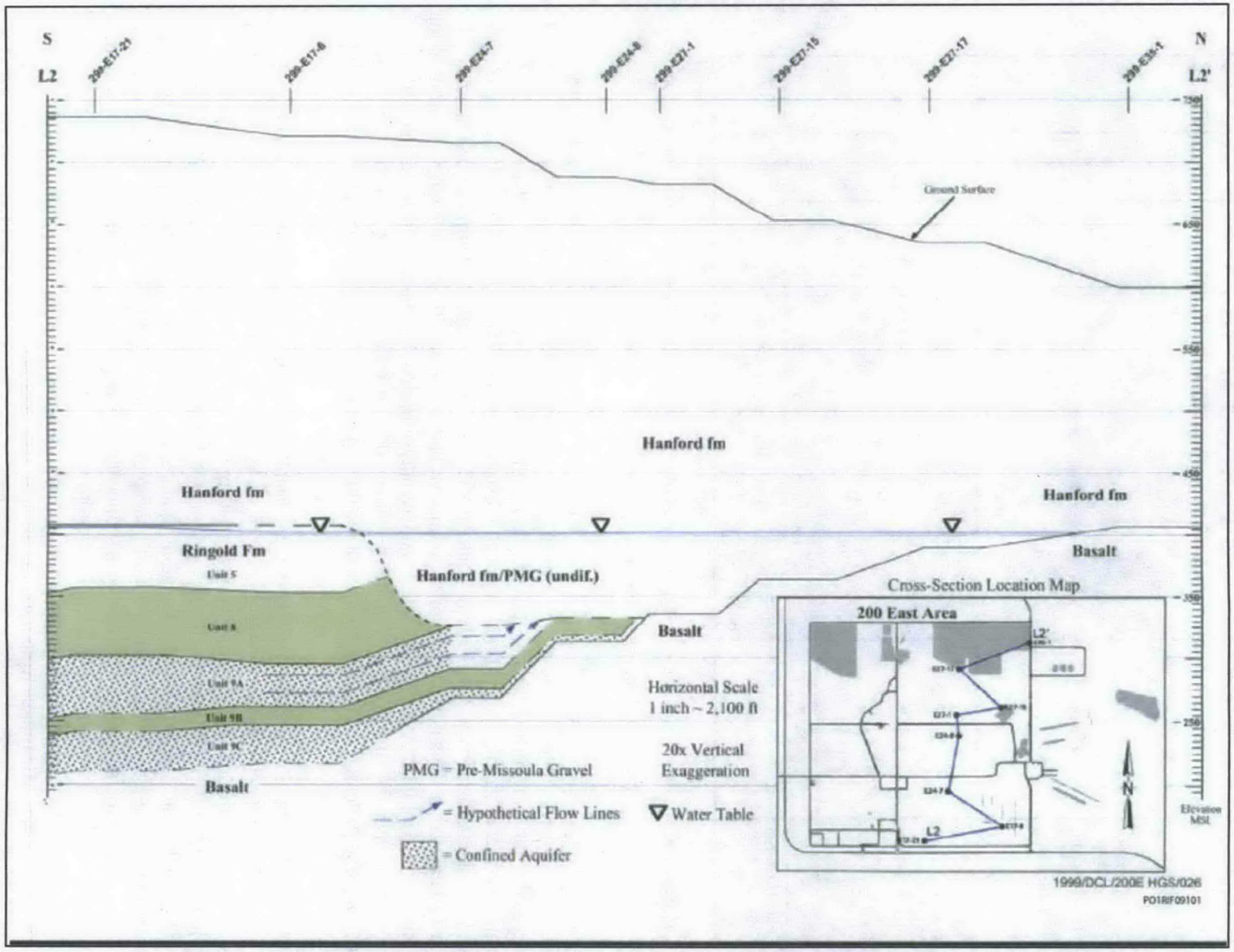
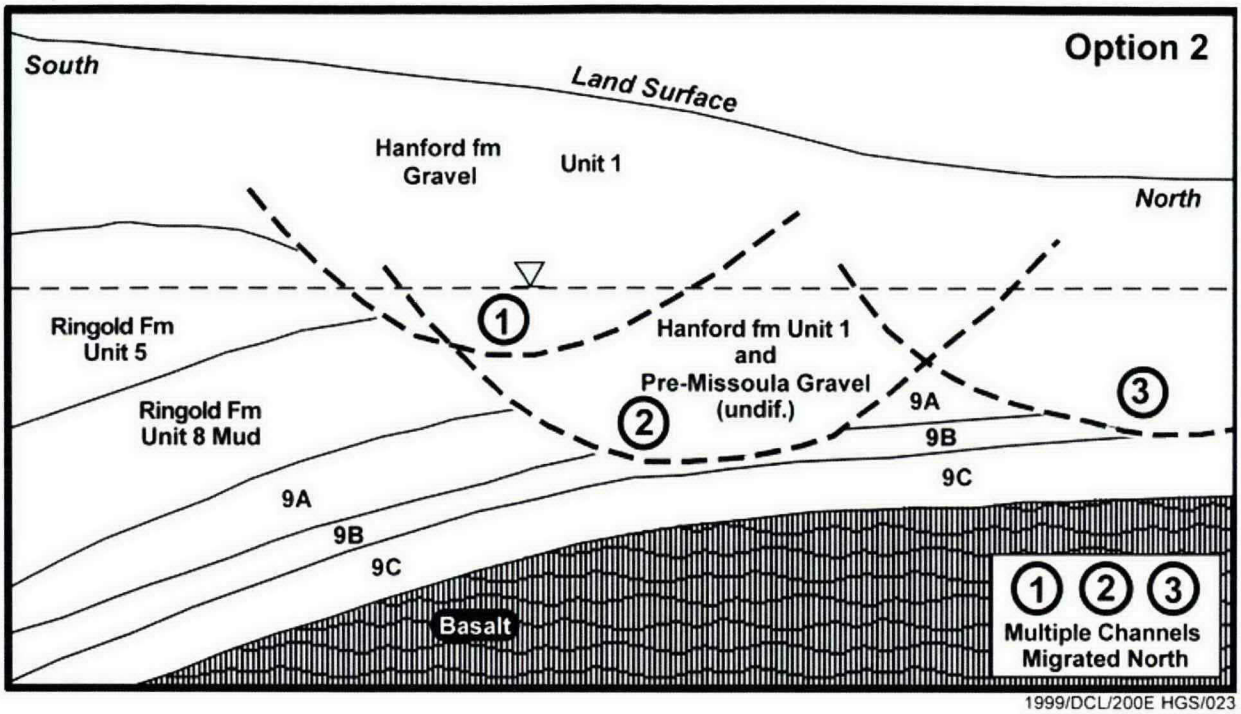



**Figure 3-7. Near Field Hydrogeology Depicting Truncation of Ringold Units onto Uplifted Basalt**




1999/DCL/200E HGS/023
PO1RIF09102

**Figure 3-8. Near Field Hydrogeology Conceptual Relationships – Multiple Migrating Channels**

Within the 200-PO-1 Near Field area (i.e., 200 East Area and vicinity), the Ringold Fm Unit E (HSU 5) is the uppermost Ringold unit and is composed of fluvial gravel that grades upward into interbedded fluvial sand and silt. Ringold Fm Unit E overlies the LMU and is present only in the southern portion of the 200 East Area, and its updip limit is interpreted the same as the LMU (Figure 3-7). It has been removed through erosion, or depositional thinning, in the northern and eastern portion of the 200 East Area. Ringold Fm sediments contain the uppermost unconfined aquifer south and west of the 200 East Area. Contaminant plumes emanating from the 200 West Area generally migrate east through this unit and into the adjacent and overlying Hanford fm sediments near the 200 East Area erosional truncation (Figure 3-7). Similar to the underlying units, this unit thickens southeast to over 70 m (230 ft) (DOE/RL-95-100).

In the Near Field, the CCU (HSU 3) is a clast-supported, sandy pebble/cobble gravel (also known as the PMGs) that sharply truncates against the underlying Ringold Fm (HSU 4 and/or HSU 5) or basalt. Three separate facies of the CCU (i.e., $CCU_z$, $CCU_c$, and $CCU_g$) are identified across the Central Plateau (Figure 3-5), but only the coarse grained $CCU_g$ is identified within the 200-PO-1 Groundwater OU. This unit (undifferentiated as HSU 3) consists of post-Ringold deposits, from the ancestral Columbia River, composed of coarse-grained, highly permeable, high-energy deposits that exist only in the central, northern, and northeastern portions of the region south of Gable Mountain.

The Hanford fm, the youngest fluvial geologic sequence within the 200-PO-1 Groundwater OU, consists of glaciofluvial sediments deposited during cataclysmic Ice Age flooding. The Hanford fm (HSU 1) is subdivided into three main facies (silt, sand, and gravel dominated) that vary vertically and laterally across the region and are difficult to correlate. In the northern portion of the 200 East Area (200-BP-5 OU), the Hanford fm sediments were deposited unconformably on basalt and form part or all of the sediments in the unconfined suprabasalt aquifer. Farther south, the Hanford fm sediments overly the older Ringold Units (Unit E, LMU, and Unit A) and may comprise the uppermost portion of the unconfined aquifer. The Near Field vadose zone is primarily composed of the Hanford fm.

Clastic dikes (Figure 3-9) are discontinuities common within Hanford fm sediments of the 200-PO-1 Groundwater OU, and may occur in the underlying Ringold Fm. They normally appear as cross cutting, vertically oriented cracks or fissures that are filled with sand, silt, clay, and minor coarser debris. Their origin is likely associated with hydraulic injection during or immediately following Pleistocene cataclysmic flooding, mass wasting, earthquakes, and other geologic processes. Clastic dikes occurring in vadose zone sediments have the potential to influence soil moisture and contaminant movement (BHI-01103, *Clastic Injection Dikes of the Pasco Basin and Vicinity*). There are no existing data about the potential influence of clastic dikes within the aquifer.

Holocene surficial deposits in the 200 East Area are dominated by very-fine-grained to medium-grained, and occasionally silty, eolian sheet sands. These deposits were removed from much of the area by past construction activities.

Topographic features of the 200-PO-1 Groundwater OU Near Field area were sculpted by Pleistocene age paleo-flood erosion and deposition, and are illustrated in Figure 3-10.

### 3.4.3 200-PO-1 Groundwater OU Far Field Suprabasalt Geology

The 200-PO-1 Groundwater OU boundary Far Field monitoring wells and transects are shown in Figure 2-2. Locations and orientations of some of the cross-sections presented in this chapter are illustrated in Figure 3-11. All of the cross-sections (Figure 3-11) are presented in Appendix D.

The 200-PO-1 Groundwater OU Far Field region covers over five times more area than the 200-PO-1 Groundwater OU Near Field (source) area without as many boreholes to support geological mapping under the area. The geologic units of the suprabasalt aquifer in the Far Field region form a larger and thicker sequence of sediments, because the basin (defined by the top of basalt surface) is much deeper than the Central Plateau region (200 East Area and 200 West Area) that forms the Near Field area. As in the Near Field region, the Ringold Fm in the Far Field is the oldest suprabasalt sediment and includes the primary units of the suprabasalt aquifer system. The Ringold Fm sediments are gravel-dominated units, designated as Unit A, Unit B/D, Unit C, and Unit E (from oldest to youngest). These high-energy gravel deposits are separated by fine-grained lacustrine and/or overbank deposits designated as the LMU and the upper Ringold unit. Geologic mapping of Unit B/D and Unit C suggests an apparent discontinuous depositional history. These units are deeper in the suprabasalt sedimentary sequence and appear relatively thin or isolated by the low-permeability Ringold mud units. The Ringold Fm LMU is relatively thick and persists throughout most of the Far Field region of the 200-PO-1 Groundwater OU. Therefore, the Ringold Fm sediments have been grouped into four main HSU intervals to support development of flow and transport models: HSU 9 (consisting of geologic Unit A), HSU 8 (consisting of geologic Unit B/D stratigraphically sandwiched within the LMU), HSU 5 (consisting of Unit C and Unit E), and HSU 4 (the upper Ringold unit).

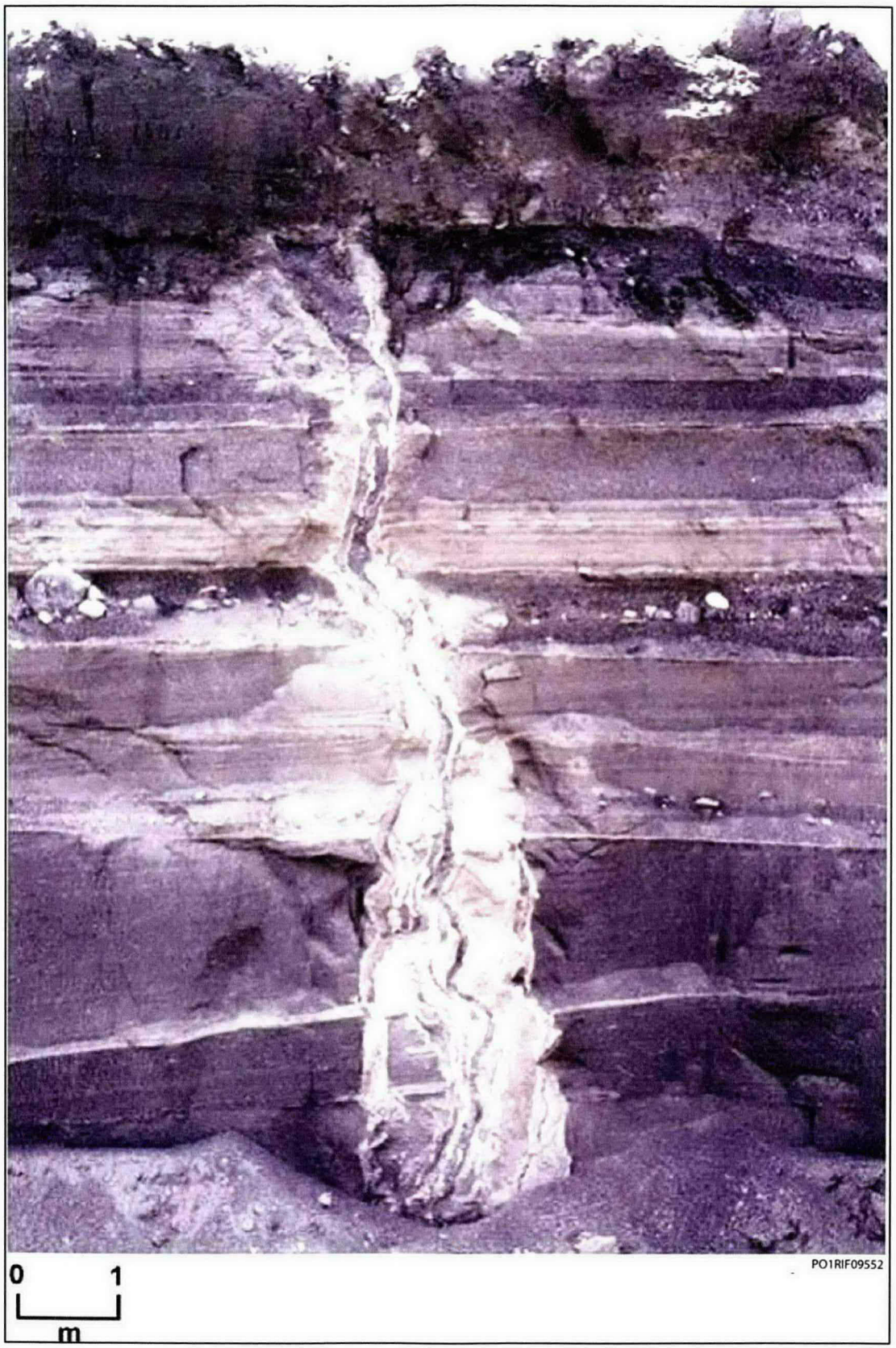



**Figure 3-9. Clastic Dike in the Hanford Formation**

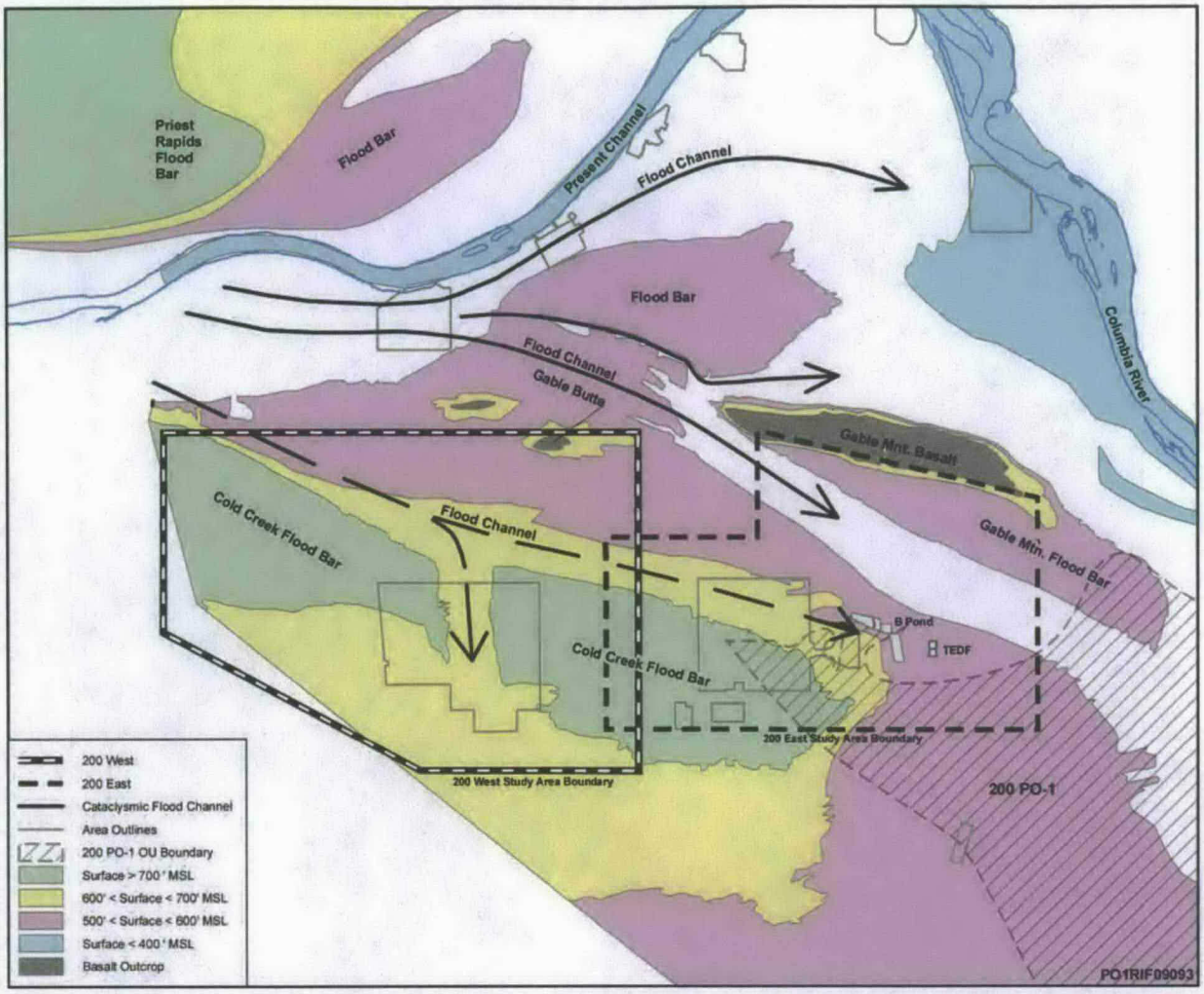



**Figure 3-10. Near Field Pleistocene Paleo-Erosional Surface Topography**

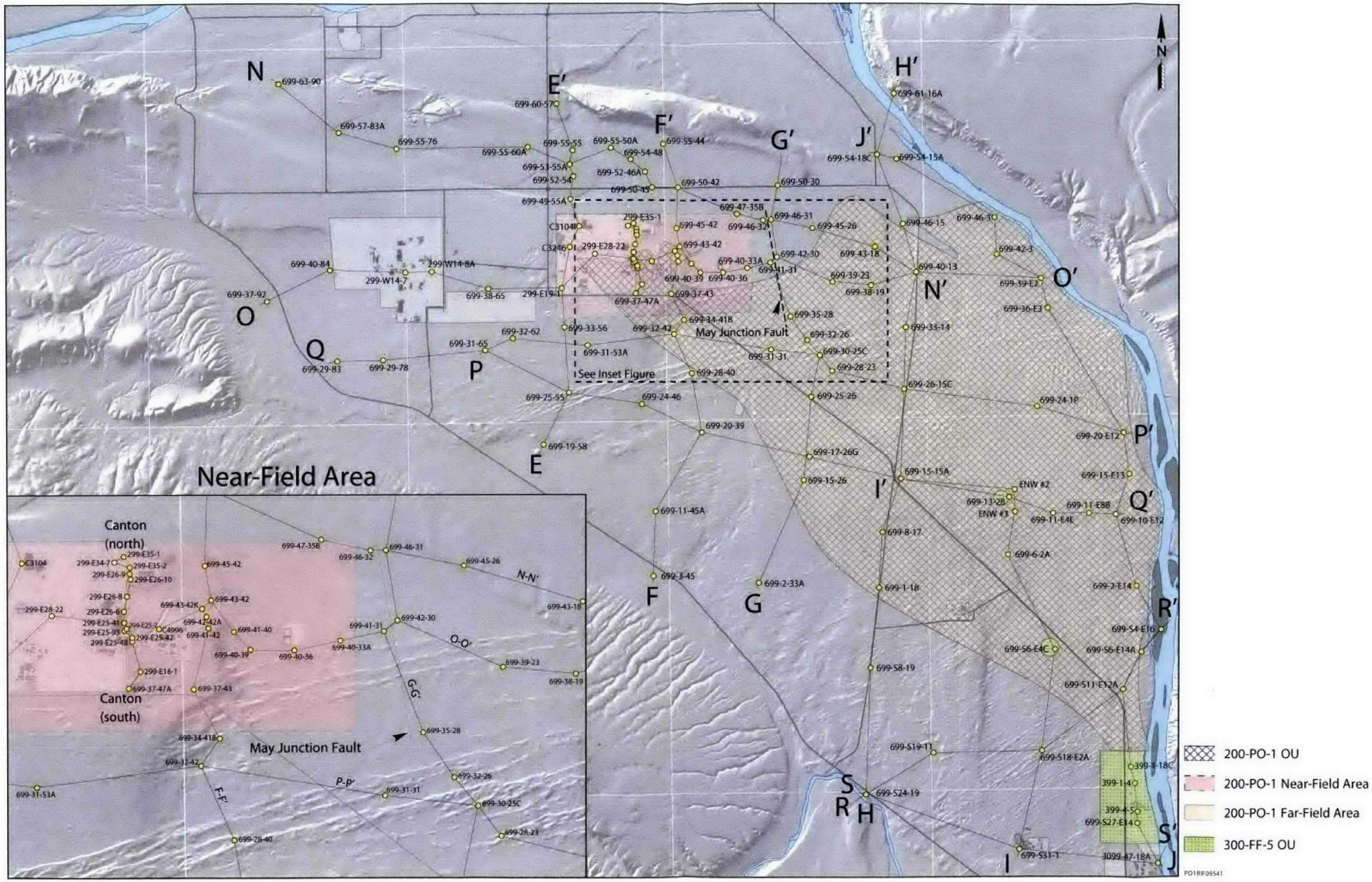



Figure 3-11. Cross-Section Location Map, 200-PO-1 Groundwater Operable Unit

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Ringold Fm Unit A (HSU 9) is the oldest and directly overlies the Elephant Mountain Basalt. Within the Far Field region, Unit A thickens to greater than 35 m (115 ft) in the center of the OU. This unit pinches out (is not present) beneath the 300-FF-5 OU to the southeast, adjacent to the Columbia River. Characterization data suggest that Unit A thickens into the Cold Creek syncline, thinning to the south out of the basin and to the east near the Columbia River (Figure 3-12 and Figure 3-13).

The LMU (HSU 8) forms a semi-regional confining unit within the suprabasalt aquifer, separating the lower saturated Ringold Fm Unit A (HSU 9) sediment from the overlying saturated Ringold Fm Unit E (HSU 5). The uppermost unconfined aquifer is contained within the geologic units overlying the LMU (i.e., Ringold Unit E, upper Ringold Unit, and saturated Hanford and Cold Creek sediments) where present. The LMU is thicker and deeper in the Far Field region within the suprabasalt aquifer system (Figure 3-12 and 3-13). The LMU is more than 33 m (110 ft) thick in the vicinity of NRDWL/SWL and thins to 6 m (20 ft) near the 300 Area; it is 15 m (50 ft) thick in the northeast portion of the OU near the Columbia River.

Within the 200-PO-1 Far Field area, the Ringold Fm Unit E (HSU 5) overlies the LMU and thickens southeast into the basin (Figure 3-12 and Figue 3-13), similar to the underlying units, and ranges to over 70 m (230 ft) thick (DOE/RL-95-100).

The upper Ringold Unit (HSU 4) overlies Unit E in the thicker portion of the basin, generally in the Far Field region downthrown from the May Junction fault, and throughout the northeast portion of the OU (Figure 3-12 and Figure 3-13). It attains a thickness up to 18 m (60 ft) toward the east. HSU 4 is a silty, sandy, fine-grained unit, and data indicate that it is less permeable.

The CCU (PMG) is a clast-supported, sandy pebble/cobble gravel that abruptly truncates the underlying Ringold Fm (HSU 4 and/or HSU 5). This coarse-grained, highly permeable, high-energy sediment exists only in the central, northern, and northeastern portions of the Far Field region of the OU, south of Gable Mountain and is generally downthrown east of the May Junction fault (Figure 3-12). The CCU ranges in thickness from 0 m (0 ft) to 46 m (150 ft) and thickens to the east-southeast. It is not identified near the southern boundary of the OU or near the 300 Area. In the Far Field region of the OU, extending toward the Columbia River, geologic mapping of the CCU reveals that portions of the interval occur at or below the water table.

The Hanford fm is the youngest geologic sequence within the 200-PO-1 Groundwater OU. Its sediments are generally the most permeable of the suprabasalt sediments. In the Far Field region of the 200-PO-1 Groundwater OU, the Hanford fm (HSU 1) is deposited unconformably on top of the Cold Creek HSU 3 unit (where present), and/or the Ringold Fm HSU 4 and/or HSU 5, and typically comprises the vadose interval above the suprabasalt aquifer (Figure 3-12 and Figure 3-13).

## 3.5 Soils

Within the Central Plateau, groundwater OUs are administratively separated from vadose zone OUs where contaminant sources are located. This RI Report discusses groundwater in the saturated zone of the 200-PO-1 Groundwater OU. Characterization of the unconsolidated sediments and soils of the vadose zone overlying the 200-PO-1 saturated zone is not a part of the scope of this document and is addressed in other documents.

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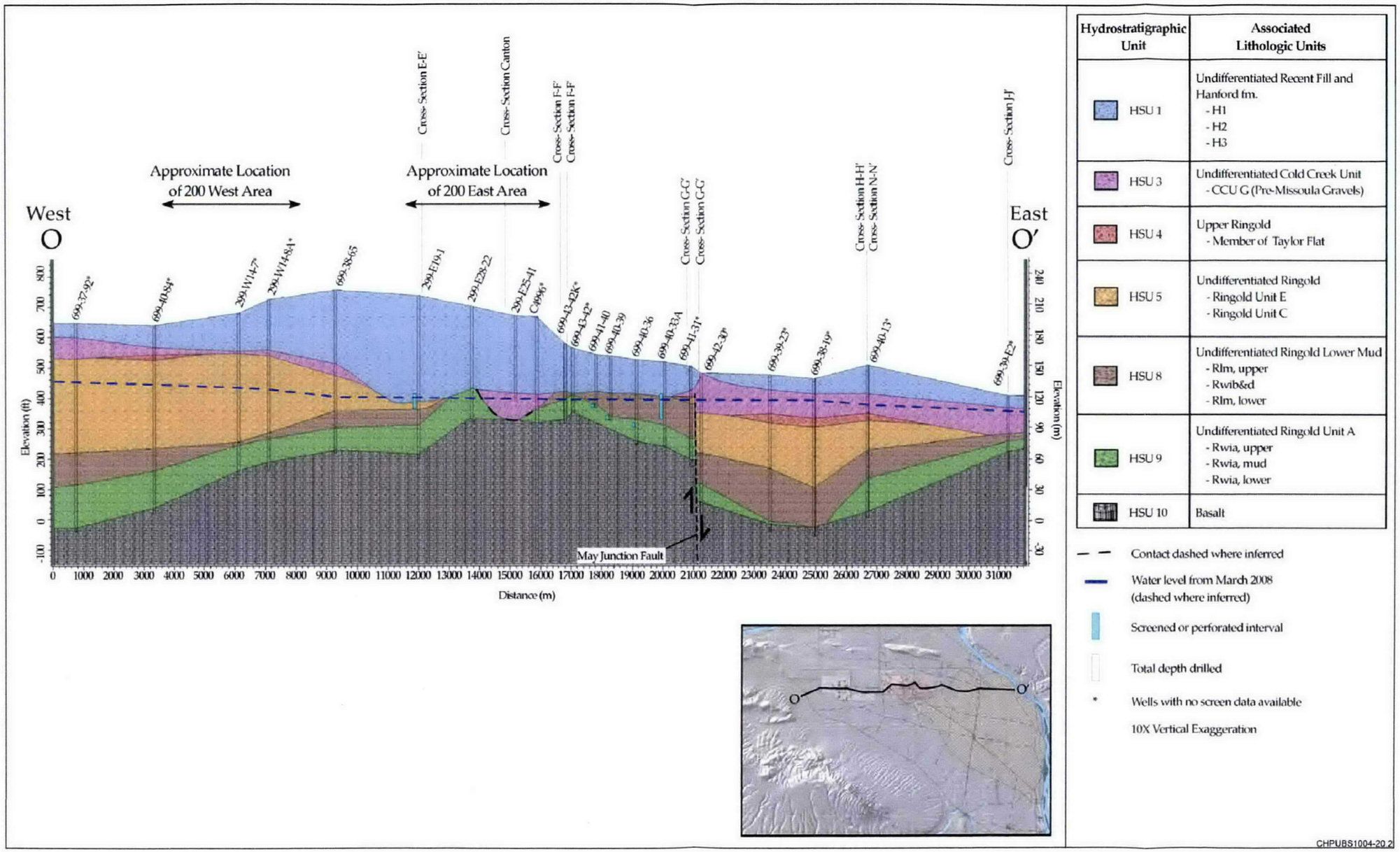


Figure 3-12. Far Field Hydrogeology Section O-O'

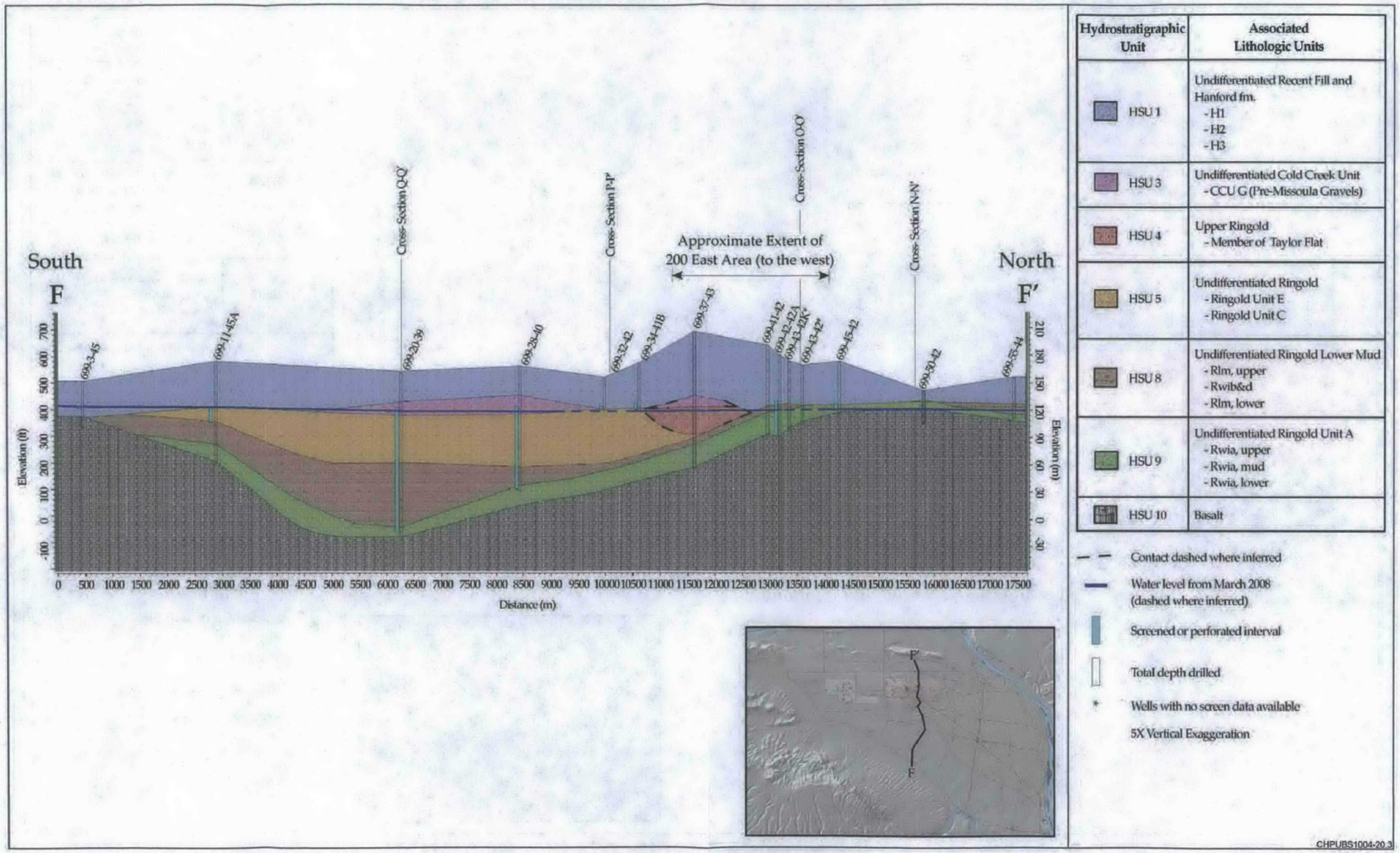


Figure 3-13. Far Field Hydrogeology Section F-F'

## 3.6 Hydrogeology

Groundwater migration is the primary contaminant transport pathway for this OU. Because the groundwater OUs on the Central Plateau are administratively segregated from the source OUs, including related vadose zone contamination, this hydrogeologic discussion focuses only on the aquifer systems in the 200-PO-1 Groundwater OU.

### 3.6.1 Summary of Aquifer Systems in the 200-PO-1 Groundwater Operable Unit

This section describes the hydrostratigraphic and groundwater flow characteristics of the confined basalt aquifers, and the semi-confined to unconfined suprabasalt aquifer system in the 200-PO-1 Groundwater OU (Figure 3-5). The uppermost suprabasalt aquifer system beneath the Hanford Site is generally unconfined to semi-confined, depending on depth below the water table. This aquifer system is located within the unconsolidated sand and gravel of the Hanford fm, and the semi-consolidated to indurated CCU (PMG) and Ringold Fm overlying basalt bedrock. Locally, layers of silt and clay strata confine and separate portions of the suprabasalt aquifer. The vadose zone beneath the 200-PO-1 Groundwater OU is composed primarily of laterally discontinuous, highly permeable Hanford fm sediment made up of silt, sand, and gravel-dominated facies.

Confined aquifers occur within the basalt flows and their sedimentary interbeds. These interbed aquifers are confined by the overlying competent basalt layer(s) and the Ringold Fm LMU where this unit lies directly on top of basalt (e.g., near the Columbia River).

Groundwater beneath the Hanford Site flows primarily from recharge areas along the elevated western and southwestern margins of the site to the east, and north toward the Columbia River. Historical flow patterns were modified by groundwater mounds created by the discharge of large volumes of process water from Hanford Site activities. Because discharges have been dramatically reduced or eliminated, the water table in the impacted areas is returning to pre-Hanford conditions (DOE/RL-97-02, *National Register of Historic Places Multiple Property Documentation Form; Historic, Archaeological and Traditional Cultural Properties of the Hanford Site, Washington*). Within the 200-PO-1 Groundwater OU, the 200 East Area groundwater mound is receding, leaving some monitoring wells dry and changing groundwater flow patterns and gradients across the Central Plateau. Subsequently, the water table in the 200 East Area has a relatively low gradient, resulting in a flat water table making interpretations of groundwater flow directions difficult. Beginning in 2002, the rate of water table decline in the 200 East Area and vicinity slowed, which suggests that the aquifer is near equilibrium. Limited permitted effluent releases still occur at the 200 Area TEDF however, located within the 200-PO-1 Near Field region, with observable water table fluctuations. It is not known if these perturbations to the upper unconfined aquifer will affect the contaminant plume flow path.

### 3.6.2 200-PO-1 Groundwater Operable Unit Hydrostratigraphy

Within the 200-PO-1 Groundwater OU, varying geologic units influence the hydrogeology for the area. Some geologic units have been combined to define the HSUs needed to facilitate groundwater modeling efforts. These geologic units were combined based on similarities in hydraulic properties, units that are not continuous, or areas where uncertainty exists about the correlation and extent of the geologic units. The primary HSUs defined within the 200-PO-1 Groundwater OU, from oldest to youngest (Figure 3-5), are:

- The Rattlesnake Ridge interbed and deeper interbeds of the Ellensburg Formation, which form confined aquifer flow zones (HSU 10).

- The Elephant Mountain Member basalt and deeper lava flows of the Saddle Mountains Basalt, which form the basalt confining horizons (HSU 10). Locally these basalts may contain fractured interflow zones.

- The Ringold Fm Unit A (HSU 9) silty sandy gravel (the basal coarse grained unit), which contain locally confined to unconfined aquifer flow zones. HSU 9 is confined and separated by the Ringold Fm LMU (HSU 8) fine-grained unit. HSU 8 separates HSU 9 from the overlying Ringold Fm Unit C and Unit E (HSU 5), and the Upper Ringold Unit (HSU 4) that makes up most of the unconfined suprabasalt aquifer system.

- The CCU (HSU 3) sandy gravel interval. HSU 3 is limited in extent to areas in the north and eastern portions of the 200-PO-1 Groundwater OU and represents a highly permeable unconfined aquifer flow zone when saturated.

- The Hanford fm unconsolidated silt, sand, and gravel (HSU 1). HSU 1 also represents a highly permeable unconfined aquifer flow zone when saturated.

### 3.6.3 Basalt and Interbed Aquifers

Several regional confined aquifers exist within the Saddle Mountains Basalt-Ellensburg Formation (HSU 10) in the 200-PO-1 Groundwater OU. The confined water bearing zones occur in the sedimentary interbeds of the Ellensburg Formation and in interflow and fractured intraflow intervals within the basalts. The uppermost regional confined aquifer in the vicinity is generally within the Rattlesnake Ridge interbed (Ellensburg Formation), but may also include the fractured flow top and bottom of the enclosing basalt flows. The upper basalt confining unit within the 200-PO-1 Groundwater OU is the Elephant Mountain Member, which has been removed locally by erosion just north of the 200 East Area (within the 200-BP-5 OU) where the basalts had been uplifted and exposed directly to the paleo-floods. No evidence of Elephant Mountain erosion exists in the 200-PO-1 Groundwater OU. However, the Rattlesnake Ridge interbed confined aquifer may be exposed to the suprabasalt unconfined aquifer north of the 200 East Area. Within the 200-PO-1 Groundwater OU, wells monitoring the basalt confined aquifers indicate an upward hydraulic head. Based on these data, and related groundwater chemistry results, it is unlikely that contamination occurring in the suprabasalt aquifer system beneath the 200-PO-1 Groundwater OU has migrated down into these basalt confined aquifers or has significantly impacted these confined aquifers. A potentiometric surface map of the basalt confined aquifer (Rattlesnake Ridge interbed) is shown in Figure 3-14. This potentiometric surface is static and does not vary seasonally.

### 3.6.4 Suprabasalt Aquifer System

The suprabasalt aquifer system comprises the uppermost aquifer system in the 200-PO-1 Groundwater OU. This aquifer system is primarily unconfined. Because of its large extent and overall thickness (up to 215 m [700 ft] thick), however, it includes localized semi-confined and confined intervals within the deeper portion of the suprabasalt sedimentary sequence. The suprabasalt aquifer system is primarily contained within the Ringold Fm, which is composed of silty sandy gravel (HSU 9, HSU 5, and HSU 4) interspersed with thick fine-grained (i.e., silty clayey) intervals (HSU 8). In some regions of the 200-PO-1 Groundwater OU, the very uppermost portion of the unconfined aquifer is actually within the lower portion of the Hanford fm (HSU 1) and/or CCU (HSU 3), which unconformably overlie the Ringold Fm (HSU 9, HSU 5, or HSU 4). These younger, more permeable HSUs can create preferential groundwater flow within the very uppermost portion of the unconfined aquifer because of their relatively higher hydraulic conductivity compared to the underlying Ringold Fm HSUs.

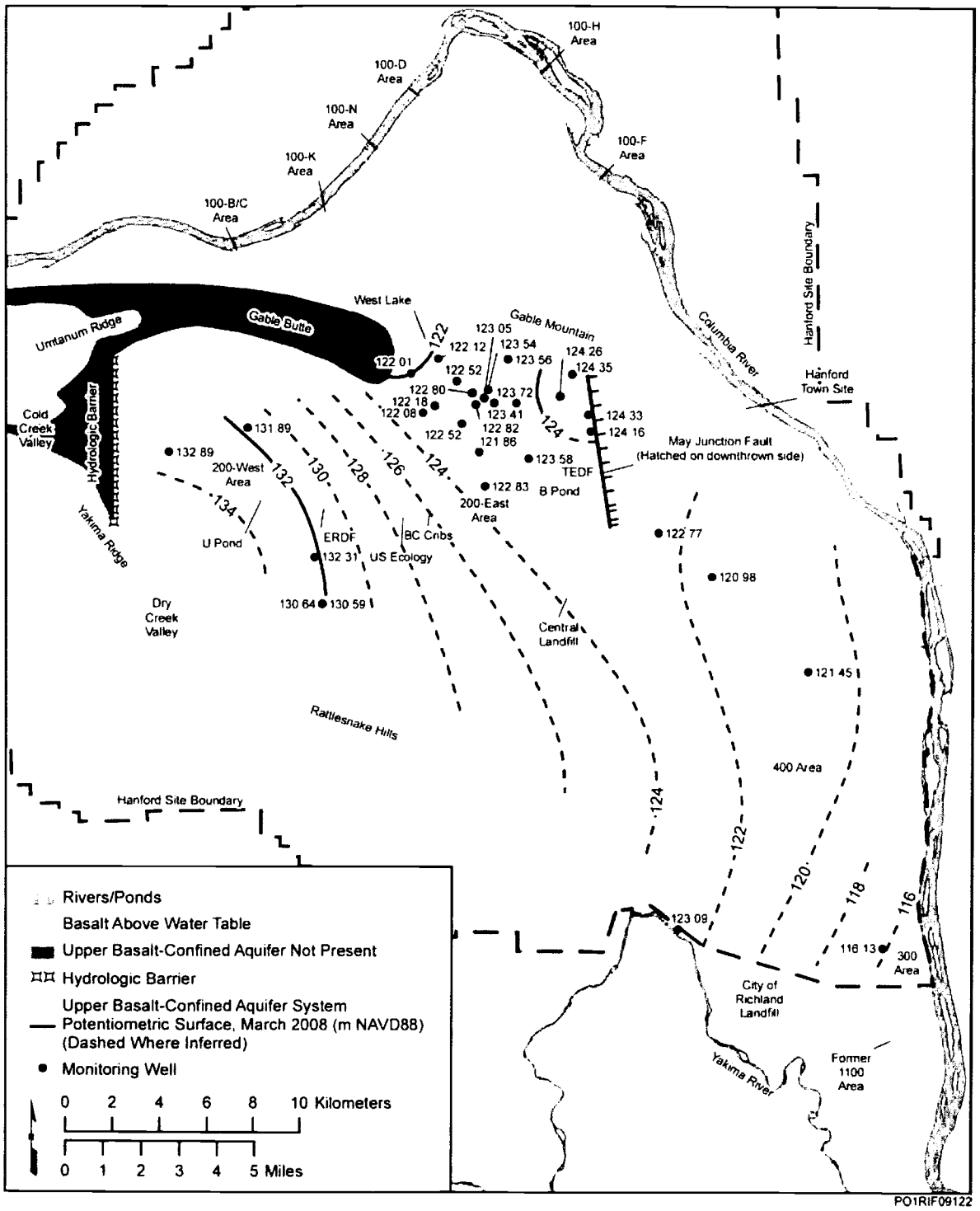


**Figure 3-14. Potentiometric Surface Map of the Basalt Confined Aquifer**

The depth to the uppermost unconfined aquifer in the Near Field (source) area of the 200-PO-1 Groundwater OU is more than 91.4 m (300 ft) near the southern boundary of the 200 East Area, and it varies in depth to near 0 m (0 ft) bgs at the Columbia River. Springs and seeps occur along the riverbanks where the aquifer flows laterally out of the ground directly into the river in places and/or down the sloping river shoreline into the river.

The Ringold Fm LMU (or HSU 8) represents the base of the unconfined suprabasalt aquifer throughout the majority of the 200-PO-1 Groundwater OU, except where HSU 8 is absent in the northern and central portions of the 200 East Area.

The thickness of the suprabasalt aquifer ranges from near 0 in the northern portions of the 200-PO-1 Groundwater OU (200 East Area Near Field), where basalt bedrock and/or HSU 8 extends above the water table, to more than 215 m (700 ft) in the central portion of the basin downthrown from the May Junction fault. Water levels in wells that penetrated the LMU are generally positioned at the top of the HSU. Figure 3-15 shows the suprabasalt aquifer thickness for the 200-PO-1 Groundwater OU. Because of depth to the aquifer and minimal natural recharge, seasonal changes to the aquifer do not occur. Figure 3-16 shows a potentiometric surface map of the lowermost portion of the suprabasalt aquifer contained within HSU 9.

### 3.6.5 Aquifer Intercommunication

Throughout most of the 200-PO-1 Groundwater OU, groundwater in the uppermost portion of the aquifer system (including the upper portions of the Ringold Fm [HSU 5 and HSU 4] and overlying Cold Creek [HSU 3] and Hanford fm [HSU 1]) is isolated from groundwater in the lower confined intervals of the Ringold Fm (HSU 9) and lower basalt confined aquifers by the Ringold Fm LMU (HSU 8) and/or other lesser defined mud/silt layers. The hydraulic head below HSU 8 is usually slightly higher than the unconfined aquifer system above HSU 8, thereby creating an upward gradient or the potential for upward groundwater flow. For instance, PUREX well characterization data collected in 1996 included potentiometric head measurements of the lower suprabasalt confined Ringold Fm Unit A (HSU 9). These head measurements were approximately 1.2 m (4 ft) higher than the potentiometric head in unconfined sediment above the LMU. The measurements were obtained from Well 699-37-47A (Borehole Data Package for Well 699-37-47A, PUREX Plant Cribs, CY 1996), which is located near the southeastern corner of the 200 East Area. Figure 3-17 illustrates the higher heads recorded in the lower confined aquifer compared to hydraulic head observations in unconfined wells within the 200-PO-1 Groundwater OU Near Field. Similar measurements illustrating an upward hydraulic head in the basalt confined aquifer are available from wells near the Far Field downgradient boundary of the 200-PO-1 Groundwater OU (i.e., in the 300 Area) near the Columbia River (Figure 3-18).

Figure 3-18 illustrates the higher heads recorded in the lower confined aquifer compared to hydraulic head observations in unconfined wells within the 200-PO-1 Groundwater OU Near Field.

The vertical offset created by the May Junction fault is another potential aquifer intercommunication area; however, hydrogeologic interpretations indicate that hydraulic cross flow is probably not significant at the fault boundary. The fault is a north-to-south trending normal displacement structure that is downthrown on the east side, which appears related to and originates on the south side of Gable Mountain. The largest displacement, estimated at greater than 61 m (200 ft), has been measured between wells drilled on both the upthrown and downthrown sides of the fault (Figure 3-19). The fault displacement (vertical offset) decreases to the south along the fault. Seismic evaluations corroborate this interpretation. Geologic correlation across the fault near the region of maximum displacement (at the northern end of the fault) indicates that permeable units in the upper unconfined aquifer (HSU 1 and HSU 3) are offset and adjacent to the confining fine grained units of the lower confined portion of the suprabasalt aquifer (HSU 8). This vertical arrangement of HSUs, therefore, limits the amount of cross flow that can occur across the fault plane. This conclusion also is validated by the regional plume migration pattern around the southern margin of the May Junction fault.

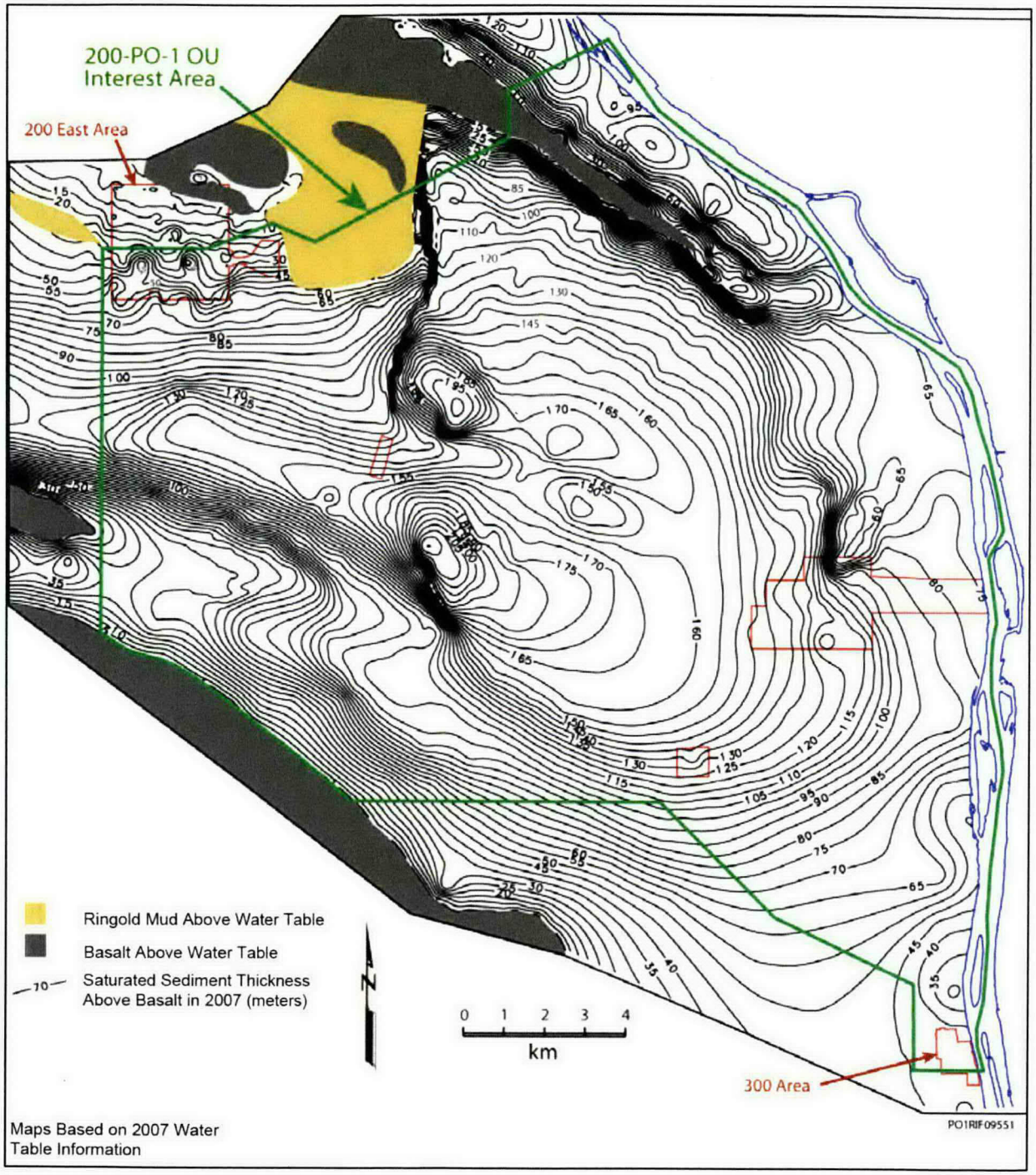


**Figure 3-15. Suprabasalt Aquifer Thickness, 200-PO-1 Groundwater OU Interest Area**

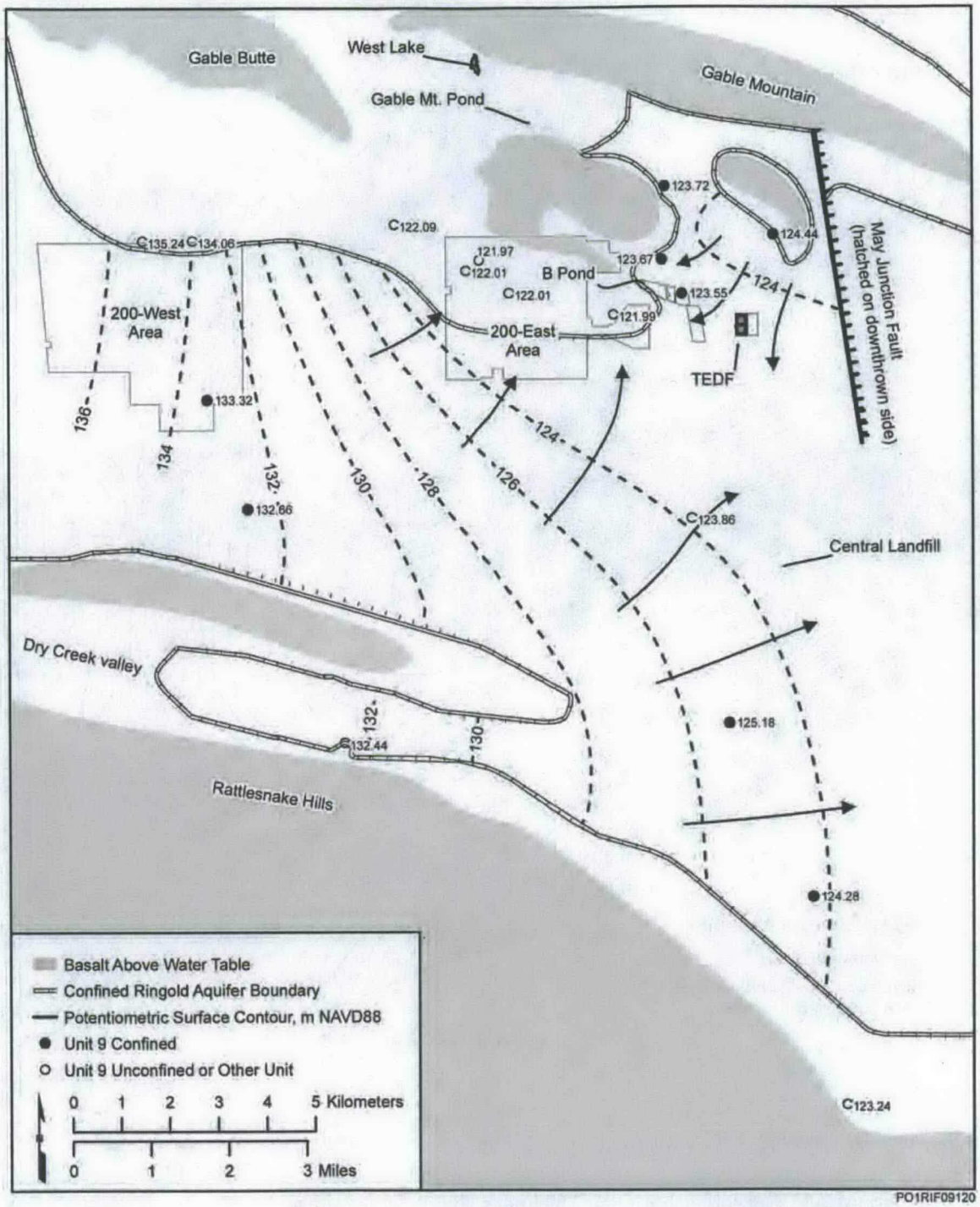


**Figure 3-16. Potentiometric Surface Map of the Lower Suprabasalt Confined Aquifer**

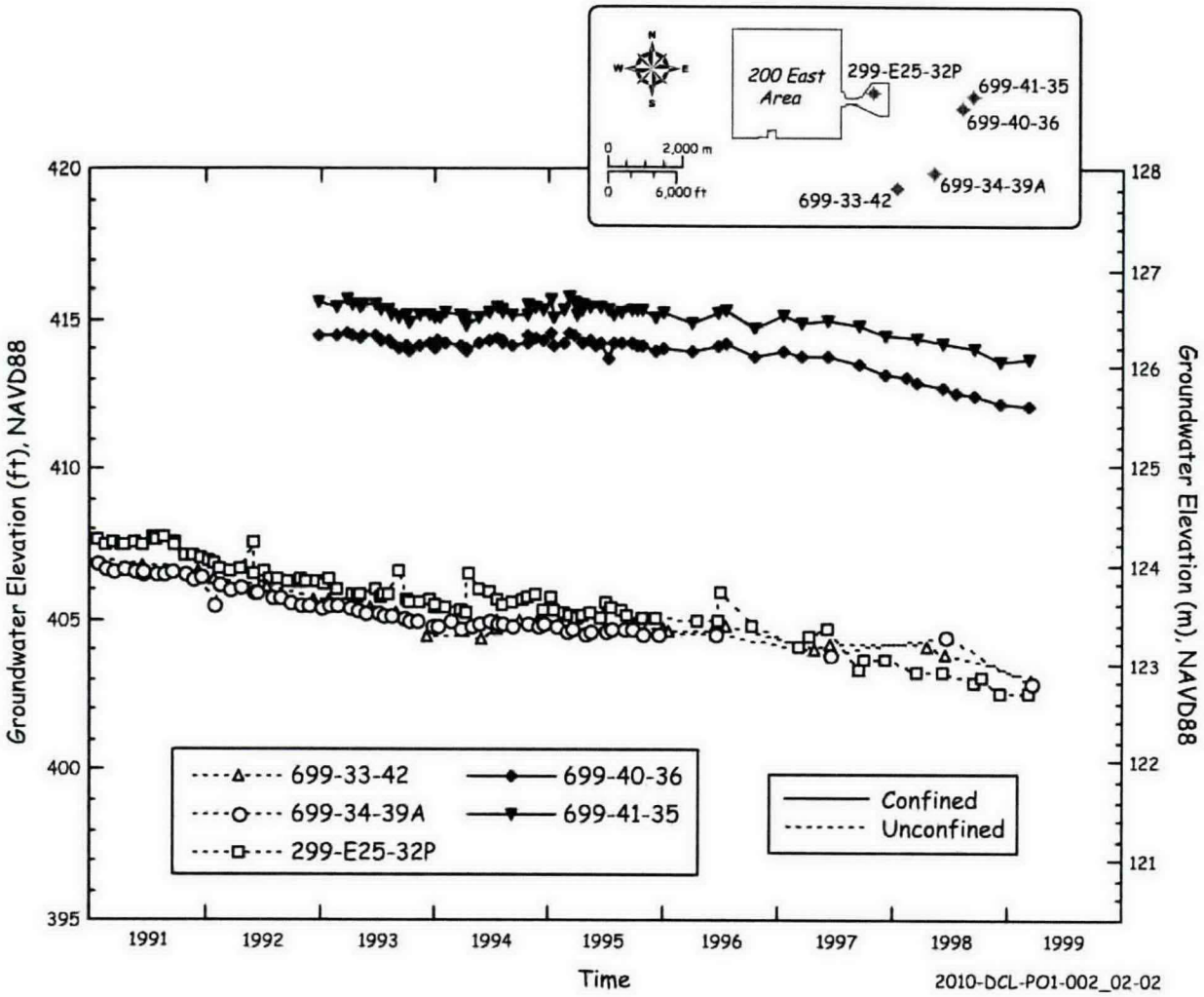


**Figure 3-17. Hydraulic Head Comparisons Between Confined and Unconfined Wells Within the Near Field**

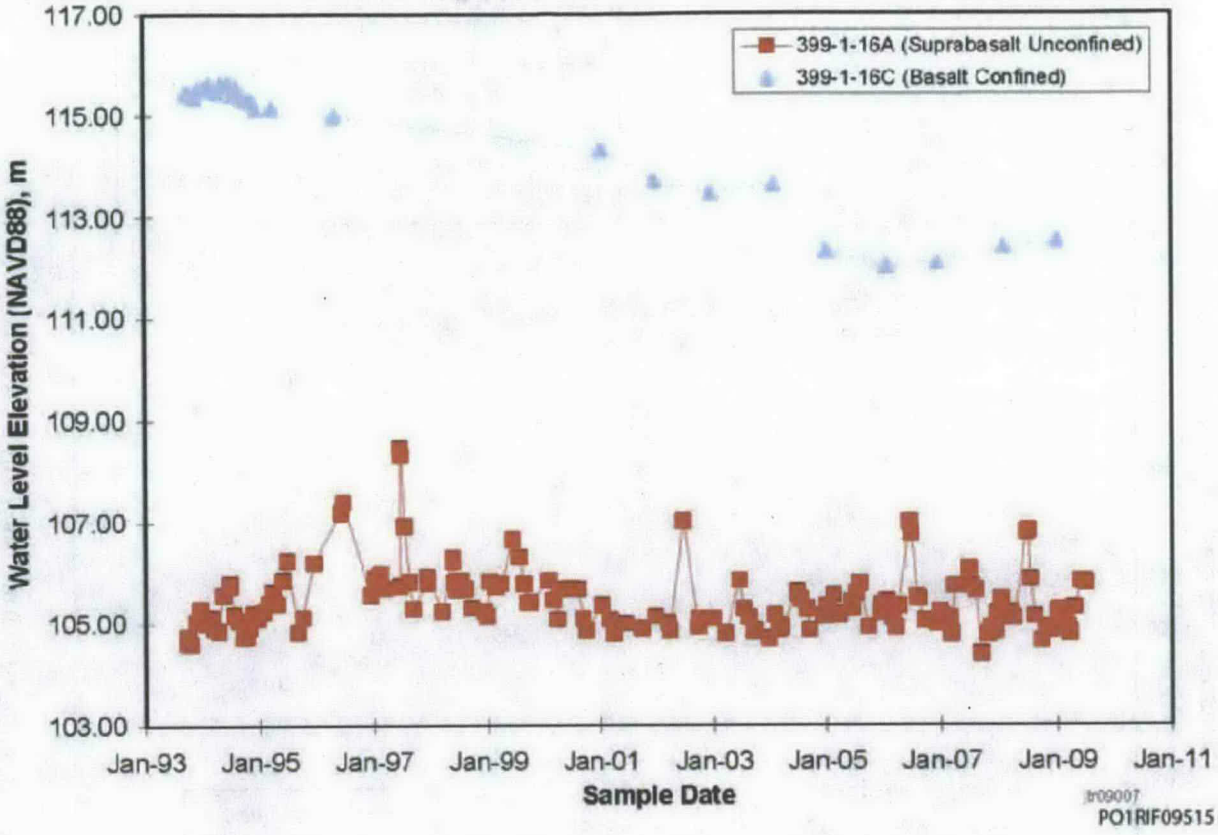


**Figure 3-18. Hydraulic Head Variations - Suprabasalt Unconfined and Basalt Confined Aquifers - Far Field**

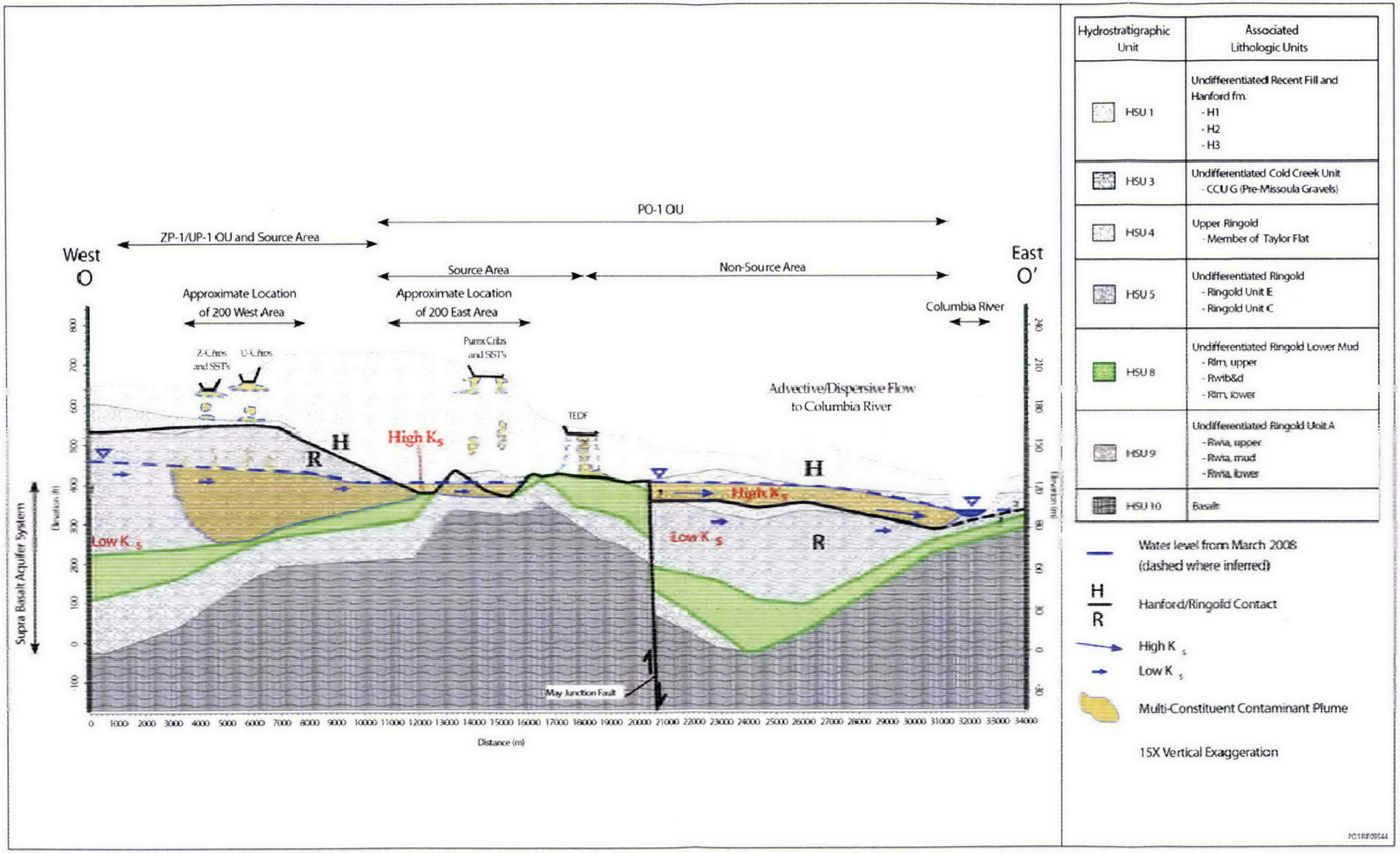


Figure 3-19. Central Plateau Contaminant Conceptual Model, 200-PO-1 Groundwater OU Current Conditions (2008)

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### 3.6.6 Effects of Site Geology on Groundwater and Plume Movement and Behavior

Varying hydraulic conductivity in the 200-PO-1 unconfined aquifer influences groundwater movement and contaminant migration. These hydraulic variations are due to changes in lithology (e.g., grain size) that define the hydrogeologic units in the aquifer system through which the groundwater moves. Both lateral and vertical changes occur in the 200-PO-1 Groundwater OU hydrogeology. Temporal changes in the aquifer thickness and semi-regional water table elevations occur at the Hanford Site and within the 200-PO-1 Groundwater OU; these changes primarily result from massive quantities of liquid effluent disposed to cribs, ponds, and ditches located on the Central Plateau (Figure 3-20).

The distribution (position and extent) of hydrogeologic units at or near the water table is a result of Miocene-Pliocene Age (Ringold Fm) geologic uplift and Pleistocene cataclysmic flood and ancestral Columbia River erosion. Understanding where these boundaries occur is key to resolving the preferential movement of contaminants with groundwater across the 200-PO-1 Far Field to the Columbia River. Figure 3-21 and Figure 3-22 depict the best estimate of the distribution of hydrogeologic units at the water table before Hanford Site operations began (i.e., estimated lowest water table elevation) and at the time maximum water table elevations were reached during Hanford operations, respectively. The primary hydrogeologic units that comprise the suprabasalt aquifer system (i.e., below the maximum water table) are shown in Figure 3-5.

Several significant geologic features influence the observed behavior of the groundwater plumes across the 200-PO-1 Groundwater OU. The Hanford-Ringold contact forms the most significant hydrogeologic interface related to the distribution of groundwater contaminants. Fluvial erosion and paleo-flooding shaped the contact between the sediments (Hanford-Ringold contact). Hydraulic testing from many boreholes across the Hanford Site revealed a significant hydraulic conductivity difference between the Hanford and Cold Creek formations and the underlying Ringold Fm sediments (e.g., Table 3-1 and Figure 3-23). This hydraulic conductivity contrast creates preferential groundwater flow through the very uppermost portion of the unconfined aquifer within the younger Hanford and/or Cold Creek formations sediments where they occur at or below the water table.

Within the Far Field region of the 200-PO-1 Groundwater OU, groundwater elevation data revealed that the regional water table occurs close to the Hanford-Ringold contact, either slightly below or above. This suggests long-term water table elevation stabilized and reached dynamic equilibrium close to this contact, and supports the previous inference that groundwater flow is much higher in the Hanford Fm than in the Ringold Fm. Geologic mapping of the Hanford-Ringold contact indicates a region downthrown from the May Junction fault that extends eastward toward the Columbia River, where the contact is below the water table (Figure 3-19 and Figure 3-24). Within this region, Hanford fm and/or CCU sediments comprise the very uppermost portion of the unconfined aquifer. Plume mapping reveals that the groundwater in this region contains contaminants from the 200 East Area, strongly suggesting a preferential groundwater flow path toward the Columbia River.

Along the Columbia River, between the Hanford town site and the 300 Area, located near the southern end of the 200-PO-1 Groundwater OU, the basalt surface is at a higher elevation than in the center of the basin. The Ringold suprabasalt units are also elevated on the gently rising basalt surface (Figure 3-12 and Figure 3-24 through Figure 3-26). The oldest Ringold Fm units that make up the suprabasalt sediment in the central portion of the OU thin toward the Columbia River (east). Ringold Fm Unit A (HSU 9) becomes very thin to nonexistent in some areas along the Columbia River (Figure 3-6). Where this occurs, the LMU (HSU 8) lies directly on top of basalt.

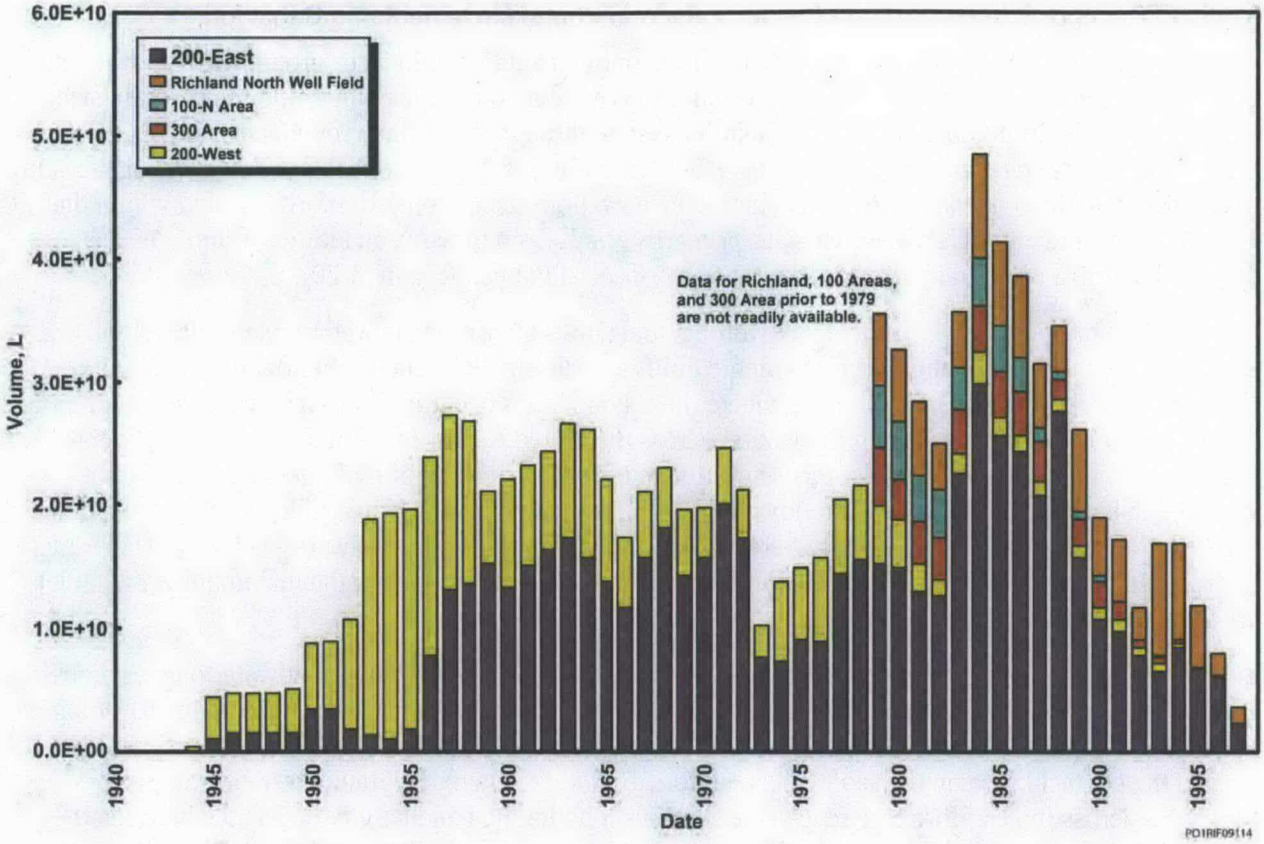


**Figure 3-20. Liquid Effluent Disposal Activities Across the Hanford Site**

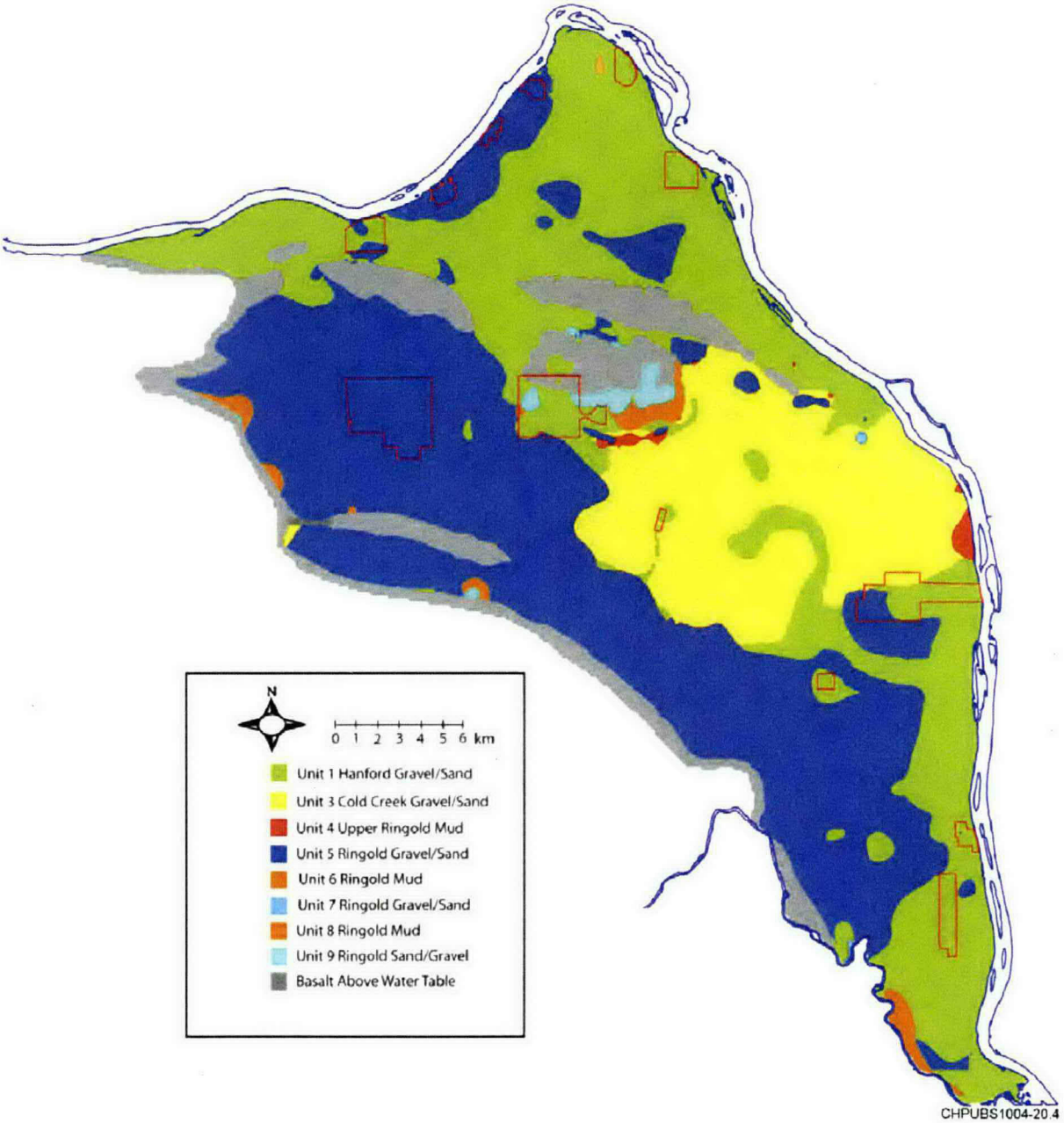


**Figure 3-21. Pre-Hanford Distribution of Hydrogeologic Units at the Water Table**

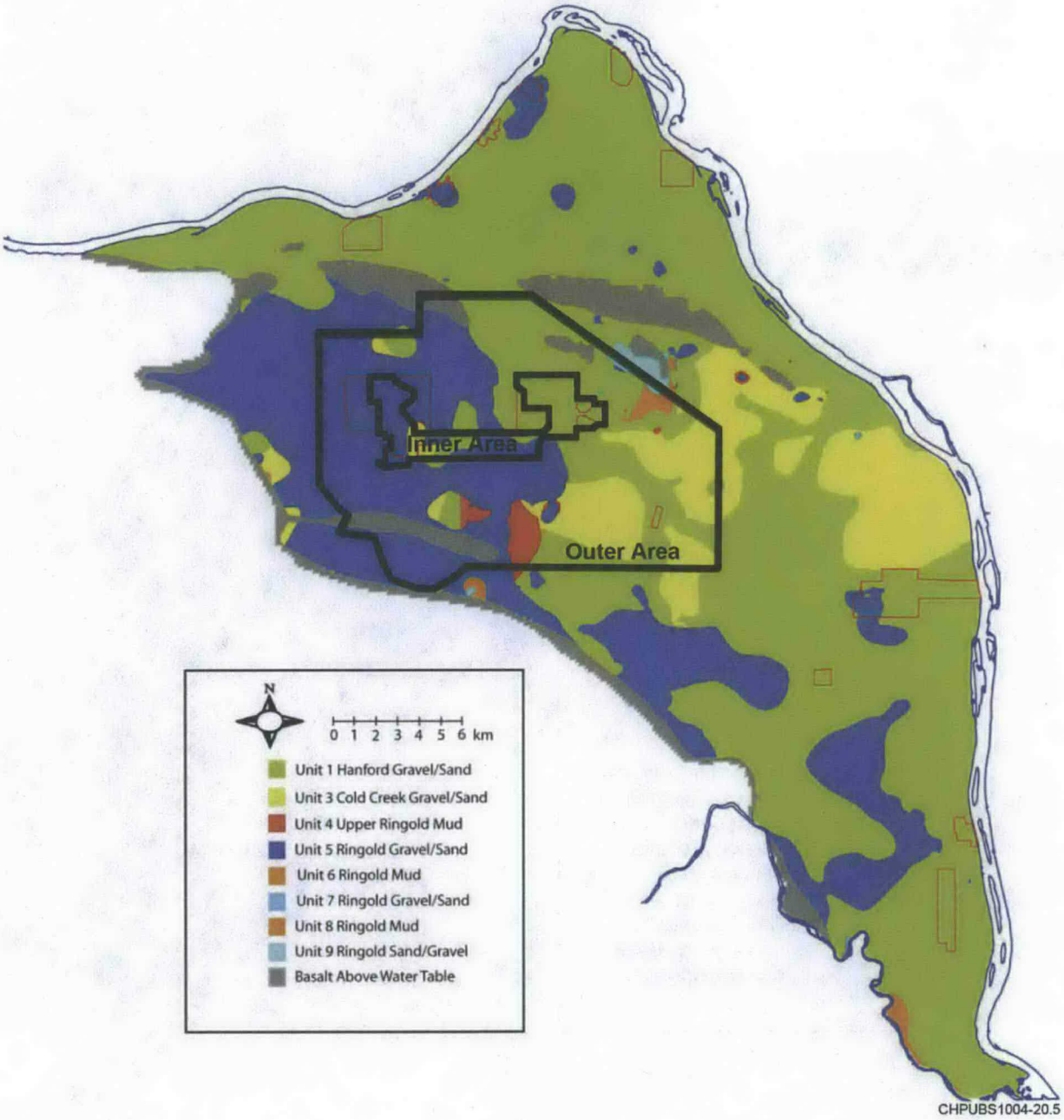


**Figure 3-22. Distribution of Hydrogeologic Units at the Water Table During Hanford Operations**

**Table 3-1. Hydraulic Conductivity Results for Well 399-1-23**

| (Zone) Test Interval (m bgs) | HSU | Type-Curve Analysis Method | | High-K Analysis Method[a] | |
|---|---|---|---|---|---|
| | | Hydraulic Conductivity, $K_h$[b] (m/day) | Specific Storage, $S_s$ ($m^{-1}$) | Hydraulic Conductivity, $K_h$[b] (m/day) | Dimensionless Damping Parameter, $C_D$ |
| (A) 12.19 - 13.26[c] | 1 | NA | NA | >100[c] | - |
| (B) 16.82 - 18.29 | 5 | 1.60 - 1.86 (1.73) | 1.0E-5 - 3.0E-5 | NA | NA |
| (C) 15.42 - 18.29 | 5 | 1.47 | 1.0E-5 | NA | NA |
| (D) 19.81 - 21.34 | 5 | 2.16 | 5.0E-5 - 1.0E-4 | NA | NA |
| (E) 18.29 - 21.34 | 5 | 1.43 | 1.0E-4 | NA | NA |
| (F) 30.78 - 33.53* | 5 | NA | NA | NA | NA |

Note: Number in parentheses is the average value for all tests.
(a) Standard type-curve analytical method is not valid for aquifer hydraulic tests exhibiting either critically or under-damped behavior. Results based on high K analysis method (Butler and Garnett 2000).
(b) Assumed to be uniform within the well-screen test section.
(c) No quantitative analysis of test is possible, due to pressure probe location during testing. Test response indicates a very high K condition. Value listed should be considered to be an assigned, lowest possible value.
* = All aquifer hydraulic test responses for this zone adversely affected by packer by-pass (leakage).
HSU = Hydro Stratigraphic Unit
NA = Not applicable or applied analytical method.

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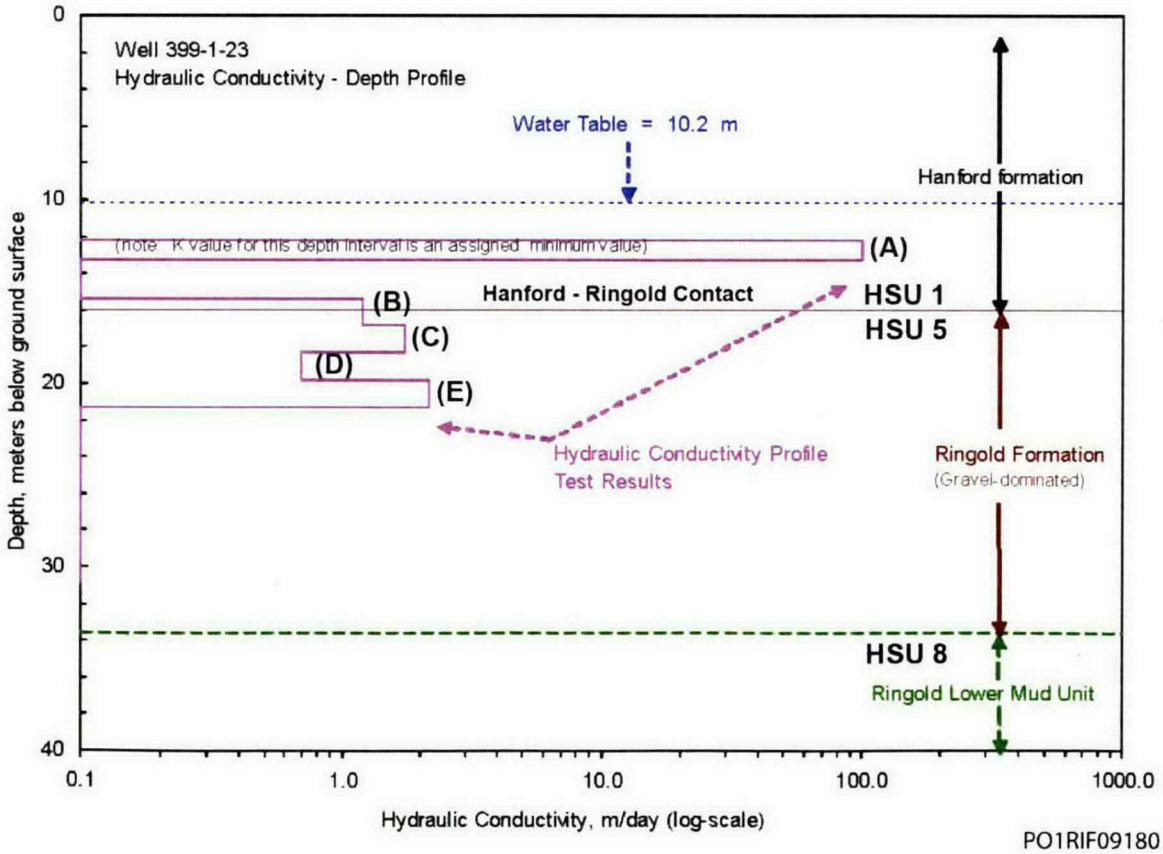


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**Figure 3-23. Variability in Hydraulic Conductivities Within the Suprabasalt Aquifer (Well 399-1-23)**

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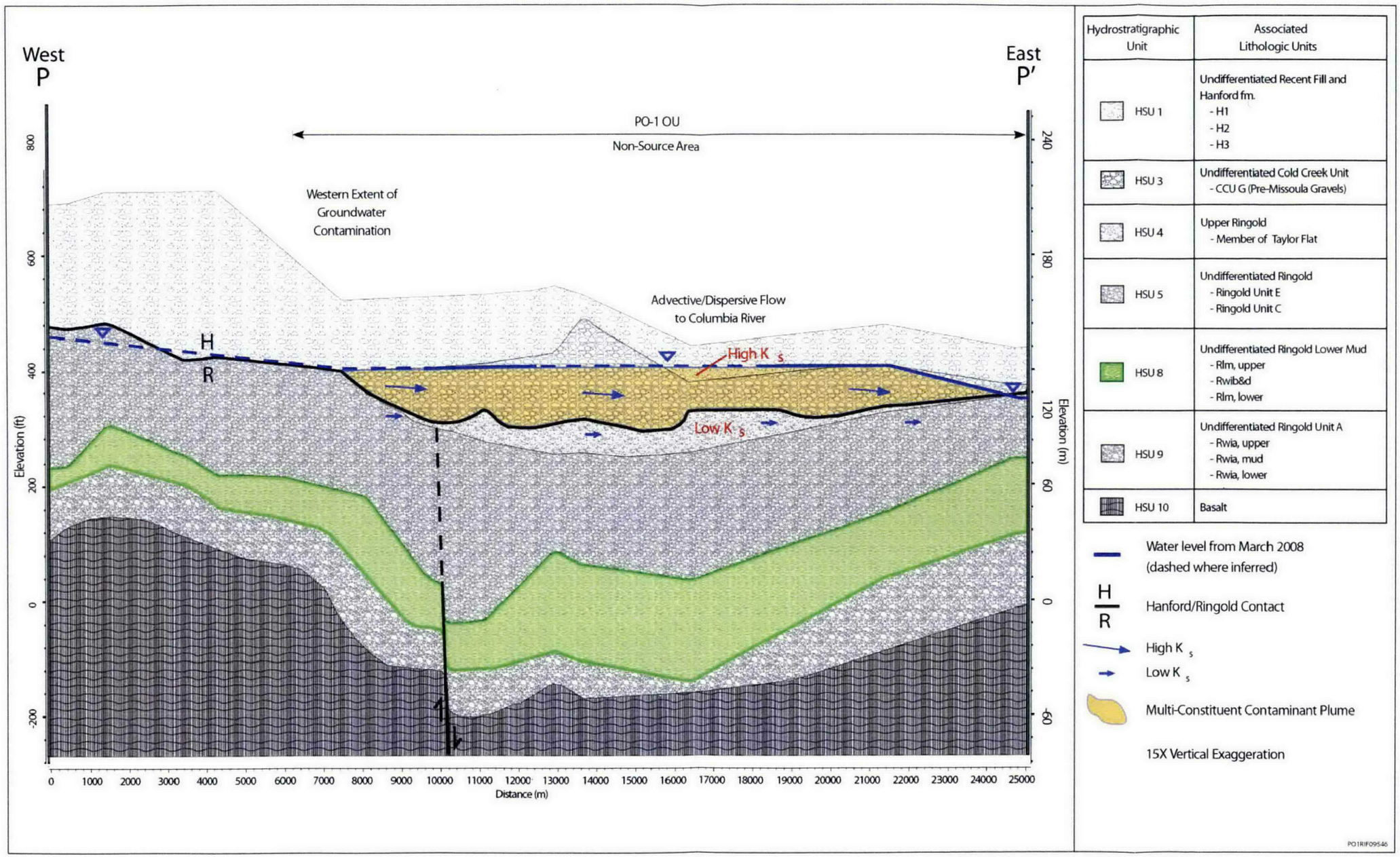


Figure 3-24. Far Field Hanford/Ringold Contact Relationships Within the Suprabasalt Aquifer

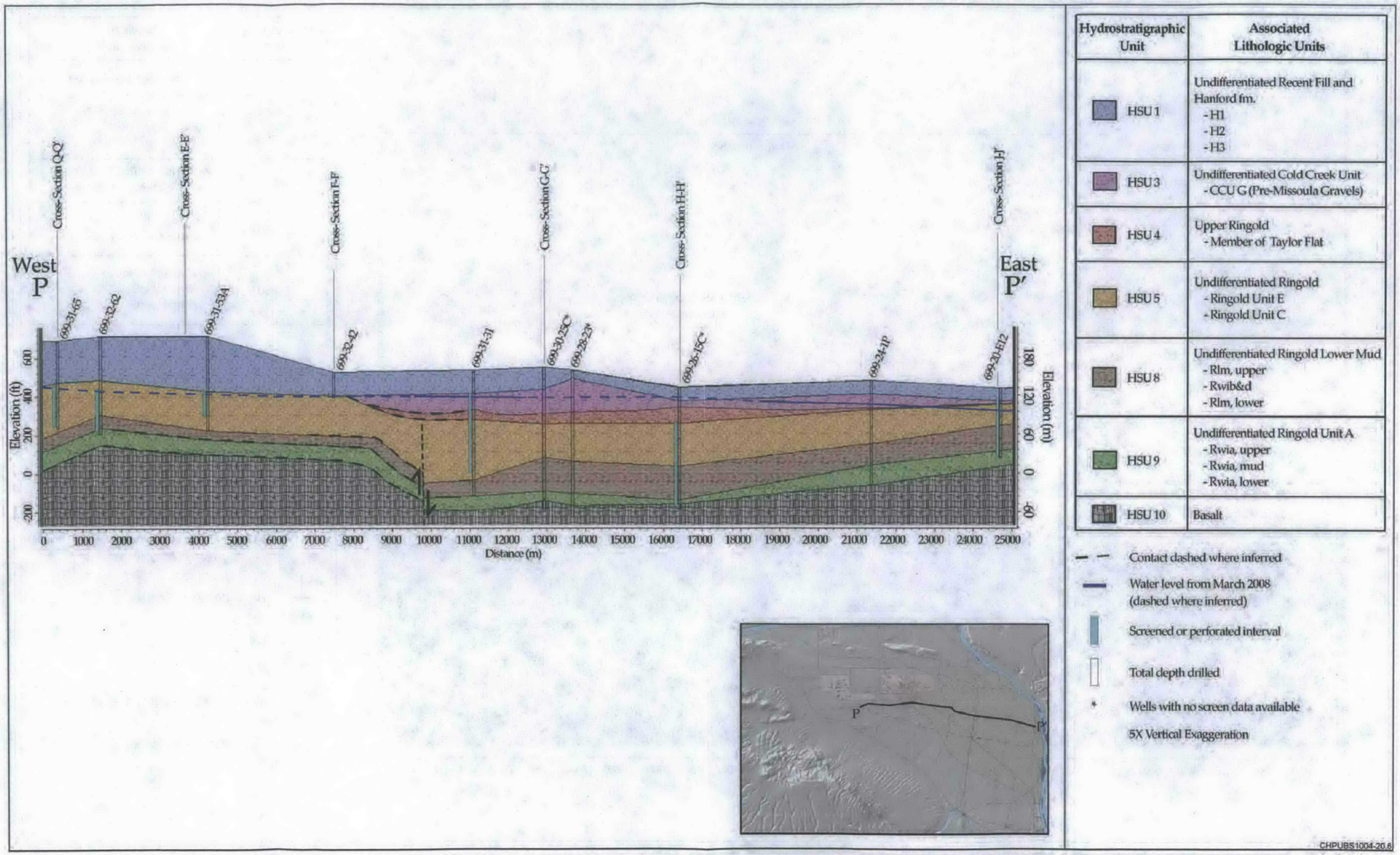


Figure 3-25. Far Field Hydrogeology Section P-P'

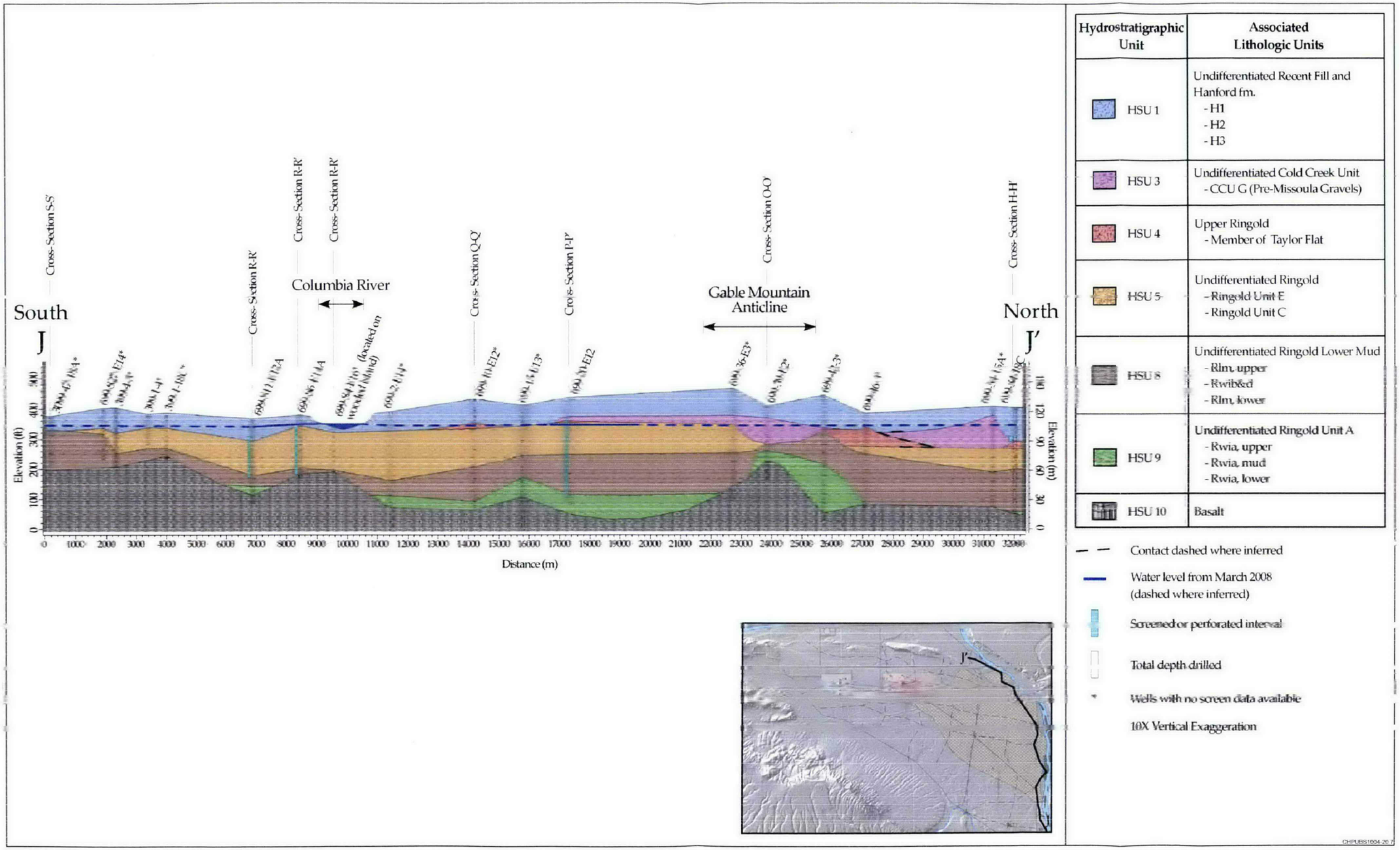


Figure 3-26. Far Field Hydrogeology Section J-J'

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Also in this region along the Columbia River, the upper Ringold Fm sediments (HSU 5) are eroded and/or reworked extensively by paleo-flooding and ancestral Columbia River flow. The best example of this surface is located in the very southeastern portion of the OU within the adjacent 300-FF-5 Groundwater OU (Figure 3-27). Recent characterization efforts, extensive drilling, and sediment and groundwater analysis within the 300-FF-5 Groundwater OU have provided a wealth of data along the Columbia River that is not available elsewhere along the river. These data support and provide analogous interpretations of the hydrogeology believed to be prevalent all along the 200-PO-1 Groundwater OU river boundary. Detailed mapping of the Hanford-Ringold contact along the river in the adjacent 300 Area (Figure 3-27), along with detailed topographic mapping of the surface of the OU, suggests that erosional channeling has occurred as the ancestral Columbia River migrated across the region from west to east, eroding downward into the Ringold sediments. Near the Columbia River, paleo erosion and channeling appears to be oriented roughly parallel to the present-day river channel, indicating that an eastward pro-grading migration of the river has occurred across the eastern 200-PO-1 Groundwater OU. As detailed in later sections, these erosional features influence contaminant migration in the area.

A key hydrogeologic feature controlling groundwater and contaminant movement out of the 200 East Area is the north-to-south oriented May Junction fault (Figure 3-12 and Figure 3-28), located east of the 200 East Area between the Near Field and Far Field regions of the 200-PO-1 Groundwater OU (see also PNNL-12261). The May Junction fault forms a significant geologic structural barrier to groundwater flow out of the 200 East Area. Structural deformation, uplift, and erosion has positioned the upthrown west side of the fault, so the Elephant Mountain Member basalt and the older Ringold Fm sediments (Unit A and the LMU) are at or above the present day water table elevation. These units are relatively low permeability units compared to the younger overlying or adjacent sediments (Ringold Fm Unit E and Hanford fm), and they create a groundwater flow barrier east of the 200 East Area near B-Pond (Figure 3-29). This feature constrains groundwater movement out of the 200 East source area to a more southeasterly flow path, forcing flow around the region occupied by uplifted basalt and the LMU.

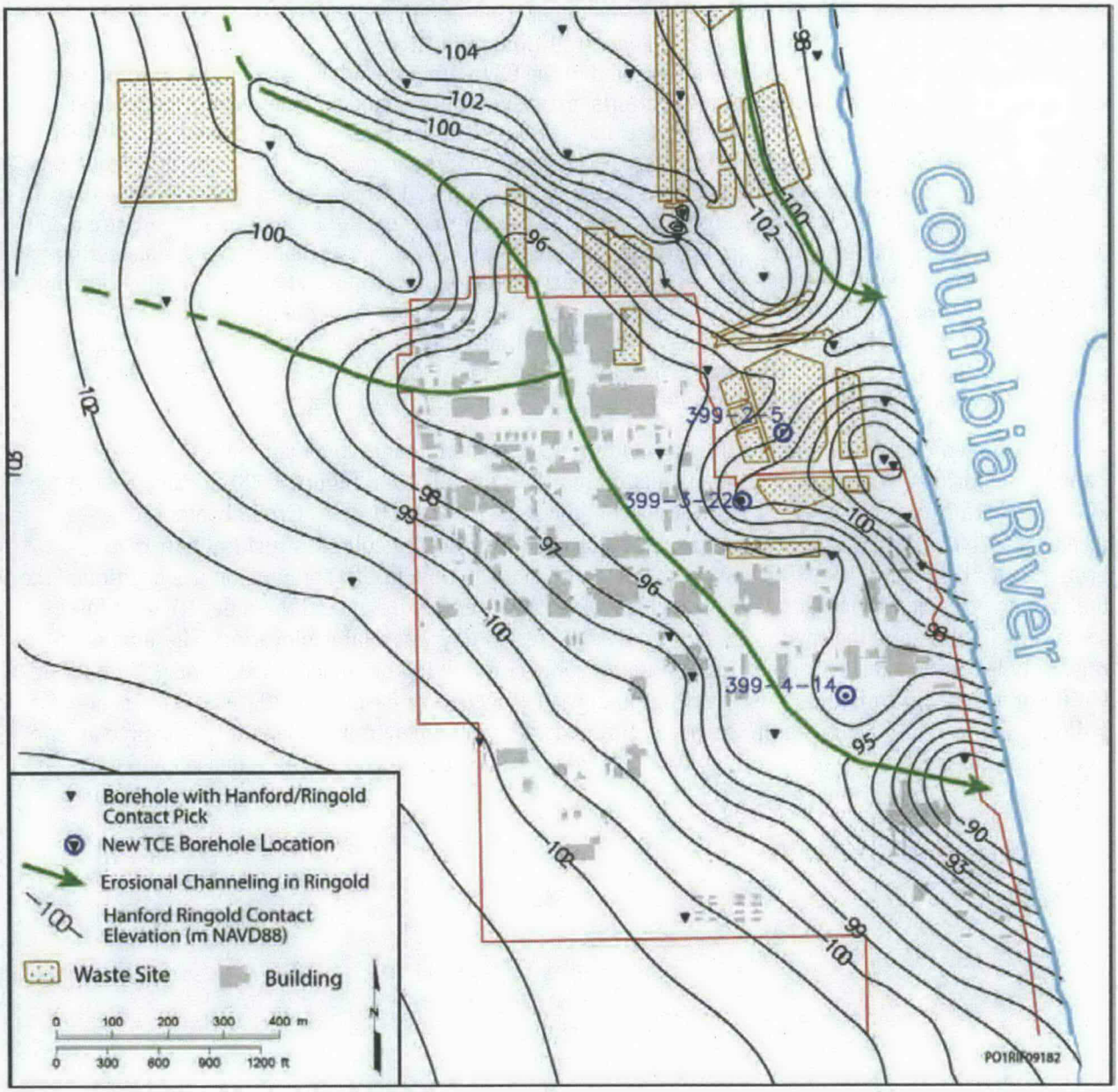


**Figure 3-27. Example of Hanford/Ringold Contact Structure Map Near Columbia River (300 Area)**

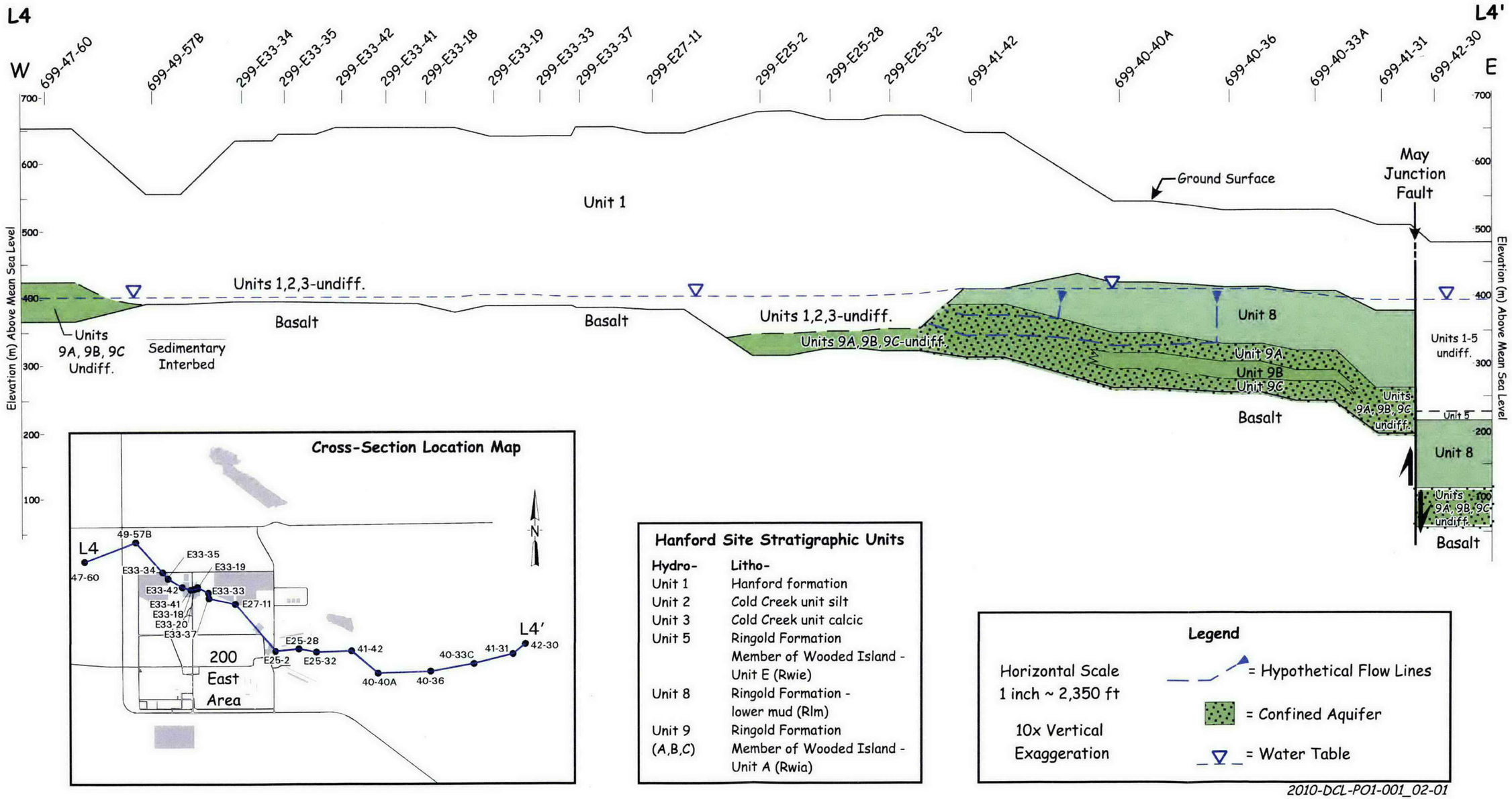


Figure 3-28. Near Field Hydrogeology Showing May Junction Fault

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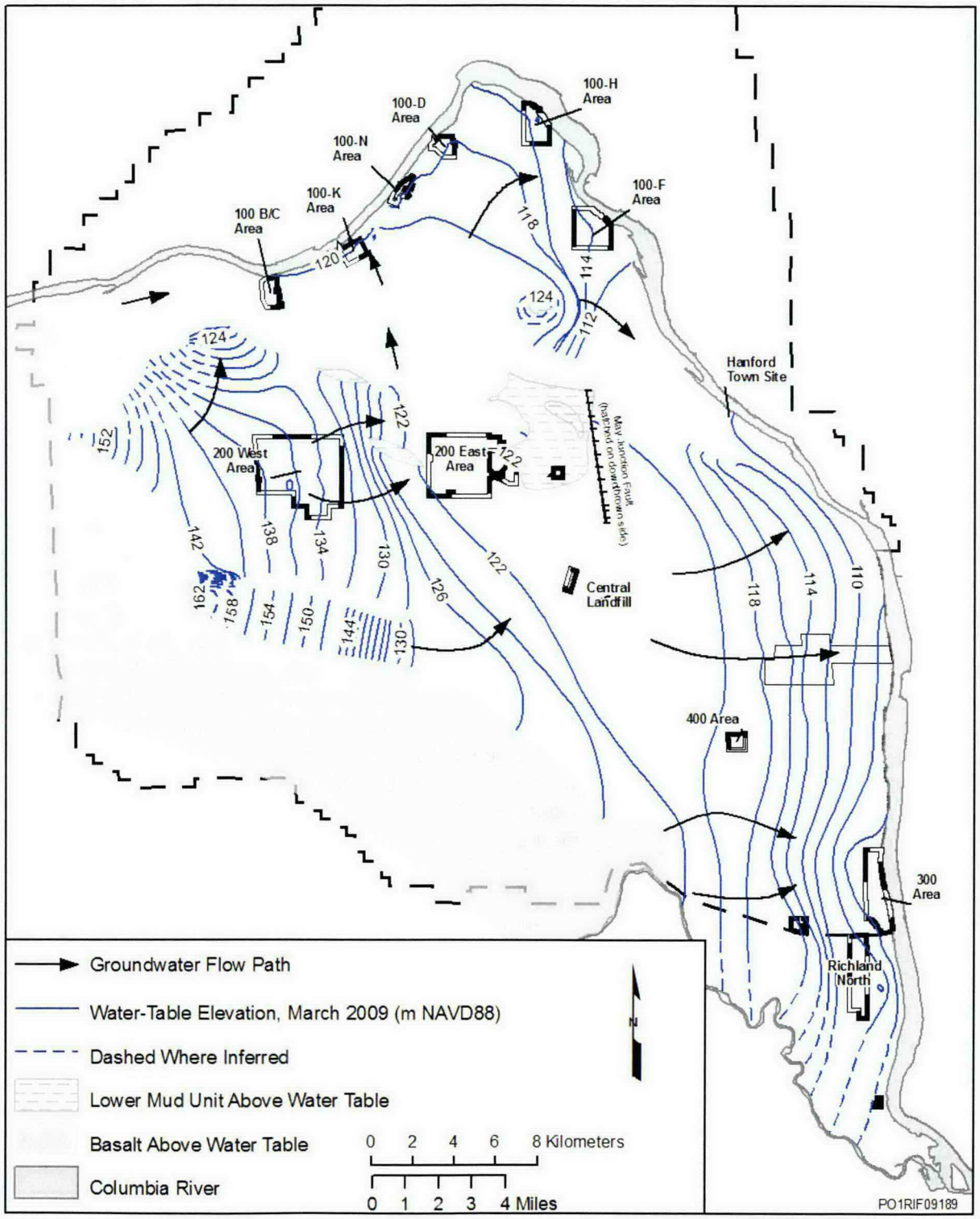


**Figure 3-29. 200 East Area Groundwater Flow Patterns (2008)**

The May Junction fault trends south into the Cold Creek syncline, and mapping suggests that the vertical displacement across the fault diminishes away from Gable Mountain into the basin (PNNL-12261). The natural dip of the Ringold Fm units into the Cold Creek Basin to the south of the 200 East Area and east (downthrown side) of the May Junction fault significantly lowers the elevation of these no-flow units (i.e., basalt and LMU) below the water table and deeper within the suprabasalt aquifer. Because these no-flow (low-permeability) units are positioned so far beneath the water table within this region of the suprabasalt aquifer system, as shown on the plume map (Figure 3-30), the Far Field region has more unrestricted lateral contaminant movement compared to the narrow plume path emanating from the Near Field region.

The topographic high formed by the Gable Mountain basalt structure, located just north of the 200-PO-1 Groundwater OU, created a hydraulic diversion that constrained the flow path of both the paleo-floods and the ancestral Columbia River. Consequently, flow was diverted around the dipping basalt nose of the Gable Mountain anticline, near the Hanford town site, creating extensive channeling that removed much of the Ringold Fm sediment and re-deposited high-permeability Cold Creek and Hanford fm sediment. Where they occur below the regional water table, the intersection of these various Cold Creek and Hanford fm sediment-filled channels creates preferential groundwater flow paths.

The location of the current Columbia River channel, adjacent to these highly eroded regions near the Hanford town site, appears to form the preferential hydraulic link between groundwater and contaminants emanating from the 200 East Area and the highest contamination concentrations detected near the Columbia River within the 200-PO-1 Groundwater OU. Plume maps overlain on the map showing the hydrogeologic units at the water table reveal this relationship and illustrate the extent of the groundwater preferential flow region. The areal extent of this preferential groundwater flow region has expanded and contracted with time, depending on the elevation of the water table. During past decades, as groundwater mounding on the Central Plateau drove contaminants and raised groundwater levels across the Far Field region, the areal extent of the plumes was much greater, spreading laterally downgradient and more or less unconstrained within saturated Hanford and Ringold Fm sediment toward the Columbia River. As the 200 Central Plateau liquid disposal sources were turned off in the mid-1990s, the groundwater flow rate and water table began a dramatic decrease (Figure 3-31). The dropping water table receded further into the Ringold Fm, slowing the movement of groundwater and contamination to the river. Areas of higher permeability, which exist in the north-central portion of the 200-PO-1 Groundwater OU where Cold Creek and Hanford fm units are still present at or below the water table, appear to provide the preferential groundwater flow path to the river for the remaining contaminants in the aquifer.

Decades of groundwater monitoring data (e.g., 1980-2008) have been evaluated and are used to illustrate the tritium groundwater plume distribution within the 200-PO-1 Groundwater OU. The tritium plume maps (Figure 3-32) illustrate that the primary contaminant flow path is the upper unconfined aquifer from the source areas in the Central Plateau eastward to the Columbia River. Superimposing the tritium plume map (Figure 3-30) with the map of the hydrogeologic units at the water table (Figure 3-21) reveals this coincident relationship between the highest tritium plume concentrations and the areas where the uppermost aquifer is within the Hanford and/or Cold Creek formations (Figure 3-33). Hydrogeologic data reveal that the Hanford and/or Cold Creek Fm sediment is generally much more transmissive than older underlying or adjacent hydrogeologic units. The regional integration of the tritium plume and the hydrogeologic units at the water table strongly suggests that groundwater and contaminant movement follows the path of least resistance (e.g., zones with the highest permeability, such as the Hanford fm and Cold Creek) (Figure 3-33). Figure 3-30 also illustrates the similar distribution pattern and implied flow path of the other major contaminant plumes (i.e., nitrate and iodine-129) in the unconfined aquifer beneath the 200-PO-1 Groundwater OU for 2008.

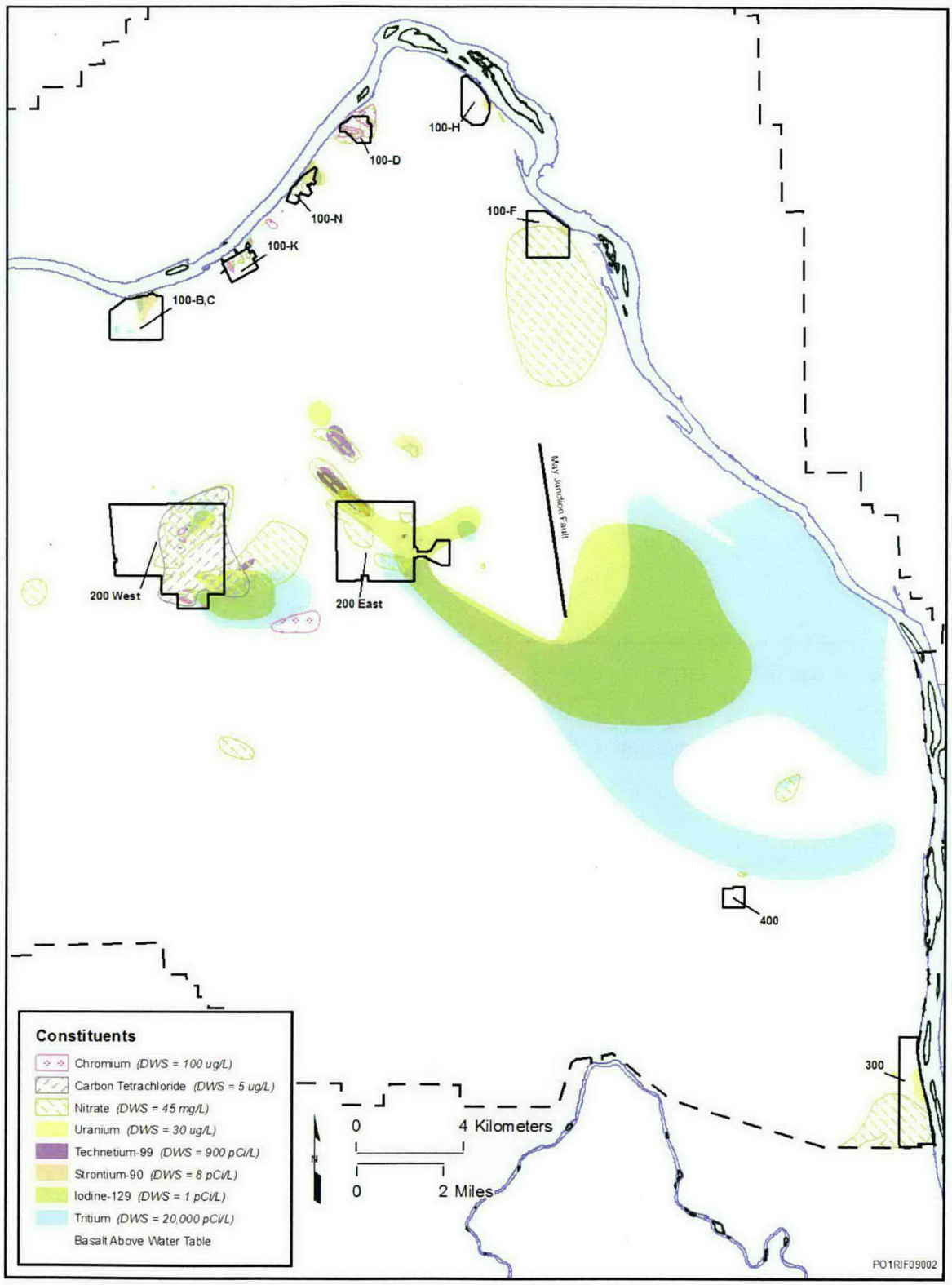


**Figure 3-30. Groundwater Contaminant Plumes Source Area to Columbia River (2008)**

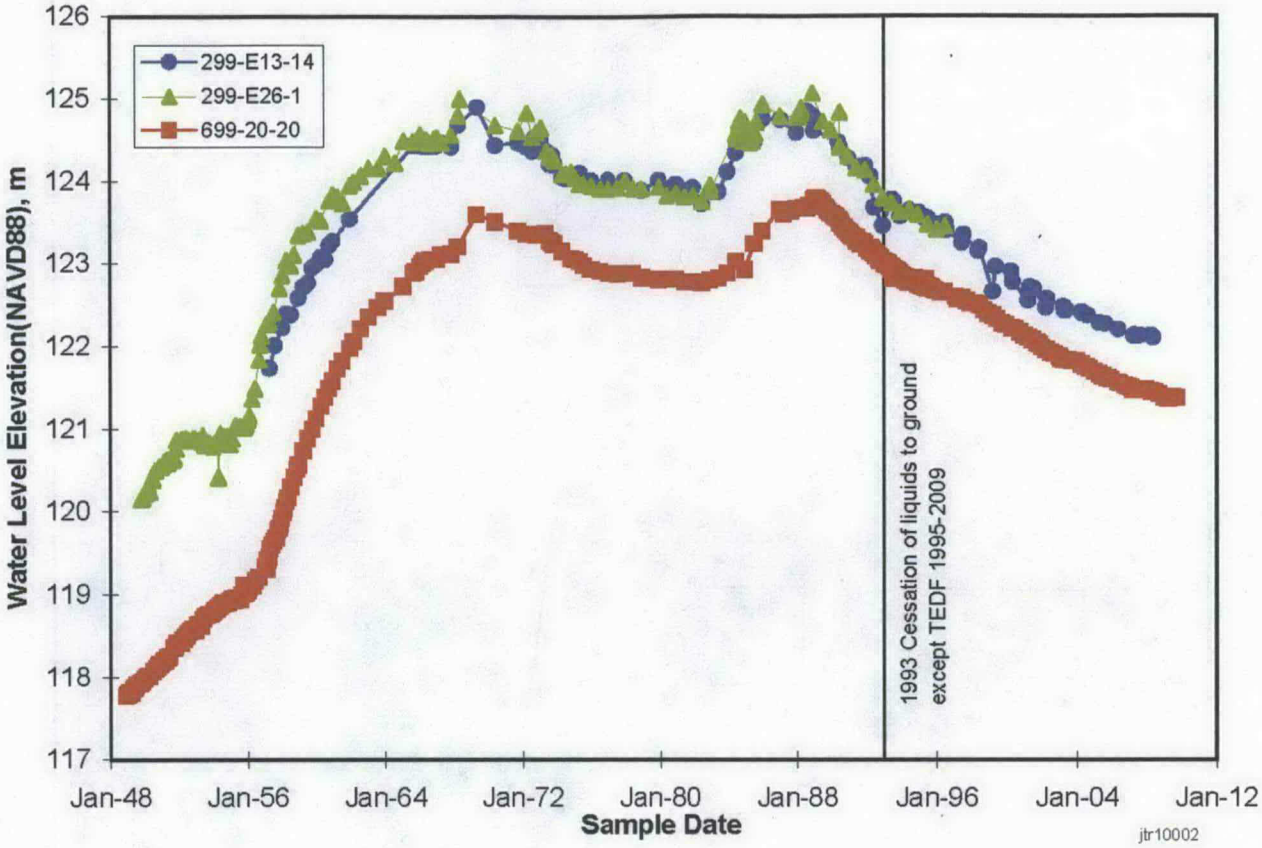


**Figure 3-31. Representative Historical Groundwater Elevations in 200 East Area**

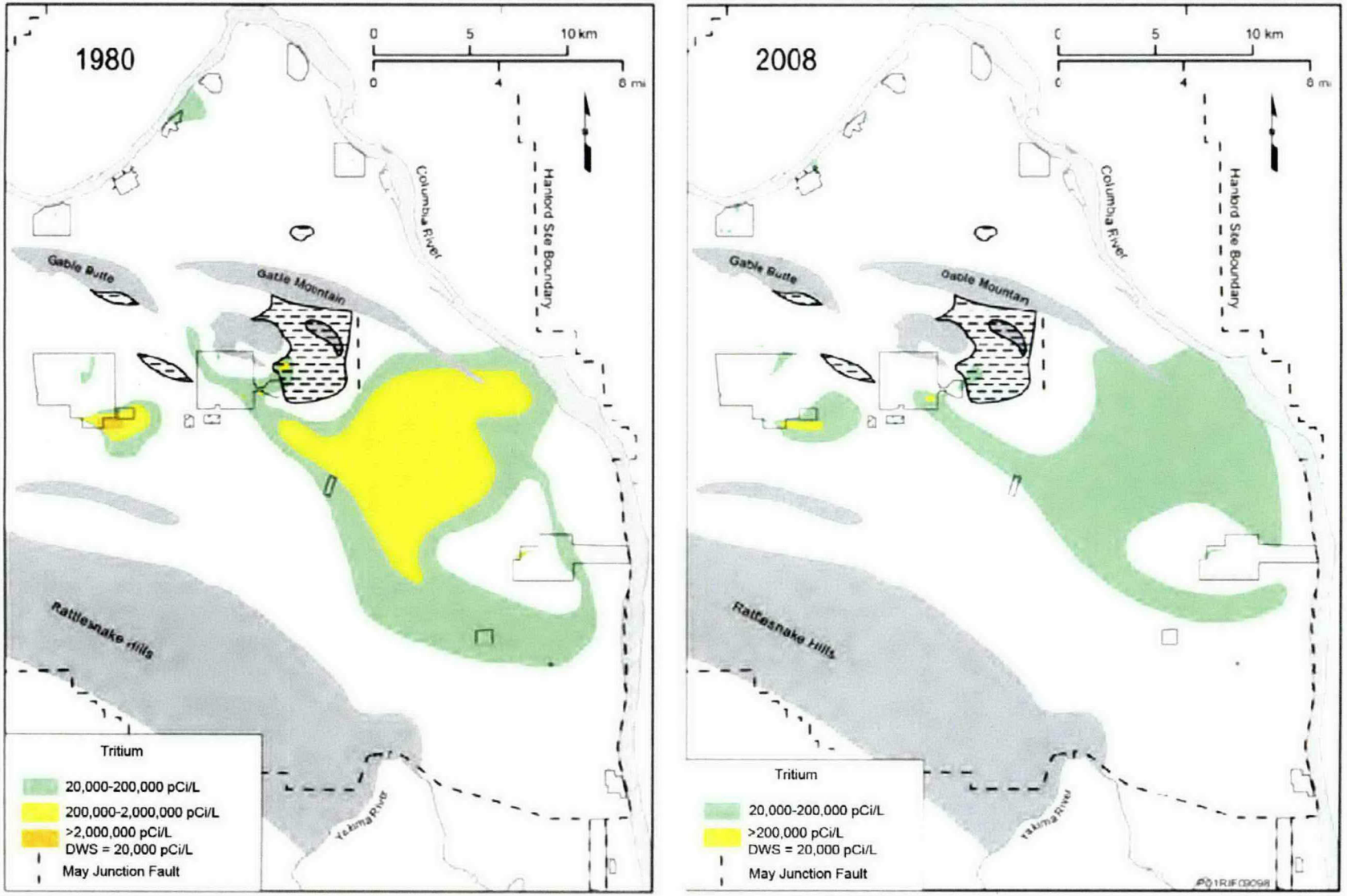


**Figure 3-32. Primary Contaminant Flow Path Within the Upper Unconfined Aquifer as Illustrated by the Evolution of Observed Tritium Plume in Groundwater**

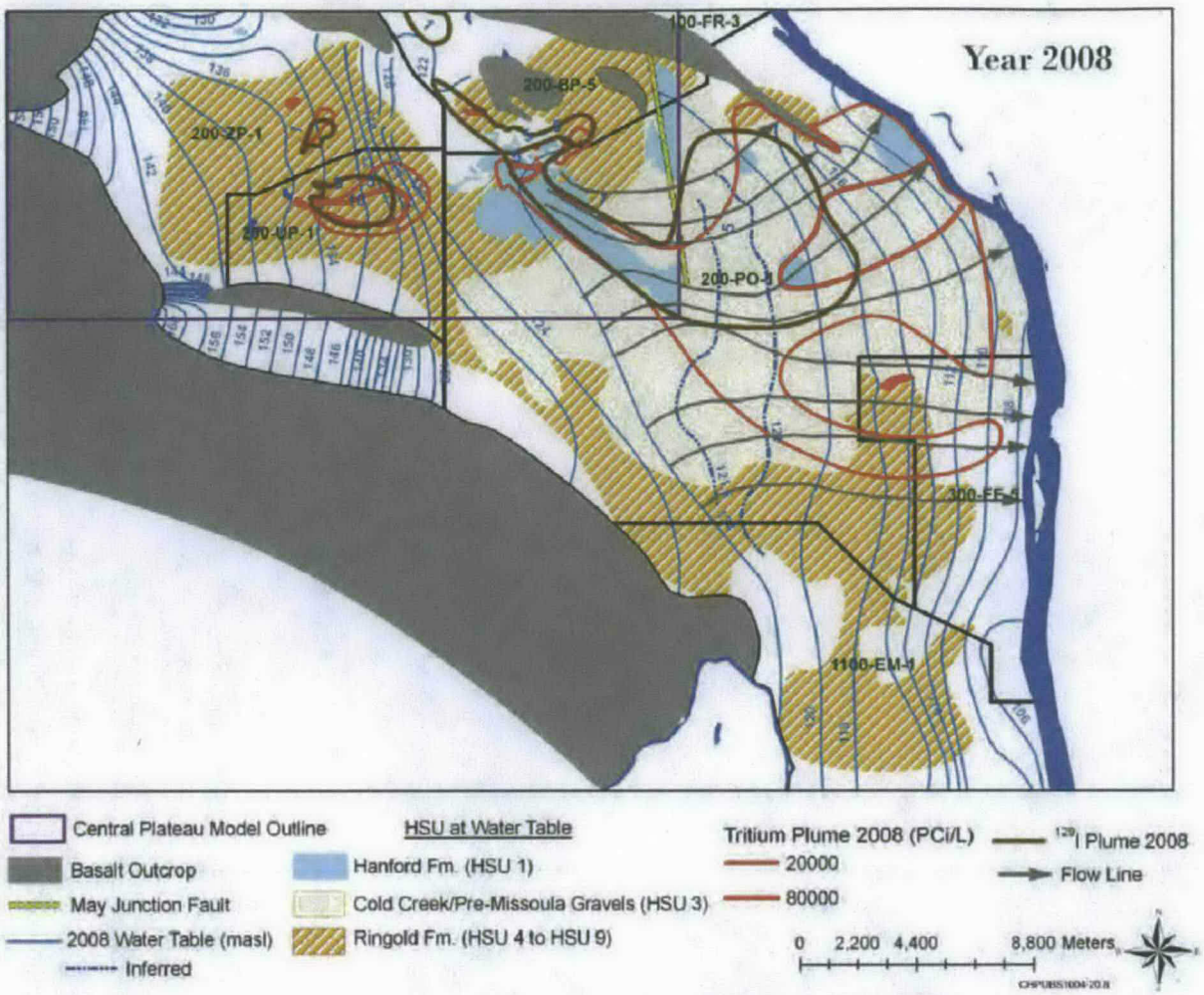


**Figure 3-33. Hydrogeology Relative to Contaminant Flow Paths**

The conditions that result in the variable hydraulic conductivity of the 200-PO-1 unconfined aquifer may be observed through analysis of sediment cores; for example, the high-permeability gravel of the Hanford fm is pictured in Figure 3-34. Figure 3-35 illustrates the Hanford-Ringold contact boundary. The low-permeability Ringold Unit E and LMU contact is shown in Figure 3-36.

Figure 3-34. Core Sample Showing Hanford Formation Gravel

Figure 3-35. Core Sample Showing Hanford-Ringold Contact

**Figure 3-36. Core Sample Showing Ringold-LMU Contact**

### 3.6.7 Conceptual Site Model

The 200-PO-1 Groundwater OU CSM is divided into Near Field (source area) and Far Field (downgradient) areas for describing the geologic and hydrogeologic features comprising the suprabasalt aquifer system and how it controls groundwater contaminant migration.

#### *3.6.7.1 Near Field 200-PO-1 Groundwater OU*

The CSM for the hydrogeology of the Near Field 200-PO-1 Groundwater OU is described in PNNL-12261. This study concluded that two aquifers occupy the suprabasalt sediments of the 200 East Area. The upper unconfined aquifer is in the Hanford fm (HSU 1) /Cold Creek (HSU 3) and/or Ringold Fm (i.e., HSU 5, Unit E). Currently, the 200-PO-1 groundwater, in the unconfined portion of the suprabasalt aquifer, generally flows southeast and east toward the Columbia River.

An underlying confined aquifer consists of undifferentiated Ringold Fm (i.e., HSU 9, Unit A) sediment separated from the overlying unconfined aquifer by the Ringold Fm LMU (HSU 8 aquiclude). This fluvial silty, sandy, gravel aquifer forms the lower suprabasalt (Ringold Fm) confined aquifer. Within the 200 East Area, groundwater flow in the confined aquifer appears to converge from the west, south, and east (Figure 3-16), upwelling and mixing with the unconfined aquifer (i.e., Hanford fm sediment), which juxtaposes the confined aquifer exposed within an erosional channel (e.g., Figure 3-7). It is postulated that groundwater was forced by head differences through this erosional channel "window" into the Ringold Fm confined aquifer (Figure 3-37).

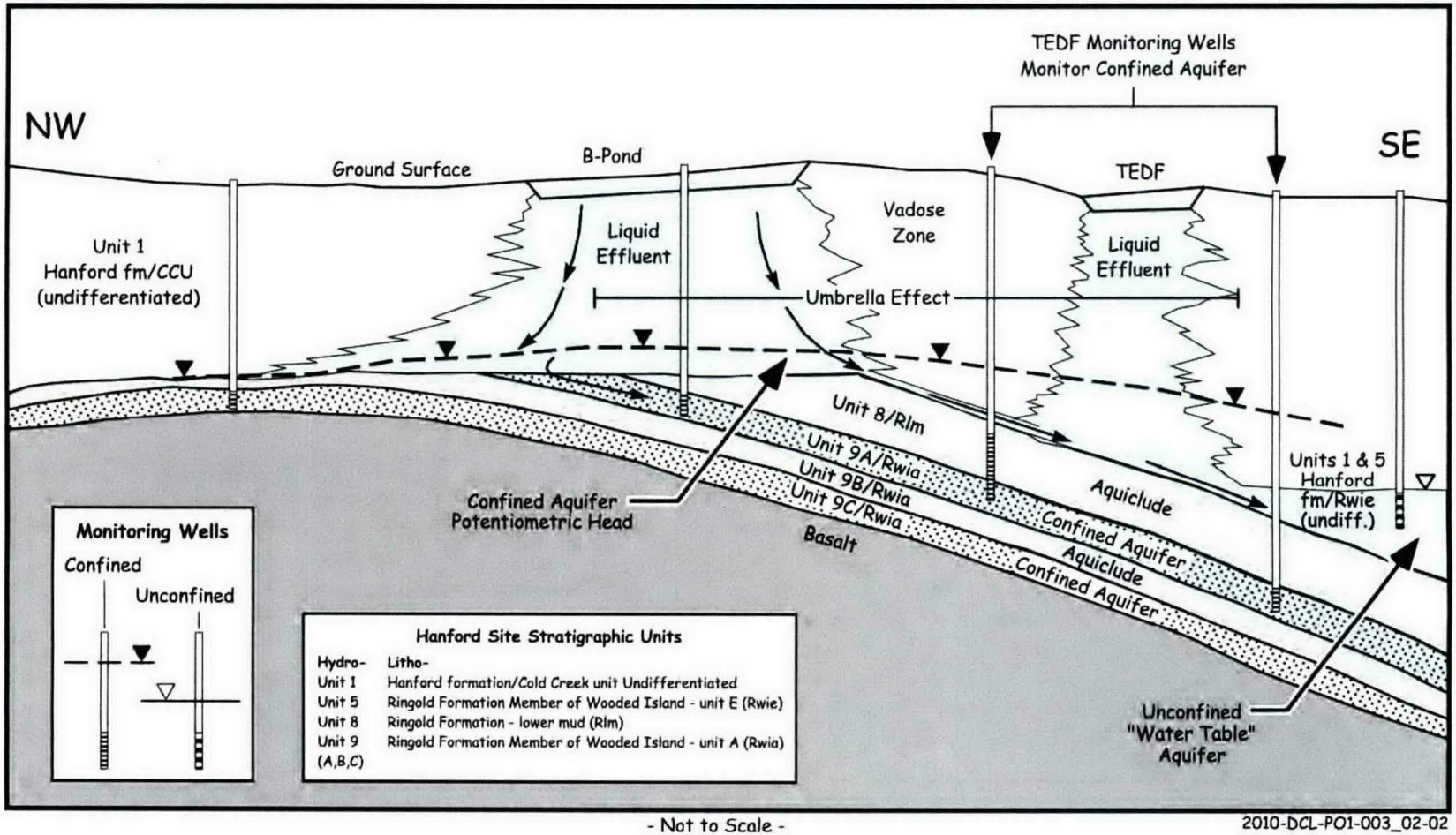


**Figure 3-37. Near Field Conceptual Site Model Aquifer Recharge Beneath B-Pond (During Historical Period of Discharge) and the Treated Effluent Disposal Facility**

A deeper confined aquifer exists in the Columbia River Basalt Group underlying the Ringold Fm. The upper basalt confined aquifer occurs within fractured basalt and sedimentary interbeds of the Upper Saddle Mountains Basalt that directly underlies the Ringold Fm confined aquifer. Groundwater generally flows from west to east within the upper basalt confined aquifer (Figure 3-14). Within the 200-PO-1 Groundwater OU, the vertical gradient is generally upward (Figure 3-38) except for the areas near B-Pond.

The 200-PO-1 Groundwater OU hydrogeology is further described in the monitoring SAP (DOE/RL 2003-04). The monitoring SAP briefly describes the three aquifers and a prominent hydrogeologic feature of the 200 East Area-a large paleo flood channel complex filled with Hanford sediments that trends northwest to southeast across the 200 East Area. The paleo flood channel complex cuts through the Ringold LMU in the 200-PO-1 Groundwater OU, resulting in direct contact of the Hanford and lower Ringold sand and gravel sediments (Figure 3-7 and Figure 3-8). The lower semi-confined (Ringold Fm) aquifer merges with the upper unconfined aquifer (Hanford fm/Cold Creek) in the vicinity of the paleo flood channel complex.

Current groundwater contamination in the 200-PO-1 Groundwater OU originated within the Near Field portion, i.e., 200 East Area and vicinity. The monitoring SAP lists waste sites grouped around three major facilities as the primary potential contributors to groundwater contamination: PUREX, B Plant, and the BC Cribs and Trenches Area where U Plant waste was disposed (Figure 3-39). The PUREX Plant and the BC Cribs and Trenches Area are located in the 200-PO-1 Groundwater OU. The B Plant is located in the 200-BP-5 Groundwater OU just north of the 200-PO-1 Groundwater OU. Six RCRA TSD units are also located in the Near Field area of the 200-PO-1 Groundwater OU: the PUREX Cribs, WMA A-AX, 216-A-29 Ditch, 216-B-3 Pond (B-Pond), and Integrated Disposal Facility (a RCRA-compliant landfill that is scheduled to begin receiving waste between FY 2014 and FY 2019). The 200 Areas TEDF (permitted by WAC) is the only remaining liquid effluent disposal facility within the Near Field area of the 200-PO-1 Groundwater OU that disposes liquid effluent directly to the ground (Figure 3-39).

During past operations, artificial groundwater recharge from effluent disposal at B-Pond, PUREX, and other waste sites generally elevated the water table throughout the 200 East Area (Figure 3-20 and Figure 3-31). These mounds influenced groundwater flow rate and direction over large areas of the 200 East Area and vicinity for over four decades. The groundwater mound under the B-Pond caused an estimated additional 10 m (35 ft) of hydraulic head. The resulting downward gradient and radial flow pattern reversed groundwater flow in the vicinity of the 200 East Area to a western direction away from the Columbia River. The B-Pond is located where the uppermost unconfined suprabasalt aquifer (primarily Hanford fm sediment) and the lower suprabasalt confined aquifer zones (primarily Ringold Fm sediment) are connected and juxtaposed. The downward gradient generated during disposal operations forced contaminants into the lower suprabasalt confined (Ringold Fm) portion of the aquifer system where the two aquifers are exposed. Alternatively, where effluent and groundwater encountered the relatively impermeable Ringold Fm LMU (HSU 8), it could have diverted laterally along the east and southeast dipping surface of HSU 8 flowing laterally down this surface to the unconfined aquifer (umbrella effect). The lithologic units and the artificial recharge at the B-Pond and TEDF are conceptually illustrated in Figure 3-37. Effluent disposal and the associated artificial groundwater recharge at the B-Pond ceased in 1997. The artificially elevated unconfined aquifer located beneath the B-Pond is now gone and exposes the HSU 8 and/or top of basalt at or above the water table (Figure 3-29) northeast of the 200 East Area.

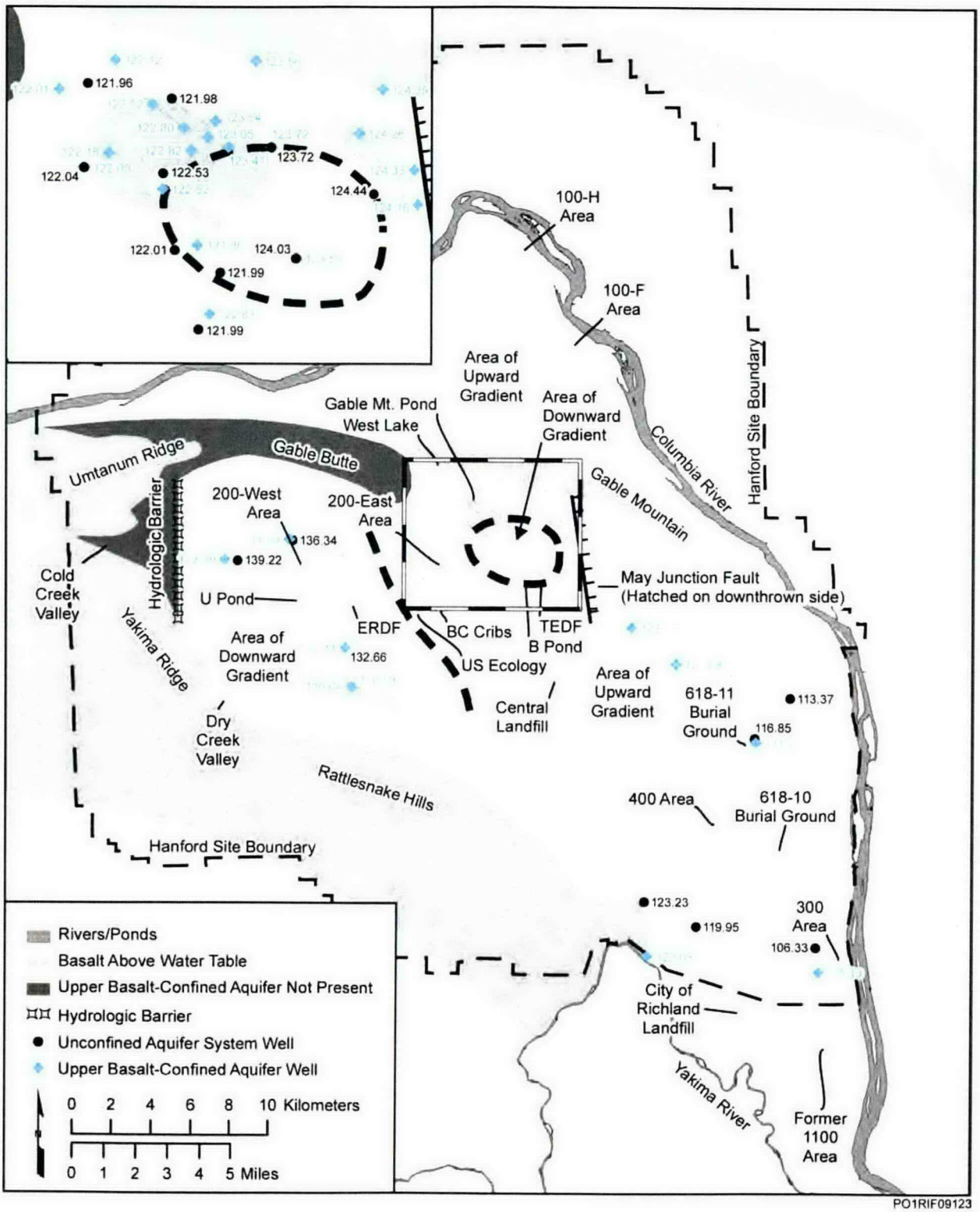


**Figure 3-38. Unconfined and Confined Aquifer Head Comparisons (2008)**

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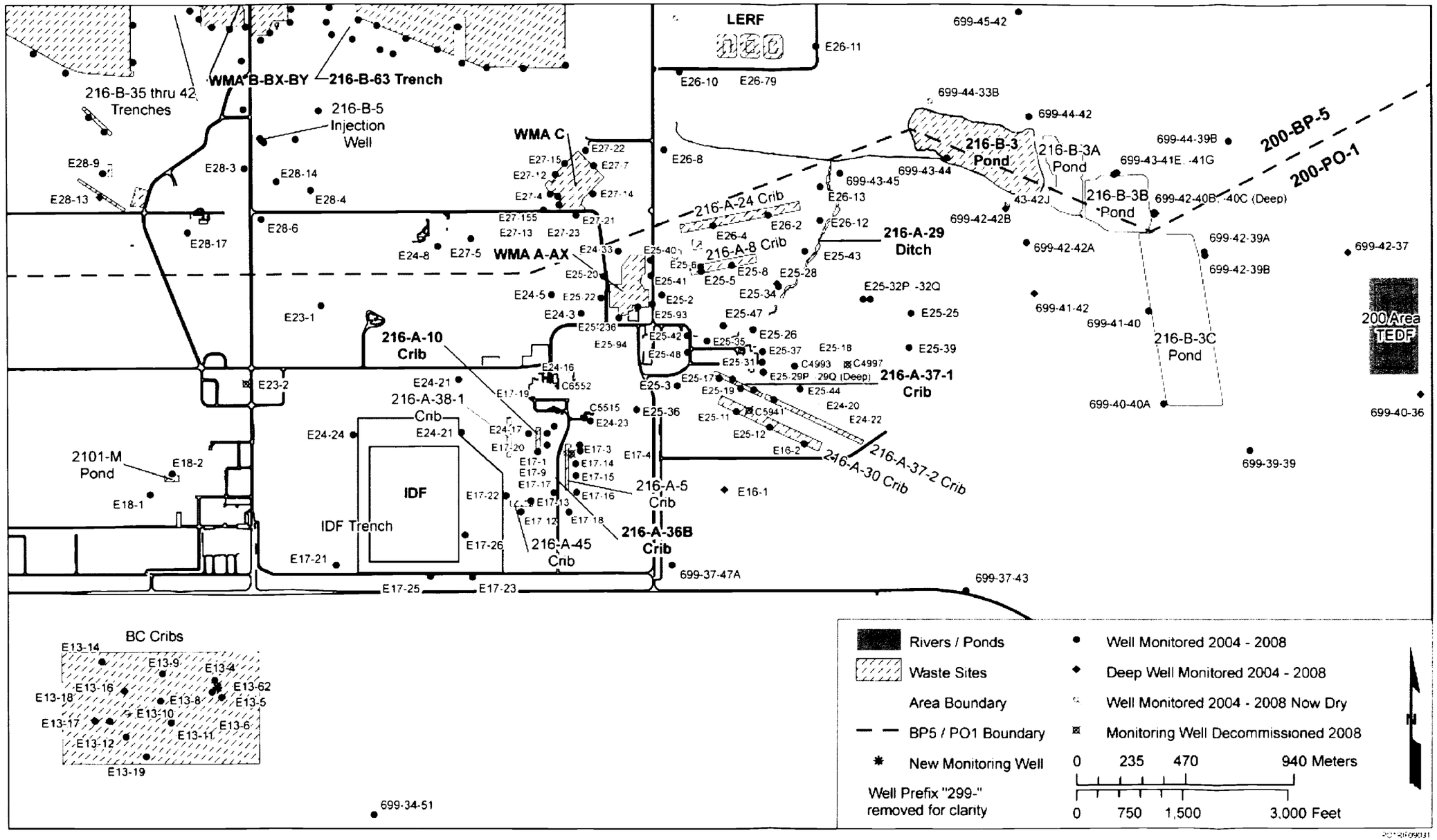


Figure 3-39. Near Field Source Area Identifying Liquid Effluent Disposal, Cribs, Ponds, and Ditches

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Sufficient effluent volumes were disposed at PUREX cribs and trenches and other waste sites to result in additional artificial groundwater recharge. The effluent volumes disposed of at PUREX sites were lower than at the B-Pond, but the associated contaminants were generally more concentrated. A CSM of the contaminant migration from the PUREX cribs to groundwater is shown in Figure 3-40. Liquid effluent migrated downward through thick vadose sediments composed primarily of permeable Hanford fm sand and gravel. Contaminated effluent impacted the aquifer below several of these cribs, spreading downgradient laterally (southeasterly) and flowed into the unconfined aquifer occupying the Hanford (HSU 1) filled channel(s) (PNNL-12261). In some areas further south, Ringold Fm sediments are located at or near the water table, and the contaminated effluent most likely moved downgradient within the upper Ringold sediment (HSU 5) and into the Hanford filled channel (HSU 1).

#### *3.6.7.2 Far Field 200-PO-1 Groundwater Operable Unit*

Known groundwater contaminants migrate downgradient within the suprabasalt aquifer system, away from the 200 East Area (Near Field source area), and across the 600 Area (Far Field) region of the 200-PO-1 Groundwater OU easterly toward the Columbia River. Three waste sites, the NRDWL and adjacent solid waste landfill (SWL), and the 400 Area sewage lagoons, exist within the Far Field region of the 200-PO-1 Groundwater OU (Figure 3-41). In addition, the 618-10 and 618-11 waste disposal sites (Figure 3-41), being addressed under the 300-FF-5 Groundwater OU, are located within the expansive 200-PO-1 Far Field region. Locally, 618-11 is being investigated for elevated tritium contamination sourced by that facility as part of the 300-FF-5 Groundwater OU RI/FS process (i.e., not a part of the 200-PO-1 OU).

Elevated uranium concentrations are present in groundwater near the 618-10 Burial Ground and the 316-4 Crib. Uranium concentrations in Well 699-S6-E4A reached 42 micrograms/L in 2004. This well was located within the excavation footprint for the 316-4 Crib and was removed when the 316-4 Crib was excavated in 2004. Well 699-S6-E4L, located on the southeast side of the burial ground, also exhibited elevated uranium concentrations during excavation of the 316-4 Crib which have gradually decreased to below 30 micrograms/L during 2006. Additional uranium isotopic analyses were performed on these two wells during 2006. The results of these analyses exhibited two distinct isotopic ratios suggesting that the uranium in these two wells was derived from different sources. The 316-4 Crib is a known source, while the 618-10 Burial Ground which did receive small containers of uranium containing liquids appears to be the secondary source. As with tritium near the 618-11 Burial Ground, uranium in this area is also under investigation as part of the 300-FF-5 OU (PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006*).

The 300-FF-5 OU also includes the industrial portion of the 300 Area located downgradient and adjacent to the southeastern boundary of the 200-PO-1Groundwater OU Far Field along the Columbia river (Figure 3-41). Past waste disposal operations within the 300 Area have contributed contamination (e.g., uranium, and TCE) to that portion of the unconfined aquifer downgradient of the 200-PO-1Groundwater OU. These contaminants are not sourced from within the 200-PO-1 Groundwater OU. Because no waste disposal sites exist in the region along the river and, therefore, no characterization has occurred. Recent detailed characterization conducted for the 300-FF-5 Groundwater OU has provided valueable hydrogeologic data not available elsewhere within the 200-PO-1 Groundwater OU Far Field region The resulting 300-FF-5 specific interpretations and conceptualizations are presented in the following sections as hydrogeologic analogy and believed to represent prevalent hydrogeologic conditions occurring within and along the adjacent 200-PO-1 Groundwater OU river shore. The 300-FF-5 hydrogeologic interpretations are supported by an extensive hydrogeologic and geochemical data set from recent drilling, characterization and science related studies. The interpretations developed for the 300 Area and used as analogy for the 200-PO-1 Groundwater OU river shore are believed to represent the most conservative conditions relative to contaminaint transport in the uppermost unconfined aquifer within the 200-PO-1

Groundwater OU river shore. The conservative claim stems from the fact that the 300 Area was impacted by decades of high volume contaminated liquid waste disposal occurring directly above the area, and yet today, the vertical extent of the detected contamination is very limited and constrained to the very uppermost portion of the unconfined aquifer within saturated Hanford sediment. Vertically downward directed artificial hydraulic head did not significantly drive dissolved groundwater contaminants deeper within the unconfined aquifer, but rather accelerated the lateral movement of the impacted groundwater away from the source within the highly permeable Hanford (HSU 1) sediment. The 200-PO-1 Groundwater OU Far Field and river shore were not impacted by overlying disposal sites; rather, contaminaints from upgradient (i.e., the Near Field source areas) are simply migrating laterally downgradient within the most permeable aquifer units near the water table and have essentially no significant vertical hydraulic driver for forcing the entrained contaminants deeper within the aquifer system.

# 200 East Area

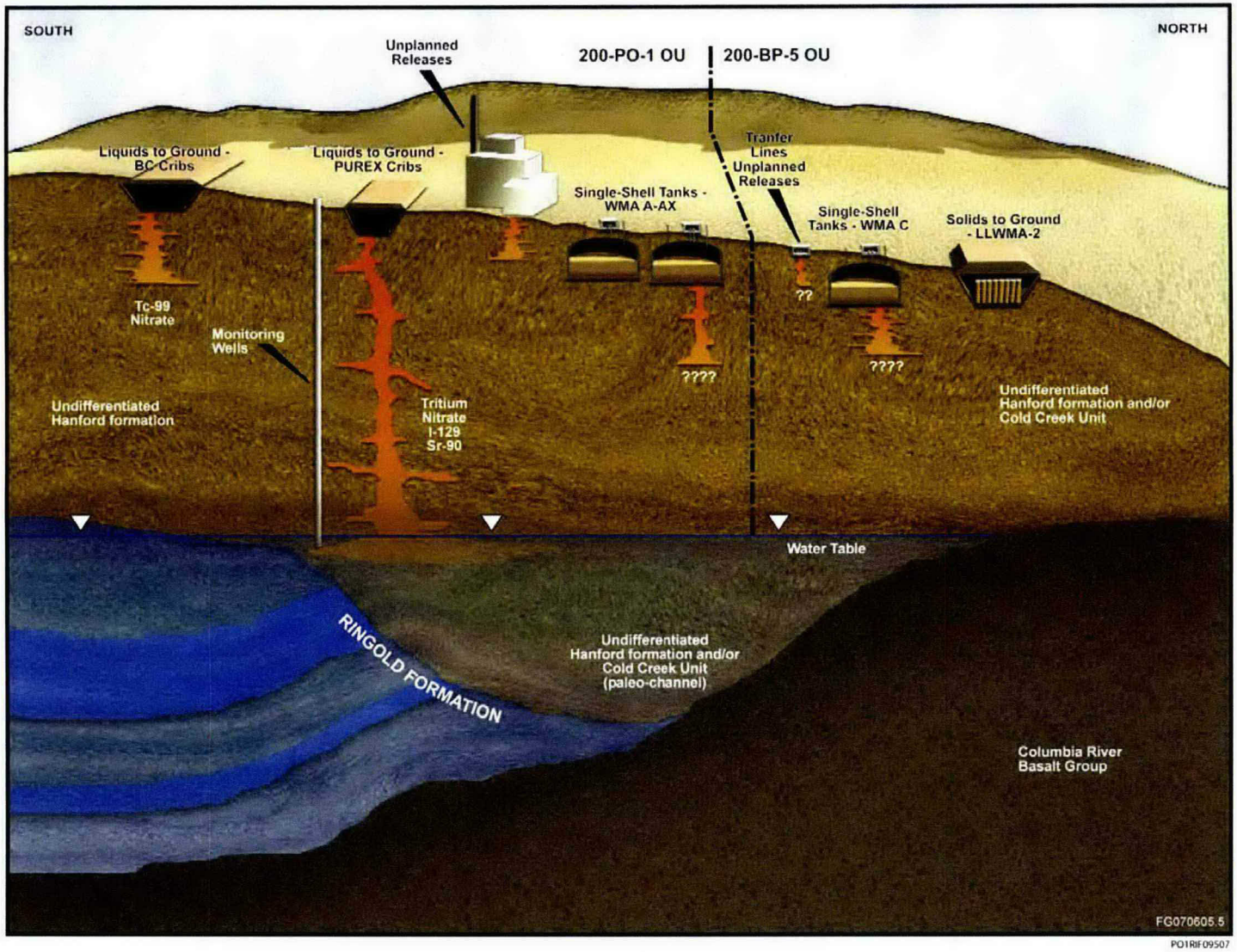


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**Figure 3-40. Near Field Conceptual Site Model**

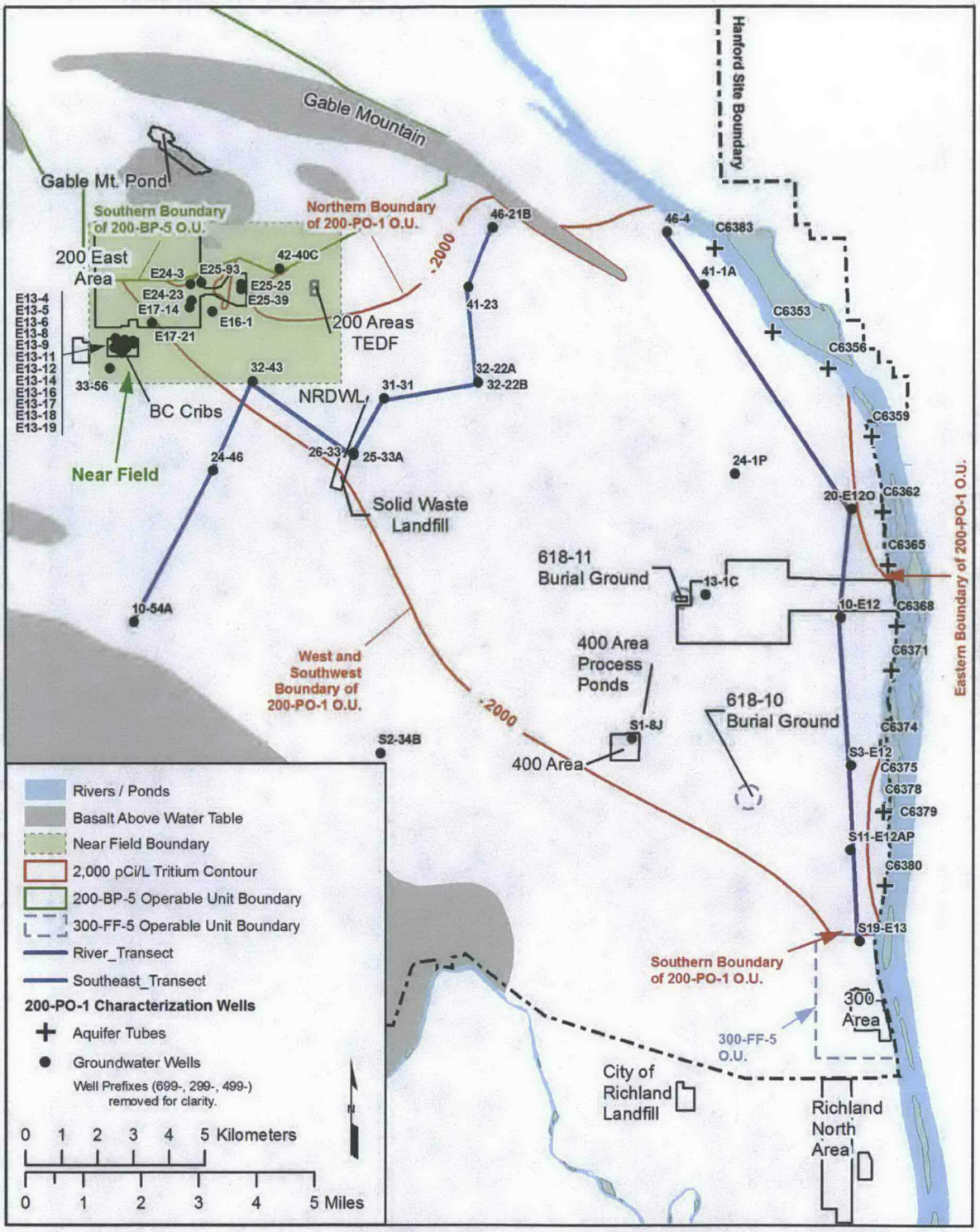


**Figure 3-41. Waste Sites Within the Far Field**

Within the 200-PO-1 Groundwater OU Far Field, tritium, nitrate, and iodine-129 are identified in the monitoring SAP as major groundwater COPC plumes that spatially coincide and merge to flow southeasterly outside of the 200 East Area toward the Columbia River (Figure 3-30). These contaminants are not sourced in the Far Field region of the 200-PO-1 Groundwater OU.

Beginning within the 200 East Area, groundwater contaminants move through the suprabasalt aquifer system downgradient of the 200 East Area (Near Field) and are constrained by structural features related to the May Junction fault (Figure 3-30), east (downgradient) of the 200 East Area sources (e.g., B-Pond and TEDF). The structural displacement creates an unconfined aquifer "no flow" zone along portions of the upthrown, west end of the fault because lower Ringold Fm sediment (i.e., LMU) and basalt are above the current water table (Figure 3-29). The fault might provide a vertical preferential flow path for groundwater to move from the Ringold confined aquifer (presumed uncontaminated) across the fault plane into the Hanford unconfined aquifer (Figure 3-28).

As contaminated groundwater moves downgradient, past the May Junction fault, it becomes less constrained by the surrounding hydrogeologic barriers and spreads laterally as it continues to migrate easterly toward the Columbia River. Preferential groundwater flow (advective) occurs vertically and horizontally within geologic units containing the most permeable sediment, typically in areas (i.e., Hanford fm and/or Cold Creek fm sediment) with thicker paleo-flood channel deposits or other high energy ancestral Columbia River deposits. The water table within the Far Field region of the 200-PO-1 Groundwater OU generally occurs near the Hanford-Ringold contact and includes areas where high permeability Hanford and/or Cold Creek sediments occur below the water table (Figure 3-21). As noted in Section 3.6.6, superimposing the tritium and iodine groundwater plumes onto the map of the hydrogeologic units at the water table (Figure 3-33) illustrates the coincidental relationship between these high permeability sediments and the groundwater plume flow path.

Within the 200-PO-1 Groundwater OU Far Field, there are no detailed hydrogeologic data available to develop a refined CSM. However, detailed characterization within the adjacent 300-FF-5 Groundwater OU in Well 399-3-18 (Figure 3-42) provides an excellent example of the differences in hydraulic properties and contaminant distributions that can occur across the Hanford-Ringold contact. In this case, uranium contamination (sourced within the 300-FF-5 Groundwater OU and not a COPC for the 200-PO-1 Groundwater OU) was analyzed and used as a depth discrete characterization tool to determine the vertical extent of contamation introduced from overlying past 300 Area liquid disposal activities. The lack of residual high levels of contamination beneath the Hanford-Ringold contact within the less permeable Ringold sediment, along with background levels of groundwater indicator parameters (e.g., specific conductance, pH, etc) indicate that contaminated groundwater did not impact this portion of the unconfined aquifer. Interpreting well characterization and groundwater monitoring data implies that most of the contaminated groundwater migrating across the 200-PO-1 Groundwater OU occurs in the uppermost portion of the suprabasalt aquifer system (Figure 3-42). As illustrated in Figure 3-12, Figure 3-13, Figure 3-25, and Figure 3-43, the suprabasalt aquifer system first thickens and then thins across the Far Field region. HSU 1, HSU 3, HSU 4, HSU 5, and HSU 8 are generally continuous across the basin and the 200-PO-1 Groundwater OU. However, HSU 9 in the lowest portion of the suprabasalt aquifer is of significantly lower hydraulic conductivity, is confined by the finer grained HSU 8, and wasn't deposited in some regions where the basin thins near the Columbia River. These data indicate that the primary groundwater contaminant flow path is primarily within the shallow, laterally continuous HSU 1 and HSU 3, and possibly within HSU 4, and/or HSU 5.

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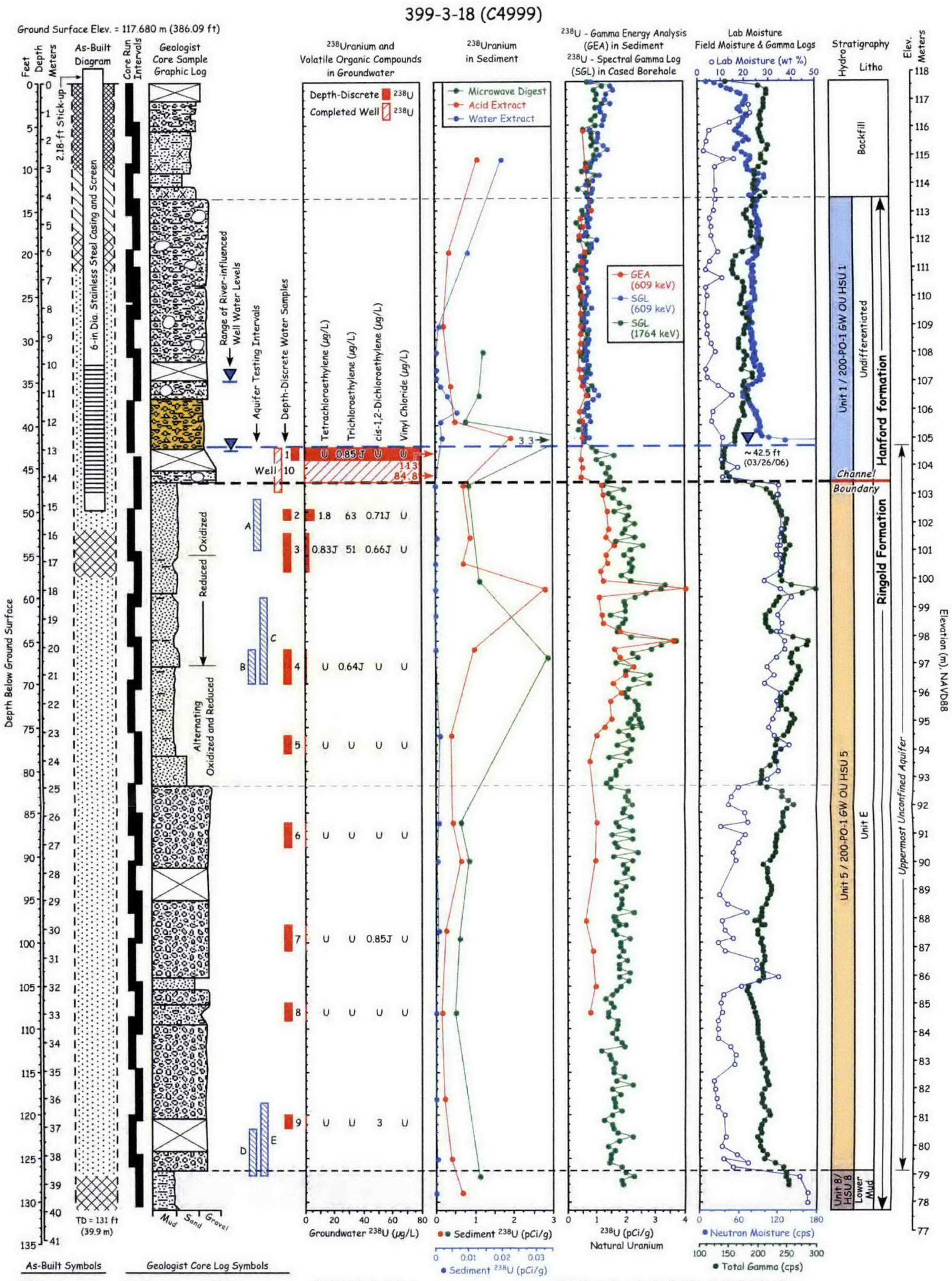


As-Built Symbols

- Portland Cement Grout
- Bentonite Crumbles
- Bentonite Pellets
- 10-20 Mesh Silica Sand
- Stainless Steel Screen

Geologist Core Log Symbols

- Lost Core or Slough Zone
- Muddy Sand
- Gravelly Sand
- Sandy Gravel
- Sandy Mud
- Sand
- Muddy Gravel
- Muddy Sandy Gravel
- Reworked Ringold Muddy Matrix
- Organic Matter
- Ash
- Undesignated Fine-grained Unit Within Ringold Fm Unit 5

VOC Result Qualifiers

J = Estimated Value
U = Analyzed for, But Not Detected

Best Estimate Values From Aquifer Testing

| Profiled Zone | Hydraulic Conductivity Profile Interval (ft) | (m) | Hydraulic Conductivity (meter/day) |
|---|---|---|---|
| A | 48.5 - 54.5 | 14.78 - 16.61 | 0.04 |
| B | 66 - 70 | 20.12 - 21.34 | Not Analyzed |
| C | 60 - 70 | 18.29 - 21.34 | 0.36 |
| E-D | 118.5 - 122.5 | 36.12 - 37.34 | 38.9 |
| D | 122.5 - 127 | 37.34 - 38.71 | 3.82 |

Field Parameters for Depth-Discrete Water Sampling

| Zone | GW Depth (ft) | Interval Sampled (ft) | Sample Method | Purged /Filtered | Elec. Cond. (µS/cm) | Temp (°C) | D.O. (mg/L) | Turb. (NTU) | pH (at °C) |
|---|---|---|---|---|---|---|---|---|---|
| NA | River | River Sample | Grab | Unfiltered | 148 | 6.6 | 10.5 | 3.09 | 8.125 (7.0) |
| 1 | 42.5 | 42.5 - 44 | Bailer | Not Purged and Unfiltered | 465 | 15.5 | 7.2 | 585 | 7.83 (15.6) |
| 2 | 49.7 | 49.7 - 51 | Bailer | | 363 | 19 | 5.13 | >1000 | 7.8 (na) |
| 3 | 42.5 | 52.5 - 57 | Bailer | | 213 | 15.9 | 4.68 | 84.4 | 8 |
| 4 | 48 | 66 - 70 | Pump | Purged and Filtered | 164 | 17.4 | 6.7 | 848 | 8.401 |
| | | | | | 161.4 | 16.7 | 7 | 587 | 8.285 |
| | | | | | 157.8 | 16.8 | 7 | 305 | 8.318 (17.4) |
| | | | | | 158 | 17.4 | 6.1 | 355 | 8.399 (17.5) |
| 5 | 43 | 76 - 78 | Pump | Purged and Filtered | 168 | 15.7 | 2.1 | 466 | 8.490 (15.9) |
| | | | | | 158 | 16.2 | 1.9 | 290 | 8.549 (16.4) |
| | | | | | 160 | 16.3 | 2.7 | 48.1 | 8.389 (16.9) |
| | | | | | 159 | 16.8 | 7 | 26.5 | 8.351 (15.0) |
| | | | | | 159 | 18 | 6.4 | 9.09 | |
| 6 | 42.4 | 86 - 89 | Pump | Purged and Filtered | 225 | 14.4 | 1.3 | 70.7 | 8.132 (15.0) |
| | | | | | 224 | 15.1 | 1.6 | 43.5 | 8.283 (14.4) |
| | | | | | 225 | 15.4 | 1.1 | 33.3 | 8.245 (14.8) |
| | | | | | 225 | 15.8 | 1.3 | 26.9 | 8.31 (15.6) |
| 7 | 41 | 98 - 101 | Pump | Purged and Filtered | 267 | 14.8 | 1.8 | 134 | 7.929 (15.7) |
| | | | | | 267 | 15 | 2 | 109 | 8.028 (15.1) |
| | | | | | 274 | 13.5 | 0.8 | 98.6 | 7.991 (15.1) |
| | | | | | 268 | 13.8 | 1.1 | 98.6 | 8.101 (14.6) |
| | | | | | 267 | 14.3 | 1 | 0.82 | 8.128 (14.5) |
| 8 | 41 | 107 - 109 | Pump | Purged and Filtered | 270 | 19.1 | 0.4 | >1000 | 8.158 (18.4) |
| | | | | | 274 | 19.1 | 0.7 | >1000 | 8.285 (18.3) |
| | | | | | 274 | 17.8 | 1 | >1000 | 8.165 (18.0) |
| | | | | | 276 | 17.9 | 0.6 | >1000 | 8.170 (18.3) |
| | | | | | 275 | 17.6 | 2.7 | >1000 | 8.185 (17.5) |
| 9 | | 120 - 121.5 | Pump | P & F | 281 | 17.2 | 1.1 | >1000 | 8.181 |
| Well (10) | 42.6 | 42.6 - 47.9 | Pump | P & F | 349 | 16.4 | 8.1 | 2.69 | 7.51 |

**Figure 3-42. Example Vertical Contaminant Distribution in Suprabasalt Aquifer System Well near the Columbia River (399-3-18)**

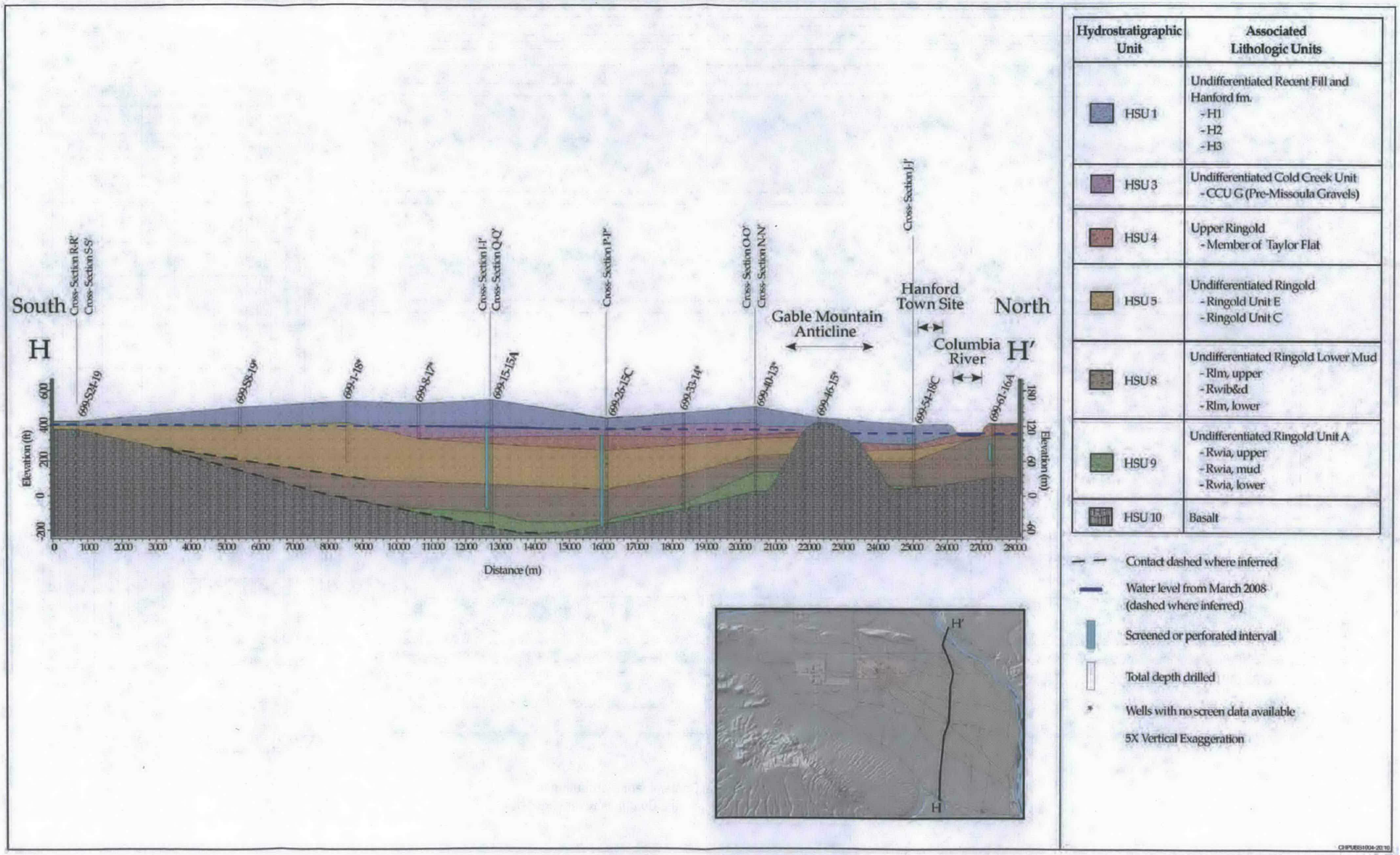


Figure 3-43. Far Field Hydrogeologic Cross-Section H-H'

The CSM for the Far Field is illustrated in Figure 3-19, Figure 3-24, Figure 3-25, and Figure 3-44. Past groundwater monitoring data and plume maps indicate that contaminated groundwater probably was sufficiently extensive to impact the Columbia River along most of the 200-PO-1 Groundwater OU boundary (Figure 3-30). Major liquid effluent discharges ceased in the mid 1990s, resulting in a declining water table and reduced groundwater flow rates. As a consequence, groundwater monitoring data determined that the extent of contaminants originating within the 200 East Area and vicinity have declined and may only be discharging to the Columbia River near the Hanford town site. The area is coincident with the uppermost aquifer that contains higher hydraulic conductivities related to Hanford and Cold Creek sediment that is present below the water table (Figure 3-33).

As contaminated groundwater approaches the Columbia River, it encounters temporally changing flow rate and direction due primarily to changes in river levels. These changes are controlled at the dams by the USACE. Groundwater flows into the hyporheic zone adjacent to the river where water mixing and flow rate change depending on relative river levels (river stage) and aquifer head (Figure 3-45). Under low river stage, primarily in the fall, winter, and early spring seasons, groundwater flows into the Columbia River (Figure 3-46) at the interface between the contributing hydrogeologic unit(s) and the river bottom (Figure 3-47). The overall footprint of this interface along the river changes depending on HSU unit thickness, river bathymetry, and relative hydraulic conductivity of the units. Figure 3-48 illustrates one example of an area that impacts the Columbia River adjacent to the 300 Area shoreline as a result of contaminant disposal within the 300-FF-5 Groundwater OU (not sourced from 200-PO-1 Groundwater OU). Figure 3-48 depicts the area of the river bathymery (bottom) that intersects saturated Hanford sediment (i.e., above the Hanford-Ringold contact) known to contain contaminated groundwater (i.e., uranium) sourced from the 300 Area. This figure provides an example of the variability in hydraulic properties and contaminant impacts to the Columbia River that can occur dependent on the aquifer boundaries and adjacent river bottom configuration.

Data available from river shore monitoring within the 300-FF-5 Groundwater OU (located adjacent to the 200-PO-1 Groundwater OU) provide another good example of preferential groundwater flow into the river. Figure 3-49 illustrates contaminant concentrations and depth variations for a 300-FF-5 specific COC (i.e., uranium) as measured in the river adjacent to the 300-FF-5 Groundwater OU (PNNL-16805). These data indicate that more contamination enters the river through the upper, more permeable Hanford fm sediment than from below in the Ringold Fm sediment; uranium contaminants in groundwater are also influenced geochemically and adsorb onto more reactive sediments (i.e., Ringold Fm). The groundwater discharge areas from the 200-PO-1 Groundwater OU into the river would be expected to exhibit similar mixing zones to those observed in the 300 Area. No sampling data are currently available to validate this hypothesis for the 200-PO-1 Groundwater OU.

Remnants of the regional tritium plume, moving with groundwater at the southeastern margin of the 200-PO-1 Groundwater OU, impact the Columbia River near the 300 Area shoreline (Figure 3-50). Tritium concentration data obtained from cross-river transects (Figure 3-51 and Figure 3-52) illustrate the level of contamination measured entering the Columbia River adjacent to the known tritium plume (PNNL-13692). Upgradient samples, taken near the Vernita Bridge, and downgradient samples (location 14) below the tritium plume path reveal relatively no tritium measured within the river. Within the plume path, the highest tritium concentrations measured in the riverbed are closest to the riverbank (suprabasalt aquifer) and probably represent areas where the aquifer water flows into the river or where less river water dilution is occurring.

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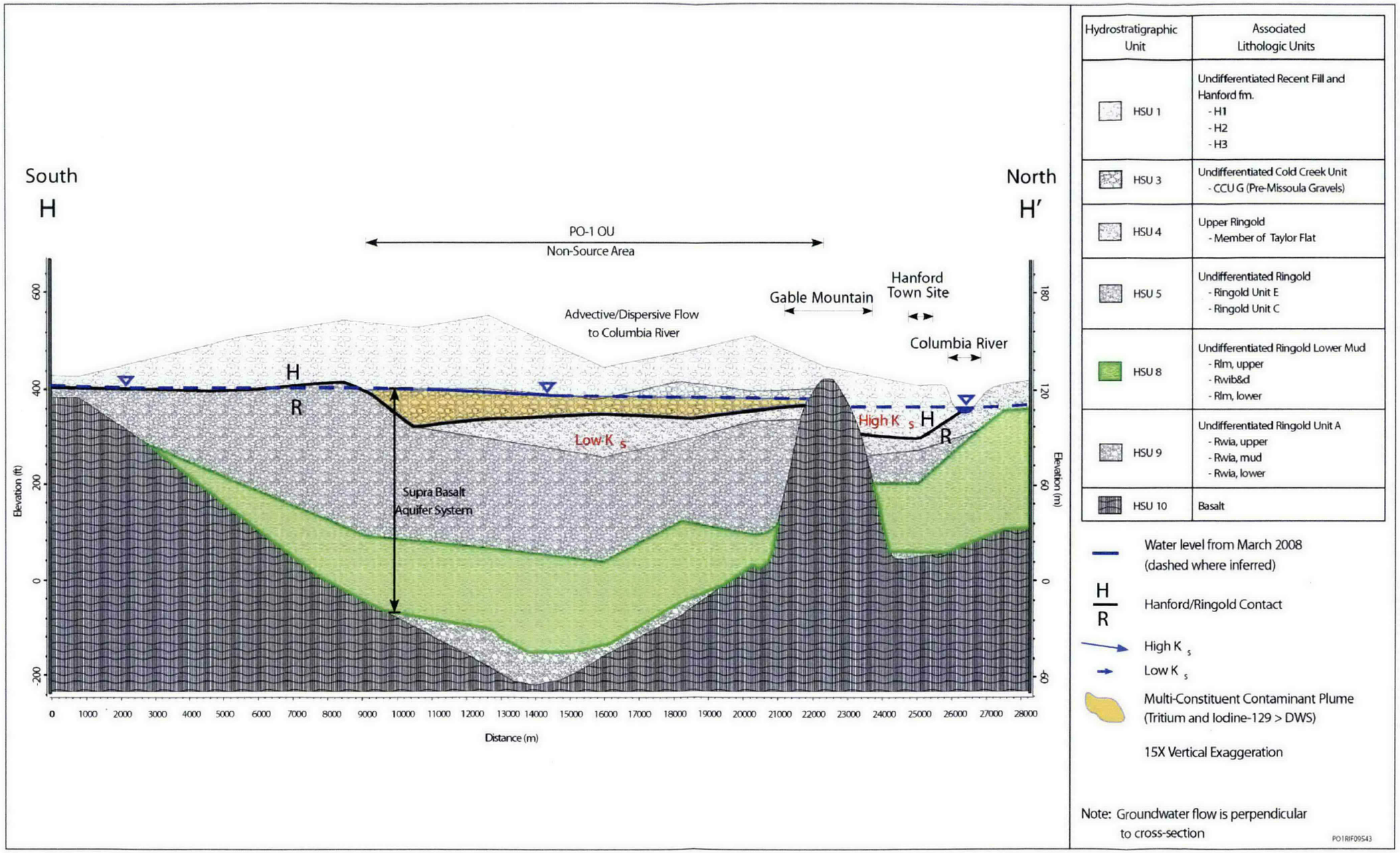


**Figure 3-44. Contaminant Conceptual Site Model for Far Field**

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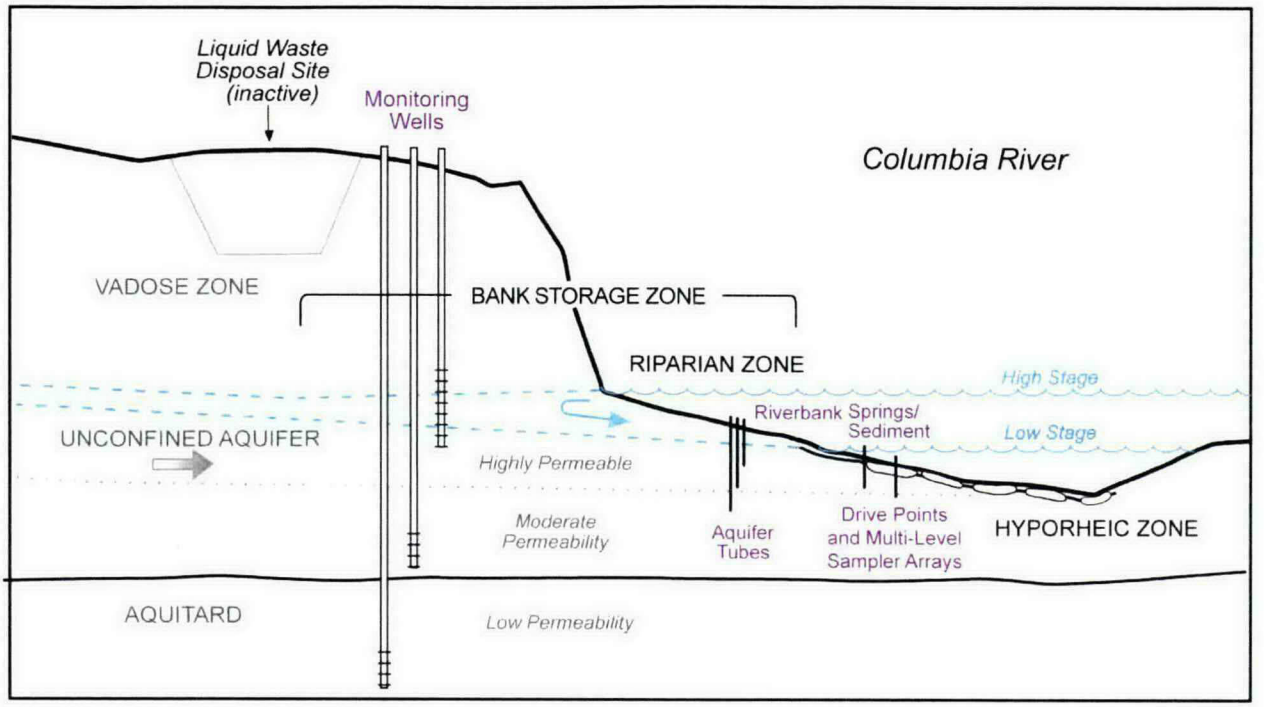


Source: PNNL-13674, Figure 1.1, with modifications

ZOI-terms-042709.ai

**Figure 3-45. Groundwater Flow of the Hyporheic Zone**

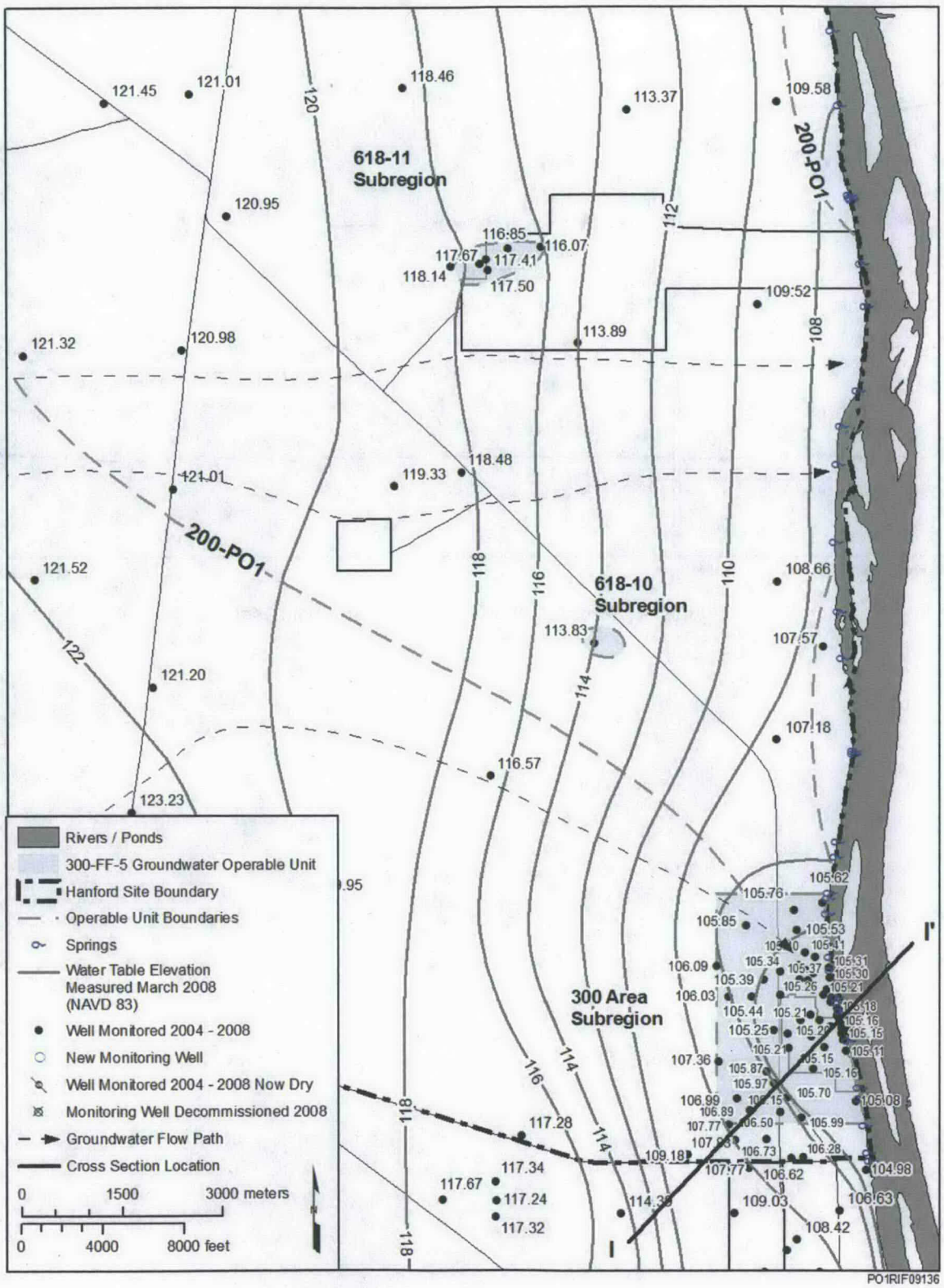


**Figure 3-46. Generalized Groundwater Flow During Low River Stage**

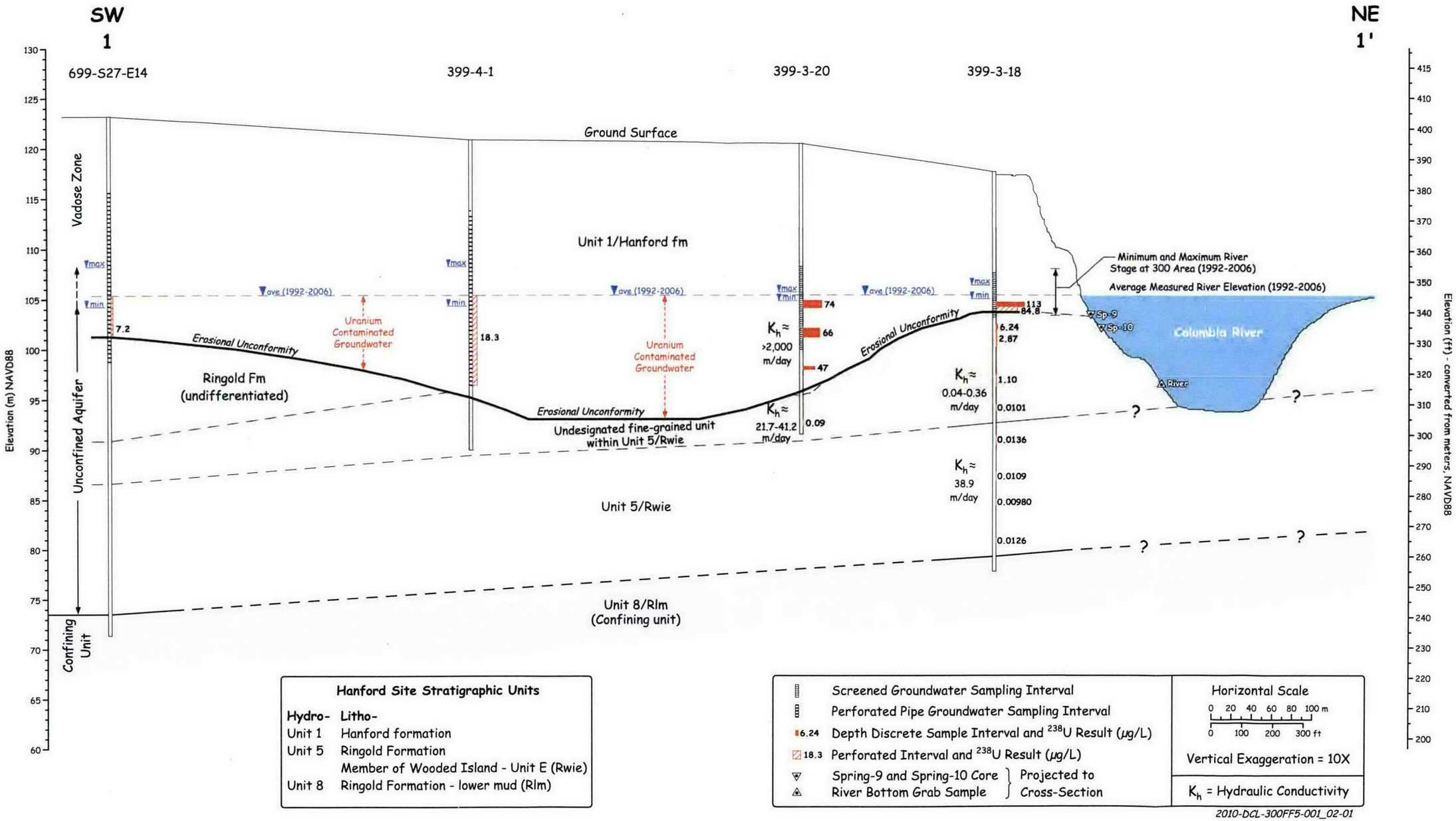


Figure 3-47. View of 300 Area Hypothetical Groundwater Flow into the Columbia River

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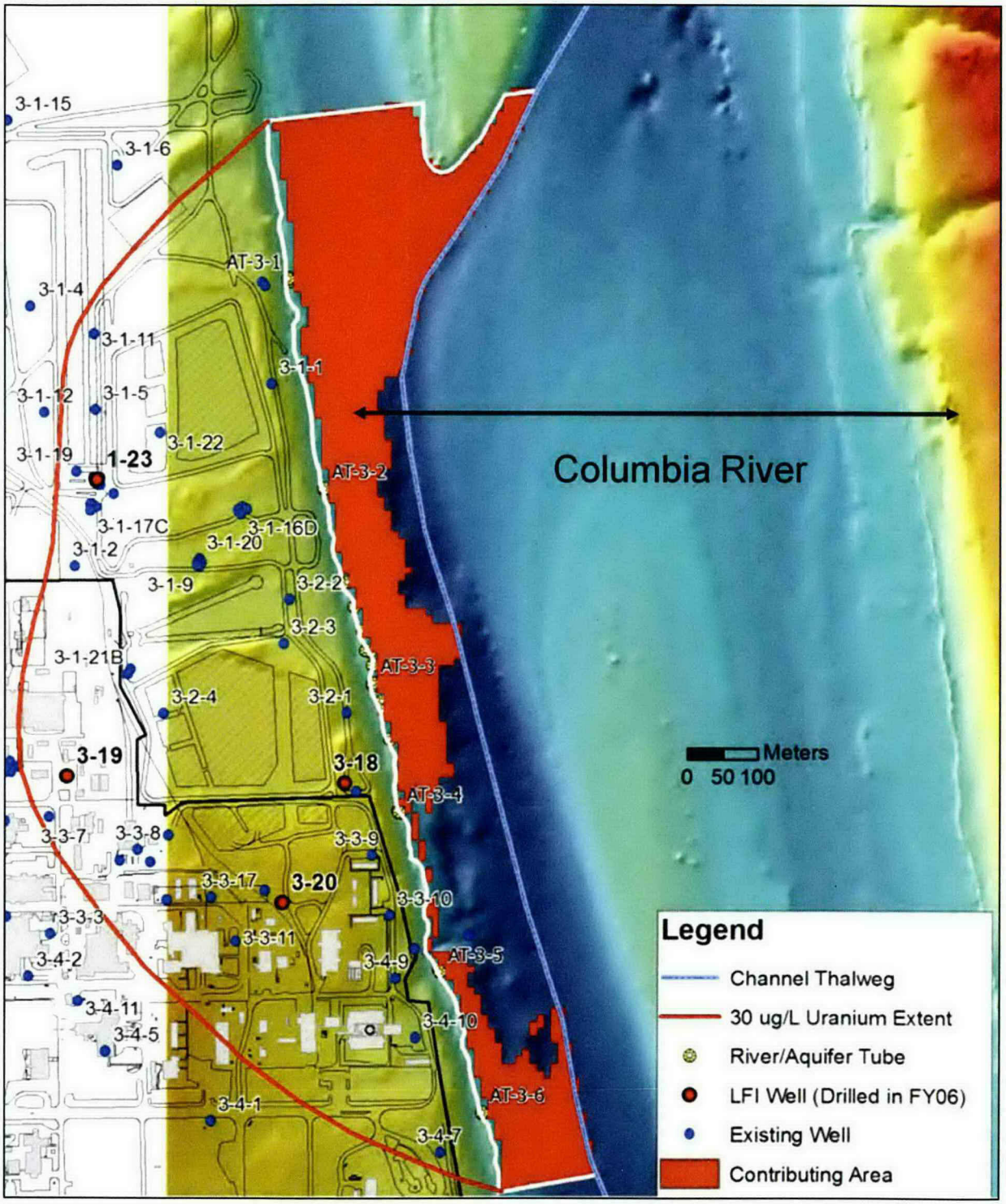



**Figure 3-48. Footprint of Potential Contaminated Groundwater Impact (Upwelling) within HSU 1 Intersected Portions of the Columbia River in the Vicinity of the 300 Area**

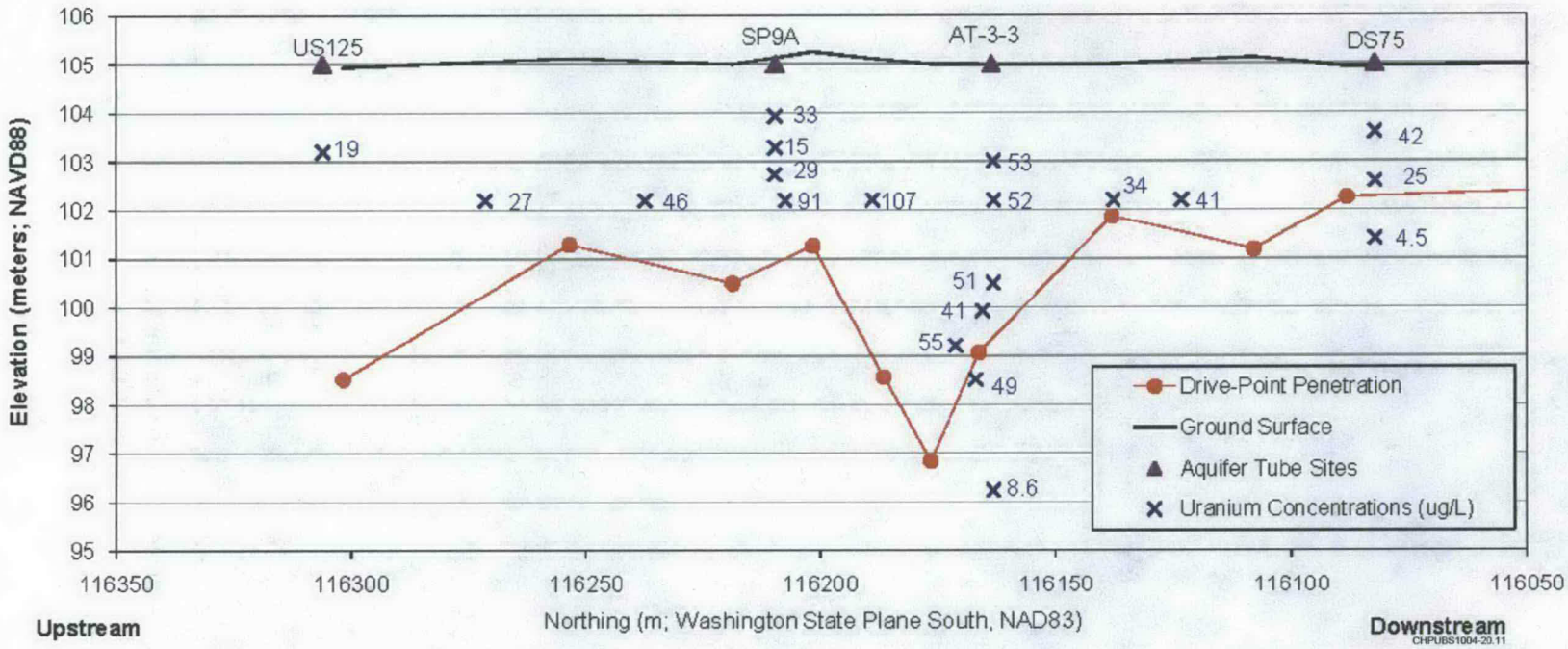
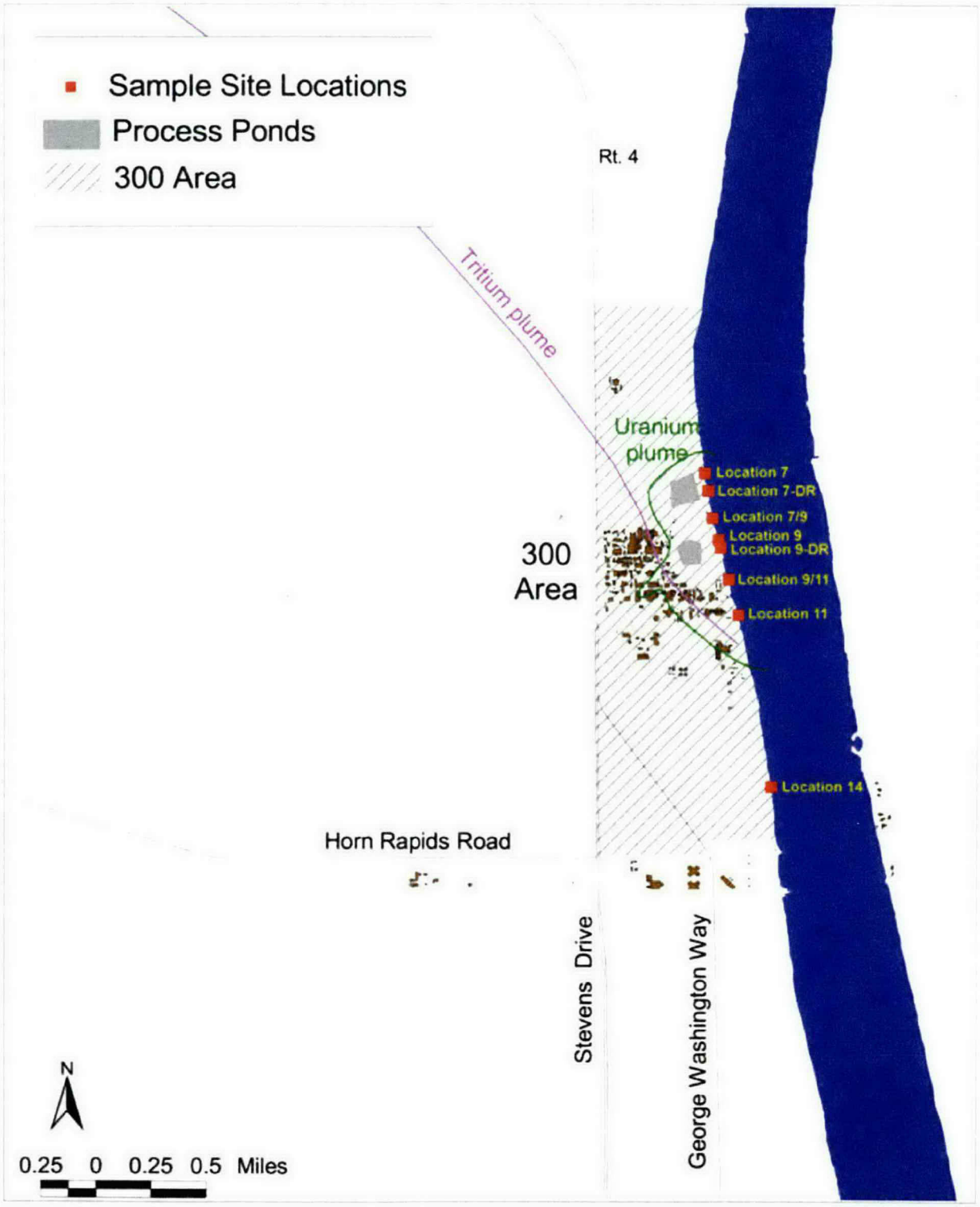



**Figure 3-49. Shoreline Variations in Uranium Concentrations (Dashed Line is Hanford/Ringold Contact)**




PO1RIF09512

**Figure 3-50. Southeastern Tritium Plume Extent (PO-1 OU) Along the 300 Area Shoreline**

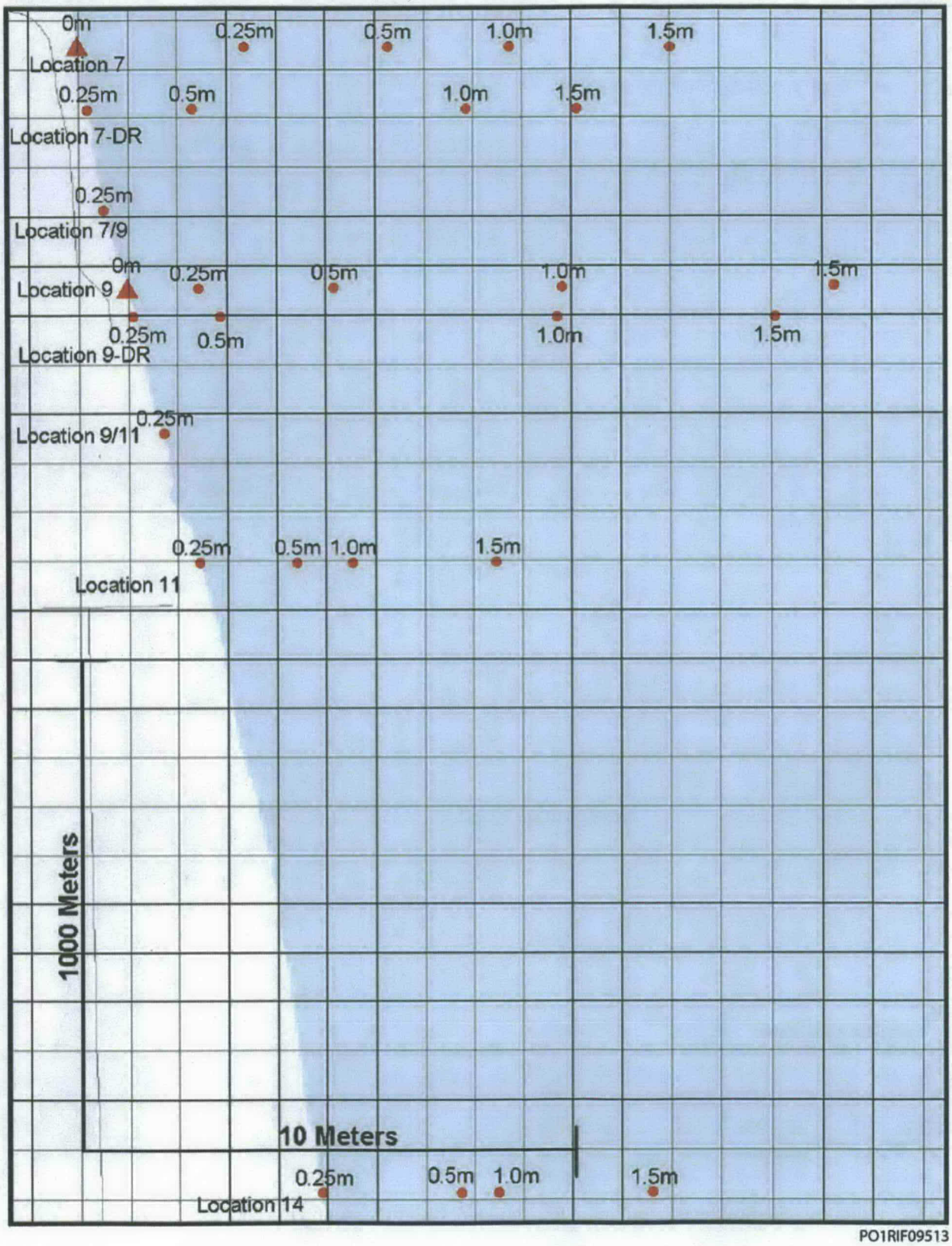
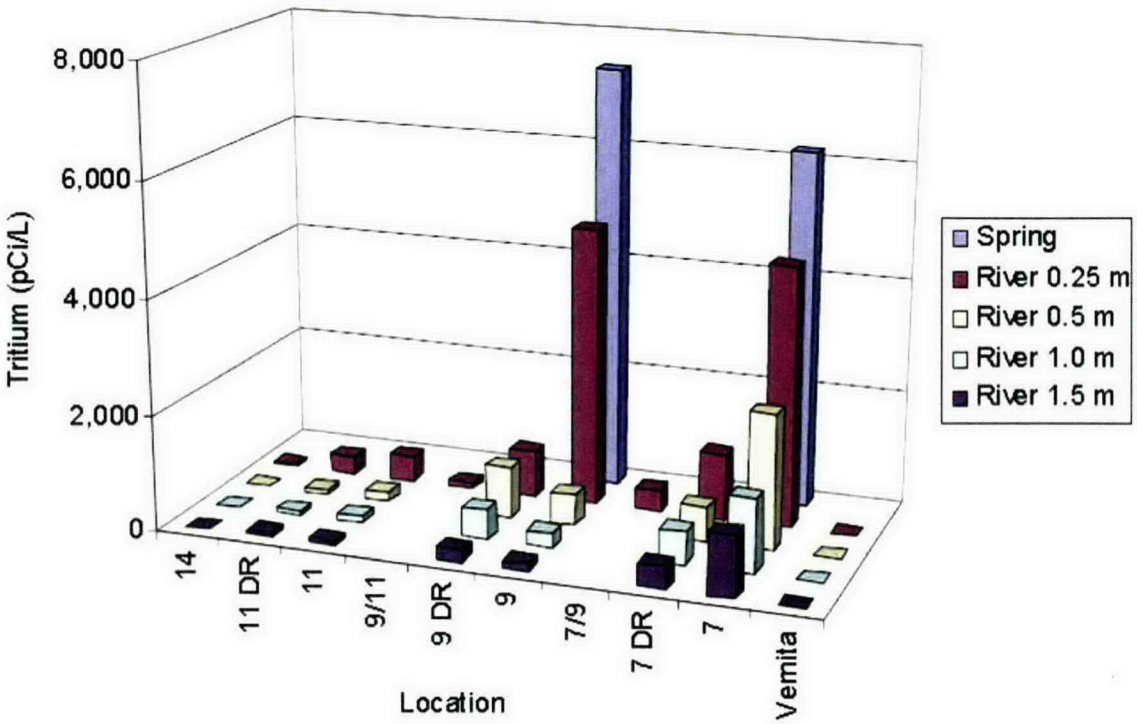



**Figure 3-51. 300 Area Columbia Riverbed Transect Sampling Locations**




PO1RIF09514

**Figure 3-52. Riverbed Tritium Concentrations – 300 Area and Vernita Bridge (2008)**

These same processes are most likely occurring near the Hanford town site in the northern portion of the 200-PO-1 Groundwater OU, where the majority of the remaining groundwater contamination (e.g.,tritum) is expected to impact the river (Figure 3-53). Additional work is being done to couple the geologic interpretations of the Hanford-Ringold contact on shore with high-resolution bathymetry imaging of the Columbia River to estimate the area of riverbed with the potential to discharge contaminants to the Columbia River.

### 3.6.8 Geochemistry

Downgradient of the major source areas (i.e., the 200 East Area and area near the 300-FF-5 Groundwater OU), assessment of vertically discrete groundwater sample data indicates that contaminated groundwater exists only in the uppermost permeable portion of the unconfined aquifer (Figure 3-47). A composite geologic log for Borehole 399-3-18 is included in Figure 3-42. Figure 3-54 illustrates the vertical geochemical variation within the upper suprabasalt aquifer near the Columbia River using the Stiff diagrams and other groundwater quality parameters, including select contaminants. Groundwater chemistry results captured for deeper intervals within the suprabasalt aquifer system (but above the confining Ringold Fm LMU) are relatively contaminant free, even beneath or adjacent to areas with significant liquid disposal volumes (PNNL-16435, *Limited Field Investigation Report for Uranium Contamination in the 300-FF-5 Operable Unit at the 300 Area, Hanford Site, Washington*). These data indicate, as described in previous sections, that only the highest permeability interval(s), typically located within the uppermost portion of the unconfined aquifer system, are impacted by liquid effluent disposal activities. PNNL-16435 provides additional evidence that these deeper intervals may still contain older groundwater that has not moved significantly or been displaced by decades of facility disposal operations (Figure 3-54). More information on Stiff and Piper plots is available in ECF-200PO1-09-2015.

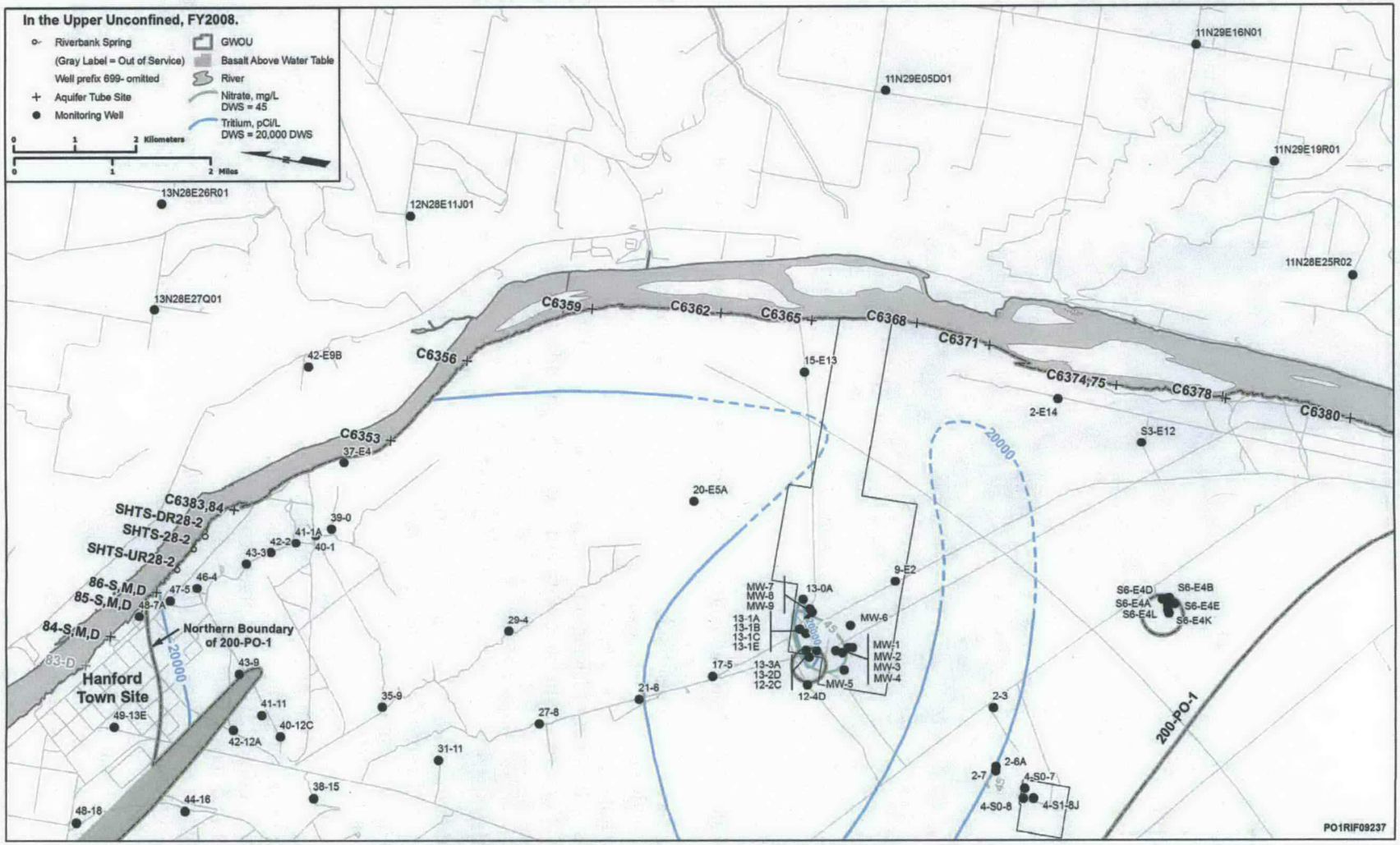



**Figure 3-53. Rivershore (Aquifer Tube) and Aquifer (Monitoring Well) Network Near the Hanford Town Site 200-PO-1 Groundwater Operable Unit**

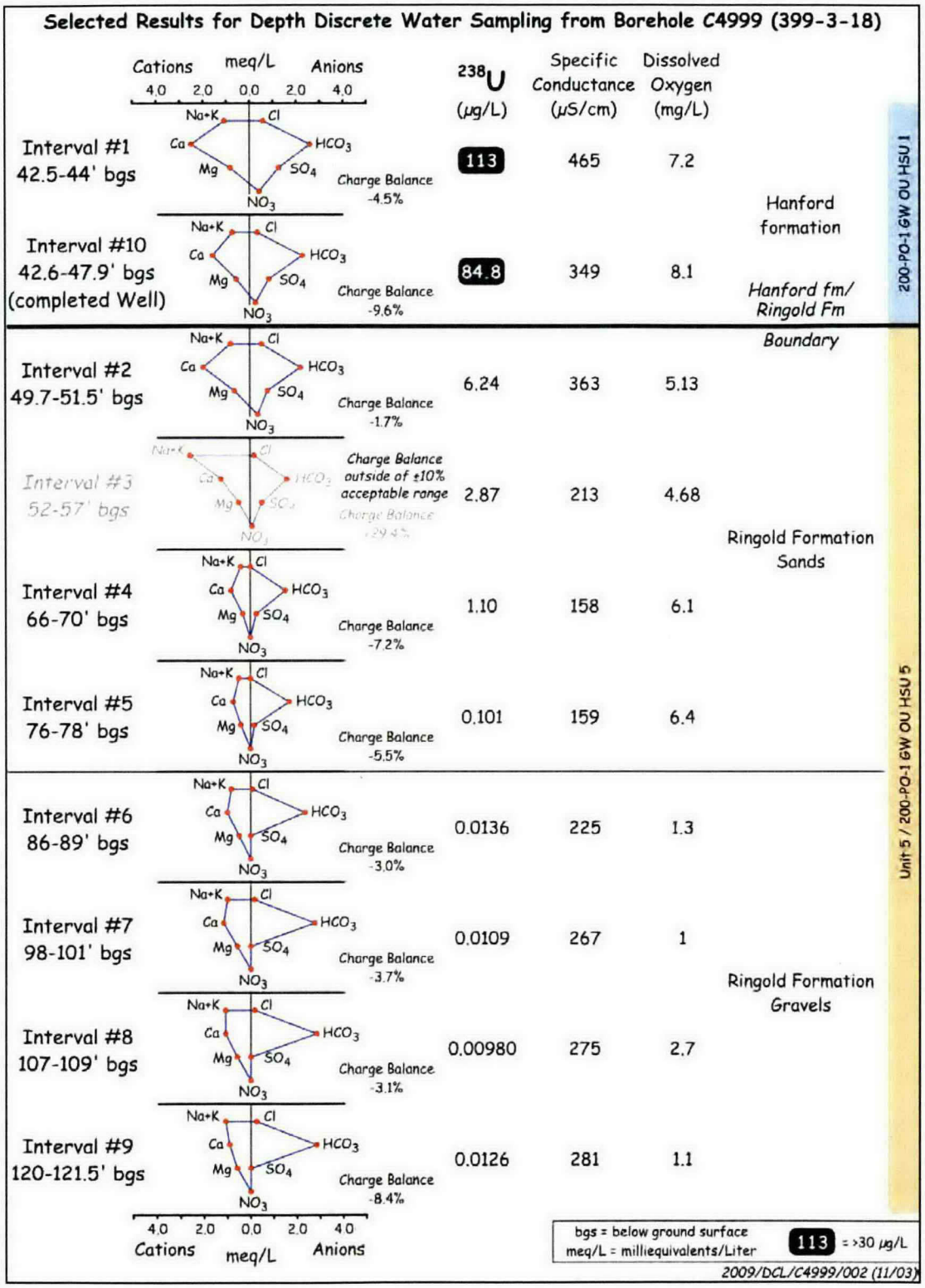



**Figure 3-54. Selected Results for Depth Discrete Water Sampling in the Suprabasalt Aquifer from Well 399-3-18**

### 3.6.9 Groundwater Recharge

Movement of contaminants in groundwater at the Hanford Site is heavily dependent on recharge to the unconfined aquifer. As the effects of past artificial discharges dissipate, the water table is expected to return to more natural conditions, and natural recharge will become the driving force when evaluating future groundwater flow conditions and related contaminant transport. Previous work on the relationship of natural recharge to groundwater movement at the Hanford Site has focused on direct recharge from infiltrating rainfall and snowmelt within the area as discussed in PNNL-14717, *Natural Recharge to the Unconfined Aquifer System on the Hanford Site from the Greater Cold Creek Watershed: Progress Report 2004.*

Except for the State-Approved Land Disposal Site (SALDS), the 200 Area TEDF, and septic drain fields, substantial artificial recharge to the vadose zone ended in the mid-1990s. Currently, the principal sources of natural recharge are precipitation and runoff infiltration along the periphery of the Pasco Basin. Part of the groundwater recharge at Hanford is provided by flow from the Greater Cold Creek watershed, a large drainage area on the western boundary of the Hanford Site that includes Cold Creek Valley, Dry Creek Valley, and the Hanford side of Rattlesnake Mountain. Small ephemeral streams such as Cold Creek and Dry Creek also lose water to the ground as they spread out on the valley plain.

Natural precipitation infiltration at or near waste management units or UPRs may provide a driving force for the mobilization of contaminants previously introduced to surface or subsurface soils. Previous field studies have been designed to assess precipitation, infiltration, water storage changes, and evaporation to evaluate the natural water balance during the recharge process. Estimated precipitation recharge values range from 0 to 10 cm/yr. The primary factors affecting precipitation recharge are surface soil type, vegetation type, topography, and year-to-year variations in seasonal precipitation. Various field studies conclude that less than 25% of the precipitation falling on typical Hanford Site soils actually infiltrates to any depth.

The depth to groundwater beneath liquid disposal sites within the 200 East Area is approximately 91 m (300 ft) bgs. Depth to groundwater decreases eastward from the 200 Area (Figure 3-55). Figure 3-55 provides the thickness of the vadose interval above the water table and also captures patterns that are believed to be ancestral Columbia River and/or paleo-flood erosional channels. Liquid disposal was the driving force for contaminant migration from the disposal sites in the 200 East Area. In 1995, the 200 East Groundwater AAMSR (DOE/RL-92-19) evaluated surface sites for potential contaminant migration to groundwater. This evaluation estimated possible groundwater impact by comparing vadose zone moisture retention capacity to the volume of liquid disposed. Those sites receiving liquid volumes greater than the retention capacity, were identified as having the potential to impact groundwater. Since 1995, RIs have progressed by source OU and are being evaluated for contributions and recharge to groundwater.

Major sources of artificial recharge to the 200-PO-1 Groundwater OU unconfined aquifer are summarized in Figure 3-39. Figure 3-37 illustrates a CSM for artificial recharge from B-Pond. Figure 3-56 illustrates the annual contribution of liquids to ground from B-Pond and the last remaining liquid effluent disposal source (i.e., TEDF). Changes in groundwater elevation at the 200-PO-1 Groundwater OU due to artificial recharge are shown on the historical water table maps (Appendix C). Comparison of the current water table map (2008) of the 200-PO-1 Groundwater OU Near Field area (Figure 3-29) to the water table map for 1993 (Figure 3-57) illustrates that groundwater mounding greatly influenced groundwater and contaminant migration prior to 1997.

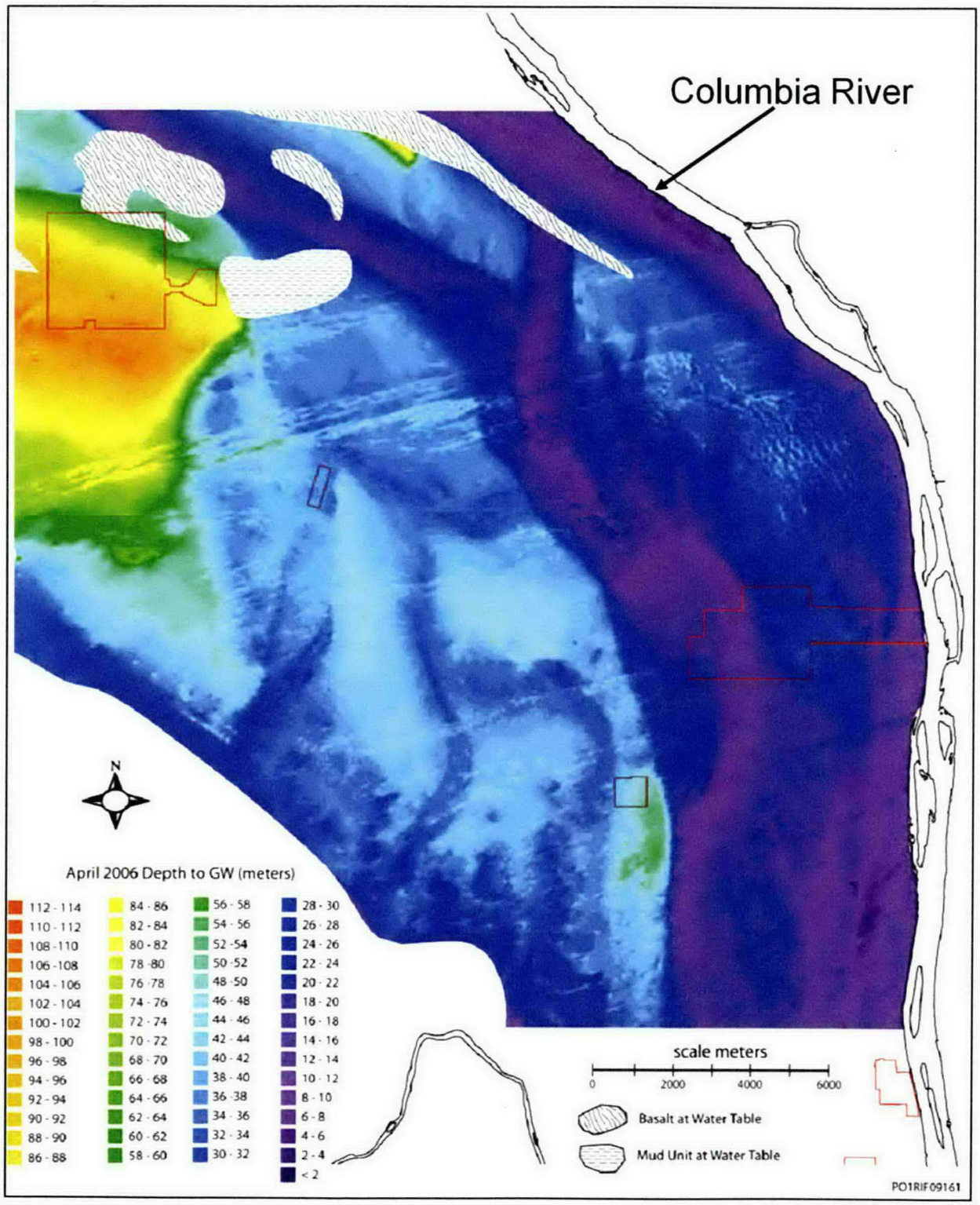



**Figure 3-55. Depth to Groundwater (Vadose Zone) in the 200-PO-1 Groundwater Operable Unit**

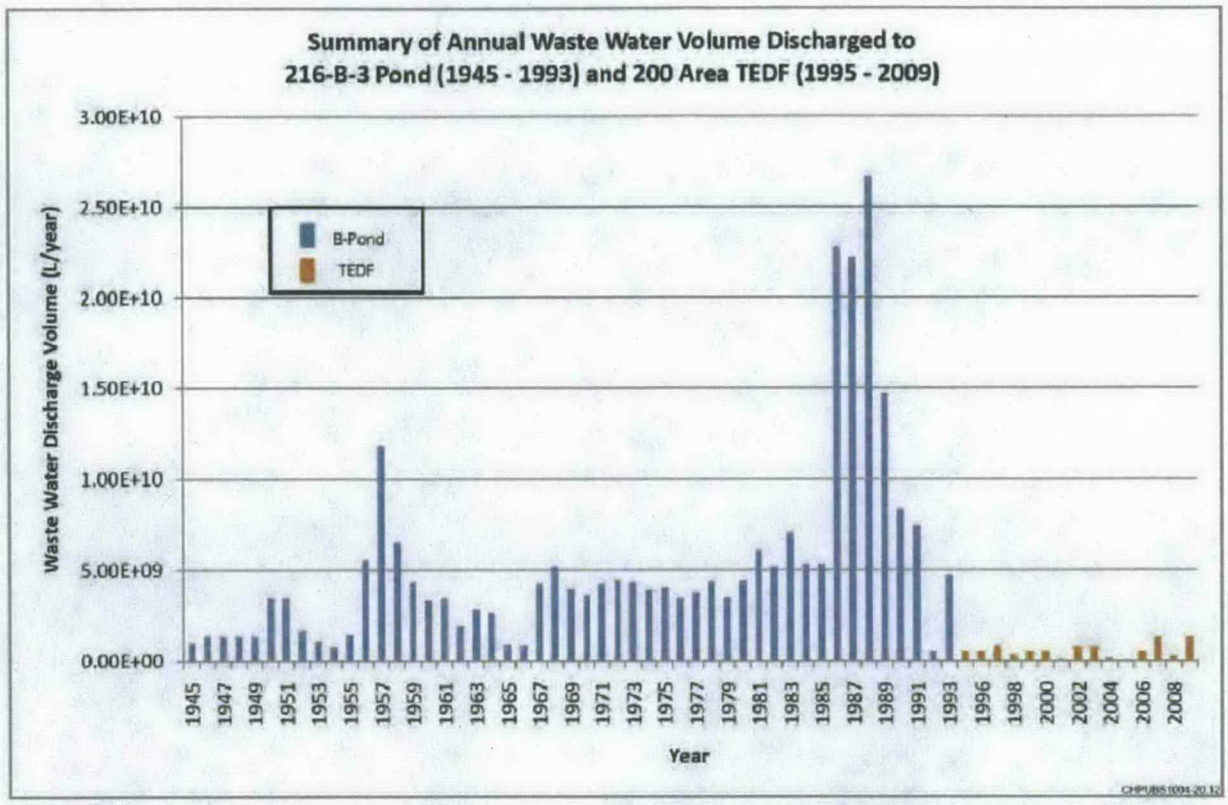



**Figure 3-56. Liquid Effluent Disposal Activities to B-Pond and the Treated Effluent Disposal Facility**

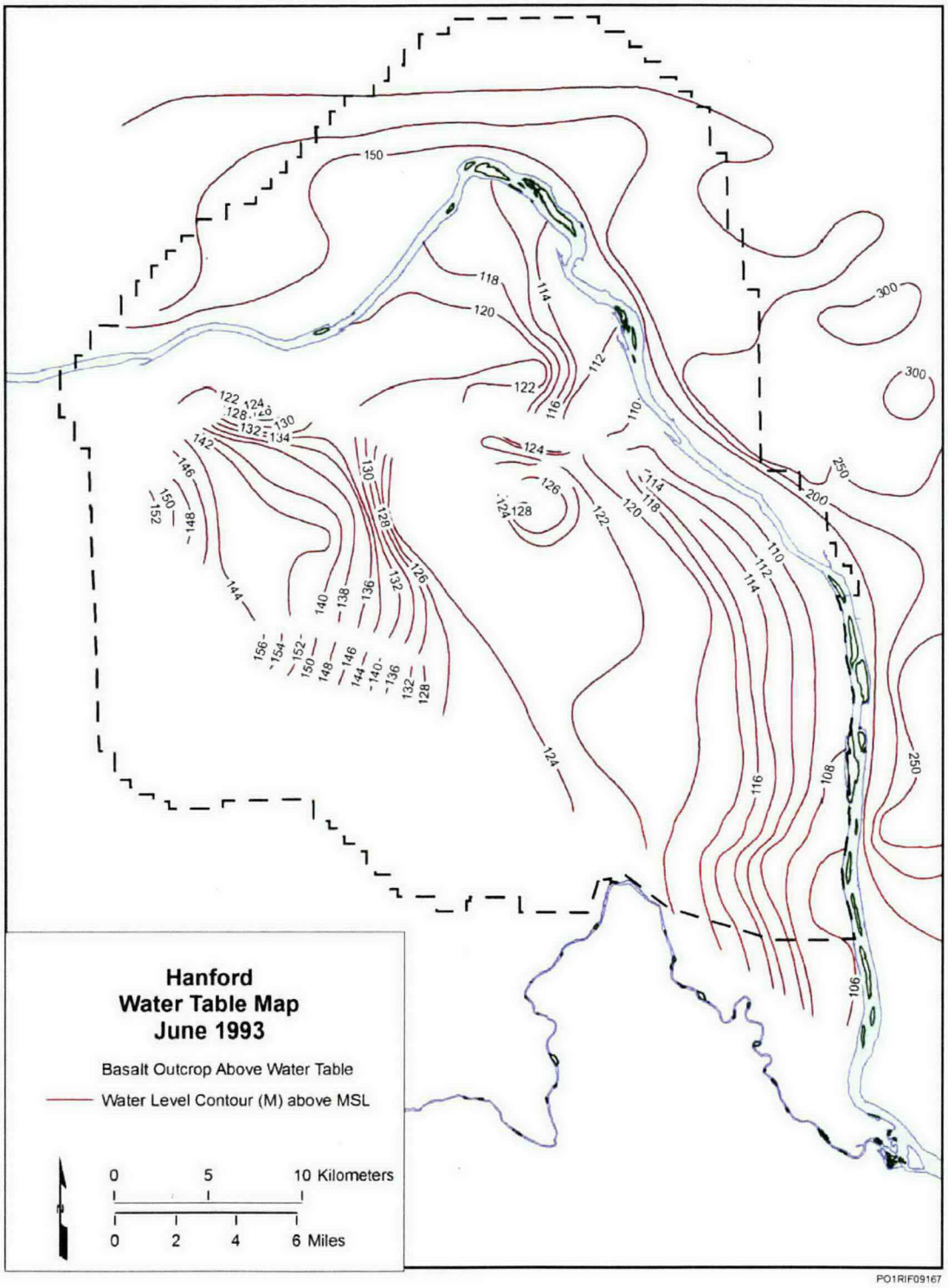



**Figure 3-57. Water Table Map of the Hanford Site (June 1993)**

### 3.6.10 Groundwater Velocity and Travel Time

Large liquid volumes were discharged to the vadose zone during Hanford Site operations (Figure 3-20 and Figure 3-56). The impact of substantial artificial recharge on the 200-PO-1 Groundwater OU unconfined aquifer system is illustrated by comparing Figure 3-21 and Figure 3-58, which pre-date Hanford Site operations, to Figure 3-22 and Figure 3-57, which illustrate some of the higher water levels during Hanford Site operations. Figure 3-29 shows the current 200-PO-1 Groundwater OU water table (2008) and the inferred groundwater flow pattern. Localized impacts of artificial recharge on the 200-PO-1 Groundwater OU semi-confined and confined aquifers are indicated by data for the Ringold and upper basalt monitoring wells that are shown in Figure 3-28.

Groundwater velocity within the shallow, unconfined aquifer of the 200-PO-1 OU between the 200 East Area and the Columbia River was estimated by inspection of arrival times of tritium concentration peaks at monitoring wells along an identified flow pathway downgradient of the apparent sources areas (Figure 3-59). The tritium arrival peak series is shown in Figure 3-59, and the apparent estimated groundwater velocity during the period examined ranged from about 250 m/yr to about 625 m/yr, with the higher velocity observed in the near river area of the aquifer where a steeper gradient was also observed. Estimated groundwater velocities, based on tritium peak arrivals in monitoring wells for selected portions of the unconfined aquifer, are shown in Table 3-2.

**Table 3-2. Estimated Groundwater Velocity in the 200-PO-1 Groundwater Operable Unit Unconfined Aquifer, Based on Arrival of Tritium Concentration Peaks**

| Aquifer Portion | Wells Inspected for Tritium Peaks and Time Period | Estimated Groundwater Velocity |
|---|---|---|
| Upgradient, near 200 East Area | MW 699-31-31 and MW-699-35-15A, 1963 to 1969 | ~433 m/yr |
| Midway between 200 East Area and Columbia River | MW 699-26-15A and MW 699-35-9, 1969 to 1990 | ~252 m/yr |
| Downgradient, Near Columbia River | MW 699-37-E4, 1990 to 1996 | ~625 m/yr |

Based on the observed tritium concentration peak arrival times shown in Figure 3-59, the apparent travel time for mobile contaminants originating within the southeast corner of the 200 East Area to reach the Columbia River was approximately 33 years (i.e., 1963 to 1996 for the observed tritium concentration peaks). This travel time is likely conservative (i.e., it overstates groundwater contaminant migration rates compared to current conditions) for the following two reasons:

- The westernmost (i.e., upgradient) monitoring history for this observation was taken from Well 699-34-41B and Well 699-31-31. Historical tritium monitoring in both of these wells was started when substantial tritium concentrations were already present in both wells. This would indicate that the actual peak concentration may have occurred some time prior to initiation of monitoring in those wells.

- The time period examined for this evaluation, as presented in Figure 3-59, includes the historical operational period (e.g., 1960s and 1970s) when substantial water discharges in the Central Plateau created large groundwater mounds, thus increasing the effective groundwater gradient across the site. Under current conditions, the historic groundwater mounds are substantially diminished, and groundwater gradient across the site is approaching pre-Hanford conditions with reduced groundwater velocity and resultant increased travel time from the Central Plateau to the Columbia River.

### 3.6.11 Groundwater/Surface Water Interactions

In the Far Field region of the 200-PO-1 Groundwater OU, the interaction between the suprabasalt aquifer groundwater and the Columbia River is illustrated in two main contaminant discharge areas: (1) the Hanford town site, and (2) the 300 Area, both adjacent to the Columbia River. The discharge boundary for the Hanford town site area is shown on Figure 3-60. Figure 3-46 illustrates the groundwater discharge boundary for the 300 Area of the 200-PO-1 Groundwater OU.

The primary 200-PO-1 Groundwater OU hydrogeologic units present in the Far Field region near the Columbia River and the 300 Area are shown in Figure 3-6. The suprabasalt hydrogeologic conditions in the Columbia River discharge zones are illustrated on the cross-section in Figure 3-47. Shoreline aquifer tube monitoring points along the Hanford town site are also used to evaluate groundwater interaction between the aquifer and the river (Figure 3-61).

Variable contaminant concentrations can be detected with depth along the river, and the variable relief and thickness of hydrogeologic boundaries are also discernable (Figure 3-61). Figure 3-48 shows the conceptual footprint of uranium associated with aquifer upwelling in the 300 Area. Similar studies are underway to determine aquifer upwelling regions near the Hanford town site.

Aquifer tubes are sampled each year based on the SAP (DOE/RL-2000-59). In FY 2008, nitrate and tritium results were obtained for new aquifer tubes installed near the Hanford town site (Figure 3-60). Only tritium values exceed the DWS of 20,000 pCi/L (DOE/RL-2008-66).

Columbia River seeps (springs are sampled each autumn by the DOE Surface Environmental Surveillance Project. Some seeps are sampled to support CERCLA OU requirements. Analytical results for seep samples, along with results for adjacent river water, are published in PNNL-17603, *Hanford Site Environmental Report for Calendar Year 2007*. Contaminant concentrations are typically much lower in seep water than in groundwater samples from wells and aquifer tubes. Of all the COPCs monitored, only tritium concentrations exceeded the 20,000 pCi/L DWS in one seep from the Hanford town site. Results of three samples from the seep ranged from 29,300 to 52,600 pCi/L (DOE/RL-2008-66).

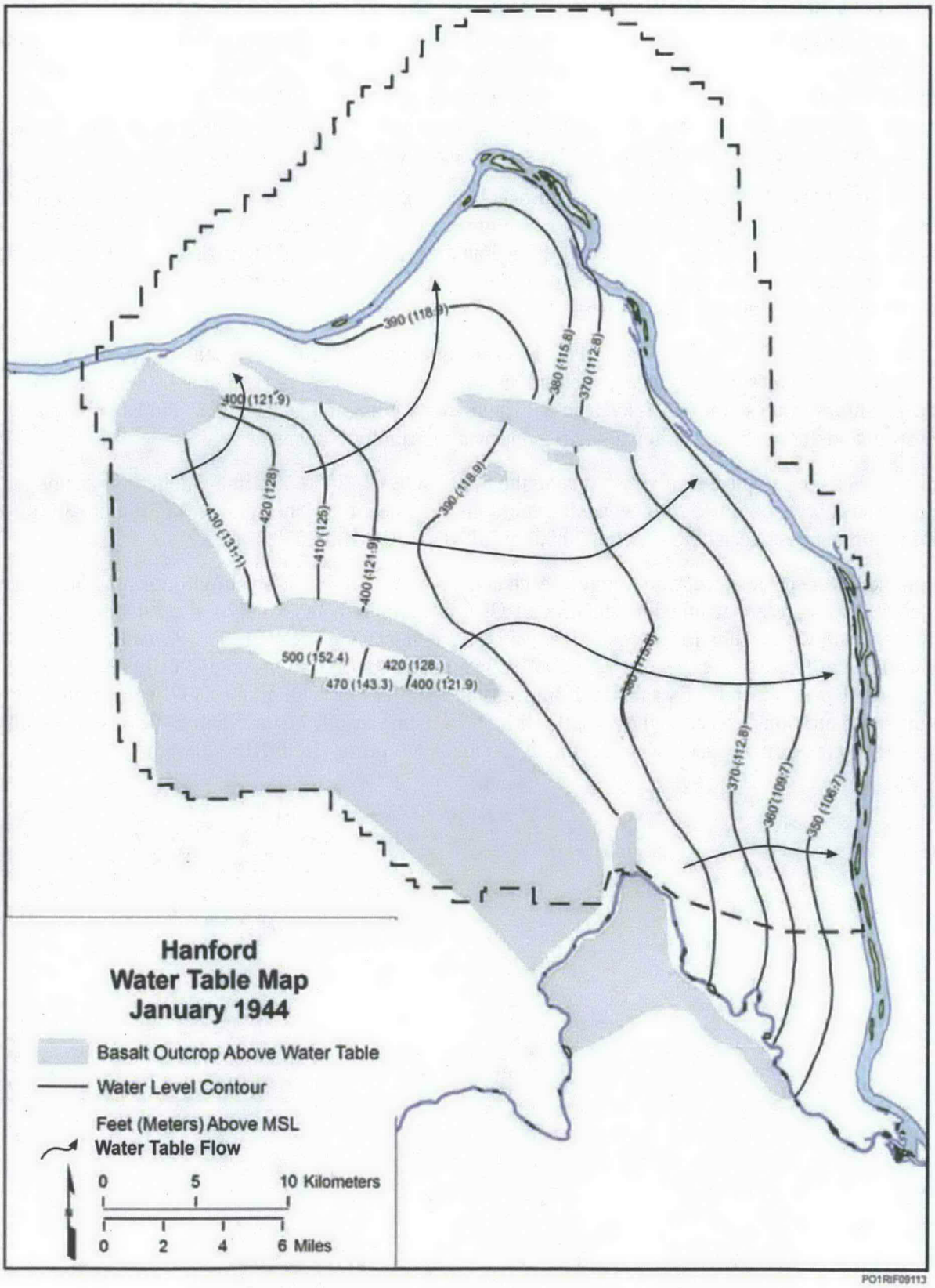



Figure 3-58. Inferred Pre-Hanford Site Operations Water Table Map

Tritium Concentration in Groundwater Time Series Plots for Selected Wells in 200-PO-1 Groundwater OU Indicating Concentration Peak Arrival Times

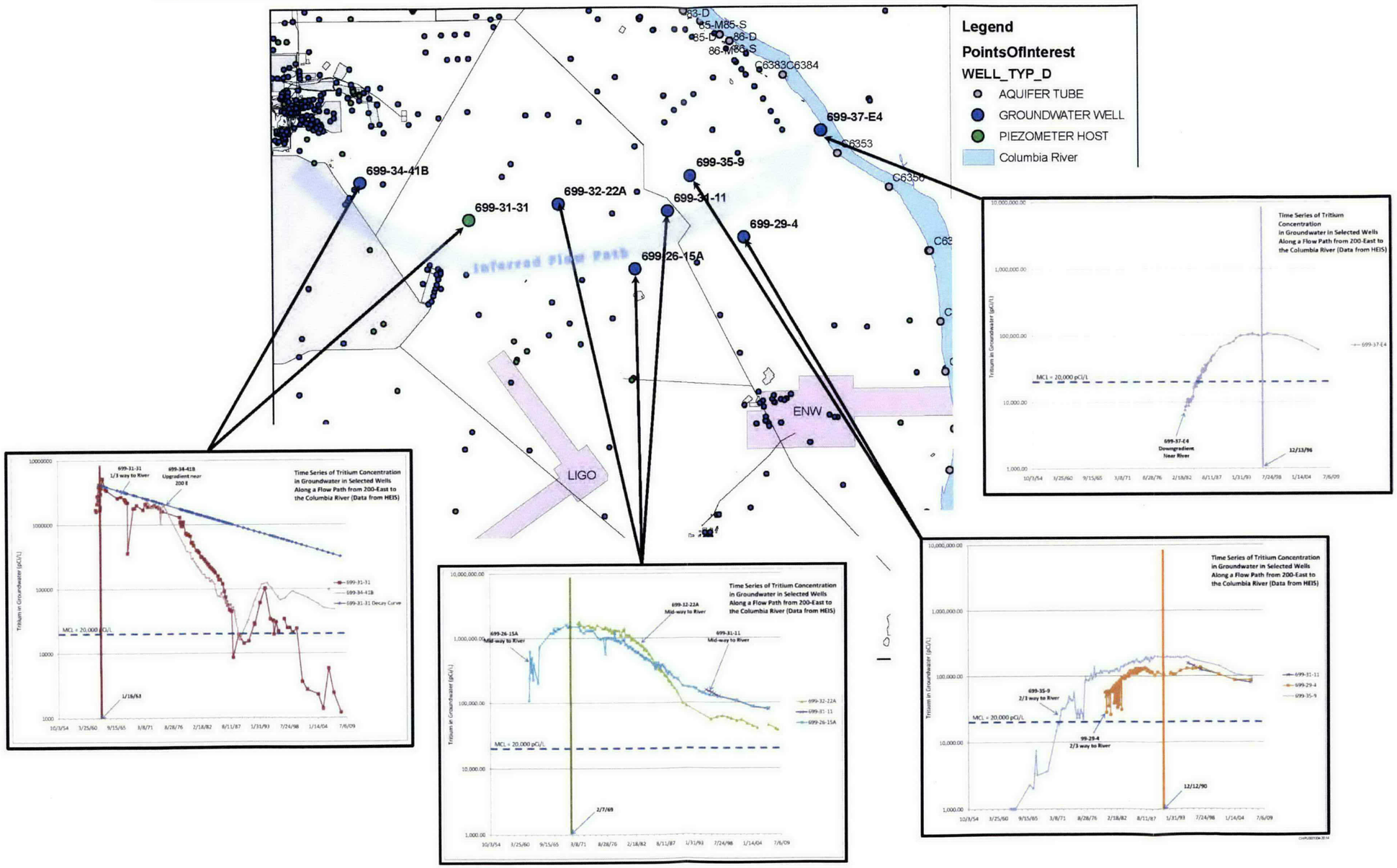



Figure 3-59. Groundwater Flow Path and Velocity Estimation Based on Peak Tritium Contaminant Arrival Time

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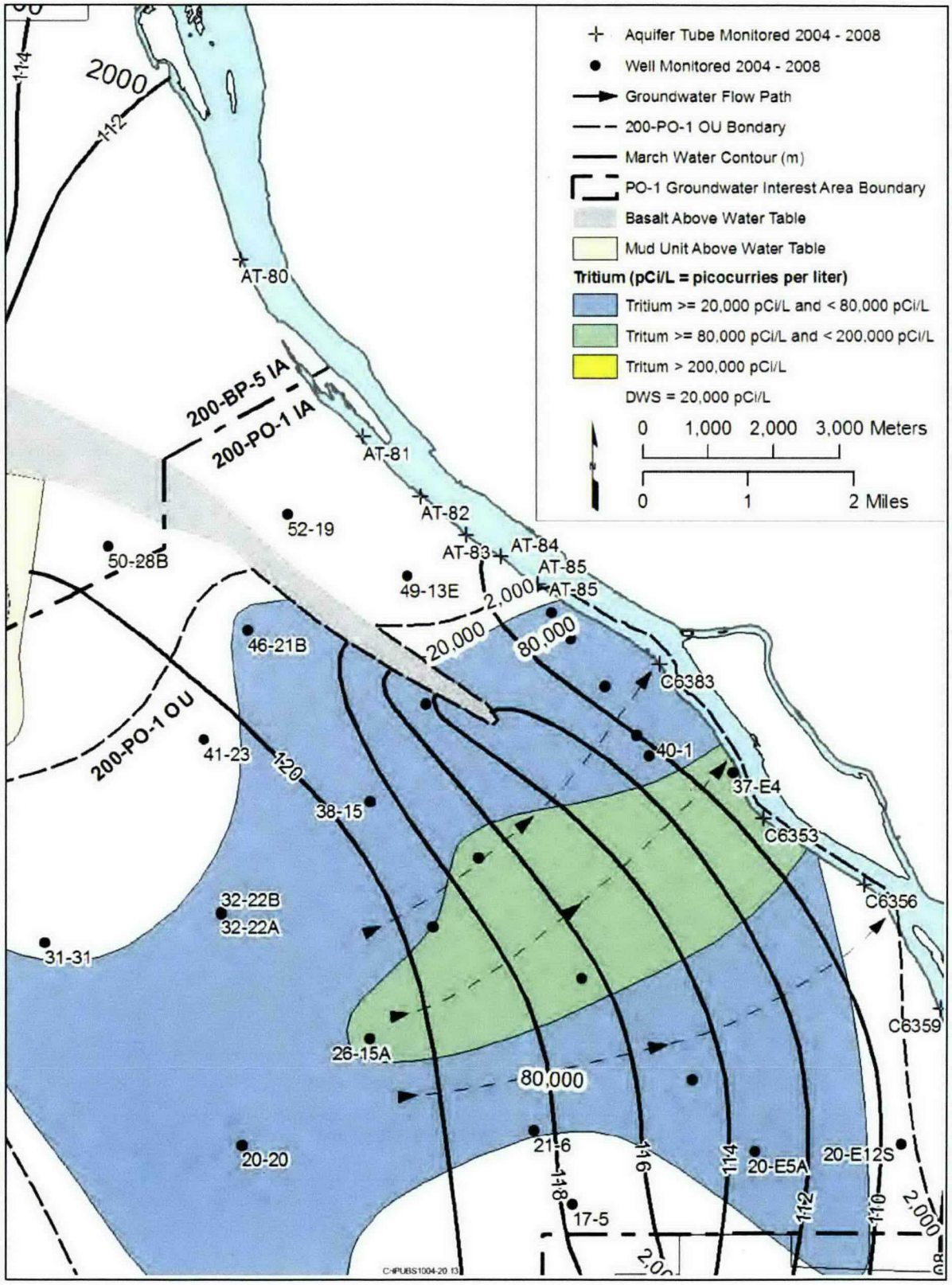



**Figure 3-60. Contaminant Preferential Flow Path at the Hanford Town Site**

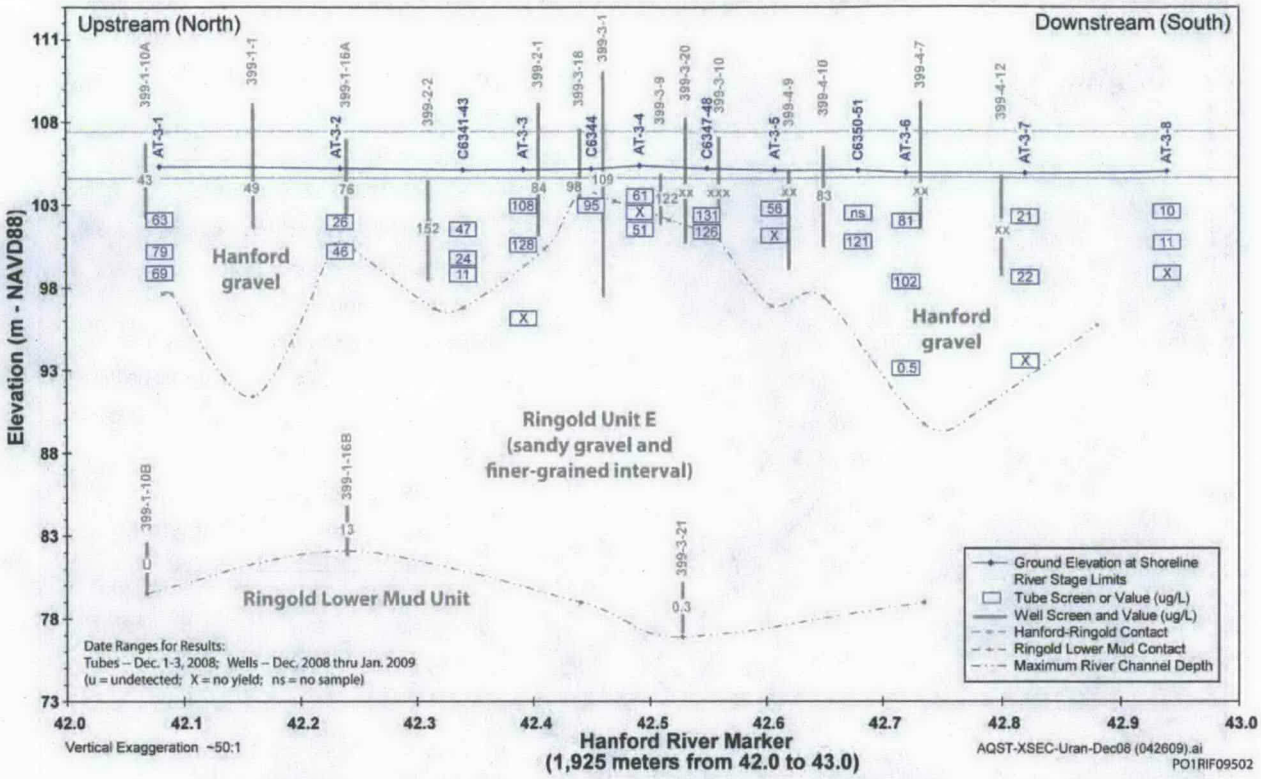
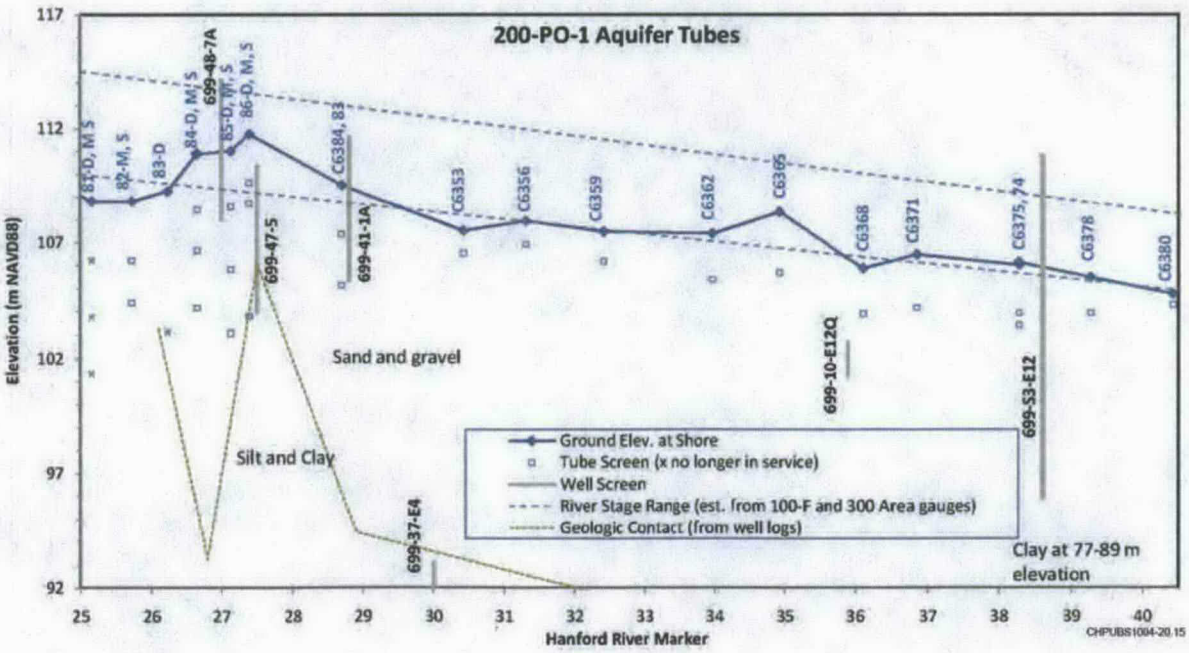



**Figure 3-61. Vertical Contaminant Uranium Concentrations Along the 300 Area Shoreline**




Note: The aquifer tube ID numbers are represented in blue, and the well ID numbers are in black.

**Figure 3-62. Aquifer Tube Distribution near the Hanford Town Site**

### 3.6.12 Summary of Aquifer Properties

Various physical properties of the unconfined aquifer were obtained from well drilling and borehole characterization activities conducted within the 200-PO-1 Groundwater OU. The property values are spatially variable (i.e., these properties vary across the Hanford Site). Model parameters were derived from the following sources:

- Porosity of HSUs was obtained from PNNL-14753, *Groundwater Data Package for Hanford Assessments*, and the data compilation were found in Appendix D of DOE/RL-2007-28, *Feasibility Study Report for the 200-ZP-1 Groundwater Operable Unit.*

- Initial values of hydraulic conductivity for HSUs were based upon the data compilation presented in Appendix D of DOE/RL-2007-28. Vertical hydraulic conductivity was assumed to be one-tenth of horizontal conductivity in all HSUs. Hydraulic conductivity values were then calibrated against measure hydraulic head data from the historic period of 1944 through 2006.

- For thickness of HSUs, stratigraphy data were obtained from PNNL-14753. The stratigraphy was lumped into five HSUs: Hanford fm, Ringold gravel Unit E and Unit C, coarse grained upper Ringold Unit B and Unit D, Ringold LMU, and coarse grained Ringold Unit A (DOE/RL-2008-56, *200-West Area Pre-Conceptual Design for Final Extraction/Injection Well Network: Modeling Analyis*; DOE/RL-2009-38, *Description of Modeling Analysis in Support of the 200-ZP-1 Remedial Design/Remedial Action Work Plan*). One of these HSUs (Ringold B and C) as described in DOE/RL-2008-56, has been combined with Ringold LMU until the 200 Area data package is completed (PNNL-17913, *Hydrogeology of the Hanford Site Central Plateau – A Status Report for the 200 West Area*). The top and bottom elevations were based on PNNL-14753. A minimum thickness of 1 m (3.3 ft) was used to represent units where they are less than 1 m (3.3 ft) thick to enhance model stability.

Full details on the source and use of these model parameters and model parameter calibration are provided in ECF-200PO1-09-2352, *200-PO-1 Groundwater Operable Unit Remedial Investigation Report – Near-Field Groundwater Contaminant Fate and Transport Modeling.*

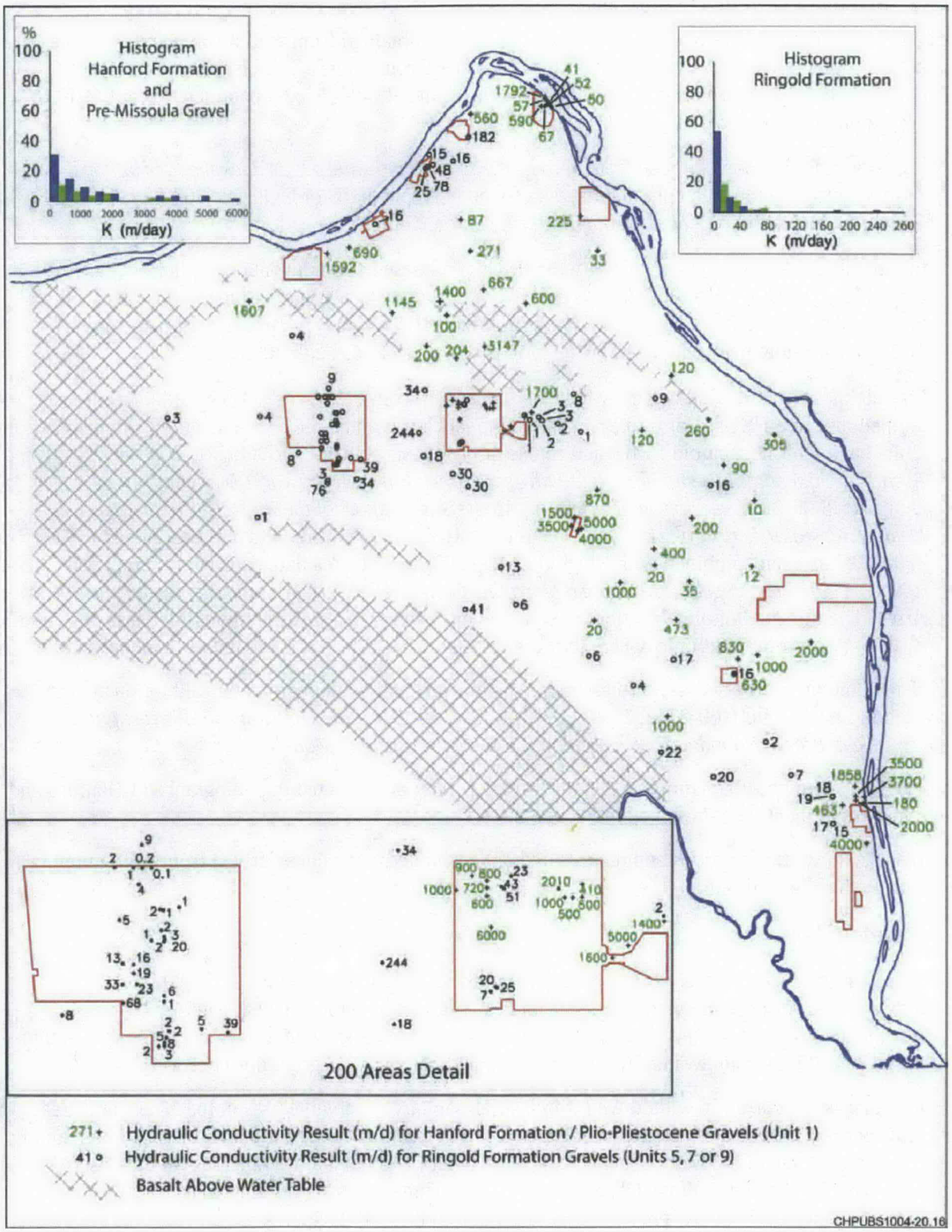
The variable sediments that comprise the unconfined aquifer are depicted in photographs of Hanford and Ringold Fm sediment core presented in Section 3.6.6.

Figure 3-63 shows the locations and relative hydraulic conductivity values derived from well pumping tests across the Hanford Site.

## 3.7 Water Use

Groundwater and surface water are removed for use extensively in the vicinity of the 200-PO-1 Groundwater OU for drinking water, process applications, and irrigation. The Columbia River also is used for the discharge of treated wastewater effluent; some treated effluent also is discharged to ground within the 200-PO-1 Groundwater OU where it eventually reaches the groundwater.

Groundwater is not currently withdrawn for industrial, sanitary, or potable uses in the Near Field area. Groundwater is withdrawn for dust supression in the 600 Area, for backup fire and sanitary water supply at the Columbia Generating Station, and for backup sanitary and potable water supply at the Laser Interferometer Gravitational Wave Observatory (LIGO). Three wells are designated as water supply wells, but only one (499-S1-8J) provides drinking water to the 400 Area.




Source: From PNNL-13641

**Figure 3-63. Hydraulic Conductivity Values Derived from Well Pump Tests**

### 3.7.1 Surface Water Use in the Vicinity of the 200-PO-1 Groundwater OU

The Columbia River is used as a source of both drinking water and industrial water for several Hanford Site facilities (PNNL-15892). The water systems of Richland, Pasco, and Kennewick drew a large portion of the 48.8 billion L (12.9 billion gal) used during 2006 from the Columbia River. Each city operates its own supply and treatment system, located downgradient and downriver of the Hanford Site. The Richland water supply system derives about 82 percent of its water directly from the Columbia River, while the remainder is split between a well field in North Richland (that is recharged from the river) and groundwater wells. The city of Richland's total water usage during 2006 was 20.1 billion L (5.3 billion gal). The Kennewick system uses two wells and the Columbia River for its water supplies. These wells serve as the sole source of water between November and March and can provide approximately 40 percent of the total maximum supply of 94.6 billion liters per day (25 million gal). Total 2006 usage in Kennewick was 13.4 billion L (3.5 billion gal). A significant number of Kennewick's residents (about 22,000 residential customers) draw irrigation water from the Kennewick Irrigation District, which has the Yakima River as its source. The city of Pasco system also draws from the Columbia River for its water needs. During 2006, Pasco consumed 15.3 billion L (4.1 billion gal). Energy Northwest operates the Columbia Generating Station northeast of the 400 Area and within the geographic boundaries of the 200-PO-1 Groundwater OU. Energy Northwest uses Columbia River water for both potable and process/cooling water applications.

## 3.8 Ecology

Terrestrial ecosystems on the Hanford Site and overlying the 200-PO-1 Groundwater OU include upland and riparian/wetland habitat. Upland habitat at the Hanford Site is influenced by the arid climate and characterized by vegetation and wildlife adapted to hot summers, cold winters, and low precipitation. Riparian habitat occurs along bodies of water and is inhabited by plants with greater requirements for water than upland plants. Wetlands are areas where some open water is present and soils and associated vegetation reflect the presence of water. The distribution of plants within the upland habitat on the Hanford Site is greatly influenced by soil type, altitude, and precipitation. Range fires, the industrial activities of humans, and the introduction of non-native species also have affected ecosystems.

The upland habitat within the Hanford Site, located within the Columbia Basin (Plateau) Ecoregion, is predominantly shrub-steppe (Stoms et al., 1997, *Preserve Selection Modeling in the Columbia Plateau*). Shrub-steppe ecosystems are typified by a shrub overstory and a grass and forb understory (Daubenmire, 1970, *Steppe Vegetation of Washington*). Lichens and mosses, often referred to as "microbiotic or cryptogamic crust," provide a soil stabilizing growth on undisturbed soils in the shrub-steppe ecosystem.

Riparian areas are vegetated wetlands, especially associated with rivers and streams, and include shoreline areas along sloughs and backwaters. Riparian habitat that occurs in association with the Columbia River includes riffles, gravel bars, backwater sloughs, and cobble shorelines. These habitats occur infrequently along the Hanford Reach and have acquired greater significance because of the net loss of wetland habitat elsewhere within the region.

Riparian areas provide nesting and foraging habitat and escape cover for many species of birds and mammals. Shoreline riparian communities are seasonally important for a variety of species. The Hanford Site is located in the Pacific Flyway, and the Hanford Reach serves as a resting area for neotropical migrant birds, migratory waterfowl, and shorebirds (TNC, 1999, *Biodiversity Inventory and Analysis of the Hanford Site, Final Report 1994-1999*). The area between the old Hanford town site (overlying the 200-PO-1 Groundwater OU) and the Vernita Bridge is closed to recreational hunting, and large numbers of migratory waterfowl find refuge in this portion of the river.

Mammals occurring primarily in riparian areas include rodents, bats, furbearers (e.g., mink [*Mustela vison*] and weasel [*Mustela* spp.]), porcupine (*Erithizon dorsatum*), raccoon (*Procyon lotor*), skunk (*Mephitis mephitis*), and mule deer. Beavers (*Castor canadensis*) rely on shoreline habitat for dens and foraging. River otters (*Lutra canadensis*) have been observed infrequently in the Hanford Reach. During the summer, mule deer rely on riparian vegetation for foraging. Mule deer use Columbia River islands for fawning and nursery areas. Beaver and muskrat (*Ondatra zibethica*) rely on shoreline habitat for dens and foraging. The Columbia River and Rattlesnake Springs provide foraging habitat for bats, including Yuma myotis (*Myotis yumanensis*), small-footed myotis (*Myotis subulatus*), silver-haired bats (*Lasionycteris octivagans*), and pallid bats (*Antrozous pallidus*), all of which feed on emergent aquatic insects (PNL-8916, *A Preliminary Survey of Selected Structures on the Hanford Site for Townsend's Big-Eared Bat* (Plecotus townsendii).

Along with the reptiles and insects identified in the grasslands discussion, five amphibians have been identified on the Hanford Site. The Great Basin spadefoot toad (*Scaphiopus intermontanus*), western toad (*Bufo boreas*), Woodhouse's toad (*Bufo woodhousei*), tiger salamander (*Ambystoma tigrinum*), and bullfrog (*Rana catesbeiana*) are the only amphibians found in immediate proximity to water on the Hanford Site (TNC, 1999; WHC-SD-EN-TI-121, *Biological Resources of the 300-FF-5 Operable Unit*).

Ecological assessments of the surface area and river within the 200-PO-1 Groundwater OU are currently being conducted as part of the ecological risk assessment and the RI work plan (DOE/RL-2008-11, *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River*).

DOE policies require that all Hanford Site projects, with the potential to have an adverse effect on biological resources, have an ecological compliance review conducted before the project starts. The purposes of the *Endangered Species Act of 1973* are to:

- Provide a means to conserve critical ecosystems.
- Provide a program for the conservation of endangered and threatened species.
- Ensure that appropriate steps are taken to achieve the purposes of the treaties and conventions established under the act.

Washington State also lists species as endangered and threatened, but such a listing does not carry the protection of the federal *Endangered Species Act of 1973*. The U.S. Fish and Wildlife Service (USFWS) has responsibility for all other federally listed species on the Hanford Site. Table 3-3 lists the species of plants and animals that occur or potentially occur on the Hanford Site and are listed as endangered, threatened, sensitive, or candidate by either the federal or state governments. The *Migratory Bird Treaty Act* prohibits taking or disturbing specified migratory birds or their feathers, eggs, or nests. All Hanford Site projects with a potential to affect federal or state-listed species of concern complied with the requirements of this act by using the ecological compliance review process as described in DOE/RL-96-32, *Hanford Site Biological Resources Management Plan* (PNNL-18427).

**Table 3-3. List of Endangered, Threatened, Sensitive, and Candidate Species Occurring or Potentially Occurring in the 200-PO-1 Area on the Hanford Site (PNNL-18427)**

| Common Name | Scientific Name | Federal Status | State Status |
|---|---|---|---|
| | **Plants** | | |
| Awned halfchaff sedge | *Lipocarpha (=Hemicarpha) aristulata* | | Threatened |
| Beaked spike-rush | *Eleocharis rostellata* | | Sensitive |
| Canadian St. John's wort | *Hypericum majus* | | Sensitive |
| Chaffweed | *Anagallis (=Centunculus) minimus* | | Threatened |
| Columbia milkvetch | *Astragalus columbianus* | Species of concern | Sensitive |
| Columbia yellowcress | *Rorippa columbiae* | Species of concern | Endangered |
| Coyote tobacco | *Nicotiana attenuata* | | Sensitive |
| Desert dodder | *Cuscuta denticulata* | | Threatened |
| Desert evening-primrose | *Oenothera caespitosa* | | Sensitive |
| Dwarf evening primrose | *Camissonia (= Oenothera) pygmaea* | | Sensitive |
| Fuzzy tongue penstemon | *Penstemon eriantherus whitedii* | | Sensitive |
| Geyer's milkvetch | *Astragalus geyeri* | | Threatened |
| Grand redstem | *Ammannia robusta* | | Threatened |
| Gray cryptantha | *Cryptantha leucophaea* | Species of concern | Sensitive |
| Great Basin gilia | *Aliciella (=Gilia) leptomeria* | | Threatened |
| Hoover's desert parsley | *Lomatium tuberosum* | Species of concern | Sensitive |
| Loeflingia | *Loeflingia squarrosa var. squarrosa* | | Threatened |
| Lowland toothcup | *Rotala ramosior* | | Threatened |
| Desert cryptantha | *Cryptantha scoparia* | | Sensitive |
| Piper's daisy | *Erigeron piperianus* | | Sensitive |
| Rosy pussypaws | *Cistanthe (=Calyptridium) roseum* | | Threatened |
| Small-flowered evening-primrose | *Camissonia (=Oenothera) minor* | | Sensitive |
| Snake River cryptantha | *Cryptantha spiculifera (=C. interrupta)* | | Sensitive |
| Suksdorf's monkey flower | *Mimulus suksdorfii* | | Sensitive |
| Umtanum desert buckwheat | *Eriogonum codium* | Candidate | Endangered |
| White Bluffs | bladderpod *Physaria (=Lesquerella) douglasii* ssp.*tuplashensis* | Candidate | Threatened |

**Table 3-3. List of Endangered, Threatened, Sensitive, and Candidate Species Occurring or Potentially Occurring in the 200-PO-1 Area on the Hanford Site (PNNL-18427)**

| Common Name | Scientific Name | Federal Status | State Status |
|---|---|---|---|
| White eatonella | *Eatonella nivea* | | Threatened |
| **Mollusks** | | | |
| California floater | *Anodonta californiensis* | Species of concern | Candidate |
| Great Columbia River spire snail | *Fluminicola columbiana* | Species of concern | Candidate |
| Shortfaced lanx | *Fisherola nuttalli* | | Candidate |
| **Insects** | | | |
| Columbia River tiger beetle[a] | *Cicindela columbica* | | Candidate |
| Silver-bordered fritillary | *Boloria selene atrocostalis* | | Candidate |
| **Fish** | | | |
| Bull trout[b] | *Salvelinus confluentus* | Threatened | Candidate |
| Leopard dace[b] | *Rhinichthys flacatus* | | Candidate |
| Mountain sucker[b] | *Catastomus platyrhynchus* | | Candidate |
| River lamprey[b] | *Lampetra ayresi* | Species of concern | Candidate |
| Spring-run Chinook salmon | *Oncorhynchus tshawytscha* | Endangered | Candidate |
| Steelhead | *Oncorhynchus mykiss* | Threatened | Candidate |
| **Amphibians and Reptiles** | | | |
| Sagebrush lizard | *Sceloporus graciosus* | Species of concern | Candidate |
| Striped whipsnake | *Masticophis taeniatus* | | Candidate |
| Western toad | *Bufo boreas* | | Candidate |
| **Birds** | | | |
| American white pelican | *Pelecanus erythrorhynchos* | | Endangered |
| Bald eagle | *Haliaeetus leucocephalus* | Species of concern | Sensitive[c] |
| Burrowing owl | *Athene cunicularia* | Species of concern | Candidate |
| Common loon | *Gavia immer* | | Sensitive |
| Ferruginous hawk | *Buteo regalis* | Species of concern | Threatened |
| Flamulated owl[b] | *Otus flammeolus* | | Candidate |
| Golden eagle | *Aquila chrysaetos* | | Candidate |
| Greater sage grouse | *Centrocercus urophasianus* | Candidate | Threatened |

**Table 3-3. List of Endangered, Threatened, Sensitive, and Candidate Species Occurring or Potentially Occurring in the 200-PO-1 Area on the Hanford Site (PNNL-18427)**

| Common Name | Scientific Name | Federal Status | State Status |
|---|---|---|---|
| Lewis's woodpecker[b] | *Melanerpes lewis* | | Candidate |
| Loggerhead shrike | *Lanius ludovicianus* | Species of concern | Candidate |
| Merlin | *Falco columbarius* | | Candidate |
| Northern goshawk[b] | *Accipter gentilis* | Species of concern | Candidate |
| Olive-sided flycatcher | *Contopus cooperi* | Species of concern | |
| Peregrine falcon | *Falco peregrinus* | Species of concern | Sensitive |
| Sage sparrow | *Amphispiza belli* | | Candidate |
| Sage thrasher | *Oreoscoptes montanus* | | Candidate |
| Sandhill crane | *Grus canadensis* | | Endangered |
| Western grebe | *Aechmophorus occidentalis* | | Candidate |
| **Mammals** | | | |
| Black-tailed jackrabbit | *Lepus californicus* | | Candidate |
| Merriam's shrew | *Sorex merriami* | | Candidate |
| Townsend's ground squirrel | *Spermophilus townsendii* | Species of concern | Candidate |
| Washington ground squirrel[b] | *Spermophilus washingtoni* | Candidate | Candidate |
| White-tailed jackrabbit | *Lepus townsendii* | | Candidate |

Notes:

a. Probable, but not observed, on the Hanford Site.

b. Reported, but seldom observed, on the Hanford Site.

c. Reclassified in January 2008.

| | | |
|---|---|---|
| Endangered | = | Species in danger of extinction within all or a significant portion of its range |
| Threatened | = | Species likely to become endangered in the foreseeable future |
| Candidate | = | Species that are believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared |
| Sensitive | = | Taxa that are vulnerable or declining and could become endangered or threatened without active management or removal of threats |
| Species of concern | = | Species that are not currently listed or candidates under the *Endangered Species Act*, but are of conservation concern within specific U.S. Fish and Wildlife Service regions |

This section lists federal and state endangered and threatened species, candidate or sensitive plant and animal species, and other species of concern potentially found on the Hanford Site. Endangered species are those in danger of extinction within all or a significant portion of their range. Threatened species are those likely to become endangered in the foreseeable future. Sensitive species are species that are vulnerable or declining and could become endangered or threatened without active management or

removal of threats. The federal list of endangered and threatened species is maintained by the USFWS in 50 CFR 17.11, "Endangered and Threatened Wildlife and Plants," "Endangered and Threatened Wildlife," and 50 CFR 17.12, "Endangered and Threatened Wildlife and Plants," "Endangered and Threatened Plants." The state lists are maintained by the *List of Plants Tracked by the Washington Natural Heritage Program* (WNHP, 2009) and the Washington Department of Fish and Wildlife (WDFW, 2009) (PNNL-18427).

For the purposes of risk assessment in the 200-PO-1 Groundwater OU, Table 3-4 outlines species which could be directly affected by the groundwater contamination and possible discharges into the Columbia River. Plants and birds were determined to be affected by based on habitat preferences established in DOE/RL 96-32.

**Table 3-4. List of Endangered, Threatened, Sensitive, and Candidate Species Affected by Discharges to the Columbia River in the 200-PO-1 Area on the Hanford Site (PNNL-18427)**

| Common Name | Scientific Name | Federal Status | State Status |
|---|---|---|---|
| | **Plants[a]** | | |
| Awned halfchaff sedge | *Lipocarpha (=Hemicarpha) aristulata* | | Threatened |
| Canadian St. John's wort | *Hypericum majus* | | Sensitive |
| Columbia yellowcress | *Rorippa columbiae* | Species of concern | Endangered |
| Desert evening-primrose | *Oenothera caespitosa* | | Sensitive |
| Fuzzy tongue penstemon | *Penstemon eriantherus whitedii* | | Sensitive |
| Geyer's milkvetch | *Astragalus geyeri* | | Threatened |
| Grand redstem | *Ammannia robusta* | | Threatened |
| Loeflingia | *Loeflingia squarrosa var. squarrosa* | | Threatened |
| Lowland toothcup | *Rotala ramosior* | | Threatened |
| Snake River cryptantha | *Cryptantha spiculifera (=C. interrupta)* | | Sensitive |
| | **Mollusks** | | |
| California floater | *Anodonta californiensis* | Species of concern | Candidate |
| Great Columbia River spire snail | *Fluminicola columbiana* | Species of concern | Candidate |
| | **Fish** | | |
| Bull trout | *Salvelinus confluentus* | Threatened | Candidate |
| Leopard dace | *Rhinichthys flacatus* | | Candidate |
| Mountain sucker | *Catastomus platyrhynchus* | | Candidate |
| River lamprey | *Lampetra ayresi* | Species of concern | Candidate |
| Spring-run Chinook salmon | *Oncorhynchus tshawytscha* | Endangered | Candidate |
| Steelhead | *Oncorhynchus mykiss* | Threatened | Candidate |

**Table 3-4. List of Endangered, Threatened, Sensitive, and Candidate Species Affected by Discharges to the Columbia River in the 200-PO-1 Area on the Hanford Site (PNNL-18427)**

| Common Name | Scientific Name | Federal Status | State Status |
|---|---|---|---|
| | **Birds[b]** | | |
| American white pelican | *Pelecanus erythrorhynchos* | | Endangered |
| Bald eagle | *Haliaeetus leucocephalus* | Species of concern | Sensitive |
| Common loon | *Gavia immer* | | Sensitive |
| Ferruginous hawk | *Buteo regalis* | Species of concern | Threatened |
| Peregrine falcon | *Falco peregrinus* | Species of concern | Sensitive |
| Western grebe | *Aechmophorus occidentalis* | | Candidate |

Notes:

a. Plants were determined directly affected based on habitats associated with each species outlined in Section D.2.5.2, Table D.4 of DOE/RL-96-32. Associated habitats selected were Bluffs, Columbia River, Islands, Riparian, and White Bluffs.

b. Birds were determined directly affected based on preferred habitat outlined in Section D.2.5.6, Table D.10 of DOE/RL-96-32. Birds preferential to freshwater were selected.

| | | |
|---|---|---|
| Endangered | = | Species in danger of extinction within all or a significant portion of its range |
| Threatened | = | Species likely to become endangered in the foreseeable future |
| Candidate | = | Species that are believed to qualify for threatened or endangered species status, but for which listing proposals have not been prepared |
| Sensitive | = | Taxa that are vulnerable or declining and could become endangered or threatened without active management or removal of threats |
| Species of concern | = | Species that are not currently listed or candidates under the *Endangered Species Act*, but are of conservation concern within specific U.S. Fish and Wildlife Service regions |

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# 4 Nature and Extent of Contamination

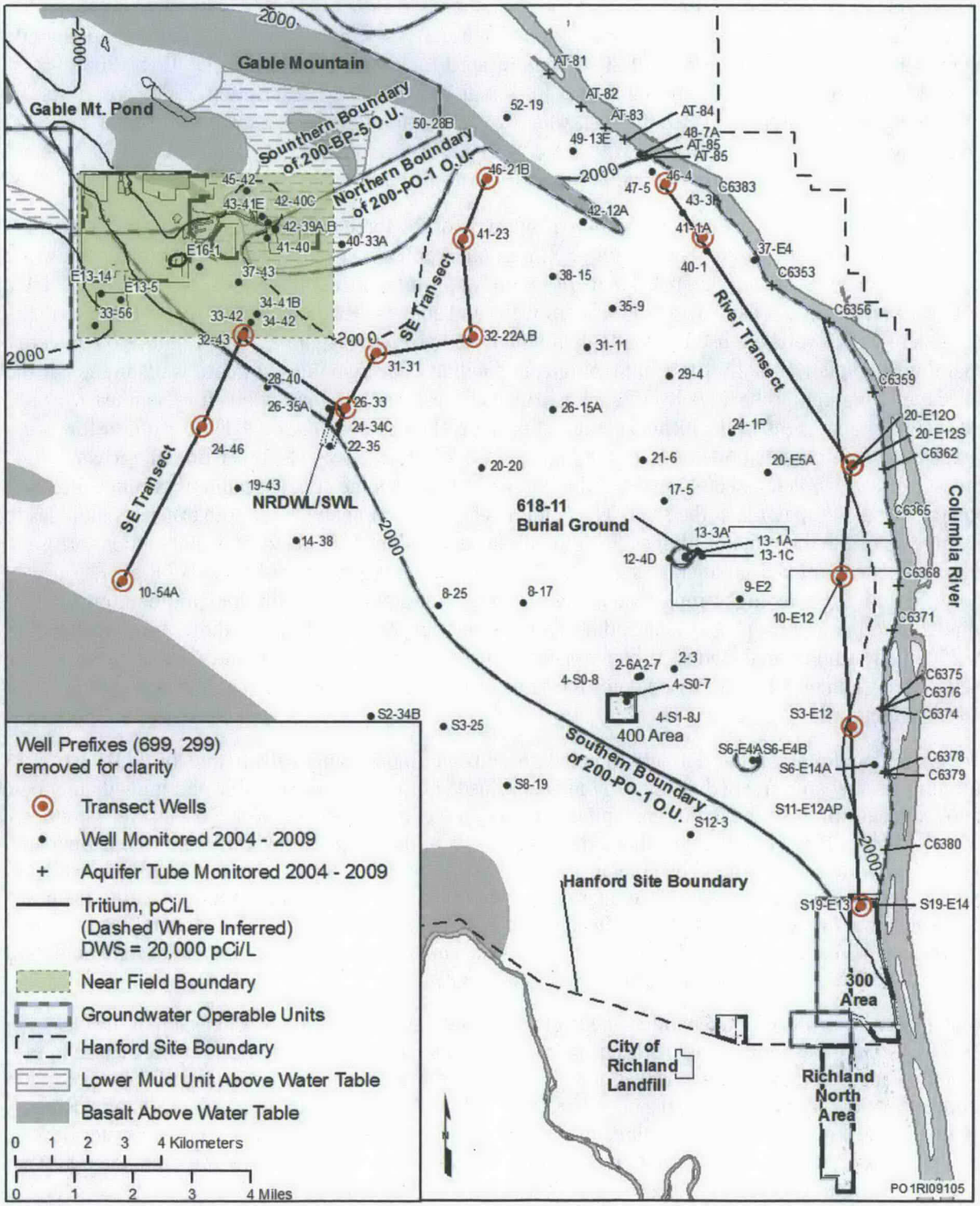
Contaminant plumes within the 200-PO-1 Groundwater OU are monitored routinely by 133 wells and 17 aquifer tubes (Figures 2-1 and 4-1) sampled annually to triennially (DOE/RL-2003-04), depending on the relevant compliance schedule. Of the 133 wells, 54 wells are used to routinely monitor groundwater near or within the 200 East Area (Near Field wells, Figure 2-1). Contaminant plume maps are prepared annually and presented in the Hanford Site Groundwater Monitoring Report (e.g., DOE/RL-2008-66, Hanford Site Groundwater Monitoring Report for Fiscal Year 2008). A description of this process is available in ECF-Hanford-10-0218, Groundwater Contamination Plume Map Contours, Fiscal Year 2008. The screening and evaluation of data, as well as the identification of COPCs for this OU, are described in ECF-200PO1-09-2018 and summarized in Section 6.1 of this RI.

The Near Field wells (Figure 2-1) are sampled annually for the three major plumes emanating from the 200 East Area (tritium, nitrate, and iodine-129), plus other potential groundwater contaminants known or suspected to occur based on the many years of groundwater monitoring in the area (DOE/RL-2003-04 and Table 2-3 and Table 2-4 have a complete list of wells and analytes for Near Field and Far Field wells). The remaining 79 wells are used to routinely monitor the Far Field (Figure 2-2 and Figure 4-1) and are generally sampled triennially for tritium, nitrate, and iodine-129. Two lines of guard wells in the Far Field area screen for a comprehensive list of analytes. One of these lines of guard wells (the Southeast Transect) contains eight wells, located southeast of the 200 East Area (Figure 4-1), to monitor for unexpected contaminants potentially migrating from the 200 East Area. The other line (the River Transect, six wells) is located along the Columbia River to assess the concentration of groundwater contamination that may reach the river. The comprehensive list of analytes for both transects includes the constituents of the three major plumes (tritium, nitrate, and iodine-129), as well as other anions, gross alpha and beta, gamma scan, metals, strontium-90, and volatile organic compounds (VOCs). The 17 aquifer tubes (6 existing, 1 replacement, and 10 new) are sampled annually for tritium, nitrate, iodine-129, other anions, gross alpha and beta, and technetium-99. The 10 new aquifer tubes installed in FY 2008 had samples analyzed for a comprehensive list of 44 analytes that are the same as those discussed in Table 4-1 (Table 4-1 contains the same analytes as Table 2-1 but also includes analytical methods).

One hundred and nine of the routinely sampled groundwater monitoring wells in the 200-PO-1 Groundwater OU are screened or open to the unconfined aquifer at the water table and immediately below where concentrations of the major contaminant plumes are generally the highest. Sixteen wells are open at intervals below the water table, yet above the lower LMU of the Ringold Fm. Only one well is open to the interval below the LMU (and above the underlying basalt) where the aquifer is often confined locally. Seven wells are screened or have open intervals in one or more of the confined aquifers within the basalt sequence below the Ringold Fm. Groundwater contaminants from the 618-10, 316-4, and 618-11 waste sites (Figure 4-1) are within the 300-FF-5 Interest Area, and the monitoring and potential remediation of those sites are addressed under the CERCLA 300-FF-5 OU.

Groundwater in the unconfined aquifer flows primarily to the southeast in the west portion of the OU (200 East Area) in response to higher heads in the west and the large paleochannel complex incised in the top of the Ringold Fm, which trends the same direction. In the central to eastern portion of the OU, groundwater flow fans outward to the northeast, east, and southeast as it approaches the Columbia River (Figure 3-25). Flow directions of the three major plumes reflect these general trends. Groundwater flow directions in the southeastern portion of the 200 East Area, and extending southeastward into the 600 Area, are difficult to interpret from water table maps because of the low hydraulic gradient in that local area. Based on the direction of the movement of the major contaminant plumes, however, the flow direction is interpreted to be southeastward. Vertical head differences in the OU generally increase with depth, forming an upward gradient. In the 200 East Area, the hydraulic head difference between the aquifers below the

Ringold Fm lower LMU and the unconfined aquifer ranges from a few centimeters to about one meter. Along the Columbia River, in the east side of the OU near Well 699-20-E12, the vertical head difference is about 10 m, while the 600 Area between the two areas has intermediate head differences.




(modified from PNNL 18)

**Figure 4-1. Far Field Wells**

**Table 4-1. Contaminants and Analytical Methods**

| Characterization Sampling and Analysis Plan | Analytical Method |
|---|---|
| 1,1,2,2-Tetrachloroethane | 8260B |
| 1,2-Dichloroethane | 8260B |
| 1,4-Dioxane | 8260/8270* |
| 2,4-Dinitrophenol | 8270 |
| Antimony | 6010B |
| Arsenic | 6010B |
| Benzene | 8260B |
| Bis(2-ethylhexyl)phthalate | 8270 |
| Bromodichloromethane | 8260B |
| Cadmium | 6010B/200.8 |
| Carbon tetrachloride | 8260B |
| Chromium | 6010B/200.8 |
| Dieldrin | 8081 |
| Dimethoate | 8270/8081* |
| Dibromochloromethane | 8260B |
| Fluoride | 300 |
| Gross alpha | 9310_ALPHABETA_GPA |
| Hexane | 8260B* |
| Heptachlor | 8081 |
| Heptachlor epoxide | 8081 |
| Iodine-129 | GEA/GPC |
| Lead | 6010B/200.8 |
| Manganese | 6010B/200.8 |
| Methylene chloride | 8260B |
| Neptunium-237 | GEA/GPC |
| Nickel | 6010B/200.8 |
| Nitrate | 300 |
| Nitrite | 300 |
| Nitrobenzene | 8270 |
| Pentachlorophenol | 8270 |
| Protactinium-231 | AEA |
| Selenium-79 | LSC |
| Strontium-90 | GPC |
| Technetium-99 | LSC |
| Thallium | 6010B/200.8 |
| Tritium | LSC |

**Table 4-1. Contaminants and Analytical Methods**

| Characterization Sampling and Analysis Plan | Analytical Method |
|---|---|
| Tetrachloroethene | 8260B |
| Trichloroethene | 8260B |
| Uranium | 6010B/200.8 |
| Uranium-234 | AEA/AS |
| Uranium-238 | AEA/AS |
| Vanadium | 6010B/200.8 |
| Vinyl chloride | 8260B |
| Zinc | 6010 B/200.8 |

Notes:
* Constituents can be requested to add to the regular list of analytes analyzed with this method.
LSC = liquid scintillation counting
AEA = alpha energy analysis
AS = alpha spectroscopy
GEA = gamma energy analysis
GPC = gas proportional counting

The exception to the general upward gradient is near B Pond and the TEDF, where the heads decrease with depth, possibly a condition remaining from the time that the B Pond System was in operation or due to the current discharges at TEDF.

The cribs, ponds, and ditches surrounding the PUREX Plant are responsible for most of the groundwater contamination in the 200-PO-1 Groundwater OU (Table 4-2). The PUREX Plant started operations in 1956, eventually replacing the Reduction-Oxidation (REDOX) Plant as the plutonium separations facility. The first PUREX operational campaign was from 1956 to 1972. Following an 11-year shutdown, the operations restarted in 1983 and shut down in December 1988 when the weapons production mission ended. Plant operation briefly restarted in December 1989 to stabilize material in the system. Groundwater contamination plumes from the PUREX Plant processes primarily contain those species associated with process condensates, including contaminants in the three major plumes (tritium, nitrate, and iodine-129). Some strontium-90 and technetium-99 also are associated with PUREX waste disposal, though technetium-99 is not found above the 900 pCi/L DWS in contaminant plumes from PUREX cribs. Technetium-99 exceeds the DWS beneath WMA A-AX.

In addition to the routine sampling of 133 wells, the 200-PO-1 Groundwater OU RI work plan (DOE/RL-2007-31, Appendix A) called for the sampling of an additional 43 wells (asterisked items in Table 2-3 and Table 2-4, and Figure 4-2) that were to be sampled one time only for an extensive list of 44 analytes (Table 4-1). The purpose of monitoring these 43 wells was to sample older, deeper, or isolated wells (and specific, routinely sampled wells) for a broad list of potential contaminants to ensure that the annual routine sampling effort had not missed any groundwater contamination. The results from this more comprehensive sampling effort are included in the discussion of the individual COPCs in Section 4.2 and Section 4.3.

**Table 4-2. Waste Sites Above the 200-PO-1 Groundwater Operable Unit**

| Waste Site | OU | PC | Waste Site | OU | PC | Waste Site | OU | PC | Waste Site | OU | PC |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cribs** | | | **Trenches** | | | **French Drains** | | | **Septic Systems** | | |
| 216-A-1 | PW-2 | N | 216-A-18 | PW-2 | Y | 216-A-11 | MW-1 | Y | 2607-E6 | ST-1[b] | N |
| 216-A-2 | PW-3 | N | 216-A-19 | PW-2 | Y | 216-A-12 | MW-1 | Y | 2607-E7 | ST-1[b] | N |
| 216-A-3 | PW-2 | Y | 216-A-20 | PW-2 | Y | 216-A-13 | MW-1 | Y | 2607-E8 | ST-1[b] | N |
| 216-A-4 | MW-1 | Y | 216-A-40 | CW-1 | N | 216-A-14 | MW-1 | N | 2607-E11 | ST-1[b] | N |
| 216-A-5 | PW-2 | Y | 216-B-20 | TW-1[a] | Y | 216-A-15 | LW-2 | Y | 2607-E12 | ST-1[b] | N |
| 216-A-6 | SC-1 | Y | 216-B-21 | TW-1[a] | Y | 216-A-16 | PO-3 | Y | 2607-EE | ST-1[b] | N |
| 216-A-7 | PW-3 | Y | 216-B-22 | TW-1[a] | Y | 216-A-17 | PO-3 | Y | 2607-EK | ST-1[b] | N |
| 216-A-8 | PW-3 | Y | 216-B-23 | TW-1[a] | Y | 216-A-23A | PO-3 | N | 2607-EL | ST-1[b] | N |
| 216-A-9 | CW-1 | Y | 216-B-24 | TW-1[a] | Y | 216-A-23B | PO-3 | N | 2607-EM | ST-1[b] | N |
| 216-A-10 | PW-2 | Y | 216-B-25 | TW-1[a] | N | 216-A-22 | MW-1 | N | 2607-EN | ST-1[b] | N |
| 216-A-21 | MW-1 | Y | 216-B-26 | TW-1[a] | Y | 216-A-26 | MW-1 | Y | 2607-EO | ST-1[b] | N |
| 216-A-24 | PW-3 | Y | 216-B-27 | TW-1[a] | N | 216-A-26-A | MW-1 | Y | 2607-EP | ST-1[b] | N |
| 216-A-27 | MW-1 | Y | 216-B-28 | TW-1[a] | Y | 216-A-28 | PW-2 | Y | 2607-EQ | ST-1[b] | N |
| 216-A-30 | SC-1 | Y | 216-B-29 | TW-1[a] | Y | 216-A-33 | MW-1 | N | 2607-ER | ST-1[b] | N |
| 216-A-31 | PW-3 | N | 216-B-30 | TW-1[a] | Y | 216-A-35 | MW-1 | N | 2607-ER1 | ST-1[b] | N |
| 216-A-32 | MW-1 | N | 216-B-31 | TW-1[a] | N | | | | 2607-EZ | ST-1[b] | N |
| 216-A-36A | PW-2 | Y | 216-B-32 | TW-1[a] | Y | **Ponds** | | | 2607-GF | ST-1[b] | N |
| 216-A-36B | PW-2 | Y | 216-B-33 | TW-1[a] | Y | 216-B-3 | CW-1 | Y | | | |
| 216-A-37-1 | PW-4 | Y | 216-B-34 | TW-1[a] | Y | 216-B-3A,B,C | CW-1 | N | **Unplanned Releases** | | |
| 216-A-37-2 | SC-1 | Y | 216-B-52 | TW-1[a] | Y | 2101-M Pond | CW-1 | N | 200-E-43 | UR-1 | N |
| 216-A-38-1 | MW-1 | N | 216-B-53-A | TW-1[a] | Y | | | | 200-E-44 | UR-1 | N |
| 216-A-39 | PO-3 | N | 216-B-53-B | TW-1[a] | N | **Ditches** | | | 200-E-103 | UR-1 | N |
| 216-A-41 | MW-1 | N | 216-B-54 | TW-1[a] | N | 216-A-29 | CS-1 | Y | 200-E-107 | UR-1 | N |
| 216-A-45 | PW-4 | Y | 216-B-58 | TW-1[a] | N | 216-A-34 | PW-4 | N | UPR-200-E-10 | UR-1 | N |
| 216-B-14 | TW-1[a] | Y | | | | | | | UPR-200-E-12 | UR-1 | N |
| 216-B-15 | TW-1[a] | Y | **Burial Sites** | | | **Tank Farms** | | | UPR-200-E-17 | UR-1 | N |
| 216-B-16 | TW-1[a] | Y | NRDWL/SWL | SW-2 | Y | 241-A (6) | SST | Y | UPR-200-E-18 | UR-1 | N |
| 216-B-17 | TW-1[a] | Y | 218-E-1 | SW-2 | N | 241-AP (7) | DST | N | UPR-200-E-19 | UR-1 | N |
| 216-B-18 | TW-1[a] | Y | | | | 241-AW (6) | DST | N | UPR-200-E-29 | UR-1 | N |
| 216-B-19 | TW-1[a] | Y | | | | 241-AX (4) | SST | Y | UPR-200-E-33 | UR-1 | N |
| | | | | | | 241-AY (2) | DST | N | UPR-200-E-36 | UR-1 | N |
| **Retention Basins** | | | | | | 241-AZ (2) | DST | N | UPR-200-E-142 | UR-1 | N |
| 207-A-North | SC-1 | N | | | | Diversion Boxes | SST | Y | UPR-200-E-143 | UR-1 | N |
| 207-A-South | SC-1 | N | | | | Diversion Boxes | DST | N | | | |

Notes:

a. 200-TW-1 was changed to 200-BC-1 in 2007.

b. 200-ST-1 was changed to 200-MG-1 in 2007.

| | | |
|---|---|---|
| DST | = | double-shell tank |
| NRDWL | = | Nonradioactive Dangerous Waste Landfill |
| OU | = | operable unit |
| PC | = | potential contribution |
| SST | = | single-shell tank |
| SWL | = | Solid Waste Landfill |

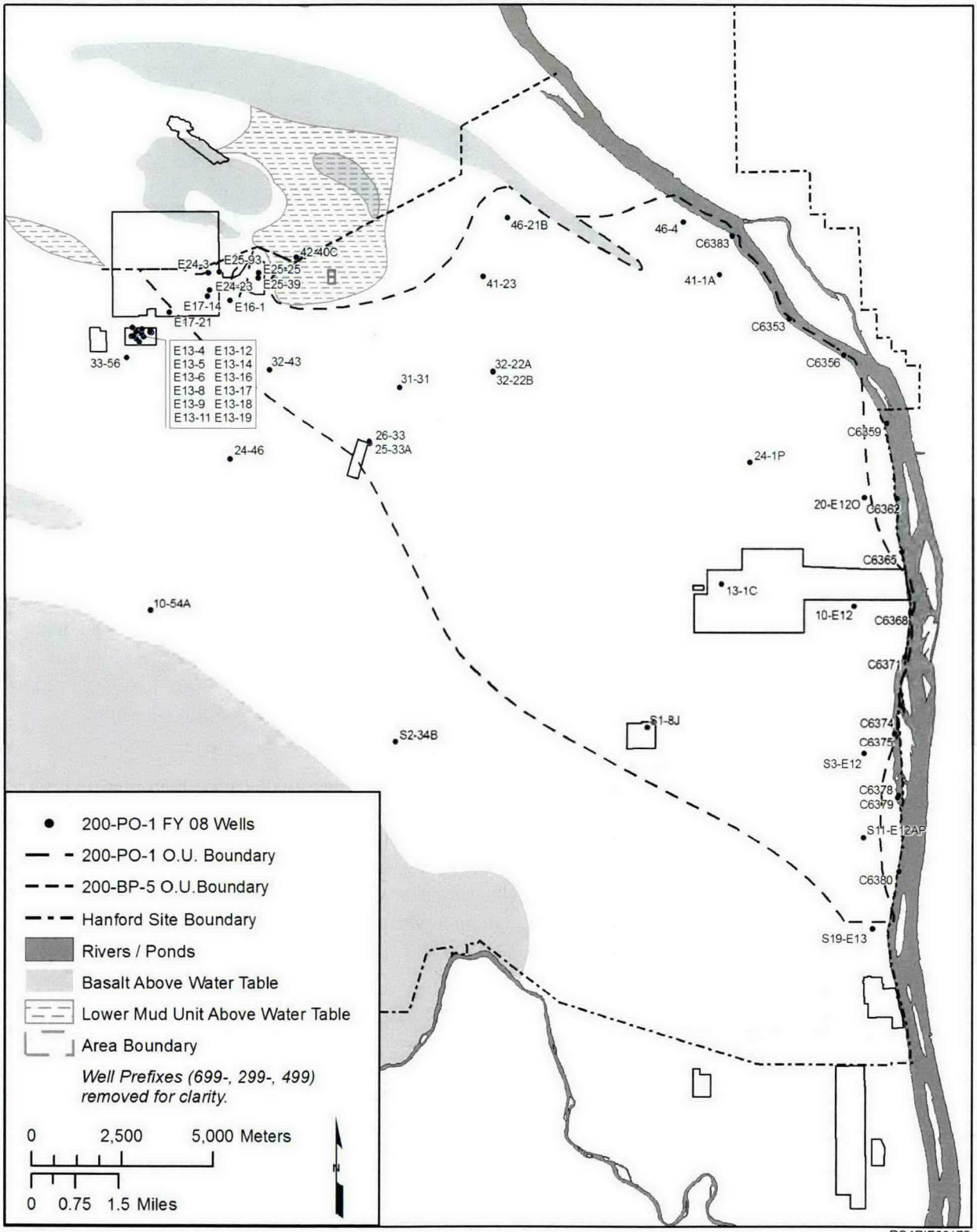



**Figure 4-2. Location of Additional Wells for Characterization Sampling**

Within the 200-PO-1 OU, shoreline springs, seeps, aquifer tubes, river water, and river sediment are monitored to determine the impact of Hanford Site groundwater contamination on the Columbia River. Shoreline springs, seeps, and aquifer tube locations are identified in Chapter 3. Results of studies upriver of the 200-PO-1 OU are included in DOE/RL-2008-46 (*Integrated 100 Area Remedial Investigation/ Feasibility Study Work Plan,* Rev. 0) and for the whole Hanford Site in PNNL-18427 (*Hanford Site Environmental Report for Calendar Year 2008*).

In the remainder of this section, the nature and extent of the six plumes of the COPCs that exceed federal DWS (MCLs) within this OU are discussed individually, including tritium, nitrate, iodine-129, strontium-90, uranium, and technetium-99. The VOCs (TCE, tetrachloroethene, and carbon tetrachloride) present in 200-PO-1 do not exceed MCLs (but do exceed risk based concentration levels) and are discussed in Section 4.2. The discussion begins with background concentrations of Hanford Site groundwater constituents (Section 4.1), then covers each COPC (Section 4.2), and finishes with a discussion on the results of sampling the 43 investigation wells specified in Appendix A of the Work Plan (Section 4.3). Much of the information in Section 4.2 is taken from the latest Hanford Site groundwater annual report (DOE/RL-2008-66). The results from the 133 routinely sampled wells (DOE/RL-2003-04) and the 43 investigation wells from Appendix A (Table A3-2) of the Work Plan (DOE/RL-2007-31) are the basis for the risk assessment discussed in Chapter 6.

## 4.1 Background Concentrations

The unconfined aquifer beneath the Hanford Site is an important component of environmental characterization activities and provides a basis for distinguishing the presence and significance of groundwater contamination. Background data also can be used to assess the levels of baseline risk to which humans or other receptors are typically exposed and to establish remediation goals. Evaluating background on a site-wide basis provides a consistent, technically defensible definition of background, as opposed to determining area-specific background compositions for each waste management unit considered for remediation across the Hanford Site.

The most comprehensive evaluation of the range of groundwater compositions from the unconfined aquifer at the Hanford Site was published in 1997 (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background*). In this study, historical Hanford Site groundwater data (and new data collected specifically for the study) were screened to eliminate samples and/or constituents that may have been affected by Hanford Site activities. The screening process was conducted in two steps: (1) using thresholds based on an upper range of background compositions to eliminate any data that show obvious signs of contamination, and (2) evaluating the location of each Hanford well with respect to known groundwater contamination and area activities.

Summary statistics computed from the data show geometric means, standard deviation, minimum and maximum values, and the 90th and 95th percentile computed for lognormal distributions. These different statistics were presented to facilitate the use of background information for different needs. Table 4-3 presents the 95$^{th}$ percentile background data for the 43 wells selected for site characterization in FY 2008.

**Table 4-3. Detected Groundwater Constituents in the 43 Wells Selected for Site Characterization in FY 2008**

| Constituent | Well | Maximum Value (for Metals – Filtered or Unfiltered) | Lab Qualifier | Detections | Background (95th Percentile) | Federal MCL or MCLG (Number of Wells Exceeding) | WAC 173-340-720 (Number of Wells Exceeding) |
|---|---|---|---|---|---|---|---|
| 1,1,1-Trichloroethane | 699-26-33 | 0.25 µg/L | J | 1 | NA | 200 µg/L | 16,000 µg/L |
| 1,1-Dichloroethane | 699-26-33 | 0.09 µg/L | J | 1 | NA | | 800 µg/L |
| 1,1-Dichloroethene | 699-26-33 | 0.19 µg/L | J | 1 | NA | 7 µg/L | 0.0729 µg/L (1) |
| Arsenic | 299-E17-14 | 7.94 µg/L filtered[3] | | 34 | 11.8 µg/L | 10 µg/L | 0.0583 µg/L (33) |
| Barium | 699-42-40C | 118 µg/L filtered | | 40 | 149 µg/L | 2,000 µg/L | 3,200 µg/L |
| bis(2-Ethylhexyl) phthalate | 299-E25-39 | 11 µg/L | B | 2 | NA | 6 µg/L (1) | 6.25 µg/L (1) |
| Cadmium | 699-41-1A | 4.6 µg/L filtered | B | 3 | 1.29 µg/L | 5 µg/L | 8 µg/L |
| Calcium | 699-10-E12 | 96,500 µg/L filtered | | 41 | 58,381 µg/L | | |
| Carbon disulfide | 699-32-22B | 0.21 µg/L | JB | 1 | NA | | 800 µg/L |
| Carbon tetrachloride | 299-17-21 | 0.13 µg/L | J | 1 | NA | 5 µg/L | 0.337 µg/L |
| Chloride | 699-S2-34B | 81,300 µg/L | D | 41 | 19,580 µg/L | 250,000 µg/L | |
| Chloroform | 299-E17-21 | 0.71 µg/L | J | 7 | NA | 70 µg/L | 7.17 µg/L |
| Chloromethane | 699-S11-E12AP | 0.86 µg/L | JB | 11 | NA | | 3.37 µg/L |
| Chromium | 699-33-56 | 71.5 µg/L filtered | | 16 | 3.17 µg/L | 100 µg/L | 24,000 µg/L |
| Cobalt | 299-E13-16 | 14.3 µg/L unfiltered | B | 5 | 1.29 µg/L | | 4.8 µg/L (4) |
| Copper | 299-E13-5 | 20.4 µg/L filtered | B | 7 | 1.04 µg/L | 1,300 µg/L | 640 µg/L |
| Fluoride | 699-S2-34B | 9,090 µg/L | D | 41 | 1,298 µg/L | 4,000 µg/L (1) | 960 µg/L (3) |
| Gross Alpha | 299-E24-23 | 33 pCi/L | | 12 | 0 pCi/L | 15 pCi/L (1) | |
| Gross Beta | 299-E25-93 | 4,400 pCi/L | | 41 | 4.15 pCi/L | | |
| Hexane | 699-13-1C | 0.32 µg/L | J | 1 | NA | | 480 µg/L |
| Iodine-129 | 299-E17-14 | 10.4 pCi/L | | 4 | 0.95 pCi/L | 1 pCi/L (4) | |

**Table 4-3. Detected Groundwater Constituents in the 43 Wells Selected for Site Characterization in FY 2008**

| Constituent | Well | Maximum Value (for Metals – Filtered or Unfiltered) | Lab Qualifier | Detections | Background (95th Percentile) | Federal MCL or MCLG (Number of Wells Exceeding) | WAC 173-340-720 (Number of Wells Exceeding) |
|---|---|---|---|---|---|---|---|
| Iron | 699-20-E12O | 1,010 µg/L unfiltered | | 38 | 1,104 µg/L | 300 µg/L (9) | 11,200 µg/L |
| Lead | 299-E13-8 | 34.5 µg/L unfiltered | | 18 | 1.3 µg/L | 15 µg/L (2) | |
| Lithium | 699-10-E12 | 12.3 µg/L filtered | | 1 | 13,729 µg/L | | 32 µg/L |
| Magnesium | 699-10-E12 | 23,400 µg/L filtered | | 41 | 31051 µg/L | | |
| Manganese | 299-E13-17 | 186 µg/L unfiltered | | 27 | 86.4 µg/L | 50 µg/L (6) | 752 µg/L |
| Methylene chloride | 699-26-33 | 1.5 µg/L | J | 1 | NA | 5 µg/L | 5.83 µg/L |
| Nickel | 299-E25-93 | 178 µg/L filtered | | 5 | 1.98 µg/L | | 320 µg/L |
| Nitrate | 299-E17-14 | 127,000 µg/L | D | 36 | 41,723 µg/L | 45,000 µg/L (3) | 115,200 µg/L (1) |
| Nitrite | 299-E25-93 | 552 µg/L | BD | 3 | 130 µg/L | 3,300 µg/L | 5,280 µg/L |
| Potassium | 699-S2-34B | 15,000 µg/L unfiltered | | 41 | 11,089 µg/L | | |
| Potassium-40 | 699-31-31 | 40.3 pCi/L | | 1 | 266 pCi/L | | |
| Protactinium-231 | 699-46-21B | 0.308 pCi/L | | 4 | NA | 15 pCi/L | |
| Selenium-79 | 299-25-93 | 32.8 pCi/L | | 2 | NA | | |
| Silver | 699-S3-E12 | 7.5 µg/L filtered | | 11 | 5.98 µg/L | 100 µg/L | 80 µg/L |
| Sodium | 699-S2-34B | 123,000 µg/L filtered | | 41 | 32,919 µg/L | | |
| Strontium | 699-10-E12 | 734 µg/L filtered | | 41 | 398 µg/L | | 9,600 µg/L |
| Strontium-90 | 299-E17-14 | 20.2 pCi/L unfiltered | | 3 | 1.14 pCi/L | 8 pCi/L (1) | |
| Styrene | 299-E16-1 | 0.81 µg/L | J | 1 | NA | 100 µg/L | 1.46 µg/L |
| Sulfate | 299-E25-93 | 137,000 µg/L | D | 41 | 54,950 µg/L | 250,000 µg/L | |
| Technetium-99 | 299-E25-93 | 8,000 pCi/L | | 13 | 0.988 pCi/L | 900 pCi/L (1) | |
| Tetrachloroethene | 699-26-33 | 2.2 µg/L | J | 1 | NA | 5 µg/L | 0.081 µg/L (1) |

**Table 4-3. Detected Groundwater Constituents in the 43 Wells Selected for Site Characterization in FY 2008**

| Constituent | Well | Maximum Value (for Metals – Filtered or Unfiltered) | Lab Qualifier | Detections | Background (95th Percentile) | Federal MCL or MCLG (Number of Wells Exceeding) | WAC 173-340-720 (Number of Wells Exceeding) |
|---|---|---|---|---|---|---|---|
| Thallium | 699-13-1C | 0.64 µg/L unfiltered | | 3 | 1.87 µg/L | 2 µg/L | 1.12 µg/L |
| Trichloroethene | 299-E24-23 | 3.1 µg/L | | 4 | NA | 5 µg/L | 0.492 µg/L (2) |
| Trichloromonofluoromethane | 699-26-33 | 0.58 µg/L | J | 1 | NA | | 2,400 µg/L |
| Tritium | 299-E17-14 | 650,000 pCi/L | | 21 | 142 pCi/L | 20,000 pCi/L (10) | |
| Uranium | 299-E24-23 | 92.8 µg/L | | 37 | 14.4 µg/L | 30 µg/L (1) | 48 µg/L (1) |
| Vanadium | 699-33-56 | 28.9 µg/L unfiltered | B | 29 | 19.3 µg/L | | 112 µg/L |
| Zinc | 299-E13-16 | 10,200 µg/L unfiltered | | 19 | 48.9 µg/L | 5,000 µg/L (1) | 4,800 µg/L (1) |

Notes:

FY = fiscal year

MCL = maximum contaminant level

MCLG = maximum contaminant level goal

## 4.2 Operable Unit Contaminants

The following section describes the nature and extent of the final COPCs resulting from the BRA presented in Chapter 6.

### 4.2.1 Tritium

Tritium is a radioactive isotope of hydrogen. Each tritium atom contains one proton and two neutrons, compared to only one proton for protium (the most abundant hydrogen isotope). Tritium decays into helium-3 with a half-life of 12.3 years. The low-energy beta radiation from tritium cannot penetrate human skin, so tritium is only dangerous if inhaled, ingested, or – if it is in water molecules, as with tritiated water—absorbed through the skin. Tritium, as groundwater contamination at the Hanford Site, is in various concentrations (i.e., activity levels – pCi/L) of tritiated water. Because tritium is part of water, it has a $K_d$ equal to zero ml/g for all practical purposes (PNNL-11800, *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site*, and PNNL-14702, *Vadose Zone Hydrogeology Data Package for Hanford Assessments*). It moves with the water molecules in groundwater without any retardation.

In the 200-PO-1 Groundwater OU, tritium occurs in two plumes: one originating in the southeastern portion of the 200 East Area (Figure 4-3) and one near the Energy Northwest Complex in the southern portion of the 200 PO-1 Groundwater OU. The southern plume originates at the 618-11 Burial Ground, which is the responsibility of the 300-FF-5 OU; it will no longer be discussed in this section. The major sources of the southeastern plume are most likely from the 216-A-10, 216-A-36B, and 216-A-37-1 Cribs (Figure 4-4) and other cribs in the southeast 200 East Area, which were used to dispose wastewater from PUREX Plant operations (PNNL-11523, *Combination RCRA Groundwater Monitoring Plan for the 216-A-10, 216-A-36B, and 216-A-37-1 PUREX Cribs*). The highest reported level of tritium during FY 2008 was 650,000 pCi/L at Well 299-E17-14 near the 216-A-36B Crib.

The 216-A-36B Crib was used to dispose condensate from nuclear fuel decladding operations in which zirconium cladding was removed from irradiated fuel by boiling in a solution of ammonium fluoride and ammonium nitrate. The process distillate discharge waste stream to the 216-A-10 Crib was characteristically acidic and contained concentrated salts, aliphatic hydrocarbons, organic complexes, and various radioactive fission products such as tritium (RHO-HS-SR-86-3 4QLIQ P, *Radioactive Liquid Wastes Discharged to Ground in the 200 Areas During 1986*). Liquid wastes sent to the 216-A-37-1 Crib included process condensate from the 242-A Evaporator and included radionuclides (including tritium), spent halogenated and non-halogenated solvents, and ammonia. With the many potential sources for tritium in the southeastern portion of the 200 East Area and because the individual plumes from various sources have coalesced into a single large plume downgradient, it is difficult to discern precisely the tritium contribution from each crib.

Concentrations of tritium generally have declined in the Far Field area. The plume attenuates naturally as a result of radioactive decay and dispersion. In addition, the source that resulted from the termination of PUREX Plant operations is continually decreasing. Figure 4-5 shows concentrations of tritium in the uppermost unconfined aquifer in 1980 and 2004.

During FY 2008, wells in the eastern portion of the 200-PO-1 Groundwater OU exhibited tritium concentrations above 80,000 pCi/L (Figure 4-3) related to historical discharges to the PUREX cribs (PNNL-11141, *Hanford Site Ground Water Monitoring for 1995*). Trend plots of tritium concentrations at wells in the western (699-24-33), central (699-20-20), and eastern (699-37-E4) portions of the area between the PUREX cribs and the Columbia River show progression of the tritium plume as it flowed with the groundwater across the Hanford Site. Figure 4-6 shows (1) the decreasing concentrations of

tritium from the first PUREX campaign at Well 699-24-33 from 1961 to 1985, and (2) the pulse from the second PUREX campaign passing the well from 1987 to 1997, with the peak around 1991. Figure 4-7 shows tritium concentrations of the first PUREX campaign from 1961 to 1989. The rise in tritium concentrations as a result of the second PUREX campaign is barely visible as a small rise around 1994. Figure 4-8 shows tritium concentrations at Well 699-37-E4, which is located close to the Columbia River near the Hanford town site. Elevated tritium concentrations as a result of the first PUREX campaign peaked from 1995 to 1998 and have been decreasing since then.

Tritium concentrations in the aquifer tubes are similar to nearby groundwater monitoring wells. The aquifer tubes with the highest concentrations of tritium (35,000 pCi/L in C6353 and 24,000 pCi/L in C6383) are located southeast of the Hanford town site, corresponding to the tritium plume with concentrations greater than 80,000 pCi/L (Figure 4-3).

Wells in the Near Field area exhibit localized higher tritium concentrations than wells in the Far Field area because they are closer to the source of tritium (Figure 4-4). Trends for tritium have been steady to rising in the Near Field area since 2005 (Figure 4-9). Well 299-E17-14 (near the 216-A-36B Crib) had a decreasing trend until FY 2005; concentrations then began to rise. During FY 2008, concentrations again began decreasing. Well 299-E24-16 (near the 216-A-10 Crib) had a decreasing trend until FY 2002, when concentrations began to rise. In the last two years, concentrations have stabilized. Tritium concentrations at Well 299-E25-19 (near the 216-A-37-1 Crib) have been relatively stable since FY 1998. It is possible that the vadose zone near the 216-A-10 and 216-A-36B Cribs is still contributing tritium to the unconfined aquifer. It is also possible that changes in tritium concentrations near these two cribs could be a result of changing groundwater flow directions after the cessation of wastewater discharges at B Pond (216-B-3 Pond in 1997). The potential for continuing contaminant contribution from residual vadose zone sources is not evaluated in this RI.

The zone of lower tritium concentrations near the Energy Northwest Complex (Figure 4-3) is likely to result from the effect of a zone of lower hydraulic conductivity in the unconfined aquifer. In this area, the water table is within the upper portion of the Ringold Fm, which may have a greater degree of local cementation.

The 200-PO-1 Groundwater OU wells screened in the middle or lower portions of the unconfined aquifer (or deeper in the confined aquifers) show very little tritium groundwater contamination. Tritium was either not detected or detected at very low concentrations (10 pCi/L) at the 200 Area TEDF during FY 2008. The wells are screened at the first occurrence of groundwater below the Ringold Fm LMU where the aquifer is locally confined (i.e., potentiometric surface is within the LMU). Well 499-S1-8J (a water supply well in the 400 Area) is screened in the lower portion of the Ringold Fm (but not confined). During FY 2008, the well had tritium levels ranging from 2,100 to 2,500 pCi/L. Nearby Well 499-S0-7, screened at the water table, had tritium values that ranged from 7,900 to 9,700 pCi/L during FY 2008. Tritium was not detected in the Laser Interferometer Gravitational Wave Observatory (LIGO) well (699-S2-34B), which is screened in the basalt-confined aquifer system. Similarly, five other deep 200-PO-1 Groundwater OU wells screened in the basalt-confined aquifer system (and sampled once every three years) showed no detectable tritium during FY 2006 (i.e., the last time they were sampled).

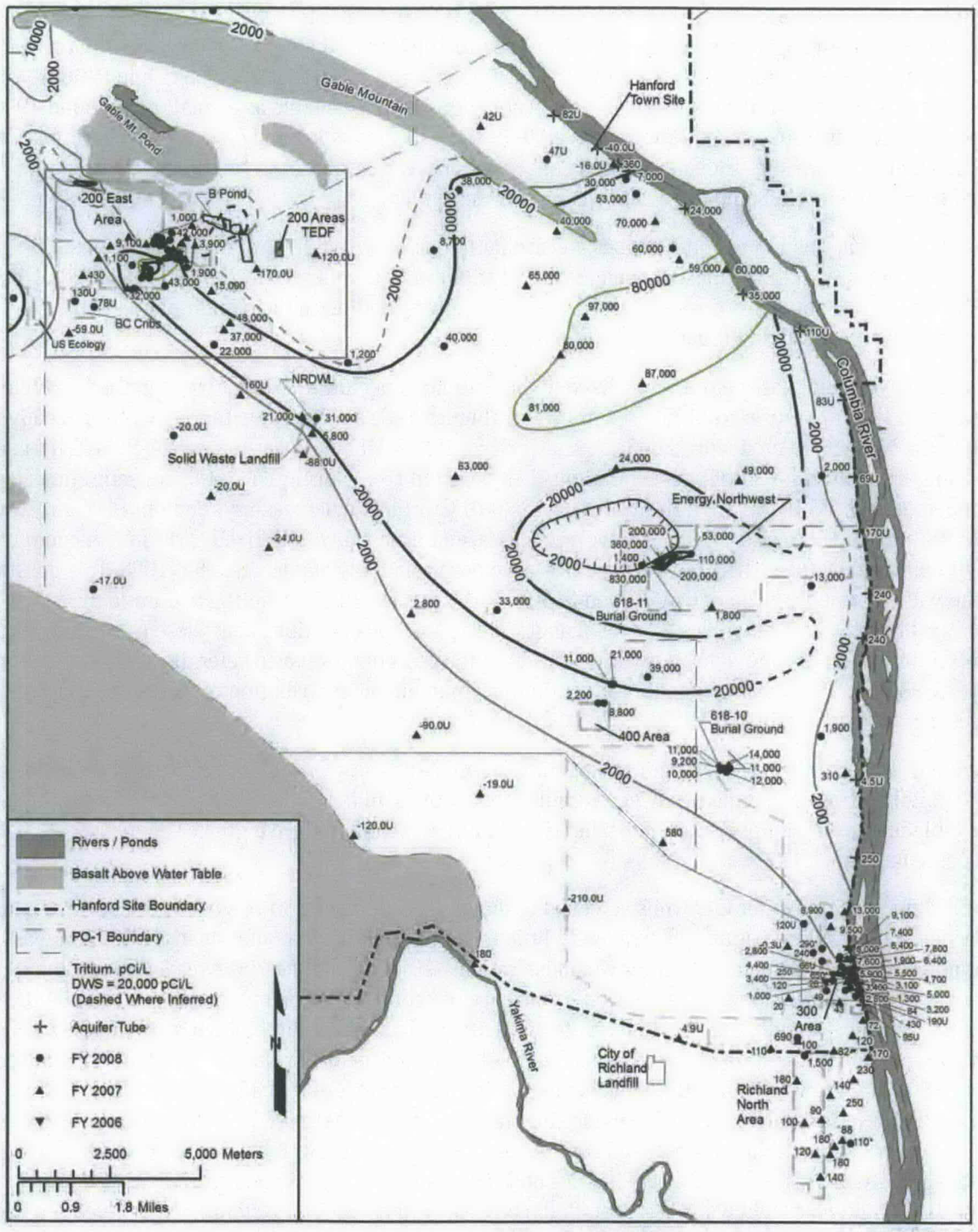



**Figure 4-3. Tritium Plume 2008**

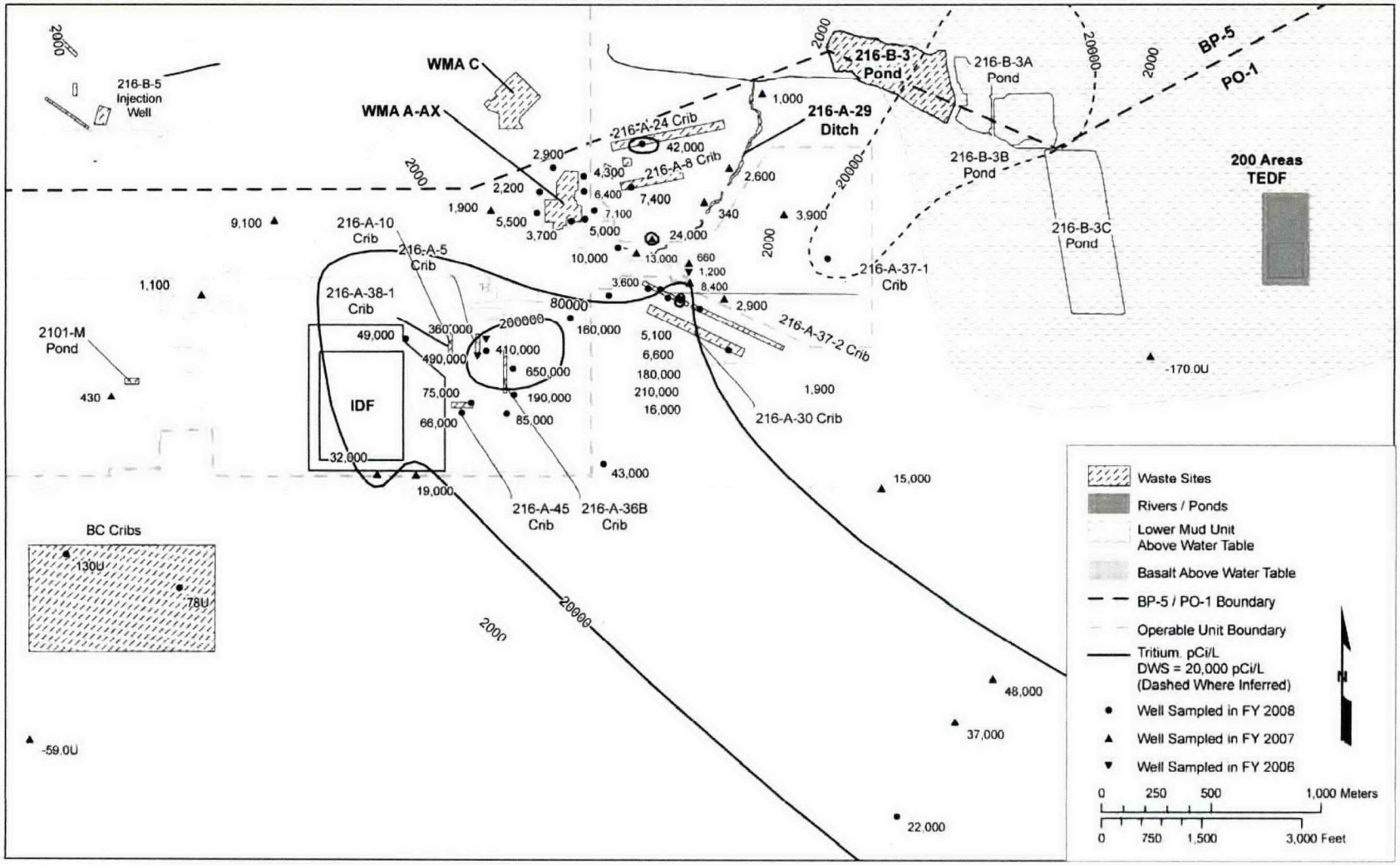



**Figure 4-4. Tritium Plume in the Near Field near the Sources of Tritium Groundwater Contamination**

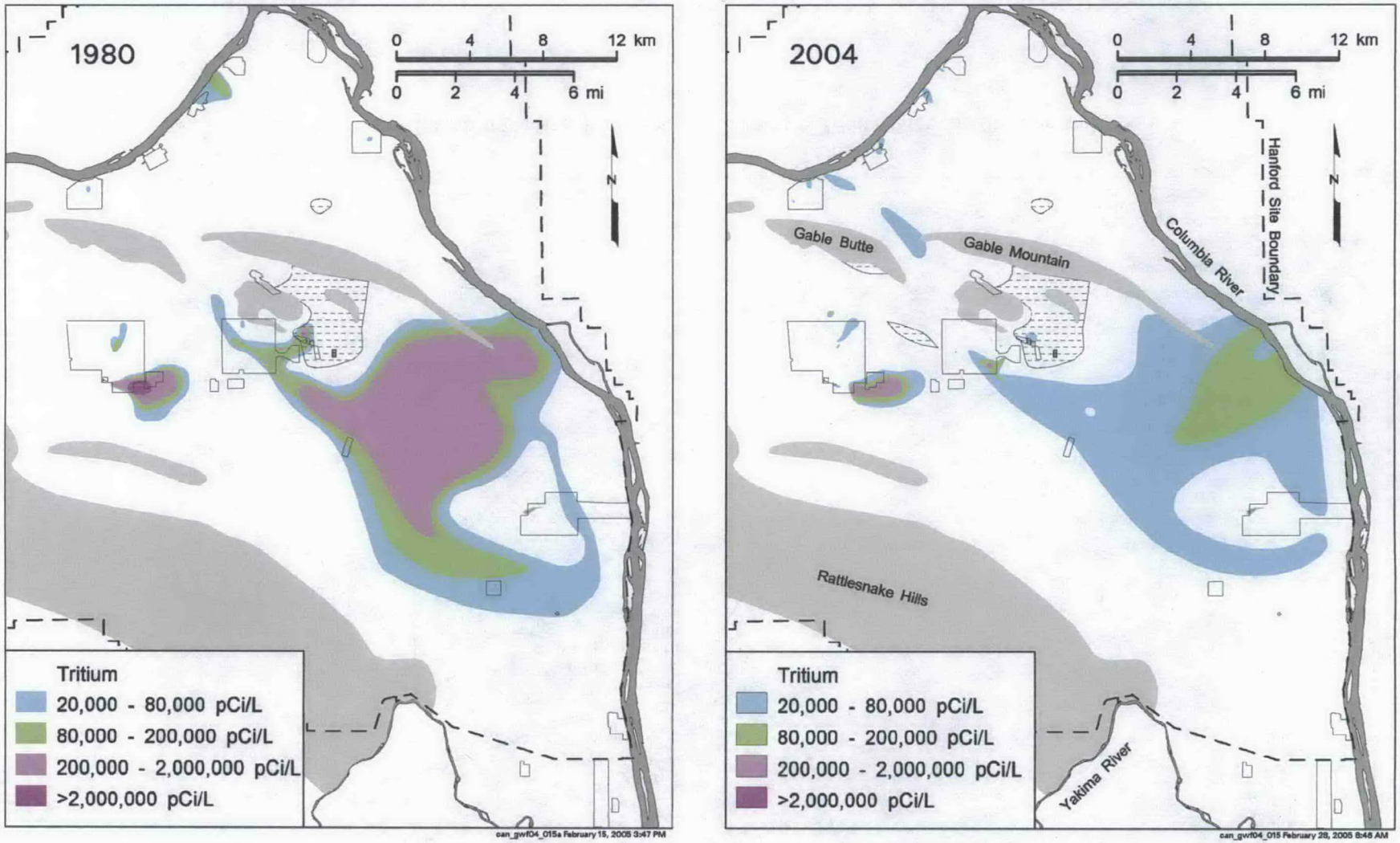



**Figure 4-5. Tritium Groundwater Plume in 1980 and 2004**

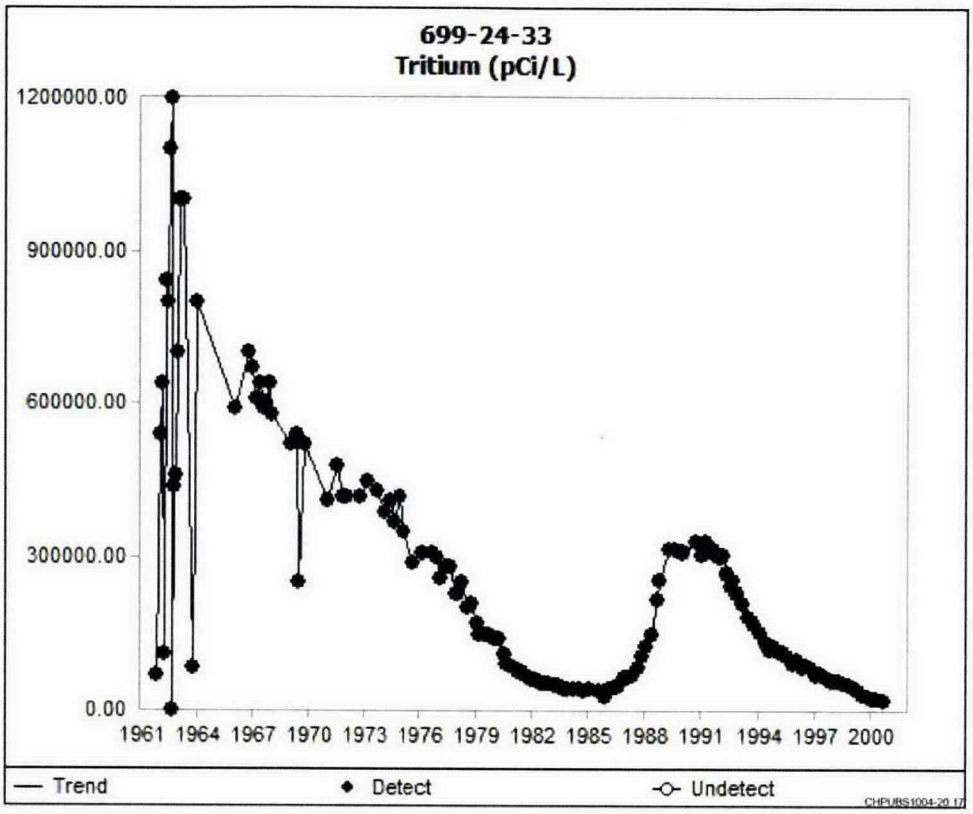



**Figure 4-6. Tritium Concentrations at Well 699-24-33 Located near NRDWL**

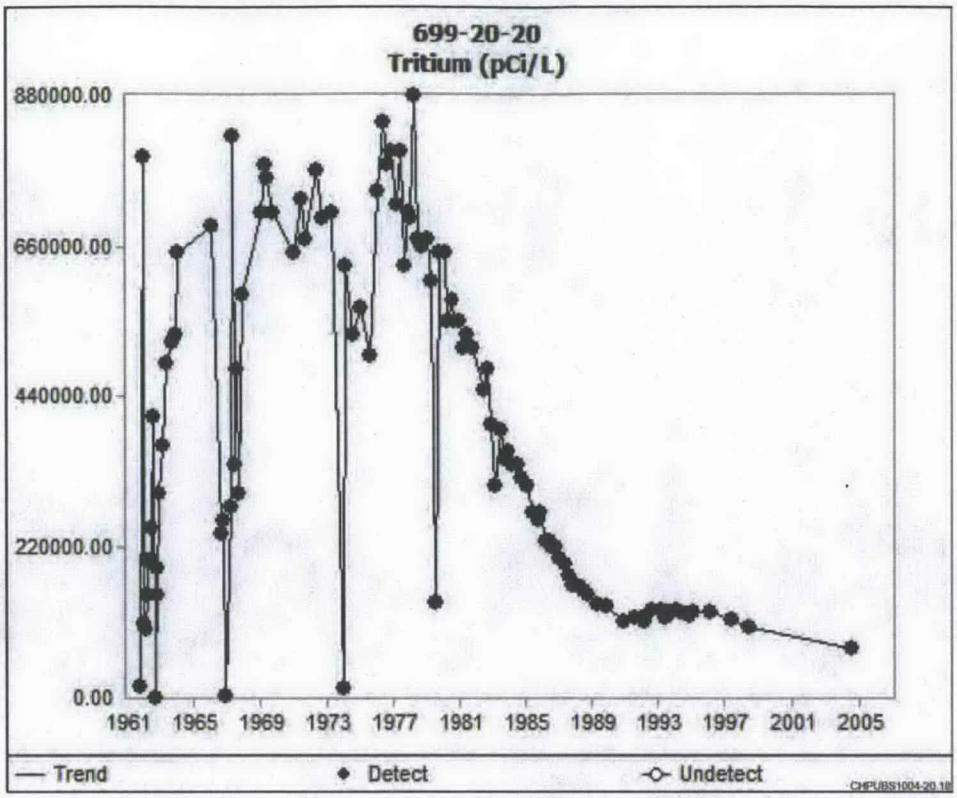



**Figure 4-7. Tritium Concentrations at Well 699-20-20 in the 600 Area**

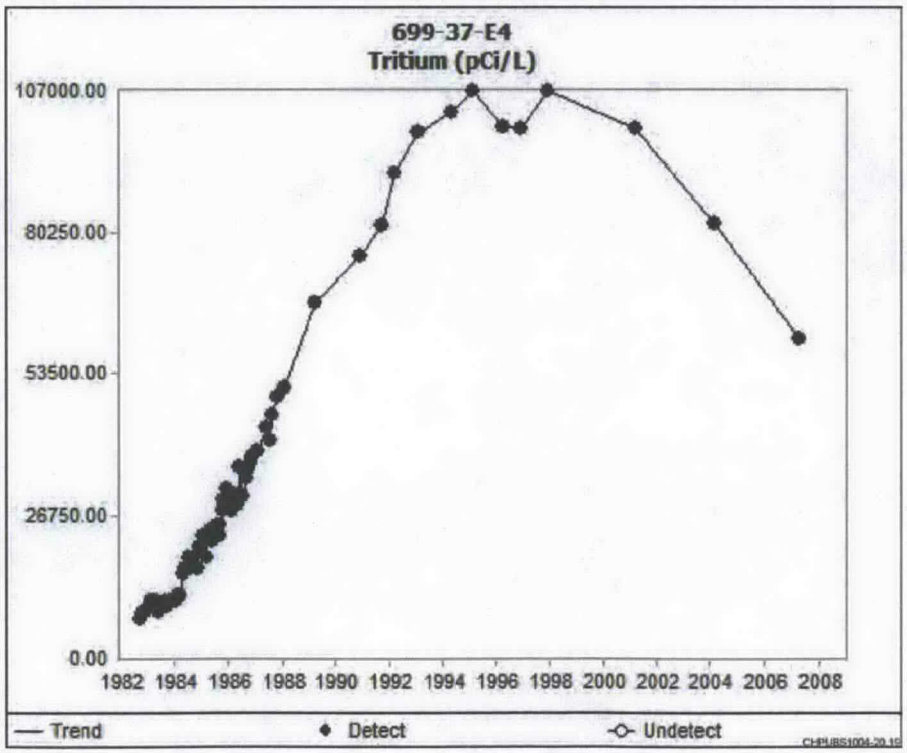



**Figure 4-8. Tritium Concentrations at Well 699-37-E4 near the Columbia River**

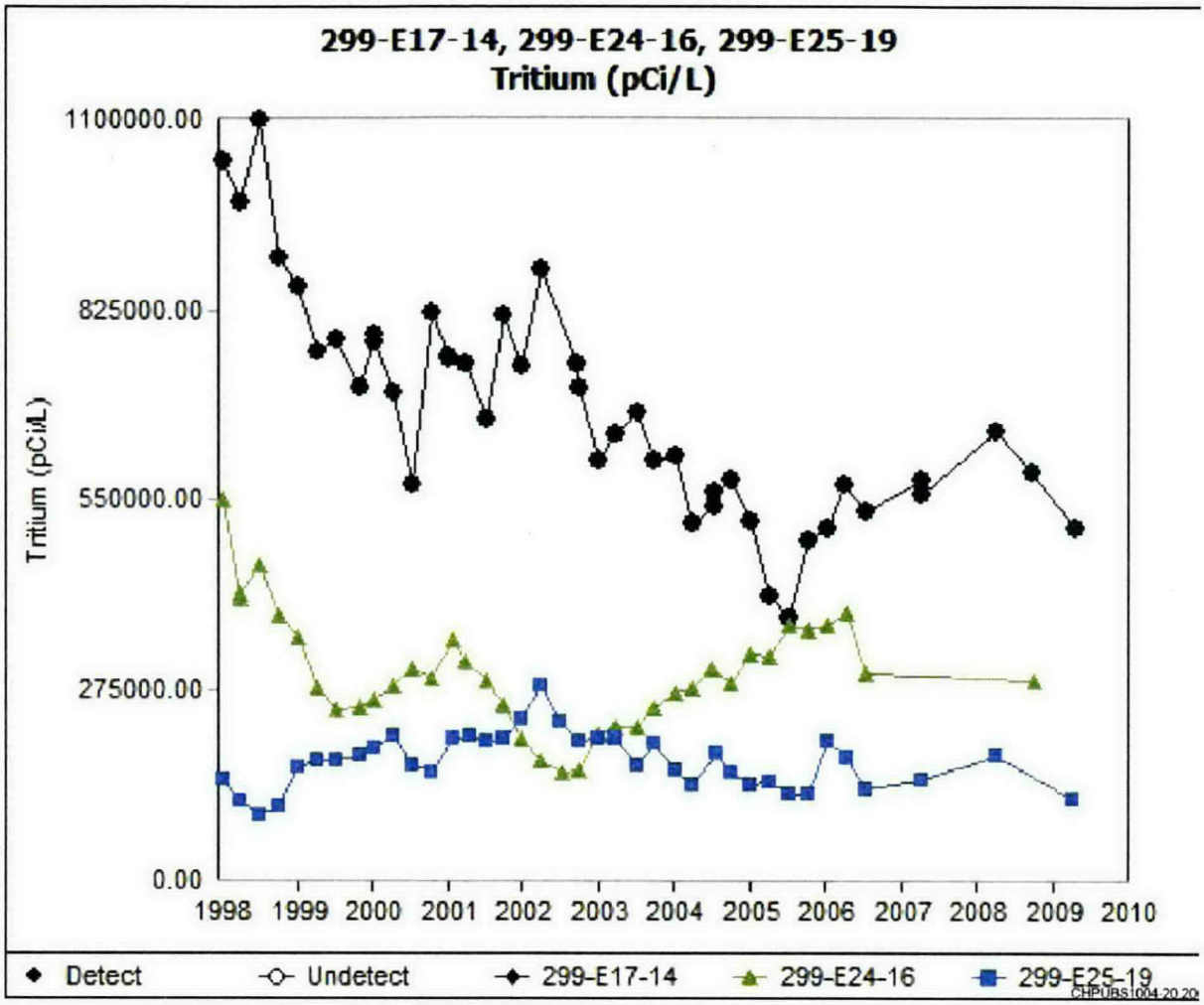



**Figure 4-9. Tritium Concentrations in Wells at PUREX Cribs**

### 4.2.2 Nitrate

The nitrate plume of the 200-PO-1 Groundwater OU had its origins at the PUREX cribs in the southeastern portion of the 200 East Area, although groundwater contaminated with lower levels of nitrate is entering from upgradient sources (west to northwest). The nitrate is most likely from the ammonium fluoride and ammonium nitrate solutions from the 216-A-36B Crib, nitric acid from the 216-A-10 Crib, and ammonia from the 216 A-37-1 Crib (RHO-HS-SR-86-3 4QLIQ P). Like tritium, nitrate has a very low $K_d$ that is close to 0 ml/g (PNNL-11800; PNNL-14702), resulting in essentially no retardation to flow in groundwater. As a result, the nitrate plume emanating from the 200 East Area extends all the way to the Columbia River on the east side of the 200-PO-1 Groundwater OU.

Although the total extent of the nitrate plume above 20 mg/L, originating in the 200 East Area (Figure 4-10 and Figure 4-11) is close to the tritium plume in extent, the area with concentrations above the 45 mg/L DWS is significantly smaller than the area with concentrations above the 20,000 pCi/L tritium DWS. Nitrate at levels above the DWS north of the 400 Area and at the Energy Northwest Complex (within the area impacted by the PUREX cribs) can be attributed to wastewater disposal in those areas. In FY 2008 and in early FY 2009, the highest nitrate concentration (127 mg/L) within the 200-PO-1 Groundwater OU was at Well 299-E17-14 at the 216-A-36B Crib (Figure 4-2 and Figure 4-4).

The nitrate plume (Figure 4-10 and Figure 4-11), with sources in the 200 East Area, appears to have dispersed slightly over previous years, except in the vicinity of the PUREX cribs and WMA A-AX. Figure 4-12 shows the nitrate plume in the 200-PO-1 Groundwater OU in 1980 and 2004. The area with nitrate concentrations over the DWS in the 200-PO-1 OU was larger in 1980 than in 2004 and 2008, although the area with concentrations greater than 20 mg/L is greater in 2008 than in 1980. The increase in total area with concentrations greater than 20 mg/L in recent years is, in part, a result of inclusion of offsite sources in the southern part of the Hanford Site near the 300 Area and the "horn" of the Yakima River that were not present earlier. The highest nitrate concentration in the aquifer tubes was 33 mg/L in C6353 near the Hanford town site for a sample collected in September 2008.

Wells near the PUREX cribs in the southeastern portion of the 200 East Area had increasing nitrate concentrations in recent years. The trend at Well 299-E24-16 (near the 216-A-10 Crib) is typical of the increasing trend (Figure 4-13). Increasing nitrate concentrations also were observed at WMA A-AX. The cause of the increase in nitrate at some of the wells in the southeastern portion of the 200 East Area is unknown, but it may be a result of shifting groundwater flow directions related to the cessation of wastewater discharges at the B Pond or to continuing groundwater contamination from the PUREX cribs and WMA A-AX.

Nitrate was detected in wells deeper in the Ringold Fm unconfined aquifer or lower confined aquifer. However, none of the deeper wells had reported nitrate concentrations exceeding the 45 mg/L DWS. At the NRDWL, nitrate concentrations were as high as 19.4 mg/L in Well 699-26-35C and 11.1 mg/L in Well 699-25-33A. These wells are screened at the top of the low-permeability unit (bottom of the unconfined aquifer) in the Ringold Fm. Beneath the Ringold Fm LMU at B Pond and the 200 Area TEDF (the uppermost aquifer), nitrate concentrations continue to be lower (less than 6.9 mg/L). In the lower portions of the unconfined aquifer beneath the 216-A-29 Ditch (Well 299-E25-28), the nitrate level was 2.1 mg/L. Nitrate was not detected (i.e., less than 0.44 mg/L) in water supply Well 499-S1-8J in the 400 Area (screened in the lower portion of the Ringold Fm). Nitrate remains undetected in Well 699-S2-34B at LIGO and in three other wells screened in the basalt-confined aquifer system beneath the 200-PO-1 Groundwater OU.

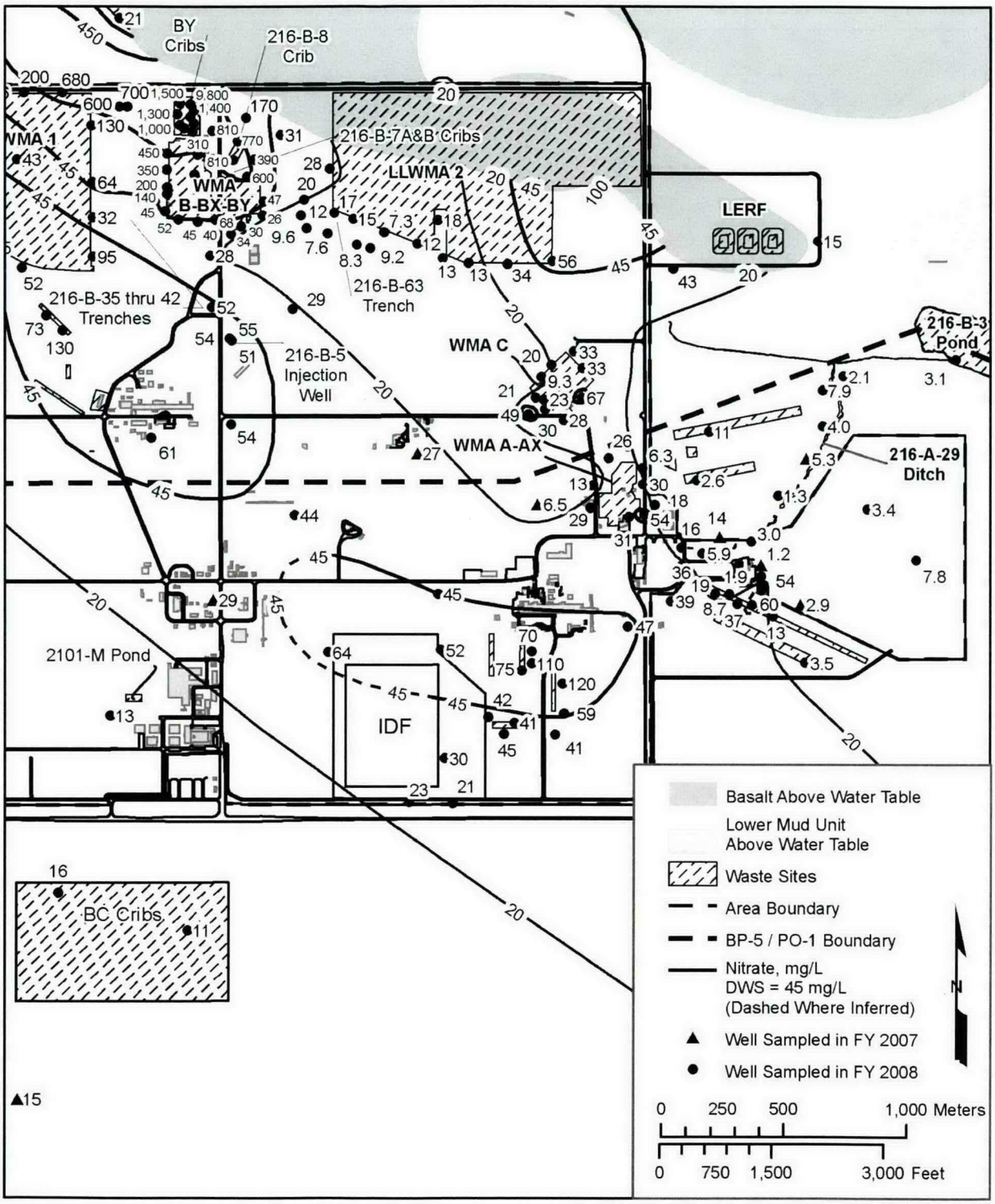



**Figure 4-10. Nitrate Concentrations in the 200-PO-1 OU Near Field, Upper Part of Unconfined Aquifer (Average FY 2007 and FY 2008 Concentrations)**

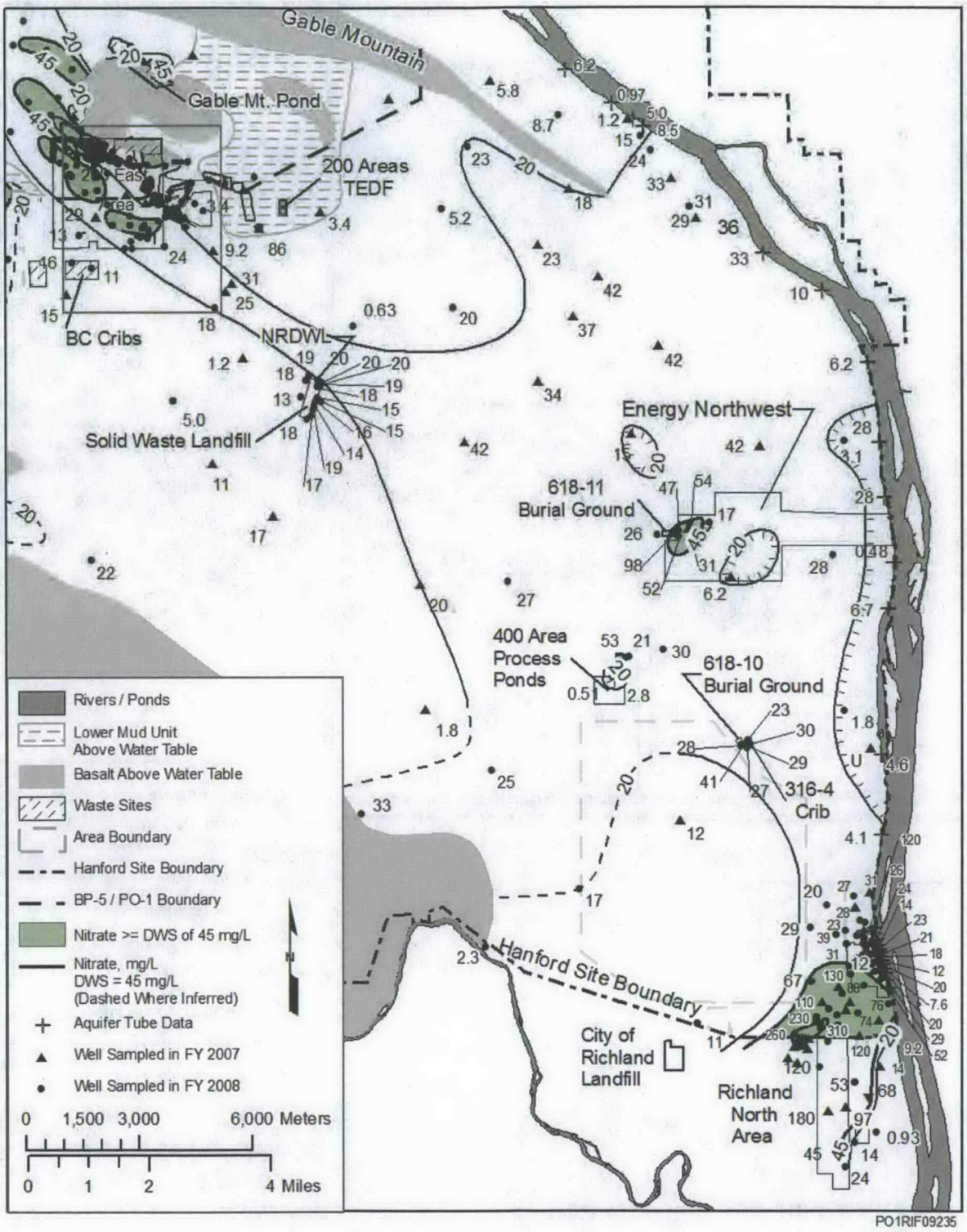



**Figure 4-11. Nitrate Concentrations in the 200-PO-1 OU Far Field, Upper Part of Unconfined Aquifer (Average FY 2007 and FY 2008 Concentrations)**

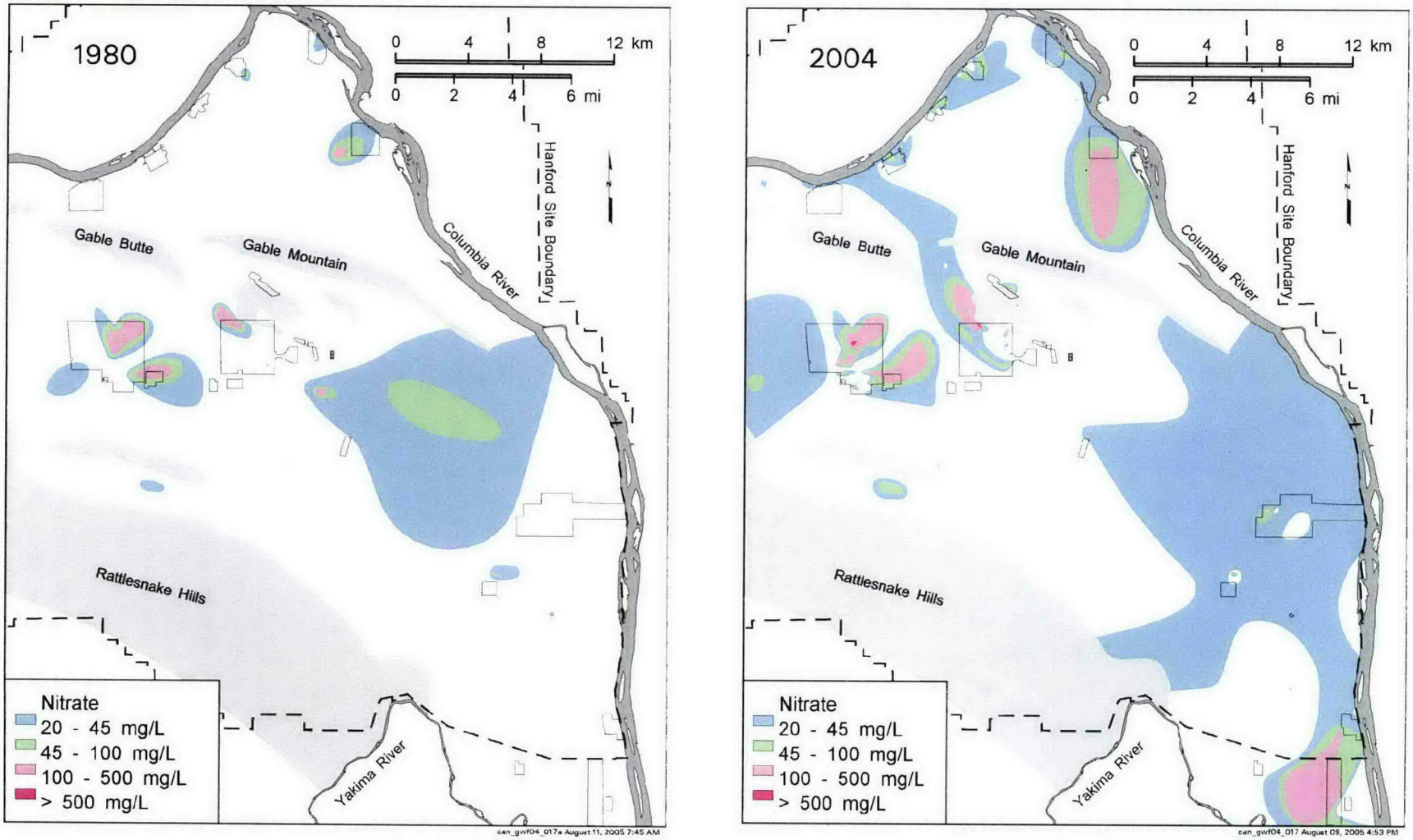



**Figure 4-12. Nitrate Groundwater Plume in 1980 and 2004**

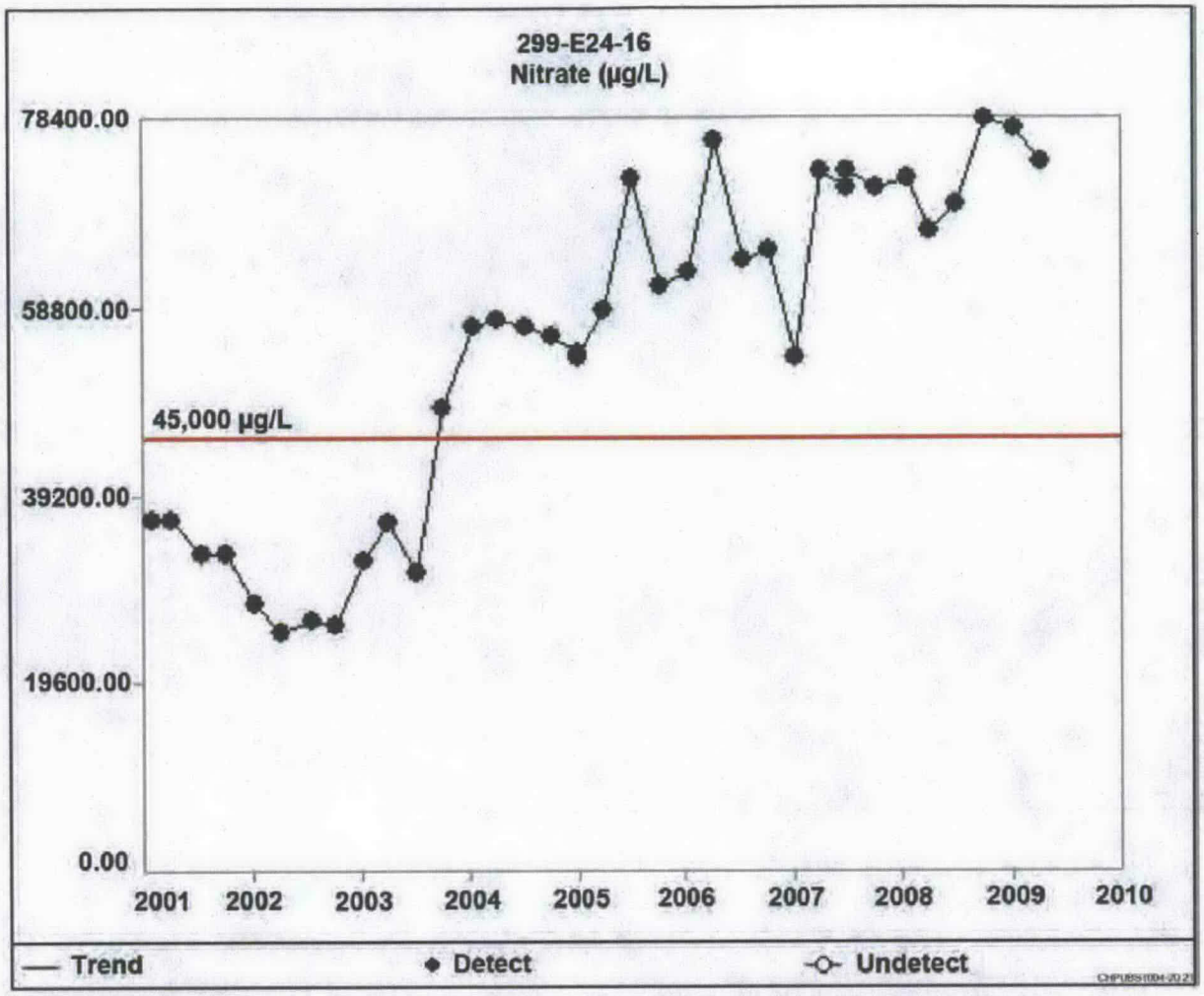



**Figure 4-13. Nitrate Concentrations in Well 299-E24-16 near the 216-A-10 Crib**

### 4.2.3 Iodine-129

Iodine-129 is primarily formed from the fission of uranium in nuclear reactors. As a result, it was one of the radioactive fission products in waste streams resulting from the separations processes in the 200 Area and was discharged to the PUREX cribs along with tritium, nitrate, and other waste products. Iodine-129 decays to xenon-129 with a half-life of 15.7 million years, with low-energy beta and gamma emissions. When it is discharged to the ground as part of wastewater streams, it has a very low $K_d$ (0.2 ml/g) with a range of zero to 2, depending on soil or aquifer conditions (PNNL-11800; PNNL-14702). With the low $K_d$, it moves easily in groundwater flow with very little retardation.

The iodine-129 plume emanating from the PUREX cribs (Figure 4-14) extends southeast into the 600 Area and appears to coincide with the northern portions of the tritium and nitrate plumes (Figure 4-3 and Figure 4-11). During FY 2008 and the early portion of FY 2009, the highest concentrations of the iodine-129 plume were near the sources of the plume in the southeastern portion of the 200 East Area. The concentrations in this area ranged from undetected to 10.4 pCi/L in Well 299-E17-14 (near the 216-A-36B Crib) for a sample collected in April 2008. The DWS for iodine-129 is 1pCi/L. The generally decreasing to stable trend for iodine-129 at Well 299-E17-14 (Figure 4-15) is typical of the stable to gradually decreasing trend for iodine-129 in the vicinity of the PUREX cribs. The plume map for iodine-129 in 1994 and 2004 (Figure 4-16) shows that the iodine-129 plume has reduced slightly in areal extent, and the portion of the plume greater than 5 pCi/L has also diminished.

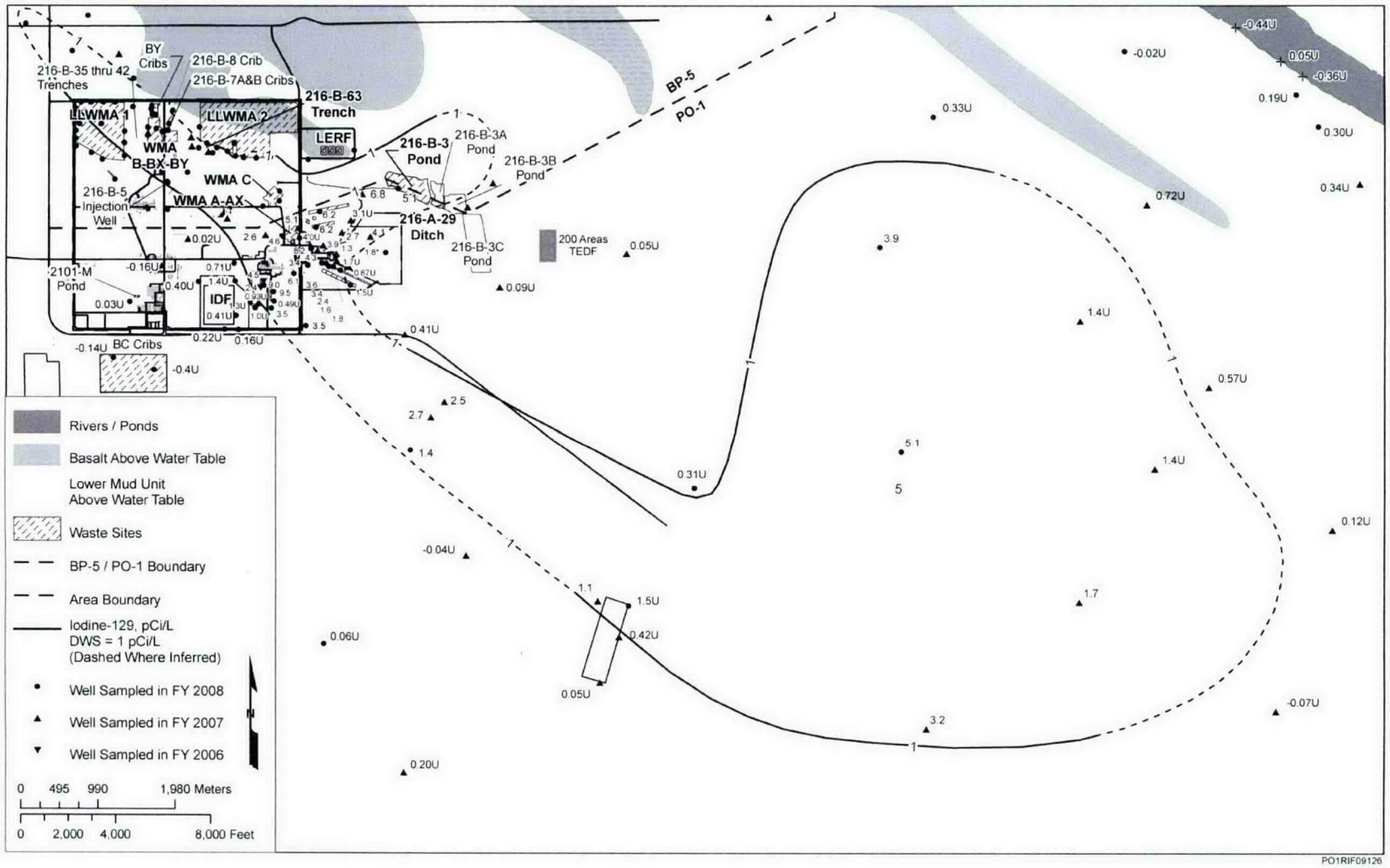



**Figure 4-14. Iodine-129 Plume**

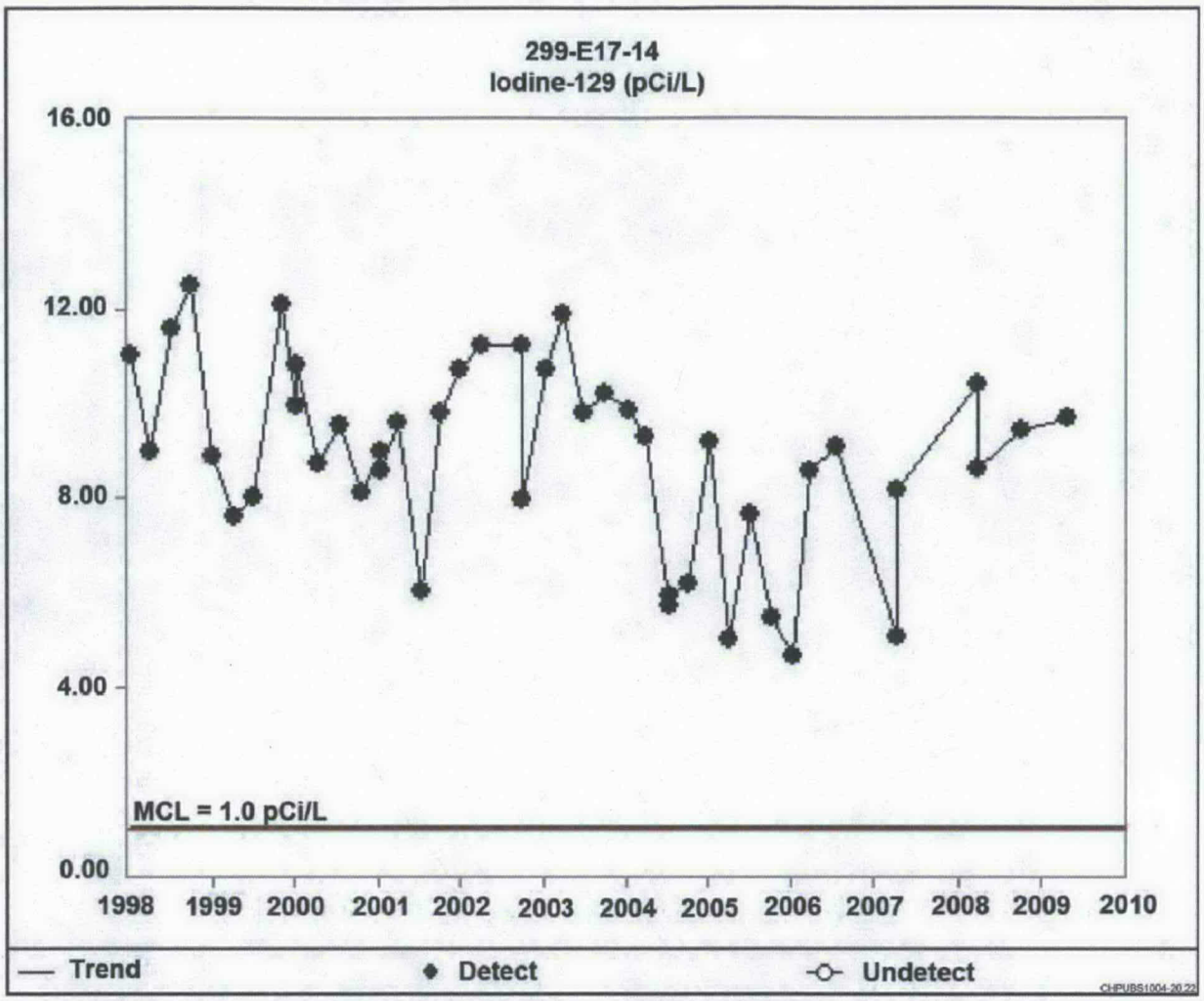



Figure 4-15. Iodine-129 Concentrations in Well 299-E17-14 at the 216-A-36B Crib

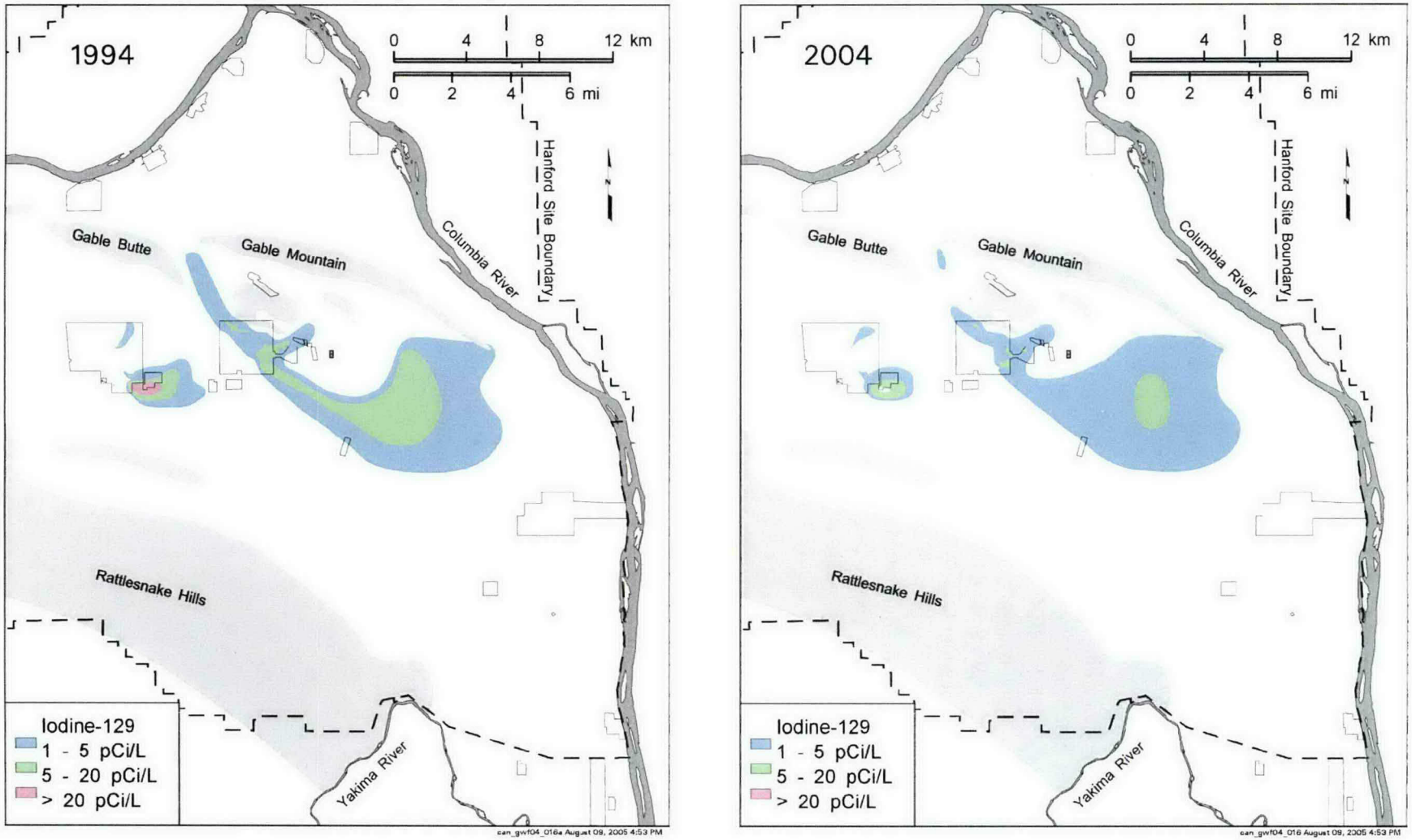



**Figure 4-16. Iodine-129 Plume in 1994 and 2004 Showing Slight Reduction in Overall Area and Reduction in Area of the Portion Greater than 5 pCi/L**

### 4.2.4 Strontium-90

Similar to iodine-129, strontium-90 is primarily formed from the fission of uranium and plutonium in nuclear reactors. Unlike iodine-129, it is a strong beta-emitter and, therefore, can be detected using the gross beta analysis as an indicator parameter along with technetium-99, another common beta-emitter in the 200-PO-1 Groundwater OU. The half-life of strontium-90 is 28.9 years. It was also one of the radioactive fission products in waste streams resulting from the separations processes in the 200 Area and discharged to the PUREX cribs. Strontium-90 has a $K_d$ of about 22 ml/g in the 200-PO-1 aquifer system, with a range of 10 to 50 ml/g, depending on soil or aquifer conditions. Because of the relatively high $K_d$, strontium-90 moves very slowly in the aquifer with groundwater flow.

The strontium-90 plume is very small in area extent as a result of the relatively high $K_d$ in the aquifer. In the vadose zone, however, strontium-90 historically exhibited greater mobility due to the lower pH and calcium in the waste stream discharged to the PUREX cribs. The only place in the 200-PO-1 Groundwater OU that strontium-90 is detected in significant concentrations is near the PUREX cribs. The only well where concentrations exceed the 8 pCi/L DWS is Well 299-E17-14 near the 216-A-36B Crib (Figure 4-17), where the concentrations have ranged from about 14 to 20 pCi/L since the well was first sampled in 1988. Other PUREX crib wells where strontium-90 has been detected (but not exceeding the 8 pCi/L DWS) are 299-E24-16 at the 216-A-10 Crib, where concentrations recently have ranged from 5 to 7 pCi/L; Well 299-E17-16 at the 216-A-36B Crib, where concentrations ranged from 2 to 3 pCi/L; and 299-E17-1 at the 216-A-10 Crib, where concentrations ranged from 1 to 2 pCi/L.

### 4.2.5 Technetium-99

Technetium-99 is a byproduct of fission of U-235 in nuclear reactors and was removed during the separations process at PUREX. It has a half-life of 211,000 years. Most technetium-99 went to the underground storage tanks, but some may have made it to the PUREX cribs. It is a beta-emitter, as is strontium-90, and can be detected with the gross beta analysis as a screening tool. Gross beta has typically been a good indicator parameter for technetium-99. The $K_d$ for technetium-99 is, for all practical purposes, equal to zero (PNNL-11800; PNNL-14702). It flows with groundwater without retardation due to absorption or ion exchange. The DWS for technetium-99 is 900 pCi/L. It generally occurs in groundwater as the pertechnetate oxyanion and, behaves much like nitrate.

The earliest technetium-99 analyses at the PUREX cribs wells in the 1980s yielded results ranging from non-detect (less than 7 pCi/L) to 600 pCi/L. Most results were substantially lower than 600 pCi/L; therefore, the technetium-99 analysis was discontinued until recently in favor of the less expensive gross beta analysis as a screening tool for beta emitters.

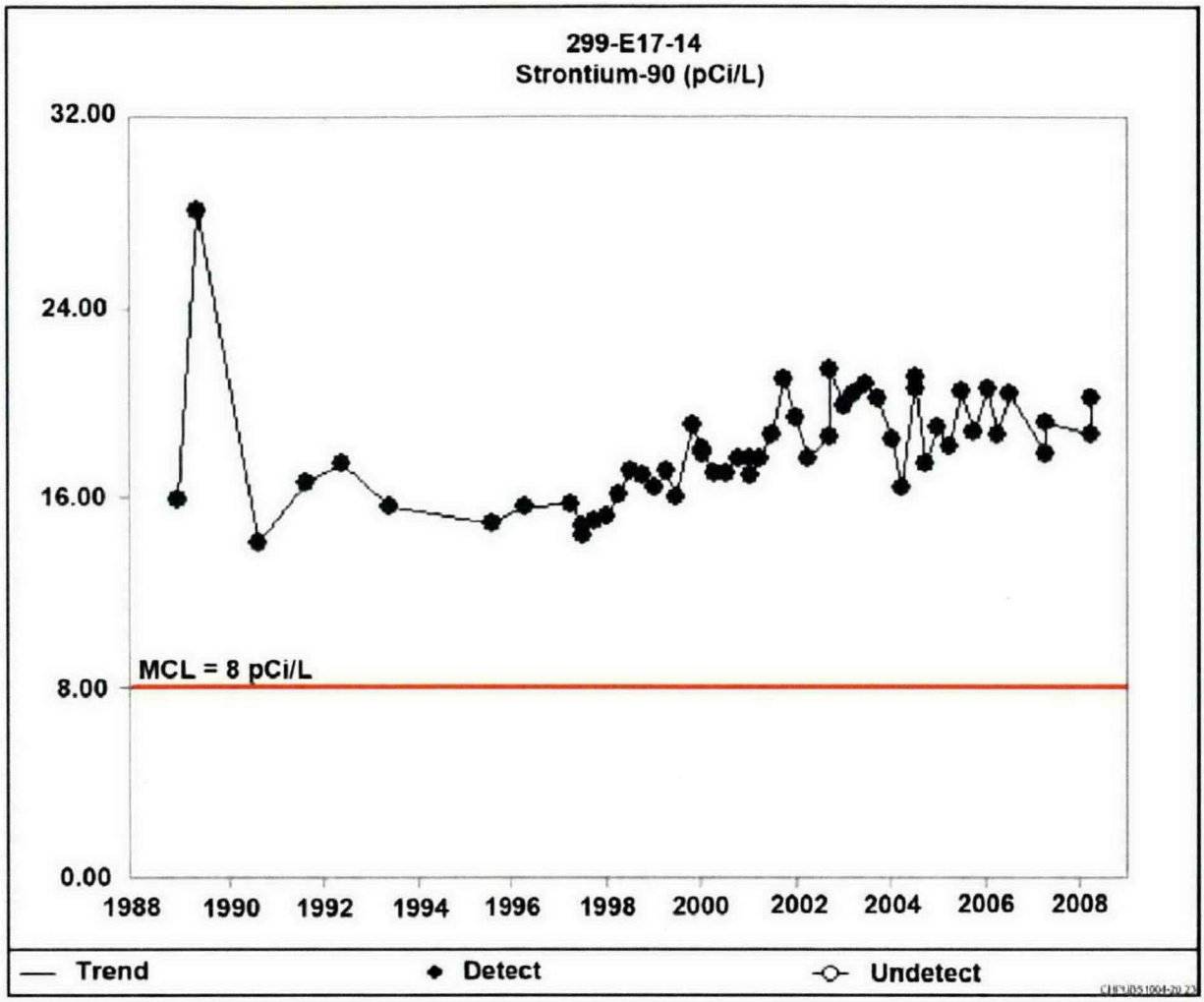



**Figure 4-17. Strontium-90 Concentrations at Well 299-E17-14 near the 216-A-36B Crib**

At WMA A-AX, technetium-99 analysis results were similar to those for the PUREX cribs with technetium-99 ranging up to a few hundred pCi/L prior to 2003. However, Well 299-E24-33, installed in 2004, exhibited increasing technetium-99 concentrations that exceeded the 900 pCi/L DWS in 2006 (Figure 4-18). The downgradient Well 299-E25-93, installed in 2003, exhibited a technetium-99 result of 13,100 pCi/L during the first sampling event in December of 2003. Subsequent results have shown a decreasing trend over time, from 13,000 pCi/L in 2004, to 3,000 in June of 2009. There is most likely an upgradient source for technetium-99 coming into WMA A-AX from the northwest (Figure 4-19), but at the same time there appears to be a local source for technetium-99 within WMA A-AX near Well 299-E25-93.

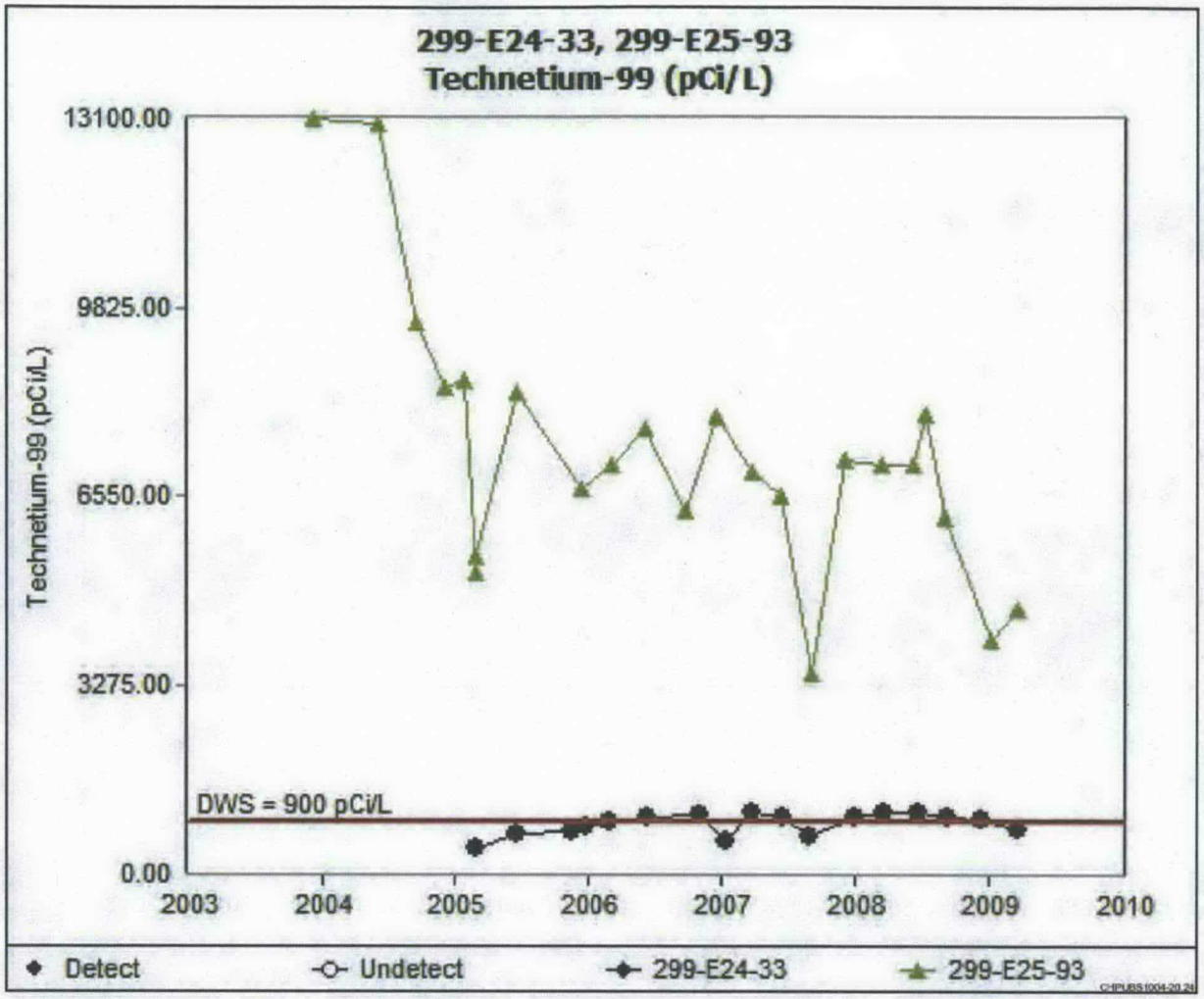



**Figure 4-18. Technetium-99 Concentrations at Well 299-E24-33 and Well 299-E25-93 at WMA A-AX**

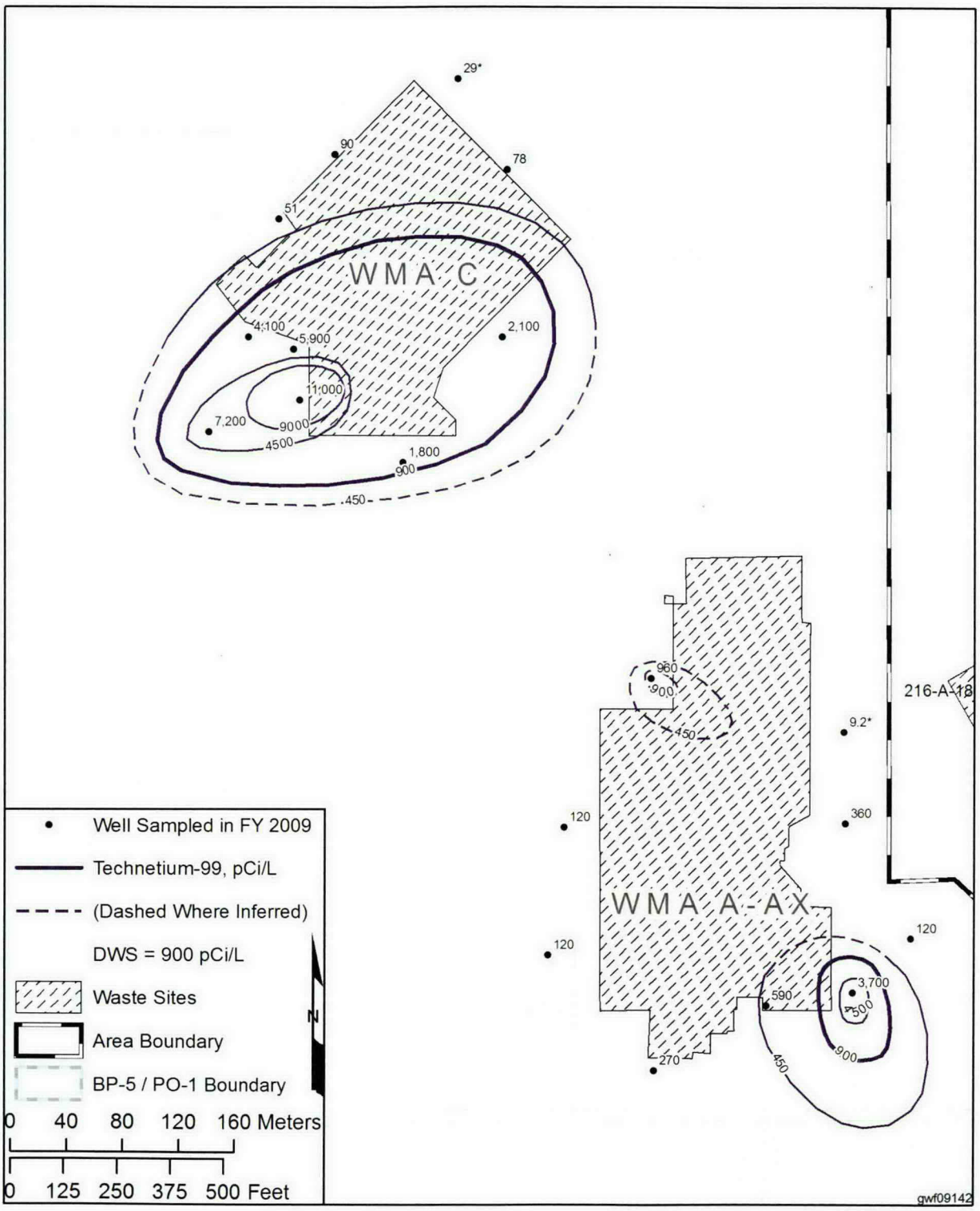



**Figure 4-19. Technetium-99 Plume Map of the WMA C and WMA A-AX in the 200 East Area**

### 4.2.6 Uranium

Naturally occurring uranium is predominantly composed of the isotopes U-238 (99.3 percent) and U-235 (0.7 percent). It decays slowly by emitting an alpha particle, and the half-lives are 4.47 billion years and 704 million years, respectively, for U-238 and U-235. Nuclear reactor fuel is composed primarily of enriched uranium that has been processed to increase the relative concentration of U-235 to a higher than natural content. The primary mass content of irradiated, or "spent," fuel removed from a nuclear reactor at the completion of the fission process remains uranium. The analyses for groundwater are either by the isotopic method or by chemical means. The DWS (30 µg/L) was established through the chemical method for total uranium. While U-238 has a small probability to fission when bombarded with neutrons in a nuclear reactor, the probability for U-235 to fission is much higher. It is mostly U-235 that provides the heat in power reactors and the fissile material for nuclear weapons. Therefore, there was an advantage to enriching the U-235 portion of the U-238/U-235 mix. The $K_d$ for uranium ranges from 0.2 to 4.0 ml/g, depending on soil or groundwater characteristics (PNNL-11800; PNNL-14702). Therefore, a uranium plume has a moderate amount of retardation as a result of absorption and ion exchange while moving through the aquifer.

Most of the uranium in spent fuel was recovered in the PUREX separations process. However, releases of uranium to steam condensate and eventually to the PUREX cribs were due to failures of the uranium nitrate hexahydrate concentrator. Prior to 2000, gross alpha was used as an indicator parameter for uranium (and other potential alpha-emitters) in wells near the PUREX Cribs because uranium concentrations were low. Starting in about 2000, however, gross alpha began rising in concentration at several wells near the PUREX cribs (Figure 4-20). Uranium was added as an analyte to several of the wells in the region in 2005 when the gross alpha results in the wells either approached or exceeded the 15 pCi/L MCL for gross alpha. The gross alpha screening indicated the potential for a local increase in uranium. Figure 4-21 shows the continued increase in uranium at Well 299-E17-14 and Well 299-E24-16 at the PUREX cribs after 2005. Subsequently, uranium was also added as an analyte at other wells in the area. The highest uranium concentration in the southeastern portion of the 200 East Area was discovered to be at 92 µg/L at the new Well 299-E24-23, which was installed in 2008 and sampled in early FY 2009. Figure 4-22 shows the recent uranium plume near the PUREX cribs. There is also a small uranium plume near the 618-10 Burial Ground that is covered under the 300-FF-5 OU.

### 4.2.7 Minor COPCs Volatile Organic Compounds (Tetrachloroethene, Trichloroethene, and Carbon Tetrachloride)

Three VOCs (tetrachloroethene, TCE, and carbon tetrachloride) are grouped in this section because they occur in the 200-PO-1 Groundwater OU in concentrations below the MCLs but occasionally above Washington State action levels [WAC 173-340-720(4)(b)(iii)(A) and (B), "Model Toxics Control Act--Cleanup," "Ground Water Cleanup Standards," "Method B Cleanup Levels for Potable Ground Water," "Standard Method B Potable Ground Water Cleanup Levels," "Human Health Protection," "Noncarcinogens," and "Carcinogens"].

#### *4.2.7.1 Tetrachloroethene*

Tetrachloroethene groundwater contamination above the 0.081 µg/L action level (WAC 173-340-720) occurs only at the SWL and NRDWL (Figure 4-1). The exact nature of the waste responsible for the VOC groundwater contamination is not known, but these compounds occurred in liquid waste and sewage disposed to trenches at these facilities. At the SWL alone, waste receipts indicate that the facility received approximately 3,800,000 to 5,700,000 liters of sewage and 380,000 liters of catch tank waste liquid (DOE/RL-90-38, Rev. 0, *Hanford Site Solid Waste Landfill Permit Application*). The sewage originated from portable toilets and septic tanks. Catch tank liquid was from the 1100 Area heavy equipment garage and bus shop, and chemical analyses showed that the liquid contained tetrachloroethene, TCE, carbon tetrachloride, and 1,1,1-trichloroethane (DOE-RL-90-38).

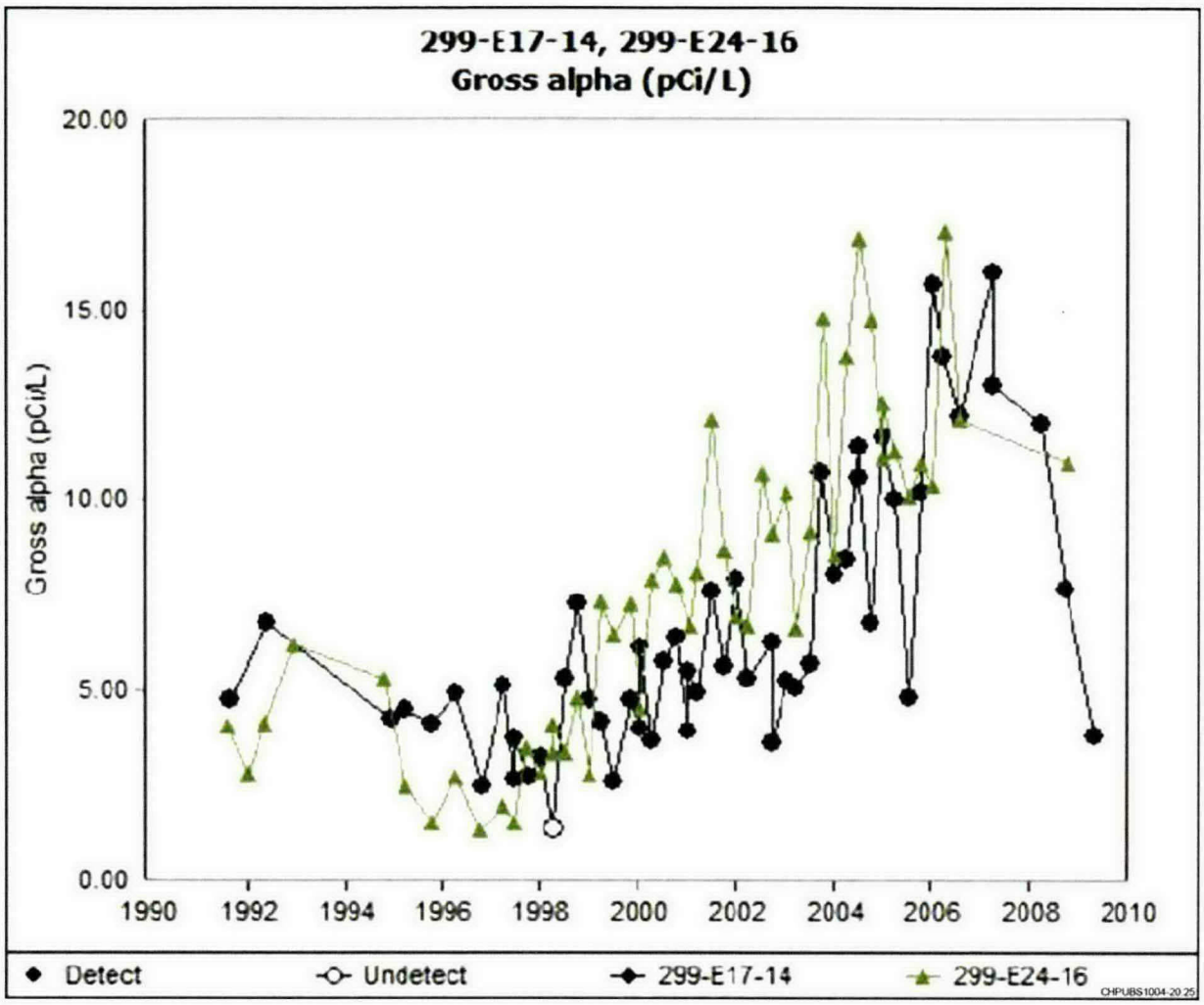



Figure 4-20. Gross Alpha Concentrations in Well 299-E17-14

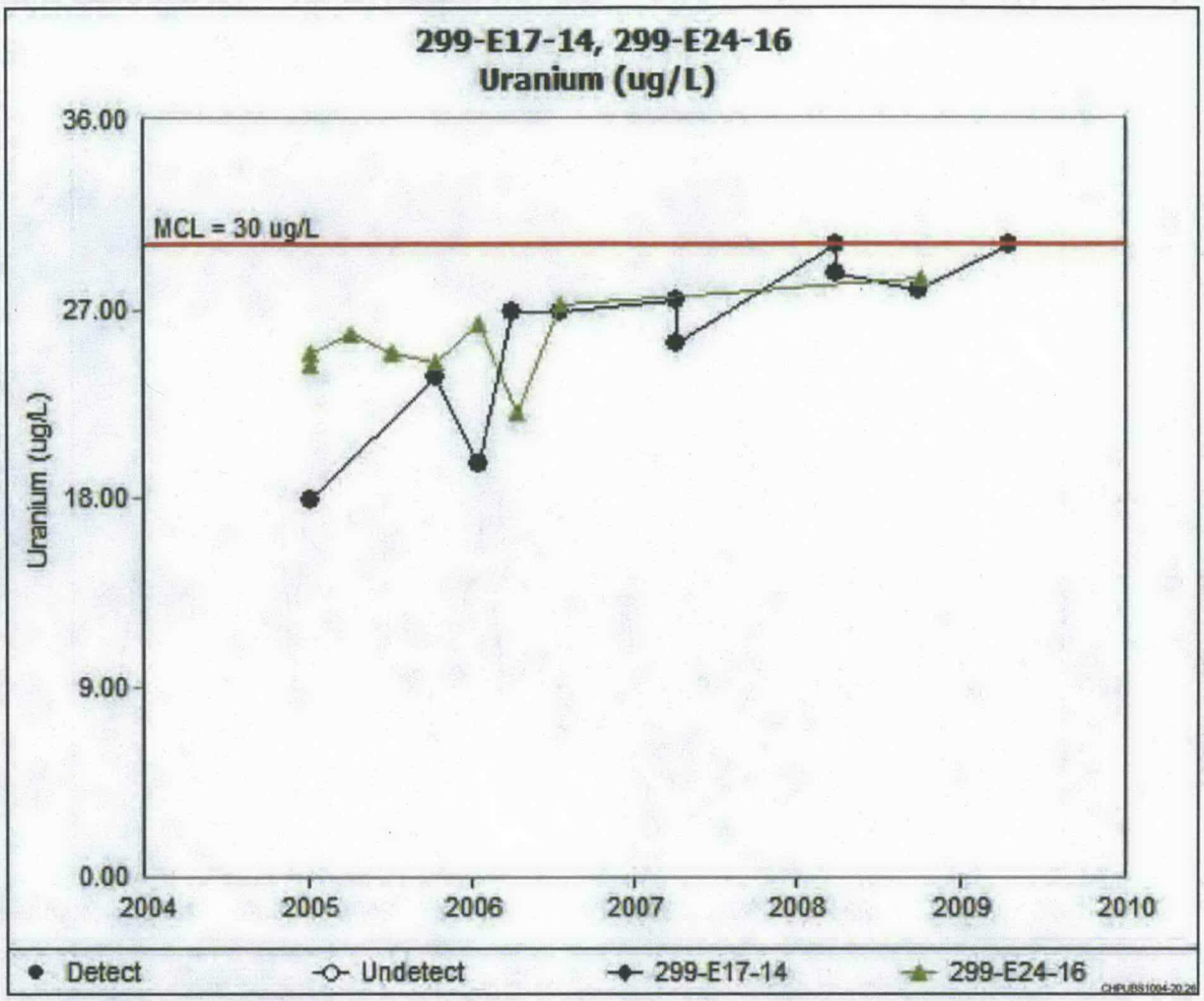



**Figure 4-21. Uranium Concentrations in Well 299-E17-14 and Well 299-E24-16 at the PUREX Cribs**

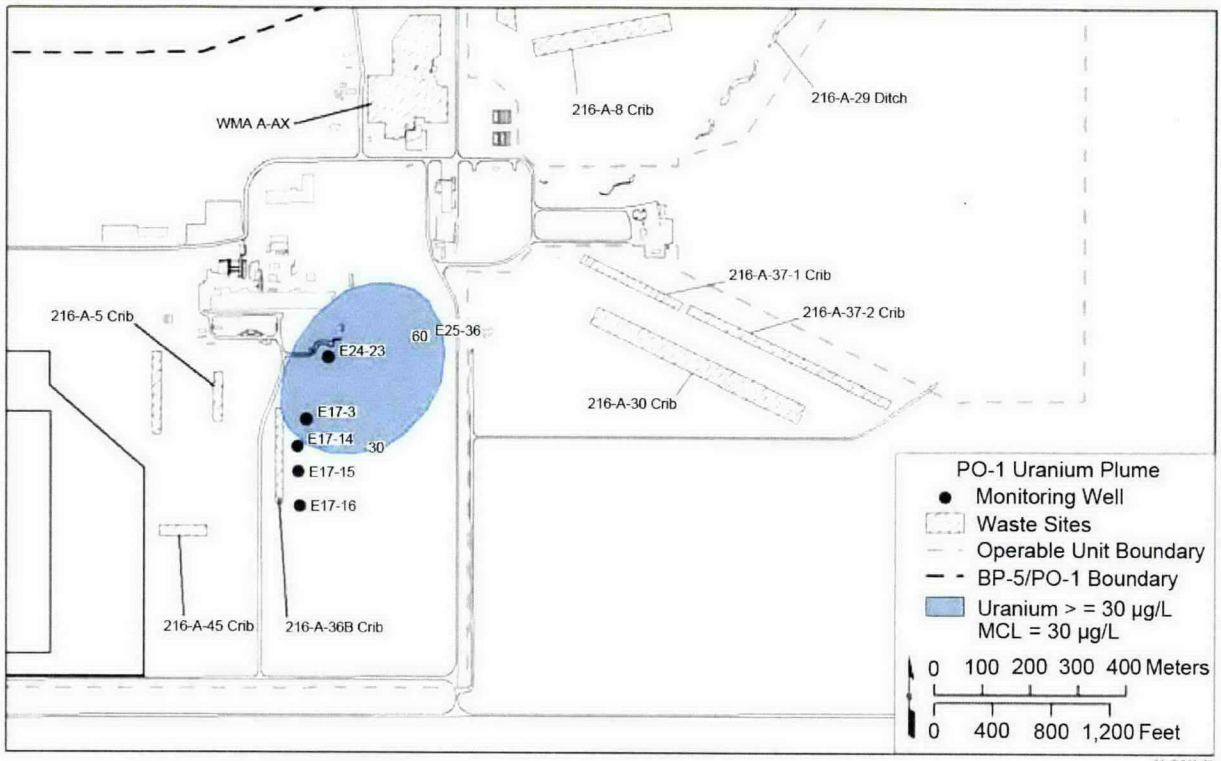



**Figure 4-22. Uranium Plume near the PUREX Cribs**

Tetrachloroethene concentrations in SWL and NRDWL wells have been decreasing since the early 1990s (Figure 4-23). Well 699-24-34C and Well 699-24-33 are typical of the wells at these two facilities and show that the decreasing tetrachloroethene concentrations continued until 2008 when there was an apparent increase in tetrachloroethene at these two wells (Well 699-24-33 is about 200 m [656.2 ft] downgradient (southeast) of Well 699-24-34C). Other wells at these two facilities show a similar decrease in tetrachloroethene concentrations and then the same unexpected rise. The unexpected rise may be due to a change in the analytical laboratory that occurred at the same time. Although the last few results (representing the new laboratory) are apparently legitimate detects, the laboratory flagged the data as "estimated values" indicating that they are above the method detection limit but below the contract-required detection limit. There are no wells located immediately southeast of the SWL (other than 699-24-33), so the downgradient extent of the tetrachloroethene plume is not known. In 1990, Well 699-8-25 (Figure 4-1) had a tetrachloroethene result of 0.3 µg/L, and Well 699-20-20 had a tetrachloroethene result of 0.18 µg/L in 1996, but with the "estimated" laboratory flag.

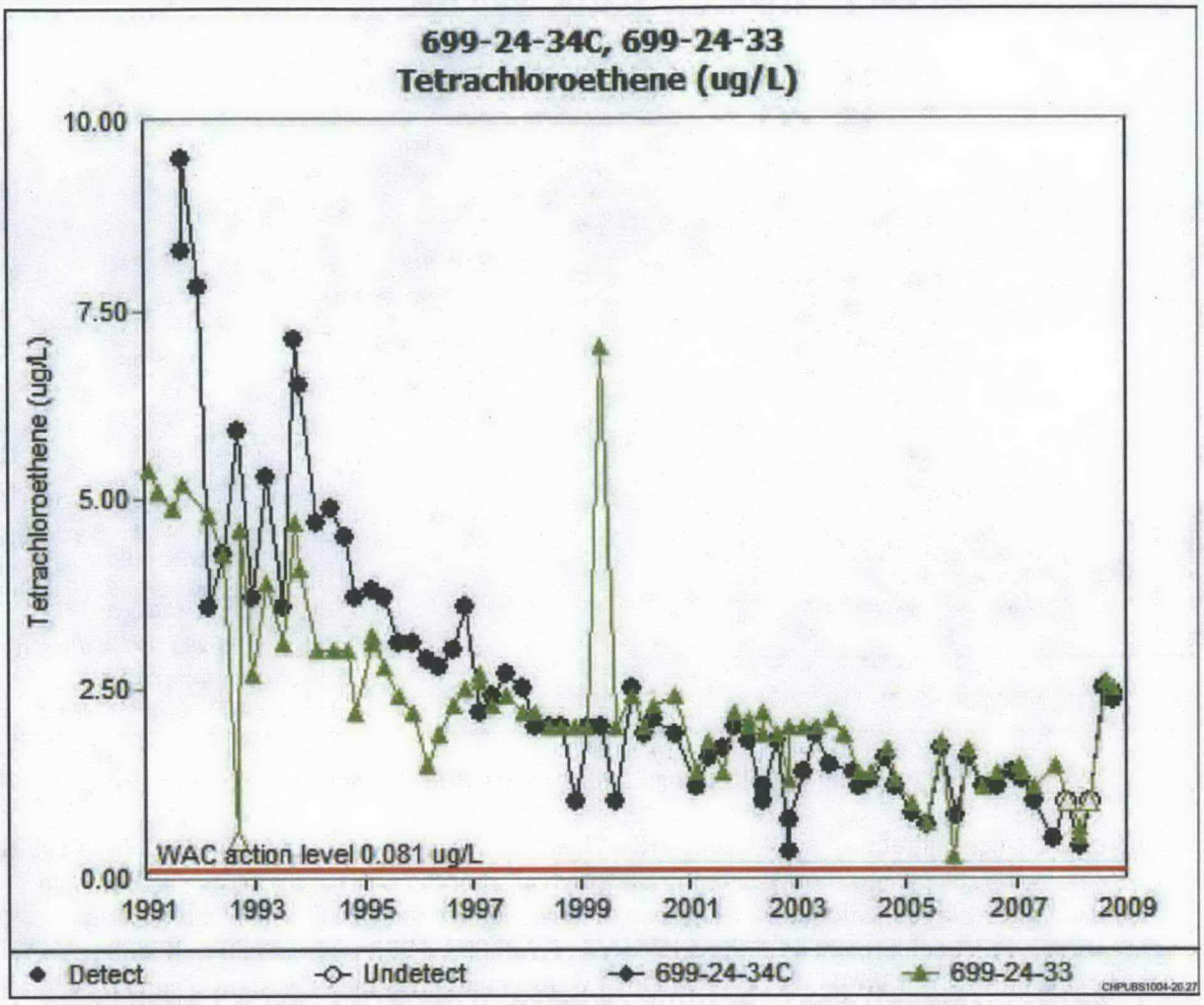



**Figure 4-23. Tetrachloroethene Concentrations in Two Wells at the Solid Waste Landfill**

### *4.2.7.2 Trichloroethene*

TCE exceeds the 0.49 µg/L WAC 173-340-720 action levels at the SWL (and nearby NRDWL) and near the PUREX cribs in the southeastern portion of the 200 East Area. The source of the groundwater contamination in the SWL/NRDWL area is similar to that which caused the contamination of tetrachloroethene. Like tetrachloroethene, TCE concentrations in groundwater at the SWL and NRDWL are decreasing with time. Figure 4-24 shows the decreasing trend for TCE at two representative wells at the SWL. In the early 1990s, concentrations were above the 5.0 µg/L MCL but by 2001, the concentrations had decreased to below 1.0 µg/L. Wells at the NRDWL generally have lower concentrations of TCE than wells at the SWL. Concentrations at both landfills are expected to decline to below the action level.

TCE in the vicinity of the PUREX cribs in the southeastern portion of the 200 East Area has only been detected (above the 0.49 µg/L action level) at four wells. The concentration range at those four wells was 0.56 to 1.7 µg/L. The well with the highest concentration was Well 299-E17-14 near the 216-A-36B Crib. The trend for TCE at the four wells is unknown due to the lack of historical data. Now that TCE has been detected over the 0.49 µg/L action level, it will be added to the analyte list for routine sampling in the area.

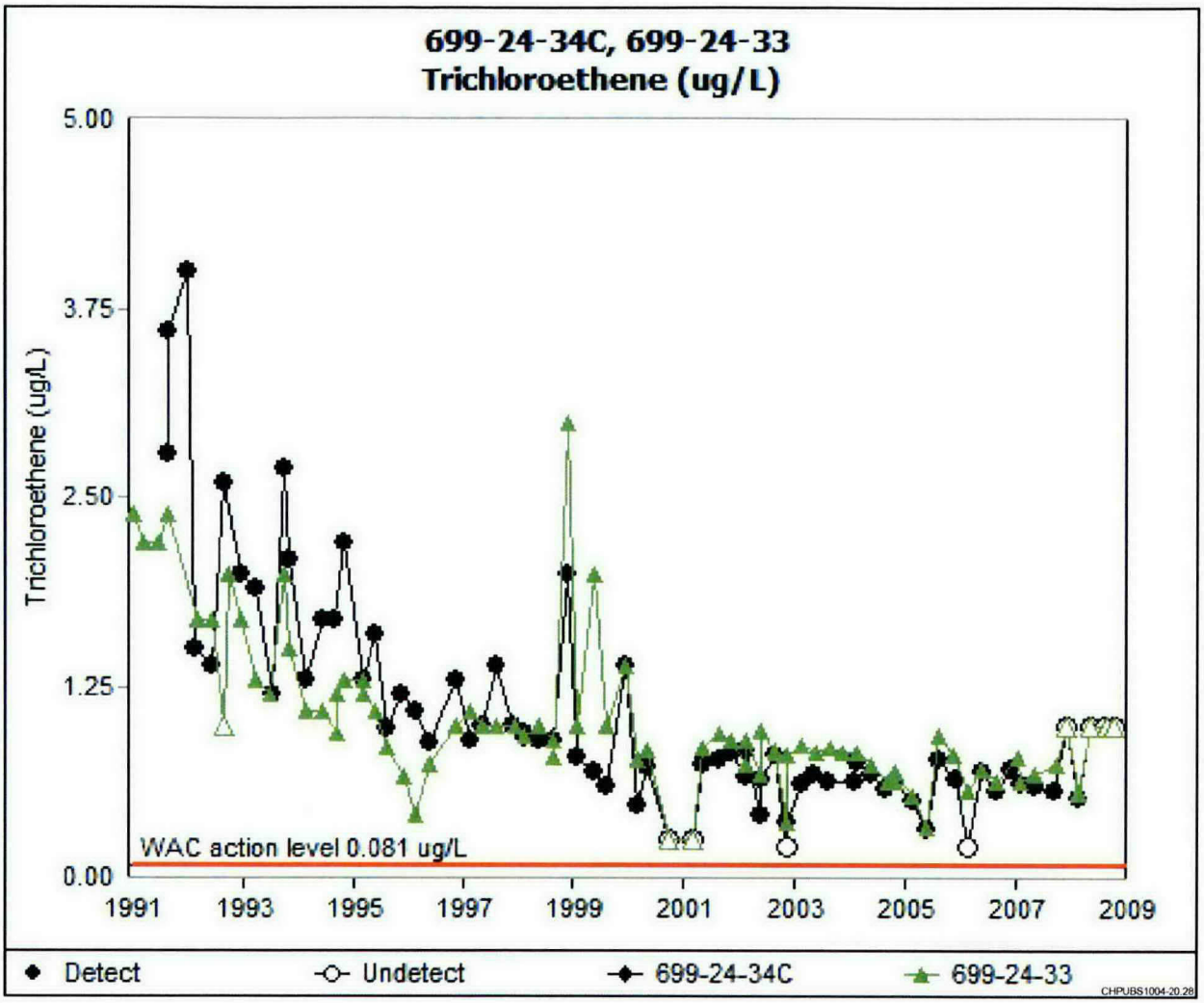



**Figure 4-24. Trichloroethene Concentrations at Two Wells at the Solid Waste Landfill**

### *4.2.7.3 Carbon Tetrachloride*

Carbon tetrachloride concentrations in concentrations greater than the 0.34 µg/L action level (WAC 173-340-720) were discovered at wells at the SWL and NRDWL, as well as one detection at Well 699-24-46 and two detections at Well 699-32-22A (Figure 4-1). All were flagged by the analytical laboratory as "estimated" detections with results at concentrations between the contractually required detection limit and the method detection limit. The potential waste sources for the detections at Well 699-24-46 and Well 699-32-22A are unknown, but carbon tetrachloride was in liquid waste and sewage disposed to trenches at the SWL and NRDWL. The highest concentration detected in the last five years was 2.0 µg/L at Well 699-26-33, a NRDWL. The very low concentrations and sporadic detections forming the trend at Well 699-26-33 (Figure 4-25) are representative of wells in the area.

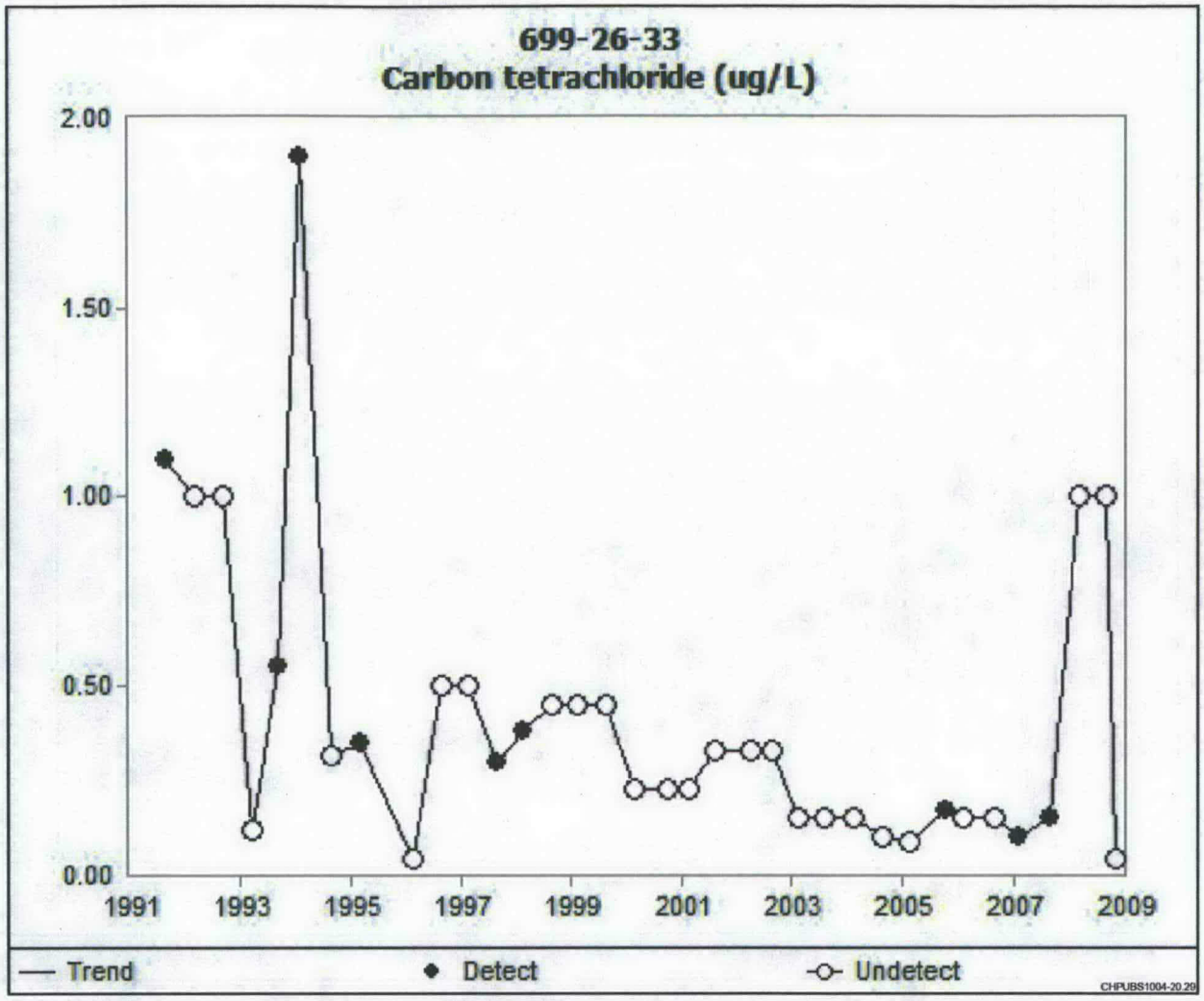



**Figure 4-25. Carbon Tetrachloride Concentrations at Well 699-26-33 at the Nonradioactive Dangerous Waste Landfill**

## 4.3 200-PO-1 RI/FS Work Plan Well Sampling Results

The 43 characterization wells selected in the RI work plan SAP (DOE/RL-2007-31, Appendix A; Figure 4-2; (Table 2-3; and Table 2-4) were each sampled one time in FY 2008 and the samples were analyzed for the constituents and methods listed in Table 4-1. Sampling efforts were unsuccessful at two of the wells, leaving 41 that were successfully sampled. Table 4-3 lists the groundwater constituents detected along with the maximum value for each detected constituent, the well where the maximum value was obtained, any laboratory qualifiers for the maximum values detected, the number of detections, the background level for the detected constituents (if they are known), and the MCL and WAC 173-340-720 limits. In parentheses behind the limits listed are the number times the limits were exceeded. For instance, the tritium MCL (20,000 pCi/L) was exceeded at 10 of the 41 wells.

Forty-nine constituents were detected. Overall, the detections were very similar to what was known from the results of sampling and analysis for the 133 routinely sampled wells. Of the 49 analytes detected, 26 were detected above background levels (at the 95 percentile), and six were either below background

levels or did not have an available background level. Concentration levels of 13 of the constituents exceeded MCLs, and 10 constituents exceeded WAC 173-340-720 limits.

### 4.3.1 Results from Remedial Investigation Work Plan Appendix A, Table A3.2-2, Groundwater Sampling

The constituents detected, organized by groups of like constituents (chlorinated hydrocarbons, naturally occurring metals, laboratory contaminants, heavy metals, anions, metals in steel, other metals, and radioactive constituents), are summarized below.

**Chlorinated Hydrocarbons** – Three of the chlorinated hydrocarbons detected had elevated concentrations that exceed WAC 173-340-720 limits. They were 1,1-dichloroethene (limit of 0.0729 µg/L), tetrachloroethene (limit 0.081 µg/L), and TCE (limit 0.492 µg/L). The maximum values detected were 0.19 µg/L for 1,1-dichloroethene and 2.2 µg/L for tetrachloroethene at the NRDWL, and 3.1 µg/L for TCE near the PUREX cribs. Toxicity values for 1,1-dichloroethene were eliminated in late 2009, and that compound is, therefore, not considered further as a COPC.

**Naturally Occurring Metals** –Arsenic, calcium, potassium, silver, sodium, strontium, barium, iron, manganese, nickel, magnesium, zinc, uranium, and vanadium were detected in most of the wells sampled. Some were detected above background levels; but, except for arsenic, iron, manganese, zinc, and uranium, none exceeded MCLs or WAC 173-340-720 limits. Because iron, manganese, and zinc are associated with well materials (steel), they are discussed in the following section titled "Metals in Steel Well Casings and Screens." The background level (at the 95 percentile) of arsenic (0.0583 µg/L WAC 173-340-720 limit) was exceeded at 33 of the 41 wells sampled. Uranium was detected in 37 of the 41 wells, exceeded background concentrations at the 95 percentile in two wells (299-E24-34 and 299-E17-14, both near the PUREX cribs), and exceeded or equaled both the MCL and WAC 173-340-720 limits in one well (299-E24-23). The results were 92.8 µg/L at Well 299-E24-23 and 30 µg/L at Well 299-E17-14.

**Laboratory Contaminants** – Bis(2-ethylhexy)phthalate and methylene chloride are typical laboratory contaminants and were detected at three wells. The reported results exceeded both the MCL and WAC 173-340-72 limits for bis(2-ethylhexy)phthalate, but the reported detection of methylene chloride did not exceed the limits.

**Heavy Metals** – Cadmium was detected in three wells, and lead was detected in 18 wells. Two of the three cadmium detections were identified by the laboratory as below their contractually required detection limit, and the other result was even lower in concentration (4 µg/L). Only 2 of the 18 lead detections exceeded the MCL (15 µg/L). The exceeding results were 34.5 µg/L at Well 299-E13-8, near the BC Cribs, and 17.5 µg/L at Well 699-24-1P in the 600 Area north of Energy Northwest. However, these lead results are for unfiltered samples. The filtered samples collected at the same time had results of 1.3 and 1.9 µg/L, respectively, which are at or only slightly above the lead background concentration (at the 95 percentile) of 1.3 µg/L.

**Anions** – Detected anions include chloride, fluoride, nitrate, nitrite, and sulfate, which are naturally occurring groundwater constituents (with the possible exception of nitrite). All were detected above their respective background concentrations at the 95 percentile at one or more of the 41 wells sampled. Only fluoride and nitrate exceeded MCLs and WAC 173-340-720 limits. The fluoride WAC 173-340-720 limit of 960 µg/L was exceeded at Well 699-S2-34B, Well 699-13-1C, and Well 699-32-22B, which are all deep wells screened in basalt aquifers (PNNL-6415; DOE/RW-0164). Elevated fluoride levels are known to occur naturally in some of the basalt confined aquifers. The highest reported result was 9,090 µg/L at Well 699-S2-34B (the LIGO well). This result also exceeds the 4,000 µg/L MCL for fluoride. Nitrate

from the PUREX cribs is one of the major contaminants of concern in the 200-PO-1 Groundwater OU, and occurs above the 95 percentile background concentration of 41,723 in 36 wells. The highest reported concentration in the 41 wells sampled was 127,000 µg/L at Well 299-E17-14 near the 216-A-36B Crib.

**Metals in Steel Well Casings and Screens** – Five metals were detected that typically comprise steel casings and screens (chromium, iron, manganese, nickel, and zinc). Three of the five metals (iron, manganese, and zinc) had elevated concentrations exceeding their representative MCLs. The MCL for iron (300 µg/L) was exceeded in nine wells, many of them screened or perforated in deeper wells. The highest concentration was 1,010 µg/L for an unfiltered sample collected from Well 699-20-E12O (a deeper well located near the Columbia River northeast of Energy Northwest). A filtered sample collected at the same time was 230 µg/L. The MCL for manganese (50 µg/L) was exceeded in six wells. Most of them are either older carbon steel wells or wells located in an area where the groundwater may be especially corrosive to stainless steel (i.e., WMA A-AX). The highest concentrations of manganese were found in Well 299-E13-17 (located near the BC cribs) with an unfiltered sample result of 186 µg/L. The filtered sample collected at the same time had a result of 173 µg/L. Likewise, the MCL for zinc (5 mg/L) was exceeded in the old carbon steel wells near the BC cribs. The most elevated zinc result was a filtered sample with the result of 10.2 mg/L at Well 299-E13-16 located near the BC cribs. An unfiltered sample collected at the same time had a similar result.

**Other Metals** – Metals like cobalt and copper also were detected in a few of the 41 wells sampled. Only cobalt had exceedances of the WAC 173-340-720, "Model Toxics Control Act –Cleanup," limit of 4.8 µg/L. The highest concentration reported was 14.3 µg/L at Well 299-E13-16 located at the BC cribs. Like iron, elevated cobalt concentrations could be from the corrosion (rusting) of the carbon steel casing used in these older wells.

**Radioactive Constituents** – Radioactive constituents detected that either exceeded background levels or exceeded one of the two limits (MCL or WAC) included gross beta, iodine-129, strontium-90, technetium-99, and tritium. All exceedances were found in wells sampled for RCRA or the 200-PO-2 OU routine SAP (DOE/RL-2003-04), or the results were discovered to be similar to known plumes. Gross beta was found to be elevated in wells where strontium-90 is elevated (i.e., 299-E17-14 near the PUREX cribs) or where technetium-99 is elevated (i.e., 299-E25-93 at WMA A-AX). Iodine-129 concentrations are elevated in wells near the PUREX cribs and in wells downgradient from the PUREX cribs. The highest concentrations are near the 216-A-36B Crib where Well 299-E17-14 had a reported result of 10.4 pCi/L. Strontium-90 exceeds its MCL at only one well (299-E17-14) with a reported result of 20.2 pCi/L. Technetium-99 exceeds its MCL at only one well (299-E25-93) with a reported result of 8,000 pCi/L. Like iodine-129, tritium concentrations exceed the MCL (20,000 pCi/L) in wells near the PUREX cribs and downgradient from the PUREX cribs. The highest tritium concentration was 650,000 pCi/L at Well 299-E17-14 near the 216-A-36B Crib.

### 4.3.2 Groundwater Sampling Results from Exploratory Boreholes

During FY 2008, grab samples of groundwater were collected from three exploratory boreholes (C6552, C4951, and C5923) as the boreholes reached the water table. (Note: Borehole C5923 was later converted to a vadose zone vapor injection well named 299-E13-62. Groundwater sample analysis results are identified in HEIS as 299-E13-62, rather than C5923.) The exploratory boreholes were at the 216-A-5 Crib, 216-A-30 Crib, and BC Cribs and Trenches (Figures 2-1, 2-3 and 2-4) and are among the 43 wells (or boreholes) selected in DOE/RL-2007-31, Appendix A. Because collecting groundwater from an exploratory borehole lacks the benefit of well development, the technique produces groundwater samples of high turbidity that must be filtered at the collection site. Therefore, the groundwater aliquots for all of the analytical methods were filtered from these three boreholes. The constituents analyzed in the

groundwater samples from the exploratory boreholes included the extensive list of 44 constituents and methods (Table 4-1).

Results from the exploratory boreholes at the 216-A-5, 216-A-30, and BC Cribs have similar results. Nothing unusual was discovered with the increased number of groundwater constituents analyzed in these exploratory boreholes, and results were typical of nearby wells. About 20 constituents were detected with most being naturally occurring constituents, or constituents with concentrations similar to background or upgradient areas. Constituents exceeding MCLs at the exploratory boreholes near the 216-A-5 and 216-A-30 cribs included manganese and tritium. The tritium concentration at those two boreholes was 250,000 and 47,000 pCi/L, respectively. Manganese at the BC Cribs borehole also exceeded the 50 µg/L MCL, but tritium was not detected. Manganese concentrations are typically elevated in the first few samples collected from new wells or boreholes due to immediate but short-lived REDOX reaction with natural metals in geological material particles that are mechanically fractured during the well drilling process.

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# 5 Contaminant Fate and Transport and Conceptual Exposure Model

Computer simulation of contaminant fate and transport was used to assist in understanding the estimated future impacts of current groundwater contamination at the 200-PO-1 Groundwater OU. Fate and transport simulation was used to estimate changes in the concentration of the contaminants (i.e., the fate of those contaminants), as well as the direction and speed in which they travel (i.e., the transport of those contaminants). These estimates were then used to evaluate potential future impacts to hypothetical receptors at selected locations within the groundwater system.

The fate and transport modeling activities performed for this groundwater OU are limited to evaluation of existing groundwater plumes. No continuing contribution from known or suspected vadose zone sources is included in this evaluation. Simulation of behavior of vadose zone sources is outside the scope of this groundwater OU investigation. These residual secondary sources of contamination in the vadose zone soil are part of the overlying waste site OUs and, as discussed in Section 1.2.1, are being addressed under the decisions that will accompany the new 200 East Inner Area and the new Deep Vadose Zone OUs identified in the Tentative Agreement. The potential for future, or continued, contaminant contribution to groundwater plumes due to residual vadose zone sources introduces uncertainty in the estimated future groundwater concentration. This uncertainty must be considered during the FS when evaluating anticipated efficacy of remedial alternatives for groundwater.

The following two techniques were used in combination to describe the estimates of contaminant fate and transport in the 200-PO-1 Groundwater OU:

1. A three-dimensional numerical model to evaluate fate and transport within the portion of the OU designated as the Near Field that is implemented using CHPRC-approved versions of MODFLOW-2000 and MT3DMS software to simulate water movement through the aquifer and contaminant migration through the aquifer, respectively.

2. An analytical method was used to estimate future concentrations of groundwater contaminants in the Far Field portion of the 200-PO-1 Groundwater OU.

The first technique simulates groundwater flow as well as contaminant fate and transport in three dimensions within the Hanford Central Plateau unconfined aquifer. The domain for the model used for the Near Field includes both 200 East and 200 West Areas and a large contiguous surrounding area. Evaluation of potential impacts from contaminant plumes that originate upstream of this OU is necessary in addition to evaluation of groundwater contamination currently contained within the OU boundaries. The second technique uses a contaminant fate and transport calculation from the outlet boundary of the model used for the Near Field to provide a basis for evaluating potential future impacts to the distal portion of the OU, including the Columbia River, which forms the unconfined aquifer's discharge boundary.

The modeling and analytical activities and results are summarized in the following subsections. Details of the groundwater fate and transport modeling for this OU are described in ECF-200PO1-09-2007, *200-PO-1 Operable Unit Remedial Investigation Report – Far-Field Contaminant Fate and Transport*, ECF-200PO1-10-0259, Rev. 1, *Central Plateau MODFLOW Model Development*, and ECF-200PO1-09-2352.

## 5.1 Groundwater Modeling Process

The fate and transport model for the 200-PO-1 Groundwater OU was developed following a systematic approach that implemented the following fundamental steps:

- Prepare an updated geologic description of the model domain describing the distinct hydrostratigraphic units (HSUs), their thickness, distribution within the domain, and elevation of the contacts between units.
- Prepare and calibrate a groundwater flow model of the Central Plateau vicinity.
- Assemble plume maps that describe the distribution of selected contaminants within the Central Plateau aquifer system and identification of contaminant transport characteristics.
- Estimate future groundwater contaminant concentrations within the Central Plateau model domain using a calibrated three-dimensional flow model and transport model.
- Estimate future groundwater contaminant concentrations at selected locations outside of the Central Plateau domain boundary and extending downgradient to the Columbia River using a calibrated one-dimensional analytical model.

### 5.1.1 Contaminants of Potential Concern Characteristics

Fate and transport of selected 200-PO-1 Groundwater OU contaminants of potential concern (COPCs) (namely, uranium, technetium-99, tritium, iodine-129, nitrate, strontium-90, tetrachloroethene, trichloroethene [TCE], and carbon tetrachloride) were simulated to evaluate future impacts to the unconfined aquifer. These contaminants were selected for transport evaluation due to their presence in this OU in discernable, broadly distributed groundwater plumes, which demonstrates that they have exhibited mobility in the past, and/or that they are present in the unconfined aquifer in developing groundwater plumes with known elevated potential for migration in the future. Characteristics of these contaminants are summarized in Table 5-1. These contaminants include both radioactive and non-radioactive contaminants, organic and inorganic contaminants, and metallic and non-metallic contaminants. The contaminants evaluated in fate and transport simulations exhibit the common characteristic of being present as dissolved constituents in groundwater.

### 5.1.2 Contaminant Mobility Discussion

The COPCs exhibit varying levels of mobility in groundwater. The COPCs are all sufficiently water-soluble, such that their solubility is not a limiting factor to their transport in the 200-PO-1 Groundwater OU aquifer system. Maximum observed concentrations of all of the contaminants examined in this simulation were below their apparent solubility limits in water. The COPCs for this OU fall into three general categories of mobility in groundwater: highly mobile, moderately mobile, and slightly mobile. The primary physical process that describes contaminant mobility in the 200-PO-1 Groundwater OU is interaction of the contaminants with the solid phase portion of the aquifer system (i.e., sorption of contaminants to geologic aquifer materials); this determines the mass of dissolved contaminants in groundwater at any particular time and/or location. The sorption process is described by the contaminant-specific distribution coefficient, or $K_d$. The contaminant $K_d$ is defined as the ratio of the concentration of contaminant sorbed onto the solid phase portion of the aquifer to the concentration of contaminant in solution in the aquifer groundwater in an equilibrium condition. Mathematically, the $K_d$ is defined simply as the ratio of the sorbed phase concentration ($c_{sorbed}$) to the solution phase concentration $c_{solution}$ at equilibrium:

$$K_d = \frac{c_{sorbed}}{c_{solution}}$$

**Table 5-1. Physical Characteristics of Selected Contaminants of Potential Concern**

| Chemical Name | Chemical Abstract System (CAS) Number | Chemical Group | MW (g/mole) | MW Ref | Radioactive Half Life (yr) | Radioactive Half Life Ref |
|---|---|---|---|---|---|---|
| Carbon Tetrachloride | 56-23-5 | Volatile | 153.82 | PhysProp | N/A | N/A |
| Iodine-129 | 15046-8-41 | Radionuclide | 129.91 | ChemBioFinder | 16,000,000 | ANL, 2007 |
| Nitrate | 14797-55-8 | Nutrient | 62.00 | ChemBioFinder | N/A | N/A |
| Technetium-99 | 14133-76-7 | Radionuclide | 98.91 | ChemBioFinder | 210,000 | ANL, 2007 |
| Tetrachloroethene | 127-18-4 | Volatile | 165.8 | ChemBioFinder | N/A | N/A |
| Trichloroethene | 79-01-6 | Volatile | 131.39 | PhysProp | N/A | N/A |
| Strontium-90 | 10098-97-2 | Radionuclide | 89.91 | ChemBioFinder | 28.8 | Table of Nuclides |
| Tritium | 10028178 | Radionuclide | 6.03 | ChemBioFinder | 12 | ANL, 2007 |
| Uranium, soluble salts | N/A | Metal | 238.03 | ChemBioFinder | N/A | N/A |

Notes:

ANL, 2007, *Radiological and Chemical Fact Sheets to Support Heath Risk Analyses for Contaminated Areas.*

ChemBioFinder = ChemBioFinder.com, 2009

Table of Nuclides = http://atom.kaeri.re.kr/ton/nuc5.html

PhysProp = PhysProp database, Syracuse Research Corporation. Downloaded from http://esc.syrres.com/interkow/physdemo.htm, 2009

MW = Molecular Weight

N/A = not applicable

Ref = Reference Source Description

Dimensionally, the units for $c_{sorbed}$ are expressed as µg of sorbed contaminant per g of solids (e.g., soil matrix), while the units for $c_{dissolved}$ are expressed as µg of dissolved contaminant per mL of water:

$$K_d \text{units} = \frac{\frac{\mu g}{g}}{\frac{\mu g}{mL}} = mL/g$$

A contaminant's $K_d$ value may be determined experimentally through laboratory batch or column leaching tests using samples of aquifer solids and actual, or simulated groundwater. Alternatively, $K_d$ may be determined through measurement of relative contaminant concentrations in groundwater and associated aquifer solids collected from a single representative location.

Contaminants classified in this study as highly mobile move freely with the water in which they are dissolved, exhibiting no direct interaction with the solid phase portion of the aquifer that would remove contaminant mass from the groundwater as it moves through the aquifer. The highly mobile contaminants exhibit a $K_d$ of 0 (no retardation). An example of a highly mobile contaminant is tritium.

Contaminants classified in this study as moderately mobile move readily with groundwater but also exhibit a moderate degree of interaction with aquifer solids. Sorptive processes generally tend to slow the rate of migration of these contaminants through the aquifer and reduce their observed concentration in groundwater with migration downgradient through the aquifer system. The definition of moderately mobile is clearly subjective; for purposes of this study, moderately mobile contaminants are identified as those contaminants exhibiting $K_d$ values greater than 0 but less than 1. An example of a moderately mobile contaminant is uranium.

Those contaminants classified in this study as slightly mobile exhibit a high degree of interaction with aquifer solids and, as a result, migrate slowly through the aquifer. Their dissolved concentration in groundwater decreases dramatically with distance from a source or release point due to the relatively large fraction of the contaminant that becomes sorbed to the aquifer solids. For this study, slightly mobile contaminants are identified as those contaminants that exhibit $K_d$ values greater than one. An example of a slightly mobile contaminant is strontium-90.

The linear isotherm ($K_d$) model used in this study is a non-specific process quantification (i.e., it does not describe a specific physical or chemical process). Sorption processes in any particular aquifer may include electrostatic ion exchange (cationic or anionic), precipitation reactions, physical adherence on particle surfaces, or combinations of multiple processes. The sorption processes may exhibit varying degrees of reversibility, as well as variations in the rate of reversibility. The $K_d$ of groundwater contaminants vary, generally as a function of differences in the content of fine textured materials (e.g., silt and clay-sized particles) in the aquifer solids; as the content of fine materials in the aquifer solids increases, $K_d$ tends to increase. As a result, contaminants tend to exhibit lower $K_d$ in coarse textured aquifer materials (i.e., sandy or gravelly materials) and higher $K_d$ in fine textured formations (i.e., silty and clayey materials). Contaminant-specific $K_d$ values for the 200-PO-1 Groundwater OU COPCs are summarized in Table 5-2. The contaminant $K_d$ values used for this study were selected from published reports describing experimental determination of $K_d$ values for specific COPCs conducted on samples of aquifer materials that represent aquifer conditions within the 200-PO-1 Groundwater OU.

**Table 5-2. Contaminant Distribution Coefficients for Contaminants of Potential Concern in Fate and Transport Modeling**

| Contaminant | $K_d$ (mL/g) |
|---|---|
| Tritium | 0 |
| Iodine-129* | 0.1 |
| Technetium-99 | 0 |
| Strontium-90 | 12 |
| Uranium | 0.4 |
| Nitrate | 0 |
| Tetrachloroethene | 0.0749 |
| Trichloroethene | 0.0250 |
| Carbon Tetrachloride | 0.0030 |

Notes:

See ECF-200PO-1-09-2007 (Table 2) for $K_d$ references.

*Spatially varying $K_d$ is applied in the Far Field transport calculation that ranges from 0 to 0.35 ml/g, based on a calibration exercise (see ECF-200PO1-09-2007).

### 5.1.3 Fate and Transport Models and Approach to Simulations

Simulation of contaminant migration in the 200-PO-1 Groundwater OU was performed following the general process described below. A detailed discussion of the contaminant fate and transport model development and the results of the fate and transport simulations, as applied to the 200-PO-1 Groundwater OU, are presented in the following three environmental calculation briefs:

- ECF-200PO1-09-2352
- ECF-200PO1-10-0259
- ECF-200PO1-09-2007

The MODFLOW and MT3DMS software were used to simulate groundwater flow and transport, respectively, in the Near Field. MODFLOW solves the groundwater flow equation to calculate hydraulic heads and groundwater flow velocities. MT3DMS uses the resultant groundwater flow velocities, along with transport characteristics of the aquifer and contaminants, to solve the groundwater advection-dispersion equation, yielding concentrations in time and space that are used to evaluate risk.

Two general categories of physical processes affect the concentration of contaminants in a groundwater plume over time: processes related to advection (the movement of water through the aquifer), and processes that are specific to the individual contaminants. For this modeling study, it was assumed that there would be no continuing releases to the aquifer from the vadose zone. Uncertainties related to modeling assumptions, including uncertainty related to potential for continuing releases from the vadose zone, are summarized in Section 5.2.2 and described in detail in ECF-200PO1-09-2007.

These specific physical processes provide the primary effects on changes in the estimated contaminant concentrations over time and distance in this Groundwater OU:

- Dilution of the contaminants, with resulting reduction in groundwater concentration, results from additional uncontaminated water entering the aquifer. This can include uncontaminated groundwater entering the model domain from the lateral domain boundaries, meteoric water entering the aquifer from the top of the domain as a fraction of the annual precipitation falling on the ground surface, and clean water discharges to the aquifer from continuing operations at the Hanford Site.
- Dispersion of the dissolved contaminants occurs as groundwater moves through the aquifer system. Contaminants tend to become more dispersed at decreasing concentrations as groundwater flows through a porous medium. Dispersion occurs as a result of small, localized variations in the water flow velocity at locations within the aquifer. This results in a more widespread distribution of the contaminant mass as distance from the point of origin increases. This process is defined by the coefficient of hydrodynamic dispersion ($D$).
- Diffusion of dissolved contaminants within groundwater occurs as a result of concentration gradients within the aquifer. The result of diffusion is similar to that of dispersion; the original contaminant mass becomes more widespread throughout the aquifer with time and overall concentrations are reduced. This process is quantified by the coefficient of molecular diffusion ($D_m$).

In addition to the advective-diffusive processes identified above, the following selected contaminant-specific processes, included in the fate and transport simulations, also affect groundwater contaminant concentrations over time and distance:

- Radioactive decay of radioactive contaminants as quantified by the half-life of each isotope.
- Degradation of organic contaminants as quantified by the degradation rate of the organic compound.

- Interaction of the contaminants with the solid phase portion of the aquifer system (i.e., sorption of contaminants to geologic aquifer materials) reduces the mass of dissolved contaminants at any particular time and/or location. This process is quantified by the contaminant-specific $K_d$.

Losses from the aquifer through evaporation of volatile contaminants (e.g., solvents and tritium) were not considered in this simulation due to groundwater depth bgs.

To perform the contaminant fate and transport simulations for the 200-PO-1 Groundwater OU, the following steps were performed:

1. A representative data set describing the geological structure and aquifer hydraulic properties of the model domain was prepared through assembly of measurements and geologic observations from montioring well and boring logs, as well as integration of surface geophysical survey data.

2. The geological structure data were used to prepare digital maps of the surfaces of geological structures within the aquifer that were the subject of the modeling exercise. A plan view of the Central Plateau model domain is shown in Figure 5-1.

3. A historical data set of groundwater elevations in groundwater monitoring wells across the model domain was assembled for use in model calibration.

4. The plumes of COPCs in groundwater were described using digital plume maps that can be integrated with the hydraulic model of the aquifer. Plumes were established for the initial simulation conditions using observed contaminant concentrations based on data collected during FY 2008 (see Section 4).

5. Model calibration was performed to compare the MODFLOW-calculated aquifer water levels to the observed historical measurements within the Central Plateau. The calibration was used to provide a representative description of the aquifer hydraulic system.

6. The contaminant plume initial conditions and calibrated groundwater flow model results were input to the MT3DMS software along with contaminant transport characteristics to simulate the future impacts of groundwater contaminants in the Central Plateau for the Near Field portion of the 200-PO-1 Groundwater OU.

7. Pipe Pathway calculations were used to estimate future concentrations of groundwater contaminants in the Far Field portion of the 200-PO-1 OU including the effects of those contaminants that migrate from the Central Plateau model domain. Three Pipe Pathways were chosen based on the extent of the tritium plume in Year 2008, as shown in Figure 5-2. The concentration of contaminants leaving the Central Plateau model domain is an input to the Far Field Pipe Pathways. The Far Field analtyical method calculates groundwater contaminant concentrations at selected locations (shown by red triangles) represented by the end of various Pipe segments.

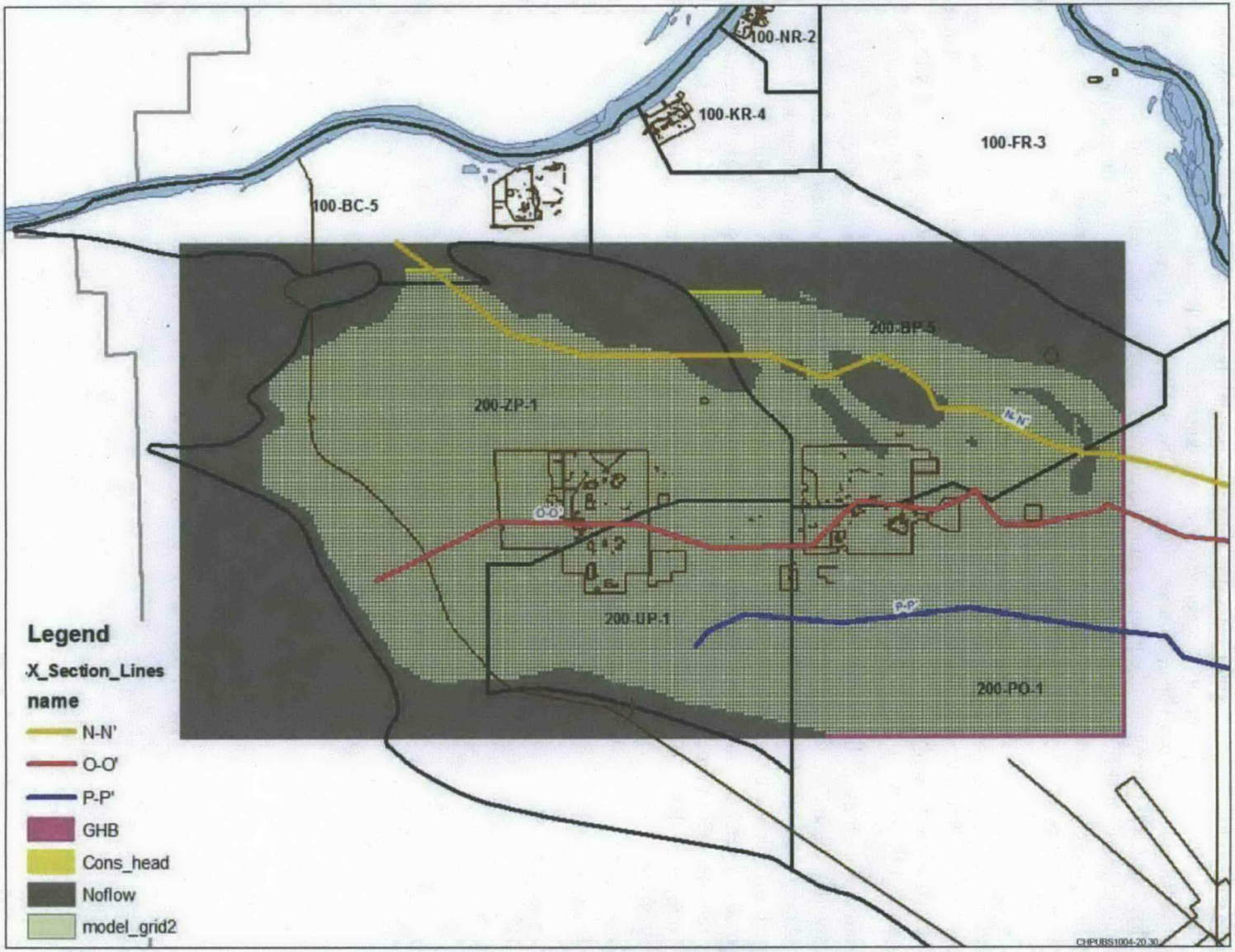
8. Far Field analytical method Pipe Pathways were calibrated using a time series of measured contaminant concentrations at selected locations along apparent flow paths between the 200 East Area and the Columbia River. The calculated contaminant concentrations generated by the analytical method were compared to contaminant concentrations observed in groundwater monitoring wells to confirm that the analytical method presents a representative description of contaminant concentrations along the identified flow paths. As with the MODFLOW model of the Central Plateau, the Pipe Pathway calculations were found to be representative of contaminant fate and transport in the Far Field portion of the 200-PO-1 Groundwater OU.

### 5.1.4 Central Plateau Near Field Hydrogeologic Conceptual Site Model Development

The aquifer is composed of a series of unconsolidated fluvial deposits that accumulated over the past several million years, with the most recent deposits having been made by cataclysmic flooding of the Columbia Basin within the last 20,000 years (the Missoula floods). In the western portion of the domain, the saturated aquifer is composed of a sequence of deposits known as the Ringold Fm. For modeling purposes, the Ringold units have been grouped into three HSUs. Directly above the basalt bedrock lays the Ringold A unit, a relatively coarse grained sand and gravel formation. Next in the sequence is the Lower Ringold Mud, an HSU composed of a mix of coarse and fine grained deposits bounded above and below by fine grained deposits; the Lower Ringold Mud unit forms a substantial restriction to vertical movement of water where it occurs. Above the Lower Ringold Mud is the more coarse grained Ringold E unit.

In the eastern portion of the model domain, the Ringold deposits have been incised by later erosional/ depositional events that have resulted in the formation of highly conductive paleo channel deposits. These erosional paleo channel complexes are filled by the Cold Creek unit (Pre-Missoula gravels) and by the flood deposits of the Hanford fm. The Cold Creek unit and Hanford fm are separate HSUs in the model.

The hydraulic properties of the five HSUs described above are treated as homogeneous effective properties within these five units. The distribution of each unit within the model domain was determined by interpolating the contacts between units from well cores and logs onto the entire model grid. These interpolated surfaces were then used to set the top and bottom elevations of the layers within the model. The five model layers vary in elevation so that the varying elevations and thicknesses of each unit are explicitly represented. In order to do this, the HSU represented by a layer changes within the model domain. To reiterate, layers do not represent individual continuous HSUs across the model domain.




Notes: Cross-sections are discussed in Section 3.4.3.

**Figure 5-1. Plan View of Central Plateau Groundwater Model Domain Boundary and Cross-Section Locations**

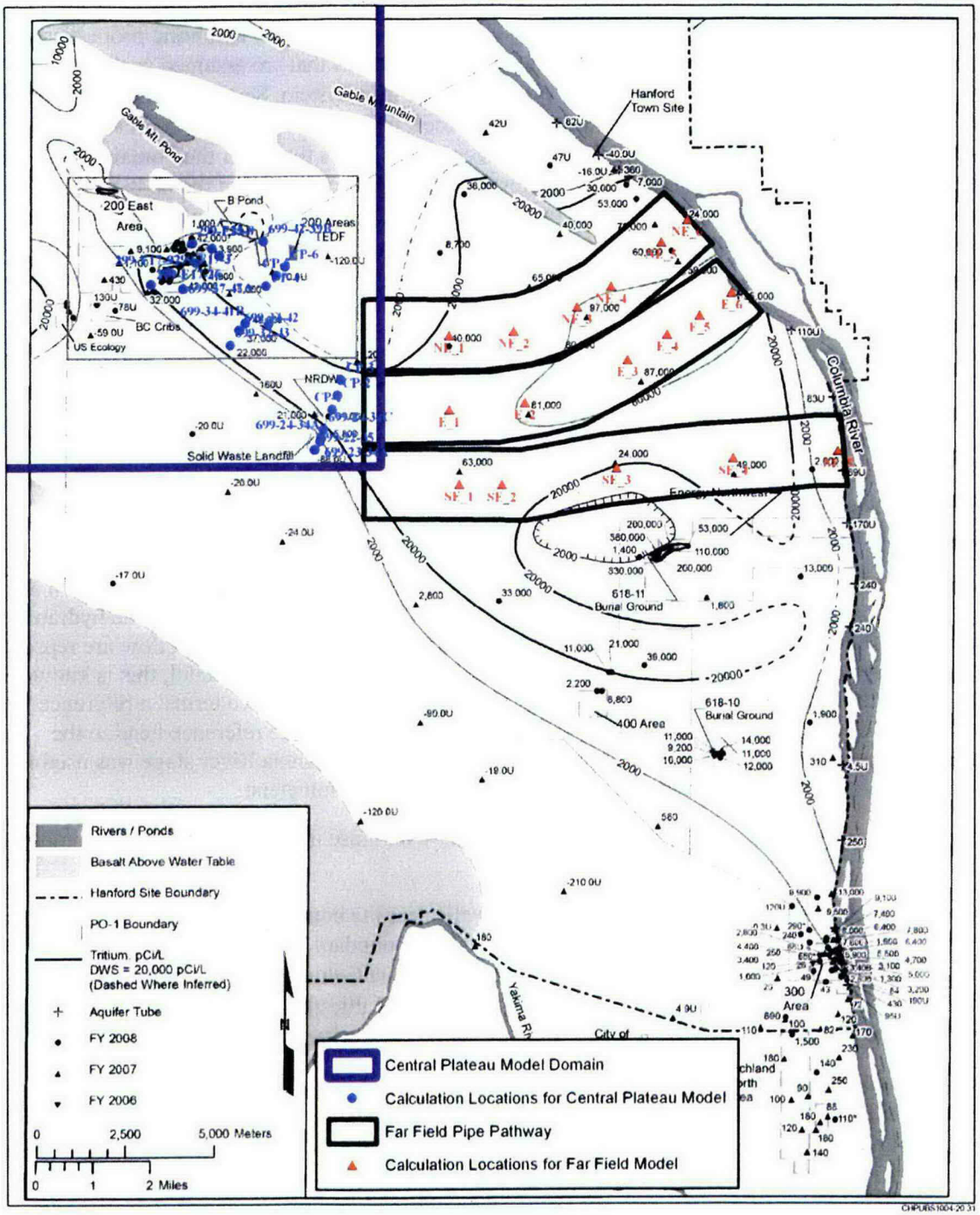



**Figure 5-2. Location and Extent of the Pipe Pathways for Transport Calculations in the Far Field Portion of the 200-PO-1 Groundwater Operable Unit and Their Location Relative to the Central Plateau Modflow Model Domain and Inferred Groundwater Tritium Plume Location**

Contaminant migration in the subsurface is primarily driven by groundwater flow. Groundwater flow directions and velocities are, in turn, a function of fluid inputs to and aquifer hydraulic properties. The model domain is surrounded and underlain by basalt formations that are assumed in these calculations to contribute a negligible amount of water to the flow system. Seven localized regions were identified that are significant inflow and outflow boundaries: two gaps in the basalt sub-crops along the northern boundary of the model domain; two subsurface stream flows that enter the domain along the surface of the basalt; natural recharge to the aquifer from precipitation; artificial recharge arising from the disposal of water in ponds, cribs, and shallow wells; and a broad region of outflow along the south-eastern and eastern edges of the model domain. Vadose zone attenuation of artificial recharge is not accounted for (i.e., water is input at the top boundary of the groundwater flow model with the timing and rates that it was disposed to the surface.

To establish representative hydraulic property values for heterogeneous HSUs, calibration using historic water level measurements was performed. Central Plateau groundwater well monitoring records for groundwater elevation and contaminant concentrations as far back as 1944 when the weapons material production facilities were first being constructed on the Central Plateau were used. The representative hydraulic conductivity of the various units was plotted until simulated hydraulic heads matched well records at selected wells. The comparison was made using head values from model layers that are consistent with the screened intervals of the monitoring wells.

The calibration was complicated by uncertainty in the boundary condition along the southeastern and eastern boundary. A mixed (Cauchy type) boundary condition was applied to represent the hydraulic character of this long boundary. The term mixed means that both hydraulic head and flow are represented in the boundary condition. According to the specifications of the MODFLOW model, this is known as a general head boundary condition. The boundary condition is specified by two terms: a reference head value, and a conductance term representing the hydraulic connection of the reference head to the boundary. Along the eastern portion of the boundary, the average Columbia River stage was used for the reference head, and the conductance was set within the following parameters:

- Flow directions through the boundary were consistent with those implied by historic contaminant plume maps.

The historic observed hydraulic heads at monitoring wells near the boundary were matched by the simulation. Along the southeastern boundary, two mixed boundary condition terms were superimposed to represent the net effect of two fluxes: one to the Columbia River for the eastern boundary, and another to represent inflow from the Dry Creek/Rattlesnake Ridge depression in the basalt bedrock. These two terms were manipulated using the same criteria used for the eastern boundary.

With calibrated parameters established, the calibrated flow model was revised to support the contaminant transport simulations by changing boundary conditions to represent future conditions. Incoming stream flow, natural recharge rates, and the hydraulic heads at the two gaps were assumed to remain unchanged over the 1,000 years simulated for fate and transport. Future planned use of the state-approved land disposal site (SALDS) and Treated Effluent Disposal Facility (TEDF) facilities represents the only sources of artificial recharge, in contrast to the historical period used for model calibration when many other large liquid discharges were included. Current and planned future use of the 200-ZP-1 pump-and-treat system was included. Current pumping for interim remediation of the 200-UP-1 U Plant, and WMA S-SX facility plumes was not included, nor was pumping for future UP-1 (as yet unplanned) final remediation. The MODFLOW groundwater flow software creates a file of transient simulated fluxes to and from each cell in the flow model. These were used, along with porosity values, to calculate groundwater velocities in the MT3DMS transport simulations.

There were five sources of contaminant distribution information used in the interpolation process measurements from screened wells:

- Discrete depth samples acquired during drilling or special sampling surveys
- A composite data set previously created for the ZP-1 OU RI/FS
- Measurements acquired from U.S. Ecology
- Contaminant plume contours interpreted for the Hanford 2008 annual groundwater monitoring report

Current contaminant distributions were prepared for the fate and transport simulations by interpolating measurements across the model domain.

A kriging technique proposed by Reed et al., 2004, "Spatial Interpolation Methods for Nonstationary Plume Data" was adopted for the interpolation algorithm to establish initial contaminant plume conditions. This technique was previously used for the 200-ZP-1 RI/FS to define contaminant distributions. A significant feature of the technique is the use of a transformation to limit the influence of very large concentration measurements which is a common problem with contaminant data. There are some significant differences between the application of kriging to the 200-ZP-1 Groundwater OU and the application to 200-PO-1 Groundwater OU. The most important of these is that contaminant distributions were estimated within the entire model domain for the 200-PO-1 RI and only in the proximity of the 200-ZP-1 OU for the 200-ZP-1 RI/FS.

The 200-PO-1 OU tends to have a predominant flow direction that is almost perpendicular to the predominant flow directions in the 200-ZP-1 and 200-UP-1 Groundwater OUs. To accommodate the tendency for contaminant plumes to align with predominant flow directions, the major principal kriging directions were oriented at 45 degrees east of north in the 200-ZP-1 and 200-UP-1 OUs and 135 degrees east of north in the 200-PO-1 Groundwater OUs. In both cases, the exponential variogram tended to be about twice as long in the major direction as in the minor direction. Longer variograms were used to estimate the distribution of contaminants that tended to have large plumes; shorter variograms were used to estimate contaminants with smaller plumes. No attempt was made to isolate the kriging of individual plumes in the 200-PO-1 Groundwater OU.

Contours of contaminant concentration from the Hanford 2008 annual groundwater monitoring report were used to assess the kriged contaminant distributions and to guide the placement of control points. Control points were used to overcome the symmetry inherent in kriging variograms. Contaminant distributions tend to be high in a source area, diminish rapidly with distance upstream of the source area, and diminish slowly with distance in the direction of flow. To force this tendency and produce the expected shapeliness of resultant plumes, control points with small values were used to constrain the upstream extent of estimated contaminants from apparent source areas in the kriging process. Contaminant contours from the Hanford 2008 annual groundwater monitoring report were used to identify source areas. Control points were also used to connect high distributions. Separated measurements of high value in the contaminant contours from the Hanford 2008 annual groundwater monitoring report indicated a single region of high concentration rather than isolated plumes. Therefore, the data input to defining existent contaminant distributions is both complex and slightly subjective. Subjectivity enters from the choice of control point location and value and from the contaminant contours from the Hanford 2008 annual groundwater monitoring report, which themselves were guided subjectively by historic knowledge and knowledge of the source area processes.

The vertical profile of contaminant data available from monitoring and characterization was not sufficient to determine a detailed three-dimensional distribution of contamination in the 200-PO-1 Groundwater OU for any of the contaminants. Simplifying assumptions were applied that extend the observed contaminant

distribution conservatively through the thickness of the upper unconfined aquifer unit. Only measurements that were acquired from well screens or discrete samples corresponding to regions of the top three layers of the model were used to estimate the horizontal extent of the contamination. The inferred contaminant concentrations were distributed through the upper three model layers. In locations where the upper layers were not saturated, the contaminants were distributed through the lower two layers. The transport simulation allowed movement into any of the five active layers.

Measurements of contaminant concentration tend to be located where contamination occurs at levels of concern. Hence, contaminant measurements at the scale of the groundwater OU are biased towards large values, and regions of low concentration have relatively sparse measurements. In addition, the treatment of non-detect measurements as one-half the detection limits biases the measurements upward away from contaminated areas. The kriging algorithm results trend toward the average of measured values where measurements are lacking. Therefore, away from regions of high concentration, the kriged results are biased towards large values. To reduce the impact on the estimates of total contamination in the groundwater OU, the kriged estimates were truncated at values of one-half of the contaminant's MCL. Below one-half the MCL value, contaminant concentrations were set to zero.

Initial contaminant distributions were combined with the flow solution from the modified MODFLOW program, along with porosity and the transport parameters described in Section 5.1.2, to form the fate and transport model for the 200-PO-1 Groundwater OU. The MT3DMS software was used to solve the groundwater advection-dispersion equations for these contaminants in order to predict how the initial contamination existing in the 200-PO-1 Groundwater OU may move during operation of the 200-ZP-1 pump-and-treat system and up to 1,000 years thereafter.

## 5.2 Groundwater Impacts

Historical releases of liquid wastes within the Hanford Central Plateau area have impacted groundwater, altering the flow system and creating contaminant plumes of varying size and concentration. The fate and transport simulation techniques described in Section 5.1 were applied to the known groundwater plumes to create an estimate of future impacts to groundwater. The future impact evaluation includes assessment of changes in the location and concentration of groundwater contaminants resulting from migration of the contaminants in groundwater and the attenuating processes that affect them.

The results of fate and transport analysis for the Near Field portion of the Central Plateau are described in Section 5.2.1. Section 5.2.2 describes the Far Field fate and transport results. A discussion of uncertainties in the estimates of future conditions is presented in Section 5.2.3.

### 5.2.1 Simulation of Contaminant Migration in the 200-PO-1 Near Field Environment

Fate and transport simulations were performed to prepare estimates of future groundwater contaminant concentrations within the unconfined aquifer in the Near Field area of the 200-PO-1 Groundwater OU. These simulations were performed for a period of 1,000 years (starting at Year 2009) using the numerical model implemented with MT3DMS described in this section. Transport of the following COPCs was simulated:

- Iodine-129
- Technetium-99
- Tritium
- Nitrate
- TCE

- Strontium-90
- Uranium
- Carbon Tetrachloride
- Tetrachloroethene

Contaminant concentration estimates were simulated throughout the model domain on the 100 m (328 ft) square calculation grid. The calculated future COPC concentrations are presented for illustration in two manners. First, the resultant calculated COPC plumes within the 200-PO-1 portion of the Central Plateau model domain at selected future time steps are presented graphically in time steps in Figure 5-4 through Figure 5-10. The highest observed concentration among the five model layers is chosen to generate these plan view plume maps. The results are displayed for selected times, while concentrations remain at or above half the MCL value. Although transport of carbon tetrachloride and tetrachloroethene is simulated, their concentrations remain below half of the MCL; thus, the plume maps are not presented.

Secondly, the estimated COPC concentrations in groundwater as a function of time are presented for selected locations (i.e., selected points of calculation) within the Central Plateau model domain and have been extracted from the complete future estimate data set. These results are presented in Table 5-3 through Table 5-9. Twenty-six points of calculation, some of which correspond to existing monitoring well locations, were selected based on the current understanding of the existing and future plume configuration for the purpose of presenting the results. These selected points of calculation are shown in Figure 5-3. Some of the selected locations coincide with the existing monitoring wells while others were chosen as part of the cross-section, or transect, across the plume. The monitoring locations relative to the tritium plume (for Year 2008) are shown in Figure 5-2 (as blue circles). The concentrations observed in groundwater for these COPCs at the initial conditions were all sufficiently high as to form a basis for evaluation in the FS, based on the COPC selection and EPC analysis presented in Chapter 6 of this report. Note that the model has five layers and thus concentration data for a given spatial location are available from each model layer. To make the comparisons more meaningful, only the highest concentration among the five layers is reported at the given time for each monitoring location. For the purpose of presentation, the number of time points have been reduced from the number of model reported timesteps, but care was taken to retain enough time points to capture the trend in concentration variation. Although the total simulated time period in the transport calculations is 1,000 years, the COPC concentration results are only displayed until the concentrations drop below half of the MCL value in the model domain. If the concentrations drop below this threshold before 125 years, then the results are displayed for 125 years.

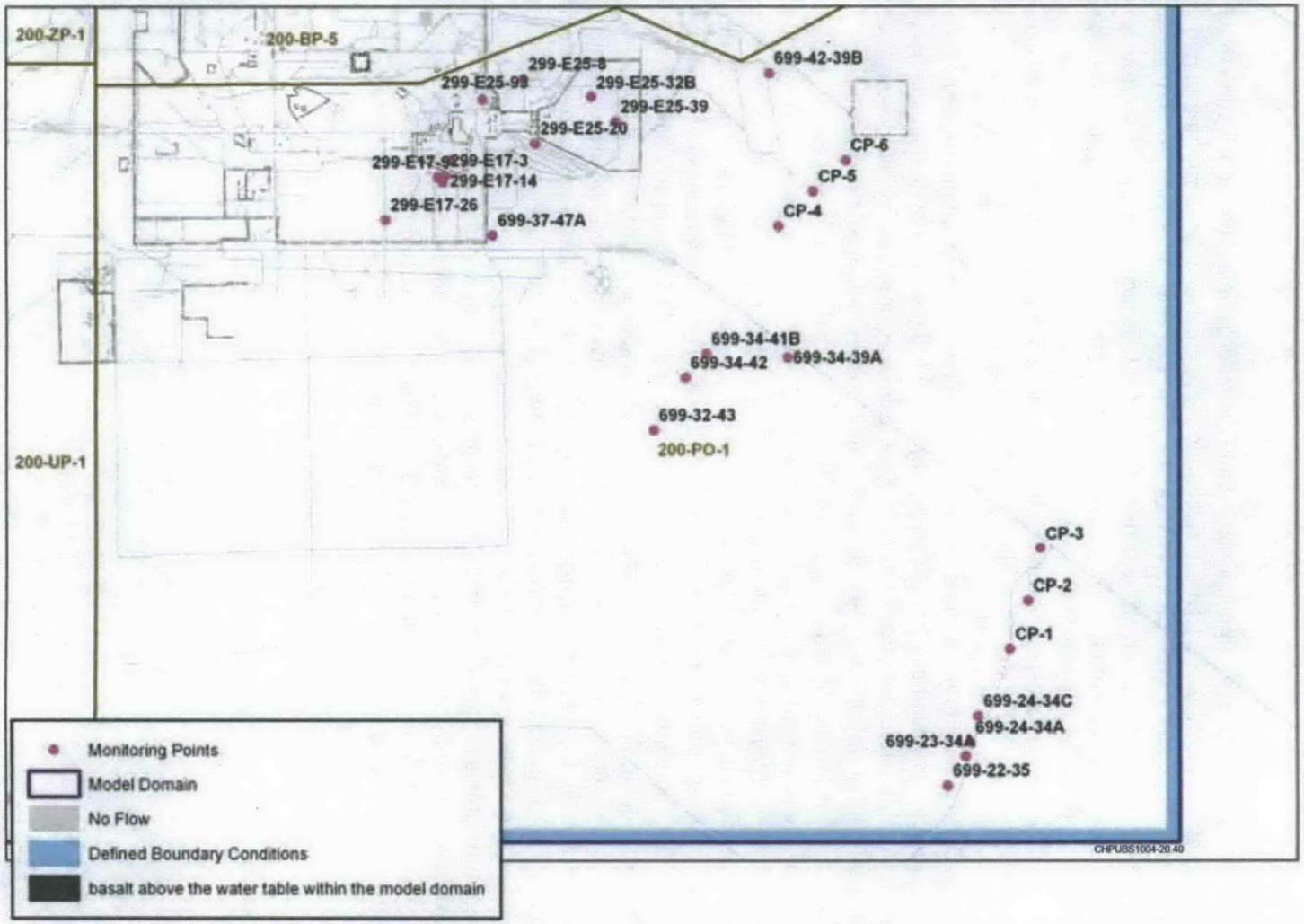



**Figure 5-3. Selected Points of Calculation for Illustration of Future COPC Concentration Trends in the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain**

#### 5.2.1.1 Iodine-129 Estimated Future Groundwater Concentrations

Iodine-129 is present in Near Field groundwater within the 200-PO-1 Groundwater OU as a continuous plume extending from the vicinity of the PUREX Plant in the southeast corner of 200 East Area to the southeast corner of the Central Plateau Groundwater Model domain. The simulated Iodine-129 plume for selected timesteps is shown in Figure 5-4 (a-d). This plume exhibits a linear aspect and generally follows the direction of groundwater flow along a paleochannel present in the unconsolidated sediments in that area. The extent and concentration distribution of the modeled plume for the initial conditions is compared with the isopleths drawn for the Hanford Site Groundwater Monitoring for FY2008 (DOE/RL-2008-66) report. Table 5-3 presents the time varying concentration results for the selected points of calculation identified in Figure 5-3. The initial maximum concentration spatially is less than 10 pCi/L at the monitoring locations but decreases gradually as a function of time. The iodine-129 plume persists over the simulated time frame due to moderate retardation and a long half-life. At the end of the simulation, the maximum concentration is less than 0.3 pCi/L. The iodine-129 plume for selected time points is shown in Figure 5-4 (a-d). After about 75 years of simulation, movement of the plume from upgradient 200-UP-1 OU into the 200-PO-1 OU is seen.

#### 5.2.1.2 Technetium-99 Estimated Future Groundwater Concentrations

Technetium-99 is present in Near Field groundwater within the 200-PO-1 Groundwater OU as a relatively small plume associated with WMA A-AX tank farm to the northeast of the PUREX Plant area. Most of the initial condition plume exhibits groundwater concentration less than 900 pCi/L (Figure 5-5a). The extent and concentration distribution of the modeled plume for the initial conditions is compared with the isopleths drawn for the Hanford Site Groundwater Monitoring for FY2008 (DOE/RL-2008-66) report. Table 5-4 presents the time varying concentration results for the selected points of calculation. The maximum concentration increases initially from about 53 pCi/L at five years to about 218 pCi/L at ten years but then gradually decreases as the contaminant mass moves downgradient. The technetium-99 plume for selected time points are shown in Figure 5-5 (a-b). Simulation results indicate that within 25 years, the concentration of technetium-99 drops below one-half the MCL.

#### 5.2.1.3 Tritium Estimated Future Groundwater Concentrations

Tritium is present in Near Field groundwater within the 200-PO-1 Groundwater OU in a linear plume oriented and collocated with the iodine-129 plume extending to the southeast from the PUREX Plant vicinity. Most of the initial condition plume exhibits groundwater concentration less than 200,000 pCi/L tritium (Figure 5-6a). The extent and concentration distribution of the modeled plume for the initial conditions is compared with the isopleths drawn for the Hanford Site Groundwater Monitoring for FY2008 (DOE/RL-2008-66) report.Table 5-5 presents the time varying concentration results for the selected points of calculation. The maximum initial concentration at the monitoring location is about 513,000 pCi/L but decreases rapidly to about 5700 pCi/L after fifty years. This is attributed to the unretarded transport of tritium away from the source and its short half-life. The tritium plume for selected time points is shown in Figure 5-6 (a-c). Simulation results indicate that after 50 years, the concentration of tritium drops below one-half the MCL.

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**Table 5-3. Maximum Near Field Concentration of Iodine-129 (pCi/L) for Selected Points of Calculation at Selected Timesteps**

| Time (Years) | 299-E17-14 | 299-E24-23 | 299-E25-93 | 299-E17-26 | 299-E17-3 | 299-E17-9 | 299-E25-20 | 299-E25-32B | 299-E25-39 | 299-E25-8 | 699-22-35 | 699-23-34A | 699-24-34A | 699-24-34C | 699-32-43 | 699-34-39A | 699-34-41B | 699-34-42 | 699-37-47A | 699-42-39B | CP-1 | CP-2 | CP-3 | CP-4 | CP-5 | CP-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 2.00E+00 | 5.47E+00 | 3.62E+00 | 0.00E+00 | 7.59E+00 | 3.89E+00 | 2.54E+00 | 2.00E+00 | 1.94E+00 | 4.44E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 8.14E-01 | 5.36E-01 | 2.58E+00 | 2.66E+00 | 2.97E+00 | 7.08E-01 | 1.20E+00 | 1.84E+00 | 6.51E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 6.86E-01 | 4.00E+00 | 3.88E+00 | 1.41E-01 | 6.79E+00 | 3.92E+00 | 3.54E+00 | 2.47E+00 | 2.06E+00 | 5.54E+00 | 2.63E-13 | 1.58E-11 | 7.84E-07 | 7.40E-02 | 5.93E-01 | 1.06E+00 | 2.30E+00 | 2.13E+00 | 2.96E+00 | 6.88E-01 | 1.26E+00 | 1.83E+00 | 9.60E-01 | 3.00E-05 | 9.68E-11 | 1.85E-13 |
| 25 | 1.04E-01 | 8.22E-01 | 1.12E+00 | 3.82E-02 | 4.20E+00 | 3.42E+00 | 1.25E+00 | 2.56E+00 | 2.56E+00 | 2.01E+00 | 3.61E-09 | 3.00E-05 | 1.90E-04 | 6.70E-02 | 1.63E-01 | 7.05E-01 | 7.27E-01 | 7.04E-01 | 2.87E+00 | 6.95E-01 | 1.20E+00 | 1.67E+00 | 7.23E-01 | 7.00E-05 | 3.00E-05 | 1.00E-05 |
| 50 | 1.79E-01 | 4.22E-01 | 3.61E-01 | 1.24E-01 | 2.21E+00 | 2.47E+00 | 4.09E-01 | 8.77E-01 | 1.10E+00 | 6.06E-01 | 9.93E-08 | 8.00E-05 | 4.70E-04 | 5.96E-02 | 1.34E-01 | 6.92E-01 | 4.25E-01 | 2.91E-01 | 2.77E+00 | 7.65E-01 | 1.19E+00 | 1.49E+00 | 8.02E-01 | 4.50E-04 | 6.20E-04 | 3.10E-04 |
| 75 | 5.87E-02 | 1.76E-01 | 1.53E-01 | 9.51E-02 | 1.24E+00 | 1.64E+00 | 2.01E-01 | 3.62E-01 | 4.56E-01 | 4.60E-01 | 2.74E-07 | 1.60E-04 | 9.00E-04 | 5.16E-02 | 1.02E-01 | 5.40E-01 | 2.47E-01 | 2.05E-01 | 2.63E+00 | 8.06E-01 | 1.15E+00 | 1.33E+00 | 8.79E-01 | 2.85E-03 | 2.22E-03 | 1.35E-03 |
| 125 | 4.30E-02 | 3.86E-02 | 1.64E-02 | 1.40E-01 | 7.49E-01 | 7.23E-01 | 1.91E-01 | 7.26E-02 | 1.46E-01 | 3.56E-01 | 7.38E-07 | 5.10E-04 | 2.00E-03 | 5.97E-02 | 9.58E-02 | 2.60E-01 | 1.24E-01 | 1.18E-01 | 2.16E+00 | 8.23E-01 | 1.03E+00 | 1.04E+00 | 9.90E-01 | 1.99E-02 | 6.57E-03 | 4.38E-03 |
| 200 | 5.91E-02 | 1.30E-02 | 3.05E-03 | 2.23E-01 | 4.35E-01 | 3.98E-01 | 1.96E-01 | 2.17E-02 | 1.13E-01 | 1.98E-01 | 1.90E-06 | 9.60E-04 | 2.83E-03 | 6.87E-02 | 1.44E-01 | 1.32E-01 | 1.17E-01 | 1.33E-01 | 1.38E+00 | 7.73E-01 | 8.65E-01 | 7.47E-01 | 9.79E-01 | 7.54E-02 | 5.18E-02 | 5.22E-03 |
| 300 | 7.90E-02 | 1.26E-02 | 1.44E-03 | 3.10E-01 | 2.10E-01 | 2.33E-01 | 1.49E-01 | 7.37E-02 | 8.40E-02 | 1.23E-01 | 4.17E-06 | 1.43E-03 | 3.86E-03 | 5.64E-02 | 2.13E-01 | 1.30E-01 | 1.46E-01 | 1.84E-01 | 6.65E-01 | 6.58E-01 | 6.72E-01 | 5.51E-01 | 7.89E-01 | 1.50E-01 | 1.53E-01 | 2.17E-02 |
| 400 | 7.77E-02 | 1.20E-02 | 9.30E-04 | 3.07E-01 | 1.09E-01 | 1.42E-01 | 1.02E-01 | 1.04E-01 | 6.56E-02 | 8.32E-02 | 1.00E-05 | 1.50E-03 | 3.55E-03 | 4.13E-02 | 2.13E-01 | 1.16E-01 | 1.36E-01 | 1.79E-01 | 3.10E-01 | 4.94E-01 | 5.12E-01 | 4.64E-01 | 6.05E-01 | 1.82E-01 | 2.02E-01 | 4.72E-02 |
| 500 | 5.83E-02 | 9.23E-03 | 6.20E-04 | 2.55E-01 | 6.18E-02 | 9.69E-02 | 6.89E-02 | 1.15E-01 | 5.33E-02 | 5.54E-02 | 1.00E-05 | 1.28E-03 | 2.85E-03 | 3.35E-02 | 1.77E-01 | 9.11E-02 | 1.05E-01 | 1.40E-01 | 2.69E-01 | 3.34E-01 | 3.82E-01 | 4.51E-01 | 5.30E-01 | 1.76E-01 | 1.90E-01 | 5.94E-02 |
| 600 | 4.32E-02 | 6.83E-03 | 4.50E-04 | 2.41E-01 | 3.89E-02 | 7.13E-02 | 4.67E-02 | 1.13E-01 | 4.46E-02 | 3.74E-02 | 1.00E-05 | 1.02E-03 | 2.38E-03 | 2.69E-02 | 1.44E-01 | 6.88E-02 | 7.78E-02 | 1.05E-01 | 2.70E-01 | 2.12E-01 | 2.80E-01 | 4.25E-01 | 4.91E-01 | 1.52E-01 | 1.53E-01 | 5.59E-02 |
| 700 | 3.41E-02 | 5.30E-03 | 3.70E-04 | 2.16E-01 | 2.67E-02 | 5.46E-02 | 3.20E-02 | 1.04E-01 | 3.86E-02 | 2.56E-02 | 1.00E-05 | 8.30E-04 | 1.91E-03 | 2.17E-02 | 1.20E-01 | 5.27E-02 | 6.07E-02 | 8.43E-02 | 2.43E-01 | 1.30E-01 | 2.30E-01 | 3.88E-01 | 4.41E-01 | 1.24E-01 | 1.14E-01 | 4.56E-02 |
| 800 | 2.73E-02 | 4.32E-03 | 3.00E-04 | 1.98E-01 | 1.93E-02 | 4.27E-02 | 2.22E-02 | 9.07E-02 | 3.50E-02 | 1.77E-02 | 1.00E-05 | 6.60E-04 | 1.52E-03 | 1.75E-02 | 9.61E-02 | 4.14E-02 | 4.85E-02 | 6.75E-02 | 2.05E-01 | 7.90E-02 | 2.11E-01 | 3.47E-01 | 3.86E-01 | 9.80E-02 | 8.25E-02 | 3.38E-02 |
| 900 | 2.04E-02 | 3.40E-03 | 3.20E-04 | 1.88E-01 | 1.46E-02 | 3.39E-02 | 1.58E-02 | 7.69E-02 | 3.23E-02 | 1.24E-02 | 4.82E-06 | 5.20E-04 | 1.20E-03 | 1.35E-02 | 7.29E-02 | 3.27E-02 | 3.75E-02 | 5.16E-02 | 1.92E-01 | 4.83E-02 | 1.89E-01 | 3.05E-01 | 3.32E-01 | 7.64E-02 | 5.89E-02 | 2.58E-02 |
| 1000 | 1.56E-02 | 2.72E-03 | 4.30E-04 | 1.71E-01 | 1.14E-02 | 2.71E-02 | 1.13E-02 | 6.39E-02 | 3.01E-02 | 8.73E-03 | 3.77E-06 | 4.00E-04 | 9.20E-04 | 1.02E-02 | 5.56E-02 | 2.53E-02 | 3.32E-02 | 3.95E-02 | 1.88E-01 | 2.98E-02 | 1.68E-01 | 2.64E-01 | 2.93E-01 | 6.67E-02 | 4.22E-02 | 2.18E-02 |

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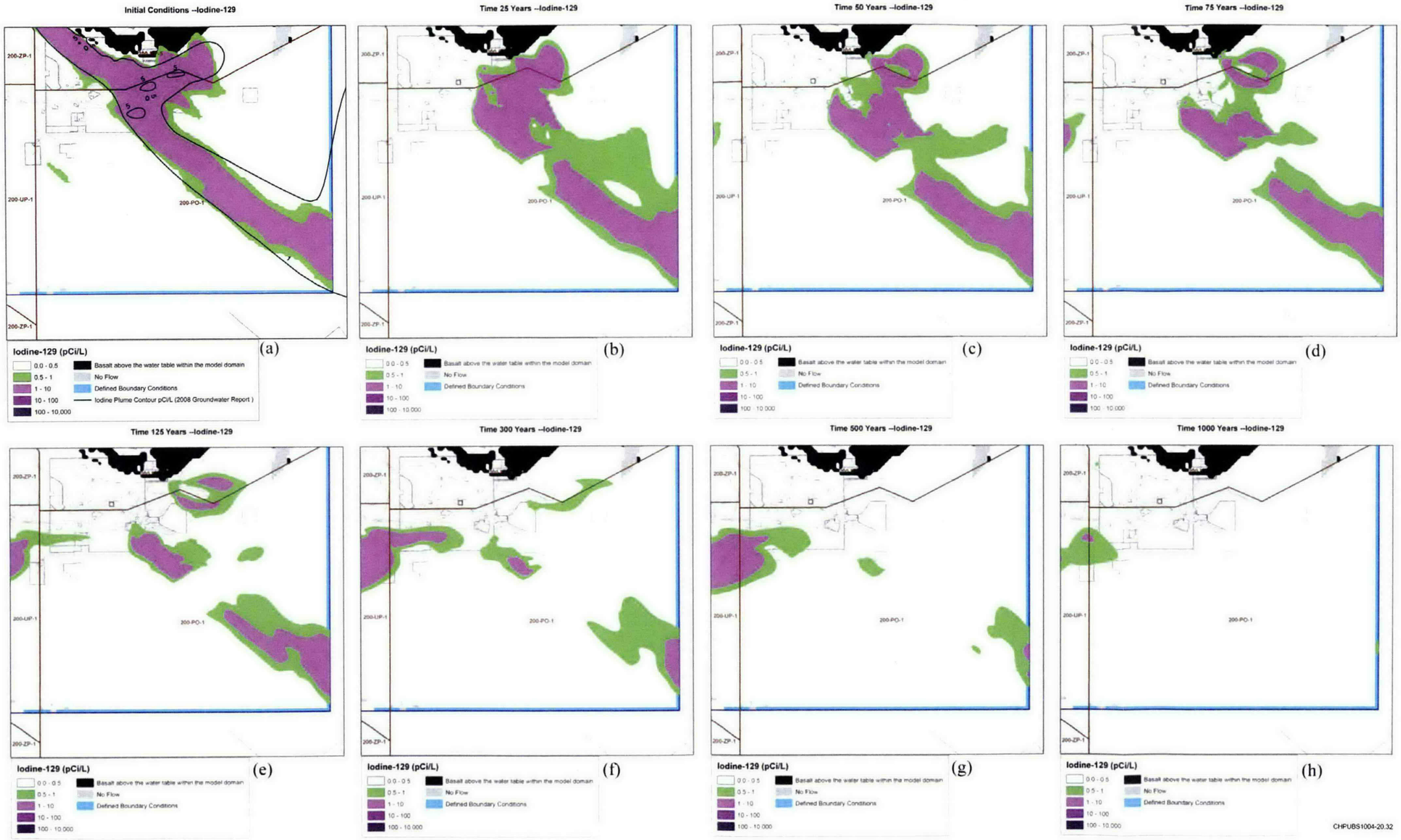


Figure 5-4. Iodine-129 Plume at Selected Times for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain

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**Table 5-4. Maximum Near Field Concentration of Technetium-99 (pCi/L) for Selected Points of Calculation at Selected Timesteps**

| Time (Years) | 299-E17-14 | 299-E24-23 | 299-E25-93 | 299-E17-26 | 299-E17-3 | 299-E17-9 | 299-E25-20 | 299-E25-32B | 299-E25-39 | 299-E25-8 | 699-22-35 | 699-23-34A | 699-24-34A | 699-24-34C | 699-32-43 | 699-34-39A | 699-34-41B | 699-34-42 | 699-37-47A | 699-42-39B | CP-1 | CP-2 | CP-3 | CP-4 | CP-5 | CP-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00E+00 | 0.00E+00 | 3.85E+03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 4.48E+01 | 6.07E+01 | 1.84E+02 | 1.52E+01 | 5.36E+01 | 4.77E+01 | 2.18E+02 | 1.37E+01 | 4.36E+00 | 1.24E+02 | 3.79E-13 | 4.55E-11 | 2.73E-06 | 3.90E-01 | 1.15E+01 | 1.44E+01 | 3.17E+01 | 2.74E+01 | 2.02E-02 | 1.37E-12 | 1.16E+01 | 6.62E+00 | 4.55E-01 | 8.70E-04 | 2.06E-08 | 2.00E-10 |
| 25 | 9.33E-01 | 2.89E+00 | 1.58E+01 | 1.24E+00 | 1.62E+01 | 1.22E+01 | 2.39E+01 | 8.74E+01 | 8.82E+01 | 6.91E+01 | 1.11E-06 | 1.61E-03 | 5.86E-03 | 3.67E-01 | 1.67E+00 | 1.15E+01 | 1.05E+01 | 5.97E+00 | 1.58E+00 | 2.96E-08 | 1.85E+00 | 2.08E+00 | 2.94E+00 | 4.36E-03 | 9.68E-03 | 5.95E-03 |
| 50 | 6.61E-01 | 2.27E-01 | 0.00E+00 | 2.01E+00 | 6.27E+00 | 5.62E+00 | 1.41E+01 | 7.95E+00 | 9.81E+00 | 3.07E+01 | 1.00E-05 | 2.70E-03 | 9.11E-03 | 2.85E-01 | 1.59E+00 | 9.12E+00 | 3.62E+00 | 2.48E+00 | 3.97E+00 | 1.08E-03 | 1.34E+00 | 1.63E+00 | 1.89E+00 | 1.24E-01 | 1.06E-01 | 6.59E-02 |
| 75 | 6.15E-01 | 1.22E-01 | 0.00E+00 | 2.04E+00 | 4.88E+00 | 3.24E+00 | 1.52E+01 | 1.60E+00 | 5.18E+00 | 2.22E+01 | 1.00E-05 | 3.83E-03 | 1.18E-02 | 2.49E-01 | 1.43E+00 | 4.18E+00 | 1.42E+00 | 1.41E+00 | 3.58E+00 | 8.47E-02 | 1.14E+00 | 1.28E+00 | 1.43E+00 | 8.34E-01 | 2.77E-01 | 1.59E-01 |
| 125 | 5.44E-01 | 8.49E-02 | 0.00E+00 | 1.97E+00 | 2.37E+00 | 2.21E+00 | 1.10E+01 | 3.49E+00 | 3.52E+00 | 1.34E+01 | 2.00E-05 | 4.58E-03 | 1.23E-02 | 2.12E-01 | 1.31E+00 | 1.19E+00 | 9.55E-01 | 1.16E+00 | 2.29E+00 | 1.76E+00 | 1.02E+00 | 1.09E+00 | 1.25E+00 | 3.52E+00 | 3.09E+00 | 2.49E-01 |

Notes:

The results for years 200 through 1000 were less than the reporting limit of ½ MCL and not presented.

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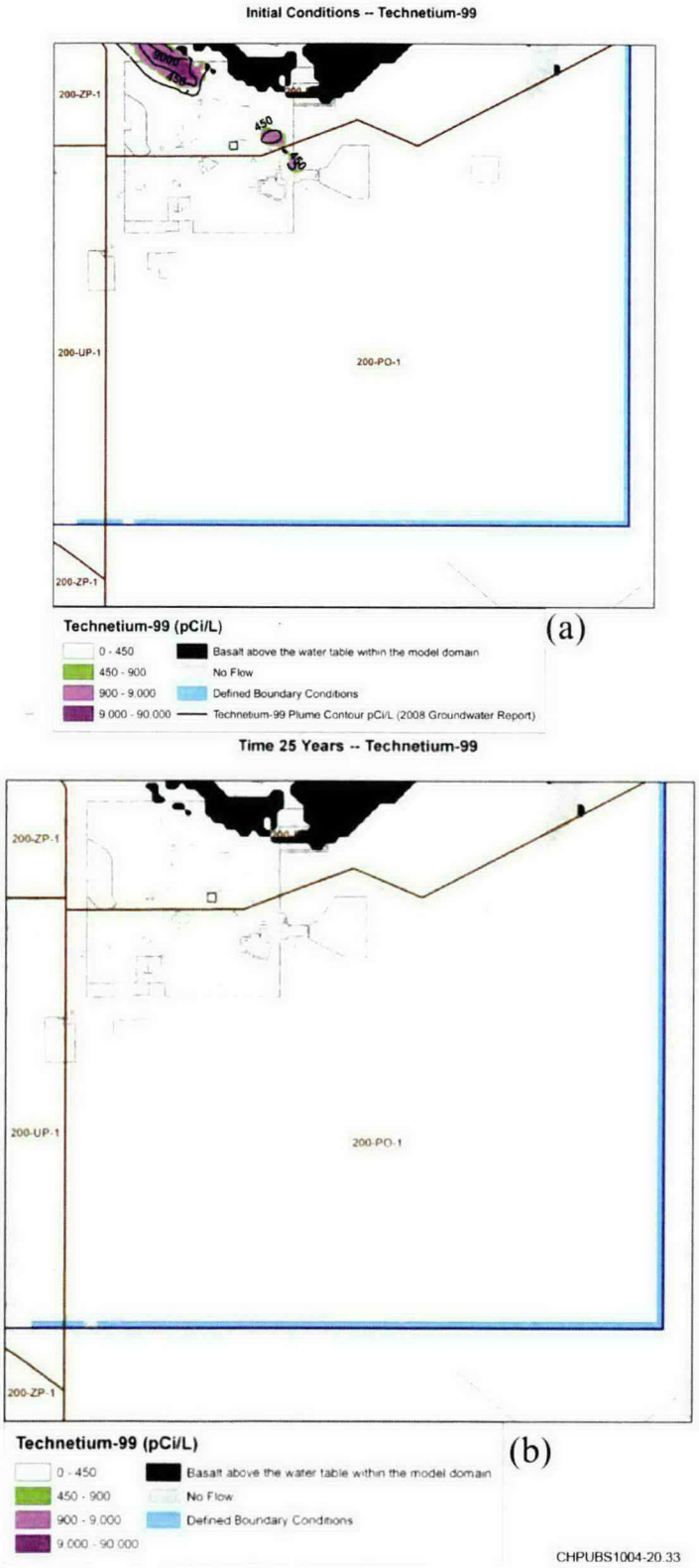


**Figure 5-5. Technetium-99 Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain**

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**Table 5-5. Maximum Near Field Concentration of Tritium (pCi/L) for Selected Points of Calculation at Selected Timesteps**

| Time (Years) | 299-E17-14 | 299-E24-23 | 299-E17-26 | 299-E17-26 | 299-E17-3 | 299-E17-9 | 299-E25-20 | 299-E25-32B | 299-E25-39 | 299-E25-8 | 699-22-35 | 699-23-34A | 699-24-34A | 699-24-34C | 699-32-43 | 699-34-39A | 699-34-41B | 699-34-42 | 699-37-47A | 699-42-39B | CP-1 | CP-2 | CP-3 | CP-4 | CP-5 | CP-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.96E+05 | 3.66E+05 | 0.00E+00 | 2.30E+04 | 5.70E+05 | 3.99E+05 | 8.31E+04 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.25E+04 | 0.00E+00 | 4.83E+04 | 3.78E+04 | 4.30E+04 | 1.34E+04 | 3.27E+04 | 2.40E+04 | 1.86E+04 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 3.25E+03 | 6.11E+04 | 5.98E+02 | 1.79E+04 | 3.37E+05 | 2.68E+05 | 7.27E+03 | 8.15E+02 | 1.21E+03 | 7.87E+02 | 1.00E-05 | 6.30E-04 | 1.76E-01 | 8.76E+02 | 6.54E+03 | 1.71E+04 | 2.39E+04 | 2.51E+04 | 3.49E+04 | 1.21E+04 | 2.35E+04 | 1.77E+04 | 1.40E+04 | 1.57E+01 | 2.53E-03 | 7.00E-05 |
| 25 | 7.52E+02 | 1.98E+03 | 1.96E+02 | 3.16E+03 | 3.53E+04 | 4.31E+04 | 2.38E+02 | 5.79E+01 | 7.84E+01 | 1.01E+02 | 7.60E-04 | 5.07E-01 | 1.82E+00 | 2.17E+02 | 1.05E+03 | 2.58E+03 | 1.58E+03 | 1.50E+03 | 1.68E+04 | 6.48E+03 | 6.68E+03 | 4.80E+03 | 4.63E+03 | 1.91E+00 | 3.35E+00 | 2.20E+00 |
| 50 | 1.24E+02 | 1.48E+02 | 1.26E+01 | 3.98E+02 | 2.76E+03 | 3.84E+03 | 3.88E+01 | 2.95E+01 | 3.46E+01 | 2.24E+01 | 8.40E-04 | 2.67E-01 | 1.05E+00 | 4.76E+01 | 2.63E+02 | 3.69E+02 | 2.53E+02 | 2.77E+02 | 5.72E+03 | 1.65E+03 | 1.42E+03 | 9.77E+02 | 1.10E+03 | 2.74E+00 | 2.73E+00 | 1.80E+00 |
| 75 | 2.70E+01 | 1.60E+01 | 5.81E-01 | 9.48E+01 | 4.01E+02 | 3.89E+02 | 8.98E+00 | 1.23E+00 | 1.84E+00 | 3.15E+00 | 3.60E-04 | 1.22E-01 | 4.33E-01 | 1.24E+01 | 6.51E+01 | 6.14E+01 | 5.58E+01 | 6.32E+01 | 1.45E+03 | 3.45E+02 | 2.95E+02 | 2.07E+02 | 2.49E+02 | 1.95E+00 | 1.54E+00 | 4.69E-01 |
| 125 | 1.23E+00 | 3.29E-01 | 1.03E-02 | 4.81E+00 | 9.53E+00 | 9.28E+00 | 4.80E-01 | 2.52E-02 | 6.89E-02 | 9.41E-02 | 7.00E-05 | 1.35E-02 | 3.86E-02 | 6.72E-01 | 3.45E+00 | 2.47E+00 | 2.56E+00 | 3.09E+00 | 5.40E+01 | 1.29E+01 | 1.19E+01 | 9.42E+00 | 1.19E+01 | 2.87E-01 | 4.28E-01 | 2.06E-01 |

Notes:

The results for years 200 through 1000 were less than the reporting limit of ½ MCL and not presented.

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**Figure 5-6. Tritium Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain**

#### 5.2.1.4 Nitrate Estimated Future Groundwater Concentrations

Nitrate (as the $NO_3^-$ ion) is present in Near Field groundwater within the 200-PO-1 Groundwater OU in a plume extending from the southeast side of the PUREX Plant and associated with the PUREX cribs. The 200-PO-1 Groundwater OU nitrate plume is not readily distinguishable from nitrate associated with sources in the 200-BP-5 Groundwater OU. The nitrate plume is collocated with other plumes in the 200-PO-1 Groundwater OU (e.g., tritium, iodine-129, TCE, and uranium). The initial condition plume exhibits groundwater concentration of generally less than 45,000 μg/L within the 200-PO-1 Groundwater OU (Figure 5-7a). The extent and concentration distribution of the modeled plume for the initial conditions is compared with the isopleths drawn for the Hanford Site Groundwater Monitoring for FY2008 (DOE/RL-2008-66) report. Table 5-6 presents the time varying concentration results for the selected points of calculation. The maximum concentration declines gradually from about 100,000 μg/L at the beginning of the simulation to about 3,500 μg/L by 300 years. The nitrate plume for selected time points is shown in Figure 5-7 (a-f). Simulation results indicate that by 300 years, the concentration of nitrate drops below one-half the MCL except for a localized area where the plume is trapped in the Ringold mud unit.

#### 5.2.1.5 Trichloroethene Estimated Future Groundwater Concentrations

TCE is present in Near Field groundwater within the 200-PO-1 Groundwater OU in a localized plume extending from the southeast side of the PUREX Plant and associated with the PUREX cribs. Another localized TCE plume area is associated with the NRDWL, located outside the 200 East Area and near the southeast corner of the Central Plateau Groundwater Model boundary. Table 5-7 presents the time varying concentration results for the selected points of calculation. The concentration of TCE varies considerably both spatially and temporally. Most locations show very small concentrations indicating limited spatial extent of the plume. The maximum concentration declines from initial value of about 0.5 μg/L to less than 0.04 μg/L by 100 years. The TCE plume of concentration greater than one-half the MCL is localized to a small patch (barely visible) in Figure 5-8 (a-b). Simulation results indicate that by 25 years, the concentration of TCE drops below one-half the MCL.

#### 5.2.1.6 Strontium-90 Estimated Future Groundwater Concentrations

Strontium-90 is present in Near Field groundwater within the 200-PO-1 Groundwater OU in a small, localized plume near the south side of the PUREX Plant and associated with the PUREX cribs. The strontium-90 plume is collocated with tritium and iodine-129 in that area. The initial condition plume exhibits groundwater concentration less than 80 pCi/L of strontium-90 (Figure 5-9a). The extent and concentration distribution of the modeled plume for the initial conditions is compared with the isopleths drawn for the Hanford Site Groundwater Monitoring for FY2008 (DOE/RL-2008-66) report. Table 5-8 presents the time varying concentration results for the selected points of calculation. The strontium-90 concentration remains negligibly small due to relatively high $K_d$ and a relatively short half-life. The strontium-90 plume of concentration greater than one-half the MCL is localized to a small area in Figure 5-9 (a-b). Simulation results indicate that by 25 years, the concentration of strontium-90 drops below one-half the MCL within the 200-PO-1 OU area.

**Table 5-6. Maximum Near Field Concentration of Nitrate (µg/L) for Selected Points of Calculation at Selected Timesteps**

| Time (Years) | 299-E17-14 | 299-E24-23 | 299-E25-93 | 299-E17-26 | 299-E17-3 | 299-E17-9 | 299-E25-20 | 299-E25-32B | 299-E25-39 | 299-E25-8 | 699-22-35 | 699-23-34A | 699-24-34A | 699-24-34C | 699-32-43 | 699-34-39A | 699-34-41B | 699-34-42 | 699-37-47A | 699-42-39B | CP-1 | CP-2 | CP-3 | CP-4 | CP-5 | CP-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 5.81E+04 | 8.18E+04 | 3.79E+04 | 0.00E+00 | 1.12E+05 | 9.71E+04 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.78E+04 | 0.00E+00 | 1.43E+04 | 1.51E+04 | 1.87E+04 | 0.00E+00 | 3.14E+04 | 2.48E+04 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.52E+04 | 7.62E+04 | 4.01E+04 |
| 5 | 1.08E+04 | 2.80E+04 | 7.59E+03 | 7.63E+03 | 9.17E+04 | 8.95E+04 | 9.27E+03 | 2.89E+02 | 1.00E+02 | 2.21E+03 | 9.02E+03 | 2.87E+02 | 7.97E+03 | 1.04E+04 | 8.80E+03 | 1.24E+04 | 1.22E+04 | 1.08E+04 | 4.68E+02 | 3.84E-06 | 6.54E+03 | 7.94E+03 | 3.71E+03 | 4.71E+03 | 7.38E+04 | 3.69E+04 |
| 25 | 3.67E+03 | 2.99E+03 | 1.80E+03 | 8.28E+03 | 3.51E+04 | 4.94E+04 | 2.05E+03 | 6.33E+03 | 6.86E+03 | 4.44E+03 | 2.02E+03 | 5.11E+02 | 2.05E+03 | 3.81E+03 | 5.95E+03 | 5.13E+03 | 5.49E+03 | 6.32E+03 | 8.83E+03 | 6.39E-01 | 4.59E+03 | 5.03E+03 | 5.36E+03 | 5.31E+03 | 5.86E+04 | 2.15E+04 |
| 50 | 1.51E+03 | 7.56E+02 | 1.68E+02 | 4.38E+03 | 1.21E+04 | 1.99E+04 | 9.02E+02 | 6.65E+02 | 8.48E+02 | 1.56E+03 | 6.87E+02 | 4.07E+02 | 8.63E+02 | 2.17E+03 | 3.31E+03 | 3.73E+03 | 2.44E+03 | 3.11E+03 | 1.90E+04 | 2.13E+01 | 2.61E+03 | 2.90E+03 | 3.30E+03 | 3.70E+03 | 4.54E+04 | 1.94E+04 |
| 75 | 1.23E+03 | 3.63E+02 | 6.52E+01 | 3.91E+03 | 8.13E+03 | 8.94E+03 | 1.01E+03 | 1.41E+02 | 4.06E+02 | 1.18E+03 | 2.76E+02 | 2.74E+02 | 4.52E+02 | 1.30E+03 | 2.69E+03 | 2.18E+03 | 1.93E+03 | 2.46E+03 | 2.09E+04 | 8.81E+01 | 2.10E+03 | 2.30E+03 | 2.54E+03 | 2.98E+03 | 3.97E+04 | 2.01E+04 |
| 125 | 9.10E+02 | 1.89E+02 | 4.85E+01 | 3.15E+03 | 3.54E+03 | 4.40E+03 | 7.69E+02 | 1.88E+02 | 2.81E+02 | 6.80E+02 | 5.58E+01 | 1.09E+02 | 1.56E+02 | 5.27E+02 | 2.18E+03 | 1.35E+03 | 1.47E+03 | 1.87E+03 | 1.32E+04 | 3.48E+02 | 1.71E+03 | 1.91E+03 | 2.06E+03 | 3.35E+03 | 3.75E+04 | 1.96E+04 |
| 200 | 1.21E+03 | 2.27E+02 | 4.57E+01 | 3.46E+03 | 1.23E+03 | 1.90E+03 | 4.21E+02 | 3.94E+02 | 1.86E+02 | 4.15E+02 | 2.39E+01 | 2.75E+01 | 4.22E+01 | 3.90E+02 | 2.30E+03 | 1.36E+03 | 1.62E+03 | 2.10E+03 | 3.97E+03 | 4.23E+02 | 1.82E+03 | 1.94E+03 | 2.04E+03 | 3.31E+03 | 3.30E+04 | 1.63E+04 |
| 300 | 1.28E+03 | 2.58E+02 | 4.27E+01 | 3.52E+03 | 8.50E+02 | 1.13E+03 | 2.08E+02 | 4.34E+02 | 1.29E+02 | 2.15E+02 | 1.63E+01 | 1.42E+01 | 2.96E+01 | 4.17E+02 | 2.43E+03 | 1.44E+03 | 1.71E+03 | 2.20E+03 | 3.71E+03 | 1.91E+02 | 1.94E+03 | 2.08E+03 | 2.16E+03 | 2.83E+03 | 2.55E+04 | 1.24E+04 |

Notes:

The results for years 400 through 1000 were less than the reporting limit of ½ MCL and not presented.

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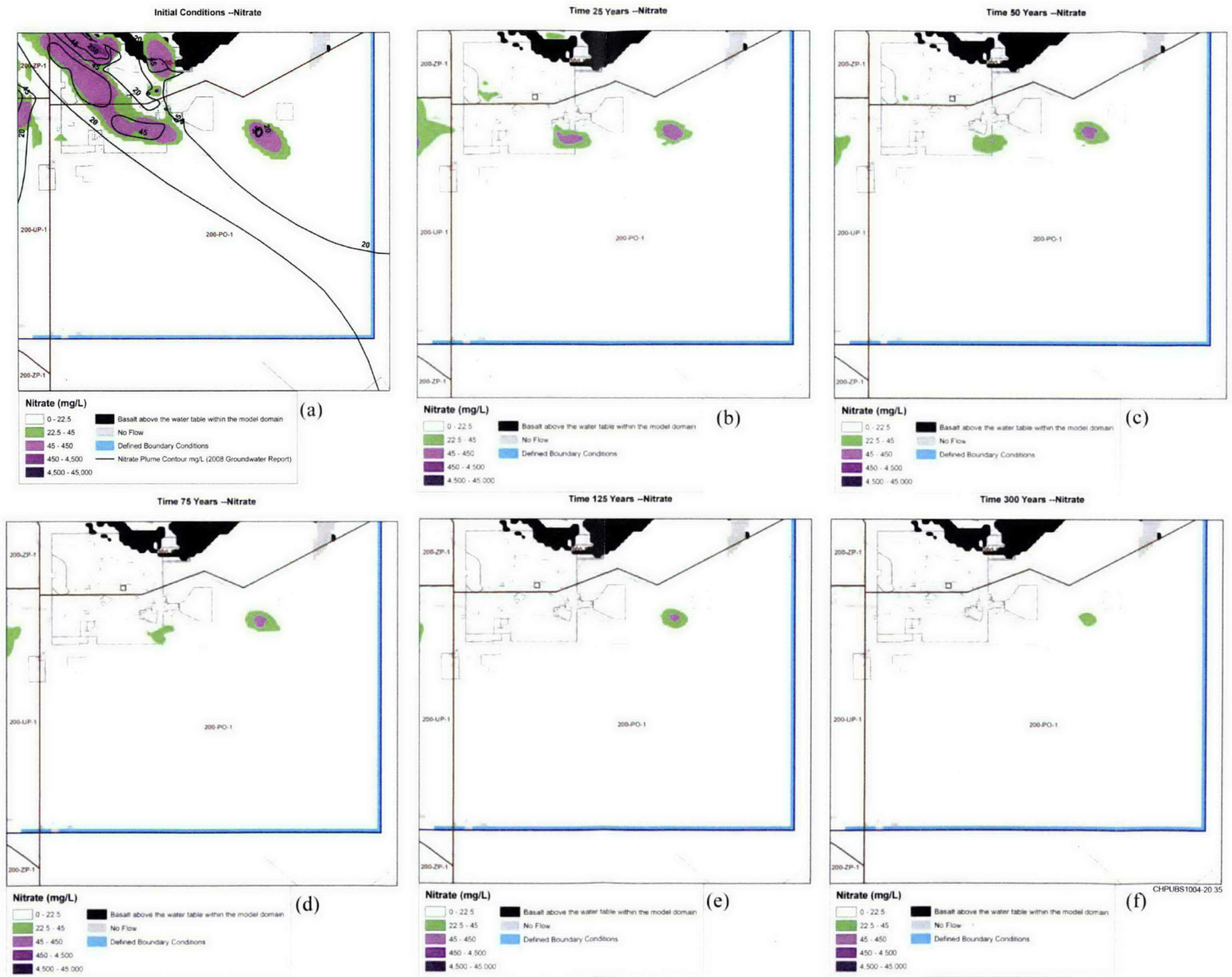


**Figure 5-7. Nitrate Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain**

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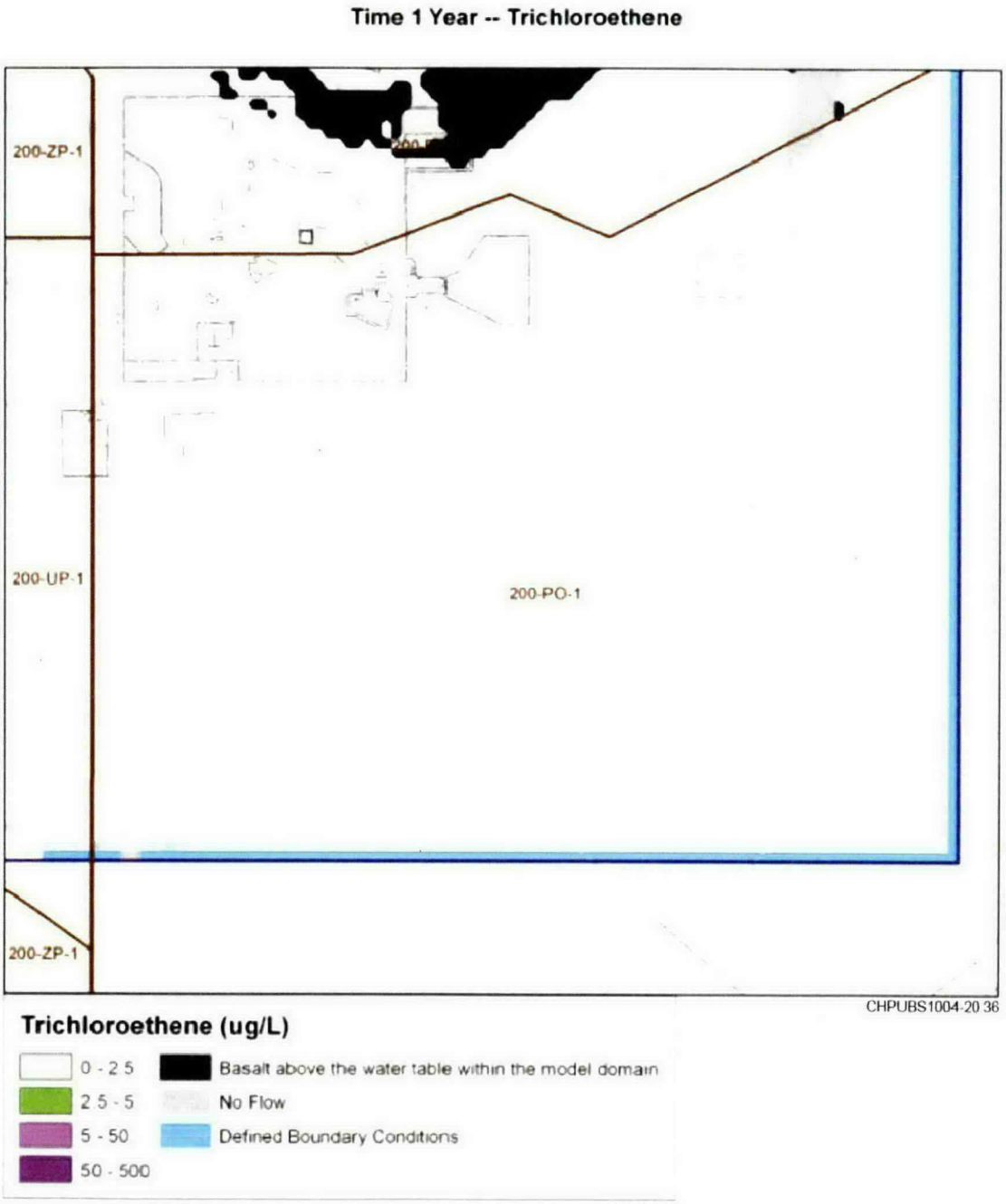


**Figure 5-8. Trichloroethene Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain**

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**Table 5-7. Maximum Near Field Concentration of Trichloroethene (µg/L) for Selected Points of Calculation at Selected Timesteps**

| Time (Years) | 299-E17-14 | 299-E24-23 | 299-E25-93 | 299-E17-26 | 299-E17-3 | 299-E17-9 | 299-E25-20 | 299-E25-32B | 299-E25-39 | 299-E25-8 | 699-22-35 | 699-23-34A | 699-24-34A | 699-24-34C | 699-32-43 | 699-34-39A | 699-34-41B | 699-34-42 | 699-37-47A | 699-42-39B | CP-1 | CP-2 | CP-3 | CP-4 | CP-5 | CP-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.55E-01 | 4.63E-01 | 4.90E-01 | 5.05E-01 | 2.78E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 1.83E-03 | 1.97E-01 | 1.02E-03 | 2.00E-05 | 2.91E-01 | 8.61E-03 | 1.16E-02 | 2.09E-08 | 1.77E-07 | 1.00E-05 | 2.68E-01 | 2.92E-01 | 3.18E-01 | 3.77E-01 | 9.21E-03 | 5.55E-03 | 8.60E-03 | 4.08E-03 | 1.00E-05 | 0.00E+00 | 2.41E-02 | 1.04E-03 | 1.60E-04 | 2.10E-07 | 1.44E-12 | 5.73E-15 |
| 25 | 5.50E-04 | 1.32E-02 | 1.50E-04 | 1.18E-03 | 1.78E-01 | 2.28E-02 | 1.08E-03 | 7.00E-05 | 5.00E-05 | 2.00E-05 | 7.24E-02 | 8.95E-02 | 1.04E-01 | 1.53E-01 | 5.10E-04 | 4.42E-03 | 4.21E-03 | 2.26E-03 | 5.91E-03 | 6.89E-17 | 7.53E-03 | 7.30E-04 | 9.70E-04 | 6.45E-07 | 1.88E-06 | 9.41E-07 |
| 50 | 2.11E-03 | 4.11E-03 | 5.00E-05 | 6.71E-03 | 7.43E-02 | 1.82E-02 | 3.80E-04 | 1.00E-05 | 1.00E-05 | 1.00E-05 | 2.85E-02 | 4.01E-02 | 4.87E-02 | 8.44E-02 | 4.56E-03 | 3.85E-03 | 3.81E-03 | 4.49E-03 | 1.65E-02 | 1.73E-11 | 1.89E-02 | 3.51E-03 | 2.88E-03 | 1.27E-06 | 1.00E-05 | 1.00E-05 |
| 75 | 3.34E-03 | 1.77E-03 | 3.00E-05 | 1.14E-02 | 5.54E-02 | 1.09E-02 | 2.70E-04 | 1.00E-05 | 1.00E-05 | 1.00E-05 | 1.33E-02 | 2.21E-02 | 2.76E-02 | 5.17E-02 | 7.42E-03 | 4.41E-03 | 5.32E-03 | 6.87E-03 | 2.69E-02 | 2.36E-09 | 2.41E-02 | 5.87E-03 | 5.60E-03 | 1.91E-06 | 2.00E-05 | 1.00E-05 |
| 125 | 5.64E-03 | 9.90E-04 | 3.00E-05 | 1.95E-02 | 2.54E-02 | 9.53E-03 | 3.50E-04 | 1.00E-05 | 1.00E-05 | 1.00E-05 | 3.58E-03 | 8.38E-03 | 1.06E-02 | 2.28E-02 | 1.52E-02 | 8.66E-03 | 1.01E-02 | 1.30E-02 | 4.07E-02 | 1.27E-07 | 1.97E-02 | 1.26E-02 | 1.20E-02 | 3.45E-06 | 3.00E-05 | 1.00E-05 |

Notes:

The results for years 200 through 1000 were less than the reporting limit of ½ MCL and not presented.

**Table 5-8. Maximum Concentration of Strontium-90 (pCi/L) for Selected Points of Calculation at Selected Timesteps**

| Time (Years) | 299-E17-14 | 299-E24-23 | 299-E25-93 | 299-E17-26 | 299-E17-3 | 299-E17-9 | 299-E25-20 | 299-E25-32B | 299-E25-39 | 299-E25-8 | 699-22-35 | 699-23-34A | 699-24-34A | 699-24-34C | 699-32-43 | 699-34-39A | 699-34-41B | 699-34-42 | 699-37-47A | 699-42-39B | CP-1 | CP-2 | CP-3 | CP-4 | CP-5 | CP-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 1.95E-01 | 3.22E-06 | 0.00E+00 | 0.00E+00 | 1.01E-02 | 1.43E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 25 | 1.57E-01 | 5.00E-04 | 0.00E+00 | 1.60E-04 | 3.73E-02 | 1.15E-01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 50 | 6.37E-02 | 1.16E-03 | 0.00E+00 | 1.90E-04 | 3.39E-02 | 4.67E-02 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.92E-07 | 0.00E+00 | 6.49E-08 | 3.68E-07 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 75 | 2.47E-02 | 1.21E-03 | 0.00E+00 | 1.00E-04 | 2.46E-02 | 1.82E-02 | 4.13E-09 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.00E-05 | 1.75E-09 | 1.00E-05 | 5.00E-05 | 3.98E-09 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 125 | 3.99E-03 | 6.00E-04 | 8.84E-08 | 3.10E-04 | 1.24E-02 | 3.10E-03 | 9.23E-09 | 0.00E+00 | 0.00E+00 | 2.31E-10 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.61E-10 | 2.30E-04 | 1.89E-07 | 1.40E-04 | 4.80E-04 | 3.13E-08 | 0.00E+00 | 4.56E-06 | 2.34E-08 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Notes:

The results for years 200 through 1000 were less than the reporting limit of ½ MCL and not presented.

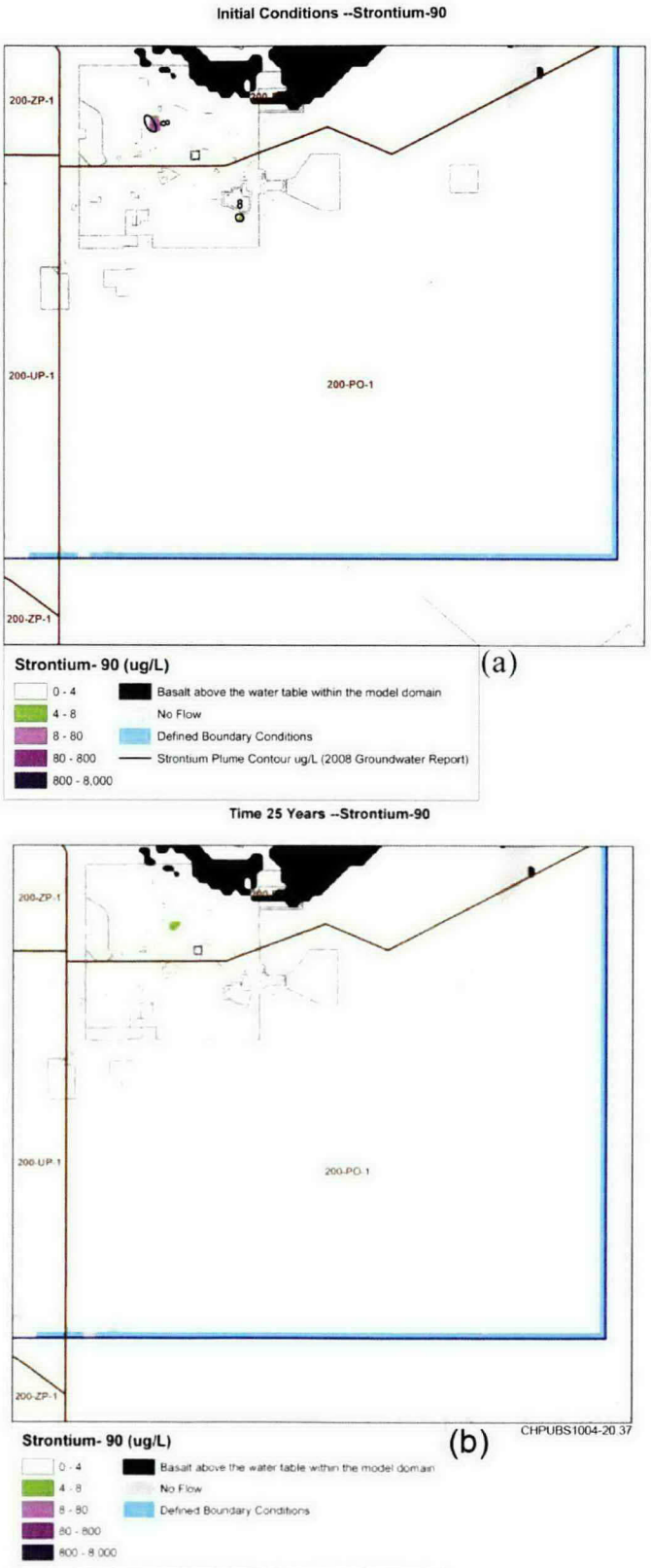


**Figure 5-9. Strontium-90 Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain**

#### 5.2.1.7 Uranium Estimated Future Groundwater Concentrations

Uranium is present in Near Field groundwater within the 200-PO-1 Groundwater OU in a localized plume near the south side of the PUREX Plant and associated with the PUREX cribs. The uranium plume is collocated with tritium and iodine-129, nitrate, and TCE in that area. The initial condition plume exhibits groundwater concentration less than 300 μg/L total uranium (Figure 5-10a). The extent and concentration distribution of the modeled plume for the initial conditions is compared with the isopleths drawn for the Hanford Site Groundwater Monitoring for FY2008 (DOE/RL-2008-66) report. Table 5-9 presents the time varying concentration results for the selected points of calculation. The maximum concentration at the monitoring location gradually declines from about 34 μg/L at initial time to about 3 μg/L at 500 years. The transport results are consistent with the moderate $K_d$ and a long half-life of uranium. The uranium plumes for selected time points are shown in Figure 5-10 (a-f). Simulation results indicate that the plume attenuates gradually and, by 300 years, the uranium concentration drops below one-half the MCL except for a localized area where the concentrations also continue to decline.

**Table 5-9. Maximum Near Field Concentration of Uranium (µg/L) for Selected Points of Calculation at Selected Timesteps**

| Time (Years) | 299-E17-14 | 299-E24-23 | 299-E25-93 | 299-E17-26 | 299-E17-3 | 299-E17-9 | 299-E25-20 | 299-E25-32B | 299-E25-39 | 299-E25-8 | 699-22-35 | 699-23-34A | 699-24-34A | 699-24-34C | 699-32-43 | 699-34-39A | 699-34-41B | 699-34-42 | 699-37-47A | 699-42-39B | CP-1 | CP-2 | CP-3 | CP-4 | CP-5 | CP-6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00E+00 | 6.01E+01 | 0.00E+00 | 0.00E+00 | 3.34E+01 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 1.42E+00 | 5.17E+01 | 1.04E-02 | 9.45E-02 | 3.43E+01 | 6.97E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.15E-10 | 0.00E+00 | 5.72E-07 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 25 | 1.02E+00 | 1.47E+01 | 6.62E-01 | 2.20E-01 | 3.52E+01 | 4.51E+00 | 1.92E-02 | 0.00E+00 | 0.00E+00 | 3.69E-10 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.45E-06 | 6.44E-10 | 6.00E-05 | 2.00E-05 | 4.71E-06 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 50 | 2.66E-01 | 5.65E+00 | 6.90E-01 | 2.72E-02 | 3.60E+01 | 3.19E+00 | 1.11E-01 | 0.00E+00 | 0.00E+00 | 1.23E-08 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 8.40E-04 | 5.76E-07 | 1.00E-02 | 5.08E-03 | 2.00E-05 | 0.00E+00 | 2.48E-10 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 75 | 1.39E-01 | 2.82E+00 | 4.10E-01 | 2.17E-02 | 3.66E+01 | 2.46E+00 | 2.60E-01 | 1.43E-10 | 4.05E-10 | 1.18E-07 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.41E-02 | 4.00E-05 | 9.85E-02 | 6.63E-02 | 4.00E-05 | 0.00E+00 | 1.38E-06 | 6.67E-08 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 125 | 7.14E-02 | 1.08E+00 | 1.27E-01 | 2.22E-02 | 3.72E+01 | 2.06E+00 | 4.37E-01 | 2.15E-09 | 0.00E+00 | 6.50E-07 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.15E-10 | 5.87E-02 | 6.10E-04 | 2.83E-01 | 2.33E-01 | 8.00E-05 | 0.00E+00 | 2.30E-04 | 1.00E-05 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 200 | 3.85E-02 | 4.31E-01 | 3.49E-02 | 1.85E-02 | 3.76E+01 | 1.91E+00 | 6.24E-01 | 1.25E-08 | 0.00E+00 | 2.40E-06 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 5.70E-08 | 1.17E-01 | 3.92E-03 | 4.57E-01 | 4.15E-01 | 1.40E-04 | 0.00E+00 | 5.01E-03 | 2.40E-04 | 4.91E-09 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 300 | 2.08E-02 | 1.80E-01 | 1.01E-02 | 1.39E-02 | 3.78E+01 | 1.97E+00 | 8.12E-01 | 4.49E-08 | 0.00E+00 | 1.00E-05 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.79E-06 | 1.56E-01 | 1.42E-02 | 5.75E-01 | 5.21E-01 | 2.40E-04 | 0.00E+00 | 3.20E-02 | 1.79E-03 | 1.17E-07 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 400 | 1.69E-02 | 9.21E-02 | 4.41E-03 | 1.84E-02 | 3.79E+01 | 2.19E+00 | 9.89E-01 | 1.09E-07 | 0.00E+00 | 2.00E-05 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.00E-05 | 1.67E-01 | 3.50E-02 | 6.64E-01 | 5.59E-01 | 3.70E-04 | 0.00E+00 | 9.10E-02 | 7.61E-03 | 1.27E-06 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 500 | 2.88E-02 | 5.51E-02 | 2.64E-03 | 7.61E-02 | 3.79E+01 | 2.47E+00 | 1.15E+00 | 2.06E-07 | 0.00E+00 | 5.00E-05 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.70E-04 | 1.67E-01 | 6.79E-02 | 7.26E-01 | 5.61E-01 | 5.40E-04 | 0.00E+00 | 1.56E-01 | 2.00E-02 | 1.00E-05 | 0.00E+00 | 0.00E+00 | 0.00E+00 |

Notes:

The results for years 600 through 1000 were less than the reporting limit of ½ MCL and not presented.

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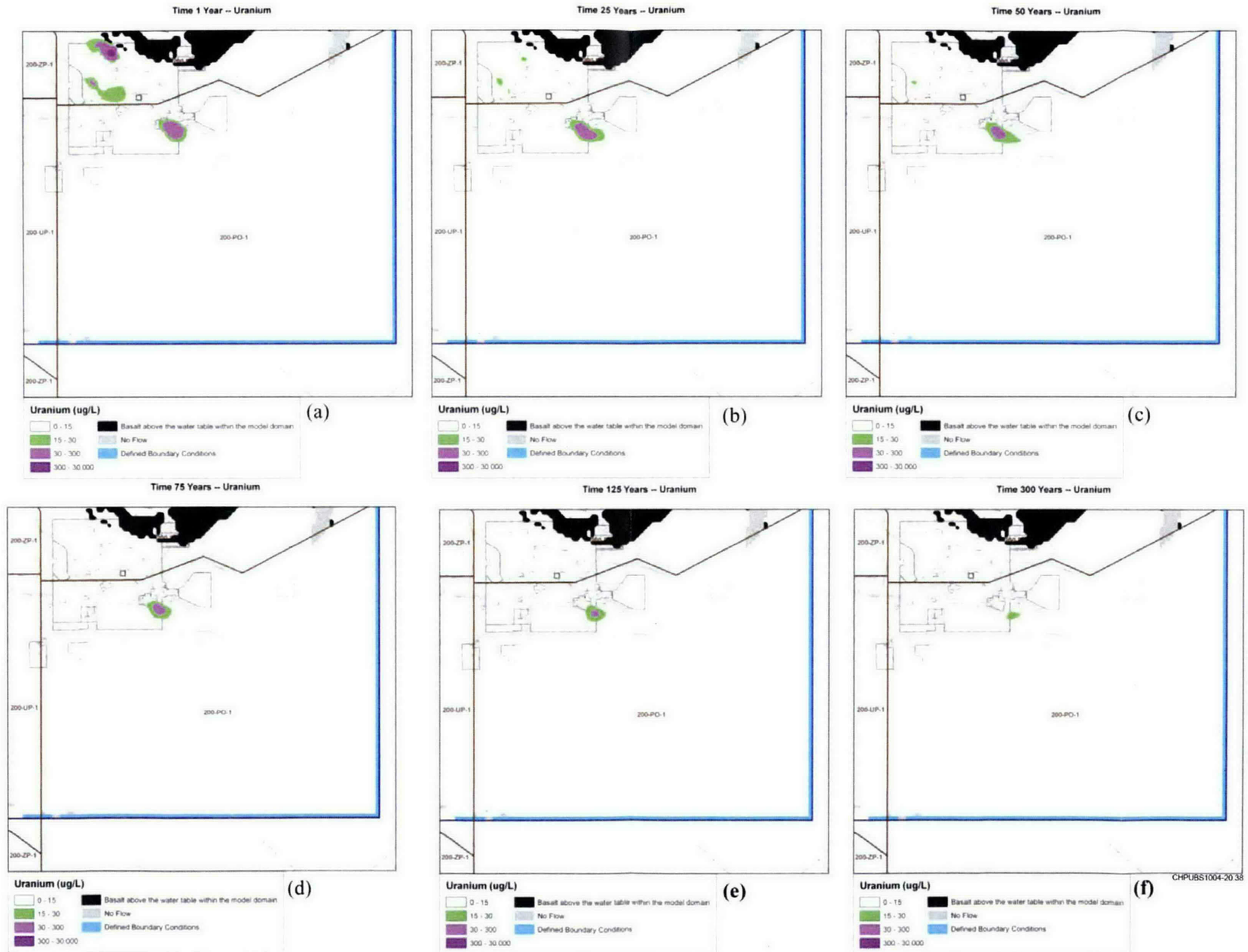


**Figure 5-10. Uranium Plume Map at Selected Time Points for the 200-PO-1 Operable Unit Near Field Area Within the Central Plateau Model Domain**

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### 5.2.2 Simulation of Contaminant Migration in the 200-PO-1 Far Field Environment

Far Field contaminant fate and transport calculations for the 200-PO-1 Groundwater OU were performed using a Pipe Pathway based contaminant transport approach. The Pipe Pathways are deemed adequate for modeling transport along flow paths that behave as stream tubes where advection is the dominant transport mechanism. The Pipe Pathways originate near the boundary of the Central Plateau model domain and extend all the way to the Columbia River. Their location and extent were chosen to capture the mass of COPCs arriving from the Central Plateau model domain in the future and to transport them along pathways defined by the existing hydraulic gradients to the discharge areas at the Columbia River (Figure 5-11). The current concentrations in the Far Field are used in the Pipe Pathways as initial conditions for the predictive calculation.

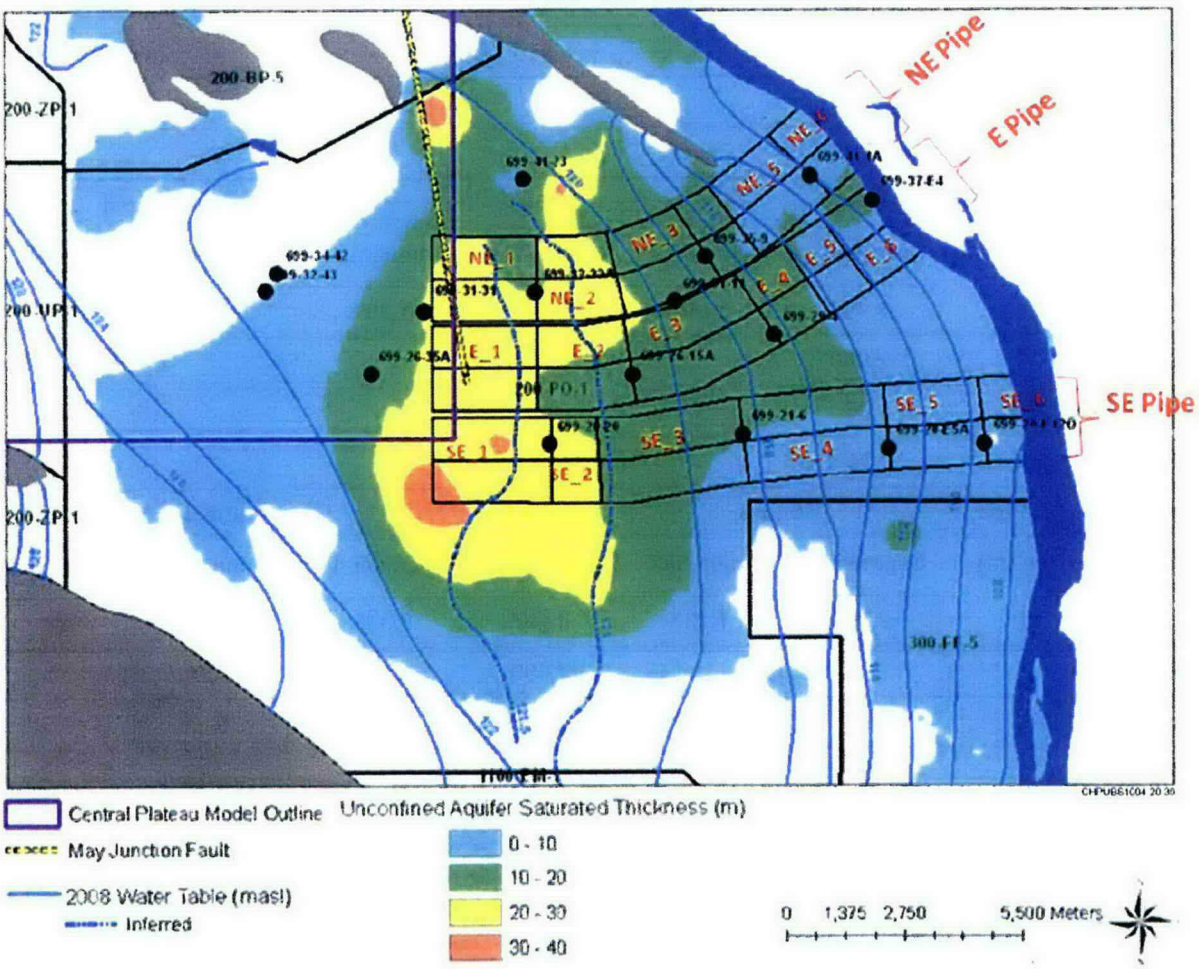


**Figure 5-11. Spatial Discretization of the Pipe Pathways Along with the Saturated Thickness Variation in the Unconfined Aquifer**

Three Pipe Pathways were deemed adequate for transport analysis of contaminants in the Far Field: one oriented in the northeast direction (NE Pipe); one towards east-northeast (E Pipe); and one towards the east-southeast (SE Pipe). Each Pipe Pathway is discretized into three zones based on the saturated thickness variation of the unconfined aquifer (0-10 m, 10-20 m, and 20-30 m), with each zone further discretized to correspond with the location of the monitoring well used in the risk assessment calculations, as shown by the placement of vertical lines in Figure 5-11. Six segments were created per Pipe Pathway,

the details of which are given in Table 5-10. Each discretized segment, for the purpose of reference, is numbered from 1 through 6 towards the downgradient direction along with the Pipe Pathway prefix. For example, for the E Pipe Pathway, the pipe segments are designated, from upgradient to the downgradient direction, as E_1, E_2, E_3, E_4, E_5, and E_6, respectively. The concentrations are calculated for the location at the end of each pipe segment.

**Table 5-10. Pipe Pathway Property Details**

| **Transport_NE Pipe** | **Zone 1** | | **Zone 2** | | **Zone 3** | |
|---|---|---|---|---|---|---|
| Length of NE Pipe (m) | Segment 1 | Segment 2 | Segment 3 | Segment 4 | Segment 5 | Segment 6 |
| | 2,457 | 1,876 | 2,012 | 976 | 1,988 | 961 |
| Width (m) | 2,000 | | 2,000 | | 2,000 | |
| Average Depth (m) | 25 | | 15 | | 5 | |
| Hydraulic Gradient | 2.5e-4 | | | | | |
| **Transport_E Pipe** | **Zone 1** | | **Zone 2** | | **Zone 3** | |
| Length of E Pipe (m) | Segment 1 | Segment 2 | Segment 3 | Segment 4 | Segment 5 | Segment 6 |
| | 2,983 | 1,661 | 3,194 | 1,339 | 1,102 | 1,102 |
| Width (m) | 2,000 | | 2,000 | | 2,000 | |
| Average Depth (m) | 25 | | 15 | | 5 | |
| Hydraulic Gradient | 2.5e-4 | | | | | |
| **Transport_SE Pipe** | **Zone 1** | | **Zone 2** | | **Zone 3** | |
| Length of SE Pipe (m) | Segment 1 | Segment 2 | Segment 3 | Segment 4 | Segment 5 | Segment 6 |
| | 2,793 | 1,133 | 3,367 | 3,336 | 2,235 | 898 |
| Width (m) | 2,000 | | 2,000 | | 2,000 | |
| Average Depth (m) | 25 | | 15 | | 5 | |
| Hydraulic Gradient | 2.5e-4 | | | | | |

The starting location of the Pipe Pathways was selected to be approximately 500 m inside the Central Plateau Groundwater Model domain (from its eastern boundary) and extends all the way to the Columbia River. The representativeness of the calculation is verified by comparing the construct to the available geologic descriptions, well logs, cross-sections, and other appropriate sources of information. The variation in the saturated thickness of the unconfined aquifer and the HSUs present in the Far Field was used to determine the adequacy of calculation discretization.

Appropriate initial conditions (Year 0) are established in the Pipe Pathways by introducing the mass of contaminants to match the concentration profile of COPCs in the Far Field region for years prior to calendar year 2009. This is achieved by introducing mass of COPCs in the Pipe Pathways in such a manner that the groundwater concentrations observed in the past few years at monitoring wells could be reasonably matched at the scale selected for the spatial discretization of the model domain.

For the predictive calculations, the flow rates were based on the estimation of current hydraulic gradients assuming they would not change appreciably over the simulated time period. A time varying concentration boundary condition was applied based on the output of the Central Plateau model. The grid blocks in the Central Plateau model that correspond to the spatial location of each of the three Pipe Pathways are identified, and the concentrations computed by the corresponding block centered nodes were averaged for each of the three Pipe Pathways. The selected grid blocks are located 500 m inside the Central Plateau Groundwater Model boundary to reduce the effects of boundary condition. In the vertical direction, only the grid blocks that are represented by HSU 1 (Hanford fm) and HSU 3 (Cold Creek/ PMG unit) were selected because they represent most of the unconfined aquifer and its most transmissive part in the Far Field transport calculations, where most of the contaminants are expected to be transported along the hydraulic gradient.

The future transport simulation concentrations (starting from calendar year 2009) of tritium, iodine-129, technetium-99, nitrate, uranium, tetrachloroethene, TCE, and carbon tetrachloride are presented in Table 5-11 through Table 5-18 at the end of each pipe segment in the East Pipe Pathway. Also presented are the time concentration plots for the three Pipe Pathways (Figure 5-12 through Figure 5-19). The future concentrations are presented up to 125 years for all COPCs except for iodine-129. The iodine-129 results are presented for the simulation duration of 1000 years to be consistent with the presentation of results in the Near Field. The concentration of strontium-90 is not presented, as the input boundary concentration is essentially zero ($< 10^{-16}$ pCi/L) along with the current Far Field concentrations.

For tritium, iodine-129, and nitrate, the upstream boundary concentrations applied are lower than the existing concentrations in the Pipe Pathways (reflecting movement of past releases). Therefore, the mass introduced at the upstream boundary does not greatly affect the future concentration. For COPCs that do not currently exist in the Far Field, namely, uranium, technetium-99, strontium-90, and chlorinated hydrocarbons, the boundary concentrations along with the effective retardation in the transport pathways primarily determine the concentrations of contaminants exiting the various Pipe segments. The breakthrough times of uranium show a greater degree of retardation compared to that for technetium-99, which is unretarded. The breakthrough curves for the various chlorinated hydrocarbons are similar to each other due to negligible retardation. However, the concentration of carbon tetrachloride shows a decline due to comparatively higher degradation rate.

The results of the Far Field transport calculations demonstrate that the peak concentrations which currently exist in the Far Field region generally decline with distance and time. For the COPCs that do not currently exist in the Far Field region, but are injected at the upstream boundary, the peak concentrations in the Far Field remains lower than those at the boundary suggesting decreasing risk.

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**Table 5-11. Predicted Far Field Concentration of Tritium (pCi/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration**

| Time (yr) | NE_Boundary | NE_1 | NE_2 | NE_3 | NE_4 | NE_5 | NE_6 | E_Boundary | E_1 | E_2 | E_3 | E_4 | E_5 | E_6 | SE_Boundary | SE_1 | SE_2 | SE_3 | SE_4 | SE_5 | SE_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 8.91E+00 | 4.04E+04 | 2.76E+05 | 9.42E+04 | 6.50E+04 | 5.59E+04 | 5.22E+04 | 1.66E+04 | 6.08E+04 | 7.32E+04 | 8.04E+04 | 8.00E+04 | 7.93E+04 | 7.87E+04 | 7.49E+03 | 5.62E+04 | 5.41E+04 | 2.98E+04 | 1.95E+04 | 1.22E+04 | 9.33E+03 |
| 5 | 1.17E+03 | 3.52E+04 | 2.01E+05 | 9.42E+04 | 6.24E+04 | 5.11E+04 | 4.68E+04 | 1.17E+04 | 4.48E+04 | 5.25E+04 | 6.07E+04 | 6.08E+04 | 6.07E+04 | 6.07E+04 | 2.79E+03 | 3.72E+04 | 3.83E+04 | 2.38E+04 | 1.83E+04 | 1.37E+04 | 1.12E+04 |
| 10 | 4.32E+03 | 2.80E+04 | 1.37E+05 | 9.76E+04 | 5.92E+04 | 4.61E+04 | 4.11E+04 | 6.55E+03 | 3.33E+04 | 3.76E+04 | 4.53E+04 | 4.56E+04 | 4.56E+04 | 4.57E+04 | 8.83E+02 | 2.68E+04 | 3.01E+04 | 2.08E+04 | 1.72E+04 | 1.37E+04 | 1.21E+04 |
| 20 | 3.20E+03 | 1.50E+04 | 5.87E+04 | 7.92E+04 | 5.64E+04 | 4.19E+04 | 3.58E+04 | 2.49E+03 | 1.79E+04 | 1.98E+04 | 2.47E+04 | 2.50E+04 | 2.51E+04 | 2.52E+04 | 1.91E+02 | 1.33E+04 | 1.67E+04 | 1.41E+04 | 1.23E+04 | 1.09E+04 | 1.03E+04 |
| 30 | 1.19E+03 | 7.02E+03 | 2.46E+04 | 4.38E+04 | 4.17E+04 | 3.59E+04 | 3.23E+04 | 1.22E+03 | 9.12E+03 | 1.07E+04 | 1.32E+04 | 1.34E+04 | 1.35E+04 | 1.36E+04 | 8.23E+01 | 6.29E+03 | 8.60E+03 | 8.62E+03 | 8.13E+03 | 7.57E+03 | 7.30E+03 |
| 40 | 5.27E+02 | 3.08E+03 | 1.06E+04 | 2.04E+04 | 2.36E+04 | 2.36E+04 | 2.31E+04 | 6.44E+02 | 4.45E+03 | 5.60E+03 | 7.07E+03 | 7.17E+03 | 7.21E+03 | 7.26E+03 | 4.24E+01 | 2.90E+03 | 4.24E+03 | 4.91E+03 | 4.91E+03 | 4.79E+03 | 4.72E+03 |
| 50 | 2.60E+02 | 1.34E+03 | 4.75E+03 | 8.93E+03 | 1.15E+04 | 1.27E+04 | 1.31E+04 | 3.57E+02 | 2.11E+03 | 2.82E+03 | 3.77E+03 | 3.83E+03 | 3.85E+03 | 3.88E+03 | 2.28E+01 | 1.31E+03 | 2.03E+03 | 2.65E+03 | 2.77E+03 | 2.80E+03 | 2.80E+03 |
| 60 | 1.42E+02 | 5.90E+02 | 2.18E+03 | 3.88E+03 | 5.20E+03 | 6.05E+03 | 6.46E+03 | 2.04E+02 | 9.87E+02 | 1.37E+03 | 1.99E+03 | 2.03E+03 | 2.04E+03 | 2.06E+03 | 1.31E+01 | 5.89E+02 | 9.45E+02 | 1.38E+03 | 1.49E+03 | 1.55E+03 | 1.57E+03 |
| 70 | 8.24E+01 | 2.65E+02 | 1.01E+03 | 1.72E+03 | 2.31E+03 | 2.74E+03 | 2.96E+03 | 1.14E+02 | 4.56E+02 | 6.51E+02 | 1.03E+03 | 1.06E+03 | 1.07E+03 | 1.08E+03 | 6.98E+00 | 2.64E+02 | 4.34E+02 | 6.93E+02 | 7.69E+02 | 8.16E+02 | 8.33E+02 |
| 80 | 4.67E+01 | 1.21E+02 | 4.68E+02 | 7.76E+02 | 1.03E+03 | 1.22E+03 | 1.32E+03 | 6.28E+01 | 2.11E+02 | 3.04E+02 | 5.25E+02 | 5.39E+02 | 5.45E+02 | 5.53E+02 | 3.71E+00 | 1.18E+02 | 1.98E+02 | 3.41E+02 | 3.86E+02 | 4.16E+02 | 4.28E+02 |
| 90 | 2.60E+01 | 5.62E+01 | 2.16E+02 | 3.56E+02 | 4.64E+02 | 5.46E+02 | 5.90E+02 | 3.46E+01 | 9.82E+01 | 1.41E+02 | 2.61E+02 | 2.69E+02 | 2.73E+02 | 2.77E+02 | 1.96E+00 | 5.31E+01 | 8.94E+01 | 1.65E+02 | 1.89E+02 | 2.06E+02 | 2.13E+02 |
| 100 | 1.42E+01 | 2.67E+01 | 9.93E+01 | 1.64E+02 | 2.12E+02 | 2.47E+02 | 2.66E+02 | 1.88E+01 | 4.64E+01 | 6.54E+01 | 1.27E+02 | 1.32E+02 | 1.34E+02 | 1.36E+02 | 1.03E+00 | 2.39E+01 | 4.03E+01 | 7.83E+01 | 9.12E+01 | 1.00E+02 | 1.04E+02 |
| 110 | 7.87E+00 | 1.31E+01 | 4.56E+01 | 7.56E+01 | 9.73E+01 | 1.13E+02 | 1.21E+02 | 1.01E+01 | 2.23E+01 | 3.06E+01 | 6.11E+01 | 6.34E+01 | 6.45E+01 | 6.58E+01 | 5.46E-01 | 1.08E+01 | 1.82E+01 | 3.69E+01 | 4.33E+01 | 4.81E+01 | 5.01E+01 |
| 120 | 4.33E+00 | 6.59E+00 | 2.10E+01 | 3.48E+01 | 4.48E+01 | 5.20E+01 | 5.57E+01 | 5.51E+00 | 1.10E+01 | 1.45E+01 | 2.91E+01 | 3.03E+01 | 3.08E+01 | 3.14E+01 | 2.88E-01 | 4.91E+00 | 8.21E+00 | 1.73E+01 | 2.04E+01 | 2.28E+01 | 2.38E+01 |
| 125 | 3.24E+00 | 4.72E+00 | 1.43E+01 | 2.36E+01 | 3.04E+01 | 3.53E+01 | 3.78E+01 | 4.06E+00 | 7.75E+00 | 1.01E+01 | 2.01E+01 | 2.08E+01 | 2.12E+01 | 2.17E+01 | 2.10E-01 | 3.31E+00 | 5.52E+00 | 1.18E+01 | 1.40E+01 | 1.56E+01 | 1.63E+01 |

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**Table 5-12. Predicted Far Field Concentration of Iodine-129 (pCi/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration**

| Time (yr) | NE_Boundary | NE_1 | NE_2 | NE_3 | NE_4 | NE_5 | NE_6 | E_Boundary | E_1 | E_2 | E_3 | E_4 | E_5 | E_6 | SE_Boundary | SE_1 | SE_2 | SE_3 | SE_4 | SE_5 | SE_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.89E-02 | 4.35E+00 | 8.90E-01 | 5.25E-01 | 4.74E-01 | 3.26E-01 | 2.47E-01 | 1.39E+00 | 9.04E-01 | 3.29E+00 | 1.92E-01 | 2.23E-01 | 2.34E-01 | 2.36E-01 | 1.12E-01 | 2.24E+00 | 1.10E+00 | 1.59E-01 | 3.27E-02 | 6.89E-03 | 2.95E-03 |
| 5 | 5.83E-02 | 3.41E+00 | 1.39E+00 | 4.13E-01 | 5.27E-01 | 4.43E-01 | 3.74E-01 | 1.09E+00 | 7.31E-01 | 2.64E+00 | 1.81E-01 | 2.04E-01 | 2.20E-01 | 2.27E-01 | 4.28E-02 | 1.92E+00 | 1.21E+00 | 2.53E-01 | 7.82E-02 | 2.49E-02 | 1.29E-02 |
| 10 | 8.47E-02 | 2.60E+00 | 1.87E+00 | 3.87E-01 | 4.96E-01 | 4.93E-01 | 4.58E-01 | 9.05E-01 | 6.65E-01 | 2.01E+00 | 1.85E-01 | 1.89E-01 | 2.03E-01 | 2.10E-01 | 2.63E-02 | 1.82E+00 | 1.41E+00 | 4.08E-01 | 1.67E-01 | 6.66E-02 | 4.17E-02 |
| 20 | 2.58E-01 | 1.52E+00 | 2.69E+00 | 7.48E-01 | 4.73E-01 | 4.71E-01 | 4.85E-01 | 6.49E-01 | 6.83E-01 | 1.16E+00 | 2.55E-01 | 1.96E-01 | 1.86E-01 | 1.86E-01 | 1.58E-02 | 1.64E+00 | 1.66E+00 | 7.39E-01 | 4.26E-01 | 2.49E-01 | 1.91E-01 |
| 30 | 5.12E-01 | 9.87E-01 | 3.16E+00 | 1.43E+00 | 7.68E-01 | 5.56E-01 | 4.97E-01 | 5.06E-01 | 7.52E-01 | 8.11E-01 | 4.03E-01 | 2.83E-01 | 2.35E-01 | 2.19E-01 | 1.34E-02 | 1.50E+00 | 1.71E+00 | 1.04E+00 | 7.47E-01 | 5.39E-01 | 4.57E-01 |
| 40 | 5.19E-01 | 8.00E-01 | 3.16E+00 | 2.17E+00 | 1.34E+00 | 9.27E-01 | 7.60E-01 | 4.28E-01 | 8.05E-01 | 7.38E-01 | 5.82E-01 | 4.37E-01 | 3.63E-01 | 3.31E-01 | 1.21E-02 | 1.40E+00 | 1.68E+00 | 1.26E+00 | 1.04E+00 | 8.54E-01 | 7.74E-01 |
| 50 | 4.06E-01 | 8.04E-01 | 2.82E+00 | 2.72E+00 | 1.99E+00 | 1.51E+00 | 1.28E+00 | 3.90E-01 | 8.29E-01 | 7.63E-01 | 7.45E-01 | 6.13E-01 | 5.35E-01 | 4.98E-01 | 1.12E-02 | 1.32E+00 | 1.61E+00 | 1.39E+00 | 1.26E+00 | 1.12E+00 | 1.06E+00 |
| 60 | 3.12E-01 | 9.02E-01 | 2.36E+00 | 2.95E+00 | 2.52E+00 | 2.11E+00 | 1.90E+00 | 3.66E-01 | 8.32E-01 | 8.00E-01 | 8.65E-01 | 7.67E-01 | 7.02E-01 | 6.69E-01 | 1.14E-02 | 1.26E+00 | 1.53E+00 | 1.46E+00 | 1.39E+00 | 1.31E+00 | 1.27E+00 |
| 70 | 2.61E-01 | 1.03E+00 | 1.93E+00 | 2.85E+00 | 2.79E+00 | 2.57E+00 | 2.42E+00 | 3.43E-01 | 8.24E-01 | 8.21E-01 | 9.39E-01 | 8.78E-01 | 8.33E-01 | 8.09E-01 | 1.10E-02 | 1.21E+00 | 1.45E+00 | 1.48E+00 | 1.45E+00 | 1.42E+00 | 1.39E+00 |
| 80 | 2.26E-01 | 1.16E+00 | 1.59E+00 | 2.55E+00 | 2.78E+00 | 2.76E+00 | 2.72E+00 | 3.22E-01 | 8.14E-01 | 8.27E-01 | 9.77E-01 | 9.46E-01 | 9.20E-01 | 9.05E-01 | 1.05E-02 | 1.16E+00 | 1.38E+00 | 1.46E+00 | 1.47E+00 | 1.46E+00 | 1.46E+00 |
| 90 | 1.92E-01 | 1.28E+00 | 1.38E+00 | 2.18E+00 | 2.56E+00 | 2.70E+00 | 2.75E+00 | 3.11E-01 | 8.06E-01 | 8.22E-01 | 9.90E-01 | 9.79E-01 | 9.67E-01 | 9.60E-01 | 9.93E-03 | 1.12E+00 | 1.32E+00 | 1.43E+00 | 1.46E+00 | 1.47E+00 | 1.47E+00 |
| 100 | 1.60E-01 | 1.36E+00 | 1.26E+00 | 1.83E+00 | 2.24E+00 | 2.47E+00 | 2.57E+00 | 2.96E-01 | 8.03E-01 | 8.14E-01 | 9.90E-01 | 9.90E-01 | 9.87E-01 | 9.84E-01 | 9.35E-03 | 1.07E+00 | 1.26E+00 | 1.39E+00 | 1.43E+00 | 1.45E+00 | 1.46E+00 |
| 110 | 1.35E-01 | 1.41E+00 | 1.22E+00 | 1.56E+00 | 1.92E+00 | 2.16E+00 | 2.28E+00 | 2.87E-01 | 8.04E-01 | 8.07E-01 | 9.81E-01 | 9.88E-01 | 9.90E-01 | 9.90E-01 | 8.85E-03 | 1.02E+00 | 1.21E+00 | 1.35E+00 | 1.39E+00 | 1.42E+00 | 1.43E+00 |
| 120 | 1.19E-01 | 1.44E+00 | 1.22E+00 | 1.38E+00 | 1.65E+00 | 1.86E+00 | 1.97E+00 | 2.79E-01 | 8.10E-01 | 8.04E-01 | 9.69E-01 | 9.79E-01 | 9.83E-01 | 9.85E-01 | 8.40E-03 | 9.73E-01 | 1.16E+00 | 1.30E+00 | 1.35E+00 | 1.38E+00 | 1.39E+00 |
| 125 | 1.14E-01 | 1.44E+00 | 1.24E+00 | 1.32E+00 | 1.55E+00 | 1.73E+00 | 1.83E+00 | 2.76E-01 | 8.14E-01 | 8.05E-01 | 9.62E-01 | 9.73E-01 | 9.78E-01 | 9.80E-01 | 8.22E-03 | 9.49E-01 | 1.13E+00 | 1.28E+00 | 1.32E+00 | 1.35E+00 | 1.37E+00 |
| 150 | 1.05E-01 | 1.38E+00 | 1.34E+00 | 1.25E+00 | 1.28E+00 | 1.33E+00 | 1.36E+00 | 2.60E-01 | 8.35E-01 | 8.19E-01 | 9.26E-01 | 9.38E-01 | 9.44E-01 | 9.47E-01 | 7.51E-03 | 8.28E-01 | 1.00E+00 | 1.16E+00 | 1.21E+00 | 1.24E+00 | 1.25E+00 |
| 175 | 1.10E-01 | 1.25E+00 | 1.38E+00 | 1.33E+00 | 1.29E+00 | 1.28E+00 | 1.28E+00 | 2.46E-01 | 8.45E-01 | 8.38E-01 | 8.95E-01 | 9.04E-01 | 9.10E-01 | 9.13E-01 | 7.05E-03 | 7.14E-01 | 8.80E-01 | 1.04E+00 | 1.08E+00 | 1.12E+00 | 1.13E+00 |
| 200 | 1.18E-01 | 1.09E+00 | 1.34E+00 | 1.37E+00 | 1.36E+00 | 1.34E+00 | 1.33E+00 | 2.35E-01 | 8.35E-01 | 8.44E-01 | 8.72E-01 | 8.79E-01 | 8.83E-01 | 8.85E-01 | 6.69E-03 | 6.11E-01 | 7.63E-01 | 9.16E-01 | 9.62E-01 | 9.94E-01 | 1.01E+00 |
| 300 | 1.68E-01 | 5.40E-01 | 8.01E-01 | 9.53E-01 | 1.03E+00 | 1.07E+00 | 1.09E+00 | 2.17E-01 | 6.54E-01 | 6.98E-01 | 8.36E-01 | 8.40E-01 | 8.42E-01 | 8.43E-01 | 6.27E-03 | 3.16E-01 | 4.05E-01 | 5.08E-01 | 5.41E-01 | 5.63E-01 | 5.73E-01 |
| 400 | 1.88E-01 | 2.78E-01 | 3.91E-01 | 4.72E-01 | 5.19E-01 | 5.49E-01 | 5.65E-01 | 1.93E-01 | 4.51E-01 | 4.86E-01 | 7.20E-01 | 7.34E-01 | 7.41E-01 | 7.44E-01 | 5.97E-03 | 1.64E-01 | 2.09E-01 | 2.65E-01 | 2.82E-01 | 2.95E-01 | 3.00E-01 |
| 500 | 1.60E-01 | 2.00E-01 | 2.31E-01 | 2.57E-01 | 2.74E-01 | 2.85E-01 | 2.91E-01 | 1.57E-01 | 3.24E-01 | 3.44E-01 | 5.43E-01 | 5.58E-01 | 5.65E-01 | 5.69E-01 | 5.04E-03 | 8.81E-02 | 1.11E-01 | 1.39E-01 | 1.48E-01 | 1.54E-01 | 1.57E-01 |
| 600 | 1.28E-01 | 1.83E-01 | 1.91E-01 | 1.96E-01 | 2.00E-01 | 2.03E-01 | 2.04E-01 | 1.26E-01 | 2.52E-01 | 2.64E-01 | 3.96E-01 | 4.06E-01 | 4.12E-01 | 4.15E-01 | 4.08E-03 | 4.93E-02 | 6.10E-02 | 7.53E-02 | 7.98E-02 | 8.30E-02 | 8.43E-02 |
| 700 | 1.05E-01 | 1.68E-01 | 1.77E-01 | 1.81E-01 | 1.82E-01 | 1.83E-01 | 1.84E-01 | 1.01E-01 | 2.03E-01 | 2.11E-01 | 2.98E-01 | 3.05E-01 | 3.08E-01 | 3.10E-01 | 3.36E-03 | 2.86E-02 | 3.49E-02 | 4.25E-02 | 4.48E-02 | 4.65E-02 | 4.72E-02 |
| 800 | 8.47E-02 | 1.46E-01 | 1.58E-01 | 1.63E-01 | 1.66E-01 | 1.67E-01 | 1.68E-01 | 8.14E-02 | 1.64E-01 | 1.71E-01 | 2.33E-01 | 2.38E-01 | 2.40E-01 | 2.42E-01 | 2.67E-03 | 1.73E-02 | 2.08E-02 | 2.49E-02 | 2.62E-02 | 2.71E-02 | 2.74E-02 |
| 900 | 6.59E-02 | 1.22E-01 | 1.34E-01 | 1.40E-01 | 1.43E-01 | 1.45E-01 | 1.46E-01 | 6.33E-02 | 1.33E-01 | 1.38E-01 | 1.87E-01 | 1.90E-01 | 1.92E-01 | 1.93E-01 | 2.06E-03 | 1.08E-02 | 1.28E-02 | 1.52E-02 | 1.59E-02 | 1.64E-02 | 1.66E-02 |
| 1000 | 5.03E-02 | 1.00E-01 | 1.11E-01 | 1.17E-01 | 1.20E-01 | 1.22E-01 | 1.23E-01 | 4.83E-02 | 1.07E-01 | 1.12E-01 | 1.50E-01 | 1.53E-01 | 1.54E-01 | 1.55E-01 | 1.58E-03 | 7.01E-03 | 8.20E-03 | 9.57E-03 | 9.99E-03 | 1.03E-02 | 1.04E-02 |

**Table 5-13. Predicted Far Field Concentration of Technetium-99 (pCi/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration**

| Time (yr) | NE_Boundary | NE_1 | NE_2 | NE_3 | NE_4 | NE_5 | NE_6 | E_Boundary | E_1 | E_2 | E_3 | E_4 | E_5 | E_6 | SE_Boundary | SE_1 | SE_2 | SE_3 | SE_4 | SE_5 | SE_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 8.94E-23 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.24E-07 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.10E-12 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 3.58E-05 | 1.36E-19 | 2.85E-33 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.97E+00 | 6.51E-15 | 2.82E-20 | 3.05E-31 | 2.58E-33 | 1.90E-34 | 2.37E-35 | 1.19E-03 | 1.77E-13 | 7.81E-20 | 1.37E-25 | 1.37E-31 | 3.34E-37 | 1.28E-39 |
| 10 | 2.12E-01 | 1.46E-15 | 6.13E-26 | 1.61E-35 | 5.66E-39 | 0.00E+00 | 0.00E+00 | 3.90E+00 | 5.90E-10 | 1.55E-16 | 1.97E-22 | 8.15E-24 | 1.29E-24 | 2.05E-25 | 3.26E-02 | 1.35E-07 | 1.51E-11 | 6.90E-17 | 3.35E-22 | 1.48E-26 | 1.95E-28 |
| 20 | 8.53E+00 | 2.18E-06 | 2.88E-16 | 6.05E-24 | 9.55E-27 | 6.63E-29 | 7.08E-31 | 2.86E+00 | 5.65E-04 | 8.98E-08 | 7.85E-14 | 4.31E-15 | 8.54E-16 | 1.60E-16 | 8.35E-02 | 2.90E-04 | 2.99E-06 | 4.57E-09 | 1.19E-11 | 5.82E-14 | 3.41E-15 |
| 30 | 5.61E+00 | 6.21E-03 | 3.40E-09 | 6.46E-15 | 1.32E-17 | 1.14E-19 | 1.68E-21 | 1.71E+00 | 3.76E-02 | 3.74E-04 | 6.66E-08 | 1.31E-08 | 5.28E-09 | 1.92E-09 | 5.79E-02 | 4.90E-03 | 3.40E-04 | 4.86E-06 | 1.42E-07 | 6.46E-09 | 1.32E-09 |
| 40 | 3.45E+00 | 1.62E-01 | 1.35E-05 | 1.71E-09 | 1.81E-11 | 5.29E-13 | 2.80E-14 | 1.45E+00 | 2.39E-01 | 1.64E-02 | 5.14E-05 | 2.00E-05 | 1.18E-05 | 6.54E-06 | 3.99E-02 | 1.59E-02 | 3.21E-03 | 1.82E-04 | 2.06E-05 | 2.98E-06 | 1.13E-06 |
| 50 | 2.86E+00 | 7.87E-01 | 1.25E-03 | 2.44E-06 | 8.87E-08 | 6.66E-09 | 8.78E-10 | 1.24E+00 | 6.10E-01 | 1.22E-01 | 2.15E-03 | 1.20E-03 | 8.64E-04 | 6.03E-04 | 3.33E-02 | 2.62E-02 | 1.02E-02 | 1.39E-03 | 3.52E-04 | 1.04E-04 | 5.69E-05 |
| 60 | 2.27E+00 | 1.72E+00 | 1.94E-02 | 2.19E-04 | 1.83E-05 | 2.67E-06 | 6.51E-07 | 1.10E+00 | 9.91E-01 | 3.81E-01 | 2.12E-02 | 1.46E-02 | 1.18E-02 | 9.35E-03 | 3.04E-02 | 3.21E-02 | 1.87E-02 | 4.69E-03 | 1.94E-03 | 8.88E-04 | 6.07E-04 |
| 70 | 1.87E+00 | 2.50E+00 | 1.12E-01 | 4.24E-03 | 6.40E-04 | 1.49E-04 | 5.41E-05 | 9.99E-01 | 1.27E+00 | 7.33E-01 | 9.30E-02 | 7.24E-02 | 6.29E-02 | 5.40E-02 | 2.82E-02 | 3.43E-02 | 2.57E-02 | 9.89E-03 | 5.61E-03 | 3.38E-03 | 2.65E-03 |
| 80 | 1.62E+00 | 2.95E+00 | 3.51E-01 | 3.20E-02 | 7.51E-03 | 2.46E-03 | 1.18E-03 | 9.33E-01 | 1.42E+00 | 1.06E+00 | 2.47E-01 | 2.09E-01 | 1.90E-01 | 1.71E-01 | 2.66E-02 | 3.44E-02 | 3.01E-02 | 1.57E-02 | 1.09E-02 | 7.87E-03 | 6.74E-03 |
| 90 | 1.46E+00 | 3.07E+00 | 7.49E-01 | 1.31E-01 | 4.30E-02 | 1.83E-02 | 1.06E-02 | 8.79E-01 | 1.46E+00 | 1.29E+00 | 4.72E-01 | 4.22E-01 | 3.96E-01 | 3.70E-01 | 2.55E-02 | 3.35E-02 | 3.22E-02 | 2.10E-02 | 1.66E-02 | 1.35E-02 | 1.22E-02 |
| 100 | 1.30E+00 | 2.98E+00 | 1.24E+00 | 3.52E-01 | 1.50E-01 | 7.81E-02 | 5.23E-02 | 8.21E-01 | 1.43E+00 | 1.41E+00 | 7.26E-01 | 6.74E-01 | 6.46E-01 | 6.17E-01 | 2.37E-02 | 3.22E-02 | 3.28E-02 | 2.50E-02 | 2.17E-02 | 1.90E-02 | 1.78E-02 |
| 110 | 1.18E+00 | 2.77E+00 | 1.72E+00 | 7.04E-01 | 3.70E-01 | 2.25E-01 | 1.67E-01 | 7.71E-01 | 1.37E+00 | 1.44E+00 | 9.58E-01 | 9.13E-01 | 8.89E-01 | 8.63E-01 | 2.25E-02 | 3.07E-02 | 3.24E-02 | 2.77E-02 | 2.55E-02 | 2.35E-02 | 2.26E-02 |
| 120 | 1.08E+00 | 2.51E+00 | 2.12E+00 | 1.14E+00 | 7.08E-01 | 4.87E-01 | 3.92E-01 | 7.76E-01 | 1.28E+00 | 1.40E+00 | 1.14E+00 | 1.10E+00 | 1.09E+00 | 1.07E+00 | 2.14E-02 | 2.93E-02 | 3.14E-02 | 2.93E-02 | 2.80E-02 | 2.67E-02 | 2.61E-02 |
| 125 | 1.06E+00 | 2.38E+00 | 2.27E+00 | 1.37E+00 | 9.10E-01 | 6.59E-01 | 5.47E-01 | 8.12E-01 | 1.24E+00 | 1.37E+00 | 1.20E+00 | 1.18E+00 | 1.16E+00 | 1.15E+00 | 2.16E-02 | 2.85E-02 | 3.09E-02 | 2.97E-02 | 2.88E-02 | 2.78E-02 | 2.73E-02 |

**Table 5-14. Predicted Far Field Concentration of Nitrate (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration**

| Time (yr) | NE_Boundary | NE_1 | NE_2 | NE_3 | NE_4 | NE_5 | NE_6 | E_Boundary | E_1 | E_2 | E_3 | E_4 | E_5 | E_6 | SE_Boundary | SE_1 | SE_2 | SE_3 | SE_4 | SE_5 | SE_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.00E+01 | 1.62E+04 | 1.47E+04 | 3.76E+04 | 3.51E+04 | 3.15E+04 | 2.99E+04 | 1.02E+02 | 2.48E+04 | 3.25E+04 | 3.94E+04 | 3.98E+04 | 4.00E+04 | 4.02E+04 | 5.27E+01 | 3.60E+04 | 3.28E+04 | 3.97E+04 | 4.22E+04 | 3.74E+04 | 3.39E+04 |
| 5 | 5.86E+00 | 1.73E+04 | 1.47E+04 | 3.23E+04 | 3.81E+04 | 3.62E+04 | 3.45E+04 | 2.49E+03 | 2.28E+04 | 3.09E+04 | 3.80E+04 | 3.86E+04 | 3.89E+04 | 3.92E+04 | 2.11E+02 | 3.22E+04 | 3.12E+04 | 3.46E+04 | 3.91E+04 | 4.08E+04 | 3.80E+04 |
| 10 | 9.56E+02 | 1.73E+04 | 1.39E+04 | 2.63E+04 | 3.59E+04 | 3.75E+04 | 3.69E+04 | 3.27E+03 | 2.14E+04 | 2.85E+04 | 3.68E+04 | 3.73E+04 | 3.76E+04 | 3.79E+04 | 5.64E+02 | 3.16E+04 | 3.30E+04 | 3.46E+04 | 3.86E+04 | 4.01E+04 | 4.05E+04 |
| 20 | 5.99E+03 | 1.52E+04 | 1.29E+04 | 1.94E+04 | 2.74E+04 | 3.26E+04 | 3.48E+04 | 3.61E+03 | 2.02E+04 | 2.41E+04 | 3.45E+04 | 3.50E+04 | 3.52E+04 | 3.55E+04 | 9.50E+02 | 2.90E+04 | 3.32E+04 | 3.49E+04 | 3.51E+04 | 3.65E+04 | 3.74E+04 |
| 30 | 5.60E+03 | 1.21E+04 | 1.32E+04 | 1.58E+04 | 2.08E+04 | 2.51E+04 | 2.73E+04 | 3.51E+03 | 1.94E+04 | 2.14E+04 | 3.15E+04 | 3.22E+04 | 3.25E+04 | 3.29E+04 | 1.04E+03 | 2.49E+04 | 3.13E+04 | 3.48E+04 | 3.49E+04 | 3.50E+04 | 3.51E+04 |
| 40 | 5.22E+03 | 9.09E+03 | 1.39E+04 | 1.40E+04 | 1.68E+04 | 1.95E+04 | 2.11E+04 | 2.94E+03 | 1.79E+04 | 2.01E+04 | 2.83E+04 | 2.90E+04 | 2.93E+04 | 2.97E+04 | 9.89E+02 | 2.05E+04 | 2.81E+04 | 3.39E+04 | 3.47E+04 | 3.49E+04 | 3.49E+04 |
| 50 | 4.19E+03 | 7.03E+03 | 1.41E+04 | 1.36E+04 | 1.47E+04 | 1.61E+04 | 1.70E+04 | 2.35E+03 | 1.58E+04 | 1.89E+04 | 2.55E+04 | 2.60E+04 | 2.63E+04 | 2.66E+04 | 8.95E+02 | 1.65E+04 | 2.41E+04 | 3.20E+04 | 3.35E+04 | 3.43E+04 | 3.45E+04 |
| 60 | 3.26E+03 | 5.89E+03 | 1.35E+04 | 1.38E+04 | 1.40E+04 | 1.45E+04 | 1.49E+04 | 2.04E+03 | 1.34E+04 | 1.72E+04 | 2.32E+04 | 2.37E+04 | 2.39E+04 | 2.41E+04 | 8.03E+02 | 1.32E+04 | 2.02E+04 | 2.92E+04 | 3.15E+04 | 3.27E+04 | 3.31E+04 |
| 70 | 2.80E+03 | 5.34E+03 | 1.24E+04 | 1.39E+04 | 1.39E+04 | 1.40E+04 | 1.41E+04 | 1.87E+03 | 1.12E+04 | 1.50E+04 | 2.13E+04 | 2.17E+04 | 2.19E+04 | 2.21E+04 | 7.23E+02 | 1.05E+04 | 1.65E+04 | 2.60E+04 | 2.87E+04 | 3.03E+04 | 3.09E+04 |
| 80 | 2.57E+03 | 5.02E+03 | 1.09E+04 | 1.34E+04 | 1.38E+04 | 1.39E+04 | 1.39E+04 | 1.78E+03 | 9.17E+03 | 1.27E+04 | 1.94E+04 | 1.98E+04 | 2.00E+04 | 2.02E+04 | 6.33E+02 | 8.39E+03 | 1.34E+04 | 2.26E+04 | 2.54E+04 | 2.73E+04 | 2.80E+04 |
| 90 | 2.42E+03 | 4.72E+03 | 9.45E+03 | 1.25E+04 | 1.33E+04 | 1.37E+04 | 1.38E+04 | 1.75E+03 | 7.50E+03 | 1.06E+04 | 1.74E+04 | 1.78E+04 | 1.81E+04 | 1.83E+04 | 5.47E+02 | 6.71E+03 | 1.08E+04 | 1.94E+04 | 2.21E+04 | 2.39E+04 | 2.47E+04 |
| 100 | 2.31E+03 | 4.38E+03 | 8.20E+03 | 1.12E+04 | 1.24E+04 | 1.30E+04 | 1.33E+04 | 1.72E+03 | 6.13E+03 | 8.72E+03 | 1.54E+04 | 1.58E+04 | 1.60E+04 | 1.63E+04 | 4.65E+02 | 5.39E+03 | 8.70E+03 | 1.63E+04 | 1.88E+04 | 2.06E+04 | 2.14E+04 |
| 110 | 2.23E+03 | 4.01E+03 | 7.19E+03 | 9.81E+03 | 1.12E+04 | 1.20E+04 | 1.24E+04 | 1.69E+03 | 5.03E+03 | 7.14E+03 | 1.33E+04 | 1.37E+04 | 1.39E+04 | 1.42E+04 | 3.97E+02 | 4.34E+03 | 6.99E+03 | 1.37E+04 | 1.59E+04 | 1.75E+04 | 1.82E+04 |
| 120 | 2.16E+03 | 3.65E+03 | 6.39E+03 | 8.57E+03 | 9.92E+03 | 1.08E+04 | 1.12E+04 | 1.63E+03 | 4.17E+03 | 5.85E+03 | 1.13E+04 | 1.17E+04 | 1.19E+04 | 1.22E+04 | 3.35E+02 | 3.51E+03 | 5.63E+03 | 1.13E+04 | 1.33E+04 | 1.47E+04 | 1.53E+04 |
| 125 | 2.10E+03 | 3.48E+03 | 6.05E+03 | 8.02E+03 | 9.30E+03 | 1.01E+04 | 1.05E+04 | 1.60E+03 | 3.82E+03 | 5.30E+03 | 1.04E+04 | 1.08E+04 | 1.10E+04 | 1.12E+04 | 3.09E+02 | 3.16E+03 | 5.05E+03 | 1.03E+04 | 1.21E+04 | 1.34E+04 | 1.40E+04 |

**Table 5-15. Predicted Far Field Concentration of Uranium (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration**

| Time (yr) | NE_Boundary | NE_1 | NE_2 | NE_3 | NE_4 | NE_5 | NE_6 | E_Boundary | E_1 | E_2 | E_3 | E_4 | E_5 | E_6 | SE_Boundary | SE_1 | SE_2 | SE_3 | SE_4 | SE_5 | SE_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 3.50E-23 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 5.80E-06 | 1.32E-31 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.37E-16 | 1.36E-32 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 10 | 1.02E-13 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 4.74E-02 | 5.60E-26 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.73E-08 | 4.83E-26 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 20 | 1.59E-07 | 5.11E-23 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.79E-01 | 4.95E-15 | 7.92E-25 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.89E-05 | 4.04E-19 | 8.11E-27 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 30 | 4.55E-05 | 2.44E-19 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.73E-01 | 1.46E-14 | 4.13E-19 | 2.74E-31 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 8.29E-05 | 3.08E-13 | 1.53E-20 | 1.76E-28 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 40 | 1.05E-03 | 1.62E-17 | 2.35E-30 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.57E-01 | 3.24E-12 | 3.34E-17 | 4.33E-25 | 1.06E-27 | 1.24E-29 | 8.61E-32 | 1.88E-04 | 1.41E-10 | 1.46E-15 | 7.37E-23 | 3.03E-30 | 0.00E+00 | 0.00E+00 |
| 50 | 8.14E-03 | 9.43E-16 | 1.26E-26 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.62E-01 | 1.61E-09 | 3.68E-16 | 4.87E-22 | 9.45E-24 | 5.62E-25 | 2.33E-26 | 3.91E-04 | 4.60E-09 | 7.43E-13 | 2.10E-18 | 9.14E-25 | 1.70E-30 | 0.00E+00 |
| 60 | 3.30E-02 | 3.57E-13 | 3.95E-24 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.60E-01 | 8.55E-08 | 3.79E-14 | 3.83E-20 | 2.26E-21 | 3.17E-22 | 3.50E-23 | 8.19E-04 | 4.76E-08 | 4.08E-11 | 1.34E-15 | 1.64E-20 | 3.23E-25 | 4.38E-28 |
| 70 | 8.75E-02 | 3.87E-11 | 3.06E-22 | 4.88E-30 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.54E-01 | 1.37E-06 | 9.37E-12 | 8.14E-19 | 9.22E-20 | 2.18E-20 | 4.36E-21 | 1.36E-03 | 2.62E-07 | 7.03E-10 | 1.20E-13 | 1.36E-17 | 2.42E-21 | 1.33E-23 |
| 80 | 1.70E-01 | 1.55E-09 | 2.40E-20 | 1.57E-27 | 5.52E-31 | 0.00E+00 | 0.00E+00 | 1.45E-01 | 1.06E-05 | 5.43E-10 | 6.37E-17 | 2.26E-18 | 5.01E-19 | 1.34E-19 | 1.89E-03 | 9.74E-07 | 6.02E-09 | 3.40E-12 | 1.86E-15 | 1.58E-18 | 2.43E-20 |
| 90 | 2.62E-01 | 2.92E-08 | 4.93E-18 | 1.60E-25 | 1.39E-28 | 4.58E-31 | 0.00E+00 | 1.36E-01 | 5.02E-05 | 1.21E-08 | 1.08E-14 | 3.90E-16 | 4.58E-17 | 5.52E-18 | 2.30E-03 | 2.85E-06 | 3.26E-08 | 4.58E-11 | 8.09E-14 | 2.17E-16 | 7.14E-18 |
| 100 | 3.39E-01 | 3.17E-07 | 5.37E-16 | 1.27E-23 | 1.34E-26 | 7.85E-29 | 6.63E-31 | 1.23E-01 | 1.68E-04 | 1.38E-07 | 6.66E-13 | 4.11E-14 | 6.69E-15 | 9.67E-16 | 2.54E-03 | 7.16E-06 | 1.29E-07 | 3.70E-10 | 1.61E-12 | 1.05E-14 | 6.09E-16 |
| 110 | 3.86E-01 | 2.26E-06 | 2.78E-14 | 2.05E-21 | 1.20E-24 | 6.76E-27 | 8.87E-29 | 1.08E-01 | 4.39E-04 | 9.83E-07 | 1.87E-11 | 1.78E-12 | 3.89E-13 | 7.71E-14 | 2.65E-03 | 1.59E-05 | 4.10E-07 | 2.07E-09 | 1.84E-11 | 2.42E-13 | 2.17E-14 |
| 120 | 4.00E-01 | 1.17E-05 | 7.84E-13 | 2.51E-19 | 1.87E-22 | 7.48E-25 | 7.58E-27 | 9.51E-02 | 9.54E-04 | 4.87E-06 | 2.92E-10 | 3.91E-11 | 1.09E-11 | 2.76E-12 | 2.67E-03 | 3.17E-05 | 1.11E-06 | 8.83E-09 | 1.39E-10 | 3.21E-12 | 4.09E-13 |
| 125 | 3.97E-01 | 2.42E-05 | 3.44E-12 | 2.19E-18 | 2.13E-21 | 9.36E-24 | 8.05E-26 | 8.90E-02 | 1.33E-03 | 9.72E-06 | 9.70E-10 | 1.50E-10 | 4.60E-11 | 1.30E-11 | 2.66E-03 | 4.31E-05 | 1.75E-06 | 1.69E-08 | 3.39E-10 | 9.94E-12 | 1.47E-12 |

**Table 5-16. Predicted Far Field Concentration of Tetrachloroethene (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration**

| Time (yr) | NE_Boundary | NE_1 | NE_2 | NE_3 | NE_4 | NE_5 | NE_6 | E_Boundary | E_1 | E_2 | E_3 | E_4 | E_5 | E_6 | SE_Boundary | SE_1 | SE_2 | SE_3 | SE_4 | SE_5 | SE_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1.76E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 2.69E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 9.34E-04 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 5.12E-03 | 1.01E-18 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.18E-03 | 1.37E-19 | 4.83E-25 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.52E-03 | 6.35E-14 | 3.71E-20 | 9.95E-27 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 10 | 3.20E-03 | 1.91E-14 | 4.63E-26 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.16E-03 | 1.09E-15 | 5.45E-22 | 9.76E-30 | 4.07E-32 | 0.00E+00 | 0.00E+00 | 1.10E-02 | 1.60E-08 | 8.98E-14 | 4.03E-21 | 5.55E-27 | 6.84E-32 | 0.00E+00 |
| 20 | 9.66E-04 | 3.70E-08 | 1.57E-19 | 8.13E-28 | 3.61E-31 | 0.00E+00 | 0.00E+00 | 6.13E-03 | 4.67E-09 | 5.59E-15 | 2.91E-23 | 1.02E-24 | 1.79E-25 | 3.24E-26 | 2.66E-02 | 1.48E-05 | 3.94E-08 | 4.69E-12 | 2.92E-16 | 3.59E-20 | 2.08E-22 |
| 30 | 2.94E-04 | 4.86E-06 | 2.69E-13 | 8.46E-21 | 1.88E-24 | 3.26E-27 | 1.83E-29 | 6.71E-03 | 7.28E-07 | 2.48E-10 | 2.75E-16 | 1.12E-17 | 1.52E-18 | 1.80E-19 | 3.71E-02 | 2.46E-04 | 4.73E-06 | 1.18E-08 | 3.72E-11 | 1.64E-13 | 7.70E-15 |
| 40 | 1.20E-04 | 4.81E-05 | 4.16E-10 | 2.13E-15 | 4.06E-18 | 2.70E-20 | 2.65E-22 | 7.77E-03 | 1.06E-05 | 4.73E-08 | 2.72E-12 | 3.64E-13 | 1.03E-13 | 2.68E-14 | 4.48E-02 | 1.23E-03 | 6.92E-05 | 7.76E-07 | 1.61E-08 | 4.58E-10 | 6.63E-11 |
| 50 | 9.64E-05 | 1.64E-04 | 3.22E-08 | 3.86E-12 | 3.21E-14 | 6.93E-16 | 2.43E-17 | 9.42E-03 | 6.08E-05 | 1.11E-06 | 6.44E-10 | 1.66E-10 | 7.18E-11 | 2.96E-11 | 4.94E-02 | 3.39E-03 | 3.86E-04 | 1.13E-05 | 6.83E-07 | 5.49E-08 | 1.48E-08 |
| 60 | 9.54E-05 | 3.28E-04 | 5.36E-07 | 5.37E-10 | 1.23E-11 | 6.08E-13 | 5.04E-14 | 1.09E-02 | 2.04E-04 | 9.60E-06 | 2.44E-08 | 9.19E-09 | 5.09E-09 | 2.73E-09 | 5.04E-02 | 6.72E-03 | 1.25E-03 | 7.28E-05 | 8.84E-06 | 1.37E-06 | 5.31E-07 |
| 70 | 7.99E-05 | 4.85E-04 | 3.67E-06 | 1.67E-08 | 8.05E-10 | 7.23E-11 | 1.09E-11 | 1.17E-02 | 4.82E-04 | 4.56E-05 | 3.32E-07 | 1.59E-07 | 1.02E-07 | 6.46E-08 | 5.33E-02 | 1.09E-02 | 2.89E-03 | 2.80E-04 | 5.56E-05 | 1.35E-05 | 6.67E-06 |
| 80 | 5.76E-05 | 5.94E-04 | 1.44E-05 | 2.02E-07 | 1.70E-08 | 2.41E-09 | 5.55E-10 | 1.19E-02 | 9.09E-04 | 1.44E-04 | 2.39E-06 | 1.35E-06 | 9.58E-07 | 6.73E-07 | 5.44E-02 | 1.56E-02 | 5.38E-03 | 7.72E-04 | 2.18E-04 | 7.28E-05 | 4.27E-05 |
| 90 | 3.97E-05 | 6.45E-04 | 3.88E-05 | 1.29E-06 | 1.69E-07 | 3.39E-08 | 1.07E-08 | 1.02E-02 | 1.48E-03 | 3.43E-04 | 1.10E-05 | 7.00E-06 | 5.36E-06 | 4.06E-06 | 5.41E-02 | 2.03E-02 | 8.61E-03 | 1.68E-03 | 6.17E-04 | 2.61E-04 | 1.73E-04 |
| 100 | 2.83E-05 | 6.47E-04 | 8.07E-05 | 5.29E-06 | 9.80E-07 | 2.60E-07 | 1.04E-07 | 9.90E-03 | 2.18E-03 | 6.68E-04 | 3.67E-05 | 2.55E-05 | 2.06E-05 | 1.66E-05 | 5.25E-02 | 2.48E-02 | 1.24E-02 | 3.11E-03 | 1.39E-03 | 7.00E-04 | 5.07E-04 |
| 110 | 2.14E-05 | 6.14E-04 | 1.39E-04 | 1.57E-05 | 3.86E-06 | 1.29E-06 | 6.16E-07 | 9.52E-03 | 2.99E-03 | 1.13E-03 | 9.57E-05 | 7.15E-05 | 6.02E-05 | 5.05E-05 | 5.05E-02 | 2.91E-02 | 1.64E-02 | 5.07E-03 | 2.64E-03 | 1.52E-03 | 1.17E-03 |
| 120 | 1.72E-05 | 5.62E-04 | 2.07E-04 | 3.64E-05 | 1.14E-05 | 4.56E-06 | 2.52E-06 | 9.02E-03 | 3.87E-03 | 1.72E-03 | 2.08E-04 | 1.64E-04 | 1.43E-04 | 1.23E-04 | 4.78E-02 | 3.29E-02 | 2.06E-02 | 7.53E-03 | 4.41E-03 | 2.82E-03 | 2.29E-03 |
| 125 | 1.57E-05 | 5.31E-04 | 2.43E-04 | 5.16E-05 | 1.79E-05 | 7.76E-06 | 4.55E-06 | 8.84E-03 | 4.32E-03 | 2.06E-03 | 2.90E-04 | 2.33E-04 | 2.06E-04 | 1.81E-04 | 4.65E-02 | 3.45E-02 | 2.26E-02 | 8.92E-03 | 5.49E-03 | 3.66E-03 | 3.04E-03 |

**Table 5-17. Predicted Far Field Concentration of Trichloroethene (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration**

| Time (yr) | NE_Boundary | NE_1 | NE_2 | NE_3 | NE_4 | NE_5 | NE_6 | E_Boundary | E_1 | E_2 | E_3 | E_4 | E_5 | E_6 | SE_Boundary | SE_1 | SE_2 | SE_3 | SE_4 | SE_5 | SE_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 7.27E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.33E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 8.83E-04 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 3.71E-03 | 1.49E-17 | 8.20E-28 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.49E-03 | 1.45E-18 | 2.06E-22 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.40E-03 | 3.18E-11 | 4.50E-18 | 6.34E-24 | 3.29E-30 | 0.00E+00 | 0.00E+00 |
| 10 | 1.36E-03 | 1.05E-10 | 2.00E-22 | 4.80E-31 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 3.51E-03 | 1.51E-12 | 3.80E-20 | 1.01E-25 | 2.94E-27 | 3.83E-28 | 4.00E-29 | 1.01E-02 | 4.11E-07 | 6.02E-11 | 1.83E-16 | 2.54E-22 | 6.77E-27 | 5.76E-29 |
| 20 | 1.15E-03 | 3.01E-06 | 3.35E-14 | 2.28E-22 | 1.32E-25 | 1.25E-27 | 1.96E-29 | 3.76E-03 | 1.50E-07 | 1.39E-11 | 3.23E-18 | 9.72E-20 | 1.40E-20 | 1.74E-21 | 2.03E-02 | 8.48E-05 | 1.19E-06 | 1.71E-09 | 2.58E-12 | 6.22E-15 | 2.20E-16 |
| 30 | 1.78E-03 | 6.87E-05 | 1.13E-09 | 9.76E-15 | 2.48E-17 | 2.14E-19 | 2.93E-21 | 4.06E-03 | 8.71E-06 | 3.80E-08 | 2.39E-12 | 3.40E-13 | 1.09E-13 | 3.13E-14 | 2.50E-02 | 8.11E-04 | 5.05E-05 | 6.61E-07 | 1.62E-08 | 5.35E-10 | 8.54E-11 |
| 40 | 1.45E-03 | 2.59E-04 | 1.81E-07 | 7.18E-11 | 1.05E-12 | 3.65E-14 | 2.14E-15 | 5.22E-03 | 7.71E-05 | 2.12E-06 | 2.18E-09 | 6.63E-10 | 3.30E-10 | 1.55E-10 | 2.66E-02 | 2.77E-03 | 4.03E-04 | 1.68E-05 | 1.47E-06 | 1.69E-07 | 5.58E-08 |
| 50 | 1.87E-03 | 4.97E-04 | 3.27E-06 | 1.30E-08 | 5.80E-10 | 4.92E-11 | 7.02E-12 | 6.42E-03 | 2.79E-04 | 2.40E-05 | 1.35E-07 | 6.08E-08 | 3.82E-08 | 2.33E-08 | 2.63E-02 | 5.75E-03 | 1.45E-03 | 1.29E-04 | 2.38E-05 | 5.41E-06 | 2.60E-06 |
| 60 | 2.83E-03 | 7.22E-04 | 1.97E-05 | 3.56E-07 | 3.38E-08 | 5.27E-09 | 1.33E-09 | 7.28E-03 | 6.25E-04 | 1.14E-04 | 2.10E-06 | 1.20E-06 | 8.70E-07 | 6.17E-07 | 2.48E-02 | 9.15E-03 | 3.34E-03 | 5.12E-04 | 1.52E-04 | 5.31E-05 | 3.19E-05 |
| 70 | 3.77E-03 | 9.17E-04 | 6.43E-05 | 3.29E-06 | 5.38E-07 | 1.29E-07 | 4.77E-08 | 7.79E-03 | 1.09E-03 | 3.19E-04 | 1.43E-05 | 9.56E-06 | 7.58E-06 | 5.93E-06 | 2.40E-02 | 1.24E-02 | 5.90E-03 | 1.34E-03 | 5.51E-04 | 2.57E-04 | 1.79E-04 |
| 80 | 4.79E-03 | 1.09E-03 | 1.45E-04 | 1.56E-05 | 3.80E-06 | 1.26E-06 | 6.01E-07 | 8.22E-03 | 1.65E-03 | 6.53E-04 | 5.64E-05 | 4.20E-05 | 3.55E-05 | 2.97E-05 | 2.24E-02 | 1.51E-02 | 8.76E-03 | 2.70E-03 | 1.39E-03 | 7.92E-04 | 6.09E-04 |
| 90 | 5.74E-03 | 1.27E-03 | 2.59E-04 | 4.74E-05 | 1.57E-05 | 6.60E-06 | 3.79E-06 | 8.30E-03 | 2.29E-03 | 1.10E-03 | 1.55E-04 | 1.24E-04 | 1.09E-04 | 9.58E-05 | 2.05E-02 | 1.71E-02 | 1.15E-02 | 4.53E-03 | 2.74E-03 | 1.80E-03 | 1.48E-03 |
| 100 | 6.74E-03 | 1.51E-03 | 3.97E-04 | 1.07E-04 | 4.47E-05 | 2.27E-05 | 1.49E-05 | 9.08E-03 | 3.00E-03 | 1.65E-03 | 3.31E-04 | 2.80E-04 | 2.54E-04 | 2.30E-04 | 1.84E-02 | 1.85E-02 | 1.40E-02 | 6.65E-03 | 4.55E-03 | 3.31E-03 | 2.86E-03 |
| 110 | 7.85E-03 | 1.86E-03 | 5.50E-04 | 1.98E-04 | 9.85E-05 | 5.75E-05 | 4.16E-05 | 9.82E-03 | 3.74E-03 | 2.28E-03 | 5.98E-04 | 5.24E-04 | 4.85E-04 | 4.49E-04 | 1.65E-02 | 1.94E-02 | 1.60E-02 | 8.89E-03 | 6.66E-03 | 5.23E-03 | 4.68E-03 |
| 120 | 9.07E-03 | 2.31E-03 | 7.14E-04 | 3.15E-04 | 1.80E-04 | 1.18E-04 | 9.14E-05 | 1.05E-02 | 4.48E-03 | 2.98E-03 | 9.59E-04 | 8.61E-04 | 8.10E-04 | 7.61E-04 | 1.46E-02 | 1.97E-02 | 1.75E-02 | 1.10E-02 | 8.87E-03 | 7.38E-03 | 6.78E-03 |
| 125 | 9.76E-03 | 2.58E-03 | 8.03E-04 | 3.81E-04 | 2.31E-04 | 1.58E-04 | 1.26E-04 | 1.12E-02 | 4.84E-03 | 3.34E-03 | 1.17E-03 | 1.06E-03 | 1.01E-03 | 9.52E-04 | 1.37E-02 | 1.96E-02 | 1.80E-02 | 1.21E-02 | 9.96E-03 | 8.48E-03 | 7.89E-03 |

**Table 5-18. Predicted Far Field Concentration of Carbon Tetrachloride (µg/L) for the Selected Points of Calculation Within Pipe Pathways Along with the Input Boundary Concentration**

| Time (yr) | NE_Boundary | NE_1 | NE_2 | NE_3 | NE_4 | NE_5 | NE_6 | E_Boundary | E_1 | E_2 | E_3 | E_4 | E_5 | E_6 | SE_Boundary | SE_1 | SE_2 | SE_3 | SE_4 | SE_5 | SE_6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 7.10E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.12E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.37E-03 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 |
| 5 | 2.57E-03 | 7.25E-17 | 7.57E-26 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 0.00E+00 | 1.49E-03 | 3.02E-18 | 2.09E-21 | 1.65E-30 | 1.87E-32 | 0.00E+00 | 0.00E+00 | 4.48E-03 | 7.38E-10 | 9.56E-16 | 1.37E-22 | 7.32E-28 | 1.27E-32 | 0.00E+00 |
| 10 | 6.93E-04 | 2.14E-09 | 2.52E-21 | 2.09E-28 | 3.33E-32 | 0.00E+00 | 0.00E+00 | 2.98E-03 | 3.98E-11 | 1.29E-18 | 3.89E-24 | 2.57E-25 | 5.33E-26 | 9.46E-27 | 1.12E-02 | 2.23E-06 | 1.44E-09 | 3.09E-14 | 4.42E-19 | 3.08E-23 | 3.52E-25 |
| 20 | 1.97E-04 | 9.13E-06 | 3.03E-12 | 5.82E-19 | 3.33E-22 | 1.22E-24 | 1.21E-26 | 5.47E-03 | 6.09E-07 | 3.58E-10 | 1.16E-15 | 7.87E-17 | 1.76E-17 | 3.50E-18 | 1.69E-02 | 1.90E-04 | 5.72E-06 | 2.49E-08 | 1.51E-10 | 1.34E-12 | 1.03E-13 |
| 30 | 4.63E-03 | 9.01E-05 | 1.55E-08 | 1.47E-12 | 1.14E-14 | 2.41E-16 | 8.67E-18 | 1.78E-02 | 1.84E-05 | 2.48E-07 | 8.99E-11 | 2.11E-11 | 9.28E-12 | 3.73E-12 | 1.61E-02 | 1.12E-03 | 1.22E-04 | 3.45E-06 | 2.00E-07 | 1.52E-08 | 3.97E-09 |
| 40 | 2.07E-02 | 1.95E-04 | 8.29E-07 | 1.99E-09 | 7.00E-11 | 4.92E-12 | 5.90E-13 | 2.41E-02 | 1.07E-04 | 6.48E-06 | 2.45E-08 | 1.02E-08 | 6.20E-09 | 3.60E-09 | 1.34E-02 | 2.62E-03 | 5.96E-04 | 4.61E-05 | 7.46E-06 | 1.51E-06 | 6.82E-07 |
| 50 | 2.91E-02 | 2.71E-04 | 6.96E-06 | 1.15E-07 | 1.04E-08 | 1.56E-09 | 3.83E-10 | 2.26E-02 | 3.65E-04 | 4.35E-05 | 6.81E-07 | 3.82E-07 | 2.76E-07 | 1.94E-07 | 1.06E-02 | 3.96E-03 | 1.43E-03 | 2.15E-04 | 6.30E-05 | 2.18E-05 | 1.31E-05 |
| 60 | 2.69E-02 | 5.85E-04 | 2.32E-05 | 1.33E-06 | 2.29E-07 | 5.75E-08 | 2.19E-08 | 2.05E-02 | 1.00E-03 | 1.64E-04 | 5.86E-06 | 3.90E-06 | 3.11E-06 | 2.44E-06 | 8.22E-03 | 4.72E-03 | 2.34E-03 | 5.61E-04 | 2.39E-04 | 1.15E-04 | 8.16E-05 |
| 70 | 2.45E-02 | 1.61E-03 | 4.87E-05 | 6.21E-06 | 1.68E-06 | 6.04E-07 | 3.07E-07 | 1.94E-02 | 2.07E-03 | 4.77E-04 | 2.72E-05 | 1.98E-05 | 1.67E-05 | 1.39E-05 | 6.39E-03 | 4.88E-03 | 3.02E-03 | 1.02E-03 | 5.59E-04 | 3.35E-04 | 2.64E-04 |
| 80 | 2.35E-02 | 3.30E-03 | 9.50E-05 | 1.68E-05 | 6.25E-06 | 2.91E-06 | 1.80E-06 | 1.98E-02 | 3.30E-03 | 1.08E-03 | 9.15E-05 | 7.03E-05 | 6.08E-05 | 5.22E-05 | 4.85E-03 | 4.62E-03 | 3.36E-03 | 1.48E-03 | 9.59E-04 | 6.66E-04 | 5.63E-04 |
| 90 | 2.43E-02 | 5.06E-03 | 2.14E-04 | 3.51E-05 | 1.54E-05 | 8.51E-06 | 5.96E-06 | 2.21E-02 | 4.34E-03 | 1.91E-03 | 2.42E-04 | 1.95E-04 | 1.73E-04 | 1.52E-04 | 3.67E-03 | 4.14E-03 | 3.39E-03 | 1.82E-03 | 1.34E-03 | 1.03E-03 | 9.13E-04 |
| 100 | 2.70E-02 | 6.39E-03 | 4.75E-04 | 7.37E-05 | 3.25E-05 | 1.91E-05 | 1.42E-05 | 2.64E-02 | 5.05E-03 | 2.74E-03 | 5.13E-04 | 4.31E-04 | 3.91E-04 | 3.54E-04 | 2.78E-03 | 3.56E-03 | 3.18E-03 | 2.01E-03 | 1.61E-03 | 1.34E-03 | 1.23E-03 |
| 110 | 3.24E-02 | 7.22E-03 | 8.98E-04 | 1.64E-04 | 6.99E-05 | 4.03E-05 | 3.00E-05 | 3.14E-02 | 5.50E-03 | 3.42E-03 | 8.88E-04 | 7.76E-04 | 7.19E-04 | 6.64E-04 | 2.18E-03 | 2.97E-03 | 2.84E-03 | 2.05E-03 | 1.75E-03 | 1.54E-03 | 1.44E-03 |
| 120 | 3.83E-02 | 7.73E-03 | 1.43E-03 | 3.40E-04 | 1.53E-04 | 8.82E-05 | 6.52E-05 | 3.56E-02 | 5.84E-03 | 3.89E-03 | 1.31E-03 | 1.18E-03 | 1.11E-03 | 1.04E-03 | 1.78E-03 | 2.43E-03 | 2.45E-03 | 1.97E-03 | 1.77E-03 | 1.61E-03 | 1.54E-03 |
| 125 | 4.07E-02 | 7.95E-03 | 1.70E-03 | 4.65E-04 | 2.19E-04 | 1.29E-04 | 9.62E-05 | 3.77E-02 | 6.02E-03 | 4.06E-03 | 1.51E-03 | 1.38E-03 | 1.31E-03 | 1.24E-03 | 1.65E-03 | 2.18E-03 | 2.25E-03 | 1.89E-03 | 1.74E-03 | 1.61E-03 | 1.55E-03 |

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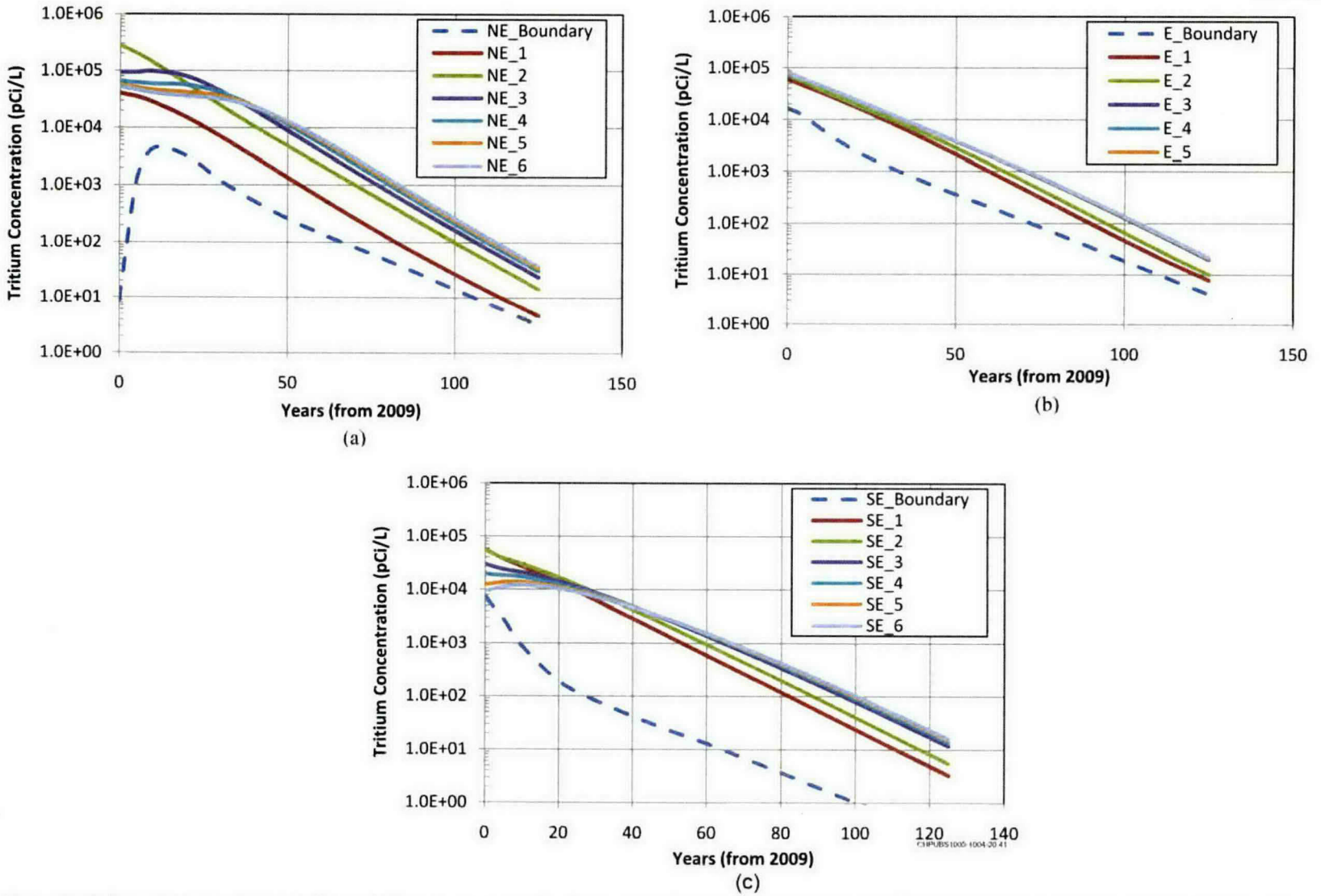
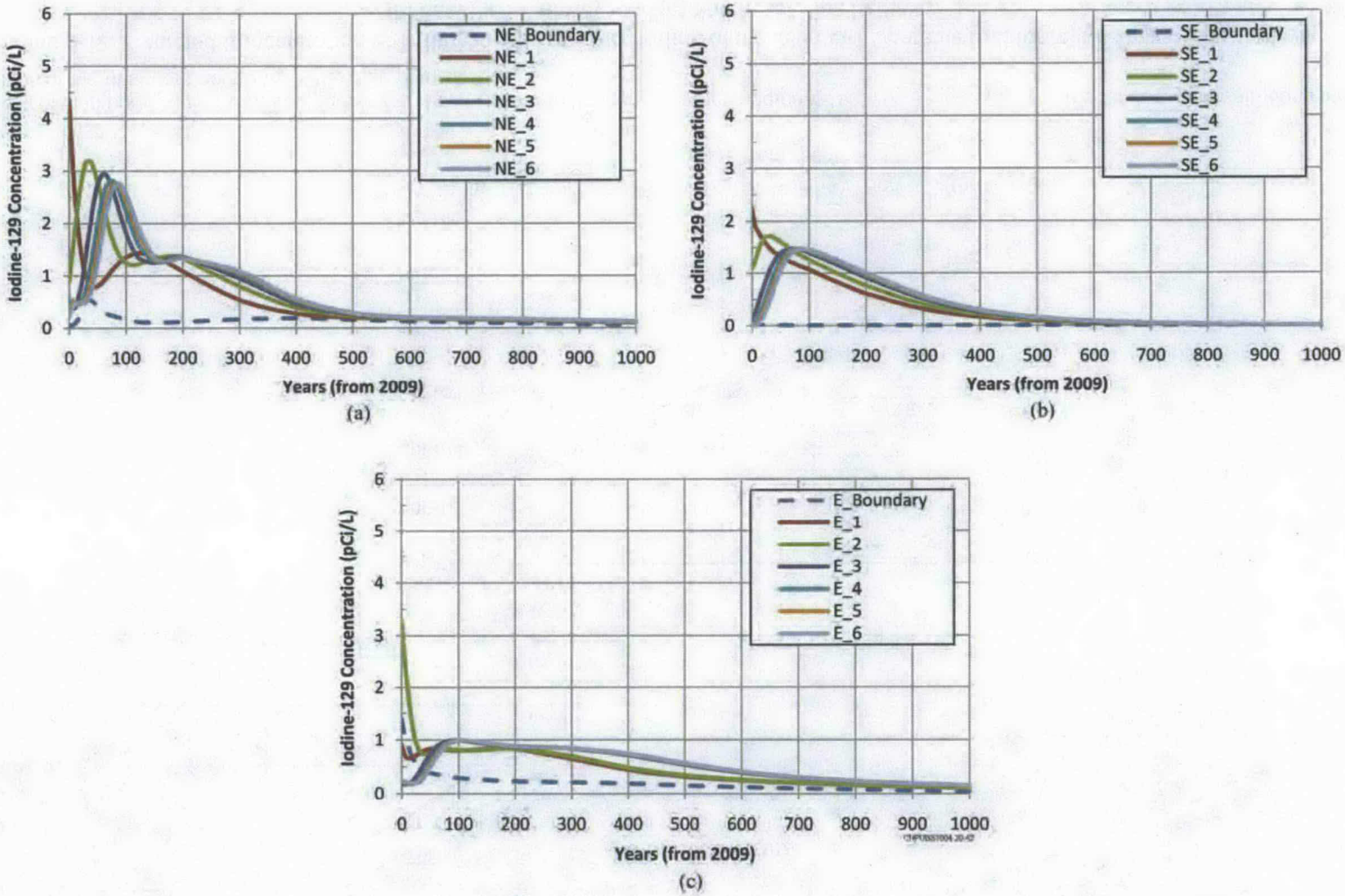


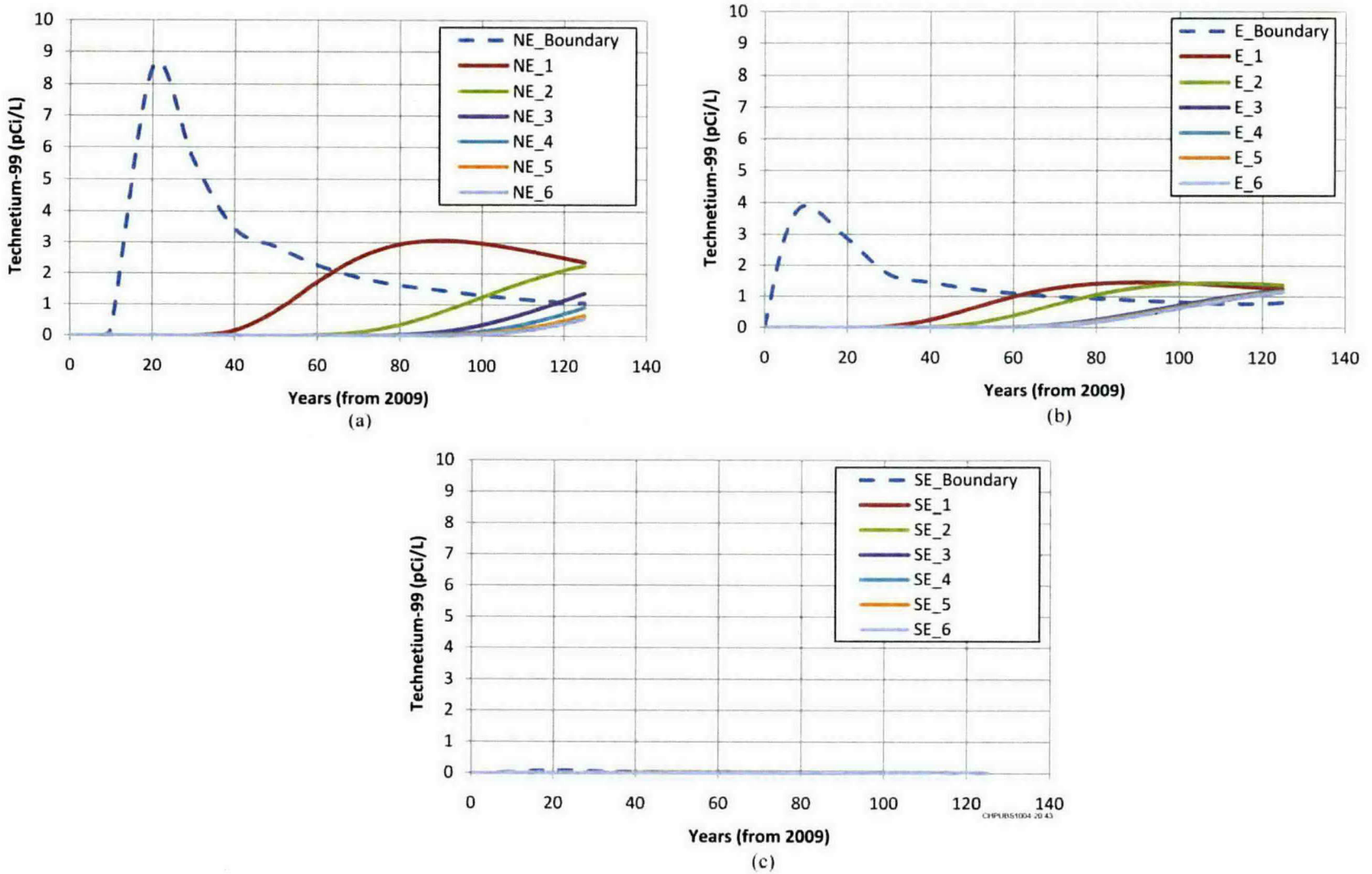

Note: The calculation points are shown in Figure 5-2 and correspond to the center of pipe segments shown in Figure 5-11; the boundary concentrations are the concentrations of the upstream boundary of the pipe pathways.

**Figure 5-12. Predicted Concentration of Tritium in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway**



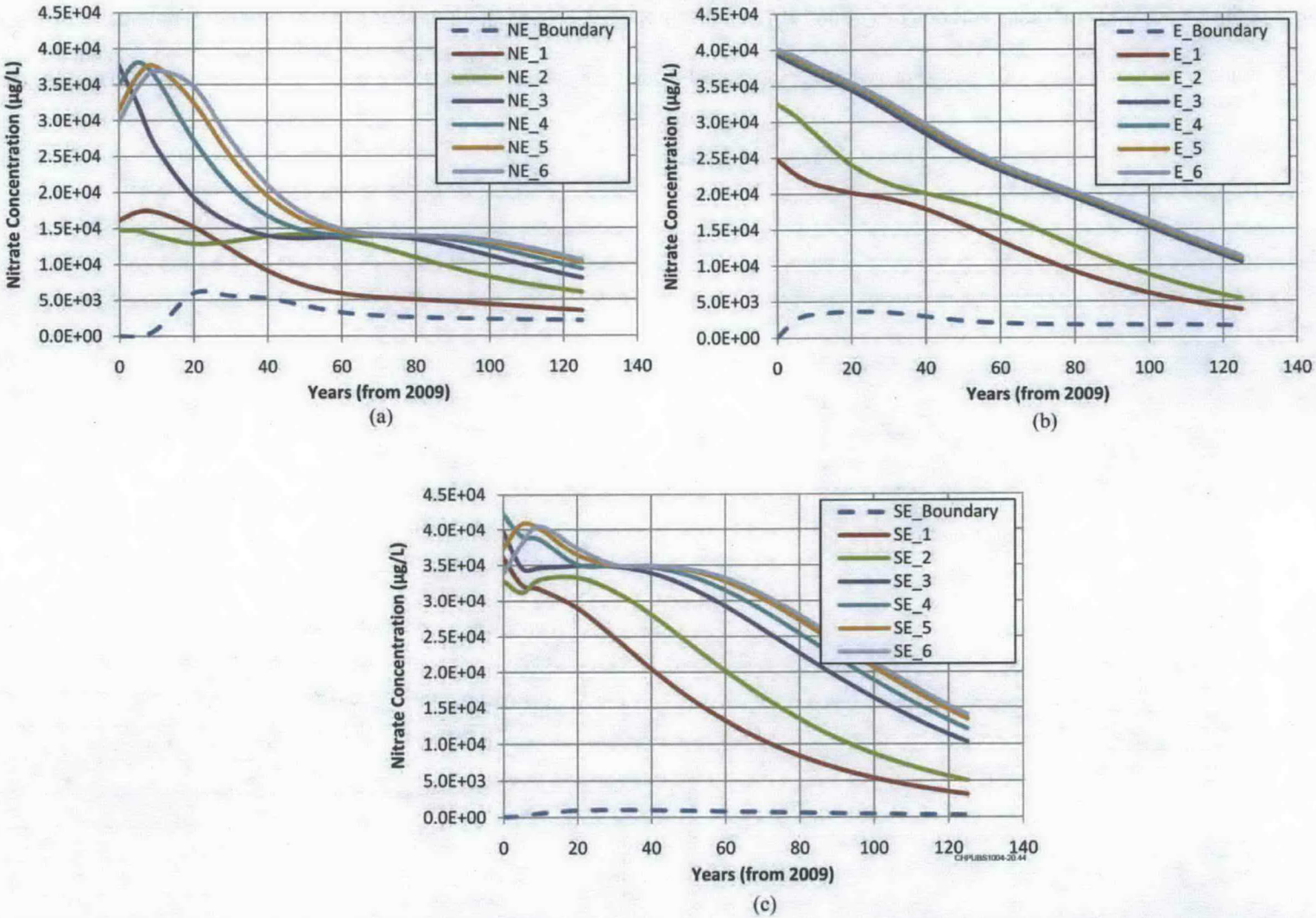

Note: The calculation points are shown in Figure 5-2 and correspond to the center of pipe segments shown in Figure 5-11; the boundary concentrations are the concentrations at the upstream boundary of the pipe pathways.

**Figure 5-13. Predicted Concentration of Iodine-129 in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway**



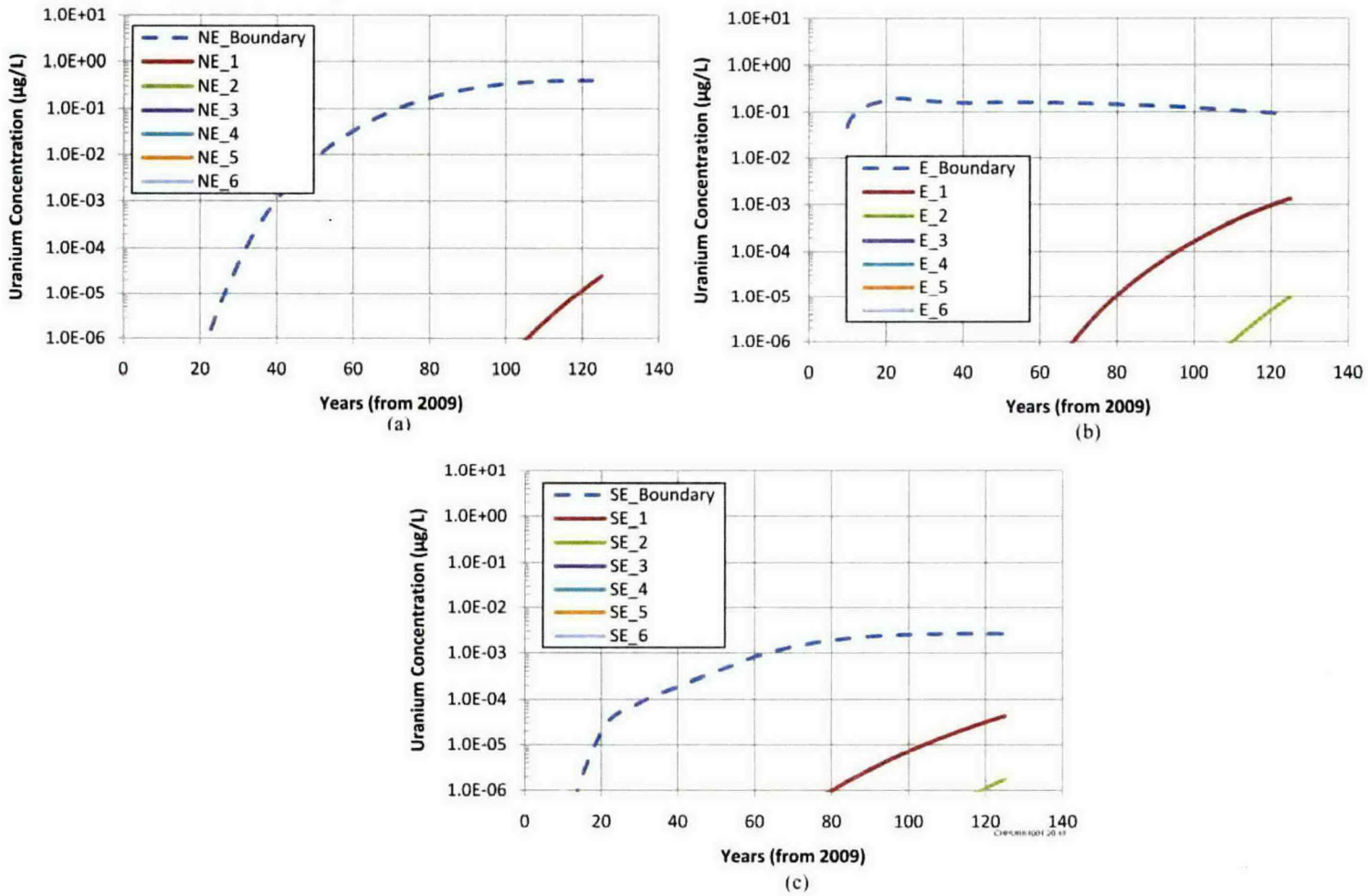

Note: The calculation points are shown in Figure 5-2 and correspond to the center of pipe segments shown in Figure 5-11; the boundary concentrations are the concentrations at the upstream boundary of the pipe pathways.

**Figure 5-14. Predicted Concentration of Technetium-99 in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway**



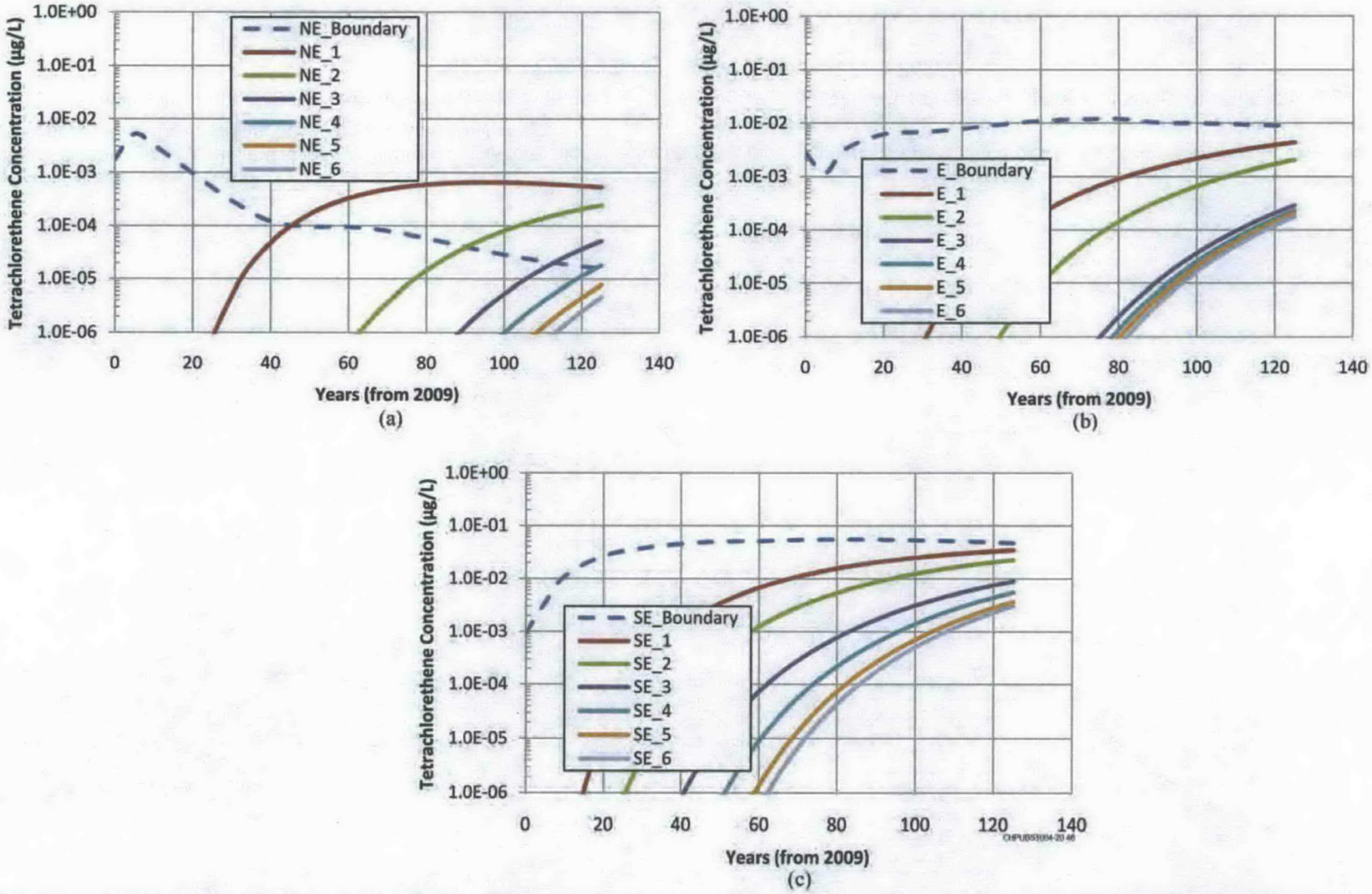

Note: The calculation points are shown in Figure 5-2 and correspond to the center of pipe segments shown in Figure 5-11; the boundary concentrations are the concentrations at the upstream boundary of the pipe pathways.

**Figure 5-15. Predicted Concentration of Nitrate in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway**



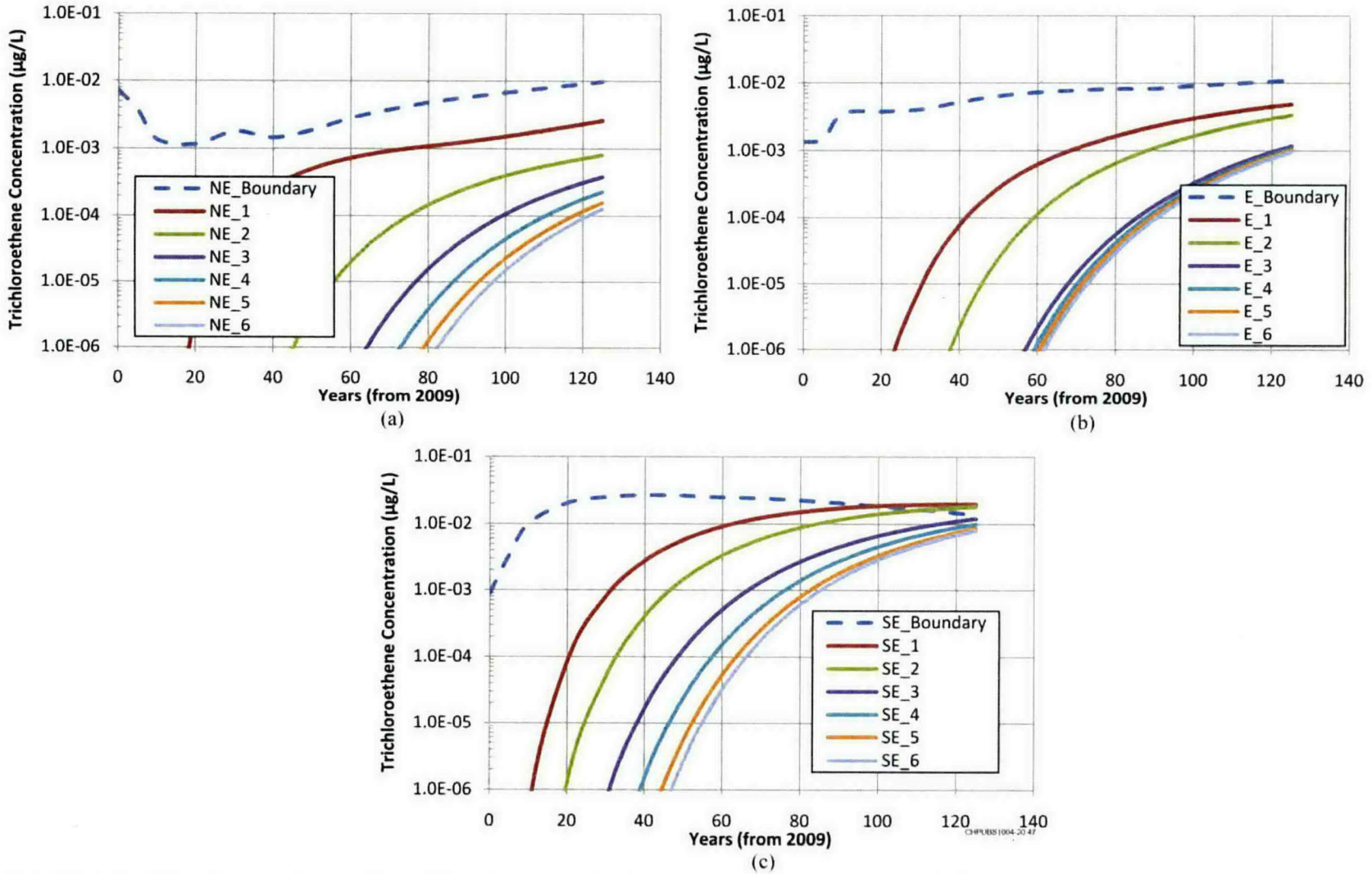

Note: The calculation points are shown in Figure 5-2 and correspond to the center of pipe segments shown in Figure 5-11; the boundary concentrations are the concentrations at the upstream boundary of the pipe pathways.

**Figure 5-16. Predicted Concentration of Uranium in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway**



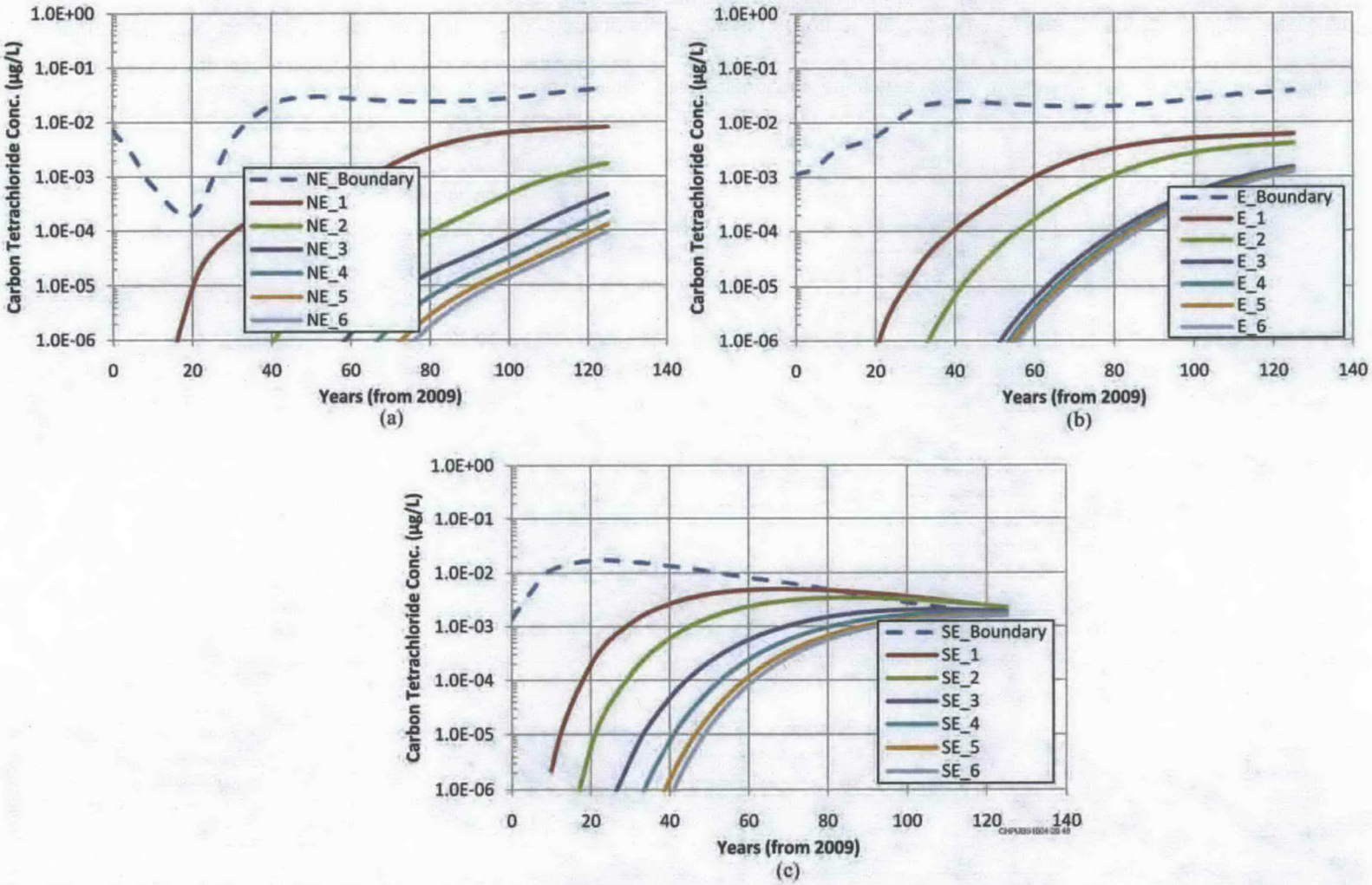

Note: The calculation points are shown in Figure 5-2 and correspond to the center of pipe segments shown in Figure 5-11; the boundary concentrations are the concentrations at the upstream boundary of the pipe pathways.

**Figure 5-17. Predicted Concentration of Tetrachloroethene in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway**




Note: The calculation points are shown in Figure 5-2 and correspond to the center of pipe segments shown in Figure 5-11; the boundary concentrations are the concentrations at the upstream boundary of the pipe pathways.

**Figure 5-18. Predicted Concentration of Trichloroethene in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway**




Note: The calculation points are shown in Figure 5-2 and correspond to the center of pipe segments shown in Figure 5-11; the boundary concentrations are the concentrations at the upstream boundary of the pipe pathways.

**Figure 5-19. Predicted Concentration of Carbon Tetrachloride in the Far Field Portion of the 200-PO-1 Operable Unit for (a) Northeast Pipe Pathway, (b) East Pipe Pathway, and (c) Southeast Pipe Pathway**

### 5.2.3 Uncertainty in Simulated Future Conditions

No attempt was made to quantify uncertainty in the fate and transport simulations. What follows is a qualitative discussion of sources of uncertainty in the simulations and how those uncertainties might influence the predictions of future contaminant distributions. Five sources of uncertainty are identified that can affect the fate and transport calculation results and the estimated future groundwater contaminant concentrations: (1) uncertainty in representing initial contaminant concentration distribution, in general, conservative estimates were applied when measurements and observations did not fully describe the contaminant distribution; (2) uncertainty caused by not including possible future, or continuing, contaminant source contributions to groundwater generally underestimates future impacts in affected areas; (3) conceptual model uncertainty in flow and transport modeling may over- or under-estimate the general rate of contaminant movement through the aquifer; (4) parameter uncertainty may affect the rate of movement of specific contaminants through the aquifer; and (5) uncertainty introduced by computational processes may over- or under-state the rate of contaminant transport and/or the estimated future contaminant concentrations. Another potential source of uncertainty that can be considered is the assumption about the future use of the Central Plateau itself. Additional discussion of simulation uncertainties is presented in the modeling calculation briefs (ECF-200PO1-09-2007, ECF-200PO1-10-0259, and ECF-200PO1-09-2352).

When the model is developed for use in FSs to compare remedial alternatives, a more thorough calibration will be undertaken along with a more thorough evaluation of model uncertainties. Further refinements of the model are also expected as the model is used for design of remedial alternatives. At that stage, a formal quantitative evaluation of model uncertainties will be presented. The identified uncertainties (e.g., potential future contribution from residual vadose zone sources) will be considered when evaluating the expected efficacy of remedial alternatives in the FS.

## 5.3 Conceptual Exposure Model

The conceptual exposure model (CEM) identifies the means by which human or ecological receptors may contact contaminants in groundwater. It addresses potential exposures that may result under current site conditions and from reasonably anticipated potential uses of groundwater within the OU. The following subsections describe the CEM as well as the results of fate and transport simulations.

This section provides the CEM for the 200-PO-1 Groundwater OU. The CEM provides a current understanding of the sources of contamination, physical setting, current and reasonably anticipated future land use, and groundwater and surface water beneficial uses, and it identifies potentially complete human and ecological exposure pathways for the 200-PO-1 Groundwater OU. Site information from previous investigations and work plans has been incorporated into the CEM to identify potential exposure scenarios. The physical characteristics of the study area and expectations for restoring groundwater to its highest beneficial use are described in detail in Chapter 3; current and reasonably anticipated future land use is described in Chapter 1.

### 5.3.1 Current and Reasonably Anticipated Future Land Use

Anticipated land use plays a key role in CERCLA cleanup decisions. DOE is responsible for designating Hanford Site land use. As the lead agency for CERLCA cleanup of the Hanford Site,[2] DOE is also responsible for identifying future land uses that will guide CERCLA risk assessment and cleanup decisions. DOE used the NEPA EIS process (DOE/EIS-0222-F) to examine land use alternatives and

[2] 52 FR 2923, "Executive Order 12580: Superfund Implementation," designated DOE as the "lead agency" for CERLA cleanup at DOE sites.

conducted this process with nine cooperating agencies and consulting Tribal governments as a basis for determining future anticipated land uses.[3] This effort resulted in the Hanford Comprehensive Land-Use Plan that DOE adopted and implemented in the ROD published on November 12, 1999 (64 FR 61615). The *Hanford Comprehensive Land-Use Plan* must be reviewed periodically to ensure that it remains current. The first review since adoption and implementation was documented in a supplemental analysis that resulted in DOE issuing an amendment to the ROD (73 FR 55824, "Amended Record of Decision for the Hanford Comprehensive Land-Use Plan Environmental Impact Statement") on September 26, 2008.

The Hanford Comprehensive Land-Use Plan Record of Decision (64 FR 61615) designated land uses for the Hanford Site. The 2008 amended ROD (73 FR 55824) maintained those anticipated land uses. Selected land-use designations that are relevant to CERCLA cleanup decision are defined below.

- 100 Areas – Conservation-Mining. An area reserved for protection of archeological, cultural, ecological, and natural resources.
- 300 Area – Industrial. An area suitable for industrial activities such as reactor operations and manufacturing.
- Central Plateau (200 Areas) – Industrial Exclusive. An area suitable for TSD of hazardous and/or radioactive waste under federal control.
- Wahluke Slope, Saddle Mountains, Fitzner/Eberhardt Arid Lands Ecology (ALE) Reserve, Gable Mountain, and Gable Butte – Preservation. An area managed for the preservation of archeological, cultural, ecological, and natural resources.
- Columbia River Corridor – High Intensity Recreation, Low-Intensity Recreation, Conservation Mining, and Preservation. High- and low-intensity recreation allow for a range of visitor-serving activities and facilities.

In June 2000, most of the lands that are designated as "preservation" were permanently withdrawn and protected by a presidential proclamation (65 FR 37253, "Proclamation 7319 of June 9, 2000: Establishment of the Hanford Reach National Monument") with the establishment of the Hanford Reach National Monument. The monument is superimposed over approximately 195,000 acres (304 square miles) of the 586-square mile DOE Hanford Site.

In April 2010, a Tentative Agreement was reached between the Tri-Party Agencies to define the new CERCLA decision structure accompanying the Central Plateau strategy, consistent with the division of decision-making between the groundwater OUs and the waste site OUs noted above. Under DOE/RL-2009-81, two major geographic areas for waste site remediation are defined:

- The Inner Area (Figure 1-1) covers approximately 10 square miles in the middle of the Central Plateau, where the bulk of the chemical processing and waste management activities occurred. The Inner Area is envisioned to be the smallest practical final cleanup footprint where waste management and containment of residual contamination will occur.

[3] The cooperating entities were the U.S Department of the Interior (Bureau of Land Management, Bureau of Reclamation, and the U.S. Fish and Wildlife Service); the City of Richland; Benton, Franklin, and Grant Counties; the Nez Perce Tribe; and the Confederated Tribes of the Umatilla Indian Reservation. Although not a cooperating agency, the Yakama Nation participated at points throughout the seven-year-long EIS process.

- The Outer Area (Figure 1-1) is greater than 65 square miles and includes much of the open area on the Central Plateau. Limited processing activity occurred in the Outer Area, and cleanup objectives for the Outer Area waste sites will be comparable to the 100 Area River Corridor waste sites.

Along with the Inner and Outer Areas, the Tentative Agreement also recognizes groundwater remediation. As acknowledged in the Hanford Site Groundwater Strategy (DOE/RL-2002-59), and DOE/RL-2007-20, and then reaffirmed in the 200-ZP-1 Final ROD (EPA et al., 2008), DOE's goal is to restore Central Plateau groundwater to its beneficial uses, unless restoration is determined to be technically impracticable. This includes the groundwater underlying both the Inner and Outer Areas.

Hanford lands, including the Hanford Reach National Monument, are expected to remain under federal ownership and control for the foreseeable future.[4] The federal government will retain ownership of the conservation and preservation areas of the Hanford Site for the foreseeable future. These areas are not expected to be defined as excess to DOE missions. Access to these areas will be controlled, as necessary, to protect human health and safety as long as active waste management operations are being conducted.

DOE recognizes that permanent disposal, isolation, and protection of disposed inventories will be required. Within this area, DOE intends to shrink the region requiring permanent isolation and control to be much smaller than the current 52 $km^2$ (20 $mile^2$ area.) Consistent with other DOE and non-DOE sites around the nation (e.g., Fernald, Rocky Flats, and Savannah River Site), Hanford's Industrial-Exclusive Area will be controlled for the foreseeable future.

### 5.3.2 Groundwater Beneficial Use

CERCLA and the NCP establish separate requirements for a groundwater remedy to be protective of HHE and to meet ARARs. This is a concept of central importance to the development of the groundwater remedy for the 200-PO-1 Groundwater OU. These separate requirements are further clarified in a memorandum (Fields, 1997a, OSWER No. 9200.4-23).

The requirement to achieve threshold protectiveness and ARAR-based requirements is established by the NCP. The NCP also establishes the requirement to return useable groundwater to beneficial use within a reasonable timeframe. The EPA generally defers to state agency definitions of useable groundwater provided under the various comprehensive state groundwater protection programs, administered by the states across the country and a state's determination of groundwater usability at CERCLA sites (EPA/540/G-88/003, 1988, *Guidance on Remedial Actions for Contaminated Ground Water at Superfund Sites*). The State of Washington defines groundwater as potable in WAC 173-340-720(2), "Model Toxics Control Act--Cleanup," "Ground Water Cleanup Standards," "Potable Ground Water Defined," unless the exclusion criteria in WAC 173-340-720(2)(a) through (c), "Potable Ground Water Defined," can be demonstrated (e.g., insufficient yield or natural constituents that make it unsuitable as a drinking water source). The groundwater beneath the Central Plateau does not meet the exclusion criteria; therefore, it is classified as potable and must be restored to beneficial use wherever practicable, and within a timeframe that is reasonably consistent with the NCP requirements. The State of Washington has further determined that the highest beneficial use for potable groundwater at most of the cleanup sites within the state, including the Hanford Site, is as a potential source of domestic drinking water (WAC 173-340-720[1][a], "General Considerations").

Groundwater beneath the Central Plateau is currently contaminated, and administrative controls prevent withdrawal of groundwater for human consumption. Under current site-use conditions, no complete

[4] Further information on Hanford land use designations and processes can be found in the *Hanford Comprehensive Land-Use Plan EIS*, the corresponding ROD (64 FR 71715) of November 2, 1999, the recently released supplement analysis (DOE, 2008), and the amended ROD (73 FR 55824) of September 26, 2008.

human or ecological exposure pathways to groundwater are assumed to exist beneath the Central Plateau. Further, regardless of land use designations for soils, groundwater within this OU is not anticipated to become a future source of drinking water until cleanup criteria are met and groundwater is restored to its highest beneficial use. However, groundwater in this risk analysis is evaluated for drinking water use to support the determination of the basis for action and to support the development of PRGs for evaluating remedial alternatives in the FS.

There are drinking water supply wells located at the 400 Area of the Hanford Site, at the Laser Interferometer Gravitational Wave Observatory (LIGO) Facility, and at Energy Northwest's Columbia Generating Station. Each of these drinking water supply wells are located within the boundaries of the 200-PO-1 Groundwater OU. These include three wells at the Hanford 400 Area (the Fast Flux Test Facility [FFTF]), one of which is in regular use and two that are emergency backup sources; three wells at Energy Northwest's Columbia Generating Station, none of which is in use; and one well at the LIGO facility.

### 5.3.3 Surface Water Beneficial Use

WAC 173-201A-600, "Use Designations—Fresh Waters," and WAC 173-201A-602, "Table 602—Use Designations for Fresh Waters by Water Resource Inventory Area (WRIA)," identify the beneficial use (or designated uses) for rivers and streams of Washington State. Designated uses for waters of Washington State can include public water supply; protection for fish, shellfish, and wildlife; as well as recreational, agricultural, industrial, navigational, and aesthetic purposes. Water quality criteria are designed to protect the designated uses and are used to assess the general health of Washington surface waters and set permit limits.

Designated uses of the Columbia River, identified in WAC Table 602, include the following:

- Aquatic life uses – Spawning and rearing
- Recreational uses – Primary contact
- Water supply uses – Drinking water, industrial water, agricultural water, and stock water
- Miscellaneous uses – Wildlife habitat, harvesting, commercial/navigation, boating, and aesthetics

### 5.3.4 200-PO-1 Groundwater Operable Unit Exposure Areas

The 200-PO-1 Groundwater OU is generally represented by the tritium plume that extends from the identified source areas in the 200 East Area to the Columbia River. The 2,000 pCi/L isopleth of tritium (one-tenth of the primary DWS) can be used to define the OU boundary on the western, northern, and eastern flanks of the plume. The western boundary of the 200-PO-1 Groundwater OU extends from the boundary of the 300 Area on the south to the intersection between the 200-PO-1 Groundwater OU and 200-BP-5 Groundwater OU on the north. The northern boundary extends from the Columbia River to the intersection of the 200-PO-1 Groundwater OU/200-BP-5 boundary. The eastern boundary of the 200-PO-1 Groundwater OU is the Columbia River, south to the 300 Area. The southern boundary is represented by the northern border of the 300 Area from the river to the western 2,000 pCi/L tritium isopleth.

The 200-PO-1 Groundwater OU is divided into three exposure areas (Near Field, Far Field, and river). The primary objectives for evaluating each exposure area are to provide information necessary to determine the need for remedial action and to use this information to select the best remedy. These objectives are achieved by performing the following steps for each exposure area:

1. EPCs for each COPC are compared to contaminant-specific ARARs for the purpose of understanding the potential for exposure to groundwater contaminants and the associated health risks.

2. Specific locations are identified within the exposure area for the purpose of evaluating remedial alternatives in the FS.

The basis for each exposure area and the known or suspected sources are described below. Exposure areas and the location of associated monitoring wells are shown in Figure 5-20.

#### *5.3.4.1 Near Field Exposure Area*

The Near Field exposure area represents the portion of the 200-PO-1 Groundwater OU where the highest contaminant concentrations have been detected. The highest concentrations are observed in the Near Field area because the historic waste water discharges that produced the plumes originate in the Near Field area. If an active secondary source control action is required as part of the selected remedy process, it would likely be applied to groundwater located within the Near Field area.

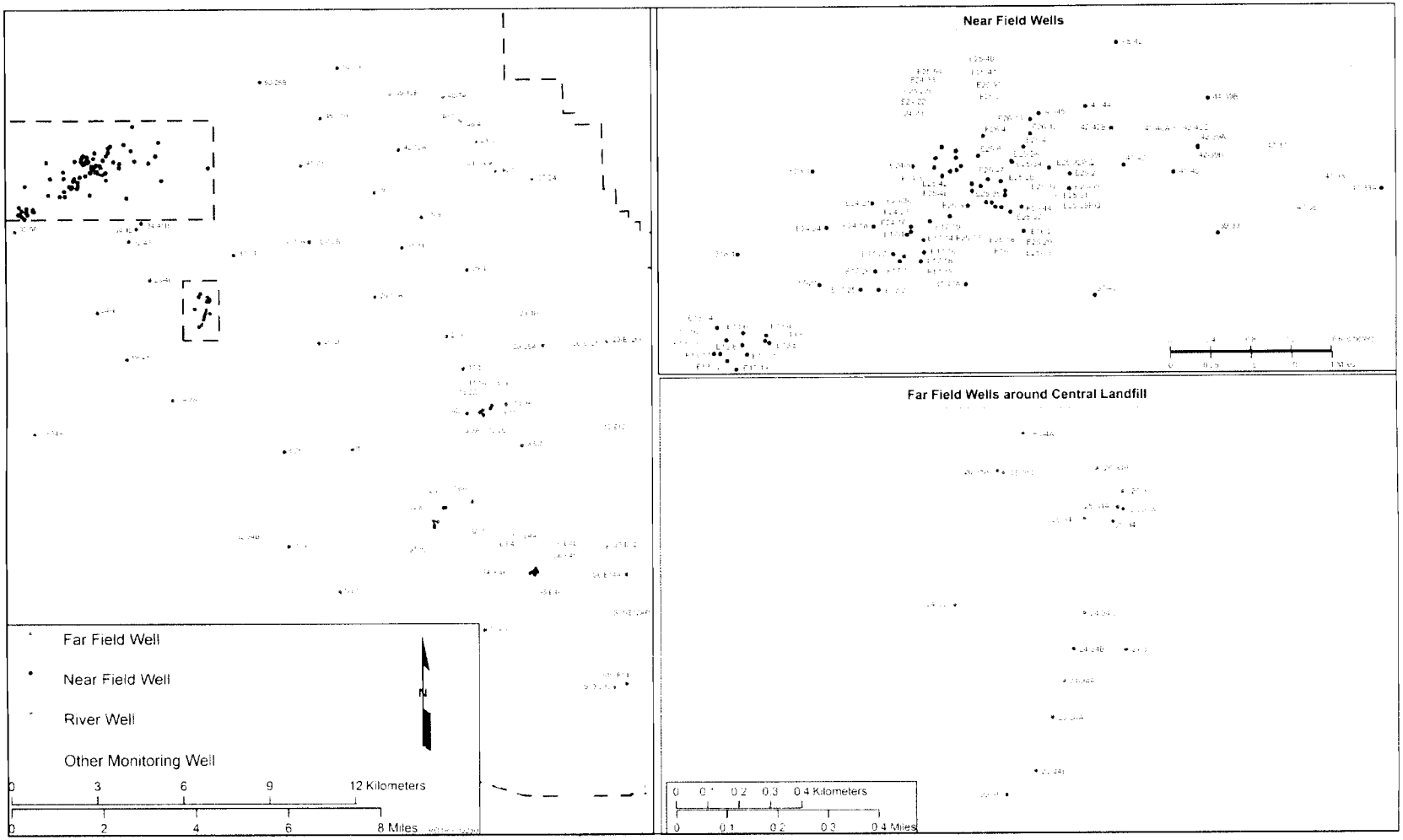



**Figure 5-20. Monitoring Wells in the 200-PO-1 Groundwater Operable Unit**

The Near Field area incorporates historic source areas within and adjacent to the 200 East Area, and downgradient to and including the SE Transect wells. Near Field monitoring is associated primarily with RCRA-permitted TSD facilities (e.g., tank farms and PUREX cribs), but also includes the non-permitted BC Cribs and Trenches Area. Waste sites grouped around two major nuclear fuel reprocessing facilities (i.e., PUREX Plant and B Plant) are the primary contributors to groundwater contamination in the 200-PO-1 Groundwater OU. The PUREX Plant is located within the footprint of the 200-PO-1 Groundwater OU. The B Plant is located in the 200-BP-5 Groundwater OU along the northern boundary of the 200-PO-1 Groundwater OU. Six RCRA TSD units are located in the Near Field area of the 200-PO-1 Groundwater OU: the PUREX cribs, WMA A-AX, the 216-A-29 Ditch, 216-B-3 Pond (B Pond), IDF (a RCRA-compliant landfill that is scheduled to begin receiving waste in FY 2018), and the NRDWL and the former SWL. A list of the monitoring wells that were used to evaluate exposure in the Near Field is provided in Table 5-19.

**Table 5-19. Summary of 200-PO-1 Groundwater Monitoring Wells in the Near Field Exposure Area**

| Groundwater Well Number | | | |
|---|---|---|---|
| 299-E13-11 | 299-E17-22 | 299-E25-22 | 299-E25-48 |
| 299-E13-12 | 299-E17-23 | 299-E25-236 | 299-E25-6 |
| 299-E13-14 | 299-E17-25 | 299-E25-25 | 299-E25-93 |
| 299-E13-16 | 299-E17-26 | 299-E25-26 | 299-E25-94 |
| 299-E13-17 | 299-E18-1 | 299-E25-28 | 299-E26-12 |
| 299-E13-18 | 299-E23-1 | 299-E25-29P | 299-E26-13 |
| 299-E13-19 | 299-E24-16 | 299-E25-3 | 299-E26-4 |
| 299-E13-4 | 299-E24-18 | 299-E25-31 | 699-37-43 |
| 299-E13-5 | 299-E24-20 | 299-E25-32P | 699-37-47A |
| 299-E13-6 | 299-E24-21 | 299-E25-32Q | 699-39-39 |
| 299-E13-8 | 299-E24-22 | 299-E25-34 | 699-40-33A |
| 299-E13-9 | 299-E24-23 | 299-E25-35 | 699-41-40 |
| 299-E16-2 | 299-E24-24 | 299-E25-36 | 699-41-42 |
| 299-E17-1 | 299-E24-3 | 299-E25-37 | 699-42-39A |
| 299-E17-12 | 299-E24-33 | 299-E25-39 | 699-42-39B |
| 299-E17-13 | 299-E24-5 | 299-E25-40 | 699-42-40A |
| 299-E17-14 | 299-E25-17 | 299-E25-41 | 699-42-42B |
| 299-E17-16 | 299-E25-18 | 299-E25-42 | 699-43-44 |
| 299-E17-18 | 299-E25-19 | 299-E25-43 | 699-43-45 |
| 299-E17-19 | 299-E25-2 | 299-E25-44 | 699-44-39B |
| 299-E17-21 | 299-E25-20 | 299-E25-47 | 699-45-42 |

#### 5.3.4.2 Far Field Exposure Area

The Far Field area represents the portion of the 200-PO-1 Groundwater OU that is located downgradient from the plume sources where contaminant concentrations have dispersed over time. Groundwater concentrations in this area are lower and cover a much larger area than concentrations observed in the Near Field area. Therefore, remedial alternatives that may be considered for the groundwater contaminants in the Far Field exposure area may differ from alternatives considered for the Near Field exposure area.

The Far Field area is defined as the area of the 200-PO-1 Groundwater OU extending from the SE Transect wells eastward to the Columbia River. The Far Field exposure area includes monitoring wells located near the 200 Area TEDF, B Pond, NRDWL, SWL, 400 Area wells, Southeast Transect wells, and the River Transect and corridor wells. A list of the monitoring wells that were used to evaluate exposure in the Far Field is provided in Table 5-20.

**Table 5-20. Summary of 200-PO-1 Groundwater Monitoring Wells in the Far Field Exposure Area**

| Groundwater Well Number | | | |
|---|---|---|---|
| 499-S0-7 | 699-21-6 | 699-26-34B | 699-42-12A |
| 499-S0-8 | 699-22-35 | 699-26-35A | 699-46-21B |
| 499-S1-8J | 699-2-3 | 699-26-35C | 699-50-28B |
| 699-10-54A | 699-23-34A | 699-2-6A | 699-52-19 |
| 699-12-2C | 699-23-34B | 699-2-7 | 699-8-17 |
| 699-12-4D | 699-24-33 | 699-28-40 | 699-8-25 |
| 699-13-0A | 699-24-34A | 699-29-4 | 699-9-E2 |
| 699-13-1A | 699-24-34B | 699-31-11 | 699-S12-3 |
| 699-13-1E | 699-24-34C | 699-31-31 | 699-S19-E14 |
| 699-13-2D | 699-24-35 | 699-32-22A | 699-S3-25 |
| 699-13-3A | 699-24-46 | 699-32-22B | 699-S6-E14A |
| 699-14-38 | 699-25-33A | 699-32-43 | 699-S6-E4A |
| 699-17-5 | 699-25-34A | 699-33-56 | 699-S6-E4B |
| 699-19-43 | 699-25-34B | 699-34-41B | 699-S6-E4D |
| 699-20-20 | 699-25-34D | 699-34-42 | 699-S6-E4E |
| 699-20-E12S | 699-26-15A | 699-35-9 | 699-S6-E4K |
| 699-20-E5A | 699-26-33 | 699-38-15 | 699-S6-E4L |
| | 699-26-34A | 699-41-23 | 699-S8-19 |

#### 5.3.4.3 Columbia River Exposure Area

The Columbia River area is a specific subset of the Far Field area that represents the discharge boundary for groundwater within the 200-PO-1 Groundwater OU. The Columbia River represents the actual exposure point for human and aquatic receptors. It is anticipated that groundwater concentrations will be protective of HHE prior to discharge into the Columbia River.

The Columbia River exposure area includes monitoring wells located within about 1,000 m (0.62 mi) of the Columbia River. This exposure area includes the river transect wells and monitoring wells that are within the Far Field area. It is assumed that groundwater in the Columbia River exposure area may represent groundwater that could discharge directly to the Columbia River. A list of the monitoring wells that were used to evaluate exposure in the Columbia River area is provided in Table 5-21.

**Table 5-21. Summary of 200-PO-1 Groundwater Monitoring Wells in the River Exposure Area**

| Groundwater Well Number | | | |
|---|---|---|---|
| 699-10-E12 | 699-40-1 | 699-46-4 | 699-49-13E |
| 699-20-E12O | 699-41-1A | 699-47-5 | 699-S19-E13 |
| 699-37-E4 | 699-43-3 | 699-48-7A | 699-S3-E12 |

### 5.3.5 Conceptual Exposure Model for Human Health and the Environment

This section describes the potential exposure pathways resulting from site contaminants, based on currently available site information. The CEM is formulated according to EPA guidance and information on contaminant sources, release mechanisms, routes of migration, potential exposure points, potential routes of exposure, and potential receptor groups associated with the 200-PO-1 Groundwater OU.

An exposure pathway can be described as the physical course that a COPC takes from the point of release to a receptor. The route of exposure is the means by which a COPC enters a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A source
- A mechanism of chemical release and transport
- An environmental transport medium
- An exposure point
- An exposure route
- A receptor or exposed population

In the absence of any one of these components, an exposure pathway is considered incomplete and, therefore, creates no risk or hazard. Figure 5-21 schematically presents the exposure pathway analysis in the form of a human and ecological CEM.

#### *5.3.5.1 Contaminant Sources*

The sources of contaminants found in the 200-PO-1 Groundwater OU are primarily nuclear fuel reprocessing waste streams generated within the 200 East Area by the PUREX Plant and B Plant, both of which discharged waste water and various liquid process waste streams containing radioactive and non-radioactive contaminants to the ground in the Near Field area. These waste streams included concentrated chemical and radiological liquid wastes, chemically and radiologically contaminated waste water, and sanitary system waste water.

Evaluation of the groundwater contaminant plumes associated with 200-PO-1 Groundwater OU excludes contaminant plumes that originate at source areas outside the 200 East Area and NRDWL (e.g., tritium plume associated with the 618-11 Burial Ground, plumes associated with the 618-10 Burial Ground and neighboring waste sites, and groundwater plumes originating from the Hanford 300 Area). These other plumes fall with the purview of the 300-FF-5 Groundwater OU.

The primary contamination sources, primary release mechanisms, and secondary contamination sources in the vadose zone soil are discussed only for context and completeness. These elements of the CEM are specifically excluded from the 200-PO-1 Groundwater OU and are being addressed under the individual source OU. The uncertainty presented by exclusion of continuing vadose zone source effects on future groundwater contaminant plumes will be considered and evaluated during analysis of remedial alternatives in the FS. Potential future contributions from vadose zone sources may affect the apparent efficacy of specific remedial alternatives and require consideration of additional technologies, or modify the application of particular alternatives.

#### *5.3.5.2 Release Mechanisms and Environmental Transport Medium*

The observed groundwater contamination in the 200-PO-1 Groundwater OU has resulted largely from the liquid wastes generated by the PUREX Plant and B Plant that were discharged to surface ponds (e.g., B Pond), and cribs and trenches (e.g., PUREX cribs) and then allowed to infiltrate into the soil column. In limited instances, injection wells were used for waste disposal in the vicinity of B Plant. The primary release mechanism, therefore, was in most cases, intentional release of liquid waste to the soil via an engineered structure intended to facilitate infiltration into the soil. UPRs of liquid wastes also occurred within the OU; these releases were generally associated with leaks, spills, or overfills of tanks, above ground and below ground pipelines, and other conveyance and storage facilities. The discharged volumes were sufficient in many instances to allow the liquid waste to reach the underlying groundwater. The contaminated groundwater in the aquifer within the 200-PO-1 Groundwater OU is the transport medium of interest for this risk evaluation. The contaminated groundwater migrates by advective downgradient flow in the direction as defined by hydraulic head differences within the aquifer. The groundwater flow direction in the 200-PO-1 Groundwater OU is generally to the southeast in the Near Field area and generally to the east in the Far Field.

The soil beneath the discharge facilities became a secondary source of contamination. Active discharges to the fuel reprocessing plant liquid waste facilities were discontinued almost 20 years ago. In some instances, however, there remain some mobile contaminants and sufficient soil moisture to cause continued slow release of soil contamination to the underlying groundwater either by continued drainage of residual soil moisture or by leaching of the soil by infiltrating precipitation. These residual secondary sources of contamination in the vadose zone soil are part of the overlying waste site OUs and, as discussed in Section 1.2.1, are being addressed under the decisions that will accompany the new 200 East Inner Area and the new Deep Vadose Zone OUs identified in the Tentative Agreement. The potential for future, or continued, contaminant contribution to groundwater plumes due to residual vadose zone sources introduces uncertainty in the estimated future groundwater concentration. This uncertainty must be considered when evaluating anticipated efficacy of remedial alternatives for groundwater during the FS. Residual secondary contaminant sources within the groundwater, as well as potential on-going contributions from vadose zone secondary sources may require consideration of additional source control actions as part of remedial alternatives.

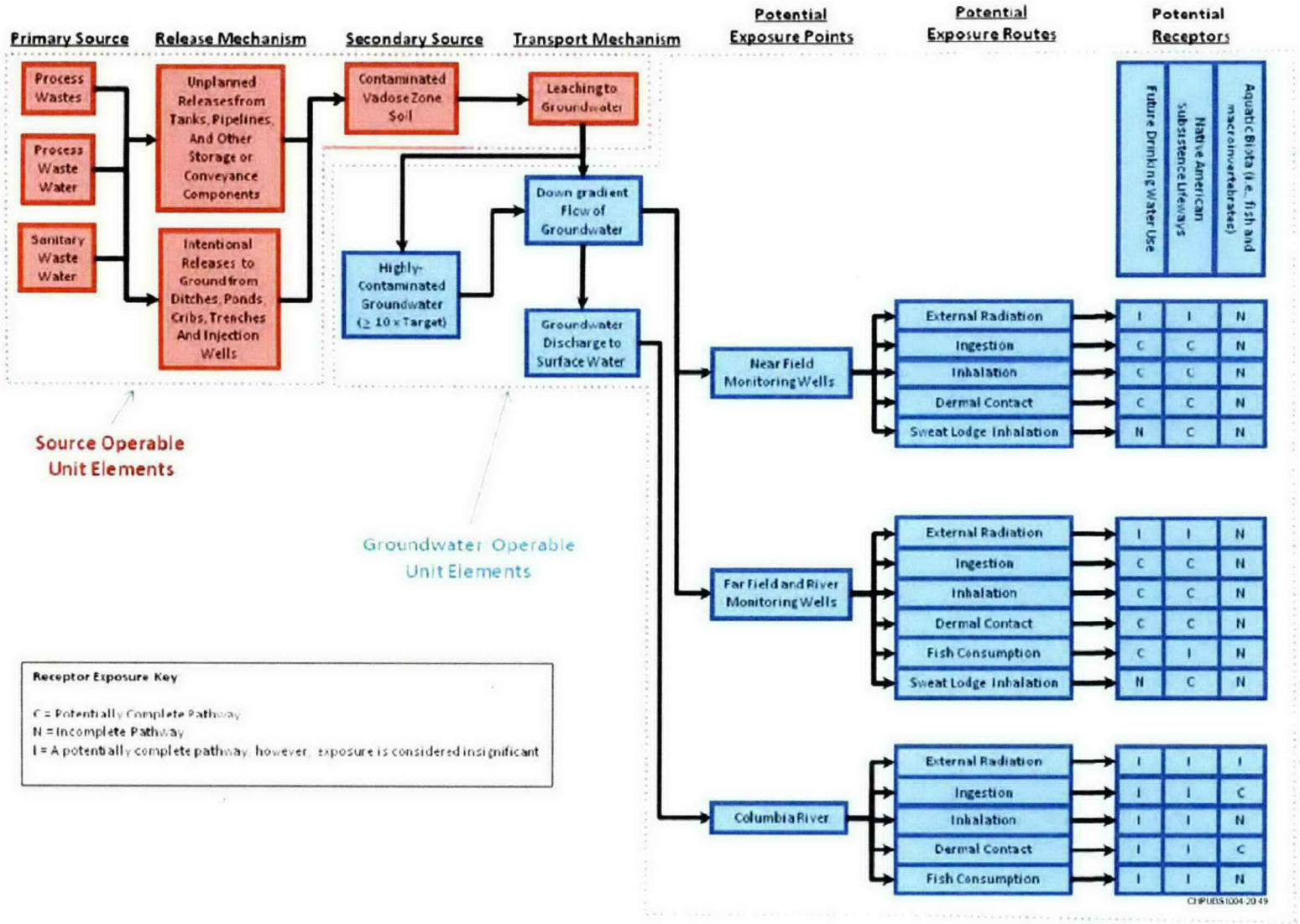



**Figure 5-21. Conceptual Exposure Model for Potential Human and Ecological Receptors in the 200-PO-1 Groundwater Operable Unit**

The SWL and NRDWL, located in the Far Field area, also received some liquid waste material that has apparently impacted groundwater. The TEDF currently receives regulated discharges of waste water from the 200 Areas; that water is allowed to infiltrate into the soil and has traveled to groundwater beneath the facility. UPRs of contaminated waste to the soil in the vicinity of the high-level waste tank farms (e.g., WMA A-AX) may also have contributed to observed groundwater contamination. All of these contamination sources, both primary and secondary sources related to residual soil contamination, are relegated to the specific source OUs for characterization and remediation.

As contaminated groundwater within the 200-PO-1 Groundwater OU flows away from sources within the Near Field portion of the OU, definable contaminant plumes have been identified and tracked in the Far Field. Groundwater within the 200-PO-1 Groundwater OU eventually discharges to the Columbia River, which forms a discharge boundary for the groundwater within the shallow unconfined aquifer in the 200-PO-1 Groundwater OU.

#### *5.3.5.3 Potentially Complete Exposure Pathways and Receptors*

There are currently no actual exposures of either human or ecological receptors to groundwater contaminants in excess of drinking water standards within the Near Field portion of the 200-PO-1 Groundwater OU. Within the Far Field portion of the 200-PO-1 Groundwater OU, a total of seven groundwater wells are designated for use as a supply of potable water. These include three wells at the Hanford 400 Area (the Fast Flux Test Facility [FFTF]), one of which is in regular use; three wells at Energy Northwest's Columbia Generating Station, one of which provides emergency backup water supply; and one well at LIGO. Groundwater that discharges to the Columbia River adjacent to the 200-PO-1 Groundwater OU is not used directly as a source of potable water; however, water from the Columbia River is used for drinking water at the Columbia Generating Station and as a supply of municipal potable water downstream at the cities of Richland, Pasco, and Kennewick, Washington. Discharge of contaminated groundwater does present a potential for exposure of aquatic receptors to OU contaminants.

For the purposes of this RI, three separate exposure areas are identified (Near Field, Far Field, and river) based on contaminant sources and groundwater plume movement to evaluate the most plausible exposure pathways that are considered for characterizing human health and ecological risks. Potential human receptors are assumed to be hypothetical future domestic groundwater users, including Native American subsistence users. Ecological receptors are limited to aquatic organisms in the Columbia River that may be exposed to contaminants in groundwater that discharges into the river.

***Near Field Exposure Area***

The Near Field exposure area represents groundwater located near known or suspected plume sources. This area was identified discretely to allow evaluation of the potentially highest contaminant concentrations in groundwater near to the original points of release. This discrete evaluation is intended to provide a basis for comparison of the Near Field conditions to those farther away (i.e., in the Far Field) and to determine whether or not Near Field conditions warrant consideration of different, or additional, remedial action alternatives. Based on this understanding, human receptors could potentially use the groundwater within this exposure area for drinking water and other domestic purposes.

Potential routes of exposure to groundwater contaminants in the Near Field include the following:

- Ingestion of contaminated water by drinking or in food preparation
- Inhalation of contaminant vapors during showering or other household activities
- Dermal contact exposure to contaminant in groundwater
- External radiation exposure from radioactive contaminants in groundwater

Although dermal contact is a potential route of exposure, the chemical-specific ARARs selected for this exposure area consider ingestion and inhalation of vapors as complete and significant pathways for exposure. The dermal contact pathway is considered a complete but insignificant pathway of exposure for the contaminants detected in groundwater at the 200-PO-1 Groundwater OU and generally does not require quantitative evaluation but is discussed qualitatively as described in WAC 173-340-720 (47)(iii)(A) and (B). External radiation exposure is also assumed to be an insignificant exposure pathway.

### *Far Field and River Exposure Areas*

The Far Field exposure area represents downgradient plume conditions. Groundwater contamination in this portion of the OU is generally present in dispersed plumes covering a large area. In addition, groundwater in these areas is expected to be ultimately discharged into the Columbia River. Groundwater contaminants in these exposure areas have the potential to discharge to the Columbia River; therefore, potential exposures to human and aquatic receptors are considered. Aquatic receptors in this instance also include benthic macro-invertebrates. The Far Field area was further subdivided to include a river exposure area. The river exposure area is identified by conditions observed in groundwater monitoring wells that are located generally with about 1,000 m (3,280 ft) of the west bank of the Columbia River adjacent to the OU. The river exposure area is assumed to exhibit conditions in groundwater representing water that may be imminently discharged to the river. Based on this understanding, human receptors could potentially use the groundwater within this exposure area for drinking water and other domestic purposes. Additionally, groundwater discharging to the Columbia River has the potential for direct uptake of site-related contaminants in surface water (assuming discharge into the Columbia River occurs) by humans and aquatic and benthic organisms.

Potential routes of exposure to groundwater contaminants in the Far Field area include:

- Ingestion of contaminated water by drinking or in food preparation
- Inhalation of contaminant vapors during showering or other household activities
- Dermal contact exposure to contaminant in groundwater
- External radiation exposure from radioactive contaminants in groundwater
- Consumption of fish from the affected portion of the Columbia River

Similar to the Near Field exposure area, the Far Field and river exposure areas do not include the dermal contact or external radiation exposure routes. Consumption of fish is addressed through the WAC 173-340-730 surface water cleanup standard. Protection of human health is addressed through a bioconcentration factor as defined in WAC 173-340-708(8) and a fish consumption rate of 54 grams per day. The surface water cleanup standard equations are provided in WAC 173-340-730(3)(iii)(A) and (B), "Surface Water Cleanup Standards," "Method B Surface Water Cleanup Levels," "Human Health Protection," "Noncarcinogens," and "Carcinogens."

The Columbia River, which forms a discharge boundary for groundwater within the 200-PO-1 Groundwater OU, represents a potentially complete exposure pathway to both human receptors and aquatic ecological receptors. Actual river water contaminant concentrations were not measured as part of this RI, however, measurement of contaminants in river water, as well as in river bottom sediments, is being conducted as part of another characterization effort under the River Corridor Contract. To evaluate the potential exposure to groundwater contaminants following discharge of groundwater to the river, the groundwater conditions observed within the OU in the near river wells (i.e., those within about 1,000 m of the river) are assumed to represent water discharged into the Columbia River. Near river groundwater concentrations are assumed to discharge directly into the Columbia River. This is a conservative assumption because it does not account for mixing and dilution that occurs prior to discharge into the

river. Those contaminant concentrations were compared to the selected ARARs. Potential routes of exposure to groundwater contaminants in the river area include:

- Ingestion of contaminated water by drinking or in food preparation
- Inhalation of contaminant vapors during showering or other household activities
- Dermal contact exposure to contaminant in groundwater
- External radiation exposure from radioactive contaminants in groundwater
- Consumption of fish from the affected portion of the river

For the Columbia River, freshwater aquatic species as a group represent the endpoint species. These include the majority of freshwater fish and invertebrate species that are anticipated to be protected in the development of surface water criteria for aquatic life protection. AWQC are generally designed to protect 95 percent of a diverse group. These water quality criteria are intended to provide a reasonable level of protection for all, except a small fraction (0.05) of, the taxa unless a commercially or recreationally important species is very sensitive. Protection of aquatic organisms and their uses is defined in PB85-227049, *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses*, as prevention of unacceptable long-term effects on: (1) commercially, recreationally, and other important species; and (2) a) fish and benthic invertebrate assemblages in rivers and streams, and b) fish, benthic invertebrate, and zooplankton assemblages in lakes, reservoirs, estuaries, and oceans. At least 44 species of fish live in the Columbia River, adjacent to the Hanford Site, and some use the river as a migration route to and from upstream spawning areas. Other species, including sculpin, spend their entire lives in small sections of the river. The shoreline areas provide rearing habitat for many fish species, which includes spawning habitat for threatened and endangered fish species.

#### 5.3.5.4 Current Exposure to Human and Aquatic Populations

Water supplies on the Hanford Site are provided by the city of Richland and by DOE-owned, contractor-operated water treatment systems, which use water from the Columbia River and wells. As discussed in Section 5.3.2, there are drinking water supply wells located at the 400 Area of the Hanford Site, at the LIGO Facility, and at Energy Northwest's Columbia Generating Station. Each of these drinking water supply wells are located within the boundaries of the 200-PO-1 Groundwater OU.

The location of wells within the 400 Area is at FFTF, a liquid sodium cooled test reactor that ceased operation in 1993. The most recent monitoring results for the 400 Area are reported in PNNL-18427. PNNL-18427 reports that the 400 Area drinking water system used groundwater from the unconfined aquifer beneath the site. Water treated in the 400 Area was pumped from three wells: Well 499-S1-8J is the primary drinking water supply well, and Wells 499-S0-8 and 499-S0-7 were designated as emergency backup sources. Treated water samples are collected from the water system and analyzed either quarterly or annually for radiological contaminants. Water samples from Wells 499-S18J, 499-S0-7, and 499-S0-8 are analyzed for gross alpha, gross beta, antimony-125, cesium-134, cesium-137, europium-152, europium-154, europium-155, iodine-129, ruthenium-106, strontium-90, technetium-99, tritium, uranium-234, uranium-235, and uranium-238. Annual average concentrations of all monitored radionuclides in Hanford Site drinking water were below state and federal MCLs during 2008.

The Washington State Department of Health (DOH) operates an environmental radiation program at the Hanford Site that monitors drinking water from the LIGO facility on an annual basis. The most recent monitoring results for LIGO are reported in DOH 320-050, *Hanford Environmental Oversight Program 2007 Data Summary Report*. The drinking water well (Well 699-S2-34B) located at the LIGO facility is completed at a depth of approximately 510 m (2,000 ft) bgs within the underlying basalt. Water samples

were analyzed in 2008 for gross alpha, gross beta, iodine-129, technetium-99, strontium-90, tritium, uranium-234, uranium-235, and uranium-238. Radionuclide concentrations in drinking water samples analyzed were below federal standards.

Energy Northwest's Columbia Generating Station uses the Columbia River as its primary drinking water source. The Columbia Generating Station had three wells (699-13-1B, 699-11-E4F (ENW-MW-31), and 699-11-E5A) that were originally installed as water supply wells. Each of the Columbia Generating Station wells are located within the boundaries of the 300-FF-5 Groundwater OU. Well 699-11-E4F and Well 699-11-E5A were drilled in 1975 to a depth of 465 ft and 372 ft, respectively, for use as water supply wells for the WPPSS number 1 plant. No screen depth or well use information is available for Wells 699-11-E4F and 699-11-E5A. Well 699-13-1B is drilled to a depth of 234 ft bgs and screened from 83 to 103 ft and again from 125 to 135 ft bgs. Well 699-13-1B is currently used for water level measurements.

As discussed in Section 5.3.3, one of the designated uses for the Columbia River is a drinking water supply. The Columbia River is a major source of drinking water supply to the cities of Richland, Pasco, and Kennewick. The drinking water monitoring project reported in PNNL-18427 reports the results of routine monitoring at the City of Richland's drinking water intake on the Columbia River. Columbia River water samples collected at the intake are analyzed for cesium-137, gross alpha, gross beta, iodine-129, plutonium-238, plutonium-239, strontium-90, technetium-99, tritium, uranium-234, uranium-235, uranium-238, and total uranium. Radionuclide concentrations in analyzed river water samples were below federal standards for protection of human health and aquatic receptors.

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# 6 Baseline Risk Assessment

A BRA was performed for the 200-PO-1 Groundwater OU to determine whether a groundwater remedial action may be required under CERCLA. The results of this risk assessment indicate that concentrations of contaminants existing at this time in the Near Field and Far Field portions of 200-PO-1 Groundwater OU exceed action levels, and remedial action should be evaluated to address groundwater contamination within the OU. The 200-PO-1 Groundwater OU BRA followed the strategy outlined below:

- Evaluate current groundwater data to identify contaminants present in groundwater in the OU. Analytical measurement data collected over the preceding five years were used to identify detected contaminants.
- Identify action levels for detected contaminants using ARARs to establish a basis for screening COPCs.
- Compare the detected contaminant concentrations to ARARs in order to identify preliminary COPCs within the entire 200-PO-1 Groundwater OU.
- Further evaluate the initial COPCs to identify and refine a final set of COPCs within each of the three exposure areas (i.e., Near Field, Far Field, and river).
- Conduct the risk characterization step on the final set of COPCs, including a determination that ARARs have been exceeded.
- The final COPCs represent contaminants that will be evaluated in the OU FS to select remedial alternatives.

EPA guidance provided in Woolford, 2009, "Summary of Key Existing EPA CERCLA Policies for Groundwater Restoration," OSWER Directive 9283.1-33, clarifies EPA's policies for determining whether a groundwater remedial action is warranted under CERCLA. In discussing the role of the BRA, the EPA memorandum quotes the preamble to the NCP:

> "The results of the baseline risk assessment are used to determine whether remediation is necessary, to help provide justification for performing remedial action, and to assist in determining what exposure pathways need to be remediated."

The memorandum then goes on to clarify when a CERCLA remedial action is appropriate:

> "A CERCLA remedial action generally is appropriate[5] in various circumstances, including: a regulatory standard that helps define protectiveness (e.g., a federal or state MCL or nonzero MCLG for current or potential drinking water aquifers) is exceeded; when the estimated risk calculated in a risk assessment exceeds a noncarcinogenic level for an adverse health effect or the upper end of the NCP risk range for "cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use,[6] the non-carcinogenic hazard index is greater than one (using reasonable maximum exposure assumptions for either the current or reasonably anticipated future land use); or the site contaminants cause adverse environmental

[5] See EPA 540-R-97-013, 1997, *Rules of Thumb for Superfund Remedy Selection*, OSWER 9355.0-69.

[6] See Clay, 1991, "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions," OSWER Directive 9355.0-03.

impacts.[7] It is important to note that all conditions do not need to be present for action and the conditions may be independent of each other."

EPA guidance provided in Clay, 1991, "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions," OSWER Directive 9355.0-30, describes how to use the BRA to make risk management decisions such as determining whether remedial action under CERCLA Section 104 or Section 106 is necessary. OSWER Directive 9355.0-30 describes the following conditions when a CERCLA action is generally warranted:

- Where the BRA indicates that a cumulative site risk to an individual using reasonable maximum exposure (RME) assumptions for either current or future land use exceeds the $10^{-4}$ excess lifetime cancer risk (ELCR) end of the risk range.
- For groundwater actions, maximum contaminant levels (MCLs) and non-zero maximum contaminant level goals (MCLGs) will generally be used to gauge whether remedial action is warranted.
- Chemical-specific standards that define acceptable risk levels also may be used to determine whether an exposure is associated with an unacceptable risk to HHE and whether remedial action under Section 104 or Section 106 is warranted.

For purposes of the 200-PO-1 OU, protectiveness of human health is evaluated by comparing groundwater concentrations to existing federal or state MCLs or nonzero MCLGs. Similarly, protectiveness of aquatic receptors is determined by the comparison of groundwater concentrations to water quality criteria established under Section 304 or Section 303 of the *Clean Water Act of 1977* as well as Washington State water quality standards. Groundwater concentrations are compared to WAC 173-340-720 and WAC 173-340-730, "Surface Water Cleanup Standards," to determine if exposure point concentrations (EPCs) exceed a hazard index (HI) greater than one or the upper end of the NCP risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use.

EPA guidance provided in Fields, 1997a, "Clarification of the Role of Applicable, or Relevant and Appropriate Requirements in Establishing Preliminary Remediation Goals under CERCLA," OSWER No. 9200.4-23, clarifies the relationship between the two key remedy selection mandates of CERCLA: (1) the requirement to protect HHE, and (2) the requirement to attain or waive, if justified, based on site-specific circumstances (i.e., ARARs). This guidance explains that it remains EPA's policy that ARARs will generally be considered protective absent multiple pathways or contaminants, where application of the ARAR would not be protective of HHE.

The CEM shows that exposure to groundwater contaminants is through direct contact/ingestion and fish consumption while other exposure pathways are considered incomplete. The risk assessment identifies multiple contaminants within the Near Field and Far Field that exceed chemical-specific ARARs. WAC 173-340-708(5)(a), "Human Health Risk Assessment Procedures," "Multiple Hazardous Substances," and WAC 173-340-708(6)(b), "Human Health Risk Assessment Procedures," "Multiple Pathways of Exposure," require that cleanup levels be adjusted downward to take into account exposure to multiple hazardous substances or multiple pathways of exposure. This adjustment needs to be made only if, without this adjustment, the HI would exceed one (1), or the total ELCR would exceed one in one hundred thousand ($1 \times 10^{-5}$). As a result, the risk assessment does not identify the need to develop cleanup levels that are more protective than ARARs.

[7] See EPA 540-R-97-013.

Additionally, several local and regional Tribes have ancestral ties to the Hanford Reach of the Columbia River and surrounding lands. The DOE has requested each Tribe to provide an exposure scenario that reflects their traditional activities. At this time, the Confederated Tribes of the Umatilla Indian Reservation (Harris and Harper, 1997, "A Native American Exposure Scenario") and the Yakama Nation (Ridolfi, 2007, *Yakama Nation Exposure Scenario for Hanford Site Risk Assessment*) have provided scenarios. A quantitative risk evaluation is included for both Tribal use scenarios which evaluates each of the potentially complete groundwater exposure pathways. The results for the Native American Risk Assessment are provided in a separate environmental calculation (ECF-200PO1-09-2115, *Native American Risk Assessment*).

## 6.1 Selection of Contaminants of Potential Concern

The first step in a BRA is a data evaluation to select the COPCs for protection of HHE. A preliminary COPC evaluation was conducted to support preparation of the 200-PO-1 OU work plan (DOE/RL-2007-31). The work plan effort evaluated groundwater analytical data collected over an 18-year period (1988 to 2006) and resulted in identifying a proposed list of 44 COPCs (DOE/RL-2007-31, Table 4-5).

For purposes of completing the BRA for the RI, the COPCs identified during the work plan phase were validated by: (1) using groundwater analytical data collected specifically for the RI (2004 to 2009), and (2) updating action levels derived from a more comprehensive set of chemical-specific ARARs than what was used in the DOE/RL-2007-31 COPC evaluation. A detailed description of the methodology used to select COPCs and the results of the process are provided in an environmental calculation (ECF-200PO1-09-2018, *Contaminant of Potential Concern Selection for the 200-PO-1 Groundwater Operable Unit*).

Identification of groundwater COPCs for the 200-PO-1 OU is a two-step process. The first step of the process identifies an initial set of COPCs that will be carried forward into the final COPC identification process that is conducted for each exposure area. The process used to select action levels for this BRA and to select groundwater contaminants that will be considered as COPCs are described in Section 6.1.2 and Section 6.1.3, respectively. The second step of the process identifies the final COPCs for each exposure area within the OU. The process used to provide further screening of the initial COPCs and selection of the final set of COPCs is described in Section 6.1.4. As described in Section 5.3.4, the 200-PO-1 Groundwater OU is divided into three exposure areas (Near Field, Far Field, and river). The process used to calculate EPCs for COPCs is described in Section 6.1.5. Finally, the risk characterization step for each exposure area is described in Section 6.2.3. The primary objective for evaluating each exposure area is to provide information necessary to justify remedial action and ultimate selection of the best remedy.

### 6.1.1 Data Used to Select Contaminants of Potential Concern

This risk assessment evaluation for the 200-PO-1 OU uses a data subset from the work plan in addition to the data collected through implementation of the RI (DOE/RL-2007-31). The last five years of data were determined to be representative of current groundwater conditions (i.e., samples collected between January 13, 2004 and March 30, 2009), and data prior to 2004 were excluded. The groundwater data set used for the initial COPC selection process consists of sampling and analytical data results collected from 177 200-PO-1 Groundwater OU monitoring wells that are screened in the unconfined, confined, and basalt aquifers. Only those monitoring wells screened in the unconfined aquifer were used when final COPCs were selected for each exposure area (Near Field, Far Field, and river). Unconfined aquifer wells are used because they are the most applicable for the depth that a groundwater supply well might be screened; in addition, the wells are screened where the groundwater contamination is present.

The analytical data set for the 200-PO-1 OU evaluation is extracted from the HEIS database. After extraction, the data are processed to obtain a single set of results per sampling location and time of collection. The data processing steps, number of records, and number of analytes associated with each step are depicted in Figure 6-1. Implementation details and results of the data processing step are presented in Section 4.0 of ECF-200PO1-09-2018.

Both filtered (dissolved) and unfiltered (total) analysis results are available in the HEIS database for some metals in the groundwater data set. However, only unfiltered results are used for selecting COPCs. Use of filtered sampling results may underestimate chemical and radiological concentrations in water from an unfiltered tap and are not used for the COPC selection process. Generally, there are more filtered metal results available than unfiltered results; however, exclusion of filtered results does not result in eliminating metals from the COPC process or underestimate EPCs.

### 6.1.2 Identification of Action Levels

Action levels are derived from readily available sources of chemical-specific ARARs. The following sources identify the chemical-specific ARARs obtained from federal regulations:

- MCLs, secondary MCLs, and non-zero MCLGs established under the *Safe Drinking Water Act of 1974*
- AWQC established under Section 304 or Section 303 of the *Clean Water Act of 1977*

The following sources identify chemical-specific ARARs obtained from Washington State regulations:

- WAC 173-340-720
- WAC 173-340-730
- WAC 246-290-310, "Group A Public Water Supplies," "Maximum Contaminant Levels (MCLs) and Maximum Residual Disinfectant Levels (MRDLs)"
- WAC 173-201A

All sources of action levels (chemical-specific ARARs) for each of the 335 analytes reported are identified in Table 5-1 of ECF-200PO1-09-2018.

The action level selected for the initial COPC selection process represents the lowest of the available chemical-specific ARARs protective of human and aquatic receptors if more than one chemical-specific ARAR exists for a certain analyte. Section 6.2.2 discusses the health basis for the above chemical-specific ARARs used both as action levels and later for characterizing health risks.

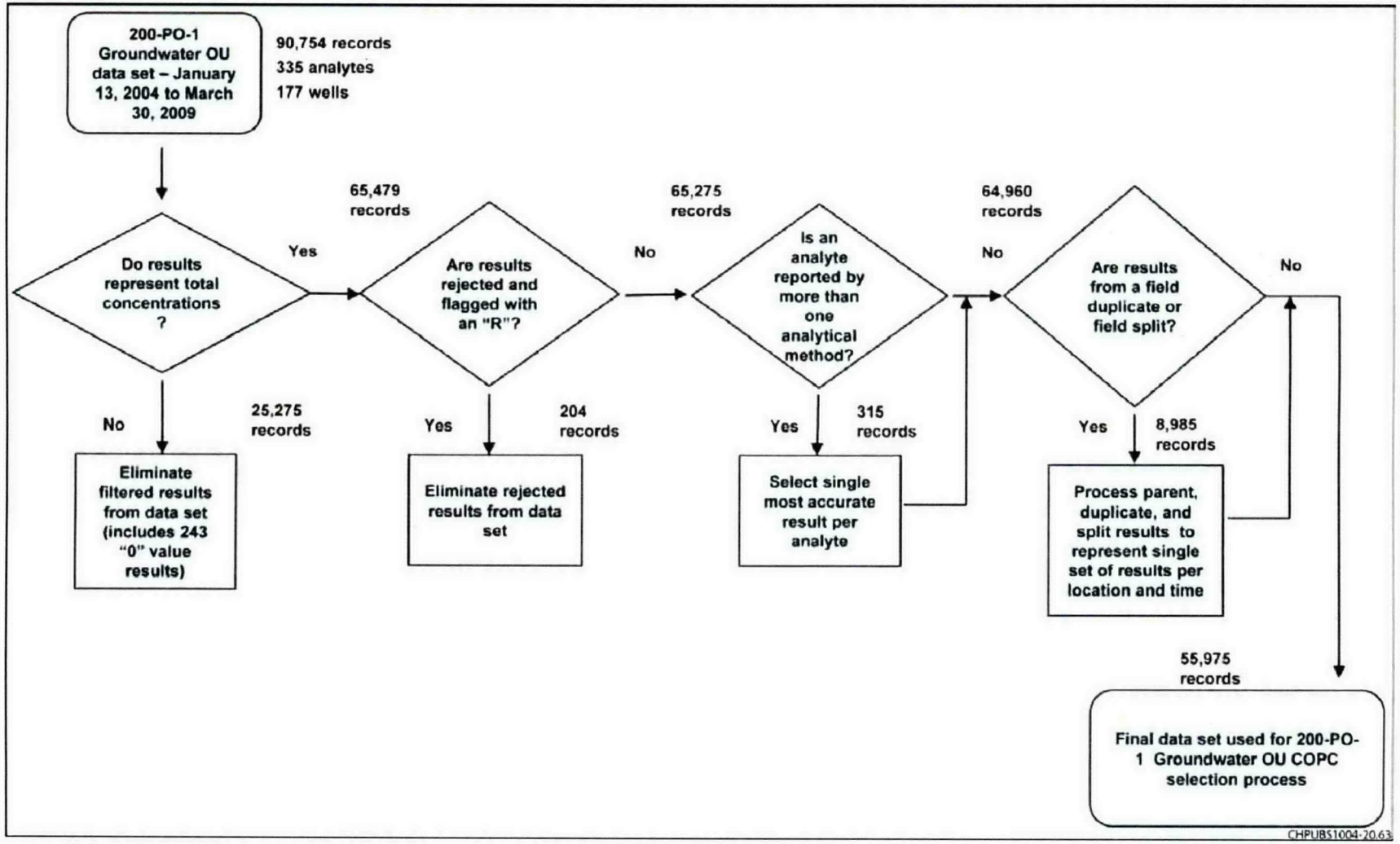



Figure 6-1. Analytical Data Processing for COPC Selection Process

The action level selected for the final COPC selection process represents the lowest of the available chemical-specific ARARs for the exposure area. The determination that a COPC poses a risk to human or ecological receptors and warrants remedial action is based on comparison with the appropriate ARAR and is not determined solely on the ARAR with the lowest value. For example, groundwater in the Far Field and river exposure areas has potential for use as a future drinking water source and as discharge to the Columbia River. Therefore, the action level selected for the final COPC selection process represents the lowest of the available chemical-specific ARARs protective of human and aquatic receptors if more than one chemical-specific ARAR exists for a certain analyte. Groundwater in the Near Field exposure area is not likely to move outside the boundaries of the OU within the 1,000-year fate and transport simulation period, thereby limiting the potential to a future drinking water source only. Therefore, the action level selected for the final COPC selection process represents the lowest of the available chemical-specific ARARs protective of human receptors if more than one chemical-specific ARAR exists for a certain analyte. A detailed description of the derivation of action levels is provided in an environmental calculation (ECF-200PO1-09-2026, *200-PO-1 Groundwater Operable Unit Remedial Investigation Report – Baseline Risk Assessment ARARs and PRG Basis*).

### 6.1.3 Process Used to Select Initial Contaminants of Potential Concern

The initial COPC selection process is used to identify those analytes carried forward into the final COPC identification process for each exposure area. This step of the process uses sampling and analysis results collected from the 177 200-PO-1 Groundwater OU monitoring wells screened in the unconfined, confined, and basalt aquifers. The purpose of grouping all sampling and analysis data is to identify analytes with detected concentrations above the lowest available action level. Comparison to the lowest of available ARARs (considered to be protective of HHE) is used to confirm that potential analytes are identified for evaluation before the data are separated into the three exposure areas discussed in Section 6.1.2. A detailed description of the screening process is provided in Section 6.0 of ECF-200PO1-09-2018. The COPC screening process steps, number of records, and number of analytes associated with each step are depicted in Figure 6-2; the steps are listed as follows:

- Apply exclusion criteria.
- Identify nondetected analytes.
- Identify analytes with maximum detected concentrations less than action levels.

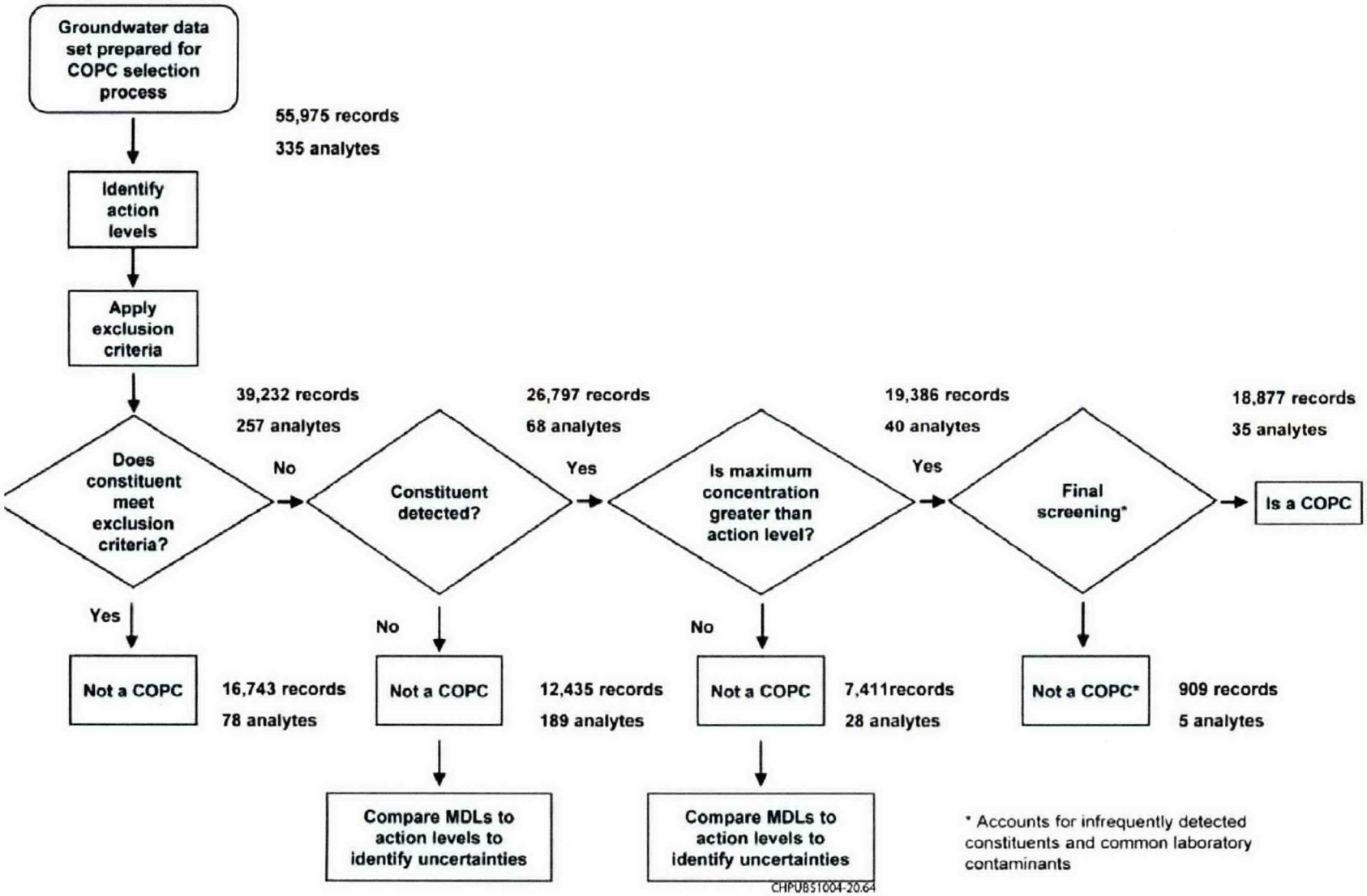



Figure 6-2. Initial COPC Identification

The results of the initial COPC selection process identified a total of 35 analytes to be carried into the final COPC process. The 35 analytes are summarized in Table 6-1.

**Table 6-1. Summary of Groundwater COPCs Selected for Final COPC Evaluation**

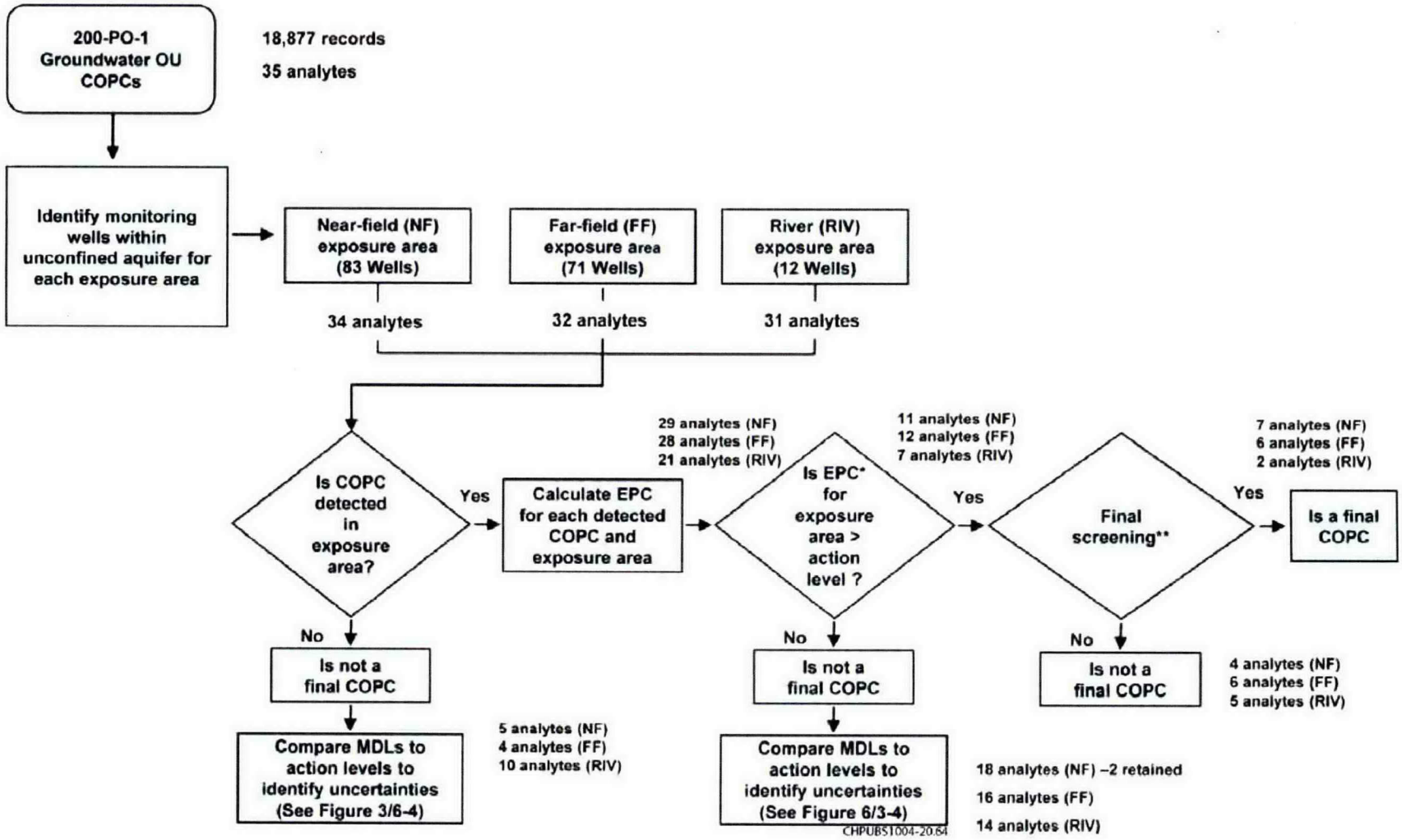
| Metals | Volatile Organic Compounds | Radionuclides |
|---|---|---|
| Aluminum | Carbon Tetrachloride | Gross Alpha |
| Antimony | Methylene Chloride | Iodine-129 |
| Arsenic | Tetrachloroethene | Strontium-90 |
| Beryllium | Trichloroethene | Technetium-99 |
| Cadmium | | Tritium |
| Chromium | **Semi-Volatile Organic Compounds** | **Anions** |
| Cobalt | | |
| Copper | | |
| Hexavalent Chromium | Tributyl phosphate | Fluoride |
| Iron | | Nitrate |
| Lead | | Nitrite |
| Manganese | | Sulfate |
| Mercury | | |
| Nickel | | |
| Selenium | | |
| Silver | | |
| Thallium | | |
| Uranium | | |
| Vanadium | | |
| Zinc | | |

Notes:

COPC = contaminant of potential concern

### 6.1.4 Process Used to Select Final Contaminants of Potential Concern

Analytes with maximum detected concentrations greater than the action level are carried forward to the final COPC selection process. The final COPC selection process identifies those analytes for evaluation in the BRA. Final COPCs are identified by comparing EPCs to their respective action levels, which is different from the process used to identify initial COPCs. As described previously, the action level represents the lowest of the available chemical-specific ARARs for the exposure area. Groundwater in the Far Field and river exposure areas has the potential as a future drinking water source and as discharge to the Columbia River. The final COPC screening process steps are depicted in Figure 6-3.




* Exposure point concentrations (EPC) will be the 90th percentile concentration.
** Accounts for secondary MCLs and anomalous detections

**Figure 6-3. Final COPC Identification**

In the process, this step groups the sampling and analytical data by exposure area and uses only monitoring wells from the 200-PO-1 OU that are screened in the unconfined aquifer. Of the 177 total wells in the initial screening, 166 wells monitor the unconfined aquifer (9 wells monitor the confined or basalt aquifers, and Well 299-E24-3 and Well 299-E25-29Q had no available data). Of the 166 monitoring wells screened in the unconfined aquifer, 83 are located in the Near Field, 71 wells are in the Far Field, and 12 are located in the river exposure area (see Table 4-1 of ECF-200PO1-09-2018). The sequential steps in the final COPC selection process are as follows:

- Identify nondetected and detected COPCs in each exposure area.
- Calculate 90$^{th}$ percentile value as the EPC for each COPC detected in an exposure area.
- Identify COPCs with EPCs less than action levels in each exposure area.
- Identify COPCs with EPCs greater than action levels in each exposure area.

An analyte specific evaluation is conducted after identifying COPCs with EPCs less than action levels and greater than action levels. These analyte specific evaluations are performed to ensure that the 90$^{th}$ percentile value is a reasonable estimate of the groundwater exposure area given the uncertainties associated with the potential for small localized plumes and continuing contributions from vadose sources. The steps of the analyte specific evaluation are depicted in Figure 6-4.

### 6.1.5 Exposure Point Concentrations

Final COPCs are identified by comparing statistical EPC estimates to action levels for each detected COPC and exposure area. EPCs are calculated as the 90$^{th}$ percentile value for each COPC from the existing groundwater data set (i.e., the last five years). The method detection limit is used as the concentration for nondetect results in the percentile calculations. The 90$^{th}$ percentile exposure is identified in EPA risk assessment guidance for describing and characterizing health risks and produces risk estimates corresponding to an RME. A description of the methodology to calculate the 90$^{th}$ percentile values and the presentation of the 90$^{th}$ percentile values are provided in an environmental calculation (ECF-200PO1-09-2027, *Calculation of Exposure Point Concentrations for the 200-PO-1 Groundwater Operable Unit*).

In general, EPA guidance in OSWER Directive 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*, recommends using an average 95 percent upper confidence limit (UCL) for estimating EPCs. However, experience at the Hanford Site indicates that averages and UCLs cannot be reliably calculated for groundwater data sets. The 200-PO-1 Groundwater OU exhibits an aquifer setting where multiple groundwater contaminants are present in overlapping plumes, and the highest concentrations have different locations within the plumes. The 90$^{th}$ percentile from a distribution of groundwater concentration data as an EPC is a different approach from OSWER 9285.6-10 guidance for estimating EPCs in risk assessments.

According to EPA/100/B-04/001, *An Examination of EPA Risk Assessment Principles and Practices*, the RME represents an exposure scenario within the realistic range of exposure, since the goal of the Superfund program is to protect against high-end, not average, exposures. The high end is defined as that part of the exposure distribution that is above the 90$^{th}$ percentile, but below the 99.9$^{th}$ percentile. The approach is consistent with EPA/600/Z-92/001, *Guidelines for Exposure Assessment*. Groundwater concentrations directly reflect potential exposures and risks, so a 90$^{th}$ percentile concentration reflects an RME scenario.

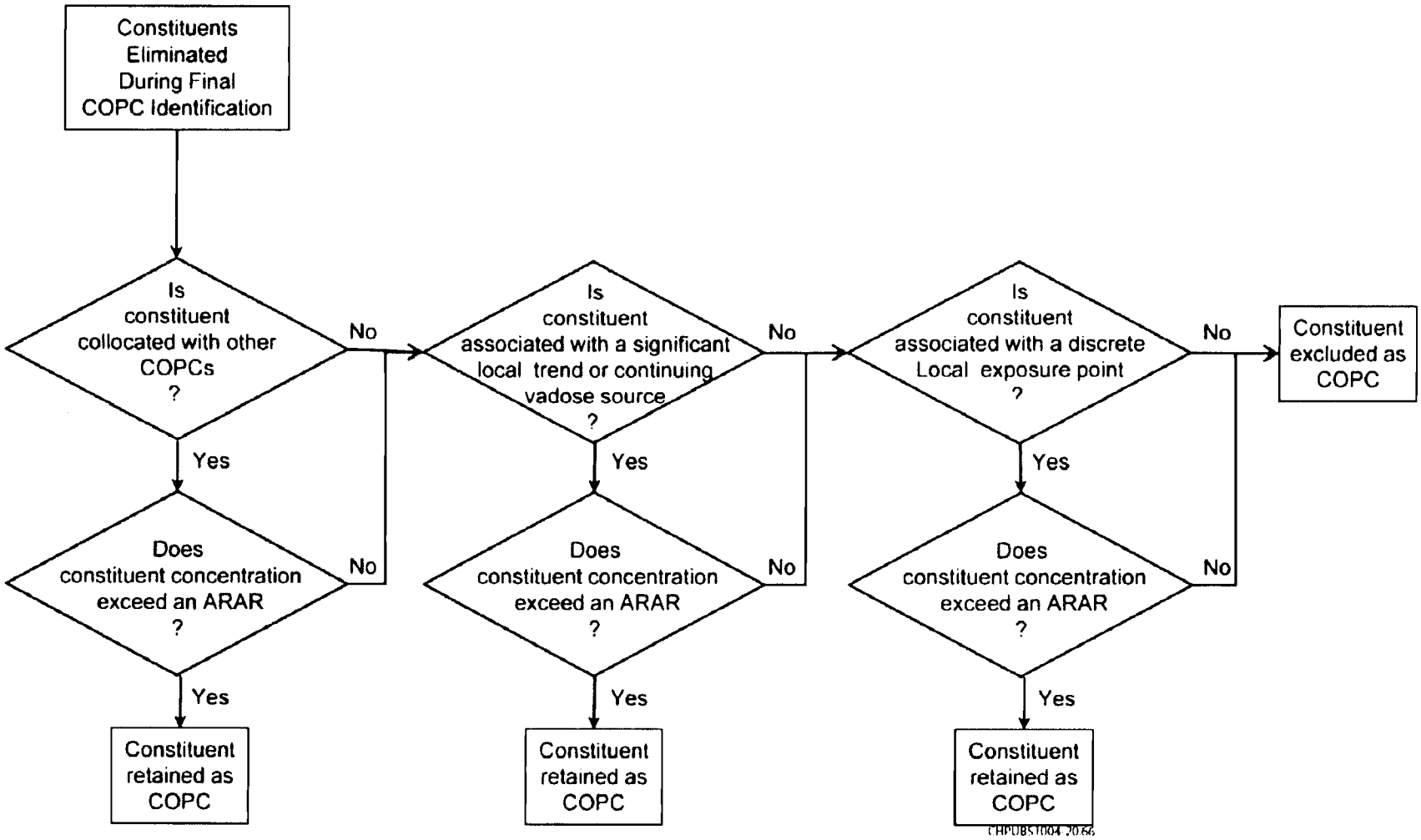



**Figure 6-4. Final COPC Verification**

## 6.2 Summary of Final Groundwater COPCs

A summary of the final COPCs identified for the 200-PO-1 groundwater OU is presented in Table 6-2. This list of final COPCs represents the analytes most likely to contribute to overall risk within each 200-PO-1 OU exposure area.

**Table 6-2. Summary of Final Groundwater COPCs Identified for the 200-PO-1 Operable Unit**

| Near Field Exposure Area | Far Field Exposure Area | River Exposure Area |
|---|---|---|
| Iodine-129 | Iodine-129 | Nitrate |
| Technetium-99 | Tritium | Tritium |
| Tritium | Nitrate | |
| Nitrate | Carbon tetrachloride | |
| Strontium-90 | Tetrachloroethene | |
| Trichloroethene | Trichloroethene | |
| Uranium | | |

Notes:

COPC = contaminant of potential concern

### 6.2.1 Exposure Assessment

The exposure assessment component typically identifies the populations that may be exposed; the routes by which these receptors may become exposed; and the magnitude, frequency, and duration of potential exposures.

The 200-PO-1 Groundwater OU is divided into three exposure areas (Near Field, Far Field, and river). The primary objectives for evaluating each exposure area are to provide information necessary to determine the need for remedial action and to use the information to select the best remedy. Section 5.3.4 provides a complete description of each exposure area including the geographic boundary, sources of contamination, and the list of wells used to evaluate exposure.

Comparison to chemical-specific ARARs assumes that exposure to groundwater occurs through use as a drinking water supply. This assumption is applicable to the current or potentially exposed future populations within the 200-PO-1 Groundwater OU. Similarly, comparison to chemical-specific ARARs assumes that groundwater concentrations measured in Far Field and near river wells are representative of concentrations discharging into the Columbia River. This assumption overstates exposure because it does not account for dispersion and mixing that occurs before and after groundwater enters the Columbia River.

All of the chemical-specific ARARs for use as a drinking water source consider ingestion as a complete and significant pathway for exposure. Washington State regulations assume that inhalation of vapors for VOCs is also a complete and significant exposure pathway. Washington State regulations do not include the dermal contact exposure route in the equations for calculation of potable groundwater cleanup levels, whereas Federal regulations consider dermal contact exposure a complete but insignificant groundwater contaminant exposure pathway. Elimination of the dermal contact exposure route from chemical-specific ARARs may result in an underestimation of the cleanup level, uncertainties associated with exclusion of this exposure route is addressed in Section 6.2.4.5. For groundwater with the potential to impact surface water, water quality standards assume that exposure to humans occurs through ingestion of water and consumption of fish tissue, and Washington State regulations assume that exposure occurs through consumption of fish tissue.

PB85-227049 describes the objectives and methodology for deriving the numerical AWQC. The AWQC are intended to provide a reasonable level of protection of all except a small fraction (0.05) of the taxa, unless a commercially or recreationally important species is very sensitive. Protection of aquatic organisms and their uses is defined in PB85-227049 as prevention of unacceptable long-term and short-term effects on: (1) commercially, recreationally, and other important species; and (2) a) fish and benthic invertebrate assemblages in rivers and streams, and b) fish, benthic invertebrate, and zooplankton assemblages in lakes, reservoirs, estuaries, and oceans.

Numeric values are expressed as two numbers: the criteria maximum concentration (CMC) and the criteria continuous concentration (CCC) which provide an appropriate degree of protection of aquatic organisms and their uses from acute and chronic toxicity to animals, toxicity to plants, and bioaccumulation by aquatic organisms. The CMC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed briefly without resulting in an unacceptable effect. EPA derives acute criteria from 48-96-hour tests of lethality or immobilization. The CCC is an estimate of the highest concentration of a material in surface water to which an aquatic community can be exposed to indefinitely without resulting in an unacceptable effect. EPA derives chronic criteria from longer-term (often greater than 28-day) tests that measure survival, growth, reproduction or, in some cases, bioconcentration. The CMC and the CCC are two of the six parts of the aquatic life criterion; the other four parts are the acute averaging period, chronic averaging period, acute frequency of allowed exceedence, and chronic frequency of allowed exceedence. The lower of the CMC or the CCC is the numeric water quality criteria used as the chemical-specific ARAR for protection of freshwater species.

### 6.2.2 Toxicity Assessment

The toxicity assessment component evaluates the relationship between the magnitude of exposure to an analyte and the likelihood of adverse health effects to potentially exposed populations. Similar to the exposure assessment, the comparison to chemical-specific ARARs takes into consideration the likelihood of an adverse health effect to occur to the potentially exposed population. The assignment of chemical-specific ARARs to COPCs is described in Section 6.1.2.

#### *6.2.2.1 State and Federal MCLs for Nonradionuclides*

The MCLG is the maximum level of a contaminant in drinking water at which no known or anticipated adverse health effects occur, allowing for an adequate margin of safety. MCLGs are non-enforceable health goals. EPA establishes the MCL based on the MCLG. The MCL is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system. Prior to the 1996 Amendments to the *Safe Drinking Water Act* (SDWA), the MCL was set as close to the MCLG as was feasible. The 1996 Amendments to the SDWA permit consideration of costs and benefits in establishing an MCL. MCLs are enforceable standards.

EPA 822-R-03-008, *Six Year Review Chemical Contaminants Health Effects Technical Support Document*, describes how MCLGs are derived. MCLGs are developed using an oral reference dose (RfD) for contaminants that exhibits a threshold toxic effect. The RfD is an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily oral exposure to the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious non-cancer effects during a lifetime. EPA generally assumes that the relative source contribution from drinking water is 20 percent of the RfD, unless other exposure data for the chemical are available. This allows 80 percent of the total exposure to come from sources other than drinking water, such as exposure from food, inhalation, or dermal contact.

EPA 822-R-03-008 also describes that EPA has used several different systems for classifying the contaminants' carcinogenicity. For drinking water contaminants regulated prior to the 1996 SDWA Amendments, the Office of Water followed a three category regulatory cancer classification system (Category I, Category II, or Category III). These categories specify decisions as to degree of concern for an agent's carcinogenic potential as a contaminant of drinking water and define, to some extent, the approach to risk management that is taken for establishing MCLGs. EPA also used the six alphanumeric categories (A, B1, B2, C, D, and E) of the cancer guidelines in EPA/630/P-03/001F, *Guidelines for Carcinogen Risk Assessment* for establishing the MCLG. The six-group classification system is often equated to the three-category system in the National Primary Drinking Water Regulations (NPDWRs) Federal Register announcements. If a chemical is a known or probable human carcinogen (Category I, generally Group A or B), the MCLG is generally set at zero because it is assumed, in the absence of other data, that there is no known threshold for carcinogenicity. If a chemical falls in Group C, an RfD approach along with an additional safety factor is used in deriving the MCLG.

EPA 815-R-03-002, *EPA Protocol for the Review of Existing National Primary Drinking Water Regulations*, was developed based on NDWAC, 2000, *Recommended Guidance for Review of Existing National Primary Drinking Water Regulations*, through consultations with stakeholders representing a wide variety of interest groups, and internal agency deliberations. The protocol outlines the approach used to review and identify NPDWRs that warrant revision to maintain, or provide for greater, public health protection. The key elements of the review process are health effects, analytical and treatment technology, other regulatory revisions (e.g., monitoring and reporting requirements), occurrence and exposure analysis and, as appropriate, economic considerations. A six-year review cycle is performed for the health effects component of the review process. The purpose of the health effects component of the review is to identify, within the limitations of EPA's available resources, new health risk assessments that indicate possible change to the MCLG and, perhaps, to the MCL. The last review was conducted in 2003 and reported in EPA 822-R-03-008.

#### 6.2.2.2 Maximum Contaminant Levels for Radionuclides in Drinking Water

Current MCLs for radionuclides are set at a 4 mrem/yr dose basis for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity concentration (including Ra-226, but excluding uranium and radon), and 5 pCi/L combined activity concentration for Ra-226 and Ra-228. A mass concentration MCL has been established for uranium as 30 µg/L. The current MCLs for beta emitters specify that MCLs are to be calculated based upon an annual dose equivalent of 4 mrem to the total body or any internal organ. It is further specified that the calculation is performed on the basis of a two liter per day drinking water intake using the 168-hour data listed in NBS Handbook 69, *Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air or Water for Occupational Exposure*.

#### 6.2.2.3 Washington State Regulations

Toxicological parameter values are obtained from the CLARC web-based compendium of technical information related to the calculation of cleanup levels under the Model Toxics Control Act (MTCA) Cleanup Regulation, WAC 173-340, available at https://fortress.wa.gov/ecy/clarc/CLARCOverview.aspx. The sources for the oral cancer potency values and RfDs are provided in the CLARC database. The sources for identifying reference doses and carcinogenic potency factors are defined in WAC 173-340-708(7), "Human Health Risk Assessment Procedures," "Reference Doses," and WAC 173-340-708(8), "Carcinogenic Potency Factor," respectively.

In general, the sources of toxicity values defined by WAC 173-340-708(7) and (8) differ from the recommended hierarchy for sources as described in Cook, 2003, "Human Health Toxicity Values in Superfund Risk Assessments," OSWER Directive 9285.7-53. As a result of this difference, toxicity values were determined using the following recommended reference hierarchy as described in Cook, 2003:

- Tier 1 – The EPA Integrated Risk Information System (IRIS)
- Tier 2 – The EPA Provision Peer Reviewed Toxicity Values (PPRTVs)
- Tier 3 – Other Toxicity Values

Tier 3 toxicity values include additional EPA and non-EPA sources of toxicity information, including: the California EPA Toxicity Criteria Database, the Agency for Toxic Substances and Disease Registry Minimal Risk Levels for Hazard Substances, and toxicity values in EPA/540/R-97/036, *Health Effects Assessment Summary Tables* (HEAST). Each of the Tier 3 toxicity values can be found at the EPA's "Regional Screening Levels for Chemical Contaminants at Superfund Sites."

When Tier 1, Tier 2, or Tier 3 toxicity values were not available for a chemical, the toxicity values from the National Center for Environmental Assessment (NCEA) were used. NCEA values can be found in the Oak Ridge National Laboratory *Risk Assessment Information System* (RAIS) database, available at: http://rais.ornl.gov/.

Toxic equivalence factors were used to calculate toxicity values for dioxins, furans, and carcinogenic polynuclear aromatic hydrocarbons as described in WAC-173-340-708(8)(d)(iii)(A).

The toxicity value published in the CLARC website was selected for final COPCs when Cook (2003) recommended a different source of information. The differences in toxicity values for final COPCs are summarized as follows:

- The oral cancer potency factor of 0.089 $(mg/kg\text{-}day)^{-1}$ published by HEAST is the value published on Ecology's CLARC website and is used to develop the WAC 173-340-720 groundwater cleanup level. HEAST has not been updated since 1997 and, therefore, does not reflect the most current source of information for the oral cancer potency factor. The source of this toxicity value is consistent with the hierarchy of toxicity values recommended in Cook, 2003. However, the oral slope factor (SFO) currently implemented by EPA for TCE in the Regional Screening Levels website is established by the California Environmental Protection Agency (CalEPA) Office of Environmental Health Hazard Assessment (OEHHA). The SFO derived by OEHHA is 0.0059 $(mg/kg\text{-}day)^{-1}$, as presented in OEHHA, 2009, *Public Health Goal for Trichloroethene In Drinking Water*. If the CalEPA values were used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would increase from 0.49 μg/L to 7.4 μg/L. While the CalEPA toxicity value may be more current, the existing value published by Ecology provides a more conservative cleanup level in groundwater.

- The RfD of 0.06 mg/kg-day for fluoride is the value published on Ecology's CLARC website and is used to develop the WAC 173-340-720 groundwater cleanup level. The RfD originally was published on IRIS, but the value provided by Ecology has not been updated since 1989, and the RfD does not reflect the most current source of information. The RfD currently implemented by EPA for fluoride is established by the CalEPA OEHHA and documented in OEHHA, 2003, *Chronic Toxicity Summary: Fluorides including Hydrogen Fluoride*. The source of this toxicity value is consistent with the hierarchy of toxicity values recommended in Cook, 2003. If the CalEPA RfD was used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would decrease from 480 µg/L to 320 µg/L.

- The RfD of 0.003 mg/kg-day that is published by IRIS is used to develop the WAC 173-340-720 groundwater cleanup level for hexavalent chromium. An oral carcinogenic potency factor has recently been published by the New Jersey Department of Environmental Protection (NJDEP). The oral carcinogenic potency factor derived by NJDEP is 0.5 $(mg/kg\text{-}day)^{-1}$ as presented in Stern, 2009, *Derivation of an Ingestion-Based Soil Remediation Criterion for $Cr^{+6}$ Based on the NTP Chronic Bioassay Data for Sodium Dichromate Dihydrate*. If the NJDEP value was used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would decrease from 48 µg/L to 0.18 µg/L.

- The RfD of 0.2 mg/kg-day that is published by the PPRTV is used to develop the WAC 173-340-720 groundwater cleanup level for 1,1-dichloroethane. An oral carcinogenic potency factor has recently been published by the CalEPA OEHHA. The oral carcinogenic potency factor derived by OEHHA is 0.0057 $(mg/kg\text{-}day)^{-1}$ as presented in OEHHA, 2003, *Public Health Goals for Chemicals in Drinking Water: 1,1 Dichloroethane in Drinking Water*. If the value published by CalEPA was used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would decrease from 1600 µg/L to 7.7 µg/L.

As discussed in Section 6.2.2, the lower of the CMC or the CCC is the numeric water quality criteria used as the chemical-specific ARAR for protection of freshwater species. EPA/505/2-90-001, *Technical Support Document For Water Quality-based Toxics Control*, explains that development of national numerical water quality criteria for the protection of aquatic organisms is a complex process that uses information from many areas of aquatic toxicology. After a decision is made that a national criterion is needed for a particular material, all available information concerning toxicity to, and bioaccumulation by, aquatic organisms is collected and reviewed for acceptability. If enough acceptable data for 48- to 96-hour toxicity tests on aquatic animals are available, they are used to derive the acute criterion. If sufficient data on the ratio of acute to chronic toxicity concentrations are available, they are used to derive the chronic or long-term exposure criteria. If justified, one or both of the criteria may be related to another water quality characteristic, such as pH, temperature, or hardness. Separate criteria are developed for freshwaters and salt waters.

### 6.2.3 Risk Characterization

Risk characterization is the summarizing step of a risk assessment. The risk characterization step is completed through the comparison of the EPC to the chemical-specific ARAR. As described earlier in this section, the comparison to chemical-specific ARARs determines whether existing groundwater concentrations are protective of HHE. It is also used to determine if current groundwater concentrations have the potential to exceed an HI greater than one or the upper end of the NCP risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use.

#### 6.2.3.1 Protectiveness Evaluation

Protectiveness of human health is determined by the comparison of 90$^{th}$ percentile groundwater concentrations to existing federal or state MCLs or nonzero MCLGs. Similarly, protectiveness of human and aquatic receptors is determined by the comparison of 90$^{th}$ percentile groundwater concentrations to water quality criteria established under Section 304 or 303 of the Clean Water Act and Washington State water quality standards.

#### 6.2.3.2 Risk Evaluation

This risk characterization step is included to address the presence of multiple exposure pathways or the potential for exposure to multiple contaminants. The presence of either one of these conditions may render ARARs not to be adequately protective. This step is also included to address the requirements of WAC 173-340-708(5)(a) and WAC 173-340-708(6)(b). These regulations require that cleanup levels be adjusted downward to take into account exposure to multiple hazardous substances or multiple pathways of exposure. This adjustment needs to me made only if, without this adjustment, the HI would exceed one (1) or the total ELCR would exceed one in one hundred thousand ($1 \times 10^{-5}$).

For the potential to exceed an HI greater than one or the upper end of the NCP risk range for cumulative carcinogenic site risk to an individual based on RME for both current and future land use, the following standards are used:

- WAC 173-340-720
- WAC 173-340-730
- National recommended water quality criteria (EPA, 2009, "Human Health for the Consumption of Water + Organism")

For the purposes of this evaluation, the potential for unacceptable human health risk is identified using the following risk thresholds:

- ELCR values are compared to the "point of departure" range of $10^{-6}$ to $10^{-4}$ that is generally used by regulatory agencies. WAC 173-340 states that cancer risks resulting from multiple hazardous substances should not exceed $1 \times 10^{-5}$ for unrestricted land use. ELCR values, within or exceeding this range, require a risk management decision that includes evaluating site-specific characteristics and exposure scenario factors to assess whether remedial action is warranted.
- An HI, i.e., the ratio of chemical intake to the RfD for all constituents, greater than 1 indicates that there is some potential for adverse non-cancer health effects associated with exposure to the COCs.

Although this risk assessment produces numerical estimates of risk, it should be recognized that these numbers might not predict actual health outcomes because they are based largely on hypothetical assumptions. Their purpose is to provide a frame of reference for risk management decision making. Interpretation of the risk estimates provided should consider the nature and weight of evidence supporting these estimates, as well as the magnitude of uncertainty surrounding them.

Protectiveness of humans from exposure to radionuclides is determined by an annual dose equivalent to the body or any internal organ, therefore a risk evaluation is not conducted for final COPCs that are radionuclides.

### *Cancer Risk Estimation Method*

The potential for cancer effects is evaluated by estimating the ELCRs. This risk is the incremental increase in the probability of developing cancer during one's lifetime in addition to the background probability of developing cancer (that is, if no exposure to site chemicals occurs). For example, a $2 \times 10^{-6}$ ELCR means that, for every 1 million people exposed to the carcinogen throughout their lifetimes, the average incidence of cancer may increase by two cases. As previously mentioned, cancer slope factors developed by the EPA represent upper bound estimates, so any cancer risks generated in this assessment should be regarded as an upper bound on the potential cancer risks rather than accurate representations of true cancer risk. The true cancer risk is likely to be less than that predicted (EPA/540/1-89/002, *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final*).

Although synergistic or antagonistic interactions might occur between cancer causing chemicals and other chemicals, information is generally lacking in the toxicological literature to predict quantitatively the effects of these potential interactions. Therefore, cancer risks are treated as additive within an exposure route in this assessment. This is consistent with the EPA guidelines on chemical mixtures (EPA/630/R-00/002, *Supplementary Guidance for Conducting Health Risk Assessment of Chemical Mixtures*). To estimate the cancer risks from exposure to an individual carcinogen from all exposure routes considered, the following equation is used:

$$Risk_I = \frac{EPC_{water}}{CUL_{carcinogen}} \times TR$$

Where:

$Risk_I$ = ELCR for individual chemical

$EPC_{water}$ = 90th percentile concentration in groundwater (µg/L)

$CUL_{carcinogen}$ = Groundwater cleanup level based on carcinogenic effect (µg/L)

TR = Target ELCR for individual hazardous substance for unrestricted land use ($10^{-6}$)

To estimate the cancer risks from exposure to multiple carcinogens from all exposure routes considered, the following equation is used:

$$Risk_T = \sum_{i}^{N} \frac{EPC_{water}}{CUL_{carcinogen}} \times TR$$

Where:

$Risk_T$ = Total ELCR for all chemicals

$EPC_{water}$ = 90th percentile concentration in groundwater (µg/L)

$CUL_{carcinogen}$ = Groundwater cleanup level based on carcinogenic effect (µg/L)

TR = Target ELCR for individual hazardous substance for unrestricted land use ($10^{-6}$)

i = The sum of the ratios for the $i^{th}$ chemical

### *Non-Cancer Risk Estimation Method*

For non-cancer effects, the likelihood that a receptor will develop an adverse effect is estimated by comparing the predicted level of exposure for a particular chemical with the highest level of exposure that is considered protective (i.e., its RfD). The ratio of the chronic daily intake divided by RfD is termed the hazard quotient (HQ).

When the HQ for a chemical exceeds 1 (i.e., exposure exceeds RfD), there is a concern for potential non-cancer health effects. To assess the potential for non-cancer effects posed by exposure to multiple chemicals, an HI approach was used according to EPA/540/1-89/002. This approach assumes that the non-cancer hazard associated with exposure to more than one chemical is additive; therefore, synergistic or antagonistic interactions between chemicals are not accounted for. The HI may exceed 1 even if all of the individual HQs are less than 1. In this case, the chemicals may be segregated by similar mechanisms of toxicity and toxicological effects. Separate HIs may then be derived based on mechanism and effect. To estimate the HQ from all exposure routes considered for an individual hazardous substance, the following equation is used:

$$HQ = \frac{EPC_{water}}{CUL_{noncarcinogen}}$$

Where:

| | | |
|---|---|---|
| HQ | = | HQ for individual chemical |
| $EPC_{water}$ | = | 90th percentile concentration in groundwater (µg/L) |
| $CUL_{noncarcinogen}$ | = | Groundwater cleanup level based on noncarcinogenic effects (µg/L) |

To estimate the HI from all exposure routes considered for multiple hazardous substances, the following equation is used:

$$HI_T = \sum_i^N \frac{EPC_{water}}{CUL_{noncarcinogen}}$$

Where:

| | | |
|---|---|---|
| $HI_T$ | = | Total HI for all chemicals |
| $EPC_{water}$ | = | 90th percentile concentration in groundwater (µg/L) |
| $CUL_{noncarcinogen}$ | = | Groundwater cleanup level based on noncarcinogenic effects (µg/L) |
| I | = | The sum of the ratios for the $i^{th}$ chemical |

### *Estimating the Sum of Fractions and 4 mrem/yr Dose Equivalent*

An annual cumulative dose equivalent of 4 millirem to the total body or any internal organ is considered protective of human health. The sum of fractions is used to determine whether the contribution of each radioisotope is greater than the cumulative annual dose equivalent of 4 millirem. The following equation is used to determine if the 4 millirem standard is exceeded when there is a mixture of radioisotopes present:

$$Sum\ of\ Fractions = \left( \frac{A\left(\frac{pCi}{L}\right)}{MCL_A\left(\frac{pCi}{L}\right)} + \frac{B\left(\frac{pCi}{L}\right)}{MCL_B\left(\frac{pCi}{L}\right)} + \ldots \right)$$

The 4 millirem standard is not exceeded if the sum of fractions is less than or equal to one. Each fraction is converted to a dose equivalent of 4 mrem/year by multiplying the fraction by 4.

#### 6.2.3.3 Results of the Chemical-Specific Applicable or Relevant and Appropriate Requirement Analysis by Exposure Area

This section identifies the final COPCs for each of the 200-PO-1 OU exposure areas (i.e., Near Field, Far Field, and river). This section determines whether the 90th percentile groundwater concentrations are considered protective and if the concentrations result in an exceedance of risk threshold standards.

A comprehensive set of chemical-specific ARARs that are considered protective of HHE were used to identify final COPCs. The lowest of the available chemical-specific ARARs applicable to the exposure area was selected for comparison if more than one chemical-specific ARAR exists for a certain analyte. With the exception of the analytes listed in Table 6-3 through Table 6-11, the 90th percentile groundwater concentrations for all COPCs were less than the lowest available chemical-specific ARAR. Additionally, the 90th percentile groundwater concentrations in the Far Field and river exposure areas did not exceed any water quality criteria established for the protection of aquatic receptors.

#### 6.2.3.4 Near Field Exposure Area

Groundwater in the Near Field exposure area is evaluated as a potential drinking water source. Table 6-3 provides a summary of the final COPCs, the 90th percentile groundwater concentration, federal and state MCLs, and the WAC 173-340-720 groundwater cleanup standards for carcinogenic and noncarcinogenic effects. Federal and state MCLs and WAC 173-340-720 groundwater cleanup levels represent the chemical-specific ARARs that were exceeded in the Near Field exposure area.

**Table 6-3. Summary of Near Field 90th Percentile Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels**

| | | | | | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|
| Near Field Final COPCs | Units | 90th Percentile Value | Federal MCL | State MCL | Non-Carcinogens | Carcinogens at $10^{-6}$ Risk Level | Carcinogens at $10^{-5}$ Risk Level |
| Iodine-129 | pCi/L | 6.4 | 1 | — | — | — | — |
| Technetium-99 | | 1,065 | 900 | — | — | — | — |
| Tritium | | 381,000 | 20,000 | — | — | — | — |
| Strontium-90 | | 6.6 | 8 | — | — | — | — |
| Trichloroethene | µg/L | 0.60 | 5 | 5 | — | 0.49 | 4.9 |
| Nitrate | µg/L | 63,500 | 45,000 | 45,000 | 25,600 | — | — |
| Uranium | | 27 | 30 | — | 48 | — | — |

Notes:

COPC = contaminant of potential concern

MCL = maximum contaminant level

**Protectiveness Evaluation.** The 90th percentile groundwater concentration for iodine-129, technetium-99, and tritium are greater than their respective federal MCL. As shown in Table 6-4, potential exposure to groundwater as a drinking water source would result in a dose greater than 4 millirem per year from each of these 3 isotopes. The 90th percentile groundwater concentrations are not considered protective of human health, thus indicating the need to take action on iodine-129, technetium-99, and tritium in the Near Field exposure area.

**Table 6-4. Summary of Near Field 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions**

| Near Field Final COPC | Units | 90th Percentile Value | Federal or State MCL | Individual Fraction |
|---|---|---|---|---|
| Iodine-129 | pCi/L | 6.4 | 1 | 6.4 |
| Technetium-99 | pCi/L | 1,065 | 900 | 1.2 |
| Tritium | pCi/L | 381,000 | 20,000 | 19.1 |
| Strontium-90 | pCi/L | 6.6 | 8 | 0.83 |
| **Sum of Fractions** | | | | **27.5** |
| **Cumulative Annual Dose (Millirem)** | | | | **110** |

Notes:
COPC = contaminant of potential concern
MCL = maximum contaminant level

Of the 83 wells in the Near Field area, 39 monitoring wells were reported with iodine-129 concentrations greater than the MCL of 1 pCi/L, only two monitoring wells are reported with technetium-99 concentrations greater than the MCL of 900 pCi/L, and 25 wells were reported with tritium concentrations greater than the MCL of 20,000 pCi/L.

The 90th percentile groundwater concentration for strontium-90 is less than the federal MCL value of 8 pCi/L. However, strontium-90 concentrations are consistently above the MCL of 8 pCi/L at Well 299-E17-14 and a single detection above the MCL is reported at well 299-E24-16. These two monitoring wells are near plume sources that originate from the PUREX cribs. A need to take action on strontium-90 for the entire Near Field area is not established based on the 90th percentile groundwater concentration; however, the remedy selected for the Near Field area should address strontium-90 at Well 299-E17-14 and Well 299-E24-16.

The 90th percentile groundwater concentration for TCE is less than the federal or state MCL value of 5 μg/L. A need to take action on TCE is not established based on the comparison of the 90th percentile groundwater concentration to the MCL.

The 90th percentile groundwater concentration for uranium is less than the federal MCL value of 30 μg/L. However, uranium concentrations at wells 299-E24-23 and 299-E25-36 are reported above the MCL of 30 μg/L. These two monitoring wells are located southeast of the plume sources that originate from the PUREX cribs. Similar to strontium-90, a need to take action on uranium for the entire Near Field area is not established based on the 90th percentile groundwater concentration; however, the remedy selected for the Near Field area should address uranium at Well 299-E24-23 and Well 299-E25-36.

The 90th percentile groundwater concentration for nitrate is greater than the federal and state MCL of 45,000 µg/L. This indicates that potential exposure to groundwater as a drinking water source may result in adverse health effects. The 90th percentile groundwater concentration is not considered protective of human health, thus indicating the need to take action on nitrate in the Near Field exposure area. Of the 83 wells in the Near Field area, 18 monitoring wells were reported with concentrations of nitrate above the MCL of 45,000 µg/L.

**Risk Evaluation**. As shown in Table 6-5, TCE is the only carcinogen identified as a final COPC in the Near Field exposure area. The ELCR associated with exposure to TCE as a drinking water source is $1.2 \times 10^{-6}$ which is slightly greater than the lower EPA threshold and the WAC 173-340 individual carcinogen threshold of $1 \times 10^{-6}$. The ELCR for TCE does not exceed the WAC 173-340-708 risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances or the upper NCP threshold of $1 \times 10^{-4}$.

**Table 6-5. Summary of Near Field 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Non-Cancer Hazard Index**

| | | | WAC 173-340-720 Cleanup Levels | | | |
|---|---|---|---|---|---|---|
| **Near Field Final COPC** | **Units** | **90th Percentile Value** | **Non Carcinogens** | **HQ/HI** | **Carcinogens at $10^{-6}$ Risk Level** | **ELCR** |
| Trichloroethene | µg/L | 0.60 | -- | -- | 0.49 | 1.2E-06 |
| Nitrate | µg/L | 63,500 | 25,600 | 2.5 | -- | -- |
| Uranium | µg/L | 27 | 48 | 0.56 | -- | -- |
| | | | **Hazard Index** | **3.0** | | |

Notes:
COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
HQ/HI = hazard quotient/ hazard index

As shown in Table 6-5, The HI for the Near Field exposure area is 3.0 which is greater than the EPA and WAC 173-340 target HI of 1. Because the toxicology effects for each of the final COPCs are different, it is appropriate to segregate the individual HQs for nitrate and uranium. The primary contributors to the non-cancer HI are nitrate (HQ = 2.5) and uranium (HQ = 0.56). The primary non-cancer health effect associated with exposure to nitrate is methemaglobenemia, and the primary non-cancer health effect associated with exposure to uranium is kidney toxicity.

### *6.2.3.5 Far Field Exposure Area*

Groundwater in the Far Field exposure area is evaluated as a potential drinking water source and also has the potential to discharge to the Columbia River. Table 6-6 provides a summary of the final COPCs, the 90th percentile value, federal and state MCLs, and the WAC 173-340-720 groundwater cleanup standards for carcinogenic and noncarcinogenic effects. With the exception of carbon tetrachloride, federal and state MCLs and WAC 173-340-720 groundwater cleanup levels represent the chemical-specific ARARs that were exceeded in the Far Field exposure area. The lowest chemical-specific ARAR for carbon tetrachloride is the water quality standard for protection of human health plus organism. As noted earlier, the 90th percentile groundwater concentrations in the Far Field exposure area did not exceed any water quality criteria established for the protection of aquatic receptors.

**Table 6-6. Summary of Far Field 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173-340-720 Groundwater Cleanup Levels**

| Far Field Exposure Area Final COPCs | Units | 90th Percentile Value | Federal MCL | State MCL | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|
| | | | | | Non-Carcinogens | Carcinogens at $10^{-6}$ Risk Level | Carcinogens at $10^{-5}$ Risk Level |
| Iodine-129 | pCi/L | 3.5 | 1 | — | — | — | — |
| Tritium | | 419,000 | 20,000 | — | — | — | — |
| Carbon tetrachloride | µg/L | 0.50 | 5 | 5 | 5.6 | 0.34 | 3.4 |
| Tetrachloroethene | | 1.5 | 5 | 5 | 80 | 0.081 | 0.81 |
| Trichloroethene | | 0.64 | 5 | 5 | — | 0.49 | 4.9 |
| Nitrate | µg/L | 46,500 | 45,000 | 45,000 | 25,600 | — | — |

Notes:
COPC = contaminant of potential concern
MCL = maximum contaminant level

**Protectiveness Evaluation.** The 90th percentile groundwater concentration for iodine-129 and tritium are greater than their respective federal MCL. As shown in Table 6-7, potential exposure to groundwater as a drinking water source would result in a dose greater than 4 millirem per year from each of these two isotopes. The 90th percentile groundwater concentrations are not considered protective of human health, thus indicating the need to take action on iodine-129 and tritium in the Far Field exposure area. Of the 71 wells in the Far Field area, nine monitoring wells were reported with iodine-129 concentrations greater than the MCL of 1 pCi/L and 25 wells were reported with tritium concentrations greater than the MCL of 20,000 pCi/L.

**Table 6-7. Summary of Far Field 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions**

| Far Field Final COPC | Units | 90th Percentile Value | Federal or State MCL | Individual Fraction |
|---|---|---|---|---|
| Iodine-129 | pCi/L | 3.5 | 1 | 3.5 |
| Tritium | pCi/L | 419,000 | 20,000 | 21 |
| **Sum of Fractions** | | | | **24.5** |
| **Cumulative Annual Dose (Millirem)** | | | | **97.8** |

Notes:
COPC = contaminant of potential concern
MCL = maximum contaminant level

The 90th percentile groundwater concentrations for iodine-129 and tritium are compared to the Tier 1 biota concentration guide (BCG) for protection of aquatic systems. The BCGs are look-up values obtained from DOE-STD-1153-2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*. The BCG values are 4E+04 pCi/L for iodine-129 and 3E+08 pCi/L for tritium, which are protective of the maximally exposed individual in a population of aquatic organisms at a level of

1 rad/day. As shown in Table 6-6, the MCL values are lower than the values that are protective of aquatic receptors. The 90th percentile groundwater concentrations of 3.9 pCi/L for iodine-129 and 419,200 pCi/L for tritium are less than the BCGs of 40,000 pCi/L and 30,000,000 pCi/L respectively, indicating action on iodine-129 and tritium would not be required for protection of aquatic organisms.

The 90th percentile groundwater concentrations for carbon tetrachloride, tetrachloroethene, and TCE are less than their respective federal and state MCL values. A need to take action on these VOCs is not established based on the comparison of the 90th percentile value to the MCL.

The 90th percentile groundwater concentration for nitrate is greater than the federal and state MCL of 45,000 µg/L. This indicates that potential exposure to groundwater as a drinking water source has the potential to result in adverse health effects. The 90th percentile groundwater concentration is not considered protective of human health, thus indicating the need to take action on nitrate in the Far Field exposure area. Of the 71 wells in the Far Field area, nine monitoring wells were reported with concentrations of nitrate above the MCL of 45,000 µg/L. Of the nine monitoring wells reported with concentrations above the MCL, four (Wells 699-12-2C, 699-13-1E, 699-13-2D, and 699-S6-E4L) are located near the 618-10 and 618-11 Burial Grounds. The 618-10 and 618-11 Burial Grounds are not part of 200-PO-1 Groundwater OU, and the need to take action associated with the presence of nitrate will be addressed in the 600 Area RI/FS.

**Risk Evaluation.** As shown in Table 6-8, the potential cumulative ELCR from all nonradiological carcinogenic COPCs is $2.1 \times 10^{-5}$, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and less than the upper NCP threshold of $1 \times 10^{-4}$. The contributors to risk include carbon tetrachloride ($1.5 \times 10^{-6}$, 7 percent contribution), tetrachloroethene ($1.9 \times 10^{-5}$, 87 percent contribution), and TCE ($1.3 \times 10^{-6}$, 6 percent contribution).

**Table 6-8. Summary of Far Field 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Non-Cancer Hazard Index**

| | | | WAC 173-340-720 Cleanup Levels | | | |
|---|---|---|---|---|---|---|
| **Far Field Final COPC** | **Units** | **90th Percentile Value** | **Non-Carcinogens** | **HQ/HI** | **Carcinogens at $10^{-6}$ Risk Level** | **ELCR** |
| Carbon Tetrachloride | µg/L | 0.50 | 5.6 | 0.09 | 0.34 | 1.5E-06 |
| Tetrachloroethene | µg/L | 1.5 | 80 | 0.02 | 0.081 | 1.9E-05 |
| Trichloroethene | µg/L | 0.64 | -- | -- | 0.49 | 1.2E-06 |
| | | | | **Total ELCR** | | **2.1E-05** |
| Nitrate | µg/L | 46,500 | 25,600 | 1.8 | -- | -- |
| | | | **Hazard Index** | **1.9** | | |

Notes:
COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
HQ/HI = hazard quotient/ hazard index

Carbon tetrachloride also exceeds the human health for the consumption of water plus organism water quality criteria value of 0.23 µg/L. The ELCR associated with this water quality criterion is $2.3 \times 10^{-6}$. The difference between the WAC 173-340-720 groundwater cleanup level and the water quality criteria is the inclusion of fish consumption. Inclusion of the fish consumption pathway may overestimate risk from exposure in the Far Field because the presence of chlorinated solvents above the $1 \times 10^{-6}$ risk level is associated with NRDWL.

Carbon tetrachloride, tetrachloroethene, and TCE are detected above the WAC 173-340-720 groundwater cleanup level in a group of 17 wells that monitor releases from the NRDWL. In addition to the 17 wells that monitor NRDWL, carbon tetrachloride is detected in Well 699-32-22B which is downgradient from NRDWL and tetrachloroethene and TCE are detected at Well 699-S6-E4L which is located downgradient from the 618-10 Burial Ground that is located in the 600 Area.

As shown in Table 6-8, the HI for the Far Field exposure area is 1.9 which is greater than the EPA and WAC 173-340 target HI of 1. Of the 71 monitoring wells in the Far Field area, 29 monitoring wells are reported with nitrate concentrations above the WAC 173-340-720 groundwater cleanup level. Of the 29 monitoring wells reported with concentrations above the groundwater cleanup level, seven (Wells 699-12-2C, 699-13-1E, 699-13-2D, 699-S6-E4D, 699-S6-E4E, 699-S6-E4K, and 699-S6-E4L) are located near the 618-10 and 618-11 Burial Grounds. The 618-10 and 618-11 Burial Grounds are not part of 200-PO-1 Groundwater OU, and the need to take action associated with the presence of nitrate will be addressed in the 600 Area RI/FS.

#### *6.2.3.6 River Exposure Area*

Groundwater in the river exposure area is evaluated as a potential drinking water source and also has the potential to discharge to the Columbia River. Table 6-9 provides a summary of the final COPCs, the 90th percentile value, federal and state MCLs, and the WAC 173-340-720 groundwater cleanup standards for carcinogenic and noncarcinogenic effects. Federal and state MCLs and WAC 173-340-720 groundwater cleanup levels represent the chemical-specific ARARs that were exceeded in the river exposure area. As noted earlier, the 90th percentile groundwater concentrations in the river exposure area did not exceed any water quality criteria established for the protection of aquatic receptors.

**Table 6-9. Summary of River Area 90th Percentile Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels**

| | | | | | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|
| **River Exposure Area Final COPCs** | **Units** | **90th Percentile Value** | **Federal MCL** | **State MCL** | **Non-Carcinogens** | **Carcinogens at $10^{-6}$ Risk Level** | **Carcinogens at $10^{-5}$ Risk Level** |
| Tritium | pCi/L | 72,200 | 20,000 | — | — | — | — |
| Nitrate | µg/L | 34,750 | 45,000 | 45,000 | 25,600 | — | — |

Notes:
COPC = contaminant of potential concern
MCL = maximum contaminant level

**Protectiveness Evaluation**. The 90th percentile groundwater concentration for tritium is greater than the federal MCL. As shown in Table 6-10, potential exposure to groundwater as a drinking water source would result in a dose greater than 4 millirem per year. The 90th percentile groundwater concentration is

not considered protective of human health, thus indicating the need to take action on tritium in the river exposure area. Of the 12 monitoring wells in the river area, six wells were reported with tritium concentrations greater than the MCL of 20,000 pCi/L.

**Table 6-10. Summary of River Area 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions**

| River Area Final COPC | Units | 90th Percentile Value | Federal or State MCL | Individual Fraction |
|---|---|---|---|---|
| Tritium | pCi/L | 72,200 | 20,000 | 3.6 |
| **Sum of Fractions** | | | | **3.6** |
| **Cumulative Annual Dose (Millirem)** | | | | **14** |

Notes:
COPC = contaminant of potential concern
MCL = maximum contaminant level

The 90th percentile groundwater concentration for tritium is also compared to the Tier 1 BCG for protection of aquatic systems. The BCGs are look-up values obtained from DOE-STD-1153-2002. The BCG value for tritium is 3E+08 pCi/L, which is protective of the maximally exposed individual in a population of aquatic organisms at a level of 1 rad/day. As shown in Table 6-9, the MCL is lower than the value that is protective of aquatic receptors. The 90th percentile groundwater concentration of 72,200 pCi/L is less than the BCG of 30,000,000 pCi/L, indicating action on tritium would not be required for protection of aquatic organisms.

The 90th percentile value for nitrate is less than the federal and state MCL of 45,000 µg/L. A need to take action on nitrate for the river exposure area is not established based on the 90th percentile groundwater concentration to the MCL.

**Risk Evaluation.** There are no carcinogenic COPCs identified for the river exposure area.

As shown in Table 6-11, the HI for the river exposure area is 1.4, which is slightly greater than the EPA and WAC 173-340 target HI of 1. Of the 12 monitoring wells in the river exposure area, 7 monitoring wells were reported with nitrate concentrations greater than the WAC 173-340-720 groundwater cleanup standard of 25,600 µg/L. This indicates that exposure to groundwater as a drinking water source does not have the potential to result in adverse health effects.

**Table 6-11. Summary of River Area 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Non-Cancer Hazard Index**

| | | | WAC 173-340-720 Cleanup Levels | | | |
|---|---|---|---|---|---|---|
| **River Area Final COPC** | **Units** | **90th Percentile Value** | **Non Carcinogens** | **HQ/HI** | **Carcinogens at $10^{-6}$ Risk Level** | **ELCR** |
| Nitrate | µg/L | 34,750 | 25,600 | 1.4 | -- | -- |
| | | | **Hazard Index** | **1.4** | | |

Notes:
COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
HQ/HI = hazard quotient/hazard index

### *6.2.3.7 Estimated Future Risk Conditions*

Future risk conditions are estimated for the Near Field and Far Field exposure areas of the 200-PO-1 Groundwater OU.[8] The purpose of estimating future risk conditions in groundwater is to estimate what changes in COPC concentrations may occur within the aquifer system over the period of time selected to indicate the practical duration of administrative control over the Hanford Site. Future groundwater concentrations are calculated to 1,000 years to identify the timeframe when each groundwater COPC meets chemical-specific ARARs. The methodology used to estimate future groundwater concentrations is described in Chapter 5 of this RI Report. The future groundwater concentrations described in Chapter 5 are used to estimate groundwater concentrations within the 1,000-year fate and transport simulation period. The methodology used to represent each exposure area spatially and chemically for the purpose of estimating future groundwater risk conditions is described below.

**Step 1 – Identify Final COPCs for Each Exposure Area.** Final COPCs for the Near Field and Far Field exposure areas are listed in Table 6-12 and Table 6-13, respectively. Future groundwater concentrations are estimated for each of the final COPCs that currently report a 90th percentile concentration greater than the MCL or when the WAC 173-340-708 cumulative risk threshold is greater than $1 \times 10^{-5}$ for multiple hazardous substances.

[8] Monitoring well locations included in the river exposure area are represented in the Far Field stream tube results.

**Table 6-12. Near Field Monitoring Wells Selected for Calculating Future Groundwater Concentrations**

| | Final COPC and Action Level | | | | | | |
|---|---|---|---|---|---|---|---|
| Well Name | Iodine-129 (1 pCi/L) | Technetium-99 (900 pCi/L) | Trichloroethene (0.49 µg/L) | Tritium (20,000 pCi/L) | Strontium-90 (8 pCi/L) | Uranium (30 µg/L) | Nitrate (25,600 µg/L) |
| 299-E17-1 | X | X | X | X | X | X | X |
| 299-E17-14 | X | X | X | X | X | X | X |
| 299-E17-22 | X | X | X | X | X | X | X |
| 299-E17-23 | X | X | X | X | X | X | X |
| 299-E17-25 | X | X | X | X | X | X | X |
| 299-E24-16 | X | X | X | X | X | X | X |
| 299-E24-20 | X | X | X | X | X | X | X |
| 299-E24-23 | X | X | X | X | X | X | X |
| 299-E24-33 | X | X | X | X | X | X | X |
| 299-E25-19 | X | X | X | X | X | X | X |
| 299-E25-20 | X | X | X | X | X | X | X |
| 299-E25-3 | X | X | X | X | X | X | X |
| 299-E25-34 | X | X | X | X | X | X | X |
| 299-E25-36 | X | X | X | X | X | X | X |
| 299-E25-93 | X | X | X | X | X | X | X |
| 299-E26-4 | X | X | X | X | X | X | X |
| 699-37-47A | X | X | X | X | X | X | X |
| 699-42-42B | X | X | X | X | X | X | X |
| 699-43-44 | X | X | X | X | X | X | X |
| 699-43-45 | X | X | X | X | X | X | X |

**Table 6-12. Near Field Monitoring Wells Selected for Calculating Future Groundwater Concentrations**

| | Final COPC and Action Level | | | | | | |
|---|---|---|---|---|---|---|---|
| **Well Name** | **Iodine-129 (1 pCi/L)** | **Technetium-99 (900 pCi/L)** | **Trichloroethene (0.49 µg/L)** | **Tritium (20,000 pCi/L)** | **Strontium-90 (8 pCi/L)** | **Uranium (30 µg/L)** | **Nitrate (25,600 µg/L)** |
| 699-45-42 | X | X | X | X | X | X | X |

Notes:

COPC = contaminant of potential concern

**Table 6-13. Far Field Monitoring Wells Selected for Calculating Future Groundwater Concentrations**

| Well Name | Iodine-129 (1 pCi/L) | Tritium (20,000 pCi/L) | Nitrate (25,600 µg/L) | Carbon Tetrachloride (0.23 µg/L) | Tetrachloroethene (0.49 µg/L) | Trichloroethene (0.49 µg/L) |
|---|---|---|---|---|---|---|
| | | | Final COPC and Action Level | | | |
| 699-20-20[a] | X | X | X | X | X | X |
| 699-20-120[a] | X | X | X | X | X | X |
| 699-20-E5[a] | X | X | X | X | X | X |
| 699-21-6[a] | X | X | X | X | X | X |
| 699-22-35 | X | X | X | X | X | X |
| 699-23-34[a] | X | X | X | X | X | X |
| 699-24-33 | X | X | X | X | X | X |
| 699-24-34C | X | X | X | X | X | X |
| 699-24-35 | X | X | X | X | X | X |
| 699-25-34A | X | X | X | X | X | X |
| 699-25-34B | X | X | X | X | X | X |
| 699-26-15[a] | X | X | X | X | X | X |
| 699-26-33 | X | X | X | X | X | X |
| 699-26-34A | X | X | X | X | X | X |
| 699-26-35[a] | X | X | X | X | X | X |
| 699-29-4[a] | X | X | X | X | X | X |
| 699-31-11[a] | X | X | X | X | X | X |
| 699-32-22A[a] | X | X | X | X | X | X |
| 699-32-43[a] | X | X | X | X | X | X |
| 699-34-42[a] | X | X | X | X | X | X |

**Table 6-13. Far Field Monitoring Wells Selected for Calculating Future Groundwater Concentrations**

| Well Name | Iodine-129 (1 pCi/L) | Tritium (20,000 pCi/L) | Nitrate (25,600 µg/L) | Carbon Tetrachloride (0.23 µg/L) | Tetrachloroethene (0.49 µg/L) | Trichloroethene (0.49 µg/L) |
|---|---|---|---|---|---|---|
| 699-35-9[a] | X | X | X | X | X | X |
| 699-37-E4[a] | X | X | X | X | X | X |
| 699-41-1A[a] | X | X | X | X | X | X |
| 699-41-23[a] | | | | | | |
| NE-2[b] | X | X | X | X | X | X |
| NE-4[b] | X | X | X | X | X | X |
| NE-6[b] | X | X | X | X | X | X |
| E-1[b] | X | X | X | X | X | X |
| E-4[b] | X | X | X | X | X | X |
| E-5[b] | X | X | X | X | X | X |
| SE-2[b] | X | X | X | X | X | X |
| SE-6[b] | X | X | X | X | X | X |

Notes:

a. Indicates well location was included in stream tube analysis.

b. Indicates stream tube location is not currently associated with an existing well.

COPC = contaminant of potential concern

**Step 2 – Identify Monitoring Well Locations within Each Exposure Area.** Monitoring well locations reported with concentrations of final COPCs greater than the action levels are identified. A list of the monitoring wells from each exposure area that report concentrations of final COPCs greater than their respective action levels is shown in Table 7-9, Table 7-10, and Table 7-11 of ECF-200PO1-09-2018. Of the 83 wells in the Near Field area, 66 wells were reported with concentrations of one or more final COPCs above the action level. A subset of 21 wells was selected to provide spatial and chemical representation of contamination within the Near Field exposure area; these wells are listed in Table 6-12.

Of the 83 wells in the Far Field and river areas, 69 wells were reported with concentrations of one or more final COPCs above the action level. A subset of 24 wells was selected to provide spatial and chemical representation of contamination within the Far Field and river exposure areas; these wells are listed in Table 6-13. The Far Field exposure area (also represents river area) is subdivided into three pipe pathways (northeast direction, east-northeast direction, and east-southeast direction) for calculation purposes and, within each of these pipe pathways, 6 spatially unique locations are identified for a total of 18 Far Field locations. This includes data from 8 stream tube locations without a currently existing corresponding well were included in the Far Field data set. In addition to the calculated stream tube data, calculated maximum concentrations for each time step were calculated for all Far Field and stream tube locations and were included in the final data set. These spatially unique locations are shown in Figure 4-2 of ECF-200PO1-09-2007.

**Step 3 – Calculate Future Groundwater Concentrations**. Future groundwater concentrations are calculated for each of the final COPCs at each of the monitoring well locations listed on Table 6-12 and Table 6-13. To determine the approximate timeframe for when cleanup levels are attained, future groundwater concentrations are selected at 25-year intervals up to a total of 200 years and at 100-year interval thereafter for each location and each final COPC.

**Step 4 – Calculate 90$^{th}$ Percentile Groundwater Concentrations**. A 90$^{th}$ percentile groundwater concentration is calculated for each final COPC within an exposure area at each 25-year and 100-year time interval. The methodology, inputs, and equations used to calculate the future 90$^{th}$ percentile groundwater concentrations are documented in ECF-200PO1-09-2390, *Exposure Point Concentrations Based on Predicted Future Concentrations of Final COPCs of the 200-PO-1 Groundwater Operable Unit*. The 90$^{th}$ percentile groundwater concentrations are then compared to the federal and state MCLs and the WAC 173-340-720 groundwater cleanup levels. The year when the 90$^{th}$ percentile value has achieved the MCL or the WAC 173-340-720 groundwater cleanup levels is identified.

Table 6-14 and Table 6-15 provide a summary of the 90$^{th}$ percentile groundwater concentrations and maximum project concentration for each of the 25-year time intervals up to 200 years and every 100 years up to the 1,000 year fate and transport simulation period. These tables also list the federal and state MCLs, and the WAC 173-340-720 groundwater cleanup standards for carcinogenic and non-carcinogenic effects which represent the chemical-specific ARARs that were exceeded in each of the exposure areas.

#### *6.2.3.8 Near Field Exposure Area*

With the exception of iodine-129, the 90$^{th}$ percentile groundwater concentrations for each of the final COPCs attenuate to concentrations below their target action level within 25 years (Year 2034). The 90$^{th}$ percentile concentration for iodine-129 attenuates below the MCL within 175 years (2184).

Maximum projected concentrations attenuate to concentrations below their target action level within 25 years for strontium-99 and technetium-99 (Year 2034), within 50 years for tritium and TCE (Year 2059), within 300 years for uranium (Year 2209), within 500 years for nitrate (Year 2509), and within 700 years for iodine-129.

**Table 6-14. Summary of Near Field 90th Percentile and Maximum Projected Future Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels**

| | | | | | | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|---|
| Near Field Final COPC | Units | Maximum Projected Concentration | 90th Percentile Value | Year | Federal or State MCL | Non-Carcinogens | Carcinogens at $10^{-6}$ Risk Level | Carcinogens at $10^{-5}$ Risk Level |
| Iodine-129 | pCi/L | 10 | 6.4 | 2009 | 1 | — | — | — |
| | | 4.3 | 2.5 | 2034 | | | | |
| | | 3.7 | 2.3 | 2059 | | | | |
| | | 3.2 | 2 | 2084 | | | | |
| | | 2.8 | 1.7 | 2109 | | | | |
| | | 2.7 | 1.4 | 2134 | | | | |
| | | 2.6 | 1.1 | 2159 | | | | |
| | | 2.5 | 0.92 | 2184 | | | | |
| | | 2.3 | 0.74 | 2209 | | | | |
| | | 1.9 | 0.40 | 2309 | | | | |
| | | 2.7 | 0.35 | 2409 | | | | |
| | | 2.8 | 0.27 | 2509 | | | | |
| | | 1.7 | 0.25 | 2609 | | | | |
| | | 1.0 | 0.24 | 2709 | | | | |
| | | 1.1 | 0.23 | 2809 | | | | |
| | | 1.2 | 0.22 | 2909 | | | | |
| | | 1.4 | 0.20 | 3009 | | | | |
| Technetium-99 | pCi/L | 13,000 | 1,065 | 2009 | 900 | — | — | — |
| | | 96 | 74 | 2034 | | | | |
| | | 44 | 4.5 | 2059 | | | | |
| | | 24 | 3.1 | 2084 | | | | |
| | | 18 | 2.2 | 2109 | | | | |
| | | 14 | 2.2 | 2134 | | | | |
| Tritium | pCi/L | 650,000 | 381,000 | 2009 | 20,000 | — | — | — |
| | | 108,490 | 10,431 | 2034 | | | | |
| | | 19,165 | 2,350 | 2059 | | | | |
| | | 2,950 | 412 | 2084 | | | | |
| | | 424 | 69 | 2109 | | | | |
| | | 68 | 12 | 2134 | | | | |
| Strontium-90 | pCi/L | 21 | 6.6 | 2009 | 8 | — | — | — |
| | | 5.2 | 0.9 | 2034 | | | | |
| | | 2.8 | 0.037 | 2059 | | | | |
| | | 1.5 | 0.014 | 2084 | | | | |
| | | 0.81 | 0.0056 | 2109 | | | | |

**Table 6-14. Summary of Near Field 90th Percentile and Maximum Projected Future Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels**

| Near Field Final COPC | Units | Maximum Projected Concentration | 90th Percentile Value | Year | Federal or State MCL | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Non-Carcinogens | Carcinogens at $10^{-6}$ Risk Level | Carcinogens at $10^{-5}$ Risk Level |
| | | 0.44 | 0.0025 | 2134 | | | | |
| Trichloroethene | µg/L | 3.1 | 0.60 | 2009 | 5 | — | 0.49 | 4.9 |
| | | 0.81 | 0.0096 | 2034 | | | | |
| | | 0.36 | 0.013 | 2059 | | | | |
| | | 0.24 | 0.015 | 2084 | | | | |
| | | 0.17 | 0.018 | 2109 | | | | |
| | | 0.11 | 0.022 | 2134 | | | | |
| Nitrate | µg/L | 154,000 | 63,500 | 2009 | 45,000 | 26,500 | — | — |
| | | 70,017 | 9,297 | 2034 | | | | |
| | | 64,706 | 8,239 | 2059 | | | | |
| | | 61,535 | 7,288 | 2084 | | | | |
| | | 58,574 | 5,844 | 2109 | | | | |
| | | 55,816 | 4,545 | 2134 | | | | |
| | | 53,140 | 3,728 | 2159 | | | | |
| | | 50,541 | 3,531 | 2184 | | | | |
| | | 48,006 | 3,835 | 2209 | | | | |
| | | 38,535 | 3,800 | 2309 | | | | |
| | | 30,104 | 3,563 | 2409 | | | | |
| | | 22,951 | 3,056 | 2509 | | | | |
| | | 23,490 | 2,427 | 2609 | | | | |
| | | Not Projected | Not Projected | 2709 | | | | |
| | | Not Projected | Not Projected | 2809 | | | | |
| | | Not Projected | Not Projected | 2909 | | | | |
| | | Not Projected | Not Projected | 3009 | | | | |

**Table 6-14. Summary of Near Field 90th Percentile and Maximum Projected Future Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels**

| | | | | | | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|---|
| **Near Field Final COPC** | **Units** | **Maximum Projected Concentration** | **90th Percentile Value** | **Year** | **Federal or State MCL** | **Non-Carcinogens** | **Carcinogens at $10^{-6}$ Risk Level** | **Carcinogens at $10^{-5}$ Risk Level** |
| Uranium | µg/L | 93 | 27 | 2009 | 30 | 48 | — | — |
| | | 71 | **9.6** | **2034** | | | | |
| | | 60 | 3.5 | 2059 | | | | |
| | | 49 | 1.8 | 2084 | | | | |
| | | 40 | 1.4 | 2109 | | | | |
| | | 37 | 1.4 | 2134 | | | | |
| | | 35 | 1.4 | 2159 | | | | |
| | | 33 | 1.5 | 2184 | | | | |
| | | **30** | 1.5 | **2209** | | | | |
| | | 21 | 1.3 | 2309 | | | | |
| | | 15 | 1.0 | 2409 | | | | |
| | | 11 | 0.8 | 2509 | | | | |
| | | 8 | 0.8 | 2609 | | | | |
| | | 7 | 0.8 | 2709 | | | | |
| | | Not Projected | Not Projected | 2809 | | | | |
| | | Not Projected | Not Projected | 2909 | | | | |
| | | Not Projected | Not Projected | 3009 | | | | |

Notes:

Highlighted cells indicate the 90th percentile and maximum projected groundwater concentrations and the year(s) at which the target action level is achieved.

COPC = contaminant of potential concern

MCL = maximum contaminant level

**Table 6-15. Summary of Far Field 90th Percentile and Maximum Projected Future Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels**

| Far Field Final COPC | Units | Maximum Projected Concentration | 90th Percentile Value | Year | Federal or State MCL | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Non Carcinogens | Carcinogens at $10^{-6}$ Risk Level | Carcinogens at $10^{-5}$ Risk Level |
| Iodine-129 | pCi/L | 7.9 | 3.5 | 2009 | 1 | — | — | — |
| | | 4.3 | 2.4 | 2034 | | | | |
| | | 3.7 | 2.8 | 2059 | | | | |
| | | 3.2 | 2.7 | 2084 | | | | |
| | | 2.8 | 2.5 | 2109 | | | | |
| | | 2.7 | 1.9 | 2134 | | | | |
| | | 2.6 | 1.4 | 2159 | | | | |
| | | 2.5 | 1.4 | 2184 | | | | |
| | | 2.3 | 1.4 | 2209 | | | | |
| | | 1.9 | 1.1 | 2309 | | | | |
| | | 2.7 | 0.84 | 2409 | | | | |
| | | 2.8 | 0.71 | 2509 | | | | |
| | | 1.7 | 0.56 | 2609 | | | | |
| | | 1.0 | 0.43 | 2709 | | | | |
| | | 1.1 | 0.33 | 2809 | | | | |
| | | 1.2 | 0.26 | 2909 | | | | |
| | | 1.4 | 0.20 | 3009 | | | | |
| Tritium | pCi/L | 2,320,000 | 419,000 | 2009 | 20,000 | — | — | — |
| | | 108,490 | 52,239 | 2034 | | | | |
| | | 20,904 | 12,890 | 2059 | | | | |
| | | 7,864 | 1,903 | 2084 | | | | |
| | | 1,766 | 257 | 2109 | | | | |
| | | 270 | 37 | 2134 | | | | |
| Carbon Tetrachloride | µg/L | 2.0 | 0.5 | 2009 | 5 | 5.6 | 0.34 | 3.4 |
| | | 0.28 | 0.063 | 2034 | | | | |
| | | 0.22 | 0.036 | 2059 | | | | |
| | | 0.26 | 0.034 | 2084 | | | | |
| | | 0.40 | 0.049 | 2109 | | | | |
| | | 0.49 | 0.065 | 2134 | | | | |

**Table 6-15. Summary of Far Field 90th Percentile and Maximum Projected Future Groundwater Concentrations, Federal and State Maximum Contaminant Levels, and WAC 173-340-720 Groundwater Cleanup Levels**

| Far Field Final COPC | Units | Maximum Projected Concentration | 90th Percentile Value | Year | Federal or State MCL | WAC 173-340-720 Cleanup Levels | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | Non Carcinogens | Carcinogens at $10^{-6}$ Risk Level | Carcinogens at $10^{-5}$ Risk Level |
| Tetrachloroethene | µg/L | 4.5 | 1.5 | 2009 | 5 | 80 | 0.081 | 0.81 |
| | | 0.59 | 0.14 | 2034 | | | | |
| | | 0.33 | **0.066** | **2059** | | | | |
| | | 0.23 | 0.045 | 2084 | | | | |
| | | 0.18 | 0.049 | 2109 | | | | |
| | | 0.14 | 0.054 | 2134 | | | | |
| Trichloroethene | µg/L | 1.6 | 6.4 | 2009 | 5 | — | 0.49 | 4.9 |
| | | 0.81 | **0.14** | **2034** | | | | |
| | | 0.36 | 0.067 | 2059 | | | | |
| | | 0.24 | 0.05 | 2084 | | | | |
| | | 0.17 | 0.037 | 2109 | | | | |
| | | 0.11 | 0.029 | 2134 | | | | |
| Nitrate | µg/L | 113,000 | 46,500 | 2009 | 45,000 | 26,500 | — | — |
| | | 70,017 | 35,502 | 2034 | | | | |
| | | 64,706 | 34,354 | 2059 | | | | |
| | | 61,535 | 29,161 | 2084 | | | | |
| | | 58,574 | **20,986** | **2109** | | | | |
| | | 55,816 | 13,694 | 2134 | | | | |
| | | 53,140 | 8,529 | 2159 | | | | |
| | | 50,541 | 5,624 | 2184 | | | | |
| | | 48,006 | 4,372 | 2209 | | | | |
| | | 38,535 | 2,258 | 2309 | | | | |
| | | 30,104 | 2,167 | 2409 | | | | |
| | | **22,951** | 1,882 | **2509** | | | | |
| | | 23,490 | 1,330 | 2609 | | | | |
| | | Not Projected | Not Projected | 2709 | | | | |
| | | Not Projected | Not Projected | 2809 | | | | |
| | | Not Projected | Not Projected | 2909 | | | | |
| | | Not Projected | Not Projected | 3009 | | | | |

Notes:

Highlighted cells indicate the 90th percentile and maximum projected groundwater concentration and the year(s) at which the target action level is achieved.

COPC = contaminant of potential concern

MCL = maximum contaminant level

#### 6.2.3.9 Far Field Exposure Area

The 90th percentile concentrations for carbon tetrachloride and TCE attenuate to concentrations below their target action level within 25 years (Year 2034), tritium and tetrachloroethene attenuate to concentrations below their target action level within 50 years (Year 2059), nitrate attenuates to concentrations below the target action level within 100 years, iodine-129 attenuates to concentrations below the target action level within 400 years (Year 2409).

Maximum projected concentrations attenuate to concentrations below their target action level within 75 years for tritium, within 500 years for nitrate (Year 2509), and 700 years for iodine-129. Due to the limitations of the fate and transport model, projected groundwater concentrations are constrained by one-half the MCL for carbon tetrachloride, tetrachloroethene, and TCE. As a result of this constraint, concentrations less than one-half the MCL are not considered reliable and concentrations near the groundwater cleanup levels cannot be attained. Therefore, maximum projected concentrations are compared to the MCL for the purposes of this evaluation. Groundwater concentrations are currently below the MCL values for carbon tetrachloride, tetrachloroethene, and TCE.

**Step 5 – Calculate Total Risk and Total Dose**. The total risk and total dose is calculated to determine if this timeframe is adequate for achieving groundwater cleanup levels. An annual cumulative dose equivalent of less than 4 millirem to the total body or any internal organ is considered protective of human health. WAC 173-340 states that cancer risks resulting from multiple hazardous substances should not exceed $1 \times 10^{-5}$ and should not exceed an HI of 1 for non-cancer health effects.

Table 6-16 and Table 6-18 summarize the maximum projected concentrations for each of the final radiological COPCs in the Near Field and Far Field areas.

Table 6-17 and Table 6-19 summarize the maximum projected groundwater concentrations for each of the final nonradiological COPCs in the Near Field and Far Field areas. The total risk and non-cancer HI are evaluated using the equations shown in Section 6.2.3.2.

#### 6.2.3.10 Near Field Exposure Area

As shown in Table 6-16, the concentrations of technetium-99, tritium, and strontium-90 are well below their respective MCLs within 125 years of the fate and transport simulation period. The sum of fractions associated with these three COPCs is 0.31 resulting in 1.27 mrem/yr annual dose. However, the concentration of iodine-129 does not reach the MCL of 1 pCi/L until 700 years into the fate and transport simulation period. The concentration of iodine-129 at Year 2709 is equal to the 4 millirem standard. As shown in Table 6-17, TCE was not carried forward into this analysis because current concentrations did not exceed the risk threshold for multiple hazardous substances.

The HI for the Near Field area is 1.5 which is greater than the EPA and WAC 173-340 target HI of 1. The contributors to the non-cancer HI are nitrate (HQ = 0.87) and uranium (HQ = 0.63). The primary non-cancer health effect associated with exposure to nitrate is methemaglobenemia, and the primary non-cancer health effect associated with exposure to uranium is kidney toxicity. Because the health effects do not affect the same target organ, it is appropriate to segregate the hazard quotients indicating that adverse health effects are not likely.

**Table 6-16. Summary of Near Field Maximum Projected Future Groundwater Concentrations and Associated Sum of Fractions**

| Near Field Final COPC | Units | Maximum Projected Concentration | Year | Federal or State MCL | Individual Fraction |
|---|---|---|---|---|---|
| Iodine-129 | pCi/L | 1.0 | 2709 | 1 | 1.0 |
| Technetium-99 | pCi/L | 14 | 2134 | 900 | 0.015 |
| Tritium | pCi/L | 68 | 2134 | 20,000 | 0.0034 |
| Strontium-90 | pCi/L | 2.8 | 2059 | 8 | 0.35 |
| | | | | **Sum of Fractions** | **1.37** |
| | | | | **Cumulative Annual Dose (Millirem)** | **5.47** |

Notes:
COPC = contaminant of potential concern
MCL = maximum contaminant level

**Table 6-17. Summary of Near Field Maximum Projected Future Groundwater Concentrations and Associated Cancer Risk and Non-Cancer Hazard Index**

| | | | | | WAC 173-340-720 Cleanup Levels | | | |
|---|---|---|---|---|---|---|---|---|
| Near Field Final COPC | Units | Maximum Projected Concentration | Year | Federal or State MCL | Non Carcinogens | HQ/ HI | Carcinogens at $10^{-6}$ Risk Level | ELCR |
| Nitrate | µg/L | 22,951 | 2134 | 45,000 | 26,500 | 0.87 | — | — |
| Trichloroethene | µg/L | 0.025 | 2134 | 5 | | | 0.49 | 5.1E-08 |
| Uranium | µg/L | 30 | 2209 | 30 | 48 | 0.63 | — | — |
| | | | | | **Hazard Index** | **1.5** | | |

Notes:
COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
HQ/HI = hazard quotient/hazard index
MCL = maximum contaminant level

**Table 6-18. Summary of Far Field Maximum Projected Future Groundwater Concentrations Associated Sum of Fractions**

| Far Field Final COPC | Units | Maximum Projected Concentration | Year | Federal or State MCL | Individual Fraction |
|---|---|---|---|---|---|
| Iodine-129 | pCi/L | 1.0 | 2709 | 1 | 1.0 |
| Tritium | pCi/L | 7,864 | 2084 | 20,000 | 0.39 |
| | | | | **Sum of Fractions** | **1.3** |
| | | | | **Cumulative Annual Dose (Millirem)** | **5.6** |

Notes:
COPC = contaminant of potential concern
MCL = maximum contaminant level

**Table 6-19. Summary of Far Field 90th Percentile Future Groundwater Concentrations Associated Cancer Risk and Non-Cancer Hazard Index**

| Far Field Final COPC | Units | Maximum Projected Concentration | Year | Federal or State MCL | WAC 173-340-720 Cleanup Levels | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Non Carcinogens | HQ | Carcinogens at $10^{-6}$ Risk Level | ELCR |
| Carbon Tetrachloride | µg/L | Not Projected | 2134 | 5 | 5.6 | | | |
| Tetrachloroethene | µg/L | Not Projected | 2134 | 5 | 80 | <0.01 | 0.081 | 6.7E-06 |
| Trichloroethene | µg/L | Not Projected | 2134 | 5 | — | — | 0.49 | 5.9E-08 |
| | | | | | **Total Risk** | | **6.7E-06** | |
| Nitrate | µg/L | 22,951 | 2509 | 45,000 | 26,500 | 0.87 | — | — |
| | | | | | **Total HI** | | **0.87** | |

Notes:
COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
HQ/HI = hazard quotient/hazard index
MCL = maximum contaminant level

#### *6.2.3.11 Far Field Exposure Area*

As shown in Table 6-18, the concentrations of tritium is well below MCLs within 75 years of the fate and transport simulation period. The sum of fractions associated with tritium is 0.39 resulting in 1.56 mrem/yr annual dose. However, the concentration of iodine-129 does not reach the MCL of 1 pCi/L until 700 years into the fate and transport simulation period. The concentration of iodine-129 at Year 2709 is equal to the 4 millirem standard.

As shown in Table 6-19, the total risk from all carcinogenic COPCs could not be calculated due to the constraints of the fate and transport model. The HI for the Far Field area is 0.87 which is less than the EPA and WAC 173-340 target HI of 1.

### 6.2.4 Uncertainties in Risk Assessment

The purpose of this risk assessment is to determine whether a groundwater remedial action is warranted under CERCLA. Estimating and evaluating health risk from exposure to environmental contaminants is a complex process with inherent uncertainties. Uncertainty reflects limitations in knowledge, and simplifying assumptions must be made to quantify health risks.

In this assessment, uncertainties are related to the COPC selection and the developing media concentrations to which receptors may be exposed, the assumptions about exposure and toxicity, and the characterization of health risks. There are uncertainties regarding quantification of health risks in terms of several assumptions about exposure and toxicity, including site-specific and general uncertainties. Based on the anticipation of uncertainty when quantifying exposure and toxicity, the health risks and hazards presented in this risk assessment may overestimate risk.

#### *6.2.4.1 Uncertainties Associated with Sampling and Analysis Data*

Current baseline conditions are represented by groundwater data collected over the last five years from 177 monitoring wells within the 200-PO-1 groundwater OU. The groundwater data set for the COPCs is over 1,500 samples available from more than 177 wells that were routinely sampled over many years. Therefore, the groundwater data set is considered adequate for risk assessment. Detection limits vary because of laboratory contracts.

Groundwater data are collected according to two different SAPs: one addressing the requirements for the *Atomic Energy Act of 1954*, and one addressing the requirements for the characterization work plan (DOE/RL-2007-31). For routine monitoring purposes, groundwater samples from Near Field wells are collected annually, and triennially for Far Field wells. However, the southeast transect and river transect wells that are located in the Far Field are collected annually. In addition, some of the monitoring wells routinely monitored are co-sampled with the TSDs, and each has a separate groundwater monitoring plan. Groundwater characterization samples were originally planned to be collected over two years; however, only one year was conducted. SAPs for routine and characterization purposes are provided in Appendix A and Appendix B of the work plan (DOE/RL-2007-31).

Sampling and analysis results comprehensively define the contaminant suite associated with existing source area plumes. However, differences in sampling frequencies (annually or tri-annually) may create uncertainties associated with the temporal representative qualities of the data set. The differences in sampling frequencies are not anticipated to influence the overall concentrations of COPCs in groundwater.

Differences in method detection limits for the same sample and between samples create uncertainties associated with confirmation of the presence or absence of COPCs at or below the action level. In addition, there is potential for overestimating or underestimating the contaminant concentrations when using the method detection limit for non-detected concentrations. Method detection limits vary as a result of changes between laboratory contracts.

Both filtered (dissolved) and unfiltered (total) analytical results are available for some metals in the groundwater data set. However, only unfiltered results are used for selecting COPCs. Use of filtered sampling results may underestimate chemical and radiological concentrations in water from an unfiltered tap and are not used for the COPC selection process. A comparison of filtered and unfiltered metals

concentrations was performed to determine if the exclusion of filtered results would omit any metals from the COPC selection process. The results of this comparison indicated that for some metals, there are more filtered metal results available than unfiltered results; however, exclusion of filtered results does not result in the elimination of metals from the COPC process or underestimate EPCs.

#### 6.2.4.2 Uncertainties Associated with Aquifer Tube Data

Monitoring wells adjacent to the Columbia River were used to determine whether groundwater discharging to the Columbia River meets chemical-specific ARARs. The results of the BRA indicate that EPCs for tritium and nitrate are greater than their action levels. Using groundwater data has the potential to overestimate exposure concentrations that discharge to the Columbia River because it does not account for how and where the groundwater and river water mix.

Water samples were collected and analyzed from 14 different aquifer tube locations for the 200-PO-1 OU RI. Table 6-20 provides a comparison of aquifer tube to groundwater results from the closest adjacent monitoring well. Table 6-20 shows nitrate and tritium results from the two most recent rounds of sampling conducted from their respective locations. In most cases, the groundwater and aquifer tube samples were not collected at the same time of the year; therefore, the results are not temporally comparable. However, these results are helpful for demonstrating the trend that concentrations measured in monitoring wells are generally greater than those measured in aquifer tubes.

#### 6.2.4.3 Uncertainties Associated with Exposure Point Concentrations

The EPCs for groundwater are calculated as the 90$^{th}$ percentile concentration. The protectiveness and risk evaluation methodology uses an RME concentration for each COPC with an exposure area rather than performing the evaluation on a specific well or location. In general, EPA Superfund guidance recommends using a 95 percent UCL on the average for estimating EPCs. However, experience at the Hanford Site indicates that averages and UCLs cannot be reliably calculated for groundwater data sets using this approach. The 200-PO-1 Groundwater OU exhibits an aquifer setting where multiple groundwater contaminants are present in overlapping plumes, and the highest concentrations have different locations within the plumes. The 90$^{th}$ percentile from a distribution of groundwater concentration data as an EPC is a different approach from Superfund guidance for estimating EPCs in risk assessments (OSWER 9285.6-10, *Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites*). However, as is described below, the 90$^{th}$ percentile exposure is identified in EPA risk assessment guidance for describing and characterizing health risks and produces risk estimates that correspond to an RME.

Additional information on possible ranges of concentrations in groundwater EPCs for the COPCs is provided in Table 6-21. Table 6-21 shows the percentile concentrations used for the protectiveness and risk evaluations, as well as the maximum, average, and 95 percent UCL concentrations using all of the data within an exposure area. For the final COPCs listed in Table 6-21, the 90$^{th}$ percentile concentrations are greater than the 95 percent UCL values for all COPCs except technetium-99 in the Near Field.

The groundwater data set is considered robust when the 90$^{th}$ percentile value is greater than the 95 percent UCL value. Generally, when data sets are large, the 95 percent UCL will approach the mean concentration. For nitrate in the Near Field, the 95 percent UCL is 34,098 µg/L and the mean is 29,704 µg/L; in contrast, the 90$^{th}$ percentile is 63,500 µg/L. Therefore, 90$^{th}$ percentile values are reasonable upper bounds of concentrations for the purposes of the risk assessment. However, if a well was drilled at the location of the maximum concentration, risks would be significantly underestimated for the COPCs where the maximum concentration is considerably larger than the 90$^{th}$ percentile value (true for four of the COPCs where the maximum concentration is more than an order of magnitude larger than the 90$^{th}$ percentile). Because only 10 percent of the data exceed the 90$^{th}$ percentile values, these very high concentrations are few and represent a very limited areal extent.

**Table 6-20. Comparison of Aquifer Tube and Monitoring Well Results**

| COPC | Well No. | Sample Date | Result | Aquifer Tube | Sample Date | Result |
|---|---|---|---|---|---|---|
| Tritium | 699-43-3 | 5/25/2004<br>9/23/2007 | 94,000 pCi/L<br>70,000 pCi/L | C6383<br>C6384 | 9/25/2008<br>3/26/2009 | 24,000 pCi/L<br>5,200 pCi/L |
| Nitrate | | 5/25/2004<br>9/23/2007 | 35,400 µg/L<br>32,800 µg/L | C6384 | 3/26/2009 | 2,920 µg/L |
| Tritium | 699-41-1A | 11/4/2008<br>2/4/2009 | 54,000 pCi/L<br>57,000 pCi/L | C6383<br>C6384 | 9/25/2008<br>3/26/2009 | 24,000 pCi/L<br>5,200 pCi/L |
| Nitrate | | 11/4/2008<br>2/4/2009 | 30,200 µg/L<br>31,900 µg/L | C6384 | 3/26/2009 | 2,920 µg/L |
| Tritium | 699-40-1 | 1/29/2004<br>1/31/2007 | 74,500 pCi/L<br>59,000 pCi/L | C6383<br>C6384 | 9/25/2008<br>3/26/2009 | 24,000 pCi/L<br>5,200 pCi/L |
| Nitrate | | 1/29/2004<br>1/31/2007 | 35,900 µg/L<br>28,900 µg/L | C6384 | 3/26/2009 | 2,920 µg/L |
| Tritium | 699-37-E4 | 3/1/2004<br>4/4/2007 | 82,000 pCi/L<br>60,000 pCi/L | C6353 | 9/23/2008<br>2/19/2009 | 35,000 pCi/L<br>36,000 pCi/L |
| Nitrate | | 3/1/2004<br>4/4/2007 | 39,800 µg/L<br>35,900 µg/L | | 9/23/2008<br>2/19/2009 | 7,500 µg/L<br>7,500 µg/L |
| Tritium | 699-20-E120 | 1/14/2008<br>3/7/2008 | <1,700 pCi/L<br>2,000 pCi/L | C6362 | 9/26/2008<br>2/24/2009 | <69 pCi/L<br><18 pCi/L |
| Nitrate | | 1/14/2008<br>3/7/2008 | 5,180 µg/L<br>3,130 µg/L | | 9/26/2008<br>2/24/2009 | 6,300 µg/L<br>6,400 µg/L |
| Tritium | 699-20-E12S | 2/12/2007 | <-86.2 pCi/L | C6362 | 9/26/2008<br>2/24/2009 | <69 pCi/L<br><18 pCi/L |
| Nitrate | | 2/12/2007 | 394 µg/L | | 9/26/2008<br>2/24/2009 | 6,300 µg/L<br>6,400 µg/L |
| Tritium | 699-10-E12 | 11/3/2008<br>2/4/2009 | 11,200 pCi/L<br>11,000 pCi/L | C6368 | 9/26/2008<br>2/19/2009 | 240 pCi/L<br><-43 pCi/L |
| Nitrate | | 11/3/2008<br>2/4/2009 | 26,600 µg/L<br>28,600 µg/L | | 9/26/2008<br>2/19/2009 | 108 µg/L<br>105 µg/L |

**Table 6-20. Comparison of Aquifer Tube and Monitoring Well Results**

| COPC | Well No. | Sample Date | Result | Aquifer Tube | Sample Date | Result |
|---|---|---|---|---|---|---|
| Tritium | 699-S3-E12 | 11/9/2008<br>1/13/2009 | 980 pCi/L<br>1,600 pCi/L | C6375 | 10/28/2008<br>3/25/2009 | 8,870 pCi/L<br>12,000 pCi/L |
| Nitrate | | 11/9/2008<br>1/13/2009 | 1,290 µg/L<br>1,110 µg/L | | 10/28/2008<br>3/25/2009 | 6,200 µg/L<br>6,100 µg/L |
| Tritium | 699-S6-E14A | 11/9/2008<br>1/13/2009 | 323 pCi/L<br><286 pCi/L | C6378 | 9/29/2008<br>3/26/2009 | <4.5 pCi/L<br><-37 pCi/L |
| Nitrate | | 6/29/2004<br>7/25/2007 | 6,200 µg/L<br>4,50 µg/L | | 9/29/2008<br>3/26/2009 | <12.1 µg/L<br>104 µg/L |
| Tritium | 699-S6-E14A | 11/9/2008<br>1/13/2009 | 323 pCi/L<br><286 pCi/L | C6378 | 9/29/2008<br>3/26/2009 | <4.5 pCi/L<br><-37 pCi/L |
| Nitrate | | 6/29/2004<br>7/25/2007 | 6,200 µg/L<br>4,50 µg/L | | 9/29/2008<br>3/26/2009 | <12.1 µg/L<br>104 µg/L |

Notes:

COPC = contaminant of potential concern

**Table 6-21. Percentile Concentrations and Summary Statistics**

| COPC | Units | No. of Measurements | 90th Percentile | Maximum | Mean | 95% UCL |
|---|---|---|---|---|---|---|
| **Near Field Exposure Area** | | | | | | |
| Iodine-129 | pCi/L | 290 | 6.4 | 10 | 4.6 | 2.7 |
| Technetium-99 | pCi/L | 225 | 1,065 | 13,000 | 1,018 | 1,667 |
| Tritium | pCi/L | 274 | 381,000 | 650,000 | 108,039 | 156,901 |
| Strontium-90 | pCi/L | 203 | 6.6 | 21 | 7.4 | 4.3 |
| Trichloroethene | µg/L | 34 | 0.60 | 3.1 | 0.75 | 0.54 |
| Nitrate | µg/L | 703 | 63,500 | 154,000 | 29,704 | 34,098 |
| Uranium | µg/L | 79 | 27 | 93 | 12 | 20 |
| **Far Field Exposure Area** | | | | | | |
| Iodine-129 | pCi/L | 133 | 3.5 | 7.9 | 3.8 | 1.7 |
| Tritium | pCi/L | 348 | 419,000 | 2,320,000 | 165,509 | 264,107 |
| Carbon Tetrachloride | µg/L | 365 | 0.50 | 2.0 | 0.48 | 0.14 |
| Tetrachloroethene | µg/L | 365 | 1.5 | 4.5 | 1.2 | 0.82 |
| Trichloroethene | µg/L | 365 | 0.64 | 1.6 | 0.53 | 0.39 |
| Nitrate | µg/L | 558 | 46,500 | 113,000 | 23,046 | 23,935 |
| **River Exposure Area** | | | | | | |
| Tritium | pCi/L | 53 | 72,200 | 94,000 | 33,584 | 70,725 |
| Nitrate | µg/L | 51 | 34,750 | 39,800 | 21,334 | 31,718 |

Notes:
COPC = contaminant of potential concern
UCL = upper confidence limit

#### *6.2.4.4 Uncertainties Associated with Exposure Assumptions*

The exposure assumptions used to develop the chemical-specific ARARs represent an RME. For estimating the RME, 95 percent UCL values (or upper-bound estimates of national averages) are generally used for exposure assumptions, and exposed populations and exposure scenarios are also selected to represent upper-bound exposures. The intent of the RME, as discussed by the EPA Deputy Administrator and the Risk Assessment Council (Habicht, 1992, "Guidance on Risk Characterization for Risk Managers and Risk Assessors"), is to present risks as a range from central tendency to high-end risk (i.e., above the 90th percentile of the population distribution). This descriptor is intended to estimate the risks that are expected to occur in small but definable "high-end" segments of the subject population (Habicht, 1992). The EPA distinguishes between those scenarios that are possible but highly improbable and those that are conservative but more likely to occur within a population, with the latter being favored in risk assessment. In general, these assumptions are intended to be conservative and yield an overestimate of the true risk or hazard.

#### 6.2.4.5 Uncertainties Associated with Dermal Contact Exposure

The chemical-specific ARARs for use as a drinking water source consider ingestion and inhalation of vapors as complete and significant pathways for exposure. For the chemical-specific ARARs, the dermal contact pathway is considered a complete but insignificant pathway of exposure for the contaminants detected in groundwater. The exclusion of the dermal contact exposure route from the chemical-specific ARARs may have the potential to underestimate the cleanup level.

EPA considers the dermal contact route to be significant if it contributes at least 10 percent of the exposure derived from the oral pathway. These results are based upon comparing two main household daily uses of water: a source for drinking and a source for showering or bathing (EPA/540/R-99/005, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment): Final*, OSWER 9285.7-02EP). Exhibit B-3 and Exhibit B-4 of EPA/540/R-99/005 provide a screening tool to focus the dermal risk assessment on those chemicals that are more likely to make a contribution to the overall risk. Exhibit B-3 indicates that dermal exposure exceeds 10 percent of drinking water for carbon tetrachloride, tetrachloroethene, and TCE. The ratio of the dermal absorbed dose from dermal to oral is 27 percent of carbon tetrachloride, 60 percent for tetrachloroethene, and 17 percent for TCE. Based on this comparison, the chemical-specific ARARs concentrations may have the potential to underestimate exposure to these final COPCs.

#### 6.2.4.6 Uncertainties Associated with Toxicity Assessment

The toxicological database was also a source of uncertainty. EPA has outlined some of the sources of uncertainty in EPA/540/1-89/002 and Cook, 2003. These sources may include or result from the extrapolation from high to low doses and from animals to humans; the species, gender, age, and strain differences in a toxin's uptake, metabolism, organ distribution, and target site susceptibility; and the human population's variability with respect to diet, environment, activity patterns, and cultural factors.

Traditionally, EPA has developed toxicity criteria for carcinogens by assuming that all carcinogens are non-threshold contaminants. However, EPA has recently published revised cancer guidelines (EPA/630/P-03/001F) that modified their former position of assuming non-threshold action for all carcinogens. This new guidance emphasizes establishing the specific toxicokinetic mode of action that leads to development of cancer. Toxicity criteria for carcinogens in the United States will be developed in the future, assuming no threshold only for contaminants that exhibit genotoxic modes of action or where the mode of action is not known. However, currently available EPA toxicity criteria for carcinogens were all derived assuming a non-threshold model.

In most of the world, non-threshold toxicity criteria are developed only for those carcinogens that appear to cause cancer through a genotoxic mechanism (Health Canada, Netherlands). Specifically, for genotoxic contaminants, the cancer dose response model is based on high- to low-dose extrapolation and assumes that there is no lower threshold for the initiation of toxic effects. Cancer effects observed at high doses in laboratory animals or from occupational or epidemiological studies are extrapolated, using mathematical models, to low doses common to environmental exposures. These models are essentially linear at low doses, so no dose is without some risk of cancer.

**Slope Factors for Trichloroethene**

The oral cancer potency factor of 0.089 $(mg/kg\text{-}day)^{-1}$ is used to develop the WAC 173-340-720 groundwater cleanup level and is obtained from HEAST (1/1/1991). HEAST has not been updated since 1997 and, in this case, the oral cancer potency factor does not reflect the most current source of information.

The SFO currently implemented by EPA for TCE is established by the CalEPA OEHHA. The source of this toxicity value is consistent with the hierarchy of toxicity values recommended in Cook, 2003. The SFO derived by OEHHA is 0.013 $(mg/kg\text{-}day)^{-1}$, as presented in OEHHA, 2009.

The OEHHA value is lower than the value of 0.00059 $(mg/kg\text{-}day)^{-1}$ for oral exposures published by the Health Effects Assessment Summary Tables published in 1991.

If the CalEPA values were used to calculate the WAC 173-340-720 groundwater cleanup level, the groundwater concentration would increase from 0.49 µg/L to 3.4 µg/L. The groundwater risks at the 90th percentile would decrease from $1.2 \times 10^{-6}$ to less than $1.8 \times 10^{-7}$ in the Near Field, and the groundwater risks would decrease from $1.3 \times 10^{-6}$ to $1.3 \times 10^{-7}$ in the Far Field. However, the cumulative risk for the Far Field area would remain above $1 \times 10^{-5}$. Use of the oral cancer potency factor from HEAST results in an overestimation of risks when compared to the SFO established by CalEPA.

#### *6.2.4.7 Uncertainties Associated with Risk Characterization*

In the risk characterization, the assumption was made that the total risk of developing cancer from exposure to site contaminants is the sum of the risk attributed to each individual contaminant. Likewise, the potential for the development of non-cancer adverse effects is the sum of the HQs estimated for exposure to each individual contaminant. This approach, in accordance with EPA guidance, did not account for the possibility that constituents act synergistically or antagonistically.

As discussed in Section 6.2.2.2, MCLs for radionuclides are set at 4 mrem/yr for the sum of the doses from beta particle and photon emitters, 15 pCi/L for gross alpha emitter activity (including Ra-226, but excluding uranium and radon), and 5 pCi/L combined for Ra-226 and Ra-228. A mass concentration MCL has been established for uranium as 30 µg/L. At this time, there are no additional federal or state standards associated with evaluating the effects of exposure to radionuclides. Risks were estimated for radioisotopes identified as final COPCs using inputs and equation 720-2 from WAC 173-340-720(4)(iii)(B) and radionuclide slope factors from HEAST. Table 6-22 shows that the MCL concentrations reported for each of the final radionuclide COPCs do not individually exceed the $10^{-4}$ ELCR end of the NCP risk range.

**Table 6-22. Maximum Contaminant Levels and ELCRs for Final COPCs**

| Final COPC | MCL (pCi/L) | Excess Lifetime Cancer Risk |
|---|---|---|
| Iodine-129 | 1 | $3.2 \times 10^{-6}$ |
| Strontium-90 | 8 | $9.8 \times 10^{-6}$ |
| Technetium-99 | 900 | $8.4 \times 10^{-5}$ |
| Tritium | 20,000 | $1.3 \times 10^{-4}$ |

Notes:
COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
MCL = maximum contaminant level

## 6.3 Ecological Risk

The ecological risk assessment for the 200-PO-1 Groundwater OU considers groundwater beneath the Central Plateau and the areas along the Columbia River. An ecological risk assessment has not been conducted at groundwater OUs where the groundwater discharges to the Columbia River. Because groundwater discharges to the Columbia River, it is appropriate to evaluate exposure to aquatic receptors from the 200-PO-1 Groundwater OU along the river shoreline. The River Corridor Baseline Risk Assessment (RCBRA) is currently being conducted to address the regulatory requirement that a BRA be performed to support final cleanup decisions along the river corridor.

The RCBRA has the following two key elements:

- The source and groundwater component (which addresses potential upland, shoreline, and groundwater risks)
- The Columbia River component (which addresses potential risks from Hanford Site releases to the Columbia River)

The process of conducting the RCBRA has included input from the Tri-Parties, the Natural Resource Trustee Council, Tribal Nations, and stakeholders.

Ecological risk evaluation has been performed by utilizing AWQC for aquatic organisms as an ARAR for the Far Field and near river exposure areas. As described in Section 6.1.2, groundwater in the Far Field and river exposure areas has the potential to discharge to the Columbia River representing a potentially complete exposure pathway to aquatic receptors. The action level selected for the final COPC selection process represents the lowest of the available chemical-specific ARARs protective of human and aquatic receptors if more than one chemical-specific ARAR exists for a certain analyte. Risk screening results indicate that AWQC, established under Section 304 or Section 303 of the *Clean Water Act of 1977* and WAC 173-201A, are not exceeded under baseline conditions.

## 6.4 Summary of the Native America Risk Assessments

Several local and regional Tribes have ancestral ties to the Hanford Reach of the Columbia River and surrounding lands. DOE has requested that each Tribe provide an exposure scenario that reflects their traditional activities. At this time, "*Exposure Scenario for CTUIR Traditional Subsistence Lifeways*" (Harris 2004) and "Application of the CTUIR Traditional Lifeways Exposure Scenario in Hanford Risk Assessments" (Harris 2008) have been provided by the CTUIR and "*A Native American Exposure Scenario*" (Ridolfi 2007) has been provided by the Yakama Nation.

The CTUIR and Yakama Nation scenarios reflect exposure conditions that assume groundwater from the 200-PO-1 groundwater OU is restored to highest beneficial use and used as a drinking water source and to make steam in a sweat lodge. Use of groundwater to irrigate crops and water livestock is not evaluated in this risk evaluation because those exposure pathways, although potentially complete, are considered insignificant and secondary to the drinking water and sweat lodge exposure pathways. Food chain pathways are generally evaluated quantitatively in the source area OUs because the RESRAD model (ANL, 2009) estimates exposure from these pathways. Contact with contaminated drill cuttings is not addressed because this assessment includes only groundwater pathway exposures.

Potentially complete exposure routes for adult and child tribal members associated with use of groundwater as a drinking water source are as follows:

- Ingestion of drinking water
- Inhalation of volatiles when showering and other domestic purposes
- Dermal contact with skin while showering and using groundwater for other domestic purposes (e.g., washing dishes)

Potentially complete exposure routes for adult tribal members associated with the use of groundwater as a source of steam in a sweat lodge are as follows:

- Inhalation of tritium, volatiles, and semivolatiles as vapors while in a sweat lodge
- Inhalation of aerosolized nonvolatiles while spending time in a sweat lodge
- Dermal contact with vapors from volatile and semivolatile compounds while in a sweat lodge
- Dermal contact with vapor and aqueous condensate while in a sweat lodge

A complete description of each of the tribal use exposure scenarios is provided in ECF-200PO1-09-2115. This environmental calculation describes the methodology, assumptions and inputs, and calculation of risks and hazards, and discusses the results of the risk assessment for each of the Native American scenarios.

## 6.5 Summary of the CTUIR Risk Assessment

This section summarizes the results for each of the three exposure areas associated with use of groundwater as a drinking water source and use of groundwater to make steam in a sweat lodge.

### 6.5.1 Use of Groundwater as a Potential Drinking Water Source

Potential exposure to groundwater as a drinking water source is evaluated under this scenario. Potential routes of exposure to groundwater include ingestion, dermal contact,[9] and inhalation of volatiles during household activities. Table 6-23 provides a summary of the risk estimates by exposure route for each exposure area evaluated. Additional detail including COPC-specific risk contributions is provided in the calculation spreadsheets presented in ECF-200PO1-09-2115.

**Table 6-23. Confederated Tribes of the Umatilla Indian Reservation Exposure Scenario – Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source**

| | Near Field Exposure Area | | Far Field Exposure Area | | River Exposure Area | |
|---|---|---|---|---|---|---|
| Exposure Route | ELCR | HI | ELCR | HI | ELCR | HI |
| | | | Nonradionuclide COPCs | | | |
| Ingestion | 8.0E-04 | 14 | 4.4E-04 | 8.4 | 5.9E-04 | 3.6 |
| Dermal | 2.8E-06 | 0.89 | 1.7E-05 | 0.11 | 2.3E-06 | 0.02 |
| Inhalation | 4.8E-07 | <0.01 | 6.7E-07 | <0.01 | 3.7E-07 | <0.01 |

[9] The dermal contact exposure route is only evaluated for nonradionuclide COPCs.

**Table 6-23. Confederated Tribes of the Umatilla Indian Reservation Exposure Scenario – Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source**

| | Near Field Exposure Area | | Far Field Exposure Area | | River Exposure Area | |
|---|---|---|---|---|---|---|
| **Exposure Route** | **ELCR** | **HI** | **ELCR** | **HI** | **ELCR** | **HI** |
| **Total** | **8.0E-04** | **15** | **4.6E-04** | **8.5** | **6.0E-04** | **3.6** |
| | | | **Radionuclide COPCs** | | | |
| Ingestion | 2.3E-03 | -- | 2.1E-03 | -- | 3.8E-04 | -- |
| Inhalation | 1.7E-04 | -- | 1.9E-04 | -- | 3.2E-05 | -- |
| **Total** | **2.4E-03** | **--** | **2.3E-03** | **--** | **4.2E-04** | **--** |
| **Total ELCR[a]** | **3.1E-03** | **--** | **2.8E-03** | **--** | **1.0E-03** | **--** |

Notes:

a. Sum of total ELCR values for nonradionuclides and radionuclides.

-- = Indicates HI not applicable

COPC = contaminant of potential concern

CTUIR = Confederated Tribes of the Umatilla Indian Reservation

HI = hazard index

ELCR = excess lifetime cancer risk

#### *6.5.1.1 Near Field Exposure Area*

The cumulative ELCR for the Near Field exposure area is $8.0 \times 10^{-4}$ for nonradiological COPCs and $2.4 \times 10^{-3}$ for radiological COPCs which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR values for tritium and technetium-99 are greater than the EPA regulatory target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with chloroform, TCE, iodine-129, and strontium-90 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for chloroform and TCE is less than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the Near Field exposure area is 15 which is greater than the EPA and WAC 173-340 target HI of 1.0. The primary contributor to the non-cancer HI is nitrate with a HQ of 2.3.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $10^{-4}$ and the HQ is greater than 1 the 90$^{th}$ percentile value of 9.1 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered a contributor to risk or HI.

Although antimony and hexavalent chromium are reported with HQs greater than 1, they are not considered contributors to the HI. The analytical method used to measure antimony is not considered reliable because detected concentrations are reported to be false positives and method detection limits are generally above the federal maximum contaminant level. Hexavalent chromium was only analyzed in three groundwater samples and was not identified as a preliminary COPC in the 200-PO-1 OU work plan (DOE/RL-2007-31).

#### 6.5.1.2 Far Field Exposure Area

The cumulative ELCR for the Far Field exposure area is $4.6 \times 10^{-4}$ for nonradiological COPCs and $2.3 \times 10^{-3}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA regulatory target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with carbon tetrachloride, chloroform, tetrachloroethene, TCE, iodine-129, and technetium-99 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for carbon tetrachloride, chloroform, TCE, and tetrachloroethene is greater than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the Far Field exposure area is 8.5, which is greater than the EPA and WAC 173-340 target HI of 1.0. The primary contributor to the non-cancer HI is nitrate with a HQ of 1.7.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $10^{-4}$ and the HQ is greater than 1, the 90$^{th}$ percentile value of 4.3 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

The individual ELCR value associated with tributyl phosphate is within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. Tributyl phosphate does not originate from a 200-PO-1 OU source instead it originates from the 618-10 burial ground therefore it is not considered to be a contributor to risk or HI.

Antimony is not considered a contributor to the HI. As discussed in the previous section, the analytical method used to measure antimony is not considered adequate for measuring its presence.

#### 6.5.1.3 River Exposure Area

The cumulative ELCR for the river exposure area is $6.0 \times 10^{-4}$ for nonradiological COPCs and $4.2 \times 10^{-4}$ for radiological COPCs which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA regulatory target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with carbon tetrachloride, chloroform, technetium-99, and strontium-90 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for carbon tetrachloride and chloroform is less than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the river exposure area is 3.6 which is greater than the regulatory the EPA and WAC 173-340 target HI of 1.0. The primary contributor to the non-cancer HI includes nitrate with a HQ of 1.2.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $10^{-4}$ and the HQ is greater than 1 the 90$^{th}$ percentile value of 6.8 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

### 6.5.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use

Potential exposure to groundwater as a source of steam in a sweat lodge is evaluated under this scenario. Potential routes of exposure to steam generated from groundwater include inhalation of vaporized volatiles and semivolatiles and aerosolized nonvolatiles and dermal contact with vaporized volatiles, semivolatiles, and nonvolatiles and condensed liquid while spending time in a sweat lodge. Table 6-24 provides a summary of the risk estimates by exposure route and exposure area. Additional detail including COPC-specific risk contributions is provided in the calculation spreadsheets presented in ECF-200PO1-09-2115.

**Table 6-24. CTUIR Exposure Scenario – Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge**

| Exposure Route | Near Field Exposure Area | | Far Field Exposure Area | | River Exposure Area | |
|---|---|---|---|---|---|---|
| | ELCR | HI | ELCR | HI | ELCR | HI |
| **Nonradionuclide COPCs** | | | | | | |
| **Inhalation in Sweat Lodge** | | | | | | |
| Volatile and Semivolatile (vapor) | 1.9E-06 | <0.01 | 2.7E-06 | <0.01 | 1.5E-06 | <0.01 |
| Nonvolatile (aerosol) | 1.3E-01 | 31 | 2.0E-04 | 8.0 | 2.5E-04 | 16 |
| Total | 1.3E-01 | 31 | 2.1E-04 | 8.0 | 2.5E-04 | 16 |
| Dermal Exposure in Sweat Lodge | | | | | | |
| Volatile and Semivolatile (vapor only) | 2.5E-10 | <0.01 | 7.5E-09 | <0.01 | 3.0E-10 | <0.01 |
| Nonvolatile (vapor and aqueous condensate) | 3.4E-6 | 1.5 | 1.6E-6 | 0.2 | 2.5E-6 | 0.03 |
| **Total** | **3.4E-6** | **1.5** | **1.6E-6** | **0.2** | **2.5E-6** | **0.03** |
| **Total Nonradionuclide COPCs** | **1.3E-01** | **33** | **2.1E-04** | **8.2** | **2.5E-04** | **16** |
| **Radionuclide COPCs** | | | | | | |
| **Inhalation in Sweat Lodge** | | | | | | |
| Volatile and Semivolatile (vapor) | 5.3E-04 | -- | 5.8E-04 | -- | 1.0E-04 | -- |
| Nonvolatile (aerosol) | 6.8E-05 | -- | 6.0E-06 | -- | 7.1E-06 | -- |
| **Total Radionuclide COPCs** | **6.0E-04** | **--** | **5.9E-04** | **--** | **1.1E-04** | **--** |
| **Total ELCR[a]** | **1.3E-01** | **--** | **8.0E-4** | **--** | **3.6E-04** | **--** |

Notes:

a. Sum of total ELCR values for nonradionuclide and radionuclide COPCs.

-- = Indicates HI not applicable

COPC = contaminant of potential concern

CTUIR = Confederated Tribes of the Umatilla Indian Reservation

HI = hazard index

ELCR = excess lifetime cancer risk

#### 6.5.2.1 Near Field Exposure Area

The cumulative ELCR for the Near Field exposure area is $1.3 \times 10^{-1}$ for nonradiological COPCs and $6.0 \times 10^{-4}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR values for cobalt and tritium are greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with beryllium, cadmium, chloroform, nickel, iodine-129, strontium-90, and technetium-99 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The HI for the Near Field exposure area is 33, which is greater than the EPA and WAC 173-340 target HI of 1.0. The primary contributors to the non-cancer HI are cadmium, cobalt, and nickel, which have HQs equal to or greater than 1.0.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $1 \times 10^{-4}$ and the HQ is greater than 1.0, the 90th percentile value of 9.1ug/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

Although the individual ELCR value associated with hexavalent chromium is greater than the EPA's regulatory target risk threshold of $1 \times 10^{-4}$ and the HQ is greater than 1.0, it is not considered a contributor to risk or HI. Hexavalent chromium was only analyzed in three groundwater samples and was not identified as a preliminary COPC in the 200-PO-1 OU work plan (DOE/RL-2007-31).

Although the individual HQ associated with manganese is greater than 1.0, manganese is not considered to be a contributor to the HI because the 90th percentile value of 7.1 µg/L is below the secondary MCL of 50 µg/L and the secondary MCL is based on aesthetic qualities and is not federally enforceable.

#### 6.5.2.2 Far Field Exposure Area

The cumulative ELCR for the Far Field exposure area is $2.1 \times 10^{-4}$ for nonradiological COPCs and $5.9 \times 10^{-4}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with chloroform, nickel, and technetium-99 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. No individual COPCs in the Far Field exposure area had a HQ greater than the EPA and WAC 173-340 target HI of 1.0.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $1 \times 10^{-4}$ and the HQ is greater than 1.0, the 90th percentile value of 4.3 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

The individual ELCR value associated with cadmium is within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and the HQ is greater than 1.0. Cadmium is not considered a contributor to risk or HI because the analytical method used to measure cadmium is not considered reliable.

Although the individual HQ associated with manganese is greater than 1.0, manganese is not considered to be a contributor to the HI because the 90th percentile value of 10.4 µg/L is below the secondary MCL of 50 µg/L and the secondary MCL is based on aesthetic qualities and is not federally enforceable.

#### 6.5.2.3 *River Exposure Area*

The cumulative ELCR for the river exposure area is 2.5 x $10^{-4}$ for nonradiological COPCs and 1.1 x $10^{-4}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of 1 x $10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of 1 x $10^{-4}$. The individual ELCR value for tritium is equal to the EPA upper target risk threshold of 1 x $10^{-4}$. Individual ELCRs associated with chloroform, nickel, and technetium-99 are within the EPA range of 1 x $10^{-4}$ to 1 x $10^{-6}$. No individual COPCs in the river exposure area had a HQ greater than the EPA and WAC 173-340 target HI of 1.0.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of 1 x $10^{-4}$ and the HQ is greater than 1.0, the 90$^{th}$ percentile value of 6.8 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

Although the individual HQ associated with manganese is greater than 1.0 and the 90$^{th}$ percentile value of 65 µg/L is above the secondary MCL of 50 µg/L, manganese is not considered to be a contributor to the HI because the secondary MCL is based on aesthetic qualities and is not federally enforceable.

## 6.6 Summary of the Yakama Nation Risk Assessment

This section summarizes the results for each of the three exposure areas associated with use of groundwater as a drinking water source and use of groundwater to make steam in a sweat lodge.

### 6.6.1 Use of Groundwater as a Potential Drinking Water Source

Potential exposure to groundwater as a drinking water source is evaluated under this scenario. Potential routes of exposure to groundwater include ingestion, dermal contact,[10] and inhalation of volatiles during household activities. Table 6-25 provides a summary of the risk estimates by exposure route for each exposure area evaluated. Additional detail including COPC-specific risk contributions is provided in the calculation spreadsheets presented in ECF-200PO1-09-2115.

**Table 6-25. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source**

| | Near Field Exposure Area | | Far Field Exposure Area | | River Exposure Area | |
|---|---|---|---|---|---|---|
| **Exposure Route** | **ELCR** | **HI** | **ELCR** | **HI** | **ELCR** | **HI** |
| | | | **Nonradionuclide COPCs** | | | |
| Ingestion | 8.7E-04 | 14 | 4.8E-04 | 8.4 | 6.4E-04 | 3.6 |
| Dermal | 2.8E-06 | 0.89 | 1.7E-05 | 0.11 | 2.3E-06 | 0.02 |
| Inhalation | 4.8E-07 | <0.01 | 6.7E-07 | <0.01 | 3.7E-07 | <0.01 |
| **Total** | **8.7E-04** | **15** | **5.0E-04** | **8.5** | **6.5E-04** | **3.6** |
| | | | **Radionuclide COPCs** | | | |
| Ingestion | 2.3E-03 | -- | 2.2E-03 | -- | 3.9E-04 | -- |
| Inhalation | 1.8E-04 | -- | 1.9E-06 | -- | 3.4E-05 | -- |

[10] The dermal contact exposure route is only evaluated for nonradionuclide COPCs.

**Table 6-25. Yakama Nation Exposure Scenario—Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source**

| | Near Field Exposure Area | | Far Field Exposure Area | | River Exposure Area | |
|---|---|---|---|---|---|---|
| **Exposure Route** | **ELCR** | **HI** | **ELCR** | **HI** | **ELCR** | **HI** |
| **Total** | **2.5E-03** | -- | **2.4E-03** | -- | **4.3E-04** | -- |
| **Total ELCR[a]** | **3.4E-03** | -- | **2.8E-03** | -- | **1.1E-03** | -- |

Notes:

a. Sum of total ELCR values for nonradionuclide and radionuclide COPCs.

-- = Indicates HI not applicable

COPC = contaminant of potential concern

HI = hazard index

ELCR = excess lifetime cancer risk

#### *6.6.1.1 Near Field Exposure Area*

The cumulative ELCR for the Near Field exposure area is $8.7 \times 10^{-4}$ for nonradiological COPCs and $2.5 \times 10^{-3}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR values for tritium and technetium-99 are greater than the EPA target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with chloroform, TCE, iodine-129, and strontium-90 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for chloroform and TCE is less than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the Near Field exposure area is 15, which is greater than the regulatory the EPA and WAC 173-340 target HI of 1.0. The primary contributor to the non-cancer HI is nitrate with a HQ of 2.3.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $10^{-4}$ and the HQ is greater than 1 the 90th percentile value of 9.1 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

Antimony and hexavalent chromium are not considered contributors to the HI. The analytical method used to measure antimony is not considered reliable because detected concentrations are reported to be false positives and method detection limits are generally above the federal maximum contaminant level. Hexavalent chromium was only analyzed in three groundwater samples and was not identified as a preliminary COPC in the 200-PO-1 OU work plan (DOE/RL-2007-31).

#### *6.6.1.2 Far Field Exposure Area*

The cumulative ELCR for the Far Field exposure area is $5.0 \times 10^{-4}$ for nonradiological COPCs and $2.4 \times 10^{-3}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with carbon tetrachloride, chloroform, tetrachloroethene, TCE, iodine-129, and technetium-99 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for carbon tetrachloride, chloroform, tetrachloroethene, and TCE is greater than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the Far Field exposure area is 8.5, which is greater than

the regulatory the EPA and WAC 173-340 target HI of 1.0. The primary contributor to the non-cancer HI includes nitrate with a HQ of 1.7.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $10^{-4}$ and the HQ is greater than 1 the 90$^{th}$ percentile value of 4.3 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

The individual ELCR value associated with tributyl phosphate is within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. Tributyl phosphate does not originate from a 200-PO-1 OU source instead it originates from the 618-10 burial ground, therefore it is not considered to be a contributor to risk or HI.

Antimony is not considered a contributor to the HI. As discussed in the previous section, the analytical method used to measure antimony is not considered adequate for measuring its presence.

#### *6.6.1.3 River Exposure Area*

The cumulative ELCR for the river exposure area is $6.5 \times 10^{-4}$ for nonradiological COPCs and $4.3 \times 10^{-4}$ for radiological COPCs which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with carbon tetrachloride, chloroform, technetium-99, and strontium-90 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for chloroform and TCE is less than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the river exposure area is 3.6 which is greater than the regulatory the EPA and WAC 173-340 target HI of 1.0. The primary contributor to the non-cancer HI is nitrate with a HQ of 1.2.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $10^{-4}$ and the HQ is greater than 1 the 90$^{th}$ percentile value of 6.8 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

### 6.6.2 Use of Groundwater as a Source of Steam for Sweat Lodge Use

Potential exposure to groundwater as a source of steam in a sweat lodge is evaluated under this scenario. Potential routes of exposure to steam generated from groundwater include inhalation of vaporized volatiles and semivolatiles and aerosolized nonvolatiles and dermal contact with vaporized volatiles, semivolatiles, and nonvolatiles and condensed liquid while spending time in a sweat lodge. Table 6-26 provides a summary of the risk estimates by exposure route and exposure area. Additional detail including COPC-specific risk contributions is provided in the calculation spreadsheets presented in ECF-200PO1-09-2115.

**Table 6-26. Yakama Nation Exposure Scenario – Summary of Risk Estimates from Use of Groundwater in a Sweat Lodge**

| Exposure Route | Near Field Exposure Area | | Far Field Exposure Area | | River Exposure Area | |
|---|---|---|---|---|---|---|
| | ELCR | HI | ELCR | HI | ELCR | HI |
| **Nonradionuclide COPCs** | | | | | | |
| **Inhalation in Sweat Lodge** | | | | | | |
| Volatile and Semivolatile (vapor) | 4.0E-06 | <0.01 | 5.6E-06 | <0.01 | 3.1E-06 | <0.01 |
| Nonvolatile (aerosol) | 2.4E-01 | 64 | 4.3E-04 | 17 | 5.2E-04 | 33 |
| Total | 2.4E-01 | 64 | 4.3E-04 | 17 | 5.2E-04 | 33 |
| **Dermal Exposure in Sweat Lodge** | | | | | | |
| Volatile and Semivolatile (vapor only) | 5.1E-10 | <0.01 | 1.5E-08 | <0.01 | 6.0E-10 | <0.01 |
| Nonvolatile (vapor and aqueous condensate) | 6.9E-6 | 3.1 | 3.3E-6 | 0.4 | 5.1E-6 | 0.07 |
| **Total** | **6.9E-6** | **3.1** | **3.3E-6** | **0.4** | **5.1E-6** | **0.07** |
| **Total Nonradionuclide COPCs** | **2.4E-01** | **67** | **4.4E-04** | **17** | **5.3E-04** | **33** |
| **Radionuclide COPCs** | | | | | | |
| **Inhalation in Sweat Lodge** | | | | | | |
| Volatile and Semivolatile (vapor) | 1.1E-03 | -- | 1.2E-03 | -- | 2.1E-04 | -- |
| Nonvolatile (aerosol) | 1.4E-04 | -- | 1.2E-05 | -- | 1.5E-05 | -- |
| **Total Radionuclide COPCs** | **1.2E-03** | **--** | **1.2E-03** | **--** | **2.2E-04** | **--** |
| **Total ELCR*** | **2.4E-01** | **--** | **1.7E-03** | **--** | **7.5E-04** | **--** |

Notes:

* Sum of total ELCR values for nonradionuclide and radionuclide COPCs.

-- = Indicates HI not applicable

COPC = contaminant of potential concern

HI = hazard index

ELCR = excess lifetime cancer risk

#### 6.6.2.1 Near Field Exposure Area

The cumulative ELCR for the Near Field exposure area is $2.4 \times 10^{-1}$ for nonradiological COPCs and $1.2 \times 10^{-3}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR values for cobalt, tritium, and technetium-99 are greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with beryllium, cadmium, chloroform, nickel, TCE, iodine-129, and strontium-90 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The HI for the Near Field exposure area is 67, which is greater than the EPA and WAC 173-340 target HI of 1.0. The primary contributors to the non-cancer HI are beryllium, cadmium, cobalt, nickel, and uranium, which have HQs greater than 1.0.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $1 \times 10^{-4}$ and the HQ is greater than 1.0, the 90$^{th}$ percentile value of 9.1ug/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

Although the individual ELCR value associated with hexavalent chromium is greater than the EPA's regulatory target risk threshold of $1 \times 10^{-4}$ and the HQ is greater than 1.0, it is not considered a contributor to risk or HI. Hexavalent chromium was only analyzed in three groundwater samples and was not identified as a preliminary COPC in the 200-PO-1 OU work plan (DOE/RL-2007-31).

Although the individual HQ associated with manganese is greater than 1.0, manganese is not considered to be a contributor to the HI because the 90$^{th}$ percentile value of 7.1 µg/L is below the secondary MCL of 50 µg/L and the secondary MCL is based on aesthetic qualities and is not federally enforceable.

#### 6.6.2.2 Far Field Exposure Area

The cumulative ELCR for the Far Field exposure area is $4.4 \times 10^{-4}$ for nonradiological COPCs and $1.2 \times 10^{-3}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with chloroform, nickel, TCE, iodine-129, and technetium-99 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The HI for the Far Field exposure area is 17, which is greater than the EPA and WAC 173-340 target HI of 1.0. The primary contributors to the non-cancer HI are nickel and uranium, which have HQs greater than 1.0.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $1 \times 10^{-4}$ and the HQ is greater than 1.0, the 90$^{th}$ percentile value of 4.3 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

The individual ELCR value associated with cadmium is within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$ and the HQ is greater than 1.0. Cadmium is not considered a contributor to risk or HI because the analytical method used to measure cadmium is not considered reliable.

Although the individual HQ associated with manganese is greater than 1.0, manganese is not considered to be a contributor to the HI because the 90$^{th}$ percentile value of 10.4 µg/L is below the secondary MCL of 50 µg/L and the secondary MCL is based on aesthetic qualities and is not federally enforceable.

#### 6.6.2.3 *River Exposure Area*

The cumulative ELCR for the river exposure area is $5.3 \times 10^{-4}$ for nonradiological COPCs and $2.2 \times 10^{-4}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with chloroform, nickel, and technetium-99 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. No individual COPCs in the river exposure area had a HQ greater than the EPA and WAC 173-340 target HI of 1.0.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $1 \times 10^{-4}$ and the HQ is greater than 1.0, the 90$^{th}$ percentile value of 6.8 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

Although the individual HQ associated with manganese is greater than 1.0 and the 90$^{th}$ percentile value of 65 µg/L is above the secondary MCL of 50 µg/L, manganese is not considered to be a contributor to the HI because the secondary MCL is based on aesthetic qualities and is not federally enforceable.

## 6.7 Summary of the EPA Tap Water Equations

This section summarizes the results for each of the three exposure areas associated with use of groundwater as a drinking water source. The intake equations and exposure assumptions were obtained from the Oak Ridge Operations Office Risk Assessment Information system website, available at http://rais.ornl.gov/tools/rais_chemical_risk_guide.html. The EPA tap water ELCR and hazard indices are included in this section for comparison purposes.

### 6.7.1 Use of Groundwater as a Potential Drinking Water Source

Potential exposure to groundwater as a drinking water source is evaluated under this scenario. Potential routes of exposure to groundwater include ingestion, dermal contact, and inhalation of volatiles during household activities. Table 6-27 provides a summary of the risk estimates by exposure route for each exposure area evaluated.

**Table 6-27. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations**

| | Near Field Exposure Area | | Far Field Exposure Area | | River Exposure Area | |
|---|---|---|---|---|---|---|
| **Exposure Route** | **ELCR** | **HI** | **ELCR** | **HI** | **ELCR** | **HI** |
| | | | **Nonradionuclide COPCs** | | | |
| Ingestion | 2.1E-04 | 2.9 | 1.1E-04 | 1.7 | 1.5E-04 | 0.74 |
| Dermal | 1.4E-06 | 0.38 | 1.7E-05 | 0.11 | 1.1E-06 | 0.01 |
| Inhalation | 2.0E-07 | <0.01 | 6.7E-07 | <0.01 | 1.5E-07 | <0.01 |
| **Total** | **2.1E-04** | **3.3** | **1.3E-04** | **1.8** | **1.5E-04** | **0.75** |
| | | | **Radionuclide COPCs** | | | |
| Ingestion | 4.5E-04 | -- | 2.1E-03 | -- | 7.6E-05 | -- |
| Inhalation | 5.6E-05 | -- | 1.9E-04 | -- | 1.1E-05 | -- |

**Table 6-27. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations**

| | Near Field Exposure Area | | Far Field Exposure Area | | River Exposure Area | |
|---|---|---|---|---|---|---|
| **Exposure Route** | **ELCR** | **HI** | **ELCR** | **HI** | **ELCR** | **HI** |
| **Total** | **5.0E-04** | -- | **2.3E-03** | -- | **8.6E-05** | -- |
| **Total ELCR[a]** | **7.1E-04** | -- | **2.4E-03** | -- | **2.4E-04** | -- |

Notes:

a. Sum of total ELCR values for nonradionuclide and radionuclide COPCs.

-- = Indicates HI not applicable

COPC = contaminant of potential concern

HI = hazard index

ELCR = excess lifetime cancer risk

#### *6.7.1.1 Near Field Exposure Area*

The cumulative ELCR for the Near Field exposure area is $2.1 \times 10^{-4}$ for nonradiological COPCs and $5.0 \times 10^{-4}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with iodine-129, strontium-90, and technetium-99 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for chloroform and TCE is less than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the Near Field exposure area is 3.3 which is greater than the regulatory the EPA and WAC 173-340 target HI of 1.0. No individual COPCs were reported with a hazard quotient greater than 1.0.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $10^{-4}$, the 90$^{th}$ percentile value of 9.1 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

Antimony and hexavalent chromium are not considered contributors to the HI. The analytical method used to measure antimony is not considered reliable because detected concentrations are reported to be false positives and method detection limits are generally above the federal maximum contaminant level. Hexavalent chromium was only analyzed in three groundwater samples and was not identified as a preliminary COPC in the 200-PO-1 OU work plan (DOE/RL-2007-31).

#### *6.7.1.2 Far Field Exposure Area*

The cumulative ELCR for the Far Field exposure area is $1.3 \times 10^{-4}$ for nonradiological COPCs and $2.3 \times 10^{-3}$ for radiological COPCs, which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. The individual ELCR value for tritium is greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with carbon tetrachloride, tetrachloroethene, TCE, iodine-129, and technetium-99 are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for carbon tetrachloride, chloroform, tetrachloroethene, and TCE is greater than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the Far Field exposure area is 1.8, which is greater than the regulatory the EPA and WAC 173-340 target HI of 1.0. No individual COPCs were reported with a hazard quotient greater than 1.0.

The individual ELCR value associated with arsenic is within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The 90th percentile value of 4.3 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

The individual ELCR value associated with tributyl phosphate is within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. Tributyl phosphate does not originate from a 200-PO-1 OU source instead it originates from the 618-10 burial ground, therefore it is not considered to be a contributor to risk or HI.

Antimony is not considered a contributor to the HI. As discussed in the previous section, the analytical method used to measure antimony is not considered adequate for measuring its presence.

#### *6.7.1.3 River Exposure Area*

The cumulative ELCR for the river exposure area is $1.5 \times 10^{-4}$ for nonradiological COPCs and $8.6 \times 10^{-5}$ for radiological COPCs which is greater than the WAC 173-340-708 cumulative risk threshold of $1 \times 10^{-5}$ for multiple hazardous substances and greater than the EPA upper target risk threshold of $1 \times 10^{-4}$. Individual ELCRs associated with carbon tetrachloride, technetium-99, and tritium are within the EPA range of $1 \times 10^{-4}$ to $1 \times 10^{-6}$. The cumulative risk for carbon tetrachloride is less than the WAC 173-340 cumulative risk threshold of $1 \times 10^{-5}$. The HI for the river exposure area is 0.75 which is less than the regulatory the EPA and WAC 173-340 target HI of 1.0.

Although the individual ELCR value associated with arsenic is greater than the EPA's regulatory target risk threshold of $10^{-4}$ and the HQ is greater than 1 the 90th percentile value of 6.8 µg/L is considered to be within the range of naturally occurring concentrations. Therefore, arsenic is not considered to be a contributor to risk or HI.

## 6.8 Comparison of Native American and EPA Tap Water Results Risk Estimates

A summary of the risk estimates and hazard indices for each of the Native American Scenarios and the EPA tap water scenario is provided in Table 6-28. Results are ingestion, dermal contact, and inhalation of volatiles during household activities.

Exposure parameters for the Native American exposure scenarios and the EPA tap water scenario differ in exposure frequency (Native American 365 day/yr; EPA tap water 350 day/yr), exposure duration (Native American 70 years; EPA tap water 30 years), drinking water ingestion rate (Native American 4 L/day; EPA tap water 2 L/day), and inhalation rate (CTUIR 25 $m^3$/day, Yakama Nation 26 $m^3$/day; EPA tap water 20 $m^3$/day. As a result, EPA tap water scenario has a lower total ELCR and HI than the Native American exposure scenarios.

The total ELCR for the Near Field exposure area for the CTUIR and Yakama Nation exposure scenarios are $8.0 \times 10^{-4}$ and $3.4 \times 10^{-3}$, respectively. The total ELCR for the EPA Tap Water scenario is $7.1 \times 10^{-4}$. The primary contributors to risk for the Native American exposure scenarios are chloroform, iodine-129, strontium-90, technetium-99, TCE, and tritium. Chloroform is not a primary contributor to the EPA Tap Water scenario. The total HI for the Near Field exposure area is 15 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA Tap Water scenario is 3.3. Nitrate is the primary contributor to the non-cancer HI for the Native American and the EPA tap water exposure scenarios.

The total ELCR for the Far Field exposure area for the CTUIR and Yakama Nation exposure scenarios are $2.8 \times 10^{-3}$ and $2.8 \times 10^{-3}$ respectively. The total ELCR for the EPA Tap Water scenario is $2.4 \times 10^{-3}$. The primary contributors to risk for the Native American exposure scenarios are carbon tetrachloride, chloroform, iodine-129, strontium-90, technetium-99, tetrachloroethene, TCE, and tritium. Chloroform and strontium-90 are not primary contributors to the EPA Tap Water scenario. The total HI for the Far

Field exposure area is 8.5 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA Tap Water scenario is 1.8. Nitrate is the primary contributor to the non-cancer HI for the Native American exposure scenarios.

The total ELCR for the river exposure area for the CTUIR and Yakama Nation exposure scenarios are $1.0 \times 10^{-3}$ and $1.1 \times 10^{-3}$ respectively. The total ELCR for the EPA Tap Water scenario is $2.4 \times 10^{-4}$. The primary contributors to risk for the Native American exposure scenarios are carbon tetrachloride, chloroform, strontium-90, technetium-99, and tritium. Chloroform and strontium-90 are not primary contributors to the EPA Tap Water scenario. The total HI for the Near Field exposure area is 3.6 for both the CTUIR and Yakama Nation exposure scenarios. The HI for the EPA Tap Water scenario is 0.75.

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**Table 6-28. Comparison of Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations**

| | | Drinking Water Ingestion | | Inhalation of Volatiles | | Dermal Contact with Water | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Exposure Scenario** | **COPC Type** | **ELCR** | **Hazard Index** | **ELCR** | **Hazard Index** | **ELCR** | **Hazard Index** | **ELCR** | **Primary Contributors to Risk** | **Hazard Index** | **Primary Contributors to Hazard Index** |
| | | | | | | **Near Field Exposure Area** | | | | | |
| CTUIR | Nonradiological | 8.0E-04 | 14 | 4.8E-07 | <0.01 | 2.8E-06 | 0.89 | 8.0E-04 | Chloroform, I-129, **H3**, Sr-90, TCE, **Tc-99** | **15** | Nitrate |
| | Radiological | 2.3E-03 | -- | 1.7E-04 | -- | -- | -- | 2.4E-03 | | -- | |
| | Total | 3.1E-03 | 14 | 1.7E-04 | <0.01 | 2.8E-06 | 0.89 | 3.2E-03 | | **15** | |
| Yakama Nation | Nonradiological | 8.7E-04 | 14 | 4.8E-07 | <0.01 | 2.8E-06 | 0.89 | 8.7E-04 | Chloroform, I-129, **H3**, Sr-90, TCE, **Tc-99** | **15** | Nitrate |
| | Radiological | 2.3E-03 | -- | 1.8E-04 | -- | -- | -- | 2.5E-03 | | -- | |
| | Total | 3.2E-03 | 14 | 1.8E-04 | <0.01 | 2.8E-06 | 0.89 | 3.4E-03 | | **15** | |
| EPA Tap Water | Nonradiological | 2.1E-04 | 2.9 | 2.0E-07 | <0.01 | 1.3E-06 | 0.36 | 2.1E-04 | I-129, **H3**, Sr-90, TCE, **Tc-99** | **3.3** | None |
| | Radiological | 4.5E-04 | -- | 5.6E-05 | -- | -- | -- | 5.0E-04 | | -- | |
| | Total | 6.5E-04 | 2.9 | 5.6E-05 | <0.01 | 1.4E-06 | 0.38 | 7.1E-04 | | **3.3** | |
| | | | | | | **Far Field Exposure Area** | | | | | |
| CTUIR | Nonradiological | 4.4E-04 | 8.4 | 6.7E-07 | <0.01 | 1.7E-05 | 0.11 | 4.6E-04 | Chloroform, Carbon tetrachloride, I-129, **H3**, Sr-90, PCE, TCE, Tc-99 | **8.5** | Nitrate |
| | Radiological | 2.1E-03 | -- | 1.9E-04 | -- | -- | -- | 2.3E-03 | | -- | |
| | Total | 2.6E-03 | 8.4 | 1.9E-04 | <0.01 | 1.7E-05 | 0.11 | 2.8E-03 | | **8.5** | |
| Yakama Nation | Nonradiological | 4.8E-04 | 8.4 | 6.7E-07 | <0.01 | 1.6E-05 | 0.10 | 5.0E-04 | Chloroform, Carbon tetrachloride, I-129, **H3**, Sr-90, PCE, TCE, Tc-99 | **8.5** | Nitrate |
| | Radiological | 2.2E-03 | -- | 1.9E-04 | -- | -- | -- | 2.4E-03 | | -- | |
| | Total | 2.6E-03 | 8.4 | 2.0E-04 | <0.01 | 1.6E-05 | 0.10 | 2.8E-03 | | **8.5** | |
| EPA Tap Water | Nonradiological | 1.1E-04 | 1.7 | 6.7E-07 | <0.01 | 1.7E-05 | 0.11 | 1.3E-04 | Carbon tetrachloride, I-129, **H3**, PCE, TCE, Tc-99 | **1.8** | None |
| | Radiological | 2.1E-03 | -- | 1.9E-04 | -- | -- | -- | 2.3E-03 | | -- | |
| | Total | 2.2E-03 | 1.7 | 1.9E-04 | <0.01 | 1.7E-05 | 0.11 | 2.4E-03 | | **1.8** | |
| | | | | | | **River Exposure Area** | | | | | |
| CTUIR | Nonradiological | 5.9E-04 | 3.6 | 3.7E-07 | <0.01 | 2.3E-06 | 0.02 | 6.0E-04 | Chloroform, Carbon tetrachloride, **H3**, Sr-90, Tc-99 | **3.6** | None |
| | Radiological | 3.8E-04 | -- | 3.2E-05 | -- | -- | -- | 4.2E-04 | | -- | |
| | Total | 9.8E-04 | 3.6 | 3.3E-05 | <0.01 | 2.3E-06 | 0.02 | 1.0E-03 | | **3.6** | |
| Yakama Nation | Nonradiological | 6.4E-04 | 3.6 | 3.7E-07 | <0.01 | 2.3E-06 | 0.02 | 6.5E-04 | Chloroform, Carbon tetrachloride, **H3**, Sr-90, Tc-99 | **3.6** | None |
| | Radiological | 3.9E-04 | -- | 3.4E-05 | -- | -- | -- | 4.3E-04 | | -- | |
| | Total | 1.0E-03 | 3.6 | 3.4E-05 | <0.01 | 2.3E-06 | 0.02 | 1.1E-03 | | **3.6** | |
| EPA Tap Water | Nonradiological | 1.5E-04 | 0.74 | 1.5E-07 | <0.01 | 1.1E-06 | 0.01 | 1.5E-04 | Carbon tetrachloride, **H3**, Tc-99 | **0.75** | None |
| | Radiological | 7.6E-05 | -- | 1.1E-05 | -- | -- | -- | 8.6E-05 | | -- | |
| | Total | 2.3E-04 | 0.74 | 1.1E-05 | <0.01 | 1.1E-06 | 0.01 | 2.4E-04 | | **0.75** | |

**Table 6-28. Comparison of Risk Estimates and Hazard Indices for the CTUIR, Yakama Nation, and EPA Tap Water Equations**

| | | Drinking Water Ingestion | | Inhalation of Volatiles | | Dermal Contact with Water | | Total | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Exposure Scenario** | **COPC Type** | **ELCR** | **Hazard Index** | **ELCR** | **Hazard Index** | **ELCR** | **Hazard Index** | **ELCR** | **Primary Contributors to Risk** | **Hazard Index** | **Primary Contributors to Hazard Index** |

Notes:

Bolded COPCs indicate that the individual ELCR is greater than $1 \times 10^{-4}$ or has a hazard quotient greater than 1.

COPC = contaminant of potential concern
ELCR = excess lifetime cancer risk
EPA = U.S. Environmental Protection Agency
H3 = tritium
I-129 = iodine-129
PCE = tetrachloroethene
Sr-90 = strontium-90
Tc-99 = technetium-99
TCE = trichloroethene

# 7 Summary and Conclusions

Historical site conditions and activities conducted to complete the 200-PO-1 Groundwater RI were evaluated to support preparation of this RI report. The BRA was performed by comparing calculated EPCs to ARARs (federal and State of Washington) established for protection of HHE. The conclusion of the BRA is that groundwater contamination levels exceed ARARs, and a basis is established for further evaluation within the CERCLA FS process. The risk evaluation performed for this RI was limited to assessment of contaminants currently in groundwater within the OU and did not consider future contaminant contribution from sources within the overlying vadose zone.

## 7.1 Summary

This RI report presents the results from implementation of the 200-PO-1 RI/FS Work Plan (DOE/RL-2007-31), which includes information generated as part of the ongoing Hanford annual groundwater monitoring program.

The 200-PO-1 Groundwater OU extends from the 200 East Area to the Columbia River and contains groundwater contaminant plumes resulting from liquid waste disposal operations at the PUREX B Plant Facilities from 1943 to 1995. In 1993, AAMSRs provided significant characterization information that supported the preparation of the RFI and CMS for the 200-PO-1 Groundwater OU in 1996 and 1997. The historical activities that contributed to the observed groundwater contamination are summarized in Chapter 1 of this report.

The CMS evaluated remedial actions for the iodine-129 and tritium plumes, which resulted in the selection of ICs with groundwater monitoring actions being conducted to present day. Tri-Party Agreement negotiations and groundwater decision strategies in 2006 identified the need for the evaluation of recent monitoring and characterization data that would supplement the RFI and CMS reports in support of a final 200-PO-1 OU remedial decision. Field investigations and a BRA were conducted in 2008 and 2009 in accordance with the 200-PO-1 RI/FS Work Plan (DOE/RL-2007-31). To provide sufficient data for conducting a BRA, 175 existing wells and 11 aquifer tubes were selected for sampling in the 200-PO-1 Groundwater OU. Groundwater analytical data collected over the past five years were identified to describe current conditions for the BRA.

The geological and hydrological conditions observed (described in Chapter 3) during this RI are generally consistent with previous understanding of the site. The investigation activities produced complementary information that helps to refine the understanding of site conditions and those areas needing further evaluation in the CERCLA FS process.

The observed nature and extent of groundwater contamination points to some contaminants (e.g., iodine-129, tritium, and nitrate) being broadly dispersed across the OU in definable plumes, while others (e.g., uranium, strontium-90, technetium-99, and chlorinated solvents) are found in relatively small, isolated areas of contamination. Figure 7-1 shows the inferred distribution of groundwater contaminants in the 200-PO-1 Groundwater OU.

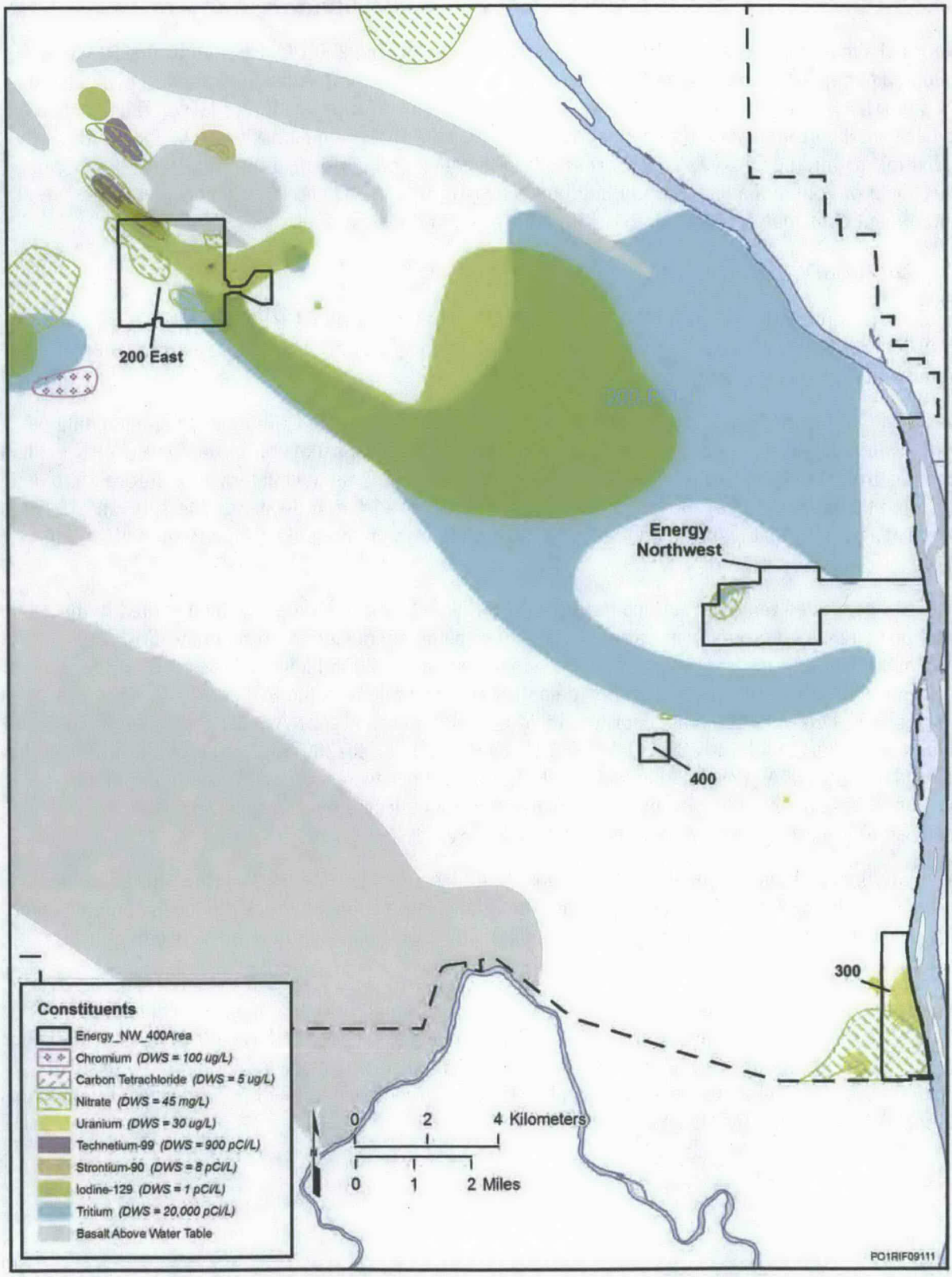


**Figure 7-1. Major Groundwater Plumes in the Hanford Central Plateau**

Groundwater within the Hanford Central Plateau, specifically within the 200-PO-1 Groundwater OU, is a dynamic system that exhibits migration at varying rates across the OU. Computational fate and transport analysis was performed using a variety of computerized tools to estimate future groundwater contaminant concentrations at selected locations within the 200-PO-1 Groundwater OU. The future contaminant concentrations were estimated and were used to calculate future effects on HHE by comparing the values against the PRGs used for the BRA.

The data reduction and analysis step included screening the results of the last five years of groundwater sampling and analysis to identify a final set of COPCs that were used in the BRA. This screening included evaluation of the 44 COPCs identified in the RI/FS work plan, as well as all other constituents reported as part of the ongoing groundwater monitoring activities within the 200-PO-1 Groundwater OU. COPC screening identified nine contaminants in groundwater within this OU that meet the criteria of final COPCs (as described in Chapter 6). Table 7-1 presents the results of this screening.

**Table 7-1. Summary of Final Groundwater COPCs**

| Metals | VOCs | Radionuclides |
|---|---|---|
| Uranium | Carbon Tetrachloride<br>Tetrachloroethene<br>Trichloroethene | Iodine-129<br>Strontium-90<br>Technetium-99<br>Tritium |
| | | **Non-radioactive Anions** |
| | | Nitrate |

Notes:
COPCs = contaminants of potential concern
VOCs = volatile organic compounds

The conditions observed during the RI support the identification of three distinct exposure areas for analysis: a Near Field area (in the general vicinity of the apparent contaminant source areas within the 200 East Area), a Far Field area (in the generally undeveloped downgradient area between the 200 East Area and the Columbia River), and a River area (located generally within one km [.6 mi] of the west shore of the Columbia River). The final COPCs that exceed groundwater standards in these exposure areas are summarized in Table 7-2; also presented are the years in which the modeling simulations predict regulatory compliance (absent any remedial action). The results in Table 7-2 conclude that further evaluation is needed for each of these exposure areas in a CERCLA defined FS.

**Table 7-2. Summary of Groundwater Conditions in the 200-PO-1 Operable Unit that Exceed Standards and Present a Basis for Feasibility Study**

| Exposure Area | Final COPC | Groundwater Standard[a] | Current Exceedance[b] | Year Maximum Projected Concentration Achieves Groundwater Standard |
|---|---|---|---|---|
| Near Field | Iodine-129 | 1 pCi/L | Yes | 2709 |
| Near Field | Technetium-99 | 900 pCi/L | Yes | 2034 |
| Near Field | Strontium-90 | 8 pCi/L | No | 2034 |

**Table 7-2. Summary of Groundwater Conditions in the 200-PO-1 Operable Unit that Exceed Standards and Present a Basis for Feasibility Study**

| Exposure Area | Final COPC | Groundwater Standard[a] | Current Exceedance[b] | Year Maximum Projected Concentration Achieves Groundwater Standard |
|---|---|---|---|---|
| Near Field | Tritium | 20,000 pCi/L | Yes | 2059 |
| Near Field | Trichloroethene | 0.49 µg/L | Yes | 2059 |
| Near Field | Nitrate | 45,000 µg/L/25,600 µg/L | Yes | 2309/2509 |
| Near Field | Uranium | 30 µg/L | No | 2209 |
| Far Field | Iodine-129 | 1 pCi/L | Yes | 2709 |
| Far Field | Tritium | 20,000 pCi/L | Yes | 2084 |
| Far Field | Carbon tetrachloride | 0.34 µg/L | Yes | 2034 |
| Far Field | Tetrachloroethene | 0.081 µg/L | Yes | 2059[c] |
| Far Field | Trichloroethene | 0.49 µg/L | Yes | 2059[d] |
| Far Field | Nitrate | 45,000 µg/L/25,600 µg/L | Yes | 2309/2509 |
| River | Tritium | 20,000 pCi/L | Yes | 2084 |
| River | Nitrate | 45,000 µg/L/25,600 µg/L | Yes | 2309/2509 |

Notes:

a. Standard Exceeded:

MCL = Maximum contaminant level established by the *Safe Drinking Water Act of 1974* groundwater cleanup

Standard = WAC 173-340-720

b. Current Exceedance:

Yes = Calculated groundwater exposure point concentration currently exceeds the applicable standard(s).

No = Calculated groundwater exposure point concentration does not currently exceed the MCL, WAC 173-340-708 risk threshold of 1 x 10-5 for multiple hazardous substances or the upper NCP threshold of $1 \times 10^{-4}$, or a noncancer hazard index of 1.

c. Represents the year that the $10^{-6}$ risk level is achieved.

d. Represents the year that the MCL of 5 µg/L is achieved.

*Safe Drinking Water Act of 1974*, 42 USC 300, et seq.

WAC 173-340-708, "Model Toxics Control Act—Cleanup," "Human Health Risk Assessment Procedures," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-708.

WAC 173-340-720, "Model Toxics Control Act—Cleanup," "Ground Water Cleanup Standards," *Washington Administrative Code*, Olympia, Washington. Available at: http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340-720.

COPC = contaminant of potential concern

## 7.2 Conclusions

The results from this RI present a need for an FS based on the presence of multiple COPCs in the 200-PO-1 OU groundwater at concentrations that exceed ARARs under conditions presented in the 200-PO-1 OU CEM and BRA.

Chapter 5 describes preliminary projections of changes in conditions over time that may affect the apparent risk. The conditions represent the effects of a no-action alternative and reflect the effects of attenuating processes as well as migration of COPCs. The estimates of future groundwater contaminant concentrations do not include potential effects of continuing contribution from any residual vadose zone contaminant sources.

Figure 7-1 shows the distribution of the major contaminant plumes at concentrations above the DWS in the upper part of the unconfined aquifer during FY 2008. A detailed location map with groundwater monitoring wells identified is provided in Appendix A.

Based on the observations and analysis conducted to meet the stated RI objectives, the following conclusions are presented in support of a final 200-PO-1 OU remedial decision:

- The observed groundwater contamination conditions confirm a basis for an FS.
- An FS is required.
- Sufficient data have been collected to support the preparation of an FS.

This report presents the following specific conclusions:

- The planned RI activities were sufficiently complete to support a baseline risk evaluation and assessment of the need for an FS.
- The following nine final COPCs that exceed groundwater standards were identified for the three exposure areas:
  - Iodine-129 (Near Field and Far Field)
  - Technetium-99 (Near Field)
  - Tritium (Near Field, Far Field, and River)
  - Nitrate (Near Field, Far Field, and River)
  - Strontium-90 (Near Field)
  - Trichloroethene (Near Field and Far Field)
  - Uranium (Near Field)
  - Carbon tetrachloride (Far Field)
  - Tetrachloroethene (Far Field)
  - Trichloroethene (Far Field)
- Potentially exposed human populations were identified on the Hanford Site within the 200-PO-1 OU. These groups represent the following workers that use groundwater from within the footprint of contamination associated with 200-PO-1 OU plumes for sanitary water supply:

- Energy Northwest's Columbia Generating Station where the facility's emergency backup water supply well is completed within the contaminated shallow unconfined aquifer of the 200-PO-1 OU.
- DOE contractor personnel at the FFTF/400 Area where the facility's sanitary water supply is provided by supply wells completed within the contaminated shallow unconfined aquifer of the 200-PO-1 OU.
- Operating personnel at LIGO where the facility's sanitary water supply is provided by a well completed deep within the confined basalt aquifer underlying the 200-PO-1 OU.

Of these three onsite human population groups, only one (personnel at the FFTF/400 Area) routinely uses contaminated groundwater for sanitary water supply. The water supply at this facility is routinely monitored to ensure that DWS for contaminants are not exceeded.

- The Columbia River adjacent to the east side of 200-PO-1 Groundwater OU is a discharge boundary for groundwater within the OU. Aquatic and benthic ecological receptors are potentially exposed to groundwater contamination associated with the 200-PO-1 OU in locations where the Columbia River forms the discharge boundary for the unconfined aquifer in the 200-PO-1 OU. Application of groundwater COPC concentrations from the selected near river monitoring wells provides a conservative EPC estimate for these receptors because that concentration does not include any mixing zone dilution that would be expected to occur with actual groundwater discharge to the river.
- Human populations downstream of the discharge point of groundwater from the 200-PO-1 OU into the Columbia River are potentially exposed to 200-PO-1 Groundwater OU contaminants. The Columbia River downstream of the Hanford Site is the source of municipal drinking water supply for the cities of Richland, Pasco, and Kennewick as well as a source of drinking water for the Columbia Generating Station. Monitoring of these drinking water supplies indicates that DWS are not exceeded for OU COPCs.

The contaminant plumes identified for the nine final COPCs in the 200-PO-1 OU present conditions that support the need for remedial action based on the present conditions. Fate and transport simulations were performed to evaluate the expected changes in contaminant plume conditions in the future. An FS is required for the 200-PO-1 OU to evaluate remedial alternatives for final COPCs within the three identified exposure areas.

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http://www5.hanford.gov/arpir/?content=findpage&AKey=D196000177.
http://www5.hanford.gov/arpir/?content=findpage&AKey=D196000178.
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(8)(d)(iii)(A), "Carcinogenic Potency Factor."

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(1)(a), "General Considerations."

(2)(a) through (c), "Potable Ground Water Defined."

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# Appendix A

# Plate Maps

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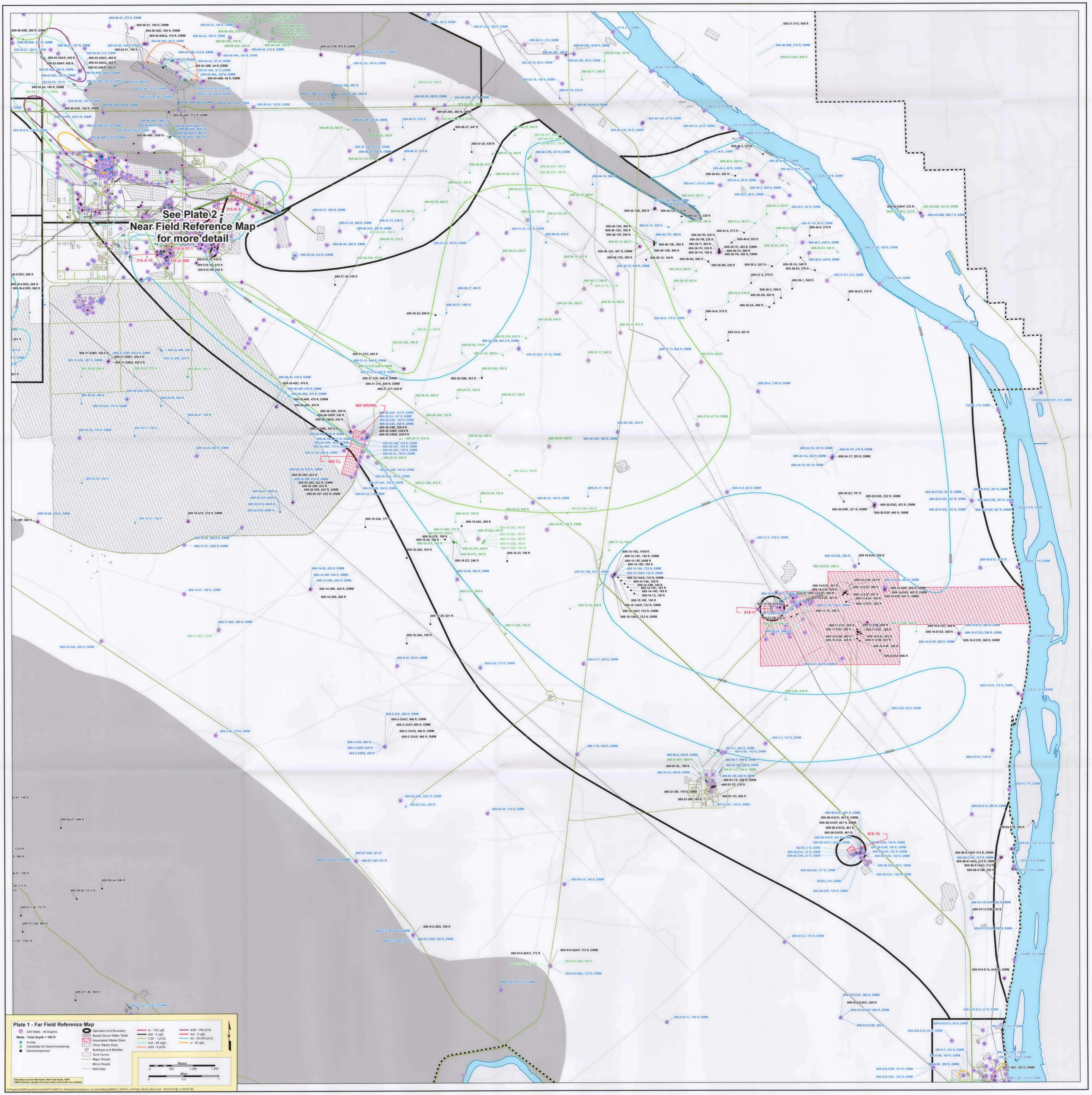
Plate 2 - Near Field Reference Map
GW Wells - All Depths
Wells - Total Depth > 150ft
In-Use
Candidate for Decommissioning
Decommissioned
Operable Unit Boundary
Basalt Above Water Table
Associated Waste Sites
Other Waste Sites
Buildings and Mobiles
Tank Farms
Major Roads
Service Roads
Railroads
cr - 100 ug/L
ctet - 5 ug/L
i129 - 1 pCi/L
no3 - 45 mg/L
sr90 - 8 pCi/L
tc99 - 900 pCi/L
tce - 5 ug/L
tri - 20,000 pCi/L
u - 30 ug/L
Meters
0 100 200 300 400 500
Feet
0 500 1,000 1,500
Well labels include Well Name, Well Total Depth, GWM
GWM indicates samples have been taken and results are available
O:\Projects\2009\OperableUnits\200PO1\090723_RemedialInvestigation_CummingsMaps\090923_200PO1_NearField_36x36_Rev1.mxd - 4/23/2010 @ 3:02:20 PM


See Plate 2 - Near Field Reference Map for more detail
600 NRDWL
600 CL
216-B-3
216-A-37-1
216-A-10
216-A-36B
618-11
618-10
Plate 1 - Far Field Reference Map
GW Wells - All Depths
Wells - Total Depth > 150 ft
In-Use
Candidate for Decommissioning
Decommissioned
Operable Unit Boundary
Basalt Above Water Table
Associated Waste Sites
Other Waste Sites
Buildings and Mobiles
Tank Farms
Major Roads
Minor Roads
Railroads
cr - 100 ug/L
ctet - 5 ug/L
i129 - 1 pCi/L
no3 - 45 mg/L
sr90 - 8 pCi/L
tc99 - 900 pCi/L
tce - 5 ug/L
tritl - 20,000 pCi/L
u - 30 ug/L
Meters
0 500 1,000 1,500
Miles
0 0.5 1
Well labels include Well Name, Well Total Depth, GWM
GWM indicates samples have been taken and results are available
O:\Projects\2009\OperableUnits\200\PO1\090723_RemedialInvestigation_CummensMaps\090923_200PO1_FarField_36x36_Rev2.mxd - 4/23/2010 @ 12:36:50 PM

# Appendix B

# Annotated Bibliography

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| Document # | Date | Authors | Title | Summary | Source Document | Background Site Descriptions (D); History (H); Processes (P); Regulatory (R) | Physical Characteristics: Geology (G); Hydrogeology (H); Climate (C); Ecology (E) | Contaminant Description(s): COPC (C); Source (S); Release (R); Plume (P); Investigation (I) | Analysis (A) & Modeling (M) | Risk Assessment | Alternatives Development |
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| BHI-00184, Rev.0 | 1995 | Bechtel Hanford, Inc.,<br><br>K.A. Lindsay | *Miocene- to Pliocene-Aged Suprabasalt Sediments of the Hanford Site, South-Central Washington* | This document describes the geologic characteristics of the Ringold Formation and presents a compilation of Ringold Formation geologic information for the Hanford Site and much of the surrounding area. The document is a very complete compilation of geologic interpretation across the Hanford site and therefore was considered a suitable foundation for the development of geologic model for the 200-PO-1 Operable Unit. Select cross-sections from this document were used to develop the geologic model (cross-sections and fence diagrams) for the RI report. | | | | | | | |
| BHI-01103, Rev. 0 | 1999 | Bechtel Hanford, Inc.<br><br>K. R. Kecht,<br>K. A. Lindsey<br>B. N. Bjornstad,<br>D. G. Horton<br>G. V. Last,<br>S. P. Reidel, | *Clastic Injection Dikes of the Pasco Basin and Vicinity* | | | | | | | | |
| BHI-01496, Rev. 0 | 2001 | Bechtel Hanford, Inc.,<br><br>B. Simpson,<br>R.A. Corbin,<br>S.F. Agnew | *Groundwater/Vadose Zone Integration Project Hanford Soil Inventory Model* | The purpose of this report was to make a first attempt to document the transition from conservative, extreme-value models to mass-balance-based models for understanding the distribution of 73 chemicals at 88 liquid waste disposal sites. Waste volume and inventory quantities for select cribs included: Hanford defined waste (HDW) transaction matrix, overall Hanford Site historical inventory from PUREX, solid waste burial grounds, graphite cores from production reactors, ancillary piping, and residues in canyon buildings.<br><br>A methodology was developed for four different types of liquid waste disposal sites, including: the specific retention cribs associated with ferrocyanide scavenging process, chemical sewer, plant cooling water, and the 241-BX-102 tank UPR. Quantitative inventory estimates with uncertainties were provided for these waste streams; the estimates were planned for a revision of the system assessment capability.<br><br>The Soil Inventory Model (SIM) was developed to perform a Monte Carlo simulation with 5,000 trials per input parameter for each soil waste site. The results are presented for the entire waste volume (solids and liquids). Both phases were computed individually for transport modeling. The data given most consideration during the creation of modeling parameters were in the following order: effluent volumes, uranium measurements, nitrate (and other large quantity chemicals) measurements, plutonium measurements, and derived values from first principles and operating documentation. For analytes with no data or with all data below detection limits, values were derived from the HDW model. | WMP-28945, Rev. 0, *Data Quality Objective Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/ Feasibility Study Process*, App. C | D, H, P | | C, S, R | M | | |

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| BNWL-B-360 | 1974 | Battelle Northwest<br><br>K.L. Kipp, R.D. Mudd | *Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973* | This document provides contoured groundwater elevation maps from 1944, 1951, 1955, 1960, 1965, 1970, 1971, 1972, and 1973, specific to the northwest corner of the 200 East Area. Information provided below is interpretative based on review of individual well monitoring data provided later in this table and select mobile contaminant concentrations discussed later in this table.<br><br>The 1944 contour map provides 10-ft contours across the Hanford Site. The overall contours indicate an easterly groundwater flow across the Site. Information appears to contradict a groundwater divide due to a basalt ridge.<br><br>The 1951 contour map shows added additional contour intervals between the 390- and 400-ft intervals shown on the 1944 map. It appears that the artificial recharge at B Pond had caused the 390-ft contour to shift significantly eastward of the 200 East Area. Mounding can be seen beneath the B Pond in this map. The contouring in this map would suggest a very low gradient to the south in the BY Crib area. The 1955 contour map is similar to the 1951 map, except that the 393-ft elevation contours have increased to 395-ft contours and the southern contour has shifted hundreds of feet to the north (e.g., north of the 200 East Area). In addition, the mound beneath B Pond has subsided and flow appears to be more north-south than east-west.<br><br>The June 1960 contour map shows increased water elevations over 1955. The 395-ft elevation contour has increased to a 402-ft contour, and the contour is drawn in the area similar to the 1951 contour. The mound beneath B Pond has increased to 410 ft. The December 1960 contour map is similar to the June 1960 groundwater contour map, except that the 402-ft groundwater elevation contour has increased to 403 ft.<br><br>The January 1965 contour map shows increases in the water elevations from 403 ft to 405 ft near the Gable Mountain Pond. The mound at B Pond has declined from 410 to 405 ft since 1960. The March 1972 contour map shows an increase in water elevations beneath the B Pond Area from 405 ft in 1965 to 415 ft.<br><br>The 405-ft contour north of the BY Crib area has shifted northward, indicating a northerly flow in this area. This information is interpreted to demonstrate that groundwater flow through the Gable Butte/Gable Mountain Gap was not significantly impacted by contaminant releases due to the influence of the Gable Mountain Pond from 1958 to 1970. | WMP-28945, App. D | | H | | | | |
| CH2M-36342-FP, Rev. 0 | 2008 | M. N. Jaraysi | *Deep Vadose Zone Contamination Due to Releases from Hanford Site Tanks* | The focus of the first phase of the Hanford Single Shell Tank RCRA Corrective Action Program was to characterize the nature and extent of past Hanford single-shell tank releases, and to characterize the resulting fate and transport of the released contaminants. Most of these plumes are below 20 m, with some reaching groundwater (at 60 to 120 m below ground surface (bgs). | | H | | C, S | | | |

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| CP-15329, Rev. 0 | 2003 | M.E. Byrnes<br>B.A. Williams | *Data Quality Objectives Summary Report for Establishing a RCRA/CERCLA/AEA Integrated 200 West and 200 East Area Groundwater Monitoring Network* | The purpose of the DQO process was to assess the current groundwater monitoring well networks for the 200 West and 200 East areas. This assessment was needed to address changing contaminant plume conditions (e.g., plume migration) and to ensure that monitoring activities meet the requirements for remediation performance monitoring (i.e., *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* [CERCLA] monitoring), Site-wide surveillance monitoring to meet the requirements of DOE orders, and detection/assessment monitoring to meet the requirements of the *Resource Conservation and Recovery Act of 1976* (RCRA). This DQO Summary Report was prepared in support of DOE's Cleanup, Constraints, and Challenges Team process.<br><br>Because of the changing shape of the groundwater contaminant plume contours over time and changing programmatic needs, the 200 West and 200 East groundwater monitoring network is required to be periodically reevaluated. The objective of the groundwater CERCLA remediation performance monitoring program is to provide a routine assessment of the effectiveness of groundwater remediation activities within the 200-PO-1 Groundwater OU. The objectives of the Site-wide surveillance-monitoring program are as follows: (1) Determine baseline conditions of groundwater quality and quantity; (2) Characterize and define hydrogeologic, physical, and chemical trends in the groundwater system; (3) Identify existing and potential groundwater contamination sources; (4) Assess existing and emerging groundwater quality problems; (5) Evaluate existing and potential offsite impacts of groundwater contamination; (6) Provide data on which decisions can be made concerning land disposal practices and the management and protection of groundwater resources.<br><br>Finally, the objective of the RCRA detection program is to identify if TSD units are impacting groundwater quality. If impacts to groundwater are detected, the objective of the RCRA assessment program is to define the rate and extent of contaminant migration.<br><br>This DQO process identified the optimum number of groundwater wells to be monitored to meet these objectives and determined that a number of new groundwater wells needed to be installed. The identity of wells in the monitoring network, sampling frequency, the analyses to be performed, the detection limit requirements, and other analytical performance requirements (e.g., precision and accuracy) were defined in this document. The resultant groundwater monitoring network fulfilled the needs of the three major Hanford Site regulatory monitoring activities (CERCLA, RCRA, *Atomic Energy Act of 1954* [AEA]). | DOE/RL-2007-31, Rev. 0, *Remedial Investigation/Feasibility Study Work Plan for 200-PO-1 Groundwater Operable Unit* | | H | P | | | |
| D&D-27257, Rev. 0, REISSUE | 2006 | FH<br><br>G.T. Berlin | *Data Quality Objectives Summary Report for Nonintrusive Characterization of Bin 3A and Bin 3B Waste Sites in the 200-SW-2 Operable Unit* | COPCs are presented for 200-SW-2 OU. | SGW-34011, Rev. 0, *Data Quality Objectives Summary Report Supporting the 200-PO-1 Groundwater Operable Unit,* Table 1-3 | | | C | | | |
| D&D-28283, Rev. 0, Reissue | 2006 | FH<br><br>G.T. Berlin | *Sampling and Analysis Instruction for Nonintrusive Characterization of Bin 3A and Bin 3B Waste Sites in the 200-SW-2 Operable Unit* | Data are presented for Bin 3A and Bin 3B Waste Sites in the 200-SW-2 OU. | SGW-34011, Table 1-3 | | | C | | | |

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| DOE ORO 26744 (RPP-26744, Rev. 0) | 2005 | R. A. Corbin<br>B. C. Simpson,<br>M. J. Anderson,<br>W. F. Danielson<br>J. G. Field<br>T. E. Jones<br>C. T. Kincaid | *Hanford Soil Inventory Model, Rev. 1* | The Hanford SIM is an extension and enhancement of previous efforts to quantify contaminant inventories in the Hanford Site waste-storage tanks. In the 1990s, the Hanford Defined Waste Model was used to predict the contents of the single- and double-shell tanks at the Hanford Site. The data gathered as part of that modeling effort included fuel processed, chemical process knowledge, and waste transfer information.<br><br>The Hanford Defined Waste Model also made an initial attempt to define what was disposed to the ground. The SIM Rev. 1 effort provides more details of what went into specific waste sites other than the tanks and provides a more complete picture of these discharges. | DOE/RL-2007-31 | | | | M | | |
| DOE/EIS-0189 | 1996 | DOE and Ecology | *Final Environmental Impact Statement for the Tank Waste Remediation System, Hanford Site, Richland, Washington* | Presents an analysis of the impacts and risk of tank waste remediation alternatives. Includes site history, waste volumes, and modeled groundwater contamination migration over time for each alternative. | SGW-34011, Table 1-3 | H | | C | M | | |
| DOE/EIS-0222-F | 1999 | | *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement* | Presents an analysis of the impacts of Hanford Site operations and presents alternatives for Hanford Site land use. Includes site history and presents groundwater contamination migration projections at the Hanford Site for tritium, iodine, chromium, strontium. EPA et al., 1999, *Record of Decision: Hanford Comprhensive Land-Use Plan Environmental Impact Statement (HCP EIS)*, was issued for the preferred land use alternative. | SGW-34011, Table 1-3 | H | | | M | R | A |
| DOE/ORP-2005-01, Rev. 0 | 2006 | DOE/ORP | *Initial Single-Shell Tank System Performance Assessment for the Hanford Site* | Presents an initial analysis of the long-term impacts of residual wastes assumed to remain after retrieval of tank wastes and closure of the single-shell tank farms at the Hanford Site. | SGW-34011, Table 1-3 | | | | | R | |
| DOE/RL-89-28, Rev. 2 | 1994 | DOE/RL | *216-B-3 Expansion Ponds Closure Plan* | This document includes a SEPA Checklist and Closure Plan for the 216-B-3 Expansion Ponds, which consist of the 216-B-3A, 216-B-3B, and 216-B-3C Ponds. The Closure Plan includes information on the facilities, processes, waste characteristics, and groundwater monitoring results in addition to closure performance standards, activities and postclosure plan. | | D, H, P, R | G, H, C | I | A | | |
| DOE/RL-91-52, Rev. 0 | 1992 | DOE/RL | *U Plant Source Aggregate Area Management Study Report* | This report presents the results of an aggregate area management study (AAMS) for the U Plant Aggregate Area located in the 200 Areas. The study provides the basis for initiating RI/FS under CERCLA or under the RCRA Facility Investigations (RFI) and Corrective Measures Studies (CMS).<br><br>This report also integrates RCRA treatment, storage, or disposal (TSD) closure activities with CERCLA and RCRA past-practice investigations. | | D, H, P, R | G, H, C | C, S, R, I | A | | |

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| DOE/RL-92-04, Rev. 0 | 1993 | DOE/RL | *PUREX Source Aggregate Area Management Study Report* | See Section 3.3 for a summary of this document. The purpose of the PUREX AAMSR was to compile and evaluate the existing body of knowledge from within the 200 East Area to support DOE/RL-91-40, Rev. 0, *Hanford Past-Practice Strategy* ([DOE/RL, 1991).<br><br>This report provides the basis for initiating an RI/FS under CERCLA or an RFI/CMS under RCRA. This report also integrates RCRA TSD closure activities with CERCLA and RCRA past-practice investigations. This document describes the general site conditions (geology, hydrology, ecology, meteorology) and the demography. The major facilities within the aggregate area are presented with information on the processes and operational history.<br><br>The report lists waste disposal activities and the types of waste that were generated, as well as quantities of waste disposed to waste management units (if known). This report also identifies chemicals used or disposed of within the aggregate area that could be of concern regarding public health/environment.<br><br>A preliminary conceptual site model that summarizes the conceptual understanding of the aggregate area with respect to types and the extent of contamination is presented, along with exposure pathways and receptors. The report also describes the screening process for determining the relative priority of follow-up action at each waste management unit. Decisions were made regarding which strategy path(s) to pursue for further actions in this area. Twenty-five out of 90 units and unplanned releases were identified as high-priority units and assessed as candidates for IRMs. Twenty-five of the 90 units were recommended to undergo LFIs. Overall, an RI was recommended for the PUREX Plant Aggregate Area. | DOE/RL-2007-31 | H, P | G | C | | R | |
| DOE/RL-92-05, Rev. 0 | 1993 | DOE/RL | *B Plant Source Aggregate Area Management Study Report* | This report provides the basis for initiating an RI/FS under CERCLA or an RFI/CMS under RCRA. This report also integrates RCRA TSD closure activities with CERCLA and RCRA past-practice investigations.<br><br>This document describes the general site conditions (geology, hydrology, ecology, meteorology) and the demography. The major facilities within the aggregate area are presented with information on the processes and operational history. The report lists waste disposal activities and the types of waste that were generated, as well as quantities of waste disposed to waste management units. This report also identifies chemicals used or disposed of within the aggregate area that could be of concern regarding public health/environment.<br><br>A preliminary conceptual site model that summarizes the conceptual understanding of the aggregate area with respect to types and the extent of contamination is presented, along with exposure pathways and receptors. The report also describes the screening process for determining the relative priority of follow-up action at each waste management unit. Decisions were made regarding which strategy path(s) to pursue for further actions in this area.<br><br>The 216-B-5 Reverse Well was the only unit recommended for an ERA. Sixty-one of the 139 units were identified as high-priority waste management units and addressed as candidates for IRMs. Seventy-three of the 139 units and unplanned releases were recommended to undergo LFIs. Overall, an RI was recommended for the B Plant Aggregate Area. | DOE/RL-2007-31 | H, P | G | C | | R | |
| DOE/RL-92-18, Rev. 0 | 1993 | DOE/RL | *Semiworks Plant Source Aggregate Area Management Study Report* | Presents a compilation of the 200 East Semiworks Source Area and inventories of chemical and radiological waste for individual sites, including an analysis of which sites are likely to have contributed to groundwater contamination are presented in this document. | SGW-34011, Table 1-3 | H, P | G | C | | R | |

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| DOE/RL-92-19, Rev. 0 | 1993 | DOE/RL | *200 East Groundwater Aggregate Area Management Study Report* | This document is part of a comprehensive review of vadose zone waste sites and groundwater contamination in the 200 Areas that cut across the boundaries of 42 location-based OUs. Prior to 1985, the operational groundwater monitoring network was designed to monitor radionuclides and nitrates to observe the response of groundwater to the storage and disposal of radioactive waste in soil at the 200 Areas.<br>In 1985, the operational groundwater monitoring well network list of constituent was expanded to include other hazardous chemicals. There were 71 wells sampled in the 200-BP-5 OU. From 1988 to 1992, these wells were sampled to define the nature and extent of contamination from various waste sites. A list of COCs were derived for each of the sites which included 11 transuranics, 6 uranium isotopes, 51 fission products, 16 metals, 14 other inorganics, 18 volatile organics, and 23 semi-volatile organics. Plume maps were created for the contaminants that exceeded groundwater quality criteria.<br>Thirteen individual plumes were identified, which were associated with the following contaminants: arsenic, Cs-137, chromium, Co-60, cyanide, gross alpha, gross beta, nitrate, I-129, Pu-239/240, Sr-90, Tc-99, and tritium. The locations of the plumes are as follows: Arsenic: Four arsenic plumes were located in the 200-PO-1 OU. Cs-137: Cs-137 plume was centered around the 216-B-5 reverse well. Chromium:<br>Two of the three chromium plumes were located in the northwest portion of the 200 East Area. Co-60: The cobalt plume is located north of the 200 East Area. Cyanide: The one cyanide plume was located around the 699-50-53A well. Gross alpha: Two of the four gross alpha plumes were located to the north of the 200 East Area: one was located at the northern end of the BY Cribs, and the other was located at the 216-B-5 reverse well. The highest concentration was located at the BY Cribs. Gross beta: Four of the six gross beta plumes were located in the 200-BP-5 OU. Two of the plumes were located to the north of the 200 East Area. One of the plumes was located north of the BY Cribs and one of the plumes was located around the 216-B-5 reverse well. Nitrate:<br>The nitrate plume was wide spread across the 200 East Area, however, the highest concentrations were associated with the 699-50-53A well and the Gable Mountain Pond wells. I-129: The iodine plumes were mainly in the 200-PO-1 OU. One of the plumes extended from an apparent center of the 216-A-10 and 216-A-45 Cribs to the southern portion of the B Tank Farm. Pu-239/240: The plutonium plume is centered at the 216-B-5 reverse well. Sr-90: Two of the strontium plumes are located in the 200-BP-5 OU. One of the plumes is located at the 216-A-25 Gable Mountain Pond and the other was located at the 216-B-5 reverse well. Tc-99: The two technetium plumes were located in the 200-BP-5 OU. Both of the plumes were located to the north of the 200 East Area. Tritium: Two of the tritium plumes were located in the 200 East Area. One of the plumes was located to the north of the 216-B-3 Pond and the other plume extended over the central portion of the 200 East Area to the southeast boundary.<br>Organic compounds detected were reported in the 200-PO-1 OU; however, no plume maps were generated. This is due to contaminant plume mapping criteria which requires the contaminant to be reported in multiple-wells that are contiguous. A limited field investigation approach was identified for a number of contaminants within the 200 East Area, where further characterization was required to confirm plume extent and validate a conceptual model for risk assessment.<br>Recommendations from the process included the following: provide additional well locations in the confined aquifer, resolve areas where single detections of contaminants were found, further define plumes represented by only one well, refine aquifer and geochemical properties, determine potential for continuing releases from the vadose zone, investigate the hydraulic interconnection between the unconfined and confined aquifer, and model contaminant travel times to the Columbia River. | WMP-28945, App. D | H, P | G | C | | R | |
| DOE/RL-92-23, | 1992 | DOE/RL | *Hanford Site Groundwater* | This document provides the evaluation process and target population (e.g., specific well locations) used to determine natural background for groundwater. | WMP-28945, | | G | | | | |

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| Rev. 0A | | | *Background* | The target population for statistical evaluation consisted of an irregular shaped zone about 3.1 mi wide between Horn Rapids and Vernita Bridge. This area was considered upgradient from the influence of the Hanford Site waste management units. This document made statistical comparisons with major cations and anions. However, the document does not provide additional information to assess environmental restoration activities at the Hanford Site. An additional report (DOE/RL-96-61, *Hanford Site Background: Part 3, Groundwater Background* [DOE/RL, 1997]) was released, which provide overall constituent background levels. | App. D | | | | | | |
| DOE/RL-92-24, Rev. 3 | 1995 | DOE/RL | *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* | This document provides description on the various sediments at the Hanford Site. The major minerals and rock types found within the various lithologies are described. The various minerals are as follows: pyroxene, plagioclase, potassium feldspar, kaolinite, muscovite, biotite, orthoclase, and various placer minerals (e.g., apatite, rutile, garnet, epidote, tourmaline, and monazite). | WMP-28945, App. C | D | G | | | | |
| DOE/RL-94-136, Rev. 0 | 1995 | DOE/RL | *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1994* | This report presents the annual hydrogeologic evaluation of 19 RCRA facilities and one nonhazardous waste facility at the U.S. Department of Energy's (DOE's) Hanford Site. Although most of the facilities no longer receive dangerous waste, a few facilities continue to receive dangerous waste constituents for treatment, storage, or disposal. The 19 RCRA facilities comprise 29 waste management units. Nine of the units are monitored under groundwater quality assessment status because of elevated levels of contamination indicator parameters. The impact of those units on groundwater quality, if any, is being investigated. If dangerous waste or waste constituents have entered groundwater, their concentration profiles, rate, and extent of migration are evaluated. Groundwater is monitored at the other 20 units to detect leakage, should it occur. This report provides an interpretation of groundwater data collected at the waste management units between October 1993 and September 1994. Groundwater quality is described for the entire Hanford Site. Widespread contaminants include nitrate, chromium, carbon tetrachloride, tritium, and other radionuclides. | | D | H | I | A | | |
| DOE/RL-95-100, Rev. 1 | 1997 | DOE/RL | *RCRA Facility Investigation Report for the 200-PO-1 Operable Unit* | See Section 3.5 for a summary of this document. The RCRA Facility Investigation Report for the 200-PO-1 Operable Unit (DOE/RL 1997a) was prepared in support of the RFI/CMS process for the 200-PO-1 Groundwater OU. The RFI document was prepared in lieu of an RFI/CMS Work Plan since the EPA, Ecology, and the DOE agreed that sufficient data were available to prepare an RFI. The RFI report summarizes existing information on the 200-PO-1 Groundwater OU presented in the 200 East Groundwater and PUREX AAMSRs (DOE/RL-92-19 [DOE/RL, 1993c] and DOE/RL-92-04 [DOE/RL, 1993a]), contaminant specific studies, available modeling data, and groundwater monitoring data summary reports. The report presents contaminant information including particular COPCs for each waste site within the 200-PO-1 Groundwater OU, as well as the potential for contaminants from these waste sites to impact groundwater. Appendix A of the RFI presents the summary of the DQO process that was implemented during planning stages for the RFI/CMS. The results from the RFI convey that the groundwater associated with the 200-PO-1 Groundwater OU was impacted by operations at the PUREX and B Plants in the 200 East Area and waste disposal from the U Plant to the BC Cribs and Trenches in the 200 West Area. | DOE/RL-2007-31 | | | C | M | | |

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| DOE/RL-95-59, Rev. 0 | 1996 | DOE/RL | *200-BP-5 Operable Unit Treatability Test Report* | This report discusses various tasks that were completed in order to determine the nature and extent of groundwater contamination from areas (e.g., BY Cribs, B-5 reverse well, and Gable Mountain Pond) with contaminant concentrations (e.g., cesium, strontium, plutonium, and technetium) exceeding national groundwater drinking levels. This information was then used to develop a conceptual model and provide risk assessments to determine contaminant concentrations at core zone boundaries or potential future concentrations and transport outside of the core zone boundary. A hydrologic assessment was completed which included the following: (1) historical review of site operations and groundwater elevation changes and contaminant trends and distribution from the beginning of operations to the current time (mid-1990s); (2) geophysical surveys using high-resolution seismic reflection; (3) exploratory drilling and sampling; (4) water well monitoring; and (5) in situ flow and velocity tests. Uncertainty in the basalt structure to the north of the 200 East Area was not resolved. In addition, some of the groundwater flow interpretations are inconsistent with observations identified in this DQO process. Finally the conceptual model and transport mechanism for technetium may not be consistent with possible changing groundwater flow conditions. | WMP-28945, App. D | | | S | M | | |
| DOE/RL-95-73, Rev. 1 | 2002 | DOE/RL | *Operation and Maintenance Plan for the 300-FF-5 Operable Unit* | Data are presented for 618-10 and 618-11 Burial Grounds within the 300-FF-5 OU. | SGW-34011, Table 1-3 | H | | C | | | |
| DOE/RL-96-59, Draft A | 1996 | DOE/RL | *200 PO-1 Operable Unit Permit Modification* | This RCRA permit modification describes a proposed interim action for the 200-PO-1 Groundwater OU. The objectives of this corrective action are to limit human exposure to contaminated groundwater and to protect the Columbia River. This permit modification has been developed in accordance with the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology et al., 1989) and summarizes more detailed information available in other documents, such as the 200 East Groundwater AAMSR (DOE/RL-92-19 [DOE/RL, 1993c]) and DOE/RL-95-100 (DOE/RL, 1997a). This permit modification fulfills the M-15-25B Milestone for the 200PO-1 Groundwater OU. | DOE/RL-2007-31 | H | | | | | A |
| DOE/RL-96-61, Rev. 0 | 1997 | DOE/RL | *Hanford Site Background: Part 3, Groundwater Background* | This document provides the background concentrations for the major and trace elements that can be used for risk assessments or remedial actions. The information was developed from a geochemical model, which built onto the hydrologic framework developed from DOE/RL-92-23 (DOE-RL, 1992). | WMP-28945, App. D | | | C | M | | |
| DOE/RL-96-66, Rev. 1 | 1997 | DOE/RL | *RCRA Corrective Measure Study for the 200-PO-1 Operable Unit* | The CMS report identified, screened, and developed potential remedial alternatives for three major contaminant plumes associated with the 200-PO-1 Groundwater OU (i.e., I-129, nitrate, and tritium). The report established objectives for evaluating potential corrective action measures for addressing contaminant plumes based on information from the RFI report and other supporting documents such as the 200 East Groundwater and PUREX AAMSRs (DOE/RL-92-19 [DOE/RL, 1993c] and DOE/RL-92-04 [DOE/RL, 1993a]). There was no further evaluation of the nitrate plume because the majority of the plume was at concentrations below the maximum contaminant level (MCL). The remedial action chosen for both I-129 and tritium was institutional control. The CMS recommended no human contact with contaminated groundwater until contaminant concentrations are reduced through natural attenuation. Restrictions on drinking water wells and providing alternate water supplies would eliminate the ingestion pathway. Access controls to the river, mainly signage and fencing, would be used to limit exposure as well. It was predicted in this report that within 50 years the concentrations of I-129 and tritium would be at or below levels of concern through natural attenuation. | DOE/RL-2007-31 | | | | | R | A |

| Document # | Date | Authors | Title | Summary | Source Document | Background Site Descriptions (D); History (H); Processes (P); Regulatory (R) | Physical Characteristics: Geology (G); Hydrogeology (H); Climate (C); Ecology (E) | Contaminant Description(s): COPC (C); Source (S); Release (R); Plume (P); Investigation (I) | Analysis (A) & Modeling (M) | Risk Assessment | Alternatives Development |
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| DOE/RL-96-81, Rev. 0 | 1997 | DOE/RL | *Waste Site Grouping for 200 Areas Soil Investigations* | The purpose of this document was to identify logical waste site groups for characterization based on criteria established in the 200 Areas Soil Remediation Strategy – Environmental Restoration Program. Specific objectives of the document included the following: (1) Finalize waste site groups based on the approach and preliminary groupings identified in the 200 Areas Soil Remediation Strategy – Environmental Restoration Program. (2) Prioritize the waste site groups based on criteria developed in the 200 Areas Soil Remediation Strategy – Environmental Restoration Program. (3) Select representative sites that best represent typical and worst-case conditions for each waste group. (4) Develop conceptual models for each waste group. Waste site group prioritization and representative site selection will support a more efficient and cost-effective approach to characterizing the 200 Area waste sites. The conceptual models developed in this document provide an initial prediction of the nature and extent of primary COPC and support the selection of representative sites and prioritization of groups. | DOE/RL-2007-31 | | | C | | | A |
| DOE/RL-98-28, Rev. 0 | 1999 | DOE/RL | *200 Areas Remedial Investigation/ Feasibility Study Implementation Plan – Environmental Restoration Program* | The Implementation Plan outlines the framework for implementing assessment activities in the 200 Area to ensure consistency in documentation, level of characterization, and decision making. The Implementation Plan also consolidates background information and other typical work plan materials, to serve as a single reference source for this type of information. This Implementation Plan does not provide detailed information about the assessment of individual waste sites or groups. Site-specific data needs, DQOs, data collection programs, and associated assessment tasks and schedules will be defined in subsequent group-specific (i.e., OU-specific) work plans. A common regulatory framework is established that integrates the RCRA, CERCLA, federal facility regulations, and Tri-Party Agreement (Ecology et al., 1989) requirements into one standard approach for 200 Area cleanup activities. The Implementation Plan also streamlines work plans that are required for each waste site group by consolidating background information providing a single referenceable source of this information. This allows the information in the group-specific work plans to focus on waste group or waste site-specific information. The background information includes an overview of the 200 Area facilities and processes, their operational history, contaminant migration concepts, and a list of COPCs. It also documents and evaluates existing information to develop a site description and conceptual model of expected site condition and potential exposure pathways. With this conceptual understanding, preliminary potential applicable or relevant and appropriate requirements, preliminary remedial action objectives, and remedial action alternatives are identified. The alternatives are broadly defined but represent potential alternatives that may be implemented at the site. The identification of potential alternatives helps ensure that the data needed to fully evaluate the alternatives are collected during the remedial investigation. The specific type and quality of data are to be defined through the site-specific DQOs and form the basis for the data collection programs. The 200 Areas strategy recognized the interrelationships between the various activities in the area and the need to integrate with other environmental restoration and Hanford Site projects/programs. The Implementation Plan describes the approach to interfacing with other programs and agencies, the integrated schedule of activities that addressed RCRA and CERCLA program requirements, and the public participation process. | DOE/RL-2007-31 | H | | C | | | |
| DOE/RL-98-72 | 1999 | DOE/RL | *Retrieval Performance Evaluation Methodology for the AX Tank Farm* | The retrieval performance evaluation methodology for the AX Tank Farm was prepared to develop methodologies and identify data needs required to support the DOE and Washington State Department of Ecology decisions. The retrieval performance evaluation uses the AX Tank Farm as a basis for demonstrating a decision tool that supports waste retrieval and tank farm closure decisions. Three strategies were developed to support a comparison of the performance of waste retrieval and tank closure options. In addition to developing strategies, an uncertainty and sensitivity analysis was conducted for the tank farm system and is presented in this document. | DOE/RL-2007-31 | | | | A | | A |

| Document # | Date | Authors | Title | Summary | Source Document | Background Site Descriptions (D); History (H); Processes (P); Regulatory (R) | Physical Characteristics: Geology (G); Hydrogeology (H); Climate (C); Ecology (E) | Contaminant Description(s): COPC (C); Source (S); Release (R); Plume (P); Investigation (I) | Analysis (A) & Modeling (M) | Risk Assessment | Alternatives Development |
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| DOE/RL-99-07, Rev. 0 | 2000 | DOE/RL | *200-CW-1 Operable Unit RI/FS Work Plan and 216-B-3 RCRA TSD Unit Sampling Plan* | This Work Plan provides the details for characterizing chemical, radiological, and physical conditions in soil at four selected waste sites in the 200-CW-1 OU. It also identifies preliminary remedial action alternatives that are likely to be considered for remediation of the OU. The preliminary remedial alternatives will be further developed and agreed to in the FS/Closure Plan, the proposed permit modification, and the eventual ROD and the Hanford Facility RCRA Permit Modification for this OU. | DOE/RL-2007-31 | | | | A | | A |
| DOE/RL-99-07, Rev. 0 | 2000 | DOE/RL | *200-CW-1 Operable Unit RI/FS Work Plan and 216-B-3 RCRA TSD Unit Sampling Plan* | This document describes the waste sent to 200-CW-1 representative waste sites (216-A-25 Gable Mountain Pond, 216-B-2-2 Ditch, 216-B-3 Main Pond, and 216-B-3-3 Ditch) and analogous sites (e.g., 216-B-2-1 and -3 Ditches, 216-B-3-1 and -2 ditches, 216 B 59 Trench and retention basin, and 216-C-9 Pond analogous sites). The list of COCs for these innocuous liquid waste streams is as follows: Am-241, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, H-3, Np-237, Ni-63, Pu-238, Pu-239/240, Sr-90, Tc-99, Th-232, U-234, U-235, U-238, arsenic, barium, beryllium, cadmium, chromium, curium, lead, mercury, nickel, silver, selenium, vanadium, zinc, ammonia, chloride, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, sulfide, acetone, 1-butanol (butyl alcohol), 2-butanone (MEK), butylated hydroxyl toluene, carbon tetrachloride, chloroform (trichloromethane), decane, trichloromethane (methylene chloride), ethanol, halogenated hydrocarbons, propanol (isopropyl alcohol), toluene, 1,1,1-trichlorethane, 1,1,2-trichloroethane, normal paraffins, naphthalene, tributyl phosphate, kerosene, and PCBs.<br><br>The 216-B-3-3 Ditch is located in the north-central portion of the 200 East Area and was the source of B Plant cooling water and PUREX cooling water and chemical sewer waste from 1970 to 1994. This ditch received one UPR of 15 kg of cadmium nitrate in May 1977.<br><br>The 216-B-3 Pond is located east of the 200 East Area and was the source of cooling water and chemical sewer effluent from PUREX. Most of the effluent contained low concentrations of radionuclides and chemicals. The pond received three UPRs. One was an approximate 2,500 Ci of mixed fission products released to the 216-B-3-1 Ditch in 1964. Another release was associated with the 1,000 Ci strontium release to 216-B-2-2 Ditch in March 1970. The third release was associated with a 15 kg release of cadmium nitrate in 1977. | WMP-28945, App. C | | | C, S, R | | | |
| DOE/RL-99-66, Rev. 1, Re-issue | 2004 | DOE/RL | *Steam Condensate/Cooling Water Waste Group Operable Units RI/FS Work Plan; Includes: 200-CW-5, 200-CW-2, 200-CW-4, and 200-SC-1 Operable Units* | Data for 200-SC-1 sites are presented as well as 200-CW-2, 200-CW-4, and 200-CW-5. | SGW-34011, Table 1-3 | H | G | C | | | |

| Document # | Date | Authors | Title | Summary | Source Document | Background Site Descriptions (D); History (H); Processes (P); Regulatory (R) | Physical Characteristics: Geology (G); Hydrogeology (H); Climate (C); Ecology (E) | Contaminant Description(s): COPC (C); Source (S); Release (R); Plume (P); Investigation (I) | Analysis (A) & Modeling (M) | Risk Assessment | Alternatives Development |
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| DOE/RL-2000-43 | 2000 | DOE/RL<br>J.E. Mecca | *Review of Generation and Flow of Recycled Uranium at Hanford* | This document describes the assessment completed to address the extent of potential exposure to recycled uranium completed in the Uranium-Trioxide Plant. Prior to the start up of the Uranium Trioxide Plant, requirements were set to permit essentially direct physical handling of the final product. This measure drove decontamination processes with respect to plutonium, gross beta, and gamma radiation. It was recognized that subsequent processing at other plants might result in fractionation or concentration of either fission products or plutonium. A letter was provided with the requirements in 1951 and later revised in 1953. However, during this time, technetium was not considered. Analytical measurements from 1959 onward from receiving plants reported technetium values in the range from 3 to 12 ppm/g of uranium. The technetium was determined to be co-processed with the recovered uranium due to the solvent extraction process used to recover the uranium and the distribution coefficient (organic/aqueous phase) for technetium. Other contaminants discussed in this report included neptunium and plutonium. | WMP-28945, App. B | H, P | | C | | | |
| DOE/RL-2000-60, Rev. 0 | 2001 | DOE/RL | *200-PW-2 Uranium-Rich Process Waste Group Operable Unit RI/FS Work Plan and Process Waste RCRA TSD Unit Sampling Plan* | Data are presented on COPCs within 200-PW-2 and 200-PW-4. | SGW-34011, Table 1-3 | | | C, S | | | A |
| DOE/RL-2001-01, Rev. 0, Re-issue | 2004 | G.B. Mitchem<br>DOE/RL | *Plutonium/ Organic-Rich Process Condensate/Process Waste Group Operable Unit RI/FS Work Plan: Includes the 200-PW-1, 200-PW-3, and 200-PW-6 Operable Units* | Data are presented on COPCs within 200-PW-1, 200-PW-3, and 200-PW-6. | SGW-34011, Table 1-3 | | | C | | | A |
| DOE/RL-2001-65, Rev. 0 | 2002 | DOE/RL | *200-MW-1 Miscellaneous Waste Group Operable Unit RI/FS Work Plan* | This document describes the waste sent to 200-MW-1 representative waste sites and analogous sites (e.g., 216-B-4, 216-B-13, 216 B 61, and 216-C-2 analogous sites). The list of COCs for these miscellaneous process facilities' ventilation stack and sand filter source waste streams is as follows: Am-241, Cs-137, Co-60, Eu-152, Eu-154, Eu-155, I-129, H-3, Pu-238, Pu-239/240, Sr-90, Tc-99, U-234, U-235, U-238, cadmium, chromium, curium, lead, mercury, silver, cyanide, fluoride, nitrate, nitrite, phosphate, sulfate, acetone, 1-butanol (butyl alcohol), benzene, 2-butanone (MEK), cis-1,2-dichloroethylene, 1,1-dichloroethane, 1,2-dichloroethane, dichloromethane (methylene chloride), ethylbenzene, methyle isobutyl ketone (MIBK), n-butyl benzene, tetrachloroethylene (PCE), toluene, trichloroethylene (TCE), trans-1,2-dichloroethylene, 1,1,1-trichlorethane, xylene, normal paraffins, tributyl phosphate, and PCBs.<br><br>The 216-B-4 and 216-C-2 sites, based on estimated waste inventories received, the construction and effluent volume received may have the greatest risk of impact to the groundwater of the analogous sites listed. Wells 299-E27-5 (cross-gradient of 216-C-2) and 299-E24-8 (likely cross-gradient while B Pond was active) only covered part of the COCs. However, no significant concentrations of mobile contaminants (e.g., nitrate, technetium, and cobalt) were reported in these wells. | WMP-28945, App. C | | | C, S, R | | | |
| DOE/RL-2001-66, Rev. 0 | 2002 | DOE/RL | *Chemical Laboratory Waste Group Operable Unit RI/FS Work Plan: Includes* | Data are presented on COPCs within both 200-LW-1 and 200-LW-2. | SGW-34011, Table 1-3 | | | C | | | A |

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| | | | *200-LW-1 and 200-LW-2 Operable Units* | | | | | | | | |
| DOE/RL-2001-49 | 2003 | DOE/RL | *Groundwater Sampling and Analysis Plan for the 200-BP-5 Operable Unit* | This document provided a summary of the background for arriving at the 10 COCs for the groundwater within the 200-BP-5 OU: Cs-137, Co-60, cyanide, I-129, nitrate, Pu-239/240, Sr-90, Tc-99, tritium, and uranium. A discussion of the extent and contour maps and of these COCs is provided. Tritium, I-129, and nitrate contamination is explained as widespread in the 200 East Area and is associated with both B Plant and PUREX operations. The BY Cribs were important sources of Tc-99, cyanide, Co-60, and nitrate contamination associated with early releases and were the main contributors for plumes that moves to the northwest. WMA-B/BX/BY appears to have contributed nitrate, Tc-99, and uranium that have migrated from the vadose zone into groundwater. Monitoring in the vicinity of the 216-B-8 Crib indicates that it has contributed nitrate to the groundwater locally. WMA-C appears to have contributed Tc-99, nitrate, and low concentrations of cyanide to groundwater. Groundwater monitoring at the 216-B-62 Crib indicates that this crib was a contributor of uranium locally. | WMP-28945, App. D | | | C, S | | | |
| DOE/RL-2002-11, Rev. 1 | 2006 | | *300-FF-5 Operable Unit Sampling and Analysis Plan* | Data are presented for 618-10 and 618-11 Burial Grounds within the 300-FF-5 OU. | SGW-34011, Table 1-3 | | | S | A | | |
| DOE/RL-2002-39, Rev. 0 | 2002 | DOE/RL<br><br>B.N. Bjornstad | *Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin* | The purpose of this document is to define a standardized stratigraphic nomenclature for post-Ringold deposits based on regional stratigraphic and sedimentary facies observations. Sedimentary deposits disconformably overlying the Ringold Formation are differentiated on the basis of grain size, sedimentary structure, color, roundness, sorting, fabric, cementation, and/or relative basalt content. Descriptions of stratigraphic units as well as correlations between multiple stratigraphic nomenclatures were used in developing the geologic description for the 200-PO-1 Operable Unit. | | | | | | | |
| DOE/RL-2002-42, Rev. 0 | 2003 | DOE/RL | *Remedial Investigation Report for the 200-TW-1 and 200-TW-2 Operable Units (Includes the 200-PW-5 Operable Unit)* | This document provides all of the sampling results for the 200-TW-1 and 200 TW 2 RIs. Specific radionuclides were reviewed to determine the extent of migration in the vadose zone. The 216-B-7A and 216-B-38 waste sites were selected as representative sites for the other associated 200-TW-1 and 200-TW-2 OU waste sites. The associated waste sites included 216-B-8, 216-B-9, and 216-B-35 through 216-B-41. | WMP-28945, App. C | D | | C, S | | | |
| DOE/RL-2002-69, Draft A | 2003 | DOE/RL | *Feasibility Study for the 200-CW-1 and 200-CW-3 Operable Units and the 200 North Area Waste Sites* | This document describes the results of soil characterization sampling and future impacts based on various remedial alternatives for the 216-A-25 Gable Mountain Pond, 216-B-3 Pond, 216-B-2-2 Ditch, and 216-B-3-3 Ditch and their analogous sites. The distribution of contamination and the long-term effectiveness and permanence for groundwater protection was modeled for five remedial actions.<br><br>• 216-A-25 Pond and 216-B-3-3 Ditch: The risk assessment for groundwater protection of chemical COCs with no action concluded that groundwater protection standards were not exceeded. Under the maintain existing soil cover, institutional controls, and monitored natural attenuation alternative, these sites were determined to be protective of groundwater for radionuclides because there was no driving force and the contaminants are sorbed onto soils.<br><br>• 216-B-3: The risk assessment for groundwater protection of chemical and radionuclide COC with no action concluded that groundwater protection standards were not exceeded.<br><br>• 216-B-2-2 through 216-B-49: The risk assessment for groundwater protection of chemical COC with no action concluded that groundwater protection | WMP-28945, App. C | D | | | M | A | |

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| | | | | standards were exceeded for PCBs. Modeling results exceeded the 1,000-year timeframe for estimated groundwater impacts. The risk assessment determined that radionuclide COCs were less than groundwater protection requirements. The "remove and dispose" alternative was proposed due to PCBs.<br><br>The representative and analogous sites overlying the 200-BP-5 OU were determined to be protective of groundwater with the soil cover, institutional controls, and natural attenuation, except for 216-B-2-1 and 216-B-2-3, which were proposed with the more aggressive remove and dispose alternative. None of the sites appear to threaten groundwater during the immediate future while remedial measures are planned. | | | | | | | |
| DOE/RL-2002-68, Rev. 0 | 2003 | DOE/RL | *Hanford's Groundwater Management Plan: Accelerated Cleanup and Protection* | This document lays out a plan developed by the DOE, in conjunction with the EPA and the Washington State Department of Ecology, to accelerate cleanup. The goal is to return groundwater to its highest beneficial use where practicable or which will at least prevent further degradation. The previous baseline shows remediation beginning in 2008 and extending to 2024. The new accelerated schedules illustrated in this document show that the baseline will begin in 2004 and be completed by 2012. The document contains discussion of specific results that can be expected using the accelerated plan for cleanup. These results and expected dates of completion include the following: (1) Remediate high-risk wastes by 2011; (2) Shrink the contaminated areas by 2112; (3) Reduce recharge by 2012; (4) Remediate groundwater by 2012; (5) Evaluate groundwater monitoring needs (ongoing).<br><br>Plans to deal with waste sites close to the tank farms require further work and will depend greatly on the strategy employed to close the tanks. The regions selected for completion by 2012 avoid those areas immediately adjacent to tank farms until an integrated approach to waste site remediation and tank closure can be developed.<br><br>In addition to accelerated schedules for cleanup and groundwater protection, the document contains definitions and discussions of various proposed groundwater protection boundaries (e.g., core zone and outside the core zone). As part of the integrated accelerated plan, an area closure strategy for the Central Plateau is discussed.<br><br>When cleanup is implemented on an area-by-area basis, these coordinated efforts to control sources, implement remedial action, and assess and monitor impact are expected to place major portions of the Central Plateau into a condition of long-term stewardship monitoring starting in 2006. | DOE/RL-2007-31 | | | | | R | |
| DOE/RL-2003-04, Rev. 1 | 2005 | DOE/RL | *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* | The objective of this SAP is to provide groundwater data necessary to track the extent and concentration of groundwater contaminant plumes. The data will be used to meet the requirements for RI/FS scoping under CERCLA; 40 CFR 300.430(b), "Remedial Investigation/Feasibility Study and Selection of Remedy"; and Site-wide surveillance monitoring under the AEA.<br><br>This document describes groundwater sampling and analysis requirements for the 200-PO-1 Groundwater OU and specifies wells and aquifer sampling tubes to be monitored, constituents to be analyzed, and the frequency of sampling. This SAP organizes the wells by their proximity to the sources of the major contaminant plumes in the 200 East Area. Wells located near the plume sources are termed near-field wells, and wells farther from sources are far-field wells. The constituents that are analyzed and their respective schedules are reported in this document.<br><br>The rationale for selecting certain COPCs for sampling and analysis is explained in detail in PNNL-14049, *Data Quality Objectives Summary Report-Designing a Groundwater Monitoring Network for the 200-BP-5 and 200-PO-1 Operable Units* (PNNL, 2002). | DOE/RL-2007-31 | | | I | A | | |

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| DOE/RL-2003-64, Draft A, Re-issue | 2004 | DOE/RL | *Feasibility Study for the 200 TW-1 Scavenged Waste Group, the 200-TW-2 Tank Waste Group, and the 200-PW-5 Fission-Product Rich Waste Group Operable Units* | This document describes the results of soil characterization sampling and future impacts based on various remedial alternatives for the 216-B-5 reverse well, 216-B-7A&B Cribs, BX Trenches, BY Cribs, and 216-B-57 Crib and their analogous sites. The distribution of contamination and the long-term effectiveness and permanence for groundwater protection was modeled for five remedial actions. The FS described waste sites and associated contaminants as summarized below.<br><br>• 216-B-5 reverse well: Sr-90, Cs-137, uranium, Pu-239/240 were identified as major vadose zone and groundwater contaminants.<br><br>• 216-B-7A&B Cribs: Monitoring required as institutional control for cyanide, fluoride, nitrate, Tc-99, U-233/234/238, and Sr-90.<br><br>• 216-B-35 through 216-B-41 (BX Trenches): Depending on the final remedy, monitoring could be required for nitrate, nitrite, uranium, Tc-99, and isotopic uranium (e.g., U 233/234/238).<br><br>• 216-B-42 through 216-B-49 (BY Cribs): Depending on the final remedy, monitoring could be necessary for antimony, cadmium, cyanide, nitrate, uranium, Tc-99, Co-60, Ra-226, and isotopic uranium (e.g., U 233/234/238).<br><br>• 216-B-50 and 216-B-57: Possible future groundwater impacts were considered. Depending on the final remedy, groundwater monitoring could be necessary for Tc 99.<br><br>Based on other findings of the FS, the long-term effectiveness and permanence for groundwater protection for the next 150 years, regardless of the alternatives, are suspect for technetium. | WMP-28945, App. C | D | | C, S | M | | |
| DOE/RL-2004-18 | 2004 | DOE/RL | *Waste Control Plan for the 200-PO-1 Operable Unit* | This Waste Control Plan governs the management of IDW generated from groundwater well sampling; aquifer sampling-tube installation and seed sampling; aquifer testing; groundwater well installation and development; aquifer sampling-tube installation and development; well maintenance, decommissioning and alteration; water-level measurements (both manual and transducer); geophysical logging; screening analysis liquids; and equipment decontamination for the 200-PO-1 Groundwater OU investigations, as appropriate. The scope of this work for the 200-PO-1 Groundwater OU is further described in DOE/RL-2003-04 (DOE/RL, 2005a). | DOE/RL-2007-31 | | | S | | | |
| DOE/RL-2004-39, Draft A, Re-issue | 2004 | DOE/RL<br><br>R.G. Bauer, L.A. Brouillard, R.O. Gruebel, R.K. Methrin | *200-UR-1 Unplanned Release Waste Group Operable Unit Remedial Investigation/ Feasibility Study Work Plan and Engineering Evaluation/Cost Analysis* | Data are presented on 200-UR-1 COPCs. | SGW-34011, Table 1-3 | | | S | | | A |
| DOE/RL-2004-66, Draft A | 2005 | DOE/RL | *Focused Feasibility Study for the BC Cribs and Trenches Waste Sites* | Data are presented on COPCs within the BC Cribs for the 216-B-26 Trench, 216-B-46 Crib, and 216-B-58 Trench. | SGW-34011, Table 1-3 | | | C | | | |

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| DOE/RL-2004-66, Draft A | 2005 | DOE/RL | *Focused Feasibility Study for the BC Cribs and Trenches Area Waste Sites* | The purpose of this Feasibility Study is to develop and evaluate alternatives for remediation of the 28 waste sites in the BC Cribs and Trenches Area and to function as a supporting document to the proposed plan. This Feasibility Study refines preliminary potential applicable or relevant and appropriate requirements, remedial action objectives, and general response actions initially identified in DOE/RL-98-28 (DOE/RL, 1999a). An initial remedial alternative development activity provided the basis for developing a focused range of viable alternatives for the BC Cribs and Trenches Area waste sites. The alternatives considered in this Feasibility Study include a range of response actions (no further action; removal, treatment, and disposal; containment [capping]; and containment combined with limited "hot spot" removal [partial removal, treatment, and disposal]) that are appropriate to address site-specific conditions. | DOE/RL-2007-31 | R | | | | | A |
| DOE/RL-2005-61, Draft A | 2006 | DOE/RL | *Remedial Investigation Report for the 200-LW-1 (300 Area Chemical Laboratory Waste Group) and 200-LW-2 (200 Area Chemical Laboratory Waste Group) Operable Units* | Data are presented on COPCs for 216-S-20 and 216-Z-7 Cribs. | SGW-34011, Table 1-3 | | | S, I | | | A |
| DOE/RL-2005-62, Draft A | 2006 | DOE/RL | *Remedial Investigation Report for the 200-MW-1 Miscellaneous Waste Group Operable Unit* | Data are presented on 200-MW-1 COPCs. | SGW-34011, Table 1-3 | | | S, I | | | |
| DOE/RL-2005-73 | 2005 | DOE/RL | *Phase I Sampling and Analysis Plan for the 200-IS-1 and 200-ST-1 Operable Units* | Data are presented for 200-IS-1 and 200-ST-1. | SGW-34011, Table 1-3 | | | S, I | | | |
| DOE/RL-2007-18, Rev. 1 | 2008 | DOE/RL | *Remedial Investigation/ Feasibility Study Work Plan for the 200-BP-5 Groundwater Operable Unit* | This work plan presented the approach, tasks, and schedules associated with the RI/FS activities for the 200-BP-5 Groundwater OU. This document describes the OU setting and preliminary conceptual site model and provides an initial rationale for the RI/FS activities summarized in the document and detailed in the associated sampling and analysis plan included as an appendix to this document. | DOE/RL-2008-01, Rev. 0, *Hanford Site Groundwater Monitoring for Fiscal Year 2007* | D, H, P, R | G, H, C, E | I | | | |

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| DOE/RL-2007-20 | 2007 | DOE/RL | *Hanford Integrated Groundwater and Vadose Zone Management Plan* | This Integrated Groundwater and Vadose Zone Management Plan discusses the role of the Groundwater Remediation Project, remediation progress and current conditions, new technologies being implemented, and an integrated plan to accomplishing cleanup and returning groundwater to its highest beneficial use where practicable, and where this cannot be achieved, to prevent further groundwater degradation.<br><br>This document updates the 2003 groundwater management plan to reflect the progress DOE has made over the past few years and lays out next steps for addressing groundwater and vadose zone contamination. The groundwater project continues to have three major objectives: (1) take actions necessary to prevent degradation of the groundwater, (2) remediate groundwater to restore it to its highest beneficial use where practicable and protect the Columbia River, and (3) monitor groundwater to identify emerging problems and guide the remediation process.<br><br>This document describes the relationship of these elements and identifies the way they will be used to guide and achieve groundwater cleanup decisions. | DOE/RL-2008-01 | | | | | | |
| DOE/RL-2007-31, Rev. 0, Appendix A | 2008 | DOE/RL | "Sampling and Analysis Plan for Remedial Investigation and Characterization of the 200-PO-1 Groundwater Operable Unit" | This SAP was designed to complement the groundwater monitoring SAP (DOE/RL-2003-04) and intended to yield new information regarding groundwater flow rates, preferential pathways for contaminant migration, and contaminant mass transport. This SAP presents a multi-faceted program to supplement site-specific vadose zone characterization for the purpose of estimating future threats to groundwater quality from existing vadose zone contamination. | | D | G, H | C, S | | | |
| DOE/RL-2007-31, Rev. 0 | 2008 | DOE/RL | *Remedial Investigation/ Feasibility Study Work Plan for 200-PO-1 Groundwater Operable Unit* | This work plan describes the approach for conducting the RI/FS to support selection of a remedial alternative for the 200-PO-1 Groundwater OU. The approach includes data collection to support the RI/FS in both the "near-field" and "far-field" regions. | | D, H, P, R | G, H | C, P, I | | | |
| DOE/ORP-2008-01, Rev. 0 | 2008 | DOE/ORP | *RCRA Facility Investigation Report for the Hanford Single-Shell Tank Waste Management Areas* | This document includes characterization, research, and field data obtained throughout the Phase 1 investigation that is packaged within the Field Investigation Reports for Waste Management Areas A-AX, C and U combined with Field Investigation Reports previously submitted of the Phase 1 characterization for the Hanford Single-Shell Tank system in accordance with requirements of the Hanford Federal Facility Agreement and Consent Order Milestone M-45-55 due to Washington State Department of Ecology on January 31, 2008. This document also summarizes impacts from the Initial Single-Shell Tank Performance Assessment. | DOE/RL-2008-01 | R | | I | | | |
| EPA 520/6-78-007A | 1978 | EPA | *Radionuclide Interactions with Soil and Rock Media, Volume 1: Processes Influencing Radionuclide Mobility and Retention, Element Chemistry and Geochemistry, Conclusions and Evaluation* | This document reports the state of knowledge of how 19 radionuclides behave in soil rock media. The report discusses the processes influencing radionuclide mobility (e.g., solid-phase and solution species, ion exchange, diffusion, replacement reactions, physical transport and filtration, saturated effects, specific retention, and Kd). Based on this understanding; the report describes the transport observations for the following radionuclides from references throughout various world settings: cobalt, cerium, europium, iodine, americium, antimony, cesium, ruthenium, strontium, technetium, thorium, neptunium, plutonium, promethium, radium, tritium, uranium, and zirconium. | WMP-28945, App. C | | G | I | A | | |
| ERDA-1538 | 1975 | ERDA | *Final Environmental Statement Waste* | This document discusses the environmental impact for radioactive and non-radioactive materials released to the environment. Laboratory and field | WMP-28945, | | G | C, I | | | |

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| | | | *Management Operations: Hanford Reservation* | observations show that the bulk of plutonium in waste solutions near neutral pH is removed from the solution by sediments relatively close to the disposal point. Plutonium is adsorbed most effectively by high surface area, high cation exchange capacity sediments with little effect from the competing salts. The retention of Sr-90 solutions is removed by ion exchange and by precipitation as SrCo3 close to the source of disposal. Cesium sorbs within the first 15 ft. Antimony sorbs only on fine silt where higher clay contents exist. | App. C | | | | | | |
| GJO-HAN-18 | 1998 | DOE-GJO<br><br>S.E. Klos | *Vadose Zone Characterization Project at the Hanford Tank Farms C Tank Farm Report* | This report presents the results of an initial baseline characterization effort based on spectral-gamma logging in existing cased boreholes within the C Tank Farm. The report provides a review of historical documents and data including gross-gamma logs, drilling logs, groundwater monitoring information, geology, hydrology, tank leak documentation, and tank operations information. Three-dimensional visualizations of gamma-emitting contaminant plumes were developed, and figures derived from these visualizations are used to illustrate the probable extent of contamination in the shallow vadose zone.<br><br>Evidence was provided through geophysical surveying of 66 tank leak detection monitoring boreholes that radionuclides Cs-137 and Co 60 were generally present in vadose zone soils near the assumed leaking tanks C-101, C-110, and C-111. This report speculates that significant amounts of contamination near tanks C-104, C-105, C-106, C-108, and C-109 indicate possible leaks from cascade lines between tanks C-104, C-105, C-106, C-108, and C-109.<br><br>Three primary recommendations were made for the C Tank Farm. The recommendations were: (1) continued spectral-gamma monitoring for all the tanks, (2) well deepening for deep vadose zone (150 ft to groundwater) characterization, and (3) installation of boreholes near C-201 through C-204 for characterization of releases previously identified. In addition, it was recommended that the vadose zone soils be characterized for contaminants not addressed through spectral-gamma logging (e.g., anions, beta emitters, metals, etc.). | WMP-28945, App. C | H, P | | C, S, R3 | | | |
| GJO-HAN-28 | 1999 | DOE-GJO<br><br>P.D. Henwood | *Vadose Zone Characterization Project at the Hanford Tank Farms B Tank Farm Report* | This report presents the results of an initial baseline characterization effort based on spectral-gamma logging in existing cased boreholes within the B Tank Farm. The report provides a review of historical documents and data, including gross-gamma logs, drilling logs, groundwater monitoring information, geology, hydrology, tank leak documentation, and tank operations information. Three-dimensional visualizations of gamma-emitting contaminant plumes were developed, and figures derived from these visualizations are used to illustrate the probable extent of contamination in the shallow vadose zone.<br><br>Evidence was provided through geophysical surveying of 50 tank leak detection-monitoring boreholes that radionuclides Cs-137 and Co 60 were generally present in vadose zone soils near the assumed leaking tanks B-101, B-103, B-105, B-107, B-110, B-111, and B-112. Recommendations mainly were to continue spectral-gamma monitoring for all of the tanks on certain timeframes. | WMP-28945, App. C | H, P | | C, S, R, P | A | | |
| HNF-34880-FP, Rev. 0 | 2008 | P.M. Rogers,<br>Z.P. Walton,<br>G.H. Neider-Westermann | *Development of Vadose-Zone Hydraulic Parameter Values* | Several approaches have been developed to establish a relation between the soil-moisture retention curve and readily available soil properties. Those relationships are referred to as pedotransfer functions. This paper describes the rationale, approach, and corroboration for use of a nonparametric pedotransfer function for the estimation of soil hydraulic-parameter values at the Yucca Mountain area in Nevada for purposes of net infiltration. This approach, shown to be applicable for use at Yucca Mountain, is also applicable for use at the Hanford Site where the underlying data were collected. | | | | | | | |
| HNF-4869, Rev. 0 | 1999 | LHMC<br><br>D.A. Reynolds | *The Fate of Organics from Hot Semiworks in CR Vault* | This document discusses 25 organic wastes received from the 201-C Hot Semiworks Facility. Although no process descriptions are provided, it may be assumed the waste sites have received at least small quantities of each organic and would form the basis for Semiworks-specific potential COCs. The compounds included hexone, citric acid, normal paraffin hydrocarbon (e.g., | WMP-28945, App. A | | | C | A | | |

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| | | | | kerosene) tributyl phosphate, ethylenediamine tetra acetic acid (EDTA), and di-2-ethylhexyl phosphoric acid (D2EPHA). | | | | | | | |
| HW-10475 | 1944 | GE | *Hanford Engineer Works Technical Manual*, Sections A, B, and C | This document discusses the various separation processes that were completed for the refinement of plutonium. The 221-B Plant building created the following separation wastes: coating removal waste, metal waste, and first- and second-cycle wastes. The coating waste is a combination of the aluminum silicate jackets with trace amounts of tin, copper, and other heavy metals dissolved by sodium hydroxide and washwater containing nitric acid. The resulting solution was sufficiently alkaline for transfer to the 241 Building (e.g., B/BX/BY Tank Farms). Several radioactive contaminants were associated with this waste based on cooling requirements, which included strontium, yttrium, zirconium, cadmium, ruthenium, tellurium, iodine, cesium, barium, lanthanum, cerium, and praseodymium. The uranium in this process was described as uranyl nitrate [$UO_2(NO_3)_2$]. The metal waste is a combination of mixed fission products, uranyl nitrate hexahydrate ([$UO_2(NO_3)_2 + 6H_2O$] or UNH), various metals, some plutonium and various solutions (e.g., $HNO_3$, $H_2SO_4$, $H_3PO_4$, $BiPO_4$, $NaNO_2$, $NaNO_3$, NaOH, $Na_2CO_3$, and $H_2O$). This document concluded that no appreciable amount of hexavalent plutonium would be formed based on pilot and plant operations. The 224 Building was used as the concentrator building for the lanthanum-fluoride/bismuth-phosphate cross-over cycle. According to the plutonium flow sheet, the bismuth-phosphate cake was sent to this facility in a nitric acid solution with approximately 3 Ci of fission products. Phosphoric acid is added to aid in the solubility of bismuth phosphate. In order to ensure plutonium in an oxidized state, potassium permanganate is added. Hydrofluoric acid is added with a lanthanum salt solution consisting of lanthanum, water, and nitric acid to precipitate the insoluble fluoride radionuclides. The waste solution contained various nitrates (i.e., sodium, potassium, chromium, manganese, and ammonium), and acids (i.e., hydrofluoric, nitric, and phosphoric). After the waste solutions were neutralized, it was considered safe to send to the ground because it contained less than 0.001% of the total fission activity and about 4% of the product. Waste was first directed to 261-B-361 tank and later to 216-B-7A&B Cribs. The 216-B-361 tank was used to settle out solids prior to overflowing to the 216-B-5 reverse well. It was overfilled with jetted waste solution and then allowed to drain to the overflow pipe connecting to the reverse well. The 216-B-5 reverse well received waste overflow from the 216-B-361 tank. Cooling water from the jacket process vessels and metal storage was sent to the 216-2-1 Ditch (e.g., 216-B-2-1). The ditch was never lined and received up to 500,000 gal per shift during full operations. Hot laboratory sink waste is disposed to a dry well (e.g., 216-B-6) near the northwest corner of the 222 Building. | WMP-28945, App. A | P | | C | | | |

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| HW-17088 | 1950 | GE<br><br>R.E. Brown, H.G. Ruppert | *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington* | This document provides a history of waste disposal to the various bismuth-phosphate waste sites and discusses characterization activities to identify and determine contaminant distribution in both the vadose and saturated zones. In 1945, the 216-B-5 reverse well began receiving waste from the 224 Building and the 5-6W cell in 221-B Plant. On September 19, 1947, a water sample from a well north of B Tank Farm (e.g., 299-E33-18) indicated the presence of alpha activity in the groundwater 2,150 ft north of the 216-B-5 reverse well. It was determined that well 216-B-5 was drilled 10 ft into the groundwater. All waste was redirected to the 201-B tank crib (e.g., 216-B-7A&B). Eighty-two new wells were installed over the next 3+ years, and 11 of the new wells were completed around the 216-B-5 reverse well. Groundwater contamination within 4 years had migrated at least 2,500 ft to the southeast (299-E23-1); the average groundwater velocity was calculated at 500 ft/yr. The migrating COCs were identified as strontium, ruthenium, and zirconium. The water was mounded by the 216-2-1 swamp and the open drainage ditch. The groundwater mound created from these open ditches was considered a benefit in that it held 216-B-5 contaminants in place. The 216-B-8 Crib received 7,500,000 L of waste containing approximately 7 g of plutonium and 12 Ci of fission products between March 1948 and January 1950. Conclusions from the field and laboratory samples reported that Hanford soils are considered good to excellent for retention capacity of contaminants. The only notable exceptions were anions, ruthenium, the alkali metals, and uranyl ion. | WMP-28945, App. D | | | S | | | |
| HW-18700-DEL | 1951 | GE | *REDOX Technical Manual* | This document not only provided the process chemistry for the REDOX process, but it also provided the first criteria for effluent waste disposal to the ground, known as cribbing. The REDOX waste stream was determined to produce 476 g/L of uranium. It was also expected that the plutonium concentration would be approximately 10 ppb of uranium concentration (e.g., 0.476 µg/L). The cribbing criteria for radionuclide wastes to the soil column are explained in this document. The criteria were based on the adsorption of a large fraction of the radionuclides to soils in the soil column, decay of the short-lived radionuclides before they reach the river (e.g., 10 to 20 years), and dilution of the waste by the groundwater. The cribs from the REDOX process received redistilled condensate, building drainage, and hexone washes. The condensate carried over small concentrations of radioactive constituents in the vapor due to the vapor velocity exceeding the rate of settling. | WMP-28945, App. A | P | | S | | | |

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| HW-19140 | 1951 | GE | *Uranium Recovery Technical Manual* | The feed for the Uranium Recovery Plant consisted of metal waste from the bismuth phosphate and REDOX processes. The bismuth-phosphate metal waste stored in 241-BX/BY/C Tank Farms was dissolved and sent to the Tributyl Phosphate Plant (221-U Building). The metal waste consisted of the following: mixed fission products, uranyl nitrate hexahydrate ([$UO_2(NO_3)_2$ + $6H_2O$] or UNH), various metals, some plutonium, and various solutions ($HNO_3$, $H_2SO_4$, $H_3PO_4$, $BiPO_4$, $NaNO_2$, $NaNO_3$, NaOH, $Na_2CO_3$, and $H_2O$). The uranyl-nitrate solution was calculated to contain 59.2 g/L of uranium. Four waste streams (e.g., high-activity liquids, low-activity liquids, cooling water and steam condensate, and gaseous waste) were produced from the uranium recovery process. High-activity liquid wastes were from the acid scrub and TBP solvent waste were neutralized and sent to the tank farms, which included B/BX/BY. The low-activity wastes were sent to the 216-ER and 216-WR Cribs. The process cooling water and steam condensate were sent to ponds in the 200 West Area, and gaseous waste was sent to stacks. The high-activity wastes that are sent to the tank farms are decontamination column waste and solvent recovery column waste that has been neutralized and concentrated and contained the following: $H_3PO_4$, $Na_3PO_4$, $HNO_3$, $NaNO_3$, $NaHSO_4$, $Na_2SO_4$, $Fe(NH_4)_2(SO_4)_2$, $Fe(OH)_3$, $NH_2SO_3H$, $NH_4OH$, uranium or UNH, plutonium, mixed fission products, water, and trace amounts of NaCl and TBP. The specific gravity of the concentrated waste was 1.4. The low-activity waste sent to the 216-ER (e.g., 216-B-12 Crib) and 216-WR Cribs (e.g., 200 West Area cribs) was condensate from the waste concentrator. The product concentrator received uranium separated solution (e.g., UNH, $H_3PO_4$, $NA_3PO_4$, $HNO_3$, $NaNO_3$, $NaHSO_4$, $NaHSO_4$, $Na_2SO_4$, $Fe(NH_4)_2(SO_4)_2$, $Fe(OH)_3$, $NH_2SO_3H$, $NH_4OH$, plutonium, mixed fission products, water, and trace amounts of TBP) from the feed pre-heater. The 216-ER Crib received up to 100 gpm for up to 8 hr/day. | WMP-28945, App. A | P | | S | | | |
| HW-22955 | 1951 | GE | *Hot Semiworks Manual Part I* | This document provides a detailed description of the 201-C Facility and equipment, plus supporting facilities, all of which were designed to provide a large-scale test bed for the REDOX process under realistic radiological conditions. Three soil-column disposal sites were initially constructed for the plant: the 216-C-1 Crib, which received process condensates and process wastes; the 216-C-2 reverse well, which received ventilation system condensates; and the 216-C-3 leaching pit, which received wastes from the 276-C Solvent Handling Building. In addition, the foundation excavation for a planned 221-C bismuth-phosphate plant was used as a pond for cooling water discharges. In addition, a large holding tank (241-CX-70) was constructed to hold high-level wastes. | WMP-28945, App. A | P | | S | | | |

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| HW-23043 | 1951 | GE<br><br>K.J. Schneider | *Flow Sheets and Flow Diagrams of Precipitation Separations Process* | This report describes the precipitation separations process in effect on October 1, 1951, for the bismuth-phosphate process.<br><br>The neutralized metal waste solution composition was described as 132 g/L or 10.5% uranyl sodium carbonate and uranyl sodium phosphate, 9.7 g/L or 0.8% of nitrate, 24.4 g/L or 1.9% of sulfate, 25.5 g/L or 2.0% of phosphate, 83.2 g/L or 6.6% of sodium, and 78.2% water with a specific gravity of 1.25.<br><br>The neutralized first-cycle waste solution composition was described as 2.59 g/L or 0.24% bismuth, 0.030 g/L or 0.003% of cerium, 0.030 g/L or 0.003% of zirconium, 1.37 g/L or 0.13% of ferric, 0.16 g/L or 0.02% of chromium, 1.98 g/L or 0.18% of ammonium, 47.3 g/L or 4.3% of sodium, 4.35 g/L or 0.40% of silicon fluoride, 26.2 g/L or 2.4% of phosphate, 93.1 g/L or 8.5% of nitrate, 4.73 g/L or 0.44% of sulfate, and 83.4% water with a specific gravity of 1.09.<br><br>The neutralized second-cycle waste solution composition was described as 1.31 g/L or 0.12% bismuth, 1.82 g/L or 0.17% of ferric, 0.06 g/L or 0.006% of chromium, 1.71 g/L or 0.16% of ammonium, 36.7 g/L or 3.5% of sodium, 3.67 g/L or 0.35% of silicon fluoride, 23.0 g/L or 2.2% of phosphate, 61.3 g/L or 5.8% of nitrate, 3.61 g/L or 0.34% of sulfate, and 87.3% water with a specific gravity of 1.05.<br><br>The neutralization of the bismuth-phosphate precipitate waste solution composition (e.g., 224 Building) was described as 1.18 g/L or 0.11% bismuth, 0.17 g/L or 0.016% of chromium, 0.33 g/L or 0.031% of manganese, 1.29 g/L or 0.11% of oxalate, 0.12 g/L or 0.011% of ammonium, 0.49 g/L or 0.045% of lanthanum, 36.8 g/L or 3.4% of sodium, 8.53 g/L or 0.79% of potassium, 5.6 g/L or 0.5% of fluoride, 3.05 g/L or 2.8% of phosphate, 42.4 g/L or 3.9% of nitrate, 0.35 g/L or 0.032% of sulfate, and 90.75% water with a specific gravity of 1.08. | WMP-28945, App. B | P | | S | | | |
| HW-30652 | 1954 | GE<br><br>H.V. Clukey | *TBP Waste Disposal Project Criteria for Cribbing Scavenged RAW* | This document, written January 1954, discusses the criteria and recommendations for cribbing nickel ferrocyanide scavenging liquid waste based on test cribbing of approximately 260,000 gal of scavenged RAW supernant. Waste site selection was based on proximity to a tank farm containing metal waste and the lithology of the underlying soils. The 200 East Area was preferred over the 200 West Area due to the more permeable soils causing less horizontal migration. Waste site spacing (50 ft between centers in the north-south direction and 75 ft between centers in the east-west direction) was based on routine discharge rates of up to 100 gpm. Larger spacing requirements were proposed for higher discharge rate. Total release volume and liquid waste concentration were based on per square foot of subsurface ground area for sorption of contaminants. Maximum volumes and cesium and strontium concentrations were limited to 6,000 gal/ft$^2$ and 100 µCi/L with a ceiling of 2,000 Ci of each, respectively. Sampling requirements consisted of analysis of liquid waste from the discharge line at a frequency of at least one sample from each 50,000 gal cribbed. Each sample was to be analyzed for pH, Cs-137, and Sr-90. In addition, a combined aliquot from a specific tank was to be analyzed for pH, Cs-137, Sr-90, total beta, rare earths, yttrium, plutonium, and uranium. Finally, combined aliquot from every fifth specific tank was to be analyzed for pH, Cs-137, Sr-90, total beta, rare earths, yttrium, plutonium, uranium, Ru-106, Ce-144, and Sb-125. | WMP-28945, App. B | P | | S | | | |

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| HW-31000-DEL | 1955 | GE | *PUREX Technical Manual* | These documents (HW-36293, *Routine UR Plant Strontium Scavenging with $Ca(NO_3)_2$* [GE, 1955]; RHO-MA-116, *PUREX Technical Manual* [RHO, 1982 {1980}]; and WHC-SD-0487, *PUREX Technical Manual* [WHC, 1989]) present detailed descriptions of the plutonium-uranium extraction process and together provide insight as to how the process changed over time. Most waste sites associated with PUREX are in the 200-PO-1 Groundwater OU. In all variations of the PUREX process, following dissolution of the fuel rods in boiling nitric acid and removal of the cladding material, the dissolved uranium/plutonium/fission product/nitric acid solution was introduced at the middle of the HA solvent extraction column where plutonium and uranium were removed from the descending inorganic solution by a rising organic extractant and diluent. The residual inorganic was highly radioactive with fission products and highly acidic. The waste stream was collected out of the bottom of the HA column and, following chemical manipulations in a feed tank, was sent to either the E-F-11 or the E-F-6 waste concentrator, depending on the date of the process. The waste concentrators boiled off about 80% of the nitric acid, which was collected and liquefied in a condenser and prepared for reuse. The residual material was discharged to a holding tank in preparation for treatment to protect underground storage tanks. The highly radioactive, fission-product-rich stream was sent to the boiling waste 241-A and 241-AX Tank Farms. With cooling, precipitates containing significant quantities of fission products formed and sludge was generated. At the same time, a supernatant with reduced particulate or precipitable matter was generated and was also identified for use at 221-B. | WMP-28945, App. A | P | | S | | | |
| HW-31767 | 1954 | GE<br><br>T.F. Evans, R.E. Tomlinson | *Hot Semiworks REDOX Studies* | Twelve separate REDOX runs were made at the Hot Semiworks Facility before the plant was decontaminated and modified for PUREX process testing. Each run was discussed in a separate report, but is summarized in this document. The 216-C-1 Crib received 13.9 million L of water with 16.5 kg of uranium, 1.5 g of plutonium, and 328 Ci of beta-emitting fission products through June 1954. This includes wastewater from REDOX processing and cleanout water used in preparation for PUREX testing. | WMP-28945, App. A | P | | S | | | |
| HW-33591 | 1954 | GE<br><br>H.G. Ruppert, K.R. Heid | *Summary of Liquid Radioactive Wastes Discharge d to the Ground – 200 Areas July 1952 through June 1954* | This document reports the effluent disposal volume, major radionuclide concentrations, date of disposal, source of the effluent waste (e.g., 241-BX-110), pH of effluent, and trench name.<br><br>The first-cycle supernant for 216-B-35 through 216-B-41 are as follows:<br><br>• 216-B-35 received 254,380 gal from 241-BX-110 with a pH of 7.6. The concentrations for uranium, cesium, strontium, and plutonium were as follows: 920 pCi/L, 580 µCi/L, 1.9 µCi/L, and 0.028 µCi/L, respectively. The total activity for each is 8.86E-4 Ci, 558 Ci, 1.83 Ci, and 0.27 Ci, respectively.<br><br>• 216-B-36 received 467,500 gal from 241-BX-111 with a pH of 9.9. The concentrations for uranium, cesium, strontium, and plutonium were as follows: 480 pCi/L, 570 µCi/L, 3.5 µCi/L, and 0.011 µCi/L, respectively. The total activity for each is 8.5E-4 Ci, 1,008.6 Ci, 6.2 Ci, and 0.2 Ci, respectively.<br><br>• 216-B-37 received 1,134,375 gal from 241-B-107, 108 gal and 109 gal with a pH of 8.0. The concentrations for uranium, cesium, strontium, and plutonium varied for each of the tanks. The total activity for each is 3.2E-3 Ci, 3,078 Ci, 7.7 Ci, and 0.056 Ci, respectively.<br><br>• 216-B-38 received 397,375 gal from either 241-BY-106 or 241-BY-110 with a pH of 7.2. The concentrations for cesium and strontium were as follows: 4.2 µCi/L and 1,230 µCi/L, respectively. The total activity for each is 6.3 Ci and 1,850 Ci, respectively. 216-B-39 received 206,250 gal from 241-BX-112 with a pH of 8.7. The concentrations for uranium, cesium, strontium, and plutonium were as follows: 1.9E-3 µCi/L, 550 µCi/L, 15 µCi/L, and 0.11 µCi/L, respectively. The total activity for each is 1.5E-3 Ci, 429 Ci, 11.7 Ci, and 0.086 Ci, respectively. | WMP-28945, App. B | P | | S | | | |

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| | | | | • 216-B-40 received 298,375 gal from 241-BY-106 or 241-BY-110 with a pH of 7.4. The concentrations for cesium and strontium were as follows: 2.1 µCi/L and 250 µCi/L, respectively. The total activity for each is 2.37 Ci and 282 Ci, respectively.<br><br>The data are contradictory of Atlantic Richfield Hanford Company documents (e.g., ARH-231, *Hanford Low Level Waste Management Reevaluation Study* [ARH, 1967]), which provided different inventories with no explanation for the difference. In addition, it appears that RHO-CD-673, *Handbook 200 Areas Waste Sites* (RHO, 1980), made additional changes without explanation for the above inventories. Therefore, these inventories are chosen to best represent the waste streams to the BX Trenches. | | | | | | | |
| HW-36293 | 1955 | GE<br><br>R.J. Sloat | *Routine UR Plant Strontium Scavenging with $Ca(NO_3)_2$* | This document, written in April 1955, reported findings from using an additional scavenging process, calcium nitrate, to scavenge strontium in the Uranium Recovery Plant. Laboratory studies reported that the addition of calcium nitrate after the nickel sulfate addition provided the pH of the waste is controlled between 8 and 10 provided between four- to six-fold decontamination of strontium based on the temperature. | WMP-28945, App. A | P | | S | | | |
| HW-36411 | 1955 | GE<br><br>R.E. Brown, K.R. Holtzinger, J.R. Raymond | *Earth Sciences Waste Disposal Monitoring Activities* | This document concluded that sodium and nitrate were valuable tracers for direction of groundwater movement. However, extremely low concentrations of nonradioactive salts discharged to the 216-B-5 reverse well precluded the use of these ions for groundwater movement. Therefore, beta-gamma emitters were used, which indicated a slow eastward movement from the vicinity of the reverse well. | WMP-28945, App. D | | | | A | | |
| HW-36717 | 1955 | GE<br><br>W.W. Schulz | *Decontamination of Uranium Recovery Process Stored Wastes Interim Report* | This report, written in May 1955, discusses the results of various initial tests required by HW-37478, *Sampling of Scavenged Waste* (GE, 1955d), to evaluate the decontamination of cesium and strontium in UR wastes using potassium ferrocyanide and calcium nitrate. Samples were collected from six tanks (C-106, C-109, C-111, C-112, BX-108, and BX-109). Results indicated that the cribbing criteria were met for all wastes. It was noted that only 500 mL of supernant were collected from each of the tanks and that this volume was not representative of the tank due to stratification. Precipitate formation was also studied to determine if line plugging may occur from the scavenged wastes being transported by line. Analysis indicated that sodium, aluminum, and iron phosphate were precipitated as a phosphate at varying temperatures. Furthermore, it was found that when aluminum was present settling took longer for the precipitates.<br><br>Based on analysis, it was determined that 2 to 3 weeks of settling was sufficient using nickel ferrocyanide scavenging of stored wastes for a 750,000-gal tank. | WMP-28945, App. B | | | S | | | |

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| HW-37478 | 1955 | GE<br><br>H.V. Clukey | *Sampling of Scavenged Waste* | This document, written in June 1955, superseded the HW-30652 (GE, 1954b) report and provided revised sampling requirements prior to disposal of scavenged liquid effluent to cribs. Increased requirements consisted of a sample of the un-neutralized waste before addition of scavenging chemicals could be analyzed for alpha, beta, cesium, strontium, and phosphate ion. The phosphate ion was necessary for adequate adsorption of strontium in soil. Also, a sample of the neutralized waste with scavenging chemicals added was requested before the waste left the separations plant. The sample was to be collected after centrifuging and to be analyzed for the same constituents as before the scavenging chemical addition. In addition, 5 to 7 days after scavenging, addition of a detailed tank analysis was requested for crib disposal acceptance. Samples were to be collected of the supernant from 5-ft intervals throughout the tank. Samples containing sludge were allowed to be returned to the tank after noting the depth of the sludge. The analysis consisted of pH, total beta, Cs-137, and Sr-90. In addition, aliquots of each sample (for a specific tank) were to be combined and analyzed for pH, Cs-137, Sr-90, total beta, rare earths, yttrium, plutonium, uranium, Ru-106, Sb-125, zirconium-niobium, curium, phosphate ion, nitrate ion, and dissolved salts. Waste line samples were considered to be sufficient every 100,000 gal for scavenged first-cycle or TBP supernant discharged to the cribs. Each sample was to be analyzed for pH, Cs-137, and Sr-90. In addition, aliquots of each sample (for a specific tank) was to be combined and analyzed for pH, Cs-137, Sr-90, total beta, rare earths, yttrium, plutonium, uranium, Ru-106, Sb-125, phosphate ion, nitrate ion, and dissolved salts.<br><br>Another requirement included that the effluent being pumped be gamma-monitored to decrease the amount of precipitates discharged to the soil column. The pump was suspended in the supernant with a floating intake as well. By this process, sludge build up in the crib would be minimized and the early abandonment of the crib would be prevented.<br><br>It appears that these requirements began in March 1955. | WMP-28945, App. B | P | | S | | | |
| HW-38562 | 1955 | GE<br><br>H.J. Paas, K.R. Heid | *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separation Facilities Thru June 1955* | See HW-33591. | WMP-28945, App. B | P | | S | | | |

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| HW-38955 | 1955 | GE<br><br>R.J. Sloat | *In-Farm Scavenging Operating Procedure and Control Data* | This document was written in September 1955 and details the "in-farm scavenging" process at C Farm. This document provided the due diligence of the initial sampling required by HW-37478 (GE, 1955d). In addition, it provides a process flow sheet of the various scavengers.<br><br>Thirteen of the 200 East Area tanks on which scavenging studies were completed varied considerably in composition since they were produced under significantly different waste treatment conditions in the TBP Plant. Ten of the tanks were produced during the early period of TBP Plant operations before scavenging was employed. Five of these tanks (C-106, C-109, C-110, C-111, and B-112) contain significant amounts of cesium and strontium and, therefore, required nickel ferrocyanide (e.g., sodium ferrocyanide and nickel sulfate) scavenging and, in some cases, supplemental calcium nitrate scavenging (e.g., C-106 and C-109). Five of the tanks (BX-108, BX-109, C-106, C-108, and C-112) were filled during periods when nickel ferrocyanide scavenging process used a lower pH of 8 to 10 and contain strontium concentrations greater than cribbing criteria (1 µCi/mL). These wastes possibly required scavenging with both nickel ferrocyanide and calcium nitrate. Three of the tanks (BY-101, BY-102, and BY-103) were filled during periods when nickel ferrocyanide scavenging was employed in the TBP Plant. Although the cesium concentration in these supernants was low enough to permit cribbing, the strontium concentrations were too high. Therefore, these supernants only required calcium addition to reduce the strontium concentration to acceptable cribbing concentrations. In addition, this document also discussed the tanks that still required sampling. | WMP-28945, App. B | P | | S | | | |
| HW-42612 | 1956 | GE<br><br>C.W. Thorne, D.L. Reid, H.A. Treibu | *Cobalt-60 in Ground Water and Separations Plant Waste Streams* | This document discusses groundwater analytical results from the groundwater monitoring wells beneath and southeast of the BY Cribs. Groundwater results from wells proximal to 216-B-46 reported Co-60 within 5 months from disposal to 216-B-46 or dispersion from other BY Cribs. Within approximately one year, Co-60 was reported in significant concentration (e.g., 0.07 µCi/L) approximately 1,000 ft to the southeast (in well 299-E33-18) of the 216-B-3 Crib. | WMP-28945, App. D | | | S | A | | |
| HW-43066 | 1956 | GE<br><br>R.B. Abrams | *History: Metal Recovery Waste Scavenging Program* | This document summarizes the scavenging process changes for cesium and strontium that occurred from September 1954 to May 1956 for acceptable crib disposal of stored TBP waste.<br><br>According to this document, the scavenging began September 29, 1954. The purpose was to chemically treat cesium and strontium so bismuth-phosphate metal waste without most of the uranium from the tributyl phosphate process could be cribbed. The scavenging process initially consisted of the addition of potassium ferrocyanide [$K_4Fe(CN)_6$ $3H_2O$], NaOH, and nickel sulfate ($NiSO_4$). Laboratory soil-column studies were completed to determine the retention capacity and cribbing criteria for scavenged effluent. The criteria initially restricted cesium and strontium concentrations that exceeded 100 µCi/L in accordance with HW-30652 (GE, 1954b). In addition, the volume of disposal could not exceed 6,000 gal/ft$^2$ of ground surface in the crib (e.g., 5.4 million gal). The final criterion was that the total curies per crib of cesium and or strontium could not exceed 4,100 Ci (e.g., 200 µCi/L multiplied by 5.4 million gal). These criteria were to ensure that cesium and strontium would not exceed the 0.1 maximum groundwater permissible limits (e.g., 1.5E-5 and 80 pCi/L, respectively). In June 1955, the in-line discharge sampling was relaxed to one sample every 100,000 gal cribbed, as reported in HW-37478 (GE, 1955d).<br><br>One of the most important parts of the scavenging process was control of the pH. The optimum pH was 9, with an acceptable range from 8 to 10. Soil column studies reported a large drop in scavenged cesium for pH above 10 and a corresponding drop for scavenged strontium for pH below 8.<br><br>The transfer data for each tank are provided in a table in the back of this document. The table provides the tank number, transfer date, associated crib number, tank sample results, and crib line results.<br><br>The report also discusses the changes that occurred during the disposal process and findings that terminated the disposal of effluent waste to 216-B-42 | WMP-28945, App. B | P | | S | | | |

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| | | | | through 216-B-49. The basis for stopping the process was the detection of beta activity in the groundwater and confirmation of Cs-137 in December 1955. | | | | | | | |
| HW-43121 | 1956 | GE<br>H.V. Clukey | *Tabulation of Radioactive Liquid Waste Disposal Facilities* | This document details the LWDF and the associated waste source site with dates of release up to early 1956. The following bismuth-phosphate waste streams were described:<br>• 216-B-2: 221B cooling water and 284B water, April 1945<br>• 216-B-3: 221B cooling water and 284B water, April 1945<br>• 216-B-4: 291B stack drainage, April 1945 to August 1947<br>• 216-B-5: 224B 5-6 and cell drain, April 1945 to October 1947<br>• 216-B-6: 222B sinks, April 1945 to November 1949<br>• 216-B-7: 224B, 221B 5-6, and 201-4 tank overflow, October 1946 to present<br>• 216-B-8: 221B 2 cycle and 5-6, March 1945 to May 1954<br>• 216-B-9: 221B 5-6, August 1948 to July 1951<br>• 216-B-10: 222B and 292 sinks, December 1949 to June 1952<br>• 216-B-11: 242B evaporator condensate, December 1951 to November 1954 | WMP-28945, App. B | P | | S | | | |
| HW-44784 | 1956 | GE | *Radioactive Contamination in Liquid Wastes Discharged to Ground at Separations Facilities Through June 1956* | These document reports the effluent disposal volume, major radionuclide concentrations, date of disposal, source of the effluent waste (e.g., 241-BY-110), pH of effluent, and crib name.<br>The scavenged TBP supernant for 216-B-43 through 216-B-49 are as follows:<br>• 216-B-43 received 557,464 gal from 241-BY-110 with a pH of 9.7. The concentrations for uranium, cesium, strontium, antimony, and plutonium were as follows: 5.9 mg/L or approximately 1.9E-3 µCi/L, 21.7 µCi/L, 635.07 µCi/L, 9.00 µCi/L, and 0.1 µg/L or approximately 0.12 µCi/L, respectively. The total activity for each is approximately 4.175E-3 Ci, 45.9 Ci, 1340 Ci, 19 Ci, and 2.47 Ci, respectively.<br>• 216-B-44 received 1,484,808 gal from 241-BY-107, 241-BY-108, and 241-BY-107, with an average pH of 9.3. The concentrations for uranium, cesium, strontium, antimony, and plutonium were as follows: 0.42 mg/L or approximately 1.408E-4 µCi/L, 116 µCi/L, 500 µCi/L, 182 µCi/L, and 1.97 µg/L, or approximately 0.12 µCi/L, respectively. The total activity for each is 7.9E-4 Ci, 651.9 Ci, 2,812 Ci, 1,024 Ci, and 0.6843 Ci, respectively.<br>• 216-B-45 received 1,297,226 gal from 241-BY-106 and 241-BY-108, with an average pH of 9.3. The concentrations for uranium, cesium, strontium, antimony, and plutonium varied for each of the tanks. The total activity for each is 1.79E-3 Ci, 1,490 Ci, 2,792 Ci, 2,870 Ci, and 0.649 Ci, respectively.<br>• 216-B-46 received 1,778,000 gal from 241-BY-107 and 241-BY-108, with an average pH of 9.7. The concentrations for uranium, cesium, strontium, antimony, and plutonium were as follows: 0.02g/L or approximately 9.0E-3 µCi/L, 20.39 µCi/L, 218.3 µCi/L, 601.3 µCi/L, and 2.47 µg/L or approximately 0.152 µCi/L, respectively. The total activity for each is 1.025 Ci, 137.2 Ci, 1,468.8 Ci, 4,047 Ci, and 1.025 Ci, respectively.<br>• 216-B-47 received 964,000 gal from 241-BY-108 and 241-BY-110, with an average pH of 9.7. The concentrations were slightly to significantly less than 216-B-46. The total activity for uranium, cesium, strontium, antimony, and plutonium were as follows: 1.89E-3 Ci, 130 Ci, 613 Ci, 2,664 Ci, and 0.345 Ci, respectively. 216-B-48 received 1,083,200 gal from 241-BY-106 and 241-BY-108, with an average pH of 9.4. The concentrations were slightly to significantly less than 216-B-46. The total activity for uranium, cesium, strontium, antimony, and plutonium were as follows: 6.4E-7 Ci, 437.9 Ci, 1,227 Ci, 1,996 Ci, and 0.29 Ci, respectively.<br>• 216-B-49 received 1,770,145 gal from 241-BY-104, 241-BY-107, and 241-BY-110, with an average pH of 9.8. The concentrations for uranium, | WMP-28945, App. B | | | S | | | |

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| | | | | cesium, strontium, antimony, and plutonium were as follows: 0.047g/L or approximately 1.0E-3 µCi/L, 59.85 µCi/L, 392.6 µCi/L, 586 µCi/L, and 1.79 µg/L or approximately 0.11 µCi/L, respectively. The total activity for each is 0.0105 Ci, 401 Ci, 2,631 Ci, 3,926 Ci, and 0.741 Ci, respectively.<br><br>The data are altered in Atlantic Richfield Hanford Company documents (e.g., ARH-231 [ARH, 1967]), which provided different inventories with no explanation for the difference. In addition, it appears that RHO-CD-673 (RHO, 1980) made additional changes without explanation for the above inventories. | | | | | | | |
| HW-49728 | 1957 | GE<br><br>W.H. Bierschenk | *The Effect of Ground-Water Mounds on the PUREX Operation* | This document discusses the groundwater mounds and their effect on groundwater flow in the 200 East Area. During B Plant operations from 1944 to March 1952, 6.5 billion gal of cooling water were discharged to B Pond. Groundwater elevations rose to approximately 405 to 406 ft above mean sea level. The elongated orientation of the plume reflected a general northwest-southeast directional permeability in this region. After B Plant was shut down, the groundwater elevations subsided about 9 ft by October 1955 to an elevation of about 397 ft. Throughout 1956, large amounts of groundwater were again discharged to B Pond. The discharges created a mound by March 1957 that was approximately 5 to 6 ft higher than the mound in 1952. Groundwater elevation records from key wells located to the south of the Gable Butte/Gable Mountain Gap indicated in 1958 a slight gradient south. Gross-beta data from late 1959 in this area reflected a southern groundwater flow. | WMP-28945, App. D | | | S | | | |
| HW-52860 | 1957 | GE<br><br>C.R. Cooley | *Standby Status Report Hot Semiworks Facility* | This report summarizes the plant's status following 10 months (May 1955 to March 1956) of PUREX testing in which 18 separate process studies were completed. Specifically, the document notes that the 216-C-1 Crib had received approximately 4.4 million L of water during the studies, in which 1,419 kg of uranium, 7 g of plutonium, and 10,400 Ci of beta emitters had been discharged to the soil column. Waste sites 216-C-2, 216-C-3, 216-C-4, 216-C-5, and 216-C-6 were used during this testing campaign, and most received minor amounts of liquid and radionuclides. | WMP-28945, App. A | | | S | | | |
| HW-54599 | 1958 | GE<br><br>W.A. Haney, J.F. Honstead | *A History and Discussion of Specific Retention Disposal of Radioactive Liquid Wastes in the 200 Areas* | The primary focus of this document for the purpose of the 200-BP-5 DQO process was the discussion of the liquid disposal of first-cycle decontamination waste to the BX Trenches (e.g., 216-B-35 through 216-B-41).<br><br>Groundwater was sampled from monitoring wells proximal to the BX Trenches. Beta-gamma contamination was detected in a well sometime after disposal to the trenches. Well 200-E33-21 was drilled to groundwater within the 216-B-36 Trench in 1957. The extent of detected radionuclide concentrations was approximately 80 ft bgs. One mechanism for supporting the detection of radionuclides in the groundwater, but not below 80 ft in the soil samples from the characterization well, was that some of the liquid effluent may have migrated vertically along the well casing where groundwater was reported (e.g., 299-E33-8).<br><br>Based on the sample results, it was concluded in this document that the specific moisture retention factor be lowered from 10% to 6% for volume release calculations. | WMP-28945, App. C | | G | I | | | |
| HW-72666 | 1963 | GE | *Hot Semiworks Strontium-90 Recovery Program* | A production program was conducted at the Hot Semiworks in 1960 through 1961 to separate mega-curie quantities of Sr-90 for thermoelectric power supplies. The program was a developmental test bed for a solvent-extraction process using an organic solvent (D2EPHA)-extraction process flowing through an inorganic, Sr-90-rich PUREX waste stream. Waste generation was reported as 416,400 L of process condensates through the duration of this report. The process ran through 1967, generating an unknown quantity of waste and disposing it to unidentified waste sites. | WMP-28945, App. A | P | | S | | | |

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| HW-83718 | 1964 | GE<br>E. Doud | *200 Areas Disposal Sites for Radioactive Liquid Wastes* | This document details the LWDF and the associated waste source site with dates of release up to early 1964. The following bismuth-phosphate waste streams were described:<br>• 216-B-7: 224B, 221B 5-6, and 201-4 tank overflow, October 1946 to 1958<br>• 216-B-11: 242B evaporator condensate, December 1951 to November 1954<br>• 216-B-35: first-cycle supernate, February 1954<br>• 216-B-36: first-cycle supernate, April 1954<br>• 216-B-37: evaporator bottoms, August 1954 to September 1954<br>• 216-B-38: first-cycle supernate, July 1954<br>• 216-B-39: first-cycle supernate, December 1953 to November 1954<br>• 216-B-40: first-cycle supernate, April 1954 to August 1954<br>• 216-B-41: first-cycle supernate, November 1954 | WMP-28945, App. B | | | S | | | |
| ISO-100 | 1967 | ISOCHEM, Inc. | *Waste Management Technical Manual* | This manual describes, in detail, most of the steps in the waste fractionization process conducted at the 221-B Facility from 1967 to approximately 1992. The waste fractionization process was designed to remove select long-lived fission products that were capable of posing long-term environmental hazards but were also capable of being used for beneficial purposes. The primary radionuclides of interest were Sr-90, Cs-137, Ce-144, Pm-147, and rare earths, with Tc-99, Am-241, rhodium/palladium, Sb-125, Np-237, and Pu-239 as secondary interests. The primary feedstock for waste fractionization was the acid waste from the 202-S REDOX and 202-A PUREX processes. The three processes generated eight relatively low-level waste streams, which required storage in tank farms. To lower that volume, a continuously operating waste concentrator boiled off excess water, which carried with it radionuclides, volatiles, and organics. This material was condensed off-line and was sent to the 216-B-62 Crib. The residual concentrated waste material sent to the 241-BY-series tank farms for storage. Steam condensate associated with 221-B operations was sent to the 216-B-55 Crib. The 216-B-2/-3 Ditches and B-3 Pond system received cooling water waste, while chemical sewer waste was discharged to the 216-B-63 Ditch. With the added waste, water volume in the tanks was driven off with two in-tank solidification units, large heaters placed into several 241-BY underground tanks. Heated air was injected into the liquid and generated water vapor from the waste. Vapors were condensed off-line and sent to the either the 216-B-50 or the 216-B-57 Cribs, which received 54.8 million L and 84.4 million L, respectively. | WMP-28945, App. A | P | | S | | | |
| LA-UR-96-3860, Rev. 4 | 1997 | LANL<br>S.F. Agnew | *Hanford Tank Chemical and Radionuclide Inventories: HDW Model* | The Hanford Defined Waste (HDW) model uses various process and transaction reports to define the various waste streams generated during active separations. The process part provided chemical and radionuclide concentrations defined by three distinct methods: (1) knowledge of the processes, (2) chemicals used and waste volumes produced, and (3) analyses of characteristic wastes.<br>Methods #1 and #2 focused mainly on technical manuals, process flow sheets, and radionuclide source-term reports. Results from models of fuel generation were then combined with the various processes to determine radionuclide and chemical partitioning.<br>The transaction reports mainly consisted of the following: waste status and transaction record summaries, Hanford high-level defense waste characterization report, supplementary information for the preliminary estimation of waste tank inventories in Hanford tanks through 1980, a history of the 200 Area tank farms, and Hanford tank logbook data set. The information from these reports provided a data set that was transferred into a balanced tank-by-tank quarterly summary transaction spreadsheet called the waste status and transaction record summary (WSTRS). Some uncertain exists with the chronology, as early recorded data did not specify exact dates of transactions. In addition, the volume reductions and continuous transfers of condensates from | WMP-28945, App. B | | | S | M | | |

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| | | | | the evaporator campaigns were not well represented. Perhaps as many as 60% to 80% of the evaporator campaign transactions are missing. While these methods provide the necessary information to define the waste stream, two critical pieces of information (i.e., the total solid volume percent and the solubility of each component in the supernant) were needed to calculate the actual compositions of the supernant and solids.<br><br>To derive estimates of the type of solids that reside within the tanks, fill records from the tank farm surveillance and waste status and summary report and other estimation reports were collected and feed into the Tank Layer Model (TLM). These estimates are made from three categories: additions from process plants directly into waste tanks, solid accumulated as a result of evaporation, and accumulations from tank-to-tank transfers. The solids that precipitate are set by evaluating component solubility and supernant analytical results from tank and evaporator operations and adjusting the fraction precipitated. The reported supernant concentrations of a species suggest a limiting solubility of that species. These values provide the method by which partitions of supernant and sludge fractions are generated. The TLM reconciles this information against the reported solid levels from WSTRS for each tank. Note that not all of the transactions that occurred in the past are recorded in the WSTRS data set. However, the two critical pieces of information that are used in the TLM analysis are the primary waste additions and the solid level measurements, both of which are well represented in WSTRS.<br><br>The Supernant Mixing Model (SMM) uses information both from WSTRS and TLM. The SMM module reads transaction information from WSTRS, sorts it to an absolute chronological order, and performs a transaction-by-transaction accounting of all the tank waste supernant for the history of Hanford. A fundamental assumption within the SMM is the ideal and complete mixing of each tank's supernant. In this approach, the volume of TLM solid layers within each tank is excluded from mixing with any supernant additions. The mass balances are limited by difference among water, oxide, and hydroxide with the various solids. The supernant concentration is equal to or less than the target solubility. Thus, each waste is kept in ion and mass balance according to the oxidation states assumed for that species.<br><br>Results of this work provide partitioning estimates of radionuclides released during historical waste disposal. These results indicate differences from historical references for various disposal inventories. An example is that the cesium and strontium inventory for the bismuth-phosphate campaign was somewhat different than historical references. This program defined cesium and strontium inventories as 35% in metal waste streams, 58.4% in the first-cycle waste, 6% in the second-cycle waste, and 0.6% in the 224 Building waste, as opposed to 88.9%, 10%, 1%, and 0.1%, respectively. The remaining radionuclides were partitioned as 88.9% metal waste, 10% as first cycle, 1% as second cycle, and 0.1% as 224. In addition, partitioning estimates for the uranium recovery process indicate that there is uncertainty in the uranium inventory tied up in the sludge. Some sources indicate that 75% of the uranium was present in the sludge while solubility calculations indicate that only 35% of the uranium was present in the sludge.<br><br>The results of this document were based on several prior documents attempting to better constrain the inventory of each constituent sent to specific waste sites. However, due to the uncertainty associated with the lack of records prior to 1970, specific site inventories were considered to have large uncertainty. Thus, more refinements of these inventories have occurred and are shown in Rev. 5 of this document. | | | | | | | |

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| PNL-5506 | 1986 | Pacific Northwest Laboratory<br><br>D.A. Zimmerman, A.E. Reisenauer, G.D. Black, M.A. Young | *Hanford Site Water Table Changes 1950 Through 1980: Data Observations and Evaluations* | This document, among other things, provides a summary of the actions taken regarding recommendations in HW-49728 (GE, 1957). The document provides the information regarding split of liquid effluent going to Gable Mountain and B Pond for the time period of 1960 to 1965. | WMP-28945, App. D | | H | S | | | |
| PNL-6907 | 1989 | Pacific Northwest Laboratory<br><br>V.L. McGhan | *Hanford Wells* | The Site Characterization and Assessment Section of the Geosciences Department at Pacific Northwest Laboratory (PNL) has compiled a list of wells located on or near the Hanford Site. Information has been updated on wells existing from the days before construction of the Hanford Works to the present. This work was funded by the DOE. The list of wells will be used by DOE contractors who need condensed, tabular information on well location, construction, and completion dates. This report does not include data on lithologic logs and ground-water contamination. Moreover, the completeness of this list is limited because of new well construction and existing well modifications, which are continually under way. Despite these limitations, this list represents the most complete description possible of data pertaining to wells on or adjacent to the Hanford Site. | | D | | | | | |
| PNL-8800 | 1993 | Pacific Northwest Laboratory<br><br>M.A. Chamness, J.K. Merz, | *Hanford Wells* | Records describing wells located on or near the Hanford Site have been maintained by Pacific Northwest Laboratory and the operating contractor, Westinghouse Hanford Company. In support of the Ground-Water Surveillance Project, portions of the data contained in these records have been compiled into the following report, which is intended to be used by those needing a condensed, tabular summary of well location and basic construction information. The wells listed in this report were constructed over a period of time spanning almost 70 years. Data included in this report were retrieved from the Hanford Envirorunental Information System (HEIS) database and supplemented with information not yet entered into HEIS. While considerable effort has been made to obtain the most accurate and complete tabulations possible of the Hanford Site wells, omissions and errors may exist. This document does not include data on lithologic logs, ground-water analyses, or specific well completion details. | | D | | | | | |
| PNL-10817 | 1995 | Pacific Northwest Laboratory<br><br>F.A. Spane, Jr., W.D. Webber | *Hydrochemistry and Hydrogeologic Conditions Within the Hanford Site Upper Basalt Confined Aquifer System* | Will be added later. | | | | | | | |
| PNNL-11523, Rev. 1 | 2005 | PNNL<br><br>J.W. Lindberg, R.P. Elmore | *Interim-Status RCRA Groundwater Monitoring Plan for the 216-A-10, 216-A-36B, and 216-A-37-1 PUREX Cribs* | This document presents a groundwater monitoring program for three RCRA waste management units combined under one groundwater quality assessment program. These three units are 216-A-10, 216-A-36B, and the 216-A-37-1 Cribs (PUREX Cribs). The three cribs were grouped together based on their proximity to one another, similar construction and waste history, and similar hydrogeologic regime. The monitoring network comprises near-field wells (in the immediate vicinity of the cribs) and far-field wells (wells downgradient). The monitoring strategy for the near-field wells is included in this plan, while the monitoring strategy for far-field wells is found in DOE/RL-2003-04 (DOE/RL, 2005a). Results of groundwater monitoring are reported annually in groundwater monitoring reports (e.g., PNNL-16346, *Hanford Site Groundwater Monitoring for Fiscal Year 2006* [PNNL, 2007]). | DOE/RL-2007-31 | | | P | A | | |

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| PNNL-11800 | 1998 | PNNL<br><br>C.T. Kincaid<br>M.P. Bergeron,<br>C.R. Cole,<br>M.D. Freshley,<br>N.L. Hassig,<br>V.G. Johnson,<br>D.I. Kaplan,<br>R.J. Serne,<br>G.P. Streile,<br>D.L. Strenge,<br>P.D. Thorne,<br>L.W. Vail,<br>G.A. Whyatt,<br>S.K. Wurstner | *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* | A composite analysis was prepared for the Hanford Site considering only sources in the 200 Area Plateau. Estimating doses to hypothetical members of the public for the Composite Analysis was a multi-step process involving the estimation or simulation of inventories; waste release to the environment; migration through the VZ, groundwater, and atmospheric pathways; and exposure and dose. Doses were estimated for scenarios based on agriculture, residential, industrial, and recreational land use. The radionuclides included in the VZ and groundwater pathway analyses of future releases were C-14, Cl-36, Se-79, Tc-99, I-129, and uranium isotopes. In addition, tritium and Sr-90 were included because they exist in groundwater plumes. Radionuclides considered in the atmospheric pathway included tritium and C-14.<br><br>The analysis indicated that most of the radionuclide inventory in past-practice liquid discharge and solid waste burial sites on the 200 Area Plateau was projected to be released in the first several hundred years following Hanford Site closure. The radionuclide doses for all of the exposure scenarios outside of a defined buffer zone were all less than 3 mrem/yr, well below the performance objectives of 100 mrem/year or the ALARA objective of 30 mrem/year.<br><br>Several sources of uncertainty were noted in the first iteration of the Composite Analysis, with the largest uncertainty associated with the inventories of key mobile radionuclides. Other sources of uncertainty in the analysis arose from the conceptual and numerical models of contaminant migration and fate in the VZ and assumption regarding source-term release models and end states.<br><br>The composite analysis demonstrated a significant separation in time between past-practice discharges and disposals, and active and planned disposal of solid waste, environment restoration waste, and immobilized low-activity waste. The higher integrity disposal facilities and surface covers of these active and planned disposal delay releases, and the releases do not superimpose on the plumes from the near-term past-practice disposals. | DOE/RL-2007-31 | | | | A | R | |
| PNNL-11800 | 1998 | PNNL<br><br>C.T. Kincaid<br>M.P. Bergeron,<br>C.R. Cole,<br>M.D. Freshley,<br>N.L. Hassig,<br>V.G. Johnson,<br>D.I. Kaplan,<br>R.J. Serne,<br>G.P. Streile,<br>P.D. Thorne,<br>L.W. Vail,<br>G.A. Whyatt,<br>S.K. Wurstner | *Composite Analysis for Low-Level Waste Disposal in the 200 Area Plateau of the Hanford Site* | Appendix E provides distribution coefficients for radionuclide materials in the ground that may interact with past releases. To accommodate the different waste source-term categories and $K_d$ zones, the $K_d$ values had to be determined for six source-type waste solutions and various stratigraphic types. Based on the waste solution for second-cycle waste (e.g., low-organic, low-salt) and with the fact that acid was added, the cobalt $K_d$ value was reduced to .2 to 5 mL/g, which is a good correlation why cobalt was detected deep in the vadose zone by geophysics surveys. | WMP-28945, App. C | P | G | C, I | | | |
| PNNL-12257, Rev. 1 | 1999 | PNNL<br><br>S.P. Reidel,<br>D.G. Horton | *Geologic Data Package for 2001 Immobilized Low-Activity Waste Performance Assessment* | This database is a compilation of existing geologic data from both the existing and new immobilized low-activity waste disposal sites for use in the 2001 Performance Assessment. Data were compiled from both surface and subsurface geologic sources. Large-scale surface geologic maps, previously published, cover the entire 200-East Area and the disposal sites. Subsurface information consists of drilling and geophysical logs from nearby boreholes and stored sediment samples. | | | | | | | |

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| PNNL-12261 | 2000 | PNNL<br><br>B.A. Williams, B.N. Bjornstad, R. Schalla, W.D. Webber | *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-East Area and Vicinity, Hanford Site, Washington* | This document provides a thorough and updated description of the hydrogeology of the 200-East Area. It presents the development of the revised conceptual hydrostratigraphic model, a revised water table map, and discusses possible groundwater flow patterns. A detailed and thorough evaluation (and integration) of existing and new data was used to enhance the previous conceptual groundwater flow model to differentiate the multiple hydrogeologic units and the related groundwater flow regimes that exist beneath the 200-East Area. Without this detailed conceptual model, it is difficult to determine where (both vertically and horizontally) the contaminants are, how they are moving, when they will impact the public, and how to track and monitor them. Detailed cross sections and tables of top of formation picks were integral in the development of the 200-PO-1 Operable Unit hydrogeologic database. | DOE/RL-2007-31 | | | H | | M | |
| PNNL-13032 | 2000 | PNNL<br><br>D.B. Barnett | *Groundwater Monitoring Plan for the Hanford Site 200 Area Treated Effluent Disposal Facility* | Seven years of groundwater monitoring at the 200 Area Treated Effluent Disposal Facility (TEDF) have shown that the uppermost aquifer beneath the facility is unaffected by TEDF effluent. Effluent discharges have been well below permitted and expected volumes. Groundwater mounding from TEDF operations predicted by various models has not been observed, and waterlevels in TEDF wells have continued declining with the dissipation of the nearby B Pond System groundwater mound. Analytical results for constituents with enforcement limits indicate that concentrations of all these are below Practical Quantitation Limits, and some have produced no detections. Likewise, other constituents on the permit-required list have produced results that are mostly below sitewide background. Comprehensive geochemical analyses of groundwater from TEDF wells have shown that most constituents are below background levels as calculated by two Hanford Site-wide studies. Additionally, major ion proportions and anomalously low tritium activities suggest that groundwater in the aquifer beneath the TEDF has been sequestered from influences of adjoining portions of the aquifer and any discharge activities. This inference is supported by recent hydrogeologic investigations which indicate an extremely slow rate of groundwater movement beneath the TEDF. Detailed evaluation of TEDF-area hydrogeology and groundwater geochemistry indicate that additional points of compliance for groundwater monitoring would be ineffective for this facility, and would produce ambiguous results. Therefore, the current groundwater monitoring well network is retained for continued monitoring. A quarterly frequency of sampling and analysis is continued for all three TEDF wells. The constituents list is refined to include only those parameters key to discerning subtle changes in groundwater chemistry, those useful in detecting general groundwater quality changes from upgradient sources, or those retained for comparison with end-of-pipe discharge chemistry. Volatile and semivolatile organic compounds, ammonia, total organic carbon, oil and grease, and radium are removed from the constituent list. Annual analysis for low-level tritium is added to the constituent list to help confirm that groundwater beneath the TEDF remains isolated from operational influences. | | D, H, P, R | G, H | C, S, R, P, I | A | | |
| PNNL-13080 | 2000 | PNNL<br><br>M.J. Hartman, ed. | *Hanford Site Groundwater Monitoring: Setting, Sources and Methods* | This report is a companion volume to the groundwater monitoring report for the Hanford Site, which is produced annually. It contains background information that does not change significantly from year to year. This report includes a description of groundwater monitoring requirements, site hydrogeology, and waste sites that have affected groundwater quality or that require groundwater monitoring. Monitoring networks and methods for sampling, analysis, and interpretation are summarized. VZ monitoring methods and statistical methods also are described. | DOE/RL-2007-31 | | | H | S | | |

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| PNNL-13404 | 2001 | PNNL<br><br>M.J. Hartman, L.F. Morasch, W.D. Webber | *Hanford Site Groundwater Monitoring for Fiscal Year 2000* | This document describes the groundwater underlying the area associated with facilities surrounding the B Plant, including the waste storage and disposal facilities north of the plant. Significant waste sources in this vicinity include the BY Cribs, the 216-B-5 injection well, and several RCRA TSD facilities. The focus of this report was to determine the general groundwater flow using plume maps, contaminant trend plots, water-level trend surface analysis, water-level hydrographs for multiple wells, and in situ flow measurements at groundwater wells. The highest uranium concentrations found during the time of this report were beneath and to the east of the BY Tank Farm (wells 299-E33-9 and 299-E33-44). A nitrate plume originating in the 200 East Area extends beyond the boundary fence line, extending northwest to the Columbia River. Increasing nitrate and Tc-99 concentrations in the central region of WMA-B/BX/BY suggest a southerly flow. However, the uranium, nitrate, and tritium concentrations are interpreted as supporting a northwest flow. This report, considering the available information on groundwater in the B Plant area, provided the following preliminary conceptual model. A groundwater divide exists, somewhere between WMA-B/BX/BY and LLWMA-1, or perhaps within the southeastern half of LLWMA-1. The conceptual model is preliminary and uncertain. | WMP-28945, App. D | | H | P | A | | |
| PNNL-13653, Rev. 2 | 2005 | PNNL<br><br>D.G. Horton, G.V. Last, T.J Gilmore B.N. Bjornstad, R.D. Mackley | *A Catalog of Geologic Data for the Hanford Site* | This report updates the previous version of the geologic data catalog (Horton et al. 2002). The earlier catalog gathered sources of existing borehole geologic data for the Hanford Site, focusing on the 100, 200, and 300 Areas, with a particular emphasis on the 200 Areas. The catalog contains information on 3,519 boreholes. This revision of the geologic data catalog incorporates new boreholes drilled between September 2002 and November 2004 as well as other older wells, particularly from the 600 Area, omitted from the earlier catalogs. Additionally, a description of available borehole geophysical log data has been included in the catalog. Presents a listing of the types of existing data and places where the data can be found (e.g., published documents, formal databases, or informal databases). | | | | | | | |
| PNNL-13763 | 2002 | PNNL<br><br>P.E. Dresel, J.C. Evans, O.T. Farmer III | *Investigation of Isotopic Signatures for Sources of Groundwater Contamination at the Hanford Site* | This report considers the application of improved analysis of chemical isotopes to evaluate the sources of groundwater contamination. This summary discusses two of the isotopic ratio methods considered for determining contaminant sources. Sixteen samples were collected during this study in the vicinity of B Plant in the 200 East Area. The results indicate that vadose zone sources are closer to wells 299-E33-9 and 299-E33-44. Concentrations in wells 299-E33-38 and 299-E33-18 indicate that these wells are further from the vadose zone source. | WMP-28945, App. D | | | | A | | |
| PNNL-13895, Rev. 1 | 2003 | PNNL<br><br>K.J. Cantrell, R.J. Serne, G.V. Last | *Hanford Contaminant Distribution Coefficient Database and Users Guide* | The purpose of this document was to compile all useful $K_d$ data determined for Hanford sediment and related materials into one database. Technical justification and application, including numerical transport modeling, of the linear sorption $K_d$ model are discussed. Bounding conditions (e.g., sediment/soil mineralogy or physical properties, solution chemistry, or contaminant loading/concentration) are key to appropriate application.<br><br>Calculated $K_d$ ranges are given with explanation of solution complexing conditions. Contaminants generally fall into three categories of Kd values: high (e.g., very low mobility), moderate (e.g., mobility), and low (e.g., high mobility). Several variables can change the expected Kd. Other observations (i.e., mineralogy, supernant chemistry, contaminant solubility for identified waste solutions, previous soil sample results, past and present groundwater data, and geophysical data) are required to reduce uncertainty.<br><br>High $K_d$ contaminants were identified as: americium, cobalt, cesium, nickel, lead, and plutonium. Complexes that could affect the expected high $K_d$ value include ethylenedaimine tetra acetic acid (EDTA), low pH solutions, cyanide, highly basic solutions, and high-salt concentrations. Sr-90, and possibly neptunium, were identified as moderate Kd contaminants. | WMP-28945, App. C | P | | C, R, I | | | |

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| | | | | Low $K_d$ contaminants were: chromium (VI valence), I-129, nitrate, neptunium, selenium, Tc-99, uranium, and carbon tetrachloride. Neptunium has a low Kd when contact time is one day or less and high calcium or EDTA concentrations exist. | | | | | | | |
| PNNL-14027 | 2002 | PNNL<br><br>R.W. Bryce, C.T. Kincaid, P.W. Eslinger, L.F. Morasch, eds. | *An Initial Assessment of Hanford Impact Performed with the System Assessment Capability* | In 1999, the DOE initiated the development of an assessment tool to model the movement of contaminants from all waste sites at the Hanford Site through the VZ, groundwater, and the Columbia River and estimate the impact of contaminants on human health, ecology, and the local cultures and economy. This tool was named the SAC. The results of the first runs performed with SAC were presented to the integration project expert panel in September 2000. The assessment: (1) Modeled the movement of contaminants from more than 500 locations throughout the Hanford Site representing 890 waste sites through the VZ, groundwater, and the Columbia River; (2) Incorporated data on 10 radioactive and chemical contaminants (carbon tetrachloride, Cs-137, chromium, I-129, Pu-239/240, Sr-90, Tc-99, tritium, total uranium, and U-238); (3) Focused on subsurface transport, the Columbia River, and risks to human and ecological health, and the economy and culture. | DOE/RL-2007-31 | | | | M | R | |
| PNNL-14049 | 2002 | PNNL<br><br>E.C. Thornton, J.W. Lindberg | *Data Quality Objectives Summary Report-Designing a Groundwater Monitoring Network for the 200-BP-5 and 200-PO-1 Operable Units* | The purpose of this document is to present the DQOs that will be used to assess the current groundwater monitoring approach and redesign the well-field network for the 200-BP-5 and 200-PO-1 Groundwater OUs. This assessment is needed to address changing contaminant plume conditions (e.g., plume migration) and to ensure that monitoring activities meet the requirements for remediation performance monitoring (i.e., CERCLA monitoring), RCRA past-practice monitoring, and Site-wide surveillance monitoring (AEA) activities as directed in DOE orders. This DQO Summary Report was prepared in response to the EPA 5-year review of groundwater remedial actions of the Hanford Site and supports Action Items 200-7 and 200-8 (EPA/240/B-01/003, *EPA Requirements for Quality Assurance Project Plans*, EPA QA/R-5 [EPA, 2001]).<br><br>Because of the changing configuration of the groundwater contaminant plume contours over time and the identification of new specific monitoring needs, the 200-BP-5 and 200-PO-1 Groundwater OU groundwater monitoring networks require periodic reevaluation. Groundwater remediation is not currently being performed in the 200 East Area. This is because some of the contaminants associated with the plumes are not considered to pose a risk to the public at current concentrations and area distributions while other contaminants are at too low a level to be effectively remediated using currently known technologies. However, monitoring groundwater contamination in the area is necessary to determine if contaminant levels are attenuating with time and to ensure that no new or previously unidentified groundwater contamination goes undetected.<br><br>This DQO process identified the optimum number of groundwater wells to be monitored to meet these objectives and determined that a number of new groundwater wells needed to be installed. The identity of wells in the monitoring network, sampling frequency, the analyses to be performed, the detection limit requirements, and other analytical performance requirements (e.g., precision and accuracy) were defined in this document. The resultant groundwater monitoring network fulfilled the needs of the three major Hanford Site regulatory monitoring activities (CERCLA, RCRA, AEA). | DOE/RL-2007-31 | | H | | | | |

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| PNNL-14187 | 2003 | PNNL<br><br>M.J. Hartman, L.F. Morasch, W.D. Webber, eds. | *Hanford Site Groundwater Monitoring for Fiscal Year 2002* | This report discusses the groundwater flow as associated with contaminant distribution of tritium, Tc-99, I-129, and nitrate because they are not significantly affected by interactions with aquifer matrix. In addition, contaminant distributions and ratios using uranium, cyanide, and Co-60 were compared to provide preliminary conceptual models for the transport of contamination. Three plumes were identified in this report. One plume consisting of nitrate, nitrite, Tc-99, and uranium is located under and east of the BY Tank Farm. Past releases from the WMAs may be the source of this contamination. Another plume with low levels of nitrate associated with relatively high tritium is found along the south border of the WMA. Movement through the vadose zone from a tritium-rich perched water table located 4.6 m above the water table under the BX Tank Farm may be the cause of this contamination. Further to the north under the BY Cribs is a plume containing high levels of nitrate, cyanide, Co-60, and Tc-99. These contaminants extend from the BY Cribs to the north, westward to the northeast corner of the LLWMA-1, and south to the northern part of BY Tank Farm, where only cyanide and Co-60 are found. Uranium is also found locally in the southern part of the BY Cribs. These contaminants are attributed to releases from the BY Cribs in the mid-1950s. In situ flow measurements conducted in FY00 indicate that the northern portion of the area under the BY Cribs and the BY Tank Farm has a low flow rate that is close to stagnant. In situ flow measurements indicate that the flow in the south is quite high. Based on water elevations in wells where the borescope data indicate a strong, consistent flow, the flow rate was calculated with the Darcy equation at 0.5 m/day for FY02. The generally southern flow beneath WMA-B/BX/BY and flow to the southwest at the 216-B-63 Trench are direct results of the declining water table, as groundwater flows in a perpendicular direction away from the southeast-northwest buried anticline. The flow divide between the southeast and northwest pathways, which was present to the southeast of the B Plant area during the Hanford Site operations, is migrating to the northwest in response to the declining water table. | WMP-28945, App. D | | H | P | | | |
| PNNL-14618, Rev. 0 | 2004 | PNNL<br><br>C.J. Murray, Y.J. Chien, P.D. Thorne | *A Geostatistical Analysis of Historical Field Data on Tritium, Technetium-99, Iodine-129, and Uranium* | The purpose of this document was to generate maps and statistics that quantify contamination in groundwater. The maps and statistics could then be compared to predictions from the SAC model, used for verification of SAC results, and then provide an estimate of the uncertainty in the history-matching data generated. The area of interest in this report was the northern portion of the 200 East Area. Using the available data from HEIS and professional judgment, inventories of tritium, technetium, iodine, and uranium were calculated. However, due to the uncertainty of the aquifer thickness in the area north of the 200 East Area, the inventory for some contaminates have a large range (e.g., technetium, 10 to 40 Ci). With such large ranges, the risk of impact to the river increases as documented in risk assessment modeling in DOE/RL-95-59 (DOE-RL, 1996). Thus, resolving the uncertainty is required. Other contaminants (e.g., iodine) indicate the potential for a substantial inventory when considering the upper limit of uncertainty (0.04 to 1.4 Ci); however, the modeling only indicate limited lateral groundwater extent above the existing MCL (1 pCi/L). Tritium only was identified in one small area with a presence above MCLs for the time period. Uranium was not modeled in the 200-BP-5 OU. | WMP-28945, App. D | | | | A | | |

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| PNNL-15070 | 2005 | PNNL<br><br>M.J. Hartman, L.F. Morasch, W.D. Webber, eds. | *Hanford Site Groundwater Monitoring for Fiscal Year 2004* | Much of the discussion in this report is based around sampling to assess the rate and extent of groundwater contamination associated with the WMA-B/BX/BY. Wells were also sampled to provide coverage of surrounding past-practice liquid effluent disposal facilities to distinguish non-tank farm sources that may have impacted groundwater quality from tank-related sources. The water driver appears to be related to long-term, steady-state recharge from natural precipitation and leaks from nearby fresh water lines. When discussing sources for the high uranium concentrations found under the BY Tank Farm, it is important to recognize that the uranium contamination does not travel alone but is associated with the mobile contaminants from the original processing source. For example, uranium levels under the BY Tank Farm, east, southeast, and north of the farm are correlated with the rising Tc-99 and nitrate contamination. However, the peak values from late 2000 to early 2001 indicate that the uranium movement is retarded with respect to the mobile Tc-99. The co-variation of the Tc-99, although offset in time, shows that the uranium has a common source with the Tc-99. The correlation between the Tc-99 and uranium trends show that the uranium is traveling with the Tc-99 and is most likely from the same contaminated soils as the elevated Tc-99, nitrate, and other corresponding contaminants. Tritium and uranium was also reported in wells 299-E33-335, 299-E33-337, and 299-E33-339. The tritium was concluded to be from the tritium-rich perched water table located in the vadose zone approximately 4.6 m above the top of the unconfined aquifer under the B and BX Tank Farms. Thus, it was concluded from this information that the tritium indicates movement to the south. | WMP-28945, App. D | | H | P | | | |
| PNNL-15315 | 2006 | PNNL<br><br>S.M. Narbutovskih, C.J. Chou | *RCRA Assessment Plan for Single-Shell Tank Waste Management Area A-AX at the Hanford Site* | This document describes a groundwater assessment plan for the single-shell tank systems in Waste Management Area A-AX at the Hanford Site. Results of these studies will assist in deciding of operations associated with the waste management area have compromised groundwater quality with dangerous waste. This plan also included a descriptive narrative with planned activities, investigations, and a tentative schedule. | | D, H, R | H | C, S, I | | | |
| PNNL-15479 | 2005 | PNNL<br><br>D.B. Barnett, R.M. Smith, C.J. Chou, J.P. McDonald | *Groundwater Monitoring Plan for the Hanford Site 216-B-3 Pond RCRA Facility* | The 216-B-3 Pond was a series of ponds for disposal of liquid effluent from past Hanford production facilities. In 1990, groundwater monitoring at B Pond was elevated from "detection" to assessment status because total organic halides and total organic carbon were found to exceed critical means in two wells. Groundwater quality assessment, which ended in 1996, failed to find any specific hazardous waste contaminant that could have accounted for the isolated occurrences of elevated total organic halides and total organic carbon. Hence, the facility was subsequently returned to detection-level monitoring in 1998. Exhaustive groundwater analyses during the assessment period incicated that only two contaminants, tritium and nitrate, could be positively attributed to the B Pond System, with two others (arsenic and I-129) possibly originating from B Pond. Chemical and radiological analyses of soil at the main pond and 216-B-3-3 ditch have not revealed significant contamination. Based on the observed, minor contamination in groundwater and in the soil column, three parameters were selected for site-specific, semiannual monitoring; gross alpha, gross beta, and specific conductance. Total organic halides and total organic carbon are included as constituents because of regulatory requirements. Nitrate, tritium, arsenic, and iodine-129 will be monitored under the aegis of Hanford site-wide monitoring. Although the B Pond System is not scheduled to advance from RCRA interim status to final status until the year 2003, a contingency plan for an improved monitoring strategy, which will partially emulate final status requirements, will be contemplated before the official change to final status. This modification will allow a more sensible and effective screening of groundwater for the facility. (OSTI) | | D, H, R | H | C, I | A | | |

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| PNNL-15955, Rev. 1 | 2007 | PNNL<br><br>S. P. Reidel, M. A. Chamness, | *Geology Data Package for the Single-Shell Tank Waste Management Areas at the Hanford Site* | This data package discusses the geology of the single-shell tank (SST) farms and the geologic history of the area. The purpose of the report is to provide the most recent geologic information available for the SST farms. The report builds upon previous reports on tank farm geology and Integrated Disposal Facility geology with information available after those reports were published. | | | G | | | | |
| PNNL-16346 | 2007 | PNNL<br><br>M.J. Hartman, L.F. Morasch, W.D. Webber, eds. | *Hanford Site Groundwater Monitoring for Fiscal Year 2006* | This report presents the results of groundwater monitoring and remediation for fiscal year 2006 on the Hanford Site. Water level monitoring was performed to evaluate groundwater flow directions, to track changes in water levels, and to relate such changes to evolving disposal practices.<br><br>The most extensive plumes are tritium, I-129, and nitrate, which all had multiple sources, and are mobile in groundwater. The largest portions of these plumes are migrating from the central Hanford Site (central plateau) to the southeast, toward the Columbia River. Concentrations of tritium, nitrate, and other contaminants continued to exceed drinking water standards in groundwater discharging to the river in fiscal year 2005. However, contaminant concentrations in river water remained low and were far below standards.<br><br>This report describes the major COPCs within the 200-PO-1 Groundwater OU including tritium, nitrate, I-129, and Tc-99 as well as other COPCs. Previous Hanford Site groundwater monitoring reports present data on the Hanford Site from 1988 to 2006 are not listed here, but can be located online at http://libraryweb.pnl.gov/. The latest document (shown here) was used as a reference guide. | DOE/RL-2007-31 | | H | P | | | |
| PNNL-16407 | 2007 | PNNL<br><br>D.B. Barnett, B.N. Bjornstad, K.R. Fecht, D.C. Lanigan, S.P. Reidel, C.F. Rust | *Geology of the Waste Treatment Plant Seismic Boreholes* | This report describes the results of the geologic studies from three mud-rotary boreholes and one cored borehole at the Waste Treatment Plant. The characterization effort within the deep boreholes included 1) downhole measurements of the velocity properties of the suprabasalt, basalt, and sedimentary interbed sequences, 2) downhole measurements of the density of the subsurface basalt and sediments, and 3) geologic studies to confirm the geometry of the contact between the various basalt and interbedded sediments through examination of retrieved core from the core hole and data collected through geophysical logging of each borehole. | | | | | | | |
| PNNL-16623 | 2007 | PNNL<br><br>T.M. Poston, R.W. Hanf, J.P. Duncan, R.L. Dirkes, eds. | *Hanford Site Environmental Report for Calendar Year 2006* | This report is prepared annually for DOE and provides an overview of activities at the Hanford Site. The report summarizes environmental data that characterize Hanford Site environmental management performance. The report also highlights significant environmental and public protection programs and efforts. Although this report is primarily written to meet DOE reporting requirements and guidelines, it also provides useful summary information for the public, Indian tribes, public officials, regulatory agencies, Hanford contractors, and public officials. | | D, R | | | | | |
| PNNL-16748 | 2007 | PNNL<br><br>W.J. Deutsch, K. J. Cantrell, K. M. Krupka | *Contaminant Release Data Package for Residual Waste in Single-Shell Hanford Tanks* | This data package provides detailed technical information about contaminant release from closed single-shell tanks necessary to support the RCRA Facility Investigation Report. The data package is a compilation of contaminant release rate data for residual waste in the four Hanford single-shell tanks (SSTs) that have been tested (C-103, C-106, C-202, and C-203). The report describes the geochemical properties of the primary contaminants of interest from the perspective of long-term risk to groundwater (uranium, technecium-99, iodine-129, chromium, transuranics, nitrate), the occurrence of these contaminants in the residual waste, release mechanisms from the solid waste to water infiltrating the tanks in the future, and laboratory tests conducted to measure release rates. | | | | C, R | A | | |

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| PNNL-17154 | 2008 | PNNL<br>K.J. Cantrell, C.F. Brown, R.J. Serne, K.M. Krupka | *Geochemical Characterization Data Package for the Vadose Zone in the Single-Shell Tank Waste Management Areas at the Hanford Site* | This data package discusses the geochemistry of vadose zone sediments beneath the single-shell tank (SST) farms at the DOE's Hanford Site. The purpose of the report is to provide a review of the most recent and relevant geochemical information available for the vadose zone beneath the SST farms and the Integrated Disposal Facility (IDF). | | | G | C, I | | | |
| PNNL-17162 | 2007 | PNNL<br>C. F. Brown, J.P. Icenhower, W. Um, B.N. Bjornstad, M.M. Valenta, C. Iovin, D.C. Lanigan, R.E. Clayton, K.N. Geiszler, E.T. Clayton, I.V. Kutnyakov, S.R. Baum, M.J. Lindberg, R.D. Orr | *Characterization of Direct-Push Vadose Zone Sediments from the 241-B and 241-BX Tank Farms* | Geochemical tests provide evidence for the transit of a plume of caustic waste solution through the sediment column at the Hanford 241-B and -BX Tank Farms. Data are characteristic of sediments that have encountered a sodium-rich, saline, caustic waste solution, as documented in other reports at other suspect contamination sites around Hanford. The water extract data for affected sediments indicate unusually high concentrations of aluminum, iron, and phosphorus. The presence of elevated concentrations of phosphorus may be the tell-tale signature of wastes derived from the bismuth-phosphate separation process. Uranium-238 was detected in nearly all sediment specimens. Other anthropogenic radioisotopes also were detected, such as cobalt-60, cesium-137, europium-154, and europium-155. These data are direct confirmation of sediment contamination. | | | G | C, I | | | |
| PNNL-6415, Rev.18 | 2007 | PNNL<br>J.P. Duncan, K.W. Burk, M.A. Chamness, R.A. Fowler, B.G. Fritz, P.L. Hendrickson, E.P. Kennedy, G.V. Last, T.M. Poston, M. Sackschewsky, M.J. Scott, S.F. Snyder, M.D. Sweeney, P.D. Thorne | *Hanford Site National Environmental Policy Act (NEPA) Characterization* | This document describes the DOE's Hanford Site environment. It is intended to provide a consistent description of the Hanford Site for the many environmental documents being prepared by DOE contractors concerning the *National Environmental Policy Act of 1969* (NEPA). No statements regarding significance or environmental consequences are provided. Two chapters are included in this document (Chapters 4 and 6), numbered to correspond to chapters typically presented in environmental impact statements (EISs) and other Hanford Site NEPA or CERCLA documentation. Chapter 4.0 (Affected Environment) describes Hanford Site climate and meteorology; air quality; geology; hydrology; ecology; cultural, archaeological, and historical resources; socioeconomics; noise; and occupational health and safety. Chapter 6.0 (Statutory and Regulatory Requirements) describes federal and state laws and regulations, DOE directives and permits, and presidential executive orders that are applicable to NEPA documents prepared for Hanford Site activities. More detailed data are available from reference sources cited or from the authors. | | D, H, P, R | | | | | |
| PNNL-SA-49780 | 2006 | PNNL<br>J.P. McDonald | *The 2002-2003 Fluctuation of the Water-Table Elevation in the 200 East Area and Vicinity: Evaluation of Potential Causes* | | DOE/RL-2008-01 | | H | | | | |
| RHO-BWI-ST-4 | 1979 | RHO<br>C.W. Myers, S.M. Price | *Geologic Studies of the Columbia Plateau: A Status Report* | This document summarizes geologic studies of the Columbia Plateau conducted mostly during the period from 1977 to 1979, with emphasis on work completed under the Basalt Waste Isolation Project, Rockwell Hanford Operations. | | D | G | | | | |
| RHO-BWI-ST-14 | 1981 | RHO<br>C.W. Myers, S.M. Price | *Subsurface Geology of the Cold Creek Syncline* | This document presents stratigraphic, lithologic and structural information and interpretation primarily for the basalt flows and interbed deposits the Hanford site. The document was originally prepared to support the baseline data used to support the siting of a nuclear waste repository. Cross-sections, isopach maps and geophysical logs are useful for the geologic interpretation for the 200-PO-1 Operable Unit. | Subsurface Geology of the Cold Creek Syncline | | | | | | |

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| RHO-MA-116 | 1980 (1982 in summary column should be 1980) | RHO<br>J.D. Moore, R.L. Walser, J.J. Fritch, eds. | *PUREX Technical Manual* | Same as HW-31000-DEL. | WMP-28945, App. A | P | | | | | |
| RHO-RE-ST-12P | 1984 | RHO<br>M.J. Graham, G.V. Last, K.R. Fecht | *An Assessment of Aquifer Intercommunication in the B Pond-Gable Mountain Pond Area of the Hanford Site* | This report describes a hydrogeologic investigation of aquifer intercommunication in the area surrounding two if the waste disposal ponds, B Pond and Gable Mountain Pond, and encompassing the 200-East Area where subsurface liquid-waste disposal facilities are located. The investigation was focused in this area because previous work indicated areas of erosion of the confining bed and the presence of contamination in the confined aquifer. Also, large increases in waste disposal activities are planned for the near future in this area. The objectives of this investigation were: (1) to establish the geologic framework controlling ground-water flow in the aquifers, (2) to determine the ground-water flow characteristics of the Rattlesnake Ridge aquifer, (3) to quantify the mixing of unconfined aquifer waters in the Rattlesnake Ridge aquifer resulting from aquifer intercommunication, (4) to delineate the area where aquifer intercommunication has occurred, and (5) to determine the levels of contamination in the Rattlesnake Ridge aquifer. | | D | G, H, C | I | A | | |
| RHO-ST-23 | 1979 | RHO<br>A. M. Tallman, K.R. Fecht, M.C. Marratt, G.V. Last | *Geology of the Separations Areas, Hanford Site, South-Central Washington* | This document provides a thorough interpretation of the major geologic units beneath and adjacent to the 200 West and 200 East Areas. Geologic cross sections are useful in supporting the geologic model development for the 200-PO-1 Operable Unit. This document also provides textural and mineralogical data for most of the major strata from core samples collected in the 200 West and East Areas. | | | | | | | |
| RPP-14283, Rev. 1 | 2004 | CHG<br>F.M. Mann, A.J. Knepp, M. Connelly | *Performance Objectives for Tank Farm Closure Performance Assessments* | In 1992, DOE, EPA, and Ecology gathered a group of stakeholders to study potential future uses for the Hanford Site land. The *Future for Hanford: Uses and Cleanup: The Final Report of the Hanford Future Site Uses Working Group* (HFSUWG, 1992) stated that the working group identified a single cleanup scenario for the Central Plateau. This scenario assumes that future uses of the surface, subsurface, and groundwater in and immediately surrounding the 200 West and 200 East Areas would be exclusive. Surrounding the exclusive area would be a temporary surface and subsurface exclusive buffer zone composed of at least the rest of the Central Plateau. As the risk from the waste management activities decrease, it is expected that the buffer zone would shrink commensurately. The "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)" (64 FR 61615), which is heavily based on HFSUWG, 1992, identified near-term land uses for the Hanford Site. The ROD prescribes the use in the 200 Areas as exclusively industrial, with much of the surrounding land having the use of preservation or conservation. It is anticipated that groundwater contamination under the core zone will preclude beneficial use for the foreseeable future, which is at least the period of waste management and institutional controls (150 years). It is assumed that the tritium and I-129 plumes beyond the control zone boundary will exceed DWSs for the period of the next 150 to 300 years. It is expected that other groundwater contaminants will remain below, or be restored to, drinking water levels outside the core zone. No drilling for water use or otherwise will be allowed in the core zone for the foreseeable future. Under this guidance, the groundwater between the core zone and the River Corridor is to be remediated between 2012 and 2035. The 2035 to 2150 timeframe continues to restrict groundwater use. After 2150, the performance objective is multiple land uses. Relevant regulations include the "National Primary Drinking Water Regulations" (40 CFR 141), the "National Secondary Drinking Water Regulations" (40 CFR 143), and the "Model Toxics Control Act—Cleanup" (WAC 173-340) cleanup regulations. Points of assessment are limited to two points the maximum point of impact at the 200 Area core zone boundary or beyond and the maximum point of impact along the Columbia or Yakima Rivers. | WMP-28945, App. D | | | | | R | |

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| RPP-14430, Rev. 0 | 2003 | CHG<br><br>M.I. Wood, T.E. Jones, B.M. Bjornstad, D.G. Horton, S.M. Narbutovskih, R. Schalla | *Subsurface Conditions Description of the C and A-AX Waste Management Area* | This document discusses the subsurface conditions relevant to the occurrence and potential migration of contaminants in the groundwater underlying the C, A, and AX Tank Farms. It also describes the available environmental contamination data and contains a limited, qualitative interpretation of the data as they apply to contaminant behavior. This document aided in selecting a characterization approach, and focused on site-specific data that defined the occurrence and migration of contaminants. The outcome of this report states that the regional distribution of contaminants near the C and A-AX Tank Farms was moderate, and it was determined that there was no clear indication of vadose contamination within these waste management areas being a source. | DOE/RL-2007-31 | | V | | | | |
| RPP-19822, Rev. 0 | 2004 | CHG<br><br>B.A. Higley, D.E. Place | *Hanford Defined Waste Model – Revision 5.0* | This version of HDW was required to provide more accurate information for the best-basis inventory (BBI), the official database for waste inventory estimates for tank farms, which uses estimates from HDW model when direct sample data is not available. Since the BBI does not use individual tank inventory estimates but instead interfaces with waste type composition estimates calculated by the HDW workbook it was determined that HDW model be revised in three areas: fuel activity estimates, chemical process simulations, and error correction<br><br>The main updates included the following:<br><br>• Relaxing conservative assumptions that all of the radionuclides in the fuel, except uranium and plutonium, remained in the tank farm system. Thus, several radionuclides (e.g., H-3, C-14, Tc-99, and I-129) were evaluated to have chemical properties that allowed them to escape or be removed from the process (i.e., partitioning of tritium to cribs via evaporator condensates, C-14 and I-129 to the atmosphere, and Tc-99 with the uranium product shipped offsite).<br><br>• Using site-specific solubility changes as opposed to global solubility factors used in Rev. 4. This increased uranium solubility by a factor of 30 in the bismuth-phosphate metal waste due to complexing of uranium with carbonate. Strontium and cesium solubility concentrations were also revised for the ferrocyanide waste stream in accordance with historical laboratory results (e.g., in the 1950s). The solubility of calcium carbonate was increased to reflect lower ionic strength because it was not part of a separations waste stream.<br><br>• Including 224 Building waste generated prior to 1952.<br><br>• Providing chemical process percentage breakdown of fission products in the various waste components of the bismuth-phosphate process are now based on process flow sheets, plant test data, and a laboratory simulation of the plutonium-product extraction step. The new process splits reduced the activity estimated for the first-cycle, second-cycle, and 224 waste streams. The new information on the bismuth-phosphate process is documented in the interoffice memorandum 7G300-02-NWK-024 issued by CH2M HILL Hanford Group, Inc. in Appendix C of RPP-19822, Rev. 0 (CHG, 2004).<br><br>• Correcting errors pertaining to the calculations of the uranium recovery and scavenging streams. The activity in the metal waste was used rather than all the bismuth phosphate activity.<br><br>• Correcting errors representing the Hot Semiworks and the B Plant waste fractionization.<br><br>• Incorporating new Oak Ridge isotope generation (ORIGEN2) fuel activity estimates for improved chemical process models (ORNL-5621, *ORIGEN2—A Revised and Updated Version of the Oak Ridge Isotope Generation and Depletion Code* [ORNL, 1980]). | WMP-28945, App. B | | | | M | | |

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| | | | | • Resolving issues and limitations identified in the BBI and HDW model.Some remaining problems exist with the program, which include the following: (1) HDW model predicts that $NiFe(CN)_6$ is insoluble and stable, (2) pH for various waste streams were varied over a significant range while the model holds the waste to a specific pH, (3) several of the chemical constituents do not reconcile with process flow sheets, (4) uncertainty in accumulated sludge or salt cake, (5) carbon dioxide adsorption and resulting formation of $NaCO_3$, (6) special recovery processes (e.g., B Plant fractionization and Hot Semiworks) are incompletely modeled or neglected by the HDW model, and (7) the HDW model does not maintain mass balances throughout the waste stream or tank inventory (e.g., frequently, waste streams chemical composition are calculated independently rather than from the waste stream which they1are dependant). | | | | | | | |
| WHC-MR-0132 | 1990 | WHC<br>J.D. Anderson | *A History of the 200 Area Tank Farms* | This document summarizes the history of liquid waste generation and subsequent handling and storage in the tank farms. | WMP-28945, App. C | D, H, P | | | | | |
| WHC-SD-0487 | 1989 | WHC | *PUREX Technical Manual* | These documents (HW-36293 [GE, 1955]; RHO-MA-116 [RHO, 1982 {1980}]; and WHC-SD-0487 [WHC, 1989]) present detailed descriptions of the plutonium-uranium extraction process and together provide insight as to how the process changed over time. Most waste sites associated with PUREX are in the 200-PO-1 Groundwater OU. In all variations of the PUREX process, following dissolution of the fuel rods in boiling nitric acid and removal of the cladding material, the dissolved uranium/plutonium/fission product/nitric acid solution was introduced at the middle of the HA solvent extraction column where plutonium and uranium were removed from the descending inorganic solution by a rising organic extractant and diluent. The residual inorganic was highly radioactive with fission products and highly acidic. The waste stream was collected out of the bottom of the HA column and, following chemical manipulations in a feed tank, was sent to either the E-F-11 or the E-F-6 waste concentrator, depending on the date of the process. The waste concentrators boiled off about 80% of the nitric acid, which was collected and liquefied in a condenser and prepared for reuse. The residual material was discharged to a holding tank in preparation for treatment to protect underground storage tanks. The highly radioactive, fission-product-rich stream was sent to the boiling waste 241-A and 241-AX Tank Farms. With cooling, precipitates containing significant quantities of fission products formed and sludge was generated. At the same time, a supernatant with reduced particulate or precipitable matter was generated and was also identified for use at 221-B. | WMP-28945, App. A | | | | | | |
| WHC-SD-EN-TI-011, Rev. 0 | 1992 | WHC<br>K.A. Lindsey | *Geology of the Northern Part of the Hanford Site: An Outline of Data Sources and the Geologic Setting of the 100 Areas* | This report outlines the types of geologic data available for the Hanford Site north of the Gable Mountain anticline and where this data can be obtained. This report also includes a discussion of the regional geology putting the study area in its geologic context. | | | G | I | | | |
| WHC-SD-EN-TI-012, Rev. 0 | 1992 | WHC<br><br>K.A. Lindsey, B.N. Bjornstad, J.W. Lindberg K.M. Hoffman | *Geology Setting of the 200 East Area: An Update* | | | | | | | | |

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| WHC-SD-EN-TI-019, Rev. 0 | 1992 | WHC<br><br>M.P. Connelly, J.V. Borghese, C.D. Delaney, B.H. Ford, J.W. Lindberg, S.J. Trent | *Hydrogeologic Model for the 200 East Groundwater Aggregate Area* | This report provides a compilation and evaluation of available hydrogeologic and geochemical data collected in and surrounding the 200 East Area. The data and evaluation efforts were conducted to support the 200 East Groundwater AAMSR (DOE/RL-92-19 [DOE/RL, 1993c]). The purpose of this document is to provide a comprehensive overview of groundwater flow characteristics in the 200 East Area. Information found in this document was incorporated into the 200 East Groundwater AAMSR where applicable. The objectives of the document were as follows: (1) Compile and analyze hydrogeologic and geochemical data collected from within and surrounding the 200 East Area; (2) Describe groundwater flow characteristics for both the unsaturated and saturated zone; (3) Develop a comprehensive hydrogeologic conceptual model for the 200 East groundwater aggregate area; (4) Identify and describe the nature and extent of groundwater contamination associated with the 200 East Area waste management operations. | DOE/RL-2007-31 | | H | | M | | |
| WHC-SD-EN-TI-290, Rev. 0 | 1994 | WHC<br><br>K.A. Lindsey, J.L. Slate, G.K. Jaeger, K.J. Swett, R.B. Mercer | *Geologic Setting of the Low-Level Burial Grounds* | This report describes the regional and site specific geology of the Hanford Sites low-level burial grounds in the 200 East and West areas. The report incorporates data from boreholes across the entire 200 Areas, integrating the geology of this area into a single framework. Geologic cross-sections, isopach maps, and structural contour maps of all major geologic units from the top of the Columbia River Basalt Group to the surface are included. The physical properties and characteristics of the major suprabasalt sedimentary units also are discussed. | | | | | | | |
| WMP-18647, Rev. 0 | 2004 | FH<br><br>W.J. Millsap | *Historical Site Assessment of the Surface Radioactive Contamination of the BC Controlled Area* | This report is a historical site assessment of the BC Cribs and Trenches Area. This assessment has three main parts: a chronological narrative, a review of the information found that is pertinent to a conceptual model, and the descriptions of the conceptual models themselves. This document also presents a comprehensive reference list of documents pertinent to disposal practices in the BC Cribs and Trenches Area. | DOE/RL-2007-31 | H | | | | | |
| WMP-25924, Rev. 0 | 2005 | FH<br><br>D. Todak | *Data Quality Objectives Summary Report for the Installation of One Groundwater Well in the 300-FF-5 Operable Unit* | Data are presented for 618-10 and 618-11 Burial Grounds within the 300-FF-5 OU. | SGW-34011, Table 1-3 | | H | | | | |
| WMP-28945, Rev. 0 | 2007 | FH<br><br>G.S. Thomas | *Data Quality Objective Summary Report in Support of the 200-BP-5 Groundwater Operable Unit Remedial Investigation/ Feasibility Study Process* | Presents data from the 200-BP-5 Groundwater OU. | SGW-34011, Table 1-3 | | H | | | | |
| WSCF20060892 | 2006 | FH<br><br>S.L. Fitzgerald | *Data Package Summary Analytical Laboratory F06-026 200-PO-1 WTP Opportunistic Sampling and Analysis Groundwater Sampling* | This document includes the narrative, analytical results, chain of custody and sampling receipt for two 200-PO-1 waste treatment plant opportunistic sampling and analysis groundwater samples. Samples were collected per instructions in HNF-SD-CP-QAPP-017, Rev. 7, *Waste Sampling and Characterization Facility Quality Assurance Program Plan.* | | | | I | A | | |

| Document # | Date | Authors | Title | Summary | Source Document | Background Site Descriptions (D); History (H); Processes (P); Regulatory (R) | Physical Characteristics: Geology (G); Hydrogeology (H); Climate (C); Ecology (E) | Contaminant Description(s): COPC (C); Source (S); Release (R); Plume (P); Investigation (I) | Analysis (A) & Modeling (M) | Risk Assessment | Alternatives Development |
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| WSCF20060893 | 2006 | FH<br>S.L. Fitzgerald | *Data Package Summary Analytical Laboratory F06-029 200-PO-1 WTP Opportunistic Sampling and Analysis Soil Sampling* | This document includes the narrative, analytical results, chain of custody and sampling receipt for four 200-PO-1 waste treatment plant opportunistic sampling and analysis soil samples. Samples were collected per instructions in HNF-SD-CP-QAPP-017, Rev. 7. | | | | I | A | | |
| WSCF20060925 | 2006 | FH<br>S.L. Fitzgerald | *Data Package Summary Analytical Laboratory F06-029 200-PO-1 WTP Opportunistic Sampling and Analysis Soil Sampling* | This document includes the narrative, analytical results, chain of custody and sampling receipt for four 200-PO-1 waste treatment plant opportunistic sampling and analysis soil samples. Samples were collected per instructions in HNF-SD-CP-QAPP-017, Rev. 7. | | | | I | A | | |
| WSCF20060939 | 2006 | FH<br>S.L. Fitzgerald | *Data Package Summary Analytical Laboratory F06-029 200-PO-1 WTP Opportunistic Sampling and Analysis Soil Sampling* | This document includes the narrative, analytical results, chain of custody and sampling receipt for eight 200-PO-1 waste treatment plant opportunistic sampling and analysis soil samples. Samples were collected per instructions in HNF-SD-CP-QAPP-017, Rev. 7. | | | | I | A | | |
| WSCF20071844 | 2007 | FH<br>S.L. Fitzgerald | *Data Package Summary Analytical Laboratory F07-060 216-B-62 Crib Well Decommissioning Sampling* | This document includes the narrative, analytical results, chain of custody and sampling receipt for one 200-PO-1 waste treatment plant opportunistic sampling and analysis groundwater sample. Sample was collected per instructions in HNF-SD-CP-QAPP-017, Rev. 7. | | | | I | A | | |
| | | | HEIS database | Select mobile contaminants were reviewed to determine extent of transport and concentrations at various wells. This work was completed to verify conceptual models provided in BNWL-B-360 (BNW, 1974) and DOE/RL-95-59 (DOE-RL, 1996). The highest gross-beta activity levels reported outside of the BY Cribs in the mid- to late 1950s are reported to the southeast in wells 299-E33-13, 299-E33-15, 299-E33-16, and 299-E33-17. After October 5, 1959, no continuous gross-beta records were found in the database from these wells until the 1990s. The concentration trends in these wells indicate that contamination from the BY Cribs migrated southward and predominately southeastward during the 1950s. Cobalt concentrations were reported in these wells from initial database entries beginning in 1960. Results were very sparse during the mid- to late 1960s, and other contaminants (tritium) became prominent in the late 1960s defining groundwater flow and contaminant transport. It appears that cobalt and gross-beta contamination migrated north from the BY Cribs, bypassing well 699-49-55A. The absence of cobalt in the early 1960s and gross beta in the late 1960s at 699-49-55A indicates basalt structural control for migration to 699-50-53A. Analytical data indicate radial contaminant flow from the BY Cribs during the 1950s and early 1960s. Tritium concentrations were reported from 1962 to present in various wells located to the north of the BY Cribs. Prior to 1973, results were sparse and generally below current drinking water levels. In 1973, concentrations increased significantly in well 699-49-57A and remained over 100,000 pCi/L through 1980. Tritium data suggest that the groundwater flow was primarily to the north and northwest at varying rates from the late 1960s until the early to mid-1990s. Since the early to mid 1990s plume maps, and nitrate and technetium trend plots have shown an apparent reversal in flow based on reported concentrations. Chloride concentrations were reviewed and compared from 1991 to present for 15 wells located north, west, and east of the B/BX/BY Tank Farms. Concentrations generally decrease with distance more to | WMP-28945, App. D | | | C | A | | |

| Document # | Date | Authors | Title | Summary | Source Document | Background Site Descriptions (D); History (H); Processes (P); Regulatory (R) | Physical Characteristics: Geology (G); Hydrogeology (H); Climate (C); Ecology (E) | Contaminant Description(s): COPC (C); Source (S); Release (R); Plume (P); Investigation (I) | Analysis (A) & Modeling (M) | Risk Assessment | Alternatives Development |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | the south and east than to the west. It appears that the recent elevated chloride concentrations are central to the BY Cribs and BY Tank Farm. Uranium concentrations were reported in the BY Crib wells starting in 1955. Results in 1956 indicated that uranium also migrated into the groundwater from the 216-B-8 Crib. Uranium concentrations were reported higher in the wells located to the south than to the north during the 1950s. However, elevated uranium concentrations were also reported in the northern wells (e.g., 299-E33-11) demonstrating radial flow. Elevated uranium concentrations may have migrated north during the absence of uranium data (from 1957-1986). This is consistent with the nitrate concentrations reported during the 1970s through mid-1980s. Nitrate concentrations beneath the BY Cribs and surrounding the BY Cribs were sparse in the early 1970s. Data indicate that spills or releases near either the BY Tank Farm or BY Cribs may have been responsible for the elevated nitrate concentrations reported in the mid-1970s. From 1995 to present, nitrate concentrations have been consistently higher in well 299-E33-16 than any other well in the northern portion of the 200 East Area. Higher concentrations also have been reported under the BY Cribs. Nitrate concentrations have demonstrated a northern flow from the early 1970s through the mid-1990s; however, over the past decade, plumes appear to be moving very slowly to the southeast. Based on all of the data presented, an interpretation including superimposed radial flow from waste sites and intermittent to predominant northerly flow from the late 1960s to the early to mid-1990s seems plausible. During this time, due to the lack of analytical results and sparse monitoring well locations, it is impossible to determine the inventory of contamination in the groundwater for technetium and uranium that may have previously migrated north and is currently present north of the 200 East Area boundary. | | | | | | | |
| | | | Virtual Library groundwater elevation data | Groundwater elevations were reviewed to determine historical groundwater flows to interpret groundwater contour maps, confirm previous assumptions of groundwater flow, and to verify possible inventory calculations completed north of the 200 East Area. Thus, several wells were reviewed for groundwater elevations from the beginning of separations activity to 2005. From the results of various elevation reports, it was determined that key wells be selected to illustrate the various groundwater flow changes within this area. Observations from the Virtual Library during the early1950s indicated that the groundwater movement proximal to the BY Cribs was to the south. Groundwater elevations indicated southern groundwater gradient south of the Gable Butte/Gable Mountain Gap as early as 1959. In late 1971 due to apparent reduced hydraulic damming effects, groundwater elevations in 299-E34-1, 699-49-57A, and 699-60-60 indicated northern flow (see Figure D-19). This may have been influenced from additional the liquid effluent disposal to 216-B-50 and 216-B-57. | WMP-28945, App. D | | H | | A | | |
| | | | *Stoller Log Data Reports* | Presents geophysical logs showing the vertical extent of vadose zone radiological contamination at various waste sites in the 200 East Area, including sites in the 200-PW-2, 200-PW-3, 200-MW-1, and 200-CS-1. | SGW-34011, Table 1-3 | | H | | A | | |
| | 2006 | U.S. Ecology | *Annual Environmental Monitoring Report for Calendar Year 2005* | Includes a compliance summary and list of contaminants for the U.S. Ecology waste disposal facility and annual groundwater-monitoring results. | SGW-34011, Table 1-3 | | | C | | | |
| | 2006 | | WIDS | The WIDS database indicates that 23.4 million L of high-salt, neutral/basic waste were discharged to the 216-C-1 Crib. Most of this waste was discharged before the start of the PUREX test processing. The 216-C-3 Crib received 5 million L of acidic waste. | WMP-28945 App. A | | | S | | | |

| Document # | Date | Authors | Title | Summary | Source Document | Background Site Descriptions (D); History (H); Processes (P); Regulatory (R) | Physical Characteristics: Geology (G); Hydrogeology (H); Climate (C); Ecology (E) | Contaminant Description(s): COPC (C); Source (S); Release (R); Plume (P); Investigation (I) | Analysis (A) & Modeling (M) | Risk Assessment | Alternatives Development |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PNNL geophysical logging records | Historical well logs from the late 1950s to the early 1970s within and proximal the 216 B 7A&B, 216-B-8, 216-B-11A&B, and 216 B 9 waste sites were reviewed. In 2002, logging results were provided in GJO-2002-343-TAR, *Hanford 200 Areas Spectral Gamma Baseline Characterization Report, 216-B-8 Crib and Adjacent Sites Waste Summary Report* (DOE-GJO, 2002). Well logs for 299-E33-58, 299-E33-59, and 299-E33-60 (located near 216-B-7A&B Cribs) were reviewed. Activity in May 1963 reported elevated gamma concentrations throughout the well length. Cesium was detected in all three of the wells. Uranium was detected in one of the wells.<br><br>The May 5, 1959, log at 299-E33-18, which is located near the 216-B-7A&B Cribs, recorded peak concentration of gamma activity from various depths. In 1968 and 1970, results were near background throughout the vadose zone, with gamma activity peaks only within the saturated zone. Information is provided for cesium, cobalt, and uranium.<br><br>The May 5, 1959, log at 299-E33-16, which is located near the 216-B-8 Crib, recorded peak concentration of gamma activity from various depths. In 1970, results were similar. Cesium was found throughout the vadose zone column and cobalt was reported in intervals. This indicates that the acid and/or other possible complexes promoted the movement of cobalt and cesium throughout the vadose zone at 216-B-8. Uranium was reported in the Stoller logs to be at or below background. It is difficult to determine how much of the 146 kg of uranium inventory remains in the vadose zone beneath the 216-B-8 Crib. Similar results were reported at the 216-B-9 Crib. In conclusion, cesium, cobalt, strontium, and uranium are believed to be in contact with groundwater from both the 216-B-8 and 216-B-9 areas.<br><br>The May 23, 1963, log at 299-E33-19, which is located near the 216-B-11B reverse well, recorded peak concentration of gamma activity from various depths. In 1970, results were similar. Information is provided for cesium and cobalt. | WMP-28945, App. C | | G | C, I | | | |
| | 2004 | J.N. Christensen, P.E. Dresel, M.E. Conrad, K. Maher, D.J. DePaolo | "Identifying the Source of Subsurface Contamination at the Hanford Site in Washington Using High-Precision Uranium Isotopic Measurements," in *Environmental Science & Technology* | This paper used isotopic analyses to investigate the link between vadose zone and groundwater contamination, to identify contamination sources, and to provide estimates of the relative proportions of contaminant uranium in the analyzed samples. The uranium isotopic composition measured in the vadose zone and groundwater samples is compared to estimates of the uranium isotopic compositions of different waste fluids to constrain the history of contamination events in the B/BX/BY Tank Farms.<br><br>The uranium isotopic data provides several lines of evidence for the source of the B/BX/BY groundwater uranium plume. It was concluded that the B 110 tank release has not been a significant source of uranium contamination in the groundwater.<br><br>The first sign of uranium contamination in well 299-E33-18 appeared in early 1993; the time and location were used as a basis for travel-time calculations for the groundwater plume. This paper also concludes that well 299-E33-34, located about 775 m from 299-E33-18, indicates a travel time of approximately 2.5 to 3 years.<br><br>Several liquid waste disposal facilities (cribs) were noted in operation close to the B/BX/BY tanks during the late 1940s and 1950s; these sites could not be completely ruled out as sources of groundwater contamination without vadose zone samples. These past releases may have contributed to the concentrations reported at 299-E33-34 rather than the BX-102 site. | WMP-28945, App. C | | | C, S, R, I | | | |

| Document # | Date | Authors | Title | Summary | Source Document | Background Site Descriptions (D); History (H); Processes (P); Regulatory (R) | Physical Characteristics: Geology (G); Hydrogeology (H); Climate (C); Ecology (E) | Contaminant Description(s): COPC (C); Source (S); Release (R); Plume (P); Investigation (I) | Analysis (A) & Modeling (M) | Risk Assessment | Alternatives Development |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DOE/RL-96-17, Rev. 5 | 2004 | DOE/RL | *Remedial Design Report/Remedial Action Work Plan for the 100 Area* | | | | | | | | |

AAMSR = aggregate area management study report
ALARA = as low as reasonably achievable
bgs = below ground surface
CHG = CH2M HILL Hanford Group, Inc.
COC = contaminant of concern
COPC = contaminant of potential concern
DOE = U.S. Department of Energy
DQO = data quality objective
Ecology = Washington State Department of Ecology
EDTA = ethylenediamine tetra acetic acid
EPA = U.S. Environmental Protection Agency
ERDA = U.S. Energy Research and Development Administration
FS = feasibility study
gpm = gallons per minute
HDW = Hanford defined waste
HEIS = Hanford Environmental Information System
HRR = high-resolution resistivity
HWIS = Hanford Waste Information System
$K_d$ = distribution coefficient
LMHC = Lockheed Martin Hanford Corporation
MCL = maximum contaminant level
ORP = Office of River Protection
OU = operable unit
PCB = polychlorinated biphenyl
PNNL = Pacific Northwest National Laboratory
PUREX = Plutonium-Uranium Extraction (Plant or process)
REDOX = Reduction-Oxidation (Plant)
RHO = Rockwell Hanford Operations
RI/FS = remedial investigation/feasibility study
RL = U.S. Department of Energy, Richland Operations Office
ROD = record of decision
SAC = system assessment capability
SAP = sampling and analysis plan
SEPA = State Environmental Policy Act
SIM = *Hanford Soil Inventory Model, Rev. 1* (RPP-26744) (CHG 2005)
TBP = tributyl phosphate
TPH = total petroleum hydrocarbon
Tri-Party Agreement = *Hanford Federal Facility Agreement and Consent Order*
TSD = treatment, storage, and/or disposal
UPR = unplanned release
VZ = vadose zone
WIDS = Waste Information Data System
WMA = waste management area

# Appendix C

# Historical Water Table Maps

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# C1 Historical Water Table Maps

Figure C-1 through Figure C-8 provide historical water table maps with changes in groundwater elevation because of artificial recharge. The figures illustrate some of the highest water levels during Hanford Site operations.

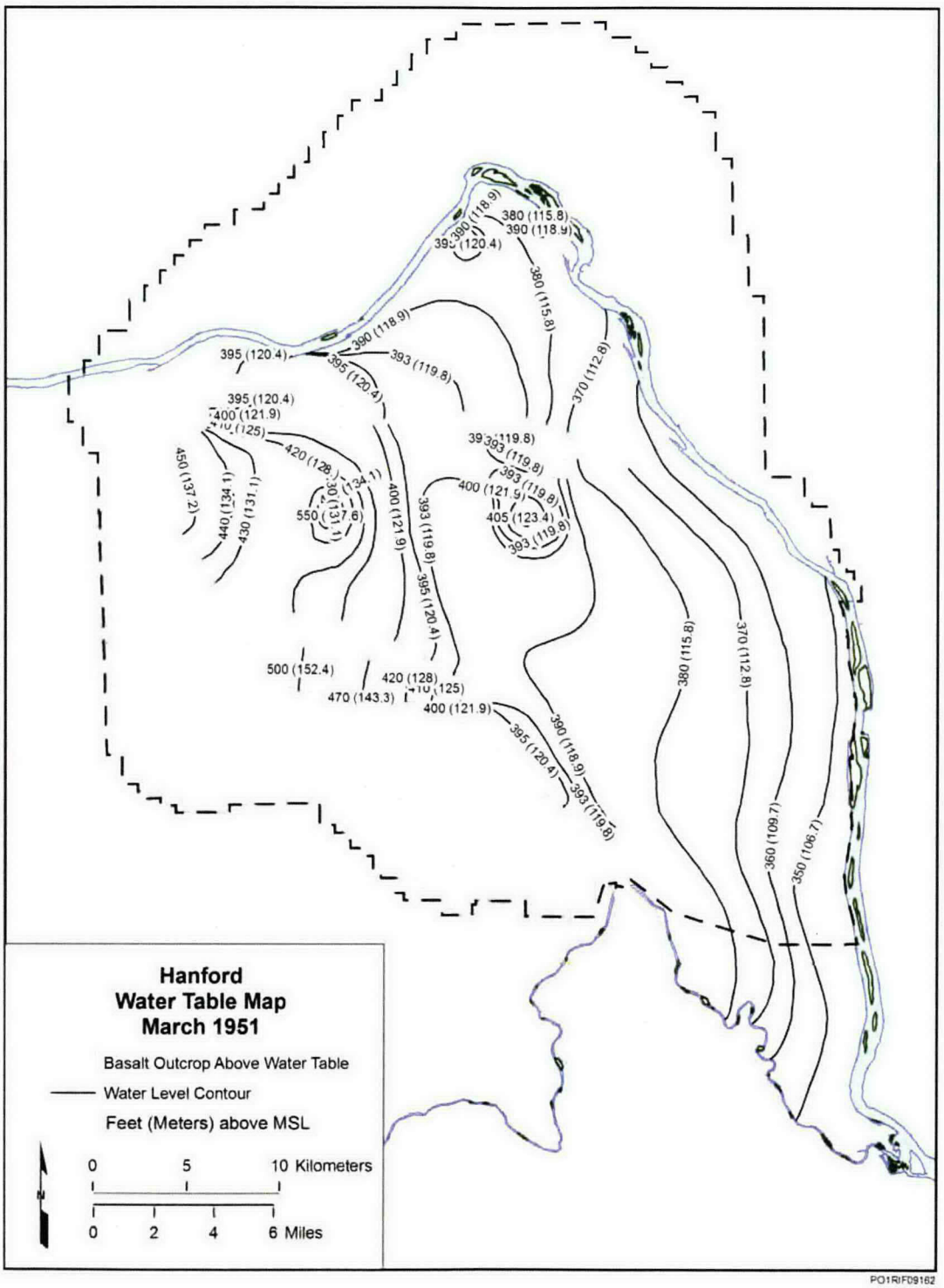



**Figure C-1. Water Table Map – March 1951**

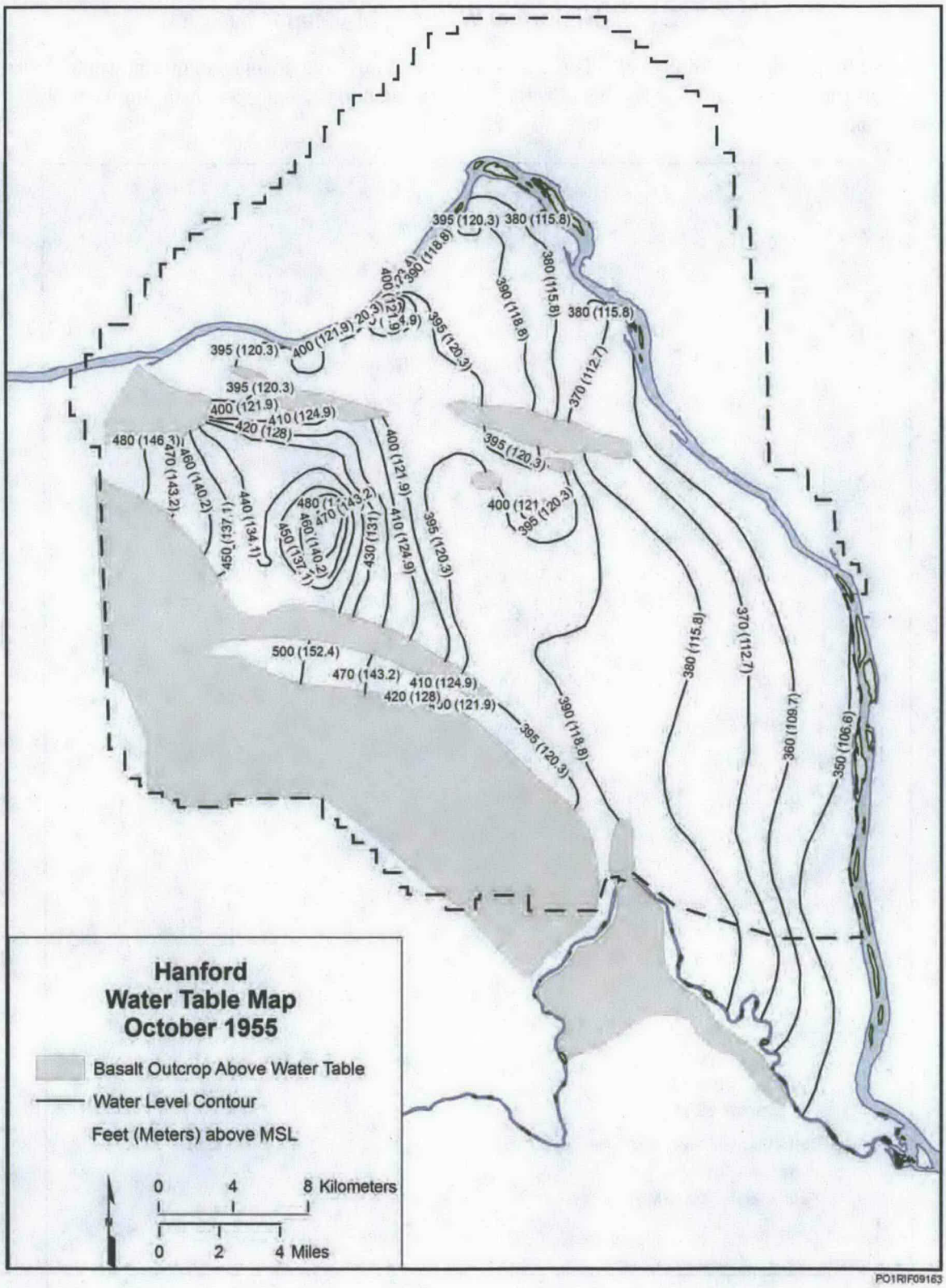



Figure C-2. Water Table Map – October 1955

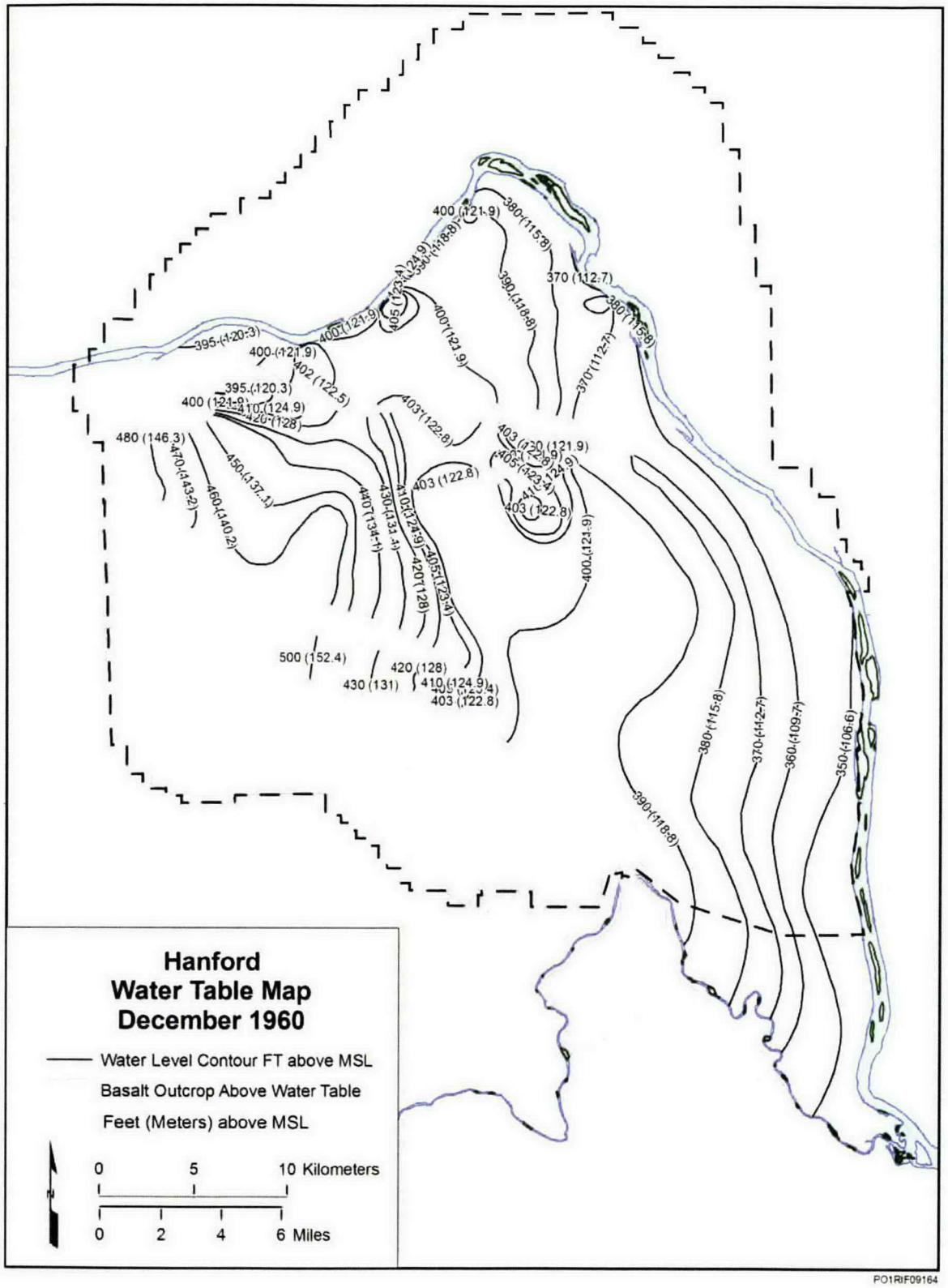



**Figure C-3. Water Table Map – December 1960**

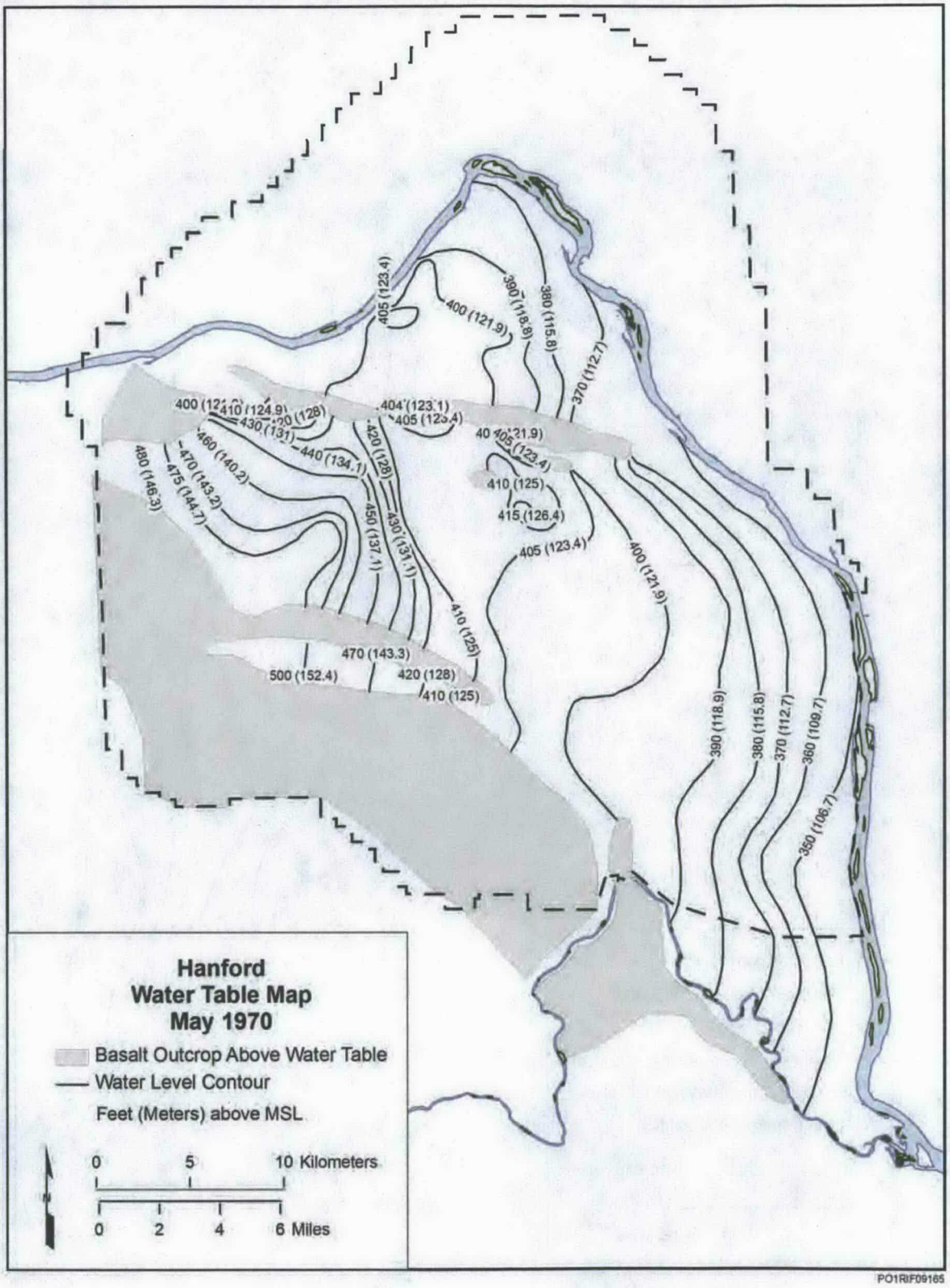
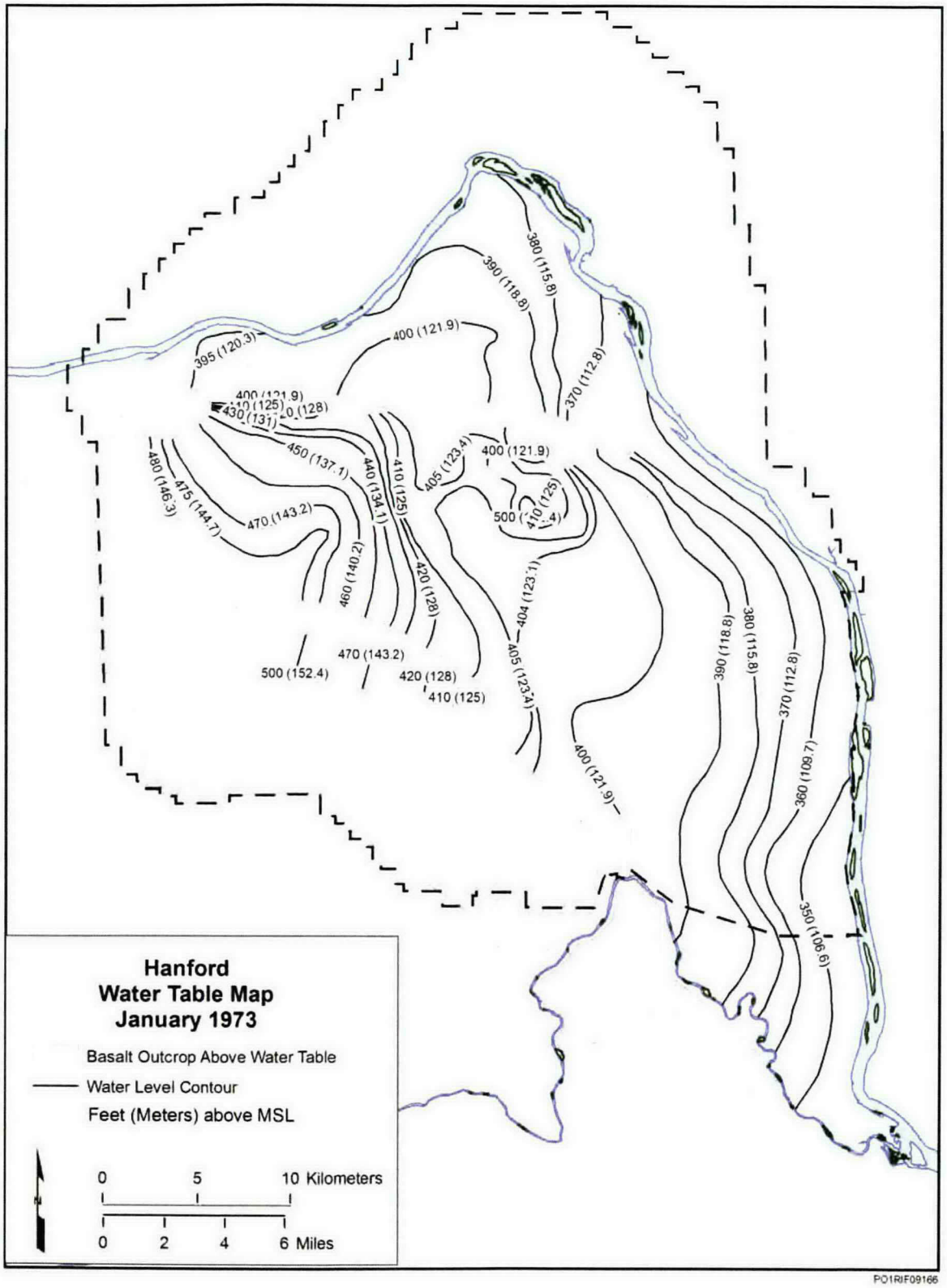



**Figure C-4. Water Table Map – May 1970**




PO1RIF09166

**Figure C-5. Water Table Map – January 1973**

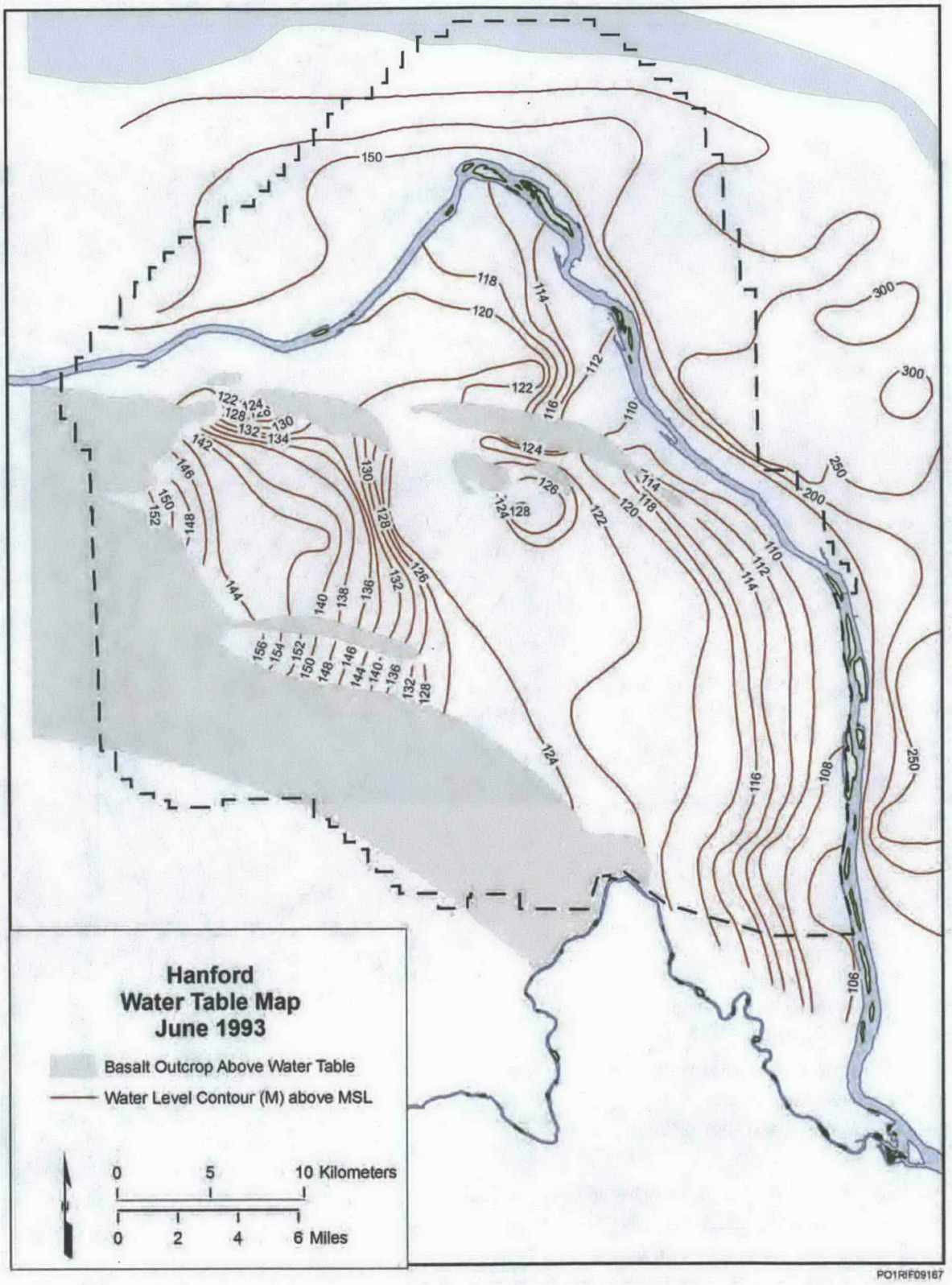



**Figure C-6. Water Table Map – June 1993**

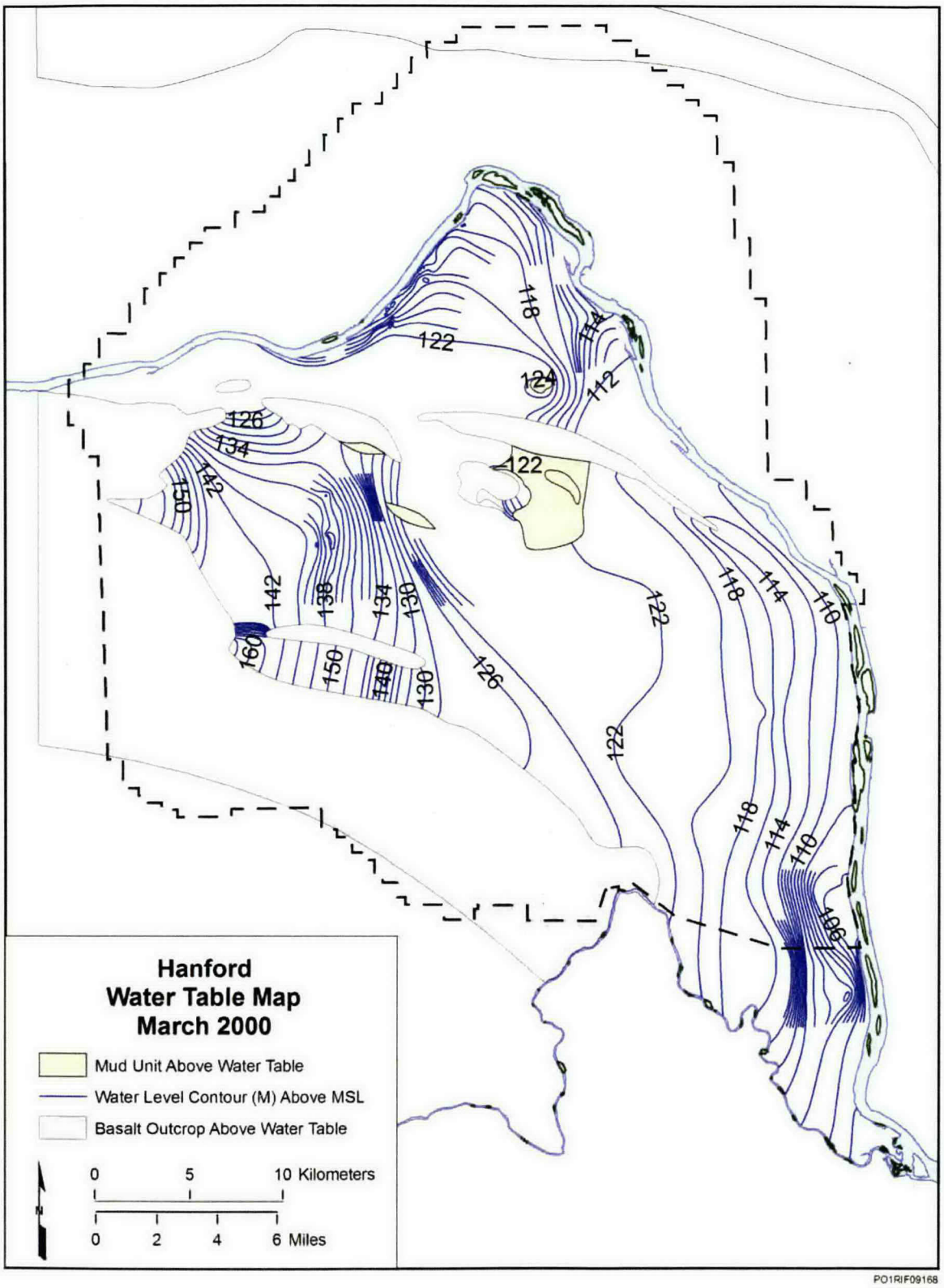



**Figure C-7. Water Table Map – March 2000**

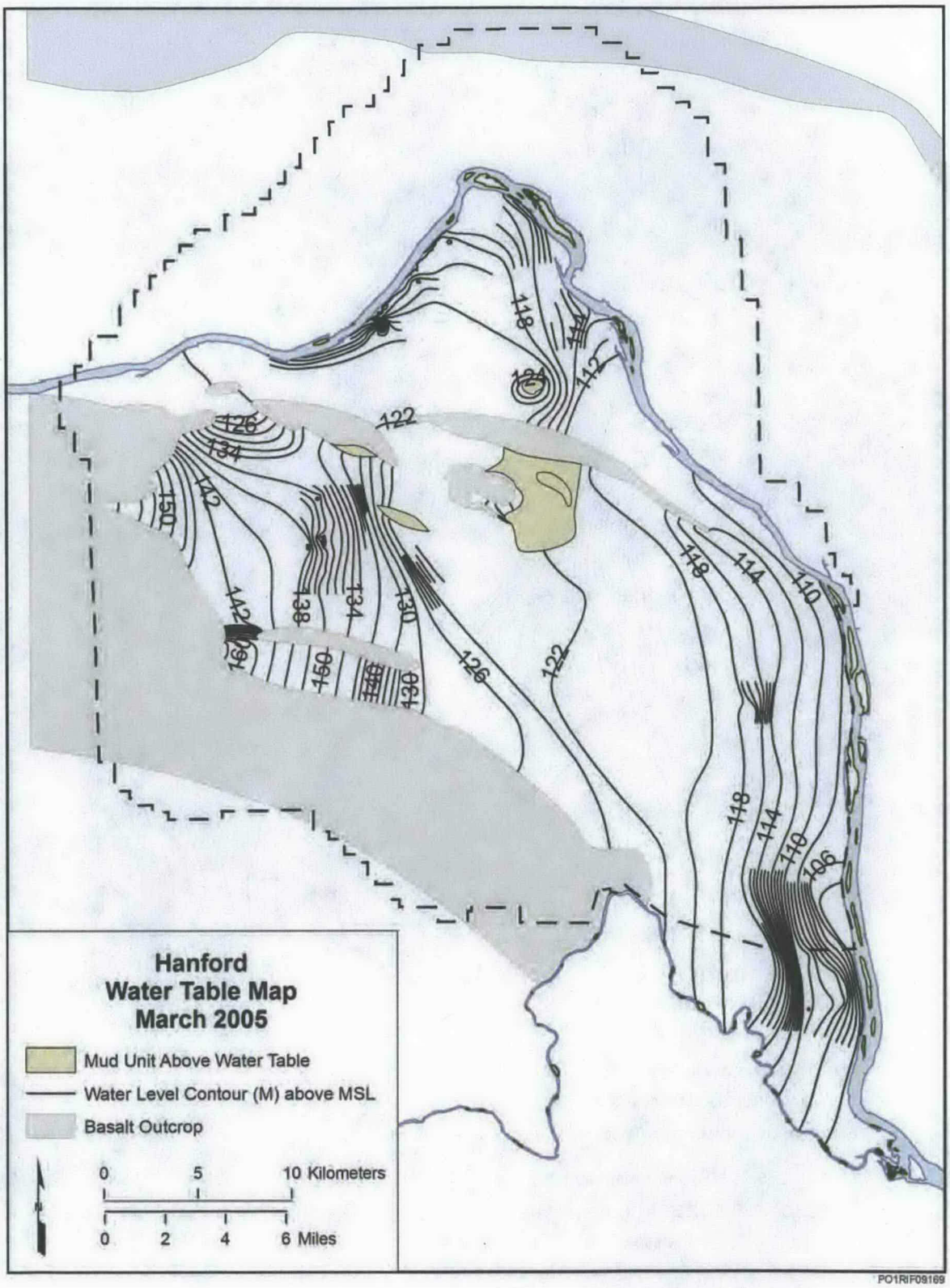



**Figure C-8. Water Table Map – March 2005**

# Appendix D

# Hydrogeologic Cross Sections for 200-PO-1 Groundwater Operable Unit

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# D1 Introduction

This appendix includes thirteen hydrogeologic cross sections, assembled to illustrate the 200-PO-1 Groundwater Operable Unit Near Field and Far Field hydrogeology. The section orientations and locations are provided on the included location map (Figure D-1). Scales are different on each section, as necessary, to illustrate the primary structural and hydrostratigraphic features, aquifer boundaries, and relative line length.

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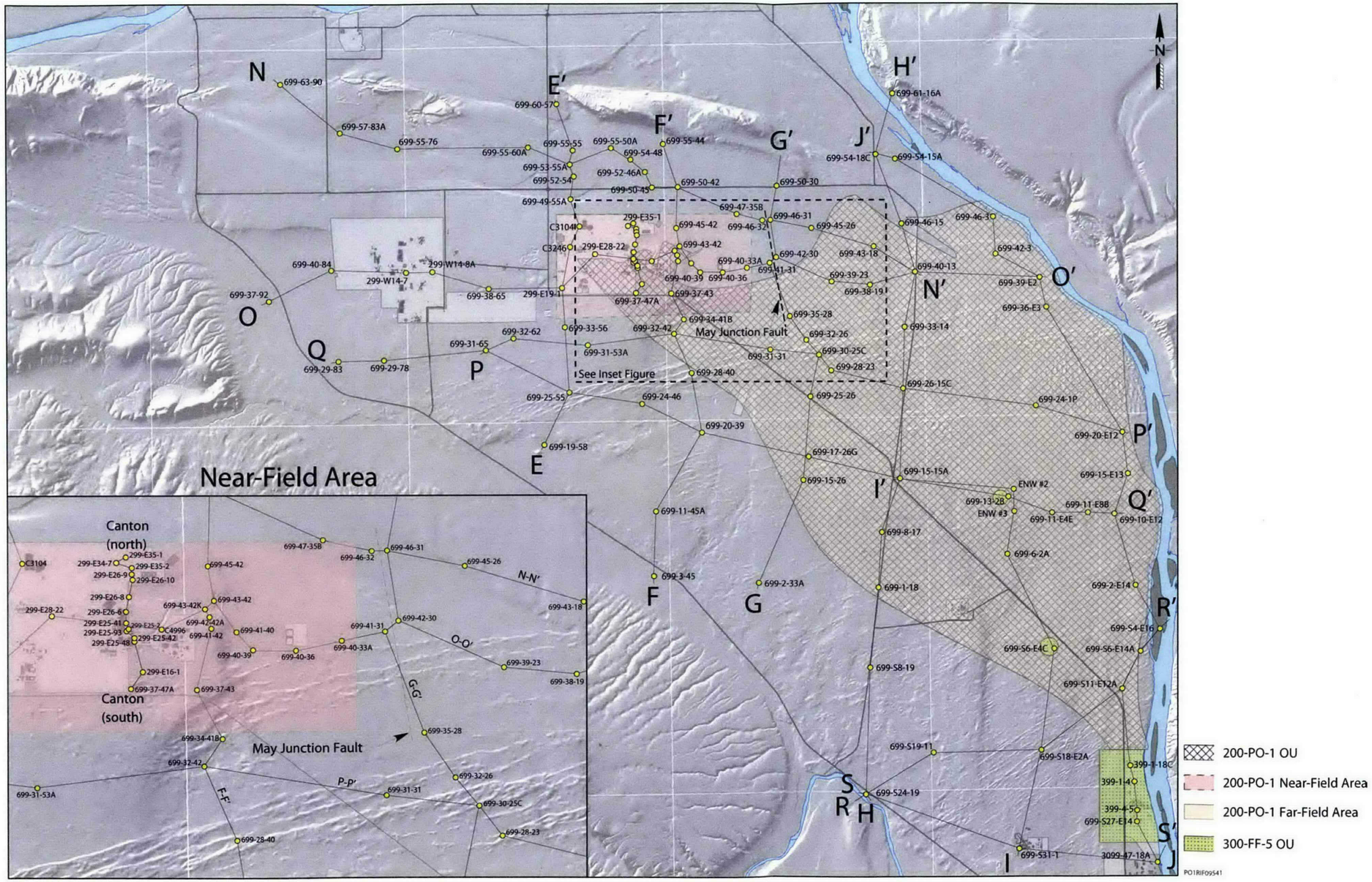


Figure D-1. Hydrogeologic Cross Section Location Map for 200-PO-1 Groundwater Operable Unit

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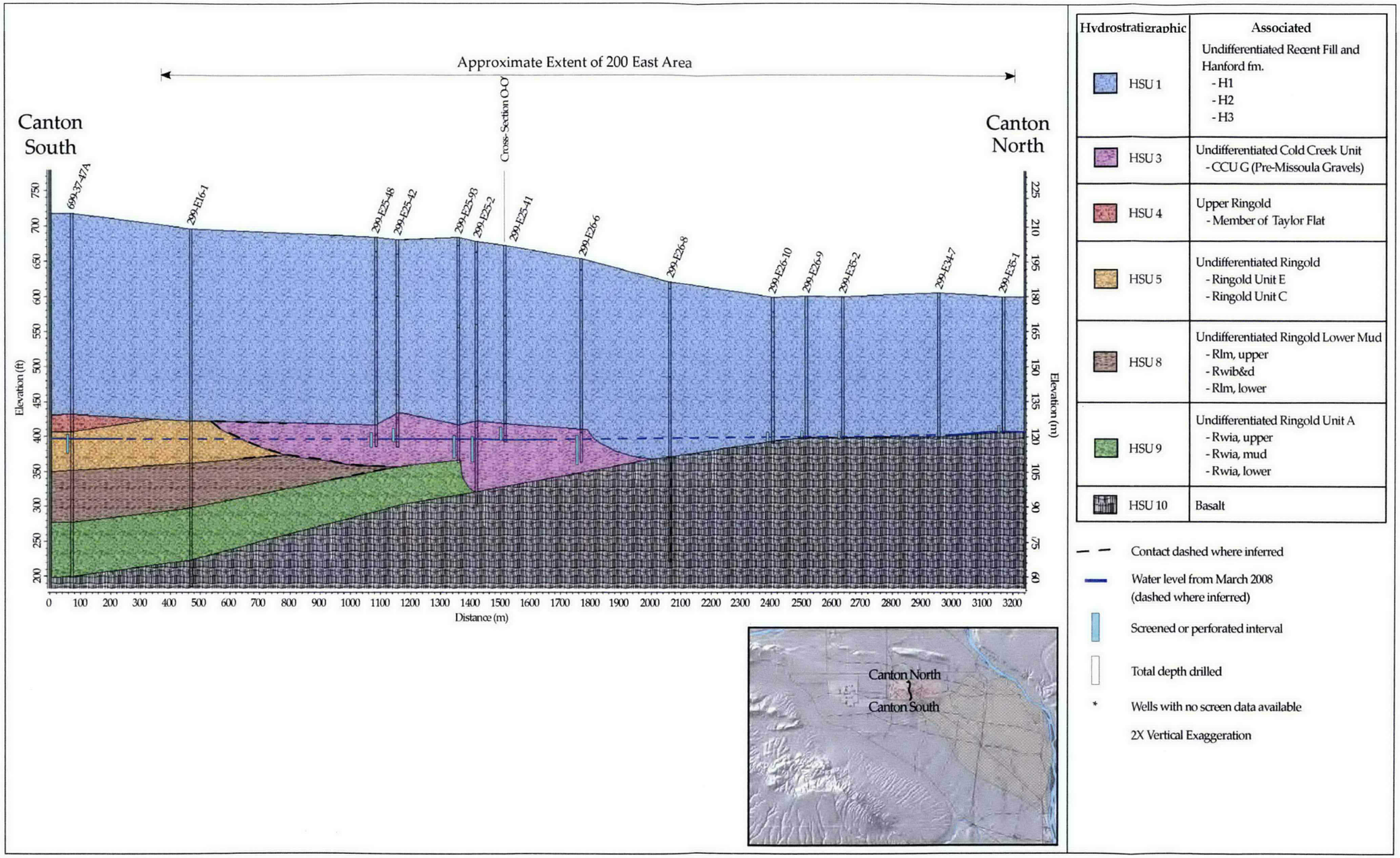


**Figure D-2. Hydrogeologic Cross Section Canton, 200-PO-1 Groundwater Operable Unit**

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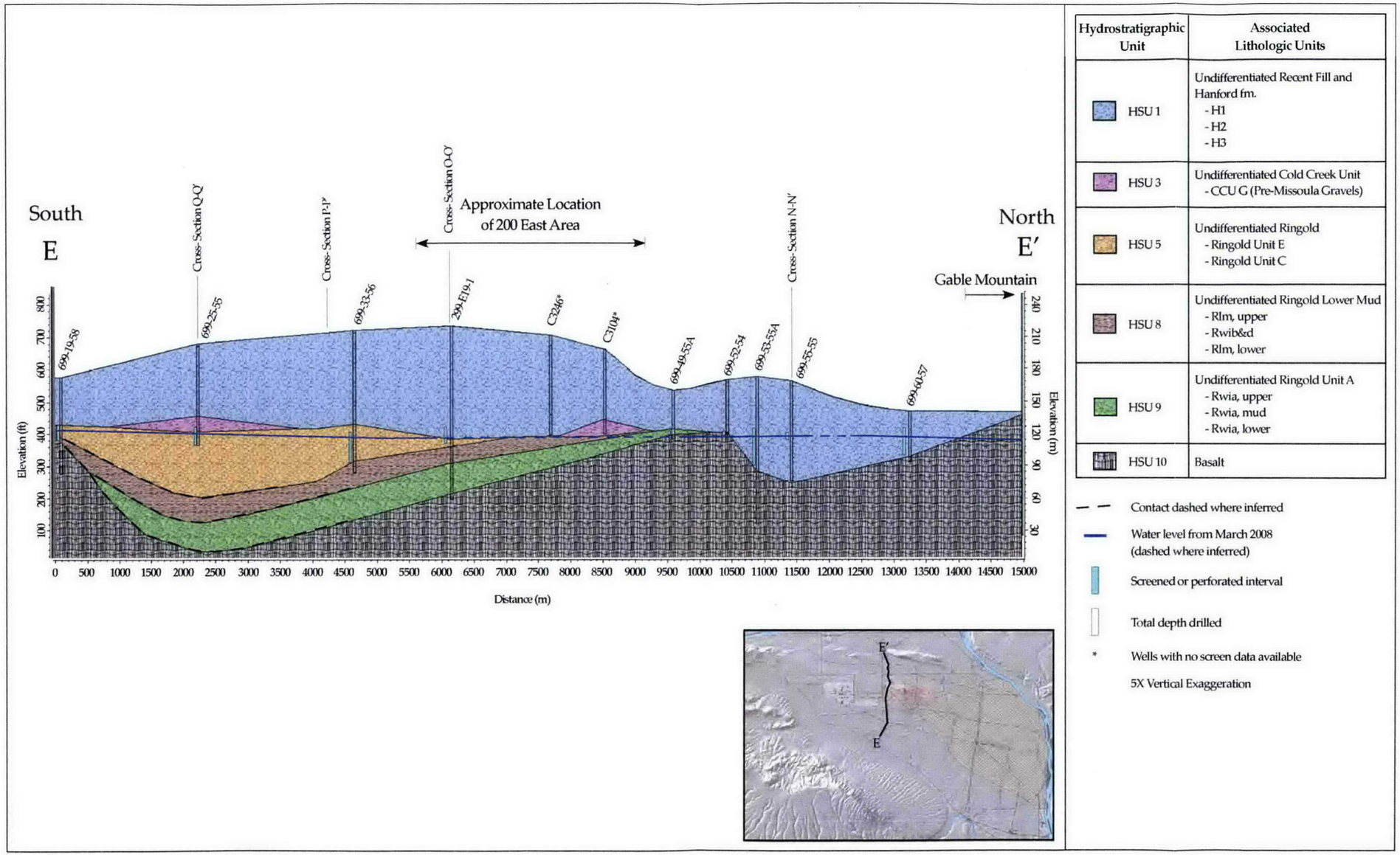


**Figure D-3. Hydrogeologic Cross Section E-E′, 200-PO-1 Groundwater Operable Unit**

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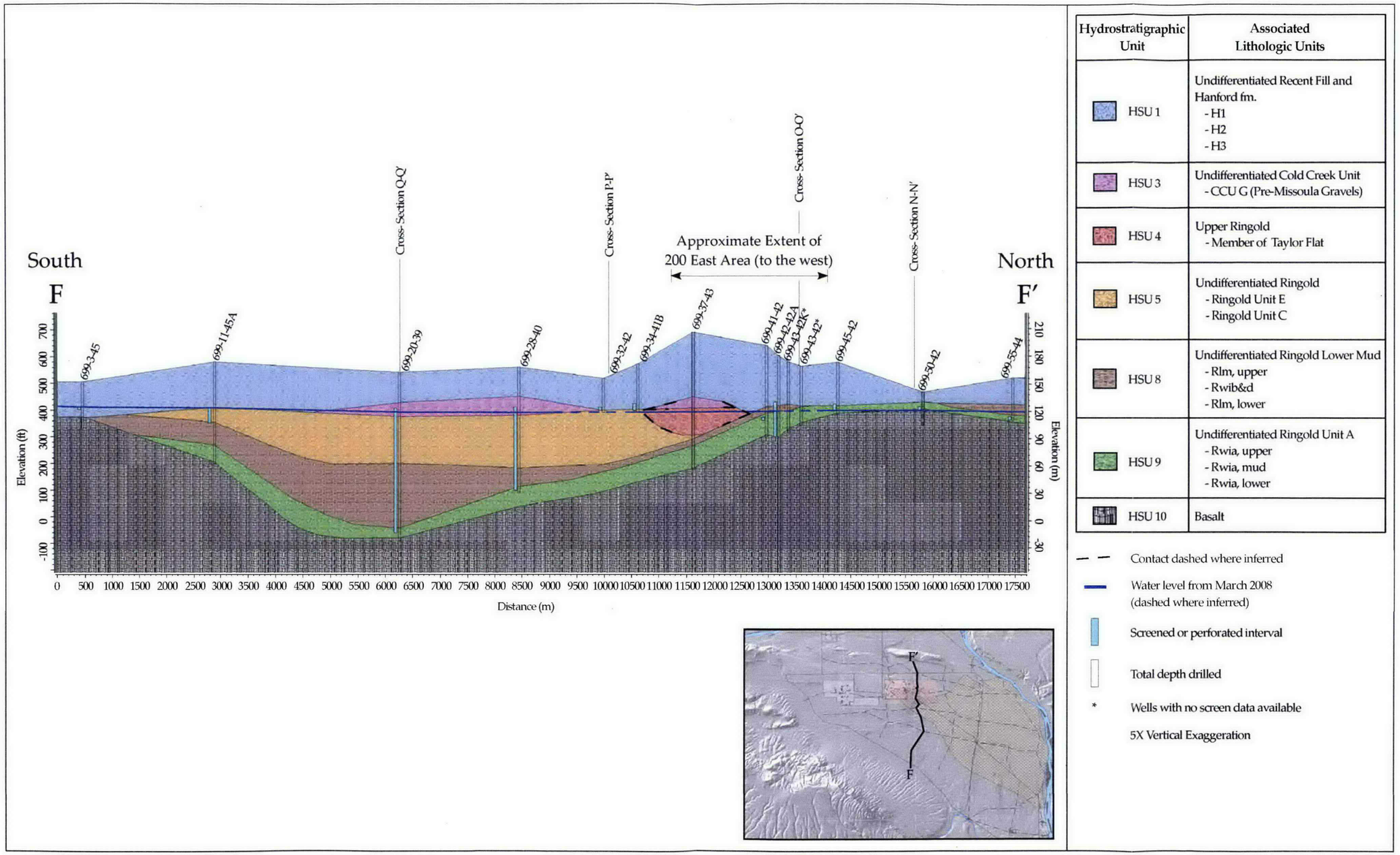


**Figure D-4. Hydrogeologic Cross Section F-F′, 200-PO-1 Groundwater Operable Unit**

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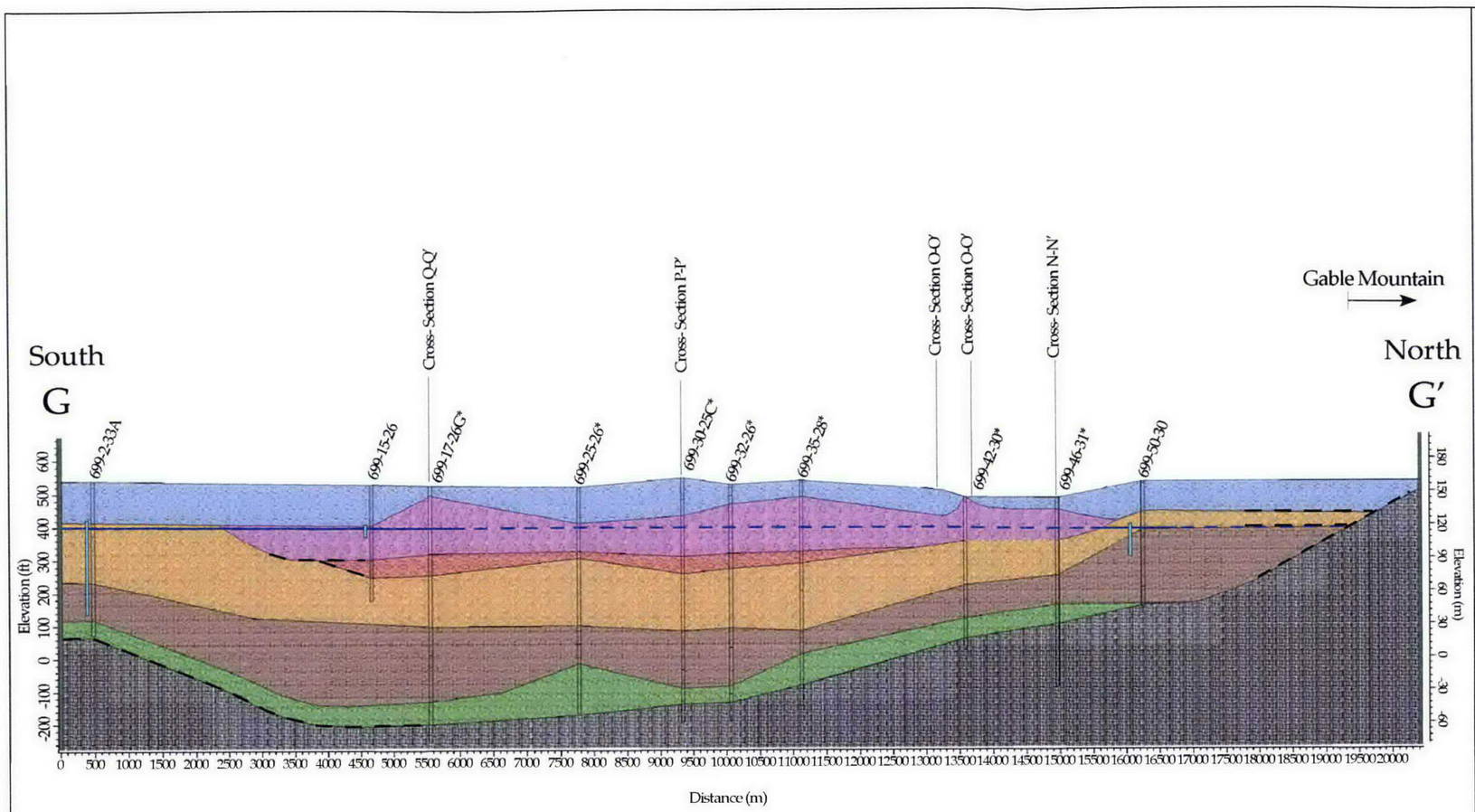


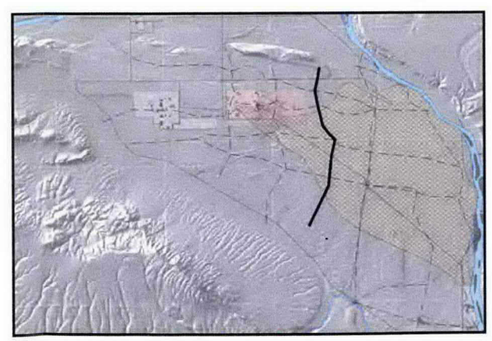

| Hydrostratigraphic Unit | Associated Lithologic Units |
|---|---|
| HSU 1 | Undifferentiated Recent Fill and Hanford fm.<br>- H1<br>- H2<br>- H3 |
| HSU 3 | Undifferentiated Cold Creek Unit<br>- CCU G (Pre-Missoula Gravels) |
| HSU 4 | Upper Ringold<br>- Member of Taylor Flat |
| HSU 5 | Undifferentiated Ringold<br>- Ringold Unit E<br>- Ringold Unit C |
| HSU 8 | Undifferentiated Ringold Lower Mud<br>- Rlm, upper<br>- Rwib&d<br>- Rlm, lower |
| HSU 9 | Undifferentiated Ringold Unit A<br>- Rwia, upper<br>- Rwia, mud<br>- Rwia, lower |
| HSU 10 | Basalt |

Contact dashed where inferred

Water level from March 2008 (dashed where inferred)

Screened or perforated interval

Total depth drilled

* Wells with no screen data available

5X Vertical Exaggeration

**Figure D-5. Hydrogeologic Cross Section G-G', 200-PO-1 Groundwater Operable Unit**

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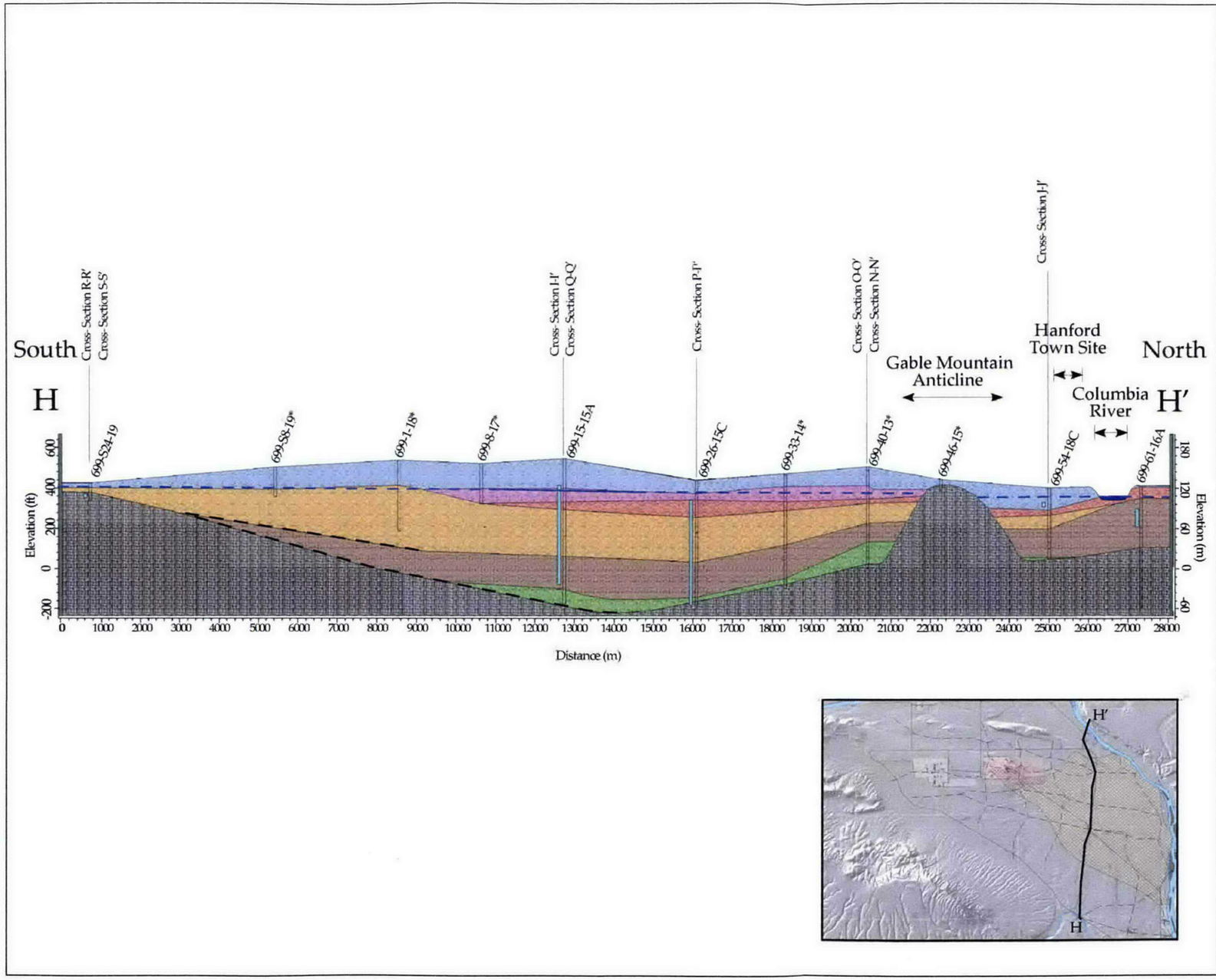


| Hydrostratigraphic Unit | Associated Lithologic Units |
|---|---|
| HSU 1 | Undifferentiated Recent Fill and Hanford fm.<br>- H1<br>- H2<br>- H3 |
| HSU 3 | Undifferentiated Cold Creek Unit<br>- CCU G (Pre-Missoula Gravels) |
| HSU 4 | Upper Ringold<br>- Member of Taylor Flat |
| HSU 5 | Undifferentiated Ringold<br>- Ringold Unit E<br>- Ringold Unit C |
| HSU 8 | Undifferentiated Ringold Lower Mud<br>- Rlm, upper<br>- Rwib&d<br>- Rlm, lower |
| HSU 9 | Undifferentiated Ringold Unit A<br>- Rwia, upper<br>- Rwia, mud<br>- Rwia, lower |
| HSU 10 | Basalt |

Contact dashed where inferred

Water level from March 2008 (dashed where inferred)

Screened or perforated interval

Total depth drilled

* Wells with no screen data available

5X Vertical Exaggeration

**Figure D-6. Hydrogeologic Cross Section H-H', 200-PO-1 Groundwater Operable Unit**

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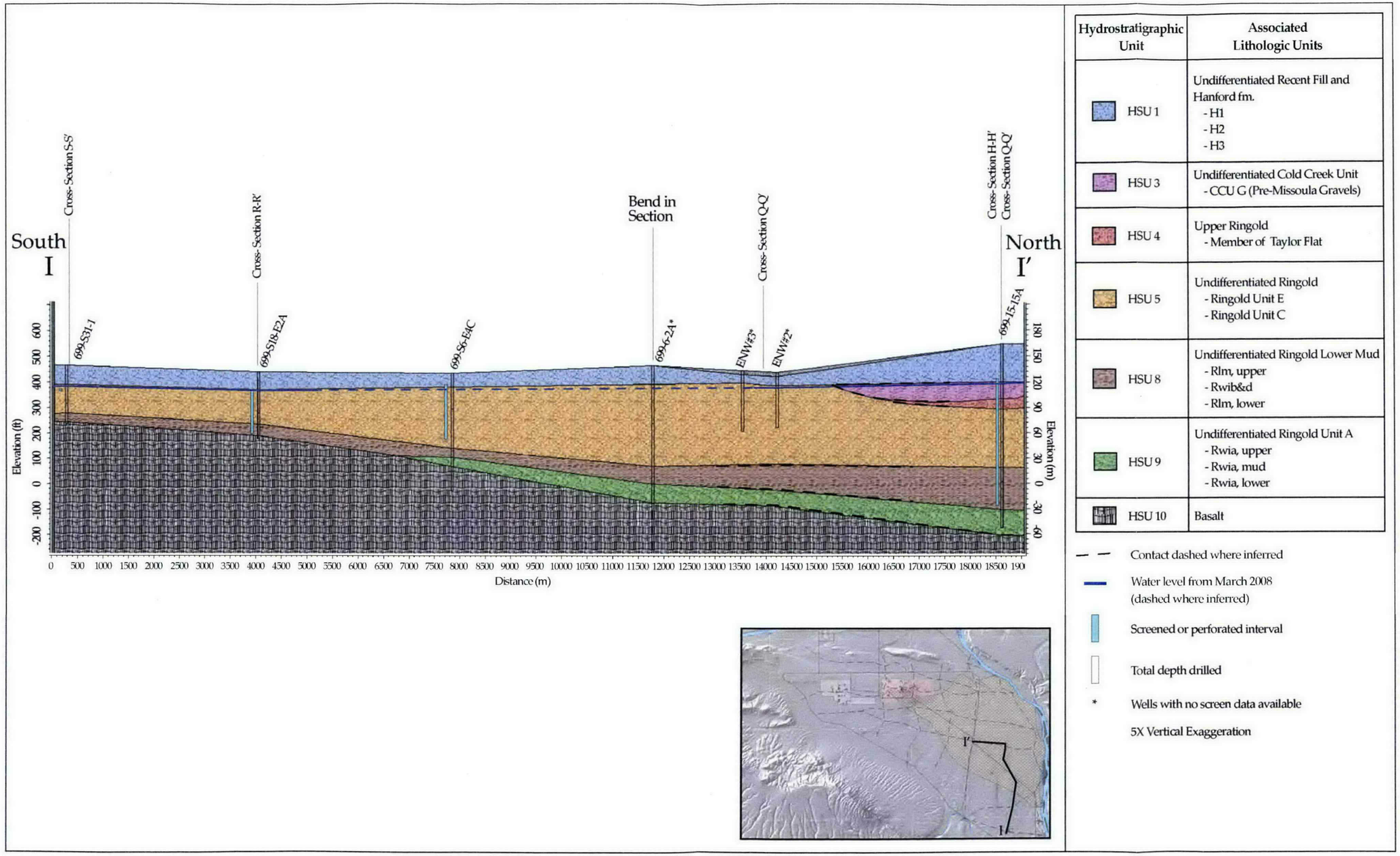


**Figure D-7. Hydrogeologic Cross Section I-I', 200-PO-1 Groundwater Operable Unit**

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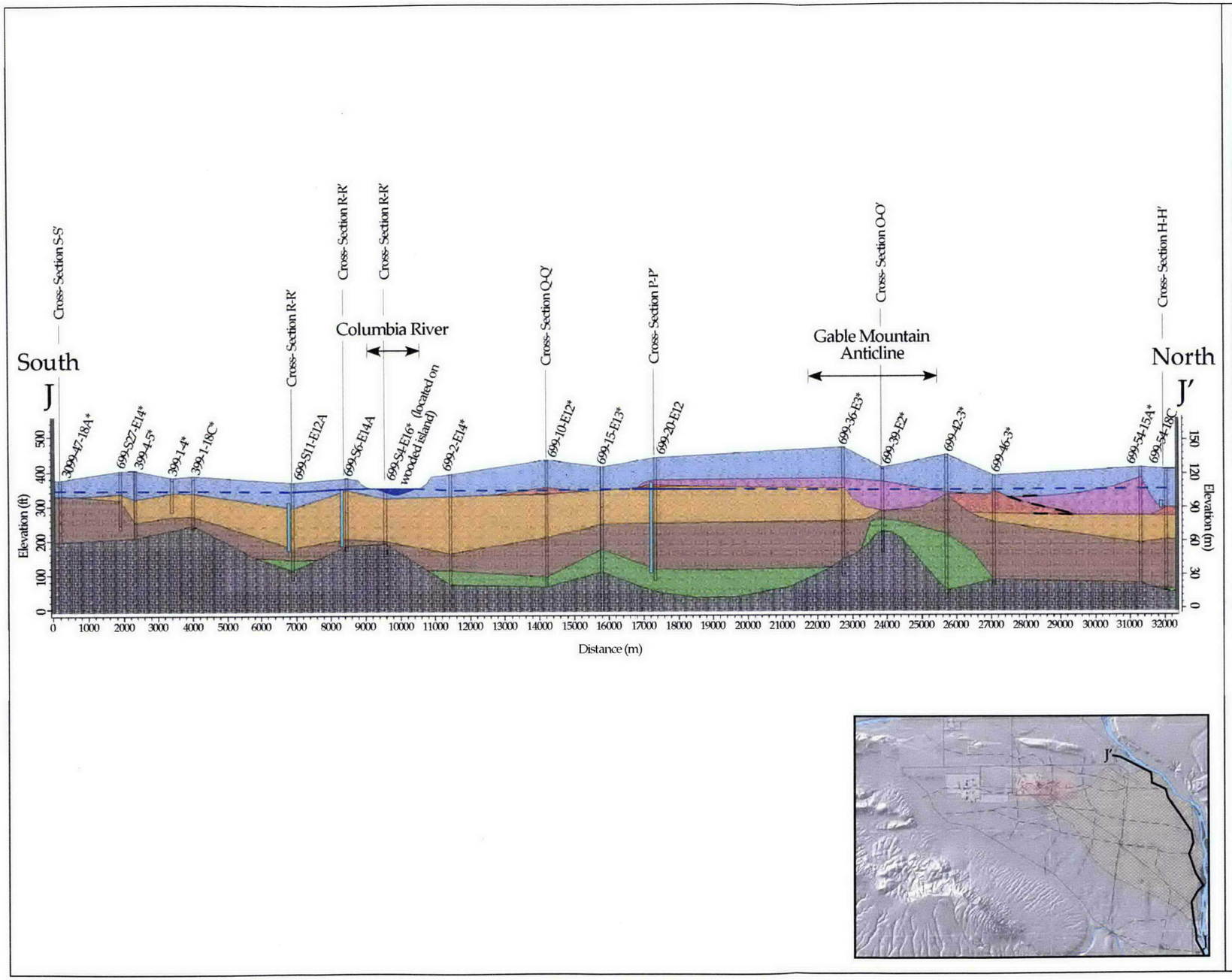


| Hydrostratigraphic Unit | Associated Lithologic Units |
|---|---|
| HSU 1 | Undifferentiated Recent Fill and Hanford fm.<br>- H1<br>- H2<br>- H3 |
| HSU 3 | Undifferentiated Cold Creek Unit<br>- CCU G (Pre-Missoula Gravels) |
| HSU 4 | Upper Ringold<br>- Member of Taylor Flat |
| HSU 5 | Undifferentiated Ringold<br>- Ringold Unit E<br>- Ringold Unit C |
| HSU 8 | Undifferentiated Ringold Lower Mud<br>- Rlm, upper<br>- Rwib&d<br>- Rlm, lower |
| HSU 9 | Undifferentiated Ringold Unit A<br>- Rwia, upper<br>- Rwia, mud<br>- Rwia, lower |
| HSU 10 | Basalt |

Contact dashed where inferred

Water level from March 2008 (dashed where inferred)

Screened or perforated interval

Total depth drilled

* Wells with no screen data available

10X Vertical Exaggeration




**Figure D-8. Hydrogeologic Cross Section J-J', 200-PO-1 Groundwater Operable Unit**

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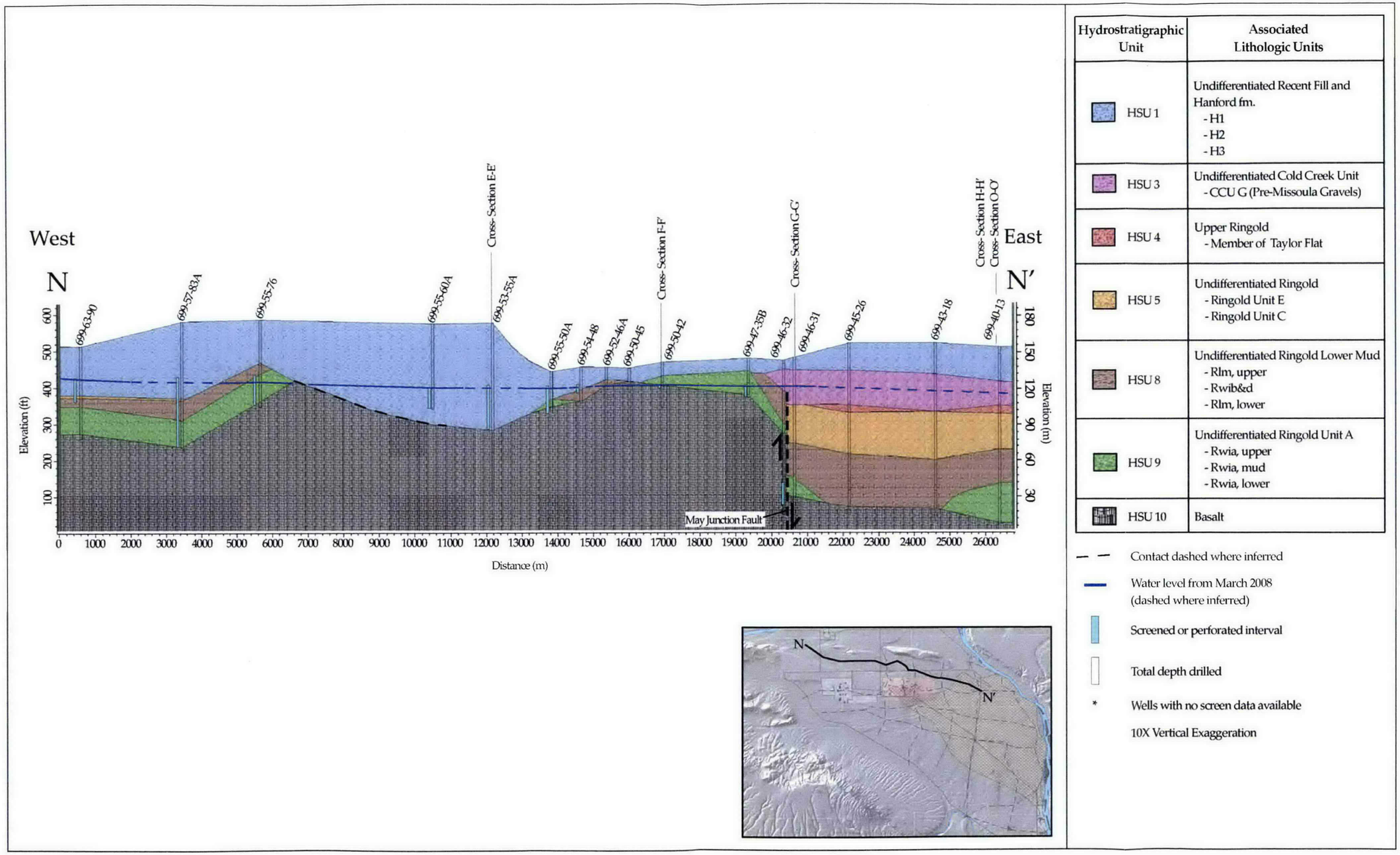


**Figure D-9. Hydrogeologic Cross Section N-N', 200-PO-1 Groundwater Operable Unit**

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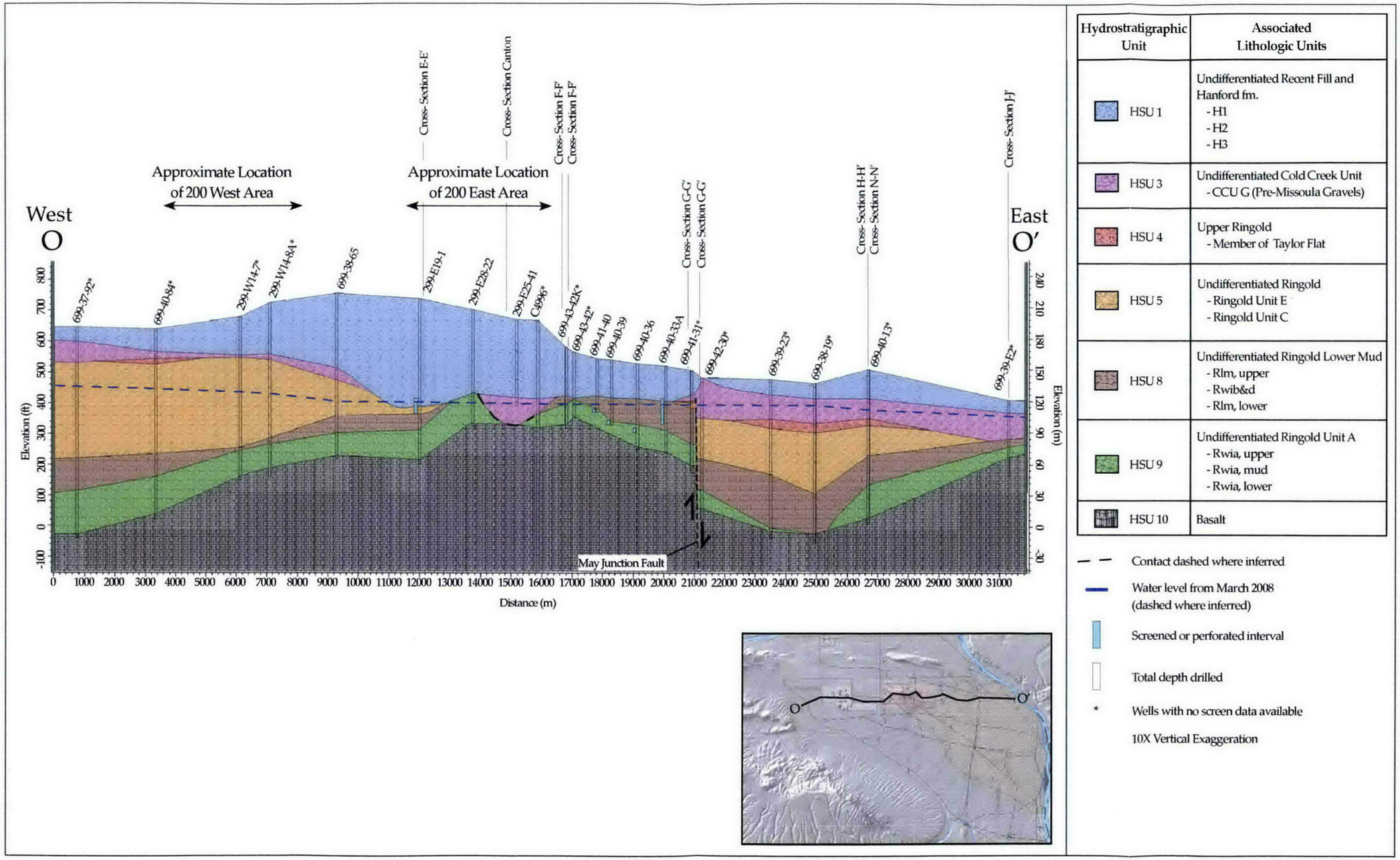


**Figure D-10. Hydrogeologic Cross Section O-O', 200-PO-1 Groundwater Operable Unit**

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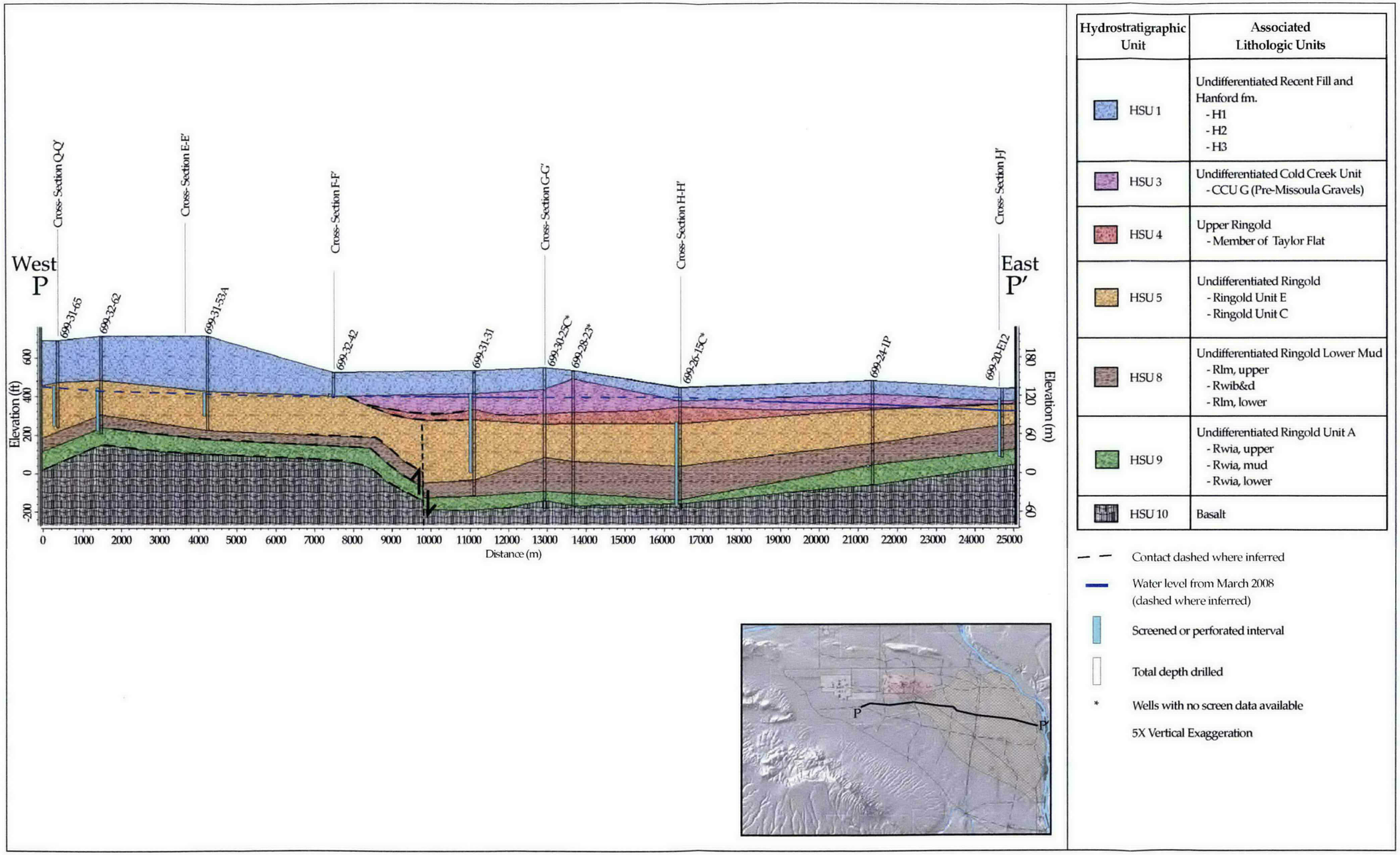


**Figure D-11. Hydrogeologic Cross Section P-P', 200-PO-1 Groundwater Operable Unit**

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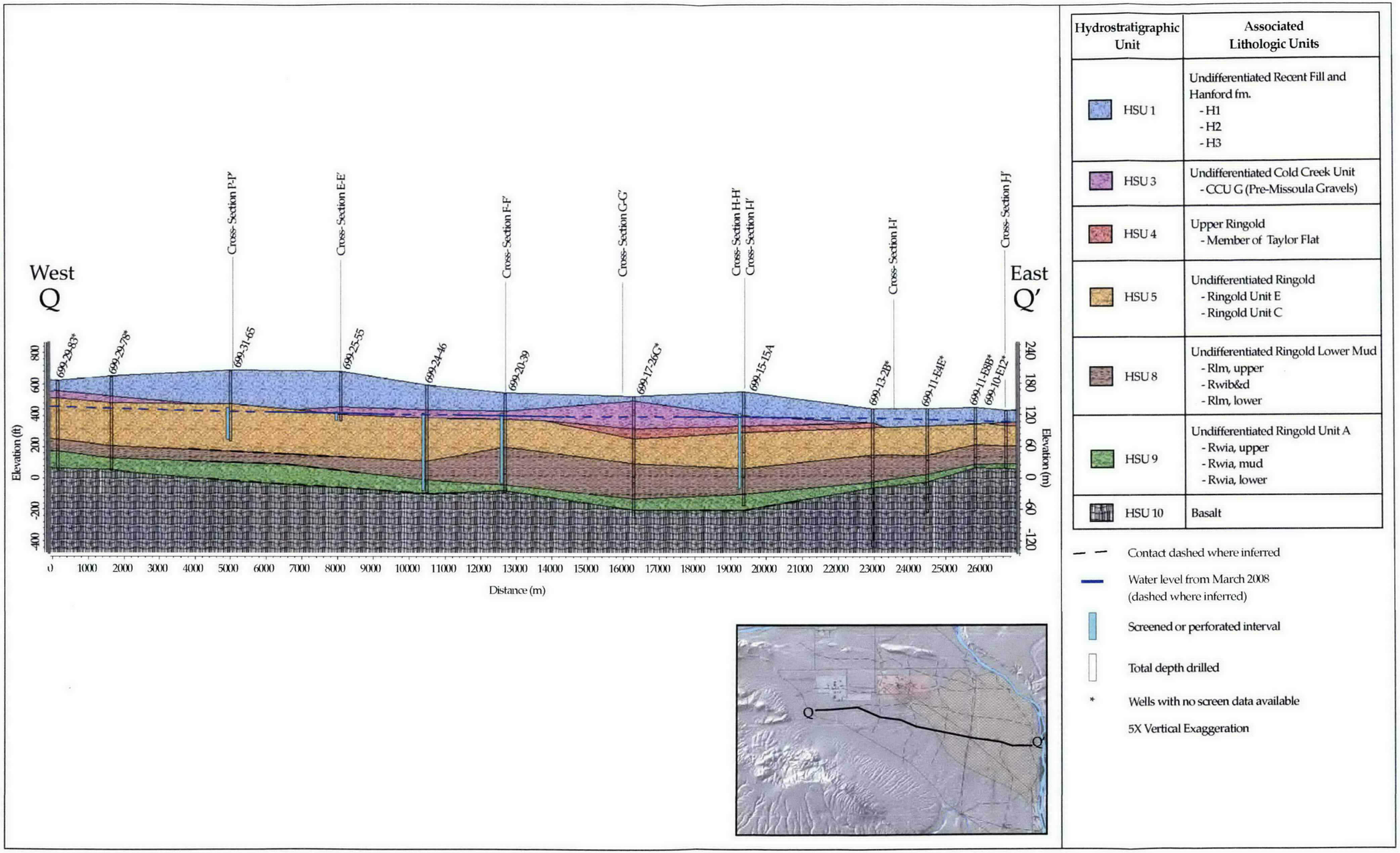


**Figure D-12. Hydrogeologic Cross Section Q-Q', 200-PO-1 Groundwater Operable Unit**

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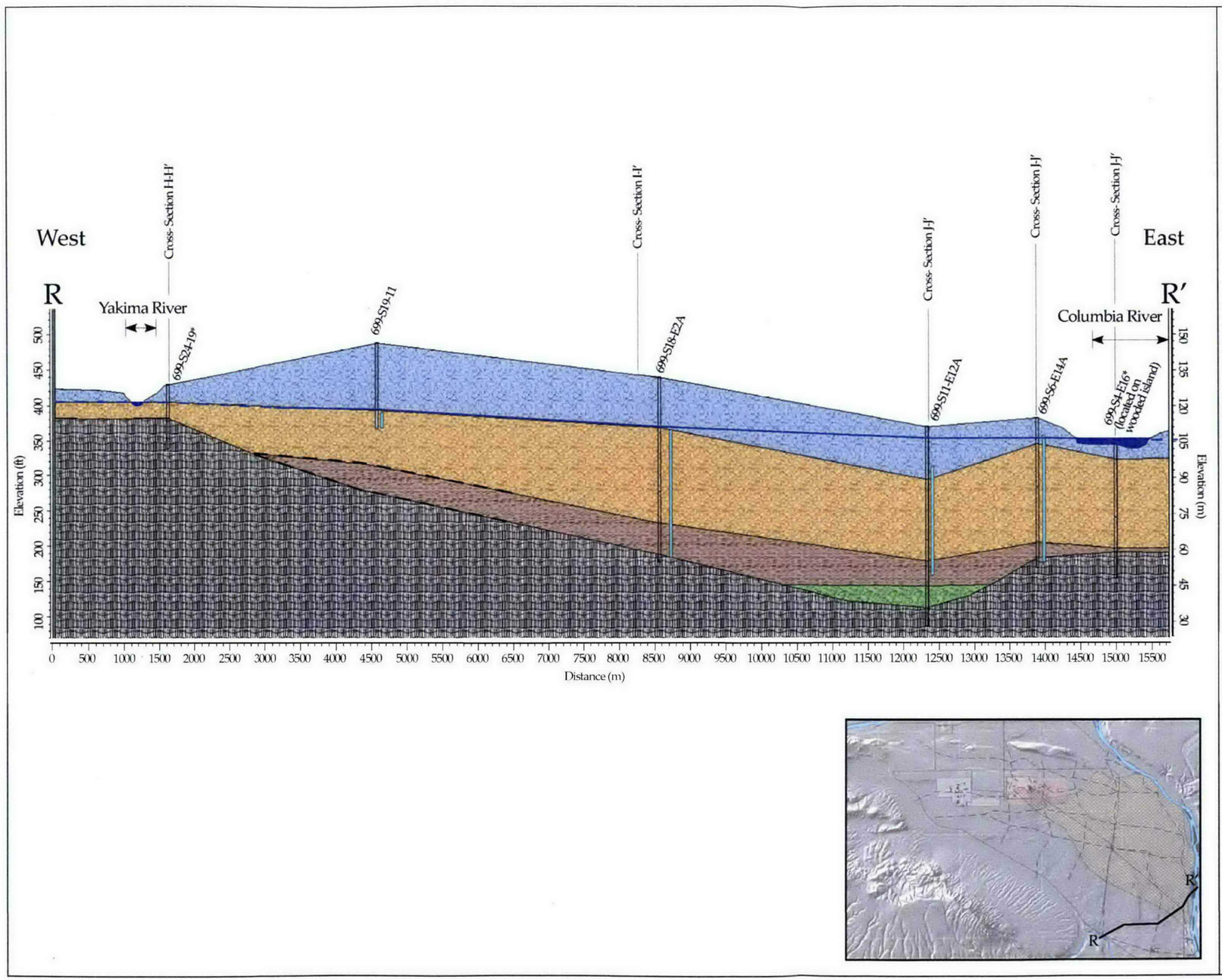


| Hydrostratigraphic Unit | Associated Lithologic Units |
|---|---|
| HSU 1 | Undifferentiated Recent Fill and Hanford fm.<br>- H1<br>- H2<br>- H3 |
| HSU 3 | Undifferentiated Cold Creek Unit<br>- CCU G (Pre-Missoula Gravels) |
| HSU 4 | Upper Ringold<br>- Member of Taylor Flat |
| HSU 5 | Undifferentiated Ringold<br>- Ringold Unit E<br>- Ringold Unit C |
| HSU 8 | Undifferentiated Ringold Lower Mud<br>- Rlm, upper<br>- Rwib&d<br>- Rlm, lower |
| HSU 9 | Undifferentiated Ringold Unit A<br>- Rwia, upper<br>- Rwia, mud<br>- Rwia, lower |
| HSU 10 | Basalt |

Contact dashed where inferred

Water level from March 2008 (dashed where inferred)

Screened or perforated interval

Total depth drilled

* Wells with no screen data available

10X Vertical Exaggeration

**Figure D-13. Hydrogeologic Cross Section R-R', 200-PO-1 Groundwater Operable Unit**

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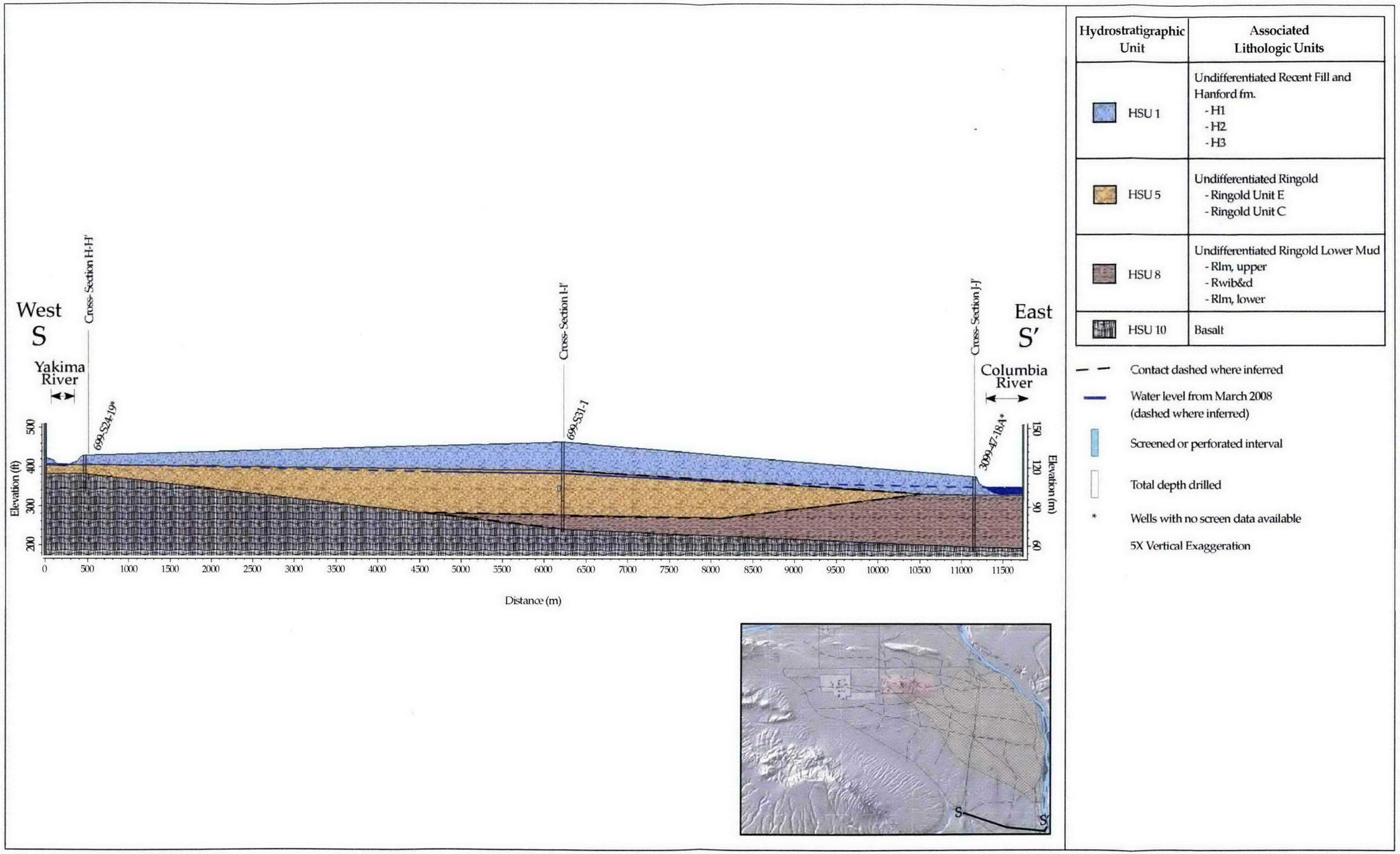


**Figure D-14. Hydrogeologic Cross Section S-S', 200-PO-1 Groundwater Operable Unit**

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# Distribution

## Onsite

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|---|---|---|
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