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# REMEDIAL INVESTIGATION/FEASIBILITY STUDY FOR THE 100-BC-1, 100-BC-2, AND 100-BC-5 OPERABLE UNITS

**NOTICE**
**The Preface that immediately follows these title pages describes the content and interim use of this Working Draft until its revision which is expected in 2016.**

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

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

Approved for Public Release;

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***APPROVED***
*By Julia R. Raymer at 8:04 am, Apr 09, 2013*

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# Preface

Please note that this working draft of the Remedial Investigation/Feasibility Study (RI/FS) for 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units, herein referred to as 100-BC, is considered a work in progress. As such, this document has not had formal DOE or Regulatory review or approval. Users are asked to be aware of this status when using or referencing this document. The purpose of placing this working draft in the Administrative Record is to allow use of the background of the operable units and their operating histories, along with recent data summaries and interpretations.

In the autumn of 2012, DOE and the Regulators made a decision to defer the selection of a preferred alternative for 100-BC: to allow ongoing source removal activities to be completed, to monitor the response of groundwater contamination after the soil remediation was complete, and to study the interaction between groundwater and the Columbia River. As a result, this RI/FS Report was placed on hold. After the remediation activities have been completed and additional monitoring performed, this RI/FS will be updated to include the new monitoring data. The date of the final RI/FS is anticipated to be 2016. Additionally, this report will include River Corridor updates and decisions that have either recently occurred or will occur between now and the time of completion of this RI/FS.

Known updates that have not been included in this RI/FS include:

- Ecological Preliminary Remediation Goal (PRG) updates
- Update of some PRGs based on updates to Integrated Risk Information System (IRIS) values
- Revised Human Health risk assessment evaluations and revised exposure scenarios
- Revisions to the groundwater model that reflect revised input parameters, and information from investigations and monitoring performed through 2012
- Incorporation of study results performed in 100-C-7:1 in the summer of 2012 (PNNL-21845)
- Incorporation and revision of interpretations of geologic and groundwater characterization data from wells installed in 2013
- Incorporation of groundwater monitoring data collected during 2013-2015 including parameters indicative of natural attenuation
- Interpretations of groundwater-surface water interactions based on data from shallow aquifer tubes installed in 2013

# Executive Summary

This document presents the results of a *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA)[1] Remedial Investigation (RI)/Feasibility Study (FS) undertaken for 100-BC. 100-BC has two source operable units (OUs) (100-BC-1 and 100-BC 2) and a groundwater OU (100-BC-5). As a result of the RI and evaluation, a determination has been made that contaminants in the vadose zone and groundwater pose a threat to the environment and that a CERCLA remedial action is warranted. Based on the 100-BC RI/FS, the U.S. Department of Energy, Richland Operations Office (DOE-RL) will issue a Proposed Plan that describes the proposed final remedies in order to receive comment from the Tribal Nations and the public. The U.S. Environmental Protection Agency and DOE-RL will issue a Record of Decision (ROD) that identifies the final remedial alternative selected for 100-BC and documents responses made to Tribal Nations and public comments.

Final remedial action decisions will address the integrated cleanup of contaminated soil, solid waste burial grounds, groundwater, and releases related to reactor buildings. The objective for all these decisions is to protect human health and the environment, including restoring groundwater to drinking water standards and achieving ambient water quality criteria in the Columbia River that protect aquatic life.

There are 140 waste sites in 100-BC. Of the 140 sites, 35 are already protective of human health and the environment. There are two reactors in 100-BC, the 105-B and 105-C reactors. The 105-C Reactor has been placed into a Safe Storage Enclosure and is not addressed in this document. However, it will be addressed in a future CERCLA decision. The 105-B Reactor is preserved as a National Historic Landmark under the Manhattan Project National Historical Park. Four waste sites associated with the 105-B Reactor are evaluated in the RI/FS. The remaining 101 sites are also evaluated in the RI/FS.

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

- Provide information concerning the physical environmental setting for 100-BC
- Draw conclusions concerning the nature and extent of contamination present in 100-BC and the potential for migration of contamination
- Evaluate the potential for adverse effects to human health and the environment if no action is taken and exposure occurs

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

- Develop and evaluate an appropriate range of remedial action alternatives for 100-BC based on unacceptable risk to human health and the environment

The RI/FS was prepared based on information gathered from historical studies and investigations, data collected during implementation of Interim Action RODs, and new field investigations. Soil cleanup actions and groundwater monitoring have been performed since the early 1990s. Much of the information needed to understand contamination has already been gathered. The recent RI work, done specifically to provide information to supplement what was already known, included installing 10 groundwater monitoring wells, 7 soil boreholes and 3 test pits to refine the conceptual site model. In addition, a select network of wells were sampled to determine spatial and temporal variations in groundwater contamination.

## Physical/Environmental Setting

The conceptual site model includes the makeup of vadose materials, groundwater, and the Columbia River. The physical characteristics of the study area influence the movement of contaminants within the environment.

The topography is relatively flat inland from the Columbia River, and changes are greatest near the Columbia River, where the riverbank slopes steeply. The semiarid climate at 100-BC has occasional high winds, and the majority of the land surface is an undeveloped shrub-steppe community. It is important to note that the shoreline has several culturally sensitive areas that need to be considered during any remediation activities.

The Hanford formation is the dominant material in the vadose zone (unsaturated zone) and consists of a sand and gravel unit that increases in thickness away from the river. The unconfined aquifer is predominantly within the Ringold Formation unit E. The lower portion of the Hanford formation is also saturated beneath most of 100-BC. The changing height of the river directly influences groundwater elevations in a zone that can stretch as far as several hundred meters inland. Water-level data and contaminant migration indicate that groundwater in the Hanford formation beneath southern 100-BC flows toward the northeast at rates ranging from 0.07 to 0.7 m/d. In northern 100-BC the aquifer is in Ringold unit E, where hydraulic conductivity is lower and the hydraulic gradient is steeper. Groundwater flow rates range from 0.03 to 0.29 m/d toward the north, except when river stage is very high and the gradient is reversed.

## Nature and Extent of Contamination

This document describes and predicts migration rate of contaminants through the physical setting (fate and transport) and evaluates the potential for contaminants to enter the Columbia River.

Waste site cleanup in 100-BC began in the mid-1990s under an Interim Action ROD and is still nearly complete. Interim action waste site cleanup consists primarily of removing and disposing of

contaminated material, then backfilling and revegetating to protect human health and the environment. The 100-C-7 and 100-C-7:1 waste sites are currently undergoing remediation. Characterization and excavation continue to reveal Cr(VI) throughout the thick vadose zone at these sites.

Remedial investigation sampling of the vadose zone identified no substantive quantities of residual contaminant mass in the vadose zone, Low concentrations of strontium-90 were detected through the vadose zone to groundwater beneath several waste sites. Low concentrations of tritium were detected through the vadose to groundwater beneath the 118-B-1 and 118-B-6 Burial Grounds. Cr(VI) concentrations beneath remediated waste sites were generally low.

Three groundwater COCs are identified at 100-BC: Cr(VI), strontium-90, and tritium. Cr(VI) is widely distributed in 100-BC groundwater and concentrations consistently exceed the ambient water quality criterion (10 µg/L). Concentrations decrease with depth in eastern 100 BC. In western 100 BC, concentrations are highest at the top and bottom of the aquifer, and lower in between. Significant increases in Cr(VI) concentrations in samples from wells north and east of the 100-C-7:1 waste site in 2011 and 2012 indicate mobilization of chromium from the waste site into groundwater.

Strontium-90 and tritium are above the drinking water standard are present in localized areas. Concentrations decline with depth in the aquifer.

Trends in Cr(VI) and tritium concentrations indicate the plumes are migrating from the southern part of 100-BC to the northeast.

## Groundwater – Surface Water Protection Evaluation

Thirty eight waste sites in 100-BC had closeout verification data following the implementation of interim action removal and disposal that was quantitatively evaluated. These sites were previously remediated to meet interim action cleanup levels (remedial action goals [RAGs]). New soil screening levels (SSLs) are established in this RI for each type of contaminant (chemical and radionuclides) and the SSLs used to assess potential threats to groundwater and surface water from these previously remediated waste sites. The SSLs were calculated using conservative scenarios that include assumptions of uniform vadose zone contamination (100:0 initial source distribution model for low distribution coefficient [$K_d$] contaminants and 70:30 initial source distribution model for high $K_d$ contaminants) and an recharge rate based on irrigated agriculture.

Six sites were identified that exceed SSLs: 100-B-1, 100-B-14:2, 100-B-18, 116-B-4, and 118-C-1. These sites could pose a threat to groundwater or surface water quality under an irrigation scenario.

Preliminary remediation goals (PRGs) for groundwater and surface water protection were calculated in a similar manner to the SSLs except that the calculation used a native vegetation (no irrigation) scenario. Comparison of waste site contaminant concentrations to the PRGs identified two waste sites (118-B-1 and 118-B-6) where leaching of tritium contaminated soil could pose a threat to groundwater and surface water protection. Additional, site-specific evaluations for these two waste sites are currently being performed.

## Human Health and Ecological Exposure Evaluation

Scenarios of how human and environmental receptors might come into contact with contaminants, with resultant health affects, were evaluated. The principal contaminants identified in the soil beneath one or more waste sites include radionuclides, metals, and polynuclear aromatic hydrocarbons. The risk assessment identified Cr(VI), tritium, Strontium-90, and trichloroethene as the principal groundwater contaminants. These soil and groundwater contaminants are evaluated for potential remedial technologies in the FS.

In addition, 81 waste sites in 100-BC had closeout verification data following the implementation of interim action removal and disposal that was quantitatively evaluated. These sites were remediated to meet interim action cleanup levels (RAGs). New SSLs are established in this RI for each environmental media of interest (soil and groundwater), each type of contaminant (hazardous substances and radionuclides), human and ecological receptors, and each potentially complete exposure pathway. The SSLs are based on updated guidance and a conservative scenario that includes assumptions of uniform vadose zone contamination (100:0 initial source distribution model for low $K_d$ contaminants and 70:30 initial source distribution model for high $K_d$ contaminants) and an infiltration/recharge rate based on irrigated agriculture. Twenty-five sites have residual contamination at depths (greater than 4.6 m [15 ft] below ground surface) that exceeds human health direct-contact SSLs. Two sites have shallow soil contamination (less than 4.6 m [15 ft] below ground surface) that exceeds human health direct-contact SSLs. No sites were identified that exceed SSLs for ecological receptors.

On the basis of the risk evaluations, analogous site data, and process information, 10 sites were advanced into the feasibility study.

## Alternatives Development

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

Remedial action objectives (RAOs) are identified for groundwater, surface water, and soil. RAOs are general descriptions of what a cleanup under CERCLA is expected to accomplish. They are narrative statements that define the extent to which waste sites require cleanup to protect human health and the environment. To meet RAOs, preliminary remediation goals (PRGs) are established for each contaminant, receptor, exposure pathway, and environmental media of interest. The PRGs are developed based on future land use, which does not include irrigated agricultural use. The interim action RAGs, SSLs, and PRGs are provided and can be used by the regulatory agency when cleanup levels are defined for each contaminant of concern in the ROD. All 140 waste sites will be evaluated against the cleanup levels defined in the ROD.

A range of response actions to meet RAOs is identified for each waste site and for contaminated groundwater. Response actions retained for each waste site include no action, excavation and disposal, ex situ treatment, in situ treatment, monitored natural attenuation (MNA), void fill grouting, surface barriers, and institutional controls. Response actions retained for groundwater include no action, monitored natural attenuation, pump-and-treat, collection, ex situ treatment, in situ treatment, hydraulic containment, and institutional controls. Process options and technologies for the range of response actions are evaluated for relative effectiveness, implementability, and cost.

The remedial technologies, retained from the screening process, were combined into remedial alternatives that provide a range of technologies for integrated waste site and groundwater remediation. With the exception of No Action, the remedial alternatives were developed to achieve the RAOs by considering the CERCLA program goals and expectations. Alternatives evaluated for waste sites include Alternative HH-1 No Action; Alternative HH-2 Maintain Existing Soil Cover (MESC), MNA, and institutional controls; Alternative HH-3 remove, treat, and dispose (RTD) Optimized with Other Technologies; and Alternative 4 Aggressive RTD. Alternatives evaluated for groundwater include Alternative GW-1 No Action; Alternative GW-2 MNA and institutional controls; Alternative GW-3 River Protection Pump-and-Treat; and Alternative GW-4 Aggressive Pump-and-Treat.

## Alternatives Evaluation

Waste sites for which remedial actions will not be started until after the ROD is signed were evaluated individually and comparatively against seven of the nine CERCLA criteria. Two criteria, overall protection of human health and the environment and compliance with applicable or relevant and appropriate requirements, are "threshold criteria." The next five are "balancing criteria" and include long-term effectiveness; reduction of toxicity, mobility, and volume (TMV) through treatment; short-term effectiveness; implementability; and cost. The two remaining "modifying criteria," state acceptance and community acceptance, will be evaluated in the responsiveness summary of the 100-BC Decision Document after the Proposed Plan goes through

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

- Alternative HH-1 (No Action) does not meet threshold criteria.
- Alternative HH-2 (MESC, MNA, and Institutional Controls) meets threshold criteria and is considered to have poor short-term effectiveness, moderate long-term effectiveness, and poor reduction of TMV through treatment. This alternative is considered to be readily implementable.
- Alternative HH-3 (RTD Optimized with Other Technologies) meets threshold criteria and is considered to have good short-term effectiveness, moderate reduction of TMV through treatment, and good long-term effectiveness. This alternative is considered to be readily implementable.
- Alternative HH-4 (Aggressive RTD) meets threshold criteria and is considered to have good short-term effectiveness, moderate reduction of TMV through treatment, and good long-term effectiveness. This alternative is considered to be moderately implementable.

Alternatives HH-3 and HH-4 perform better than Alternative HH-2 for short-term effectiveness, long-term effectiveness, and TMV reduction through treatment. Costs for the alternatives progressively increase based on the level of remedial action with Alternative HH-2 being the lowest cost alternative that meets the threshold criteria and Alternative HH-4 being the highest cost alternative.

The analysis of the groundwater alternatives showed:

- Alternative GW-1 (No Action) does not meet threshold criteria.
- Alternative GW-2 (MNA and ICs with Contingency) meets threshold criteria and is considered to have poor short-term effectiveness, moderate long-term effectiveness, and poor reduction of TMV through treatment. This alternative is considered to be readily implementable.
- Alternative GW-3 (River Protection Pump-and-Treat) meets threshold criteria and is considered to have good short-term effectiveness, moderate reduction of TMV through treatment, and good long-term effectiveness. This alternative is considered to be moderately implementable.
- Alternative GW-4 (Aggressive Pump-and-Treat) meets threshold criteria and is considered to have good short-term effectiveness, moderate to high reduction of TMV

through treatment, and good long-term effectiveness. This alternative is considered to be moderately implementable.

Alternatives GW-3 and GW-4 perform better than Alternative GW-2 for short-term effectiveness and TMV reduction through treatment. Costs for the alternatives progressively increase based on the level of remedial action with Alternative GW-2 being the lowest cost alternative that meets the threshold criteria and Alternative GW-4 being the highest cost alternative.

The analysis provides enough information to be able to recommend a preferred alternative in the Proposed Plan that describes the proposed final remedies in order to receive comment by the Tribal Nations and the public.

There will be a period of time between when the ROD is approved and when the required Remedial Design/Remedial Action Work Plan (RD/RAWP) is prepared and issued. During this time period, DOE-RL plans to continue remedial activities such as waste site RTD remediation. In order for the these actions to be consistent with the final action remedy selection, the current Interim Action RD/RAWPs will be modified using the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement) (Ecology, EPA, and DOE, 1989)[2] change notice process to include the final cleanup levels specified in the ROD.

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

# Contents

**1 Introduction ..... 1-1**
1.1 Purpose and Scope of Report ..... 1-7
1.2 Site Background ..... 1-9
1.2.1 Site Description ..... 1-10
1.2.2 Hanford Site and Operational History ..... 1-10
1.2.3 Previous Investigations and Remediation ..... 1-30
1.2.4 Summary ..... 1-65
**2 Study Area Investigation ..... 2-1**
2.1 Remedial Investigation Activities ..... 2-1
2.1.1 Significant Work Plan Deviations ..... 2-2
2.1.2 Data Sets ..... 2-17
2.1.3 Historical Information Review ..... 2-18
2.1.4 Surface Features ..... 2-18
2.1.5 Contaminant Source Investigations ..... 2-18
2.1.6 Land and Water Use Surveys ..... 2-18
2.1.7 Meteorological Investigations ..... 2-18
2.1.8 Air Investigations ..... 2-18
2.1.9 Surface Water and Sediment Investigations ..... 2-20
2.1.10 Geologic Investigations ..... 2-25
2.1.11 Soil and Vadose Zone Investigations ..... 2-29
2.1.12 Groundwater Investigations ..... 2-34
2.1.13 Ecological Investigations ..... 2-43
2.1.14 River Corridor Supplemental Investigations ..... 2-44
2.2 Field Activity Documentation ..... 2-46
**3 Physical Characteristics of the Study Area ..... 3-1**
3.1 Surface Features ..... 3-1
3.2 Meteorology ..... 3-1
3.3 Surface Water Hydrology ..... 3-6
3.3.1 Columbia River ..... 3-6
3.3.2 Surface Water Use ..... 3-10
3.4 Geology ..... 3-10
3.4.1 Geologic Setting ..... 3-10
3.4.2 Stratigraphy ..... 3-11
3.4.3 Data from New Wells and Boreholes ..... 3-21
3.5 Soil and Vadose Zone ..... 3-49
3.5.1 Soil ..... 3-49
3.5.2 Vadose Zone ..... 3-50
3.6 Hydrogeology ..... 3-57
3.6.1 Hydrostratigraphy ..... 3-57

3.6.2 Hydrogeologic Properties ..... 3-61
3.6.3 Groundwater Flow ..... 3-64
3.6.4 Zone of Surface Water/Groundwater Interaction ..... 3-74
3.6.5 Groundwater Chemistry ..... 3-76
3.7 Artificial Water Systems ..... 3-79
3.8 Demography and Land Use ..... 3-81
3.9 Ecology ..... 3-82
3.9.1 River Corridor Flora ..... 3-84
3.9.2 River Corridor Fauna ..... 3-84
3.9.3 Threatened and Endangered Species ..... 3-89
3.9.4 River Corridor Food Web and Receptors ..... 3-93
3.10 Cultural Resources ..... 3-94
3.10.1 Prehistoric Archaeology ..... 3-95
3.10.2 Other Human Resources ..... 3-95
3.10.3 Cold War Resources ..... 3-96
3.11 Summary of Physical Setting ..... 3-96
**4 Nature and Extent of Contamination ..... 4-1**
4.1 Background Concentrations ..... 4-6
4.1.1 Historical Agricultural Activities ..... 4-6
4.1.2 Hanford Site Soil Background ..... 4-7
4.2 Vadose Zone Contamination ..... 4-10
4.2.1 Waste Site Characterization ..... 4-12
4.2.2 Potential Stainless Steel Contamination of 100-BC RI Samples ..... 4-78
4.2.3 Contaminants above Background at Remediated Waste Sites ..... 4-80
4.2.4 Nature and Extent of Contamination in Soil Samples from Monitoring Wells ..... 4-80
4.2.5 100-BC Vadose Zone Constituent Summary ..... 4-93
4.2.6 Summary of LFI Data not associated with 100-BC RI ..... 4-94
4.3 Groundwater Contamination ..... 4-105
4.3.1 Groundwater Contaminant Statistics ..... 4-105
4.3.2 Groundwater Contaminant Plumes ..... 4-122
4.3.3 Vertical Distribution of Contaminants in Groundwater ..... 4-145
4.3.4 Soil Chemistry in Aquifer and Aquitard ..... 4-160
4.4 Columbia River Surface Water and Sediments ..... 4-162
4.4.1 Groundwater Upwelling Investigations at 100-BC ..... 4-163
4.4.2 Sitewide Environmental Monitoring of Surface Water and Sediments ..... 4-168
4.5 Biota ..... 4-171
4.6 Air ..... 4-174
4.6.1 Site-Wide and Offsite Ambient-Air Monitoring ..... 4-174
4.6.2 Ambient Air Monitoring Near Facilities and Operations ..... 4-174
4.7 Summary of Nature and Extent of Contamination ..... 4-175
4.7.1 Operational Period ..... 4-175

4.7.2 Post-Operations, Pre-Interim Remediation ..... 4-176
4.7.3 Post-Interim Remediation ..... 4-176
4.7.4 Human and Ecological Receptors/Exposure Pathways ..... 4-178
**5 Contaminant Fate and Transport ..... 5-1**
5.1 Evaluation Process for Assessment of Groundwater and Surface Water Protection ..... 5-2
5.2 Overview of the 100-BC Conceptual Site Model ..... 5-6
5.2.1 Contaminant Sources ..... 5-7
5.2.2 Release Mechanisms ..... 5-8
5.2.3 Potential Routes of Migration ..... 5-9
5.3 Contaminant Persistence ..... 5-12
5.3.1 Nonradionuclide Chemical Constituents ..... 5-13
5.3.2 Radionuclide Constituents ..... 5-14
5.4 Vadose Zone Contaminant Migration Assessment ..... 5-15
5.4.1 Factors Affecting Contaminant Migration in the Vadose Zone ..... 5-16
5.5 Batch Leach Tests ..... 5-24
5.5.1 Batch Leach Testing Data Evaluation ..... 5-25
5.5.2 Uncertainty in Batch Leach Testing Results ..... 5-33
5.5.3 Development of a Hexavalent Chromium $K_d$ for Vadose Zone Simulations from Batch Leach Testing Results ..... 5-41
5.6 Vadose Zone Modeling Methods and Results ..... 5-42
5.6.1 Initial Contaminant Distribution ..... 5-42
5.6.2 Simulation Duration ..... 5-45
5.7 Groundwater/Surface Water Protection Soil Screening Level and Preliminary Remediation Goal Development ..... 5-46
5.7.1 Identification of Peak Groundwater Concentrations ..... 5-47
5.7.2 Comparison of Waste Site EPCs to SSLs ..... 5-47
5.7.3 Comparison of Waste Site EPCs to PRGs ..... 5-62
5.8 Saturated Zone Modeling Methods and Results ..... 5-67
5.8.1 Simulation Tools ..... 5-67
5.8.2 Model Construction ..... 5-68
5.8.3 Contaminant Transport/Plume Simulations ..... 5-71
5.9 Uncertainties in Simulating Contaminant Fate and Transport ..... 5-87
5.9.1 Uncertainty in the Conceptual Site Model ..... 5-87
5.9.2 Uncertainty in the Initial Contaminant Distribution ..... 5-88
5.9.3 Uncertainty in Contaminant Transport Parameters ..... 5-88
5.9.4 Uncertainties, Assumptions, and Limitations Specific to Vadose Modeling ..... 5-88
5.9.5 Uncertainties, Assumptions, and Limitations Specific to Groundwater Modeling ..... 5-89
5.10 Summary of Contaminant Fate and Transport ..... 5-91
**6 Human Health Risk Assessment ..... 6-1**
6.1 Role of the RCBRA and the RI/FS Risk Assessment ..... 6-2
6.1.1 Evaluation of Residual Risks for Interim Action ROD Cleanups from the RCBRA ..... 6-3
6.1.2 RI/FS Soil Risk Assessment (Unrestricted Land Use) ..... 6-12

6.1.3 RI/FS Soil Risk Assessment (Reasonably Anticipated Future Land Use Scenarios) ..... 6-18
6.1.4 Other Residential Land Use Scenarios in RCBRA ..... 6-21
6.2 Soil Risk Assessment ..... 6-26
6.2.1 Data Analysis ..... 6-27
6.2.2 Exposure Point Concentrations ..... 6-31
6.2.3 Exposure Assessment ..... 6-41
6.2.4 Toxicity Assessment ..... 6-70
6.2.5 Risk Characterization ..... 6-74
6.2.6 Uncertainties in the Soil Risk Assessment ..... 6-109
6.3 Groundwater Risk Assessment ..... 6-123
6.3.1 Findings of the River Corridor Baseline Risk Assessment ..... 6-125
6.3.2 Identification of Contaminants of Potential Concern ..... 6-126
6.3.3 Exposure Assessment ..... 6-171
6.3.4 Toxicity Assessment ..... 6-173
6.3.5 Risk Characterization ..... 6-175
6.3.6 Risk Characterization Results Using Chemical Specific ARARs by Exposure Area ..... 6-178
6.3.7 Risk Characterization Results of the EPA Tap Water Scenario ..... 6-184
6.3.8 Uncertainties in the Groundwater Risk Assessment ..... 6-196
6.4 Risk Assessment Conclusions of the Riparian and Nearshore Environment from RCBRA and the Columbia River Component ..... 6-209
6.4.1 Risk Assessment Conclusions from the River Corridor Baseline Risk Assessment ..... 6-209
6.4.2 Risk Assessment Conclusions from the Columbia River Component ..... 6-214
6.4.3 Risk Assessment Conclusions for River Pipelines ..... 6-215
6.5 Summary and Conclusions ..... 6-216
6.5.1 Conclusions for the Soil Risk Assessment ..... 6-217
6.5.2 Conclusions for the Groundwater Risk Assessment ..... 6-224
**7 Ecological Risk Assessment ..... 7-1**
7.1 Identification of Contaminants of Potential Concern ..... 7-4
7.1.1 Data Summary ..... 7-4
7.1.2 Data Quality Assessment ..... 7-4
7.1.3 Identification of COPCs ..... 7-5
7.2 Problem Formulation ..... 7-6
7.2.1 Site Setting ..... 7-6
7.2.2 Simplified Ecological Exposure Model ..... 7-7
7.2.3 Assessment Endpoints ..... 7-12
7.3 Effects and Exposure Assessment ..... 7-13
7.3.1 Effects Assessment ..... 7-14
7.3.2 Exposure Assessment ..... 7-27
7.3.3 Drinking Water Exposure ..... 7-39
7.3.4 PRGs ..... 7-40
7.3.5 Estimation of Exposure Point Concentrations in Waste Sites ..... 7-46
7.4 Risk Characterization ..... 7-48

7.4.1 Risk Characterization for Radionuclides and Aroclors ..... 7-54
7.4.2 Characterization Relative to Background ..... 7-54
7.4.3 Further (Refined) Characterization Relative to PRGs ..... 7-55
7.4.4 Characterization of Risk through Ingestion of Drinking Water ..... 7-55
7.4.5 Screening Evaluation Results ..... 7-55
7.4.6 Results of Background Characterization ..... 7-56
7.4.7 Results of PRG Characterization ..... 7-57
7.4.8 Characterization of Drinking Water Ingestion ..... 7-60
7.4.9 Uncertainties Assessment ..... 7-60
7.5 Assessment of Risks in Riparian, Nearshore Media, and Columbia River ..... 7-68
7.5.1 Summary of Results and Conclusions of RCBRA ..... 7-68
7.5.2 Summary of Results and Conclusions of CRC ..... 7-71
7.5.3 100-BC Area River Effluent Pipeline Investigations ..... 7-72
7.5.4 Summary of the Evaluation of Riparian Soils ..... 7-73
7.5.5 Summary of Evaluation of Nearshore and Columbia River ..... 7-75
7.5.6 Conclusions ..... 7-79
7.6 Risk Conclusions and Scientific Management Decision Point ..... 7-80
7.6.1 Scientific Management Decision Point Considerations ..... 7-80
7.6.2 Recommendations for Evaluating Wildlife in Future Assessments at Unremediated Waste Sites ..... 7-82
7.6.3 Recommendations for Evaluating Plants and Invertebrates in Future Assessments at Unremediated Waste Sites ..... 7-107
7.6.4 Evaluation of Sediment in Future Assessments and at Unremediated Waste Sites Below the Ordinary High Water Mark ..... 7-109
**8 Identification and Screening of Technologies ..... 8-1**
8.1 Remedial Action Objectives ..... 8-1
8.1.1 Contaminants of Concern ..... 8-1
8.1.2 Potential Applicable or Relevant and Appropriate Requirements ..... 8-2
8.1.3 Remedial Action Objectives ..... 8-22
8.1.4 Preliminary Remediation Goals ..... 8-23
8.2 General Response Actions ..... 8-33
8.2.1 Target Remediation Areas ..... 8-34
8.3 Identification and Screening of Technology Types and Process Options ..... 8-48
8.3.1 Identification and Screening of Technologies ..... 8-48
8.3.2 Evaluation of Technologies and Selection of Representative Technologies ..... 8-72
**9 Development and Screening of Alternatives ..... 9-1**
9.1 Development of Remedial Alternatives ..... 9-1
9.1.1 Waste Sites ..... 9-2
9.1.2 Groundwater ..... 9-3
9.1.3 Common Elements ..... 9-4
9.2 Description of Waste Site Alternatives ..... 9-8
9.2.1 S-1—No Action ..... 9-11

9.2.2 S-2—Maintain Existing Soil Cover (MESC), Monitored Natural Attenuation (MNA) and Institutional Controls (Institutional Controls) ..... 9-11
9.2.3 Alternative S-3 – Limited RTD Optimized with Other Technologies ..... 9-12
9.2.4 Alternative S-4 – Aggressive RTD ..... 9-14
9.3 Description of Groundwater Alternatives ..... 9-16
9.3.1 Alternative GW-1—No Action ..... 9-23
9.3.2 Alternative GW-2—MNA and Institutional Controls ..... 9-43
9.3.3 Alternative GW-3—River Protection Pump-and-Treat ..... 9-43
9.3.4 Alternative GW-4 —Aggressive Pump-and-Treat ..... 9-61
9.4 Remedial Alternative Screening Evaluation ..... 9-73
9.4.1 Waste Site Alternative Screening ..... 9-73
9.4.2 Groundwater Alternatives Screening ..... 9-74
**10 Detailed and Comparative Analysis of Alternatives ..... 10-1**
10.1 Description of CERCLA Evaluation Criteria ..... 10-2
10.1.1 Overall Protection of Human Health and the Environment ..... 10-4
10.1.2 Compliance with Applicable or Relevant and Appropriate Requirements ..... 10-4
10.1.3 Long Term Effectiveness and Permanence ..... 10-4
10.1.4 Reduction of Toxicity, Mobility, and Volume through Treatment ..... 10-5
10.1.5 Short Term Effectiveness ..... 10-5
10.1.6 Implementability ..... 10-5
10.1.7 Cost ..... 10-6
10.2 Individual Analysis of Alternatives ..... 10-7
10.2.1 Waste Site Alternatives ..... 10-7
10.2.2 Groundwater Plume Alternatives ..... 10-21
10.3 Comparative Evaluation of Alternatives ..... 10-30
10.3.1 Overall Protection of Human Health and the Environment ..... 10-30
10.3.2 Compliance with ARARs ..... 10-35
10.3.3 Long Term Effectiveness and Permanence ..... 10-35
10.3.4 Reduction of Toxicity Mobility and Volume through Treatment ..... 10-36
10.3.5 Short Term Effectiveness ..... 10-36
10.3.6 Implementability ..... 10-37
10.3.7 Cost ..... 10-37
10.4 NEPA Values ..... 10-37
10.5 Coordination of Interim and Final CERCLA Remedial Activities ..... 10-41
10.6 CERCLA and RCRA Corrective Action ..... 10-46
**11 References ..... 11-1**

## Appendices

**A Site Map ..... A-i**
**B Annotated Bibliography ..... B-i**
**C Supporting Information for Wells and Boreholes ..... C-i**

**D Analytical Data** ..... D-i
**E Waste Site Summary** ..... E-i
**F Fate and Transport Modeling Documentation** ..... F-i
**G Summary of Risk Characterization Results with Inclusion of Background Concentrations** ..... G-i
**H Ecological Risk Assessment Calculation Briefs** ..... H-i
**I Technology Screening—Technologies Not Retained** ..... I-i
**J Alternative Development Supporting Documentation** ..... J-i
**K Environmental Cost Estimate for 100-BC Vadose Zone and Groundwater RI-FS** ..... K-i
**L Nonoperational Area Evaluation** ..... L-i
**M Riparian/Nearshore Evaluation** ..... M-i

## Figures

Figure 1-1. Hanford Site Map ..... 1-2
Figure 1-2. 100-BC Operable Units and Reactors ..... 1-3
Figure 1-3. Conceptual Site Model ..... 1-9
Figure 1-4. Northeastern Aerial View of the B Reactor in 1944 ..... 1-12
Figure 1-5. The B Reactor in 2005 ..... 1-13
Figure 1-6. Northeastern Aerial View of the C Reactor (at right) in 1953 ..... 1-14
Figure 1-7. The C Reactor during ISS Implementation in 1998 ..... 1-14
Figure 1-8. The C Reactor after ISS (2007) ..... 1-15
Figure 1-9. Cooling Water Process Flow Diagram ..... 1-19
Figure 1-10. River Effluent Outfall Structures during Operations ..... 1-22
Figure 1-11. Tritium Storage Cells at 104-B2 Building ..... 1-28
Figure 1-12. 100-BC Major Features during Reactor Operations in 1966 ..... 1-40
Figure 1-13. Conditions at 100-BC in April 2010 ..... 1-41
Figure 1-14. Southern View of 100-BC Showing Primary Liquid Waste Disposal Features (April 2002) ..... 1-51
Figure 1-15. 100-BC High-Priority Radioactive Liquid Effluent Disposal Sites ..... 1-53
Figure 1-16. Area Addressed by 100-BC Orphan Sites Evaluation Process ..... 1-59
Figure 2-1. 100-BC Field Characterization Sampling Locations ..... 2-16
Figure 2-2. 2008 Near-Facility Air Sampling Locations for Radionuclides at 100-BC (after Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2008 [PNNL-18427 APP 2]) ..... 2-19
Figure 2-3. Columbia River Pore Water Sampling Locations at 100-BC ..... 2-22
Figure 2-4. Remedial Investigation for Site Releases to the Columbia River—Phase III Characterization Sample Locations for 100-BC ..... 2-23
Figure 2-5. Remediation of 100-C-7 Waste Site, Spring 2011 ..... 2-30
Figure 2-6. General Well Design ..... 2-37

Figure 2-7. Aquifer Tube Installation ..... 2-41
Figure 3-1. 100-BC Topography ..... 3-2
Figure 3-2. Dust Storm at Hanford Site Construction Camp, ca. 1944 ..... 3-5
Figure 3-3. Columbia River Flow Volume at Priest Rapids Dam ..... 3-7
Figure 3-4. Groundwater Monitoring Wells and Vadose Borings in 100-BC ..... 3-8
Figure 3-5. Columbia River Stage at 100-BC Gauge Station ..... 3-9
Figure 3-6. Stratigraphy and Hydrogeologic Units of 100-BC ..... 3-11
Figures 3-7. Geologic Cross Section K-K' (West) ..... 3-13
Figures 3-8. Geologic Cross Section K-K' (East) ..... 3-14
Figures 3-9. Geologic Cross Section A-A' ..... 3-15
Figure 3-10. Elevation of Top of Ringold Unit E, 100-BC (Hanford/Ringold Contact) ..... 3-18
Figure 3-11. Top of Ringold Mud, 100-BC ..... 3-20
Figure 3-12. Summary of Characterization Data for Well 199-B2-14 ..... 3-29
Figure 3-13. Summary of Characterization Data for Well 199-B2-15 ..... 3-30
Figure 3-14. Summary of Characterization Data for Well 199-B2-16 ..... 3-31
Figure 3-15. Summary of Characterization Data for Well 199-B3-50 ..... 3-32
Figure 3-16. Summary of Characterization Data for Well 199-B3-51 ..... 3-33
Figure 3-17. Summary of Characterization Data for Well 199-B4-14 ..... 3-34
Figure 3-18. Summary of Characterization Data for Well 199-B5-5 ..... 3-35
Figure 3-19. Summary of Characterization Data for Well 199-B5-6 ..... 3-36
Figure 3-20. Summary of Characterization Data for Well 199-B5-8 ..... 3-37
Figure 3-21. Summary of Characterization Data for Well 199-B8-9 ..... 3-38
Figure 3-22. Summary of Characterization Data for Borehole C7842 at the 116-B-11 Retention Basin ..... 3-39
Figure 3-23. Summary of Characterization Data for Borehole C7843 (Well 199-B5-52) at the 116-C-5 Retention Basin ..... 3-40
Figure 3-24. Summary of Characterization Data for Borehole C7844 at the 116-B-5 Crib ..... 3-41
Figure 3-25. Summary of Characterization Data for Borehole C7845 at the 118-B-6 Burial Ground ..... 3-42
Figure 3-26. Summary of Characterization Data for Borehole C7846 (Well 199-B4-15) at the 100-B-5 Trench ..... 3-43
Figure 3-27. Summary of Characterization Data for Borehole C7849 at the 118-C-3 Reactor Fuel Storage Basin ..... 3-44
Figure 3-28. Summary of Characterization Data for Borehole C8239 at the 118-B-8 Reactor Fuel Storage Basin ..... 3-45
Figure 3-29. Summary of Characterization Data for Borehole C7883, North of 100-C-7 ..... 3-46
Figure 3-30. Summary of Characterization Data for Borehole C7884, North of 100-C-7 ..... 3-47
Figure 3-31. Soil Types of 100-BC ..... 3-49
Figure 3-32. Thickness of Saturated Hanford Formation, 100-BC ..... 3-59
Figure 3-33. Thickness of Unconfined Aquifer, 100-BC ..... 3-60

Figure 3-34. Vertical Hydraulic Conductivity of Sediment Samples from 100-BC Wells and Boreholes ..... 3-63
Figure 3-35. Water Table beneath 100-BC, March 2010 ..... 3-65
Figure 3-36. Water Table beneath 100-BC, March 2011 ..... 3-66
Figure 3-37. Hydraulic Gradients in 100-BC ..... 3-69
Figure 3-38. Hydrographs from Automated Water Level Network at 100-BC ..... 3-71
Figure 3-39. Water Levels in Well 199-B3-1, 1962 to 2011 ..... 3-74
Figure 3-40. Illustration of Zone of Interaction and River Bank Seepage ..... 3-75
Figure 3-41. Pore Water Conductivity and Temperature Anomaly Patterns Measured during Phase IIa near the 100-BC Area, Upstream Portion ..... 3-77
Figure 3-42. Pore Water Conductivity and Temperature Anomaly Patterns Measured during Phase IIa near the 100-BC Area, Downstream Portion ..... 3-78
Figure 3-43. Spider Diagrams Illustrating General Groundwater Chemistry in 100-BC ..... 3-79
Figure 3-44. 100-BC Export Water System ..... 3-80
Figure 3-45. Distribution of Vegetation Types before the Wildfire in 2000 ..... 3-87
Figure 3-46. Trophic Structure for the Ecological Community of the RCBRA ..... 3-94
Figure 4-1. Cr(VI) Waste Sites in 100-BC 4-2
Figure 4-2. Strontium-90 Waste Sites in 100-BC ..... 4-3
Figure 4-3. Tritium Waste Sites in 100-BC ..... 4-4
Figure 4-4. Locations of Former Orchards, Farms, and Waste Sites in 100-BC ..... 4-7
Figure 4-5. Vertical Profile from Borehole C7842 ..... 4-16
Figure 4-6. Vertical Profile from LFI Borehole 199-B5-4 ..... 4-21
Figure 4-7. Vertical Profile from Borehole C7844 ..... 4-24
Figure 4-8. Vertical Profile from Borehole C7849 ..... 4-31
Figure 4-9. Vertical Profile from Borehole C7846 (Well 199-B4-15) ..... 4-37
Figure 4-9. Vertical Profile from Borehole C7846 (Well 199-B4-15) (cont.) ..... 4-38
Figure 4-10. Vertical Profile from Borehole C7847 ..... 4-45
Figure 4-10. Vertical Profile from Borehole C7847 (cont.) ..... 4-47
Figure 4-11. Vertical Profile from Borehole C8239 ..... 4-48
Figure 4-11. Vertical Profile from Borehole C8239 (cont.) ..... 4-50
Figure 4-12. Vertical Profile from Borehole C7845 ..... 4-54
Figure 4-13. Vertical Profile from LFI Test Pit ..... 4-59
Figure 4-14. Vertical Profile from Borehole C7843 (Well 199-B3-52) ..... 4-60
Figure 4-15. Vertical Profile for Test Pit at 116-B-6B ..... 4-63
Figure 4-16. Vertical Profile from Test Pit 118-B-8:3 ..... 4-68
Figure 4-16. Vertical Profile from Test Pit 118-B-8:3 (cont.) ..... 4-69
Figure 4-17. Vertical Profile from Test Pit 116-B-9 ..... 4-71
Figure 4-18. Vertical Profile from 116-C-1 Process Effluent Trench ..... 4-77
Figure 4-19. Vertical Soil Profile from Well 199-B2-16 (Borehole C7784) ..... 4-82

Figure 4-20. Vertical Soil Profile from Well 199-B3-51 (Borehole C7785) ..... 4-85
Figure 4-21. Vertical Soil Profile from Well 199-B8-9 (Borehole C7508) ..... 4-87
Figure 4-22. Vertical Soil Profile from Well 199-B5-8 (Borehole C8244) ..... 4-89
Figure 4-23. Vertical Soil Profiles for Well 199-B2-14 ..... 4-92
Figure 4-24. Vertical Soil Profiles for Well 199-B3-50 ..... 4-92
Figure 4-25. Vertical Soil Profiles for Well 199-B5-5 ..... 4-93
Figure 4-26. Vertical Soil Profiles for Well 199-B5-6 ..... 4-93
Figure 4-27. Groundwater Monitoring Wells Used in Statistical Evaluation ..... 4-106
Figure 4-28. Spatial/Temporal Sampling Times as Related to River Stage at 100-BC ..... 4-123
Figure 4-29. Cr(VI) in 100-BC Unconfined Aquifer, Spring 2010 ..... 4-124
Figure 4-30. Cr(VI) in 100-BC Unconfined Aquifer, Fall 2010 ..... 4-125
Figure 4-31. Cr(VI) in 100-BC Unconfined Aquifer, 2011 ..... 4-126
Figure 4-32. Cr(VI) in 100-BC Unconfined Aquifer, February 2012 ..... 4-127
Figure 4-33. Dissolved Chromium in Wells in Southern 100-BC ..... 4-129
Figure 4-34. Dissolved Chromium in Wells in Western 100-BC ..... 4-129
Figure 4-35. Dissolved Chromium in Well 199-B3-47 ..... 4-130
Figure 4-36. Dissolved Chromium in Wells 199-B3-1 and 199-B3-46 in Northeastern 100-BC ..... 4-130
Figure 4-37. Dissolved Chromium in Aquifer Tubes and Near River Wells, 100-BC ..... 4-131
Figure 4-38. Strontium-90 in 100-BC Unconfined Aquifer, Spring 2010 ..... 4-133
Figure 4-39. Strontium-90 in 100-BC Unconfined Aquifer, Fall 2010 ..... 4-134
Figure 4-40. Strontium-90 in 100-BC Unconfined Aquifer, 2011 ..... 4-135
Figure 4-41. Strontium-90 in Well 199-B4-4 ..... 4-136
Figure 4-42. Strontium-90 Wells 199-B3-1 and 199-B3-46 ..... 4-136
Figure 4-43. Tritium in 100-BC Unconfined Aquifer, Spring 2010 ..... 4-138
Figure 4-44. Tritium in 100-BC Unconfined Aquifer, Fall 2010 ..... 4-139
Figure 4-45. Tritium in 100-BC Unconfined Aquifer, 2011 ..... 4-140
Figure 4-46. Declining Tritium Levels in Wells in and Near 100-BC. ..... 4-141
Figure 4-47. Tritium in Wells 199-B3-47 and 199-B5-2 ..... 4-141
Figure 4-48. Increasing Tritium Levels in Wells in Eastern 100-BC ..... 4-142
Figure 4-49. Nitrate in Wells 199-B3-1, 199-B3-47 and Aquifer Tube 06-M ..... 4-143
Figure 4-50. Trichloroethene in 100-BC Unconfined Aquifer (Maximum Concentration, January 2010 through February 2012) ..... 4-144
Figure 4-51. Trichloroethene in Wells 199-B5-5, 199-B5-6, and 199-B5-8 ..... 4-145
Figure 4-52. Vertical Distribution of Contaminants in Well 199-B2-14 ..... 4-147
Figure 4-53. Vertical Distribution of Contaminants in Well 199-B2-16 ..... 4-148
Figure 4-54. Vertical Distribution of Contaminants in Well 199-B3-50 ..... 4-149
Figure 4-55. Vertical Distribution of Contaminants in Well 199-B3-51 ..... 4-151
Figure 4-56. Vertical Distribution of Contaminants in Well 199-B5-6 ..... 4-152
Figure 4-57. Vertical Distribution of Contaminants in Well 199-B5-5 ..... 4-153

Figure 4-58. Vertical Distribution of Contaminants in Well 199-B5-8 ..... 4-154
Figure 4-59. Vertical Distribution of Contaminants in Well 199-B8-9 ..... 4-155
Figure 4-60. Cross Section of 100-BC Chromium Plume, West to East Near River ..... 4-157
Figure 4-61. Cross Section of Chromium Plume, Western 100-BC, South to North ..... 4-158
Figure 4-62. Cross Section of Chromium Plume, Eastern 100-BC, South to North ..... 4-159
Figure 4-63. Pore Water Cr(VI) Concentrations at 100-BC ..... 4-167
Figure 4-64. Daily Average River Stage during 100-BC Pore Water Sampling ..... 4-168
Figure 4-65. Dissolved Chromium Concentrations in 100-BC Shoreline Springs ..... 4-171
Figure 4-66. Terrestrial Upland Biota Sampling Locations in 100-BC ..... 4-173
Figure 5-1. Screening Process for Groundwater/Surface Water Protection at Sites with Measurement Data Describing Site Conditions ..... 5-3
Figure 5-2. 100-BC Groundwater Mound during Operations (1967) ..... 5-11
Figure 5-3. Prototype Hanford Barrier Cover in 2007 Dominated by Tall Sage (*Artemisia tridentata*) Covering Most of the Soil Surface, 13 Years after Plant Community Establishment ..... 5-18
Figure 5-4. Representative Stratigraphic Columns for 100-BC STOMP Model Simulation ..... 5-22
Figure 5-5. Soil Batch Leach Vertical Profile for Test Pits 116-B-6B and 116-B-9 ..... 5-34
Figure 5-6. Soil Batch Leach Vertical Profile for Test Pit 118-B-8:3 and Well 199-B8-9 (C7508) ..... 5-35
Figure 5-7. Soil Batch Leach Vertical Profile for Wells 199-B2-16 (C7784) and 199-B3-51 (C7785) ..... 5-36
Figure 5-8. Soil Batch Leach Vertical Profile for Borehole C7842 and Well 199-B3-52 (C7843) ..... 5-37
Figure 5-9. Soil Batch Leach Vertical Profile for Boreholes C7844 and C7845 ..... 5-38
Figure 5-10. Soil Batch Leach Vertical Profile for Well 199-B4-15 (C7846) and Borehole C7847 ..... 5-39
Figure 5-11. Soil Batch Leach Vertical Profile for Boreholes C7849 and C8239 ..... 5-40
Figure 5-12. Soil Batch Leach Vertical Profile for Well 199-B5-8 (C8244) ..... 5-41
Figure 5-13. Breakthrough Simulated in Representative Soil Column for Range of $K_d$ Values based on 100:0 Initial Source Distribution ..... 5-46
Figure 5-14. Model Simulated Cr(VI) Distribution in Unconfined Aquifer Groundwater – Year 2010 ..... 5-72
Figure 5-15. Model Simulated Cr(VI) Distribution in Unconfined Aquifer Groundwater – Approximate Year 2020 ..... 5-73
Figure 5-16. Model Simulated Cr(VI) Distribution in Unconfined Aquifer Groundwater - Approximate Year 2035 ..... 5-74
Figure 5-17. Model Simulated Cr(VI) Distribution in Unconfined Aquifer Groundwater – Approximate Year 2060 ..... 5-75
Figure 5-18. Model Simulated Cr(VI) Distribution in Unconfined Aquifer Groundwater – Approximate Year 2110 ..... 5-76
Figure 5-19. Model Simulated Cr(VI) Distribution in Unconfined Aquifer Groundwater – Approximate Year 2160 ..... 5-77
Figure 5-20. Model Simulation of Strontium-90 Distribution in Unconfined Aquifer Groundwater – Approximate Year 2010 ..... 5-78

Figure 5-21. Model Simulation of Strontium-90 Distribution in Unconfined Aquifer Groundwater – Approximate Year 2020 ..... 5-79
Figure 5-22. Model Simulation of Strontium-90 Distribution in Unconfined Aquifer Groundwater – Approximate Year 2035 ..... 5-80
Figure 5-23. Model Simulation of Strontium-90 Distribution in Unconfined Aquifer Groundwater – Approximate Year 2060 ..... 5-81
Figure 5-24. Model Simulation of Strontium-90 Distribution in Unconfined Aquifer Groundwater – Approximate Year 2110 ..... 5-82
Figure 5-25. Model Simulation of Tritium Distribution in Unconfined Aquifer Groundwater – Approximate Year 2010 ..... 5-83
Figure 5-26. Model Simulation of Tritium Distribution in Unconfined Aquifer Groundwater – Approximate Year 2015 ..... 5-84
Figure 5-27. Model Simulation of Tritium Distribution in Unconfined Aquifer Groundwater – Approximate Year 2020 ..... 5-85
Figure 5-28. Model Simulation of Tritium Distribution in Unconfined Aquifer Groundwater – Approximate Year 2025 ..... 5-86
Figure 6-1. Data Processing and Reduction Steps for the 100-BC Source OU ..... 6-34
Figure 6-2. Analyte Identification Steps for the 100-BC Source OU Dataset ..... 6-36
Figure 6-3. Decisions Logic for Computing 100-BC Exposure Point Concentrations ..... 6-39
Figure 6-4. Overview of COPC Identification Process ..... 6-128
Figure 6-5. Monitoring Well Locations within the 100-BC-5 Groundwater OU ..... 6-130
Figure 6-6. Data Processing and Reduction Steps for the 100-BC-5 Groundwater OU Dataset ..... 6-131
Figure 6-7. COPC Identification Process for the 100-BC-5 Groundwater OU: Part 1 ..... 6-147
Figure 6 8. COPC Identification Process for the 100 BC 5 Groundwater OU: Part 2 ..... 6-148
Figure 6-9. Analyte Specific Evaluation Process for EPCs Less than Action Levels ..... 6-165
Figure 6-10. COPC Identification Analyte Specific Evaluation Process for EPCs Greater than Action Levels ..... 6-170
Figure 7-1. Conceptual Ecological Site Model for Terrestrial Habitats in Hanford Site Upland Environment ..... 7-9
Figure 7-2. Hanford Site Upland Environment Terrestrial Food Web ..... 7-10
Figure 8-1. 100–BC Sites Not Evaluated in the Feasibility Study ..... 8-37
Figure 8-2. 100-BC Sites Exceeding Human Health PRGs for Direct Contact with Deep Contaminated Soil ..... 8-38
Figure 8-3. 100-BC Waste Sites to be Remediated Under Interim Actions ..... 8-42
Figure 8-4. 100-BC Sites Remaining for Remedial Action ..... 8-44
Figure 8-5. 100-BC Sites Exceeding Human Health PRGs for Direct Contact with Shallow Contaminated Soil ..... 8-45
Figure 8-6. 100-BC Sites Exceeding Surface Water and and/or Groundwater Protection PRGs ..... 8-46
Figure 8-7. 100-BC ARCL, Special Case, and B Reactor Museum Sites ..... 8-47
Figure 8-8. Standard Excavation ..... 8-75
Figure 8-9. Deep Excavation ..... 8-76
Figure 8-10. Onsite Disposal: The Environmental Restoration Disposal Facility ..... 8-77

Figure 8-11. Offsite Disposal (Offsite Landfill and Offsite Repository) ..... 8-78
Figure 8-12. In Situ Biological Treatment (Vadose Zone) ..... 8-79
Figure 8-13. Monitored Natural Attenuation ..... 8-80
Figure 8-14. Void-Fill Grouting ..... 8-81
Figure 8-15. Surface Barriers ..... 8-82
Figure 8-16. Groundwater Extraction System and Onsite Discharge ..... 8-83
Figure 8-17. Ion Exchange ..... 8-84
Figure 8-18. Vertical Wells ..... 8-85
Figure 8-19. Surface Infiltration ..... 8-86
Figure 8-20. Beneficial Reuse ..... 8-87
Figure 8-21. Water Flushing (Groundwater) ..... 8-88
Figure 8-22. In Situ Chemical Reduction (Groundwater) ..... 8-89
Figure 8-23. In Situ Biological Treatment Anaerobic (Groundwater) ..... 8-90
Figure 8-24. Reactive Chemical Barrier (In Situ Redox Manipulation Groundwater) ..... 8-91
Figure 8-25. Hydraulic Containment via Extraction (Groundwater) ..... 8-92
Figure 9-1. Modeled Cr(VI) Plume, Initial Conditions ..... 9-19
Figure 9-2. Modeled Strontium-90 Plume, Initial Conditions ..... 9-20
Figure 9-3. Modeled Tritium Plume, Initial Conditions ..... 9-21
Figure 9-4. Modeled Cr(VI) Concentration Trends for all Alternatives ..... 9-25
Figure 9-5. Modeled Strontium-90 Concentration Trends for all Alternatives ..... 9-26
Figure 9-6. Modeled Tritium Concentration Trends for all Alternatives ..... 9-27
Figure 9-7. Frequency Diagrams of Cr(VI) Mass in the Aquifer for all Alternatives ..... 9-29
Figure 9-8. Frequency Diagrams of Strontium-90 Mass in the Aquifer for all Alternatives ..... 9-30
Figure 9-9. Frequency Diagrams of Tritium Mass in the Aquifer for all Alternatives ..... 9-31
Figure 9-10. Alternative GW-1 - Modeled Cr(VI) Plume, Year 25 ..... 9-33
Figure 9-11. Alternative GW-1 – Modeled Cr(VI) Plume, Year 50 ..... 9-34
Figure 9-12. Alternative GW-1 – Modeled Cr(VI) Plume, Year 75 ..... 9-35
Figure 9-13. Alternative GW-1 - Modeled Strontium-90 Plume, Year 25 ..... 9-36
Figure 9-14. Alternative GW-1 – Modeled Strontium-90 Plume, Year 50 ..... 9-37
Figure 9-15. Alternative GW-1 – Modeled Strontium-90 Plume, Year 60 ..... 9-38
Figure 9-16. Alternative GW-1 – Modeled Tritium Plume, Year 5 ..... 9-39
Figure 9-17. Alternative GW-1 – Modeled Tritium Plume, Year 10 ..... 9-40
Figure 9-18. Alternative GW-1 – Modeled Tritium Plume, Year 15 ..... 9-41
Figure 9-19. Alternative GW-2 - Modeled Cr(VI) Plume, Year 10 ..... 9-43
Figure 9-20. Alternative GW-2 - Modeled Cr(VI) Plume, Year 25 ..... 9-44
Figure 9-21. Alternative GW-2 – Modeled Cr(VI) Plume, Year 50 ..... 9-45
Figure 9-22. Alternative GW-2 – Modeled Cr(VI) Plume, Year 75 ..... 9-46
Figure 9-23. Preliminary Design of Groundwater Remediation Components for Alternative GW-3 ..... 9-49
Figure 9-24. Alternative GW-3 - Modeled Cr(VI) Plume, Year 5 ..... 9-53

Figure 9-25. Alternative GW-3 - Modeled Cr(VI) Plume, Year 10 ..... 9-54
Figure 9-26. Alternative GW-3 - Modeled Cr(VI) Plume, Year 25 ..... 9-55
Figure 9-27. Alternative GW-3 – Modeled Cr(VI) Plume, Year 50 ..... 9-56
Figure 9-28. Alternative GW-3 – Modeled Cr(VI) Plume, Year 75 ..... 9-57
Figure 9-29. Preliminary Design of Groundwater Remediation Components for Alternative GW-4 ..... 9-61
Figure 9-30. Alternative GW-4 – Modeled Cr(VI) Plume, Year 5 ..... 9-65
Figure 9-31. Alternative GW-4 – Modeled Cr(VI) Plume, Year 10 ..... 9-66
Figure 9-32. Alternative GW-4 – Modeled Cr(VI) Plume, Year 25 ..... 9-67
Figure 9-33. Alternative GW-4 – Modeled Cr(VI) Plume, Year 50 ..... 9-68
Figure 9-34. Alternative GW-4 – Modeled Cr(VI) Plume, Year 75 ..... 9-69

## Tables

Table 1-1. Overarching Goals for Hanford Site Cleanup ..... 1-5
Table 1-2. Chemicals Used in 100 BC Water Treatment, 1945 ..... 1-20
Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions ..... 1-31
Table 1-4. Summary of Removal Action Documents at 100 BC ..... 1-41
Table 1-5. Summary Information on the Status of 100 BC Facilities (June 2012) ..... 1-42
Table 1-6. Summary of Sites Investigated in the Initial Radiological Characterization—1975 ..... 1-44
Table 1-7. High-Priority Waste Sites and IRM Candidates Identified by LFIs in 100 BC with Subsequent Remedial Action Decision. ..... 1-45
Table 1-8. Summary of 100 BC LFI Intrusive Vadose Zone Characterization within Selected Waste Sites ..... 1-46
Table 1-9. Summary Information on 100 BC Sites (June 2012) ..... 1-49
Table 1-10. Classification/Reclassification Status of 100 BC 1 Waste Sites (June 2012) ..... 1-50
Table 1-11. Classification/Reclassification Status of 100 BC 2 OU Waste Sites (June 2012) ..... 1-50
Table 1-12. 100 BC High Priority Radioactive Liquid Effluent Disposal Sites ..... 1-52
Table 1-13. 100-BC Sites That are Not Considered Further in the RI/FS ..... 1-55
Table 2-1. Data Gaps and Work Conducted Under 100-BC Remedial Investigation ..... 2-4
Table 2-2. Supplemental Investigations and Other Primary Investigations ..... 2-9
Table 2-3. Summary of Soil Samples Collected for 100-BC ..... 2-11
Table 2-4. Summary of Water Samples Collected for 100-BC ..... 2-14
Table 2-5. Analytes for Columbia River Remedial Investigation (Phase III) Sampling ..... 2-24
Table 2-6. Summary of Additional Samples Collected near 100-BC during the Columbia River Remedial Investigation ..... 2-24
Table 2-7. Summary of Construction Information for New Wells and Boreholes at 100-BC ..... 2-26
Table 2-8. Borehole and Test Pit Locations and Rationale for Investigation of Waste Site ..... 2-31
Table 2-9. 100-BC Aquifer Tests ..... 2-39
Table 2-10. 100-BC Automated Water Level Monitoring Stations ..... 2-39
Table 2-11. 100-BC Aquifer Tubes Installed in 2010 ..... 2-42

Table 2-12. Dates of 100-BC Spatial/Temporal Groundwater Sampling (2010) ..... 2-43
Table 2-13. Field Activity Documentation ..... 2-46
Table 3-1. Monthly and Annual Minimum Temperatures from 1945 through 2009 ..... 3-3
Table 3-2. Monthly and Annual Maximum Temperatures from 1945 through 2009 ..... 3-3
Table 3-3. Average, Minimum, and Maximum Monthly and Annual Precipitation from 1947 through 2009 ..... 3-4
Table 3-4. Monthly and Annual Prevailing Wind Directions, Average Speeds, and Peak Gusts at Hanford Meteorological Station, 50 ft Level, 1945 through 2004 ..... 3-4
Table 3-5. Summary of Geologic and Well Construction Data for Wells and Boreholes in and near 100 BC ..... 3-25
Table 3-6. Physical Property Results for Samples Collected in the Vadose Zone ..... 3-51
Table 3-7. Vertical Hydraulic Conductivity as Determined by Laboratory Testing of Split-Spoon Samples ..... 3-54
Table 3-8. Van Genuchten Parameters and Fitted Vertical Saturated Hydraulic Conductivity Data for Three Sandy Gravel Soil Samples ..... 3-57
Table 3-9. Bulk Density and Percent Moisture of 100-BC Aquifer and Aquitard, Based on Sediment Samples ..... 3-61
Table 3-10. Horizontal Hydraulic Conductivity Estimates for 100-BC Aquifer and Aquitard, Based on Slug and Pumping Tests ..... 3-64
Table 3-11. Estimated Recharge Rates for Dominant Soil Types in 100-BC ..... 3-67
Table 3-12. Hydraulic Gradient and Groundwater Flow Estimates for 100-BC ..... 3-68
Table 3-13. Vertical Hydraulic Gradients in 100-BC ..... 3-72
Table 3-14. Flora Threatened and Endangered Species List ..... 3-90
Table 3-15. Fauna Threatened and Endangered Species List ..... 3-92
Table 4-1. Background Concentrations in Hanford Site Soil 4-8
Table 4-2. 100-BC Soil Analytes Excluded from Further Consideration ..... 4-10
Table 4-3. Remedial Investigation Target ..... 4-12
Table 4-4. 116-B-14 Trench—Summary of Contaminant Soil Data ..... 4-14
Table 4-5. 116-B-5 Crib Summary of Contaminant Soil Data ..... 4-18
Table 4-6. 16-B-5 Crib Borehole C7844, Interval 10 (Sample B27J76) Chromium, Copper, Molybdenum, and Nickel Results Relative to Neighboring Interval Sample Results ..... 4-25
Table 4-7. 118-C-3:2 Fuel Storage Basin Summary of Contaminant Soil Data ..... 4-28
Table 4-8. 100-B-5 Trench Borehole C7846 (Well 199-B4-15) Summary of Contaminant Soil Data ..... 4-34
Table 4-9. 118-B-8:1 Fuel Storage Basin —Summary of Contaminant Soil Data ..... 4-41
Table 4-10. 118-B-6 Burial Ground—Summary of Contaminant Soil Data ..... 4-52
Table 4-11. 116-C-5 Retention Basin (Well 199-B3-52) —Summary of Contaminant Soil Data ..... 4-57
Table 4-12. 116-B-6B Crib Summary of Contaminant Soil Data ..... 4-62
Table 4-13. 118-B-8:3 Process Sewer Summary of Contaminant Soil Data ..... 4-65
Table 4-14. 116-B-9 French Drain Summary of Contaminant Soil Data ..... 4-70
Table 4-15. 116-C-1 Process Effluent Trench - Summary of Contaminant Soil Data ..... 4-75

Table 4-16. Elevated Metal Concentrations in 100-BC Area RI Samples ..... 4-78
Table 4-17. C7846, Interval 2 (Sample B27Y42), Chromium and Nickel Results Relative to Neighboring Intervals and Duplicate Sample Results ..... 4-79
Table 4-18. C7842, Interval 10 (Sample B27FF5), Chromium and Nickel Results Relative to Upper Interval Sample Results ..... 4-79
Table 4-19. Well 199-B2-16—Summary of Contaminant Soil Data ..... 4-81
Table 4-20. Well 199-B3-51—Summary of Contaminant Soil Data ..... 4-84
Table 4-21. Well 199-B8-9—Summary of Contaminant Soil Data ..... 4-86
Table 4-22. Well 199-B5-8—Summary of Contaminant Soil Data ..... 4-88
Table 4-23. Summary of Vadose Zone Contaminant Data from Pre-RI Monitoring Wells ..... 4-91
Table 4-24. Constituents Detected Above Background in RI Vadose Zone Characterization Samples ..... 4-94
Table 4-25. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100-BC Radionuclides (Table 1 of 2) ..... 4-97
Table 4-25. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100-BC Radionuclides (Cont.) ..... 4-98
Table 4-26. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Metals (Table 1 of 2) ..... 4-99
Table 4-26. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Metals (Table 2 of 2) ..... 4-99
Table 4-27. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Organic Compounds and Anions (1 of 4) ..... 4-100
Table 4-27. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Organic Compounds and Anions (2 of 4) ..... 4-101
Table 4-27. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Organic Compounds and Anions (3 of 4) ..... 4-102
Table 4-27. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Organic Compounds and Anions (4 of 4) ..... 4-103
Table 4-28. Groundwater Summary Statistics for 100-BC ..... 4-107
Table 4-29. Summary of Groundwater Contaminant Evaluation ..... 4-121
Table 4-30. 100-BC Plume Areas (2011) ..... 4-122
Table 4-31. Summary of Soil Chemistry Data from New Monitoring Wells, Samples Collected below the Water Table ..... 4-160
Table 4-32. Concentrations of Chromium in Columbia River Pore Water at 100-BC ..... 4-164
Table 4-33. Sitewide Environmental Monitoring Results for Shoreline Springs in 100-BC ..... 4-170
Table 5-1. Recharge Rate for Different Time Periods in STOMP Model Simulations ..... 5-19
Table 5-2. Relative Mobility of Selected 100-BC Contaminants of Potential Concern ..... 5-23
Table 5-3. Calculated Soil-Water Partition Coefficients ($K_d$) ..... 5-27
Table 5-4. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with 1-D Model Implemented in the STOMP Code for Screening Level and Preliminary Remediation Goal Calculations in 100-BC-1 and 100-BC-2 Operable Units ..... 5-43

Table 5-5. Summary of Chemical SSLs and PRGs Protective of Groundwater and Surface Water Calculated with STOMP ..... 5-49
Table 5-6. Summary of Radionuclide SSL and PRGs Protective of Groundwater Calculated with STOMP ..... 5-57
Table 5-7. Interim Remediated Waste Sites in 100-BC ..... 5-59
Table 5-8. Waste Sites with EPCs Greater than SSLs Protective of Groundwater or Surface Water. 5-63
Table 5-9. Waste Sites with EPCs Greater than PRGs Protective of Groundwater ..... 5-65
Table 5-10. Waste Sites with EPCs Greater than PRGs Protective of Surface Water ..... 5-65
Table 5-11. Summary of Selected Primary Fate and Transport Simulation Input Parameters Used with Groundwater Flow and Transport Model Implemented in the MODFLOW and MT3DMS Codes for in the 100-BC-5 Operable Unit ..... 5-69
Table 6-1. Summary of Residential Scenario Risk Assessment Results for Chemical Carcinogens ..... 6-5
Table 6-2. Summary of Residential Scenario Risk Assessment Results for Noncarcinogens ..... 6-7
Table 6-3. Summary of Residential Scenario Risk Assessment Results for Radionuclides ..... 6-10
Table 6-4. Comparison of Methods and Assumptions Used for the Residential Scenario ..... 6-13
Table 6-5. Summary of Differences in Exposure Assumptions for the Resident Monument Worker between the RCBRA and RI/FS Risk Assessment ..... 6-19
Table 6-6. Summary of Differences in Exposure Assumptions for the Casual User between the RCBRA and RI/FS Risk Evaluation ..... 6-20
Table 6-7. Summary of Total Risks and Noncancer Hazards for the Subsistence Farmer Scenario ..... 6-23
Table 6-8. Summary of Waste Sites with Verification Data in the 100-BC-1 and 100-BC-2 OUs ..... 6-28
Table 6-9. Summary and Definition of Decision Unit Types ..... 6-33
Table 6-10. Example Conversion from Activity- to Mass-Based Concentration (pCi/g to µg/kg) for Uranium Isotopes and Summation to Produce a Mass-Based Total Uranium Concentration (µg/kg) ..... 6-41
Table 6-11. Summary of Preliminary Remediation Goals for the 100-B/C Source OU ..... 6-49
Table 6-12. Summary of Total Risks for the 100-BC-1 and 100-BC-2 Shallow Zone Waste Sites for the Residential Scenario ..... 6-81
Table 6-13. Summary of Total Risks for the 100-BC-1 and 100-BC-2 Deep Zone Waste Sites for the Residential Scenario ..... 6-92
Table 6-14. Summary of Total Risks for the 100-BC-1 and 100-BC-2 Shallow Zone Waste Sites for the Resident Monument Worker Scenario ..... 6-98
Table 6-15. Summary of Total Risks for the 100-BC-1 and 100-BC-2 Shallow Zone Waste Sites for the Casual Recreational User Scenario ..... 6-104
Table 6-16. Summary of Human Health Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data ..... 6-119
Table 6-17. List of Historical Contaminants of Potential Concern in the 100 BC 5 Groundwater OU ..... 6-126
Table 6-18. Monitoring Wells Used in the Baseline Risk Assessment from the 100 BC 5 Groundwater OU ..... 6-129

Table 6-19. Summary of Federal and State Water Quality Criteria Used as Action Levels for the 100-BC-5 Groundwater OU ..... 6-135
Table 6-20. Summary of Groundwater Analytes that Meet Exclusion Criteria in the 100-BC-5 Groundwater OU ..... 6-152
Table 6-21. Summary of Analytes that Were Not Detected in the 100-BC-5 Groundwater OU ..... 6-155
Table 6-22. Summary of Groundwater Analytes that Do Not Exceed an Action Level in the 100-BC-5 Groundwater OU ..... 6-158
Table 6-23. Summary of Analytes that Exceed an Action Level in the 100-BC-5 Groundwater OU ..... 6-159
Table 6-24. Comparison of Exposure Point Concentration to Action Levels for the Near-River Exposure Area ..... 6-163
Table 6-25. Comparison of Exposure Point Concentration to Action Levels for the Upland Exposure Area ..... 6-164
Table 6-26. Summary of Groundwater COPCs Identified for the 100 BC 5 Groundwater OU ..... 6-171
Table 6-27. Summary of Current Conditions 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173 340 720 Groundwater Cleanup Levels for the Near-River Exposure Area (Human Health Action Levels) ..... 6-178
Table 6-28. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State Water Quality Standards for the Near-River Exposure Area (Aquatic Action Levels) ..... 6-179
Table 6-29. Summary of 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions for the Near-River Exposure Area ..... 6-179
Table 6-30. Summary of 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Noncancer Hazard Index for the Near-River Exposure Area ..... 6-181
Table 6-31. Summary of Current Conditions 90th Percentile Groundwater Concentrations, Federal and State MCLs, and WAC 173 340 720 Groundwater Cleanup Levels for the Upland Exposure Area (Human Health Action Levels) ..... 6-182
Table 6-32. Summary of Current Conditions 90th Percentile Groundwater Concentrations, and Federal and State Water Quality Standards for the Upland Exposure Area (Aquatic Action Levels) ..... 6-182
Table 6-33. Summary of 90th Percentile Current Groundwater Concentrations and Associated Sum of Fractions for the Upland Exposure Area ..... 6-183
Table 6-34. Summary of 90th Percentile Current Groundwater Concentrations and Associated Cancer Risk and Noncancer Hazard Index for the Upland Exposure Area ..... 6-184
Table 6-35. Summary of Risk Estimates from Use of Groundwater as a Potential Drinking Water Source Using EPA Tap Water Equations ..... 6-185
Table 6-36. Near-River Exposure Area – Summary of Tap Water Scenario --Cancer Risk Results for Nonradiological and Radiological Analytes in Groundwater ..... 6-187
Table 6-37. Near-River Exposure Area Summary of Tap Water Scenario -- Noncancer Hazard Results for Nonradiological Analytes in Groundwater ..... 6-189
Table 6-38. Upland Exposure Area – Summary of Tap Water Scenario -- Cancer Risk Results for Nonradiological and Radiological Analytes in Groundwater ..... 6-191
Table 6-39. Upland Exposure Area—Summary of Tap Water Scenario -- Noncancer Hazard Results for Nonradiological Analytes in Groundwater ..... 6-193

Table 6-40. Percentile Concentrations and Summary Statistics for Analytes in the 100-BC-5 Groundwater OU Dataset ..... 6-198
Table 6-41. Summary of 90th Percentile Groundwater Concentrations, Associated Cancer Risk, and Associated Sum of Fractions for Radioactive COPCs in the Near-River Exposure Area ..... 6-206
Table 6-42. Summary of 90th Percentile Groundwater Concentrations, Associated Cancer Risk, and Associated Sum of Fractions for Radioactive COPCs in the Upland Exposure Area ..... 6-206
Table 6-43. Summary of Total Risks and Noncancer Hazards for the Riparian and Nearshore in the 100-BC OUs ..... 6-210
Table 7-1. SSLs in Upland Soil for Plants and Soil Invertebrates ..... 7-17
Table 7-2. Wildlife (Birds and Mammals) SSLs for Radionuclides ..... 7-23
Table 7-3. Wildlife (Birds and Mammals) SSLs for Nonradionuclides ..... 7-33
Table 7-4. PRGs for Wildlife (Birds and Mammals) ..... 7-43
Table 7-5. Final Recommended Soil PRGs for Plants and Invertebrates ..... 7-46
Table 7-6. Remediated Waste Sites Exceeding SSLs and Background for Surface Soils (0 to 4.6 m [0 to 15 ft]) ..... 7-48
Table 7-7. Remediated Waste Sites Exceeding PRGs for Surface Soils (0 to 4.6 m [0 to 15 ft]) ..... 7-57
Table 7-8. Summary of Ecological Risk Comparisons for RI Data, CVP/RSVP Data, and LFI Data ..... 7-65
Table 7-9. Riparian, Nearshore, and Riverine COECs from the RCBRA and CRC ..... 7-70
Table 7-10. Summary of Factors Considered for Scientific Decision Management Process ..... 7-83
Table 7-11. Freshwater Sediment PRGs ..... 7-109
Table 8-1. Summary of Soil and Groundwater COCs and COPCs ..... 8-2
Table 8-2. Potential Federal and Washington State ARARs and TBCs for 100 BC ..... 8-7
Table 8-3. Summary of 100 BC Operable Unit Human Health, Groundwater Protection, Surface Water Protection, and Ecological Soil PRGs ..... 8-25
Table 8-4. 100 BC 5 Groundwater OU PRGs ..... 8-29
Table 8-5. Summary of 100 BC Waste Site Status ..... 8-36
Table 8-6. Period for Decay to Residential RBSLs of Deep Zone Soil Concentrations at 100 BC Waste Sites ..... 8-39
Table 8-7. Sites Evaluated in Feasibility Study - Basis for Action ..... 8-43
Table 8-8. Screening Table—Technologies for Radionuclides, Cr(VI), Other Metals, and Organic Compounds in Waste Sites, Hanford Site River Corridor, 100 BC ..... 8-49
Table 8-9. Screening Table—Technologies for Cr(VI) and Other COPCs in Groundwater, Hanford Site River Corridor, 100 BC ..... 8-56
Table 8-10. Categories and Types of Current Hanford Site Institutional Controls ..... 8-65
Table 9-1. ICs Implemented at Waste Sites Post Remediation* ..... 9-6
Table 9-2. Retained Technologies Applied to Waste Site Remedial Action Alternatives ..... 9-9
Table 9-3. Remedial Components for Waste Site Remedial Action Alternatives ..... 9-10
Table 9-4. Description of Alternative Components for Alternative S-2— MESC, MNA, and ICs ..... 9-11

Table 9-5. Description of Alternative Components for Alternative S-3 Limited RTD Optimized with Other Technologies ..... 9-13
Table 9-6. Description of Alternative Components for Alternative S-4—Aggressive RTD ..... 9-15
Table 9-7. Retained Technologies Applied to Groundwater Remedial Action Alternatives ..... 9-17
Table 9-8. Model Predicted Time to Achieve Groundwater PRGs ..... 9-28
Table 9-9. Description of Alternative Components for Alternative GW-2—MNA and Institutional Controls ..... 9-47
Table 9-10. Description of Alternative Components for Alternative GW-3 River Protection Pump-and –Treat ..... 9-51
Table 9-11. Description of Alternative Components for Alternative GW-4 – Aggressive Pump-and-Treat ..... 9-63
Table 10-1. Summary of CERCLA Criteria ..... 10-3
Table 10-2. CERCLA Evaluation Summary for Alternative S-1: No Action ..... 10-8
Table 10-3. CERCLA Evaluation Summary Alternative for S-2: MESC, MNA, and Institutional Controls ..... 10-11
Table 10-4. CERCLA Evaluation Summary Alternative for S-3: RTD Optimized with Other Technologies ..... 10-14
Table 10-5. CERCLA Evaluation Summary Alternative for S-4: Aggressive RTD ..... 10-18
Table 10-6. 100-BC-5 COC Groundwater Plume Attributes ..... 10-21
Table 10-7. CERCLA Evaluation Summary for Alternative GW-1: No Action ..... 10-22
Table 10-8. CERCLA Evaluation Summary Alternative for GW-2: Institutional Controls and MNA ..... 10-23
Table 10-9. CERCLA Evaluation Summary Alternative for GW-3: River Protection Pump-and-Treat ..... 10-26
Table 10-10. CERCLA Evaluation Summary Alternative for GW-4: Aggressive Pump-and-Treat ..... 10-28
Table 10-11. Comparative Analysis of Waste Site Alternatives ..... 10-31
Table 10-12. Comparative Analysis of Groundwater Alternatives ..... 10-33
Table 10-13. Comparison of Remedial Alternative Costs a for the 100-BC-1 and 100-BC-2 Source Operable Units ..... 10-38
Table 10-14. Comparison of Remedial Alternative Costs for the 100-BC-5 Groundwater Operable Unit ..... 10-40

# Terms

| | |
|---|---|
| AEA | Atomic Energy Act of 1954 |
| AEC | Atomic Energy Commission |
| alum | aluminum sulfate |
| AMSL | above mean sea level |
| ANL | Argonne National Laboratory |
| ARAR | applicable or relevant and appropriate requirement |
| ASTM | American Society for Testing and Materials |
| ATSDR | Agency for Toxic Substances and Disease Registry |
| AUF | area use factor |
| AWQC | Ambient Water Quality Criterion |
| B.P. | before present (time) |
| BAF | Bioaccumulation factor |
| BDL | Below detection limit |
| BG | background |
| bgs | below ground surface |
| BRA | baseline risk assessment |
| CAA | Clean Air Act of 1990 |
| CalEPA | California Environmental Protection Agency |
| CAS | Chemical Abstract Service |
| CCC | criteria continuous concentration |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act of 1980 |
| CLARC | Cleanup Levels and Risk Calculations |
| CMC | criteria maximum concentration |
| COC | contaminant of concern |
| COPC | contaminant of potential concern |
| COPEC | contaminant of potential environmental concern |
| CRC | Columbia River Component |
| CSM | conceptual site model |
| CSS | Colorado Silica Sand |
| CTUIR | Confederated Tribes of the Umatilla Indian Reservation |

| | |
|---|---|
| CUL | groundwater cleanup level |
| CV | coefficient of variation |
| CVP | cleanup verification package |
| CWA | Clean Water Act of 1977 |
| CY | calendar year |
| D&D | decommissioning and demolition |
| D4 | deactivation, decontamination, decommissioning, and demolition |
| DAD | dermal absorbed dose |
| DDF | dummy decontamination facility |
| DDT | dichlorodiphenyltrichloroethane |
| DOE | U.S. Department of Energy |
| DOE-RL | U.S. Department of Energy, Richland Operations Office |
| dpm | disintegrations per minute |
| DQA | data quality assessment |
| DQO | data quality objective |
| EcoSSL | ecological soil screening level |
| 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 |
| EQL | estimated quantitation limit |
| ERA | environmental risk assessment |
| ERAGS | Ecological Risk Assessment Guidance for Superfund |
| ERDF | environmental restoration disposal facility |
| ESD | explanation of significant differences |
| ET | evapotranspiration |
| ETF | Effluent Treatment Facility |
| EWS | export water system |
| FC | Federal Candidate |
| FCo | Federal Species of Concern |
| FE | Federal Endangered |

| | |
|---|---|
| FS | feasibility study |
| FSB | fuel storage basin |
| FY | fiscal year |
| GCW | groundwater circulation well |
| GEAE | Generic Ecological Assessment Endpoint |
| GHG | greenhouse gas |
| GRA | general response action |
| GPR | ground-penetrating radar |
| GPS | global positioning system |
| HAER | Historic American Engineering Record |
| HCP EIS | Hanford Comprehensive Land-Use Plan Environmental Impact Statement |
| HEAST | health effects assessment summary tables |
| HEIS | Hanford Environmental Information System |
| HHRA | human health risk assessment |
| HI | hazard index |
| HMS | Hanford Meteorological Station |
| HQ | hazard quotient |
| HRNM | Hanford Reach National Monument |
| HSP | health and safety plan |
| I&E | internally and externally cooled |
| ICP | inductively coupled plasma |
| ID | identifier |
| IDL | instrument detection limit |
| IEUBK | integrated exposure uptake biokinetic |
| IRIS | integrated risk information system |
| IRM | interim remedial measures |
| ISGR | in situ gaseous reduction |
| ISRM | in situ redox manipulation |
| ISS | interim safe storage |
| ITER | International Toxicity Estimates for Risk |
| ISV | in situ vitrification |
| $K_d$ | distribution coefficient |

| | |
|---|---|
| $K^s$ | saturated hydraulic conductivity |
| LDR | land disposal restriction |
| LFI | limited field investigation |
| LIDAR | light detection and ranging |
| LOAEC | lowest observed adverse-effect concentration |
| LOAEL | lowest observed adverse-effect level |
| LOEC | lowest observed effect concentration |
| MATC | maximum allowable toxicant concentration |
| MCL | maximum contaminant level |
| MCLG | maximum contaminant level goal |
| MDA | minimum detectable activity |
| MDL | method detection limit |
| MESC | Maintain Existing Soil Cover |
| MNA | monitored natural attenuation |
| MRDL | maximum residual disinfectant level |
| MTCA | Model Toxic Control Act |
| MW | molecular weight |
| m.y. | million years |
| NA | not applicable |
| NCP | national contingency plan |
| ND | no data |
| NEPA | National Environmental Policy Act of 1969 |
| NHPA | National Historic Preservation Act of 1966 |
| NJDEP | New Jersey Department of Environmental Protection |
| NPDES | National Pollutant Discharge Elimination System |
| NPL | National Priorities List |
| NPV | net present value |
| NRHP | National Register of Historic Places |
| NTU | nephelometric turbidity unit |
| O&M | operations and maintenance |
| OEHHA | Office of Health Hazard Assessment |
| ORNL | Oak Ridge National Laboratory |

| | |
|---|---|
| OSE | orphan site evaluation |
| OSWER | Office of Solid Waste and Emergency Response (EPA) |
| OU | operable units |
| PA | preliminary assessment |
| PAH | polynuclear aromatic hydrocarbon |
| PCB | polychlorinated biphenyl |
| PCE | perchloroethylene |
| PEF | particulate emission factor |
| PNNL | Pacific Northwest National Laboratory |
| PRZ | periodically rewetted zone |
| PPE | personal protective equipment |
| PPRTV | Provisional Peer Reviewed Toxicity Value |
| PQL | practical quantitation limit |
| PRG | preliminary remedial goal |
| PVC | polyvinyl chloride |
| Q | qualifier |
| QA | quality assurance |
| QC | quality control |
| QRA | qualitative risk assessment |
| RA | risk assessment |
| RACER | Remedial Action Cost Engineering and Requirements |
| RAG | remedial action goal |
| RAIS | Risk Assessment Information System |
| RAO | remedial action objective |
| RBSL | risk based screening level |
| RCBRA | River Corridor Baseline Risk Assessment |
| RCRA | Resource Conservation and Recovery Act of 1976 |
| RCW | Revised Code of Washington |
| RD/RA | remedial design/remedial action |
| RD/RAWP | remedial design/removal action work plan |
| RDR/RAWP | remedial design report/remedial action work plan |
| RESRAD | RESidual RADiation |

| | |
|---|---|
| RfD | reference dose |
| RI | remedial investigation |
| RMA | Radiological Materials Area |
| RME | reasonable maximum exposure |
| ROD | record of decision |
| RSVP | remaining site verification package |
| RTD | removal, treatment, and disposal |
| RUM | Ringold Formation upper mud |
| SAP | sampling and analysis plan |
| SARA | Superfund Amendments and Authorization Action of 1986 |
| SDWA | Safe Drinking Water Act of 1974 |
| SE | state endangered |
| SEM | simultaneously extracted metals |
| SESP | Surface Environmental Surveillance Program |
| SI | site investigation |
| SMDP | Scientific Management Decision Point |
| SOF | sum of fractions |
| SOP | standard operating procedures |
| SR-RAD | total beta radiostrontium |
| SS | state sensitive |
| SSL | soil screening level |
| ST | state threatened |
| STOMP | Subsurface Transport Over Multiple Phases |
| SVOC | semivolatile organic compound |
| SX | possibly extinct or extirpated from Washington |
| $T_{1/2}$ | half-life |
| TBC | to be considered |
| TCN | transportation control number |
| TERA | Toxicology Excellence for Risk Assessment |
| TI | technical impracticability |
| TIC | total inorganic carbon |
| TMV | toxicity, mobility, and volume |

| | |
|---|---|
| TOC | total organic carbon |
| TPA | Tri-Party Agreement |
| TPH | total petroleum hydrocarbons |
| Tri-Party Agreement | Hanford Federal Facility Agreement and Consent Order |
| TRV | toxicity reference value |
| TSCA | Toxic Substances Control Act of 1976 |
| TSD | temporary storage and disposal |
| U | undetected |
| UCL | upper confidence level |
| UPL | upper prediction limit |
| UPR | unplanned release |
| USFWS | U.S. Fish and Wildlife Service |
| USGS | U.S. Geological Survey |
| UTL | upper tolerance limits |
| VOC | volatile organic compound |
| WCH | Washington Closure Hanford |
| WDFW | Washington Department of Fish and Wildlife |
| WIDS | Waste Information Data System |

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2

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# Lab Qualifiers

| | |
|---|---|
| B | INORGANICS and WETCHEM – The analyte was detected at a value less than the contract required detection limit (RDL), but greater than or equal to the IDL/MDL (as appropriate).<br><br>ORGANICS – The analyte was detected in both the associated QC blank and in the sample.<br><br>RADIONUCLIDES – The associated QC sample blank has a result >= 2X the MDA and, after corrections, result is >= MDA for this sample. |
| D | All – Analyte was reported to a secondary dilution factor, typically DF>1 (i.e., the primary preparation required dilution to either bring the analyte within the calibration range or to minimize interference). Required for organics/wetchem if the sample was diluted. |
| J | ORGANICS – Estimated value; (1) constituent detected at a level less than the RDL or PQL and greater than or equal to the MDL, (2) estimated concentration for tentatively identified compounds (TICs).<br><br>Note – For HEIS data generated before December 1, 2002, laboratories may have applied a "J" qualifier to non-organic results. When applied, application was based primarily on criteria comparable to statement (1) above. Before January, 1998, validation qualifiers (including "J") were recorded in the LAB_QUALIFIER field without identification as validation qualifiers. |
| N | ALL (except GC/MS based analysis) – Spike and/or spike duplicate sample recovery is outside control limits.<br><br>ORGANICS (GC/MS only) – Presumptive evidence of compound based on mass spectral library search. |
| U | ALL – Analyzed for but not detected above limiting criteria. Limiting criteria may be any of the following: valve reported <0; valve reported < counting error; valve reported < total analytical error; value_rptd <=contract MDL/IDL/MDL/PQL. Note – When another qualifier accompanies a "U" qualifier the result is always considered non-detected. The qualifier combinations "UJ" and "UL" indicate that the result was non-detected, but the detection limit (i.e., value reported in the VALUE_RPTD or MIN_DETECTABLE_ACTIVITY[rad analysis only] fields was estimated. |

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# 1 Introduction

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

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

This document presents the results of a CERCLA Remedial Investigation (RI) and Feasibility Study (FS) undertaken for 100-BC (Figure 1-1). The information contained in this RI/FS supports a Proposed Plan, which will go through a public review and provide the basis for a Record of Decision (ROD). The ROD for 100-BC will apply to the source OUs 100-BC-1 and 100-BC-2, and the 100-BC-5 Groundwater OU (Figure 1-2). Much of Chapter 1 is devoted to summarizing the assessment and remediation work, treatability tests, and other relevant studies. This historical information is presented to provide a comprehensive picture of current 100-K site conditions and establishes a foundation for the remainder of the RI/FS document.

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

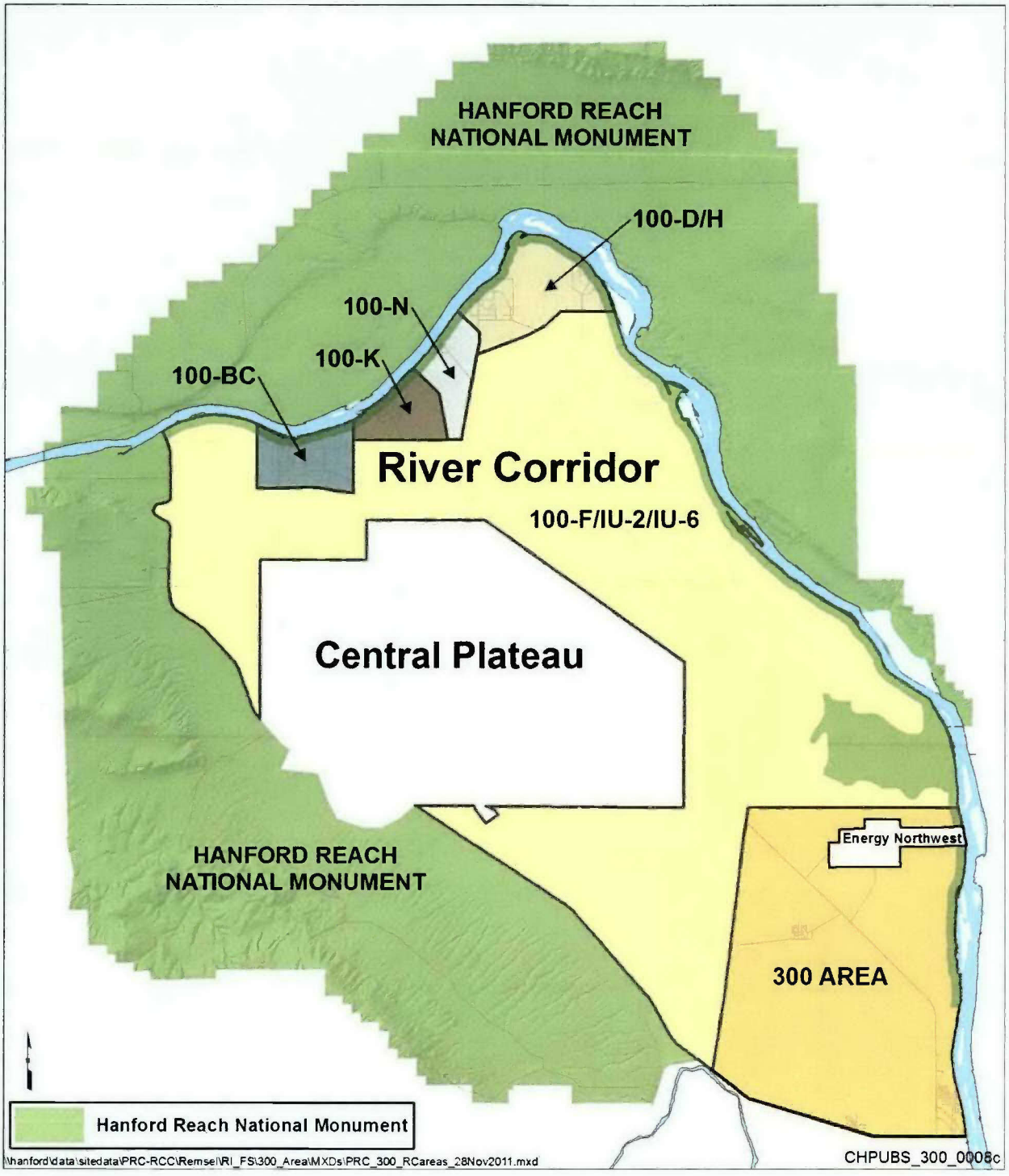


Figure 1-1. Hanford Site Map

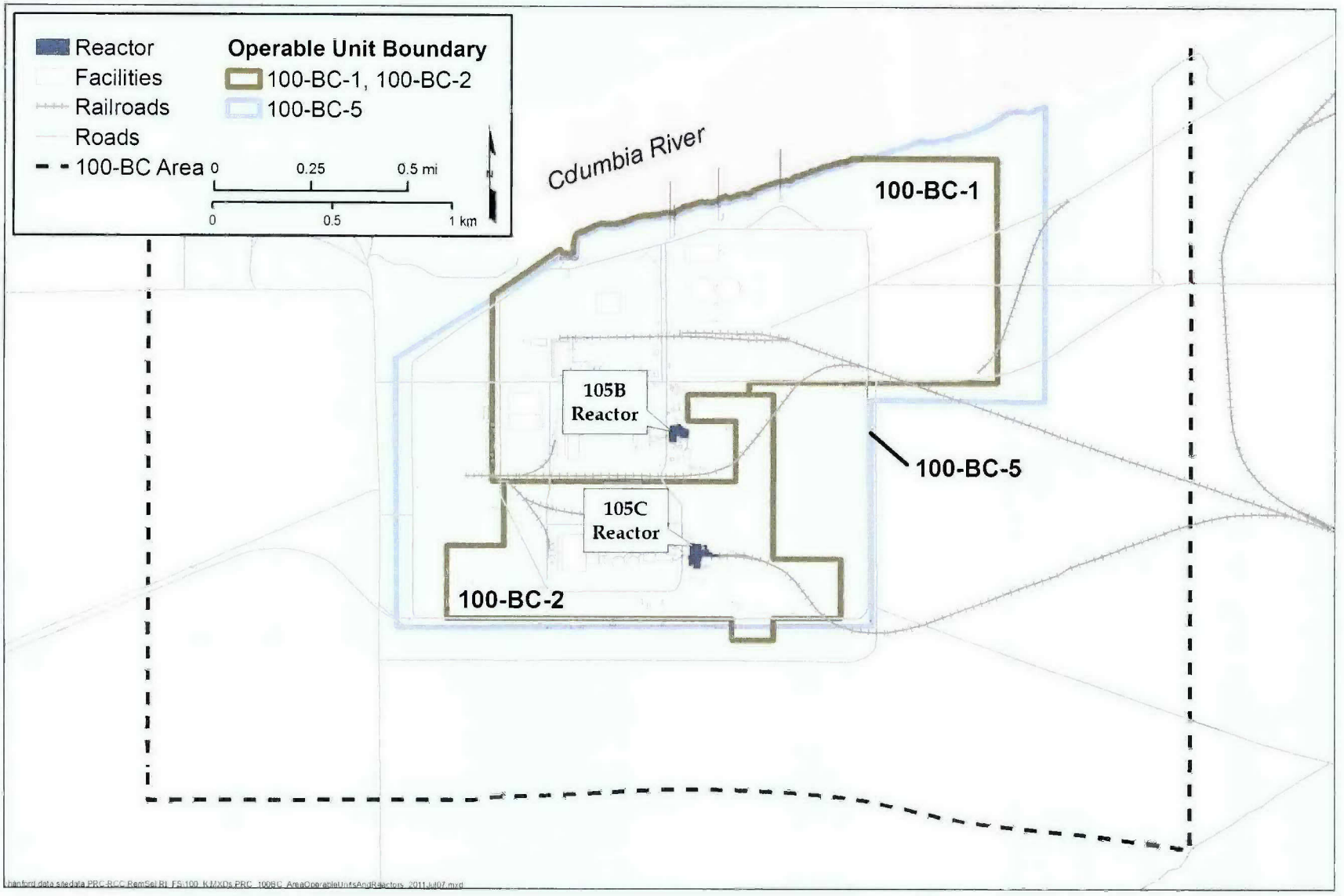


Figure 1-2. 100-BC Operable Units and Reactors

In 1991, the Tri-Parties determined there was a need to prioritize the CERCLA investigations and identify early actions to address waste sites and groundwater contamination. The *Hanford Past-Practice Strategy* (hereinafter called Past-Practice Strategy [DOE/RL-91-40]) provided the basis for prioritizing investigations and cleanup actions across the Hanford Site. This strategy emphasized the need to address waste sites and groundwater contamination that may pose a near-term impact to HHE. In addition, the strategy proposed a bias for action to clean up waste sites and existing contamination where the remedy was evident.

For 100-BC, the Past-Practice Strategy (DOE/RL-91-40) translated into limited field investigations (LFIs) being completed. Three LFIs were conducted, one for each of the OUs, between 1993 and 1994 (*Limited Field Investigation Report for the 100-BC-1 Operable Unit* [DOE/RL-93-06], *Limited Field Investigation Report for the 100-BC-2 Operable Unit* [DOE/RL-94-42], and *Limited Field Investigation Report for the 100-BC-5 Operable Unit* [hereinafter called the 100-BC-5 LFI (DOE/RL-93-37)]). The LFI results identified 21 waste sites and the process (cooling water) effluent pipelines in 100-BC-1 and 14 sites in 100-BC-2 for interim remedial actions. Radionuclides, metals, and organics were analyzed in the LFI samples.

The 100-BC-5 groundwater OU was not recommended for interim actions because the LFI (100-BC-5 LFI [DOE/RL-93-37]) concluded there was low risk related to the usage at the time and under the frequent-use and occasional-use exposure scenarios examined. Monitoring of key groundwater contaminants was recommended to continue until remedial actions associated with source OUs were completed.

The LFIs indicated that liquid waste disposal sites in the 100-BC-1 OU were primarily responsible for the continuing release of hexavalent chromium (Cr(VI)) above established limits to the groundwater. The results of these studies led to the selection of interim actions to remediate source contamination within the 100-BC-1 OU under the following interim action ROD:

- *Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-95/126), September 1995

The interim remedial action objectives (RAOs) for the cleanup of waste sites within the 100-BC-1 OU were focused on protecting human health from contaminants in the soil, and protection of groundwater and the Columbia River from adverse impacts. Since the first interim action ROD, the scope of the interim actions has been expanded to include additional waste sites in the 100-BC-1 OU as well as the100-BC-2 OU. This was accomplished under an amendment to the 1995 ROD as well as two additional RODs:

- *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)* (hereinafter called the 100 Area Remaining Sites ROD [EPA/ROD/R10-99/039]), July 1999

- *Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington* (hereinafter called the 100 Area Burial Grounds ROD [EPA/ROD/R10-00/121]), September 2000

Current River Corridor cleanup work is progressing under Interim Action RODs. An objective of waste cleanup is to remove sources of contamination and contaminated environmental media that are close to the Columbia River, and place in the Environmental Restoration Disposal Facility (ERDF) for final

disposal on the Central Plateau. Reducing the concentrations of contaminants entering the Columbia River and restoring the groundwater to beneficial use remains the key objective of groundwater remediation within 100-BC. Interim RAOs for the cleanup of waste sites with the 100-BC-1, 100-BC-2, 100-DR-1, and 100-DR-2 OUs focused on protecting human health from contaminants in the soil, controlling the sources of groundwater contamination to minimize the impacts to groundwater resources, and protecting the Columbia River from further adverse impacts.

DOE is the lead federal agency at Hanford, per CERCLA, *Superfund Implementation* (Executive Order 12580), and the TPA (Ecology et al., 1989a). DOE develops implementation strategies and conducts response actions in this lead federal agency role. With implementation of the Past-Practice Strategy (DOE/RL-91-40) and progress with the interim remedial actions, DOE prepared the *Hanford Site Cleanup Completion Framework* (hereinafter called Cleanup Completion Framework [DOE/RL-2009-10]) to describe the cleanup strategy (Table 1-1). One of the principal components of the framework is the River Corridor, which consists of approximately 570 $km^2$ (220 $mi^2$) of the Hanford Site along the Columbia River. It includes a contiguous area that extends from the 100 and the 300 Areas to the Central Plateau boundaries (Figure 1-1).

**Table 1-1. Overarching Goals for Hanford Site Cleanup**

| Goal | Description |
|---|---|
| 1 | Protect the Columbia River. |
| 2 | Restore groundwater to its beneficial use to protect human health, the environment, and the Columbia River. |
| 3 | Clean up River Corridor waste sites and facilities to protect groundwater and the Columbia River, shrink the active cleanup footprint to the Central Plateau, and support anticipated future land uses. |
| 4 | Clean up Central Plateau waste sites, tank farms, and facilities to protect groundwater and the Columbia River; minimize the footprint of areas requiring long-term waste management activities; and support anticipated future land uses. |
| 5 | Safely manage and transfer legacy materials scheduled for offsite disposition, including special nuclear material (including plutonium), spent nuclear fuel, transuranic waste, and immobilized high-level waste. |
| 6 | Consolidate waste treatment, storage, and disposal operations on the Central Plateau. |
| 7 | Develop and implement institutional controls and long-term stewardship activities that ensure protection of HHE after cleanup activities are completed. |

Source: *Hanford Site Cleanup Completion Framework* (DOE/RL-2009-10)
Note: Status as of May 2011
HHE = human health and the environment

For sites in the River Corridor, final remedial actions are expected to restore groundwater to drinking water standards and protect aquatic life in the Columbia River by achieving ambient water quality criteria (AWQC) at groundwater discharge points to the river. Unless technically impracticable, these objectives will be achieved within a reasonable period. If RAOs are not achievable in a reasonable period or are determined to be technically impracticable, programs will be implemented to prevent further migration of the plumes, prevent exposure to contaminated groundwater, and evaluate further risk reduction opportunities as new technologies become available. Cleanup actions will support reasonably anticipated future land uses consistent with the Hanford Reach National Monument (HRNM) and the "Record of

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

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

This RI/FS builds on this body of previous work, including the River Corridor Baseline Risk Assessment (RCBRA) (*River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*, hereinafter called RCBRA Volume I [DOE/RL-2007-21, Rev. 0]) and the Columbia River Component (CRC) (*Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment and Volume II: Baseline Human Health Risk Assessment*, hereinafter called CRC [DOE/RL-2010-117]), discussed in Chapters 6 and 7, to provide a comprehensive understanding of current site conditions as they have been affected by the extensive remediation effort to date, and to present and evaluate a set of alternatives for addressing the remaining environmental risks at 100-BC.

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

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

Per the CERCLA process this RI/FS for 100-BC was undertaken in accordance with *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* (hereinafter called the Integrated Work Plan [DOE/RL-2008-46], which contains the planning elements that are common to all the Hanford Site 100 Area source and groundwater OUs, and *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 3: 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units* (hereinafter called the 100-BC Work Plan [DOE/RL-2008-46-ADD3]), which is specific to 100-BC. These work plans were developed to outline the requirements for an RI/FS which was intended to support reaching a final decision for the OUs within the 100 Area NPL (40 CFR 300, Appendix B) Site.

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

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

- Chapter 10—Detailed Analysis of Alternatives
- Chapter 11—References

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

- Appendix A—Site Maps
- Appendix B—Annotated Bibliography
- Appendix C—Supporting Information for Wells and Boreholes
- Appendix D—Analytical Data
- Appendix E—Waste Site Table and Reclassification Analyte Table
- Appendix F—Fate and Transport Modeling Documentation
- Appendix G—Human Health Risk Assessment Tables and Calculation Brief
- Appendix H—Ecological Risk Assessment Calculation Brief
- Appendix I—Technology Screening- Not Retained Technologies
- Appendix J—Alternative Development Supporting Documentation
- Appendix K— Cost Estimates
- Appendix L— Nonoperational Area Evaluation
- Appendix M— Riparian and Near Shore Evaluation

## 1.1 Purpose and Scope of Report

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

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

This RI/FS has the following objectives:

- Provide information concerning the physical and environmental setting, and site characterization.
- Draw conclusions concerning the nature and extent of contamination present at the site, the potential for migration of contamination from the site, and the potential for adverse human health and environmental effects if no action is taken at the site and exposure occurs. This is achieved by evaluating historical and operational information about the site, contaminants of potential

concern (COPCs), potential migration pathways, potential receptors, exposure (dose), and contaminant toxicity.

- Develop, screen, and evaluate an appropriate range of alternatives that ensure the protect ion of HHE.
- Present a detailed analysis of the alternatives to allow decision makers to select a site remedy.

EPA is the lead regulatory agency for 100-BC and, as such, has the primary responsibility for overseeing all remedial action activities to ensure they meet applicable requirements. DOE is responsible for performing all 100-BC remedial actions. DOE is issuing this RI/FS for 100-BC as a component of CERCLA and the "National Oil and Hazardous Substances Pollution Contingency Plan" (hereinafter called National Contingency Plan or NCP [40 CFR 300]). Under DOE's CERCLA/NEPA Policy, established in 1994, DOE relies on the CERCLA process for review of actions to be taken under CERCLA, i.e., no separate NEPA document or NEPA process is ordinarily required. In conducting the CERCLA process, DOE addresses NEPA values (such as analysis of cumulative, off-site, ecological, and socioeconomic impacts) to the extent practicable and includes a brief discussion of impacts in CERCLA documents or other site environmental documents as appropriate.

The U.S. Department of Energy, Richland Operations Office (DOE-RL) will issue a Proposed Plan detailing the proposed final remedies for comment by the Tribal Nations and the public. EPA and DOE-RL will issue a ROD for the 100-K OUs, which will include responses to the comments received and the 100-K final remedies. After the ROD is issued, a remedial design/remedial action work plan (RD/RAWP) will be developed, approved, and implemented.

The conceptual site model (CSM) is used in this RI/FS to present a framework for evaluating the data from 100-BC. The American Society for Testing and Materials *Standard Guide for Developing Conceptual Site Models for Contaminated Sites* (ASTM E1689-95) defines the CSM as "a written or pictorial of an environmental system and the biological, physical, and chemical processes that determine the transport of contaminants from sources through environmental media to environmental receptors within the system." For the 100-BC Work Plan (DOE/RL-2008-46-ADD3), the CSM was used as a base to integrate relevant site information, determine whether information including data were missing (data gaps), and identify additional information to be collected. The data and information needs identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3), and the data and information collected during the RI are presented in Chapter 2. In Chapters 2 through 7, the CSM is refined by the additional information and then used to identify and evaluate potential risk to HHE.

Figure 1-3 presents the basic activities associated with a CSM. For an exposure pathway to be complete, all the components must be present:

- "Source" is the location from which a contaminant enters the physical setting. The primary sources of contaminants were releases related to reactor operations and are described in this chapter. These primary sources may produce a secondary source. Secondary sources are created when the contaminants are mixed in the vadose zone and then the groundwater. Reactor operations at 100-BC have ceased; therefore, this document focuses on secondary contaminant sources in the vadose zone and groundwater plus potential risk to HHE. These secondary sources are described in Chapter 4.
- "Release Mechanisms" are the actions necessary to release contaminants to the environment, such as resuspension of contaminated particulate matter, surface runoff, leaching to the vadose zone, plant intrusion, animal burrowing, erosion, or groundwater migration. Release mechanisms and relevant 100-BC physical features are introduced in Chapter 3 and discussed in Chapter 5.

- "Transport" is movement of a radiological, chemical, or physical agent in the environment from a source to environmental media where human or ecological exposure could occur. Contaminants introduced into the environment can be transported between environmental media such as air, vadose zone, groundwater, and surface water as a result of interconnecting release mechanisms. Transport is discussed in Chapter 5.

- "Exposure" is the process by which a contaminant comes into direct contact with the body, tissues, or exchange boundaries of an organism, human, plant or animal (for example, ingestion, inhalation, dermal absorption, or root uptake). Potential exposure scenarios are discussed in Chapters 6 and 7.

- "Receptors" include humans and other organisms (e.g., plants, animals, and other species) that may come into contact with the contaminants. Chapters 6 and 7 evaluate exposure to receptors.

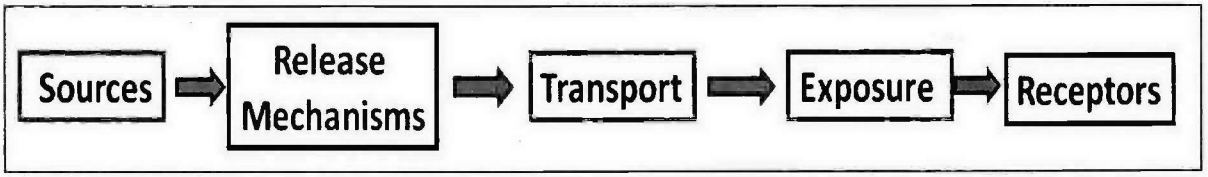


**Figure 1-3. Conceptual Site Model**

In Chapters 8 through 10, the refined CSM supports the identification of relevant remedial technologies, the development of remedial alternatives, and the evaluation of the effectiveness of remedial alternative in interrupting the exposure pathway of contaminants to human and environmental receptors.

## 1.2 Site Background

The Hanford Site encompasses approximately 1,517 $km^2$ (586 $mi^2$) in south-central Washington State, within Benton, Franklin, and Grant Counties. The site stretches approximately 50 km (30 mi) north to south and about 40 km (24 mi) east to west, immediately north-northwest of the confluence of the Yakima and Columbia Rivers; the Cities of Kennewick, Pasco, and Richland (the Tri-Cities); and the City of West Richland. The Columbia River flows 80 km (50 mi) through the northern part of the Hanford Site and, turning south, forms part of the Site's eastern boundary. The Yakima River runs near the southern boundary of the Hanford Site, joining the Columbia River at the City of Richland. Two small east-west trending ridges, Gable Butte and Gable Mountain, are located in the central portion of the site, just south and southwest of 100-BC. Lands adjoining the site to the west, north, and east are principally range and agricultural. State Routes 240 and 24 skirt the southwestern and northern portions of the site, respectively.

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

The River Corridor includes approximately 8,300 acres of historical farmsteads of which approximately 5,000 acres are historical orchard lands. Within the farmstead areas and specifically for the orchard lands, lead

arsenate was applied as a pesticide. The farming life at Hanford came to an abrupt halt in 1943 when the U.S. government took possession of the land to produce weapons-grade plutonium as a part of the Manhattan Project. Lead arsenate use in Washington State effectively terminated in 1948, when dichlorodiphenyltrichloroethane (DDT) became widely available to the public (*Re-establishing Apple Orchards in the Chelan-Manson Area* [Benson et al., 1969]).

The persistence of residuals from lead arsenate that was applied as a pesticide before Hanford operations began is a concern that merits an assessment of potential impacts to human health and the environment. To address this concern, the Tri-Parties have established the 100-OL-1 orchard lands OU (TPA [Ecology et al., 1989a] change notice C-12-01). An RI of the 100-OL-1 OU will be conducted to determine if actions are needed to mitigate potential environmental or human health impacts. If results from the RI indicate a need for action, an FS will be conducted to identify and evaluate a range of remedial alternatives. A work plan to identify the objectives and scope of the RI for the 100-OL-1 OU will be developed and submitted for regulator review by April 30, 2013 in accordance with TPA (Ecology et al., 1989a) Milestone M-015-95.

### 1.2.1 Site Description

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

The 100-BC area is located in the northern portion of the Hanford Site adjacent to the Columbia River. It is the western-most reactor area and is adjacent to the 100-K Area to the east. It covers more than 11.54 $km^2$ (4.45 $mi^2$) of land along the southern shore of the Columbia River. The 100-BC boundary at the river is the ordinary low water mark, which is characterized by the presence of the "green line" of algae delineating the permanently inundated portion of the river channel. The section of the Columbia River along 100-BC defines a portion of the HRNM, which is an important ecological, cultural, historical, and recreational feature. The HRNM extends from the base of Priest Rapids Dam to the slack water of Lake Wallula near the southern boundary of the 300 Area.

### 1.2.2 Hanford Site and Operational History

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

With the exception of the waste sites in orchard areas, the historical parcels of land planted with fruit trees are not within the scope of this RI/FS. Throughout the River Corridor, there is approximately 1,820 ha (4,500 ac) of cultivated orchard lands. Within the 100-BC area, there are two orchard parcels totaling 31 ha (76 ac). Pre-Hanford orchard areas will be addressed separately and identified as appropriate through the TPA-MP-14 process with WIDS operable unit and waste site designations. Historical

potentially hazardous substance releases within the orchard lands will be characterized and a determination made whether a separate process is necessary.

#### 1.2.2.1 Hanford Site History Overview

The Hanford Site was selected for plutonium production in 1942 as part of the Manhattan Project, primarily because of the availability of water from the Columbia River and access to power from the Bonneville and Grand Coulee dams. The remote location and weather conditions of the area, which allowed for nearly year-round construction, also contributed to the site selection. Land acquisition for the Hanford Site took place in February 1943 and represented one of the largest land procurements (approximately 160,000 ha [400,000 ac]) carried out during World War II. Site construction began in March 1943, and was largely completed with the first three reactors (B, D, and F) coming online by April 1945.

Between 1947 and 1955, the Atomic Energy Commission (AEC) added five new reactors (C, H, DR, KE, and KW) at the Hanford Site, while at the same time boosting the output of the three Manhattan Project reactors (B, D, and F). Incremental improvements in the basic components of the World War II reactors and a construction program to build reactors that incorporated these changes accounted for doubling the plutonium output at the Hanford Site in 1952 and 1953.

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

By the 1960s, however, the nation's plutonium stockpile was much larger than deemed necessary, and plutonium production at the Hanford Site gradually decreased. In 1964, the AEC shut down the H, DR, and F Reactors, followed by D Reactor in 1967 and the B Reactor in 1968. All the remaining reactors (C, KE, and KW) at the Hanford Site were shut down from 1969 through1971 (with the exception of N Reactor), along with the fuel manufacturing and separation plants. N Reactor was shut down in 1986 following the Chernobyl explosion in the former Soviet Union, and was transitioned to cold standby in 1989 with the end of the Cold War, signaling the close of the Hanford Site's production mission and the start of its cleanup mission. During the Manhattan Project and Cold War, more than 67,000 kg (147,000 lb) of plutonium were produced at the Hanford Site, 13,000 kg (29,000 lb) of which were fuel grade plutonium. The Hanford Site produced the entire nation's nuclear arsenal plutonium between 1945 and 1963, and accounted for more than 65 percent of all plutonium in the history of U.S. plutonium production.

The environmental impacts associated with the ultimate disposition of the reactors were evaluated in *Addendum (Final Environmental Impact Statement): Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE/EIS-0119F). The Environmental Impact Statement (EIS) ROD ("Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington," hereinafter called the NEPA ROD [58 FR 48509]), documented the selection of interim safe storage (ISS) for the reactors. ISS is the provision of an upgraded, weather-resistant shell to isolate the reactor core until remedial activities are conducted. Subsequent to the issuance of this ROD, DOE conducted a Supplemental Analysis that evaluated the feasibility of dismantlement. ISS activities have been completed for both B and C Reactors.

### 1.2.2.2 100-BC Operational History

The B and C Reactors were the focus of production activities at 100-BC. The two reactors were supported by multiple facilities associated with services for water treatment, air filtration, nuclear fuel handling, effluent disposal, and laboratories, with various other administrative buildings (*100-B Area Technical Baseline Report* [WHC-SD-EN-TI-220]).

The B Reactor construction, which started in March 1943, was completed in 13 months. After comprehensive equipment testing, the reactor was first activated on September 26, 1944. Figure 1-4 shows the B Reactor during its production period in 1944. This reactor was the first of three original Hanford Site reactors built during World War II with a primary mission of plutonium production for the development of an atomic bomb. The design, operation, and waste management process at the B Reactor was the first of its kind in practice. The original Hanford Site reactors represented the basis for subsequent reactor design and conduct of operations, especially with regard to handling radioactive materials, and waste management.

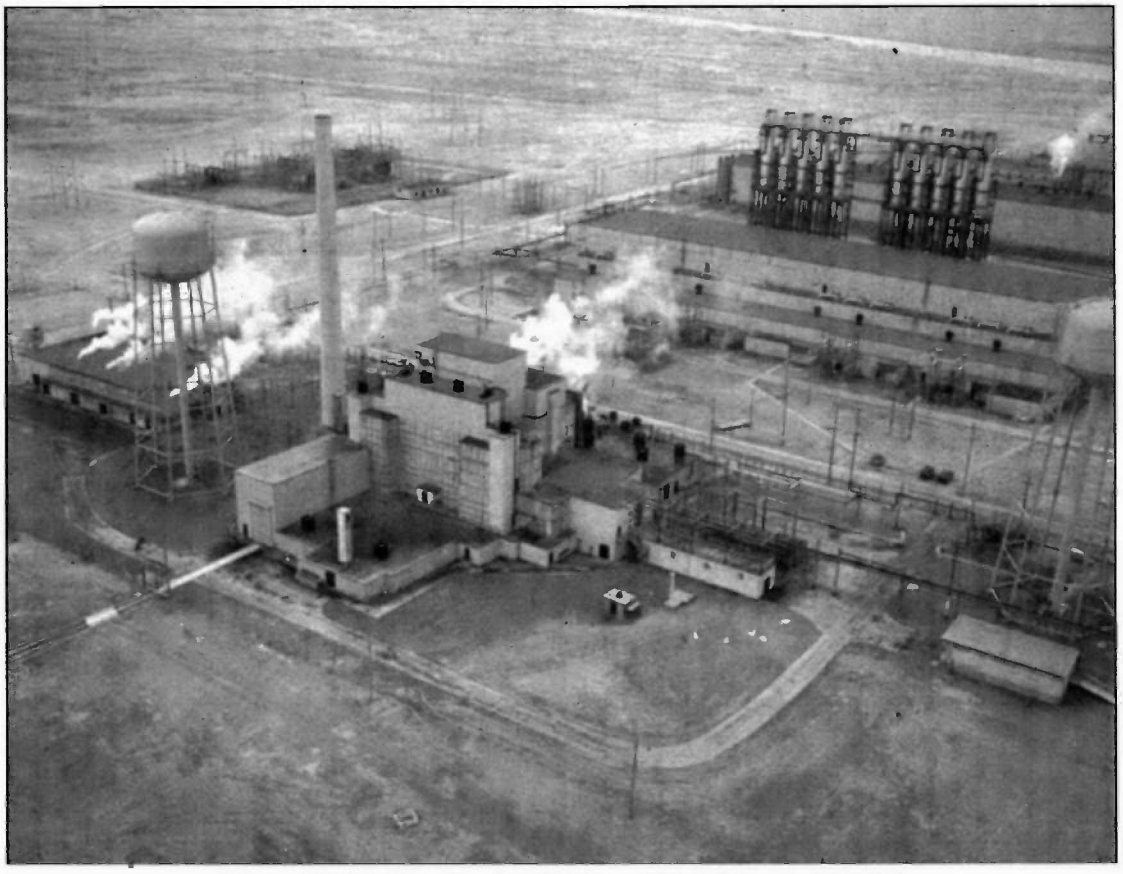

**Figure 1-4. Northeastern Aerial View of the B Reactor in 1944**

After its war-time production, the B Reactor was thought to be nearing the end of its effective operational life because of the growth and distortion of its graphite core. From March 1946 to June 1948, the reactor was taken offline to preserve its capability, and held in a "standby" status. Subsequent improvements in processes and technologies allowed the restart of the reactor in July 1948. The B Reactor was permanently deactivated in 1968. The B Reactor is currently slated for historic preservation, with conversion of the facility into a public museum (Figure 1-5).

**Figure 1-5. The B Reactor in 2005**

The C Reactor was constructed during 1951 and 1952, with initial startup on November 18, 1952. In addition to its plutonium production mission, the C Reactor was used for reactor physics and operations testing and as a pilot-scale version for the next generation of reactors at 100-K (*Summary of 100 B/C Reactor Operations and Resultant Wastes, Hanford Site* [WHC-SD-EN-RPT-004]). The C Reactor was deactivated in April 1969, and has subsequently been placed into ISS until its final disposition.

The ISS process is a series of actions taken to protect deactivated reactors from environmental degradation and to prevent the spread of contamination by providing an upgraded, weather-resistant shell to isolate the reactor core until remedial activities are conducted. These actions also minimize the facility footprint by removing peripheral reactor building structures and equipment and disposing of the debris. The ISS process was initiated in 1996 and completed in 1998 (*Surplus Reactor Final Disposition Engineering Evaluation* [DOE/RL-2005-45]). Figure 1-6 shows the C Reactor from 1953, Figure 1-7 shows the reactor during ISS in 1998, and Figure 1-8 shows the reactor after ISS completion in 2007.

### *1.2.2.3 100-BC Process History*

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

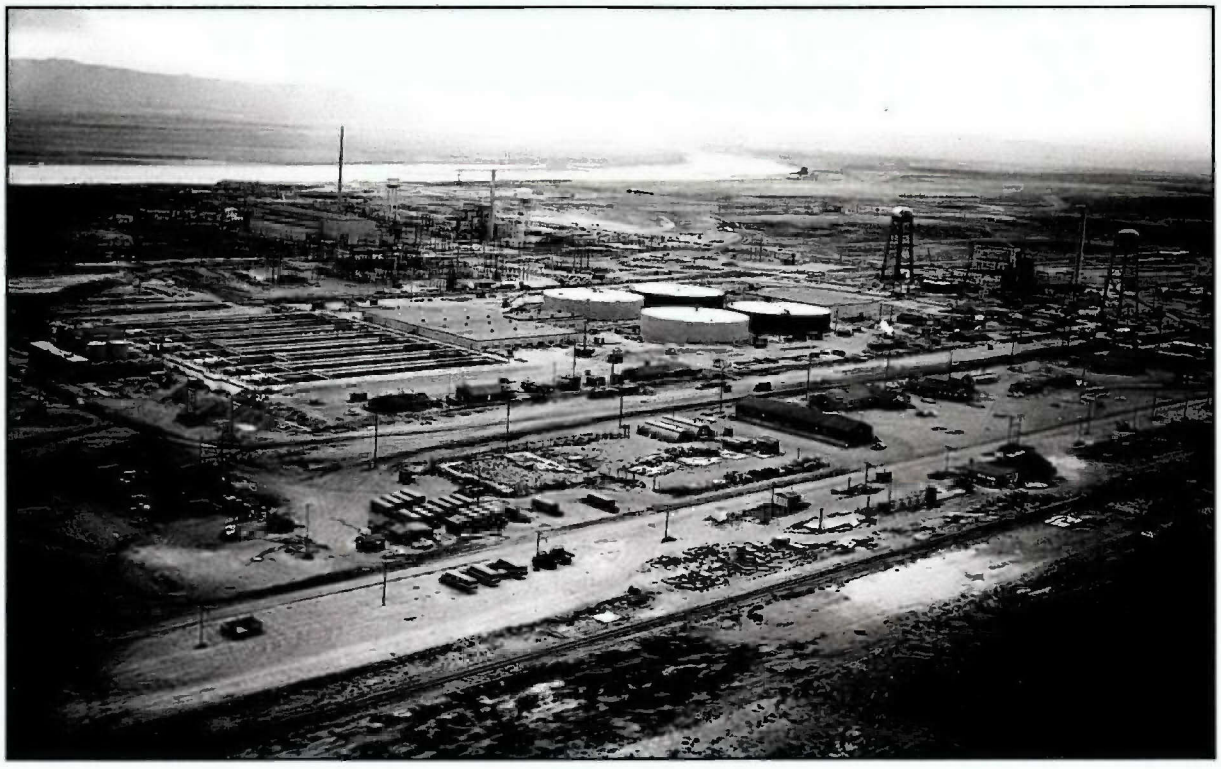

Figure 1-6. Northeastern Aerial View of the C Reactor (at right) in 1953

Figure 1-7. The C Reactor during ISS Implementation in 1998

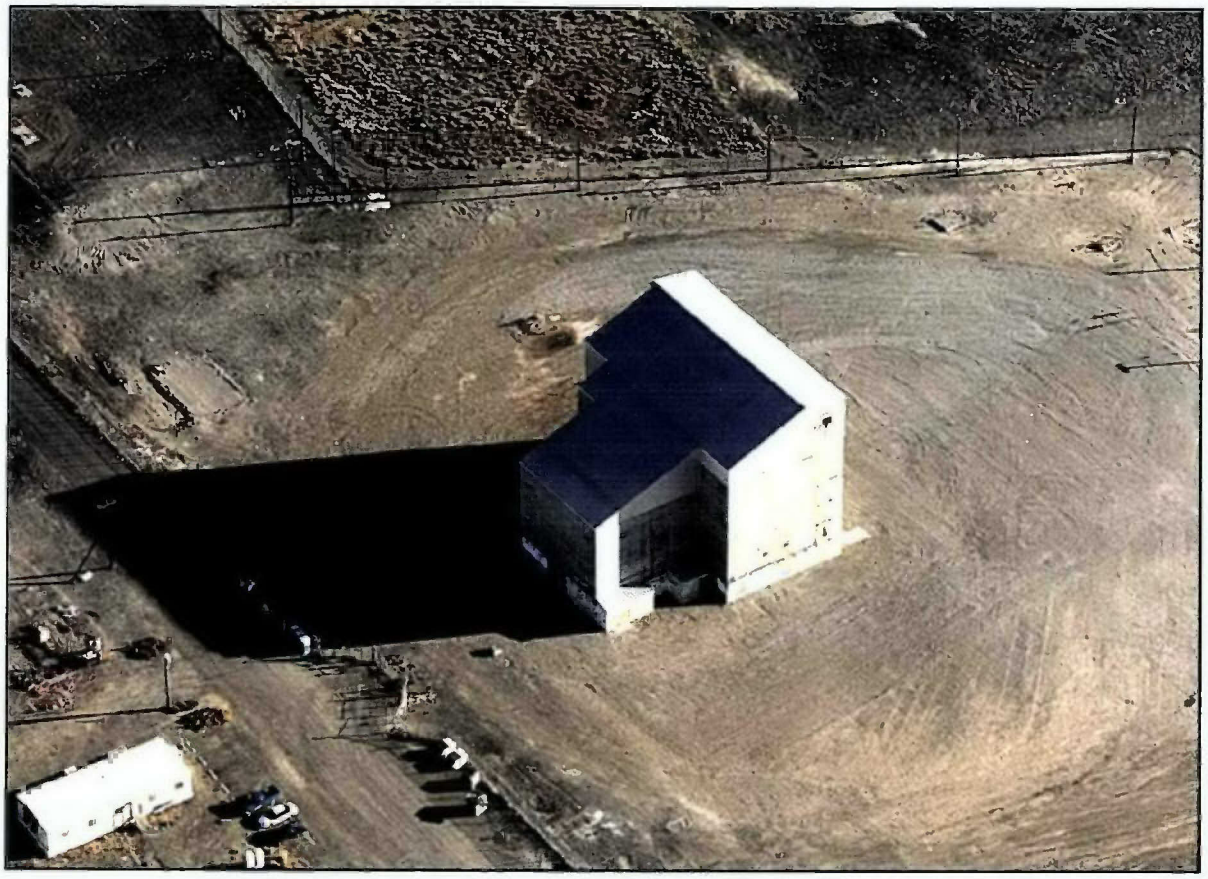

**Figure 1-8. The C Reactor after ISS (2007)**

Waste streams from the reactor production process include the following:

- Process inputs:
  - Raw materials to be processed through the reactor
  - Process chemicals for water conditioning and inhibiting corrosion (for example, sodium dichromate) because water management was crucial to the operation of the reactors and represented a major input subsystem
  - Materials used for reactor maintenance, such as acids, solvents, and solid metal components
- Process outputs:
  - Product and waste isotopes, such as plutonium-239 and strontium-90, respectively
  - Radioactively and chemically contaminated materials (solid and liquid wastes)
  - Radioactively and chemically contaminated cooling water

Reactors generated a variety of radionuclides (*Radiological Characterization of the Retired 100 Areas* [UNI-946]; *100-K Area Technical Baseline Report* [WHC-SD-EN-TI-239]). Principal radionuclides at specific areas in the reactor were as follows:

- Thermal shields—cobalt-60 and nickel-63
- Reactor graphite cores—tritium and carbon-14

- Process tubes (and the film inside the process tubes)—manganese-54, cobalt-60, zinc-65, europium-154, cesium-137, and strontium-90

Liquid wastes from reactor operations and associated facilities were released to the vadose zone and the Columbia River. Solid wastes were disposed in burial grounds associated with the facilities. Sites for wastes intentionally or unintentionally released to or buried within 100-K included trenches, cribs, French drains, retention basins, pipelines, burial grounds, and unplanned spills and releases, each of which is described in the following text. More detailed discussions on the nature and extent of the contaminants associated with these processes are provided in Chapter 4.

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

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

***French Drains.*** Subsurface liquid waste disposal sites were designed to percolate wastewater into the ground without exposure to the atmosphere (e.g., 116-B-4). These sites were usually constructed with a 1 m (3 ft) diameter, open or gravel-filled pipe placed vertically to less than 5 m (16 ft) below ground surface (bgs). French drains typically received low volumes of low-level radioactive waste for disposal.

***Solid Waste Burial Grounds.*** These areas were used for near-surface disposal of solid waste containing radioactive and nonradioactive hazardous substances, construction debris (such as steel, concrete, and wood) from reactor modifications, contaminated construction equipment, contaminated vadose zone material, irradiated reactor parts, and low-level radioactive combustible material (*Estimates of Solid Waste Buried in 100 Area Burial Grounds* [WHC-EP-0087]; *Historical Events—Reactors and Fuels Fabrication* [RL-REA-2247]), for example, 118-B-1.

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

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

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

The primary activities associated with environmental contamination at 100-BC were the production and use of treated Columbia River water to cool the reactors during operations. Over the operational lifetime of the B and C Reactors, approximately 5 trillion L (about 1.3 trillion gal) of cooling water were produced and passed through these reactors. As cooling water was produced and used, intentional effluent disposal

and unintentional discharges of process chemicals introduced contaminants directly to the soil and into the Columbia River.

Once the plutonium production and other missions at the reactors ended, the reactors were deactivated. The infrastructure networks, consisting of support facilities and buildings, were then placed in standby mode or decommissioned. These decommissioning activities occurred in phases according to their age and capabilities of the facilities and as resources allowed (*Resource Book–Decommissioning of Contaminated Facilities at Hanford* [PNL-MA-588]; *Summary of the Hanford Site Decontamination, Decommissioning, and Cleanup FY 1974 Through FY 1990* [WHC-EP-0478]). Following a Sitewide safety and housekeeping inspection in 1973, a program was developed to dispose and decommission surplus facilities, including those facilities located in 100-BC. This effort progressed as resources allowed from 1974 through 1990, with building demolition, surplus equipment salvage or redeployment, and active operations maintenance at a minimal level.

The environmental impacts associated with the ultimate disposition of the reactors were evaluated in the *Addendum (Final Environmental Impact Statement): Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* (DOE/EIS-0119F). The Environmental Impact Statement (EIS) ROD ("*Record of Decision: Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington*", hereinafter called the NEPA Reactor Decommissioning ROD [58 FR 48509]) documented the selection of ISS for the reactors. As part of "Record of Decision: Hanford Comprehensive Land-Use Plan Environmental Impact Statement (HCP EIS)" (64 FR 61615), DOE declared the 105-B Facility would be preserved as a museum.

#### 1.2.2.4 Reactor Mechanics and Layout

The B and C Reactors were graphite-moderated, water-cooled reactors that were used to produce weapons-grade plutonium. The typical reactor building was designated as Building 105, and was approximately 37 × 46 × 37 m (120 × 150 × 120 ft) high. It contained a reactor block, control rod and safety rod facilities, a reactor control room, a spent fuel discharge pool, fuel storage basin (FSB) and associated fuel handling equipment, fans and ducts for the ventilation and recirculating gas systems, and supporting offices, shops, and laboratories. General specifications for 105-B and 105-C are provided in *Radiological Characterization of the Retired 100 Areas* (UNI-946).

The main components of a reactor included:

- The reactor moderator stack; an assembly of graphite blocks, some of which are cored to provide channels for the process tubes, control and safety rods, and other equipment
- Aluminum process tubes that held the aluminum-clad uranium metal fuel elements and provided channels for cooling water
- Control and safety rods, monitoring equipment, and experimental test holes
- Cast iron thermal and laminated steel and Masonite® biological shields
- A welded steel plate box that enclosed the biological shield and served to confine the gas atmosphere within the reactor

® Masonite is a registered trademark of the Masonite Corporation, Tampa, Florida.

### 1.2.2.5 Cooling Water

A continuous supply of high-quality cooling water was essential to reactor operations to prevent reactor core damage from heat generated by the fission reactions. Many of the facilities in 100-BC were part of this cooling water system. At a daily use rate of 190 to 380 million L (50 to 100 million gal) of cooling water per reactor, this system generated the largest waste volume in the area (*Remedial Investigation/Feasibility Study Work Plan for the 100-BC-1 Operable Unit, Hanford Site, Richland, Washington*, hereinafter called 100-BC-1 Work Plan [DOE/RL-90-07]; *Remedial Investigation/Feasibility Study Work Plan for the 100-BC-2 Operable Unit, Hanford Site, Richland, Washington*, hereinafter called 100-BC-2 Work Plan [DOE/RL-91-07]). In general, cooling water obtained from the Columbia River was circulated in a single pass through the reactor, giving these reactors the name "single pass" reactors. The water was circulated through fuel process tubes, cooling tubes embedded in the thermal shield and reactor horizontal control rods. The cooling water exiting the reactor contained radioactive materials from the reactor and chemical contaminants added to treat the raw water before use, such as sodium dichromate. After exiting the reactor, the cooling water passed through a retention basin system, where short-lived radionuclides decayed and the water thermally cooled. The water was subsequently discharged to the river, with water directed to overflow trenches starting in 1946 until 1968. Figure 1-9 presents a simplified description of the cooling water flow from the Columbia River, through the reactor, and back to the river.

***Water Treatment and System Infrastructure.*** The cooling water systems for both the B Reactor and the C Reactor were very similar. The 181-B River Pump House pumped water used for the B Reactor directly from the Columbia River either to the 183-B Water Treatment Facility or to the 182-B Reservoir. Water from the holding reservoir was normally used to supply the 184-B Powerhouse and the export water system, discussed in detail in Section 3.7. The reservoir water could also be pumped to the 183-B Water Treatment Facility and, in cases of reactor cooling emergencies, directly to the B Reactor. For the C Reactor, water was pumped directly from the Columbia River by the 181-B River Pump House, which served both reactors (*Hazards Summary Report: Volume 3 – Description of the 100-B, 100-C, 100-D, 100-DR, 100-F and 100-H Production Reactor Plants* [hereinafter called Hazards Summary Report (HW-74094 VOL 3)]), to the 183-C Water Treatment Facility.

At the 183-B (or 183-C) Water Treatment Facility, the water was treated to remove impurities by conventional physical and chemical treatment. Water was treated with chemical additives including:

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

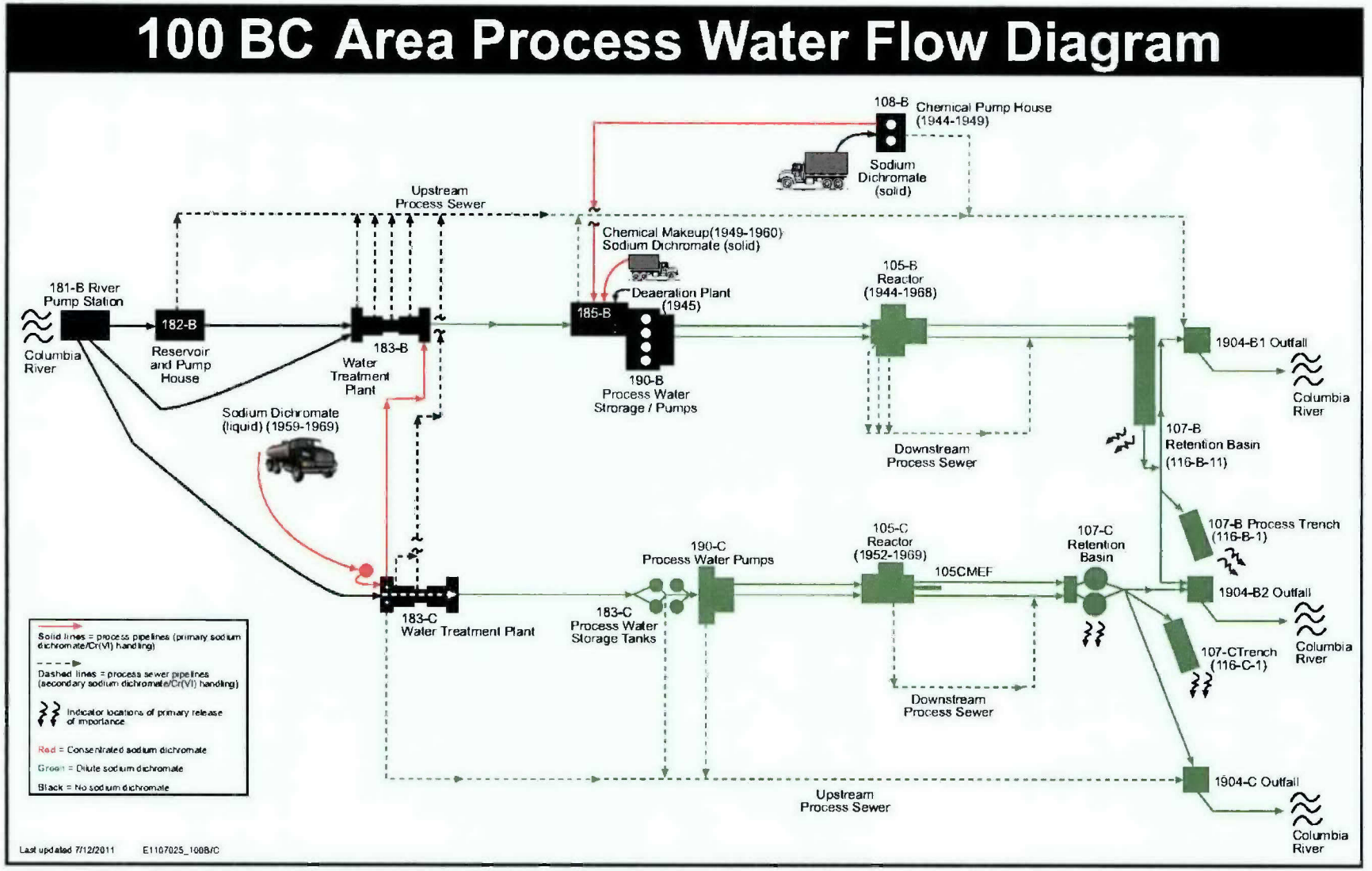


Figure 1-9. Cooling Water Process Flow Diagram

Additional chemicals, including sodium dichromate, were also used in other parts of the water treatment process. The approximate annual consumption for 1945 for some of the water treatment chemicals in 100-BC is shown in Table 1-2 (*Summary of 100 B/C Reactor Operations and Resultant Wastes, Hanford Site* [WHC-SD-EN-RPT-004]).

**Table 1-2. Chemicals Used in 100-BC Water Treatment, 1945**

| Compound | Amount used | |
|---|---|---|
| Chlorine | 288,000,000 lb | 130,600,000 kg |
| Ferric sulfate | 3,600,000 lb | 1,600,000 kg |
| Sodium silicate | 3,600,000 lb | 1,600,000 kg |
| Lime | 960,000 lb | 435,000 kg |
| Sodium dichromate | 300,000 lb | 136,000 kg |

As production increased, however, the amount of the various chemicals was also adjusted. Water treatment changes in the early 1950s altered the chemical composition of the cooling water. This included an increase in the use of alum and the reduction of the use of lime (*Summary of 100 B/C Reactor Operations and Resultant Wastes, Hanford Site* [WHC-SD-EN-RPT-004]).

The alum was produced in the upper floor of the 183-B (or 183-C) Treatment Building by mixing bauxite with sulfuric acid. The bauxite was stored in bunkers on the third floor and the concentrated sulfuric acid was stored in steel tanks outside of 183-B (or 183-C) (Hazards Summary Report [HW-74094 VOL 3]; 100-BC-1 Work Plan [DOE/RL-90-07]; 100-BC-2 Work Plan [DOE/RL-91-07]). The additives were introduced as the water passed down a flume into a mixing chamber. From there, the water was transferred to a basin equipped with paddle wheel flocculators. The specifications for the different additives and filtration are discussed in *Process Specifications Reactor Cooling Water Treatment* (HW-28505).

After passing through the flocculators, the water passed to one of eight open-air settling basins, also located within the 183-B (or 183-C) Facility, where the heavier particulates were allowed to settle out. After the particulates settled out of the water, an organic polyelectrolyte was added to the water and the water was filtered through gravel, sand, and crushed anthracite coal. Those filters associated with the B Reactor were routinely backwashed and wastewater discharged to the process sewer that led to the Columbia River via the 1904-B1 Outfall Structure (100-BC-1 Work Plan [DOE/RL-90-07]). The filters associated with the C Reactor were backwashed periodically and the resulting wastewater was presumably discharged (but this was not documented) to the process sewer that led to the Columbia River via the 1904-C Outfall (100-BC-2 Work Plan [DOE/RL-91-07]).

Following filtration, the B Reactor water was piped to two 19 million L (5 million gal) capacity clearwells and then to large-capacity storage tanks (four tanks at 6.65 million L [1.75 million gal] each) located in the 190-B Building west of the 105-B Reactor Building. Sodium dichromate was added continuously at the inlet of these tanks so that the cooling water concentration was maintained at 2 mg/L ± 0.2 mg/L, to inhibit corrosion (*Process Specifications Reactor Cooling Water Treatment* [HW-28505]; *Process Standards – Water Plant* [HW-27155]). Water was also pumped from the clearwells to two elevated emergency storage tanks (1.14 million L [300,000 gal] each) adjacent to the B Reactor.

At the C Reactor, water was pumped to two 11 million L (3 million gal) clearwells in the 183-C Building for temporary storage and then into storage tanks (four tanks with 20 million L [5.25 million gal] capacity each) located west of the 190-C Building. Water was also pumped into two elevated emergency storage tanks (1 million L [300,000 gal] each) located north and south of the C Reactor. The cooling water in the clearwells west of the 190-C Building was maintained at approximately 2 mg/L sodium dichromate, by adding sodium dichromate at the inlet of these tanks in order to inhibit corrosion (*Process Specifications Reactor Cooling Water Treatment* [HW-28505], 100-BC-2 Work Plan [DOE/RL-91-07]). The water stored in the respective clearwells for the B and C Water Treatment Trains was then passed to a high-pressure pumping station located in the 190-B (or 190-C) Building, and delivered to a valve pit in the 105-B Reactor (or 105-C Reactor) Building, and then to the respective reactor.

Conversion of the fuel element production lines to make mostly the internally and externally cooled (I&E) (annular) fuel elements began in 1957 (*Equipment Design Scope Conversion of 313 to I & E Production* [HW-47887]). In-reactor production tests were conducted from 1955 through 1956, and production of I&E (annular) fuel began in 1956. The production lines were then committed to production of the I&E (annular) fuel elements in 1957 (*Equipment Design Scope Conversion of 313 to I & E Production* [HW-47887]). This modified process was the same for each of the single pass reactors, which includes the B Reactor and the C Reactor. The modified design of the fuel elements permitted cooling water to flow through the center of the element as well as around the outside. Cooling water also flowed through cooling pipes located in the thermal shield, and the horizontal control rods and experimental test holes that penetrated the reactor core. The cooling water streams from all flow pathways were recombined before leaving the reactor. Another significant waste stream that was combined with the cooling water effluent was the diatomaceous earth slurry used regularly to remove scale deposits from heat transfer surfaces. This slurry was a major source of solids in the cooling water.

The B Reactor started up in 1944 with a cooling water flow rate of about 40,000 gal/min, which was maintained until at least 1953. By shutdown in 1968, the flow rate had been increased to about 90,000 gal/min to support the progressive increases in plutonium production rates. The C Reactor started up in 1952 with a cooling water flow rate of about 60,000 gal/min and by shutdown in 1969 had a cooling water flow rate capacity of about 100,000 gal/min (*Hanford Works Monthly Report December, 1947* [HW-8438-DEL]; *Irradiation Processing Department Monthly Report September 1961* [HW-71230]; and *Monthly Record Report Irradiation Processing Department December, 1956* [HW-47615-DEL]). The reactor cooling water flow rates increased with increasing production rates over the period from 1944 to 1969. The average cooling water flow rate for each reactor was reported in monthly reports.

While the water was in the reactor, it absorbed thermal energy from the nuclear process and became contaminated with radioactive isotopes (*100-B Area Technical Baseline Report* [WHC-SD-EN-TI-220]; 100-BC-2 Work Plan [DOE/RL-91-07]). Several sources of radioactive contamination were as follows:

- The high neutron flux in the reactor core activated elements in the cooling water and created numerous short-lived radionuclides. These short-lived radionuclides are no longer of interest in the environment. Those species with half-lives greater than 3 years that may be of interest in the current environment include tritium, carbon-14, cobalt-60, nickel-63, strontium-90, cesium-137, europium-152, europium-154, europium-155, uranium-233/234, uranium-235, uranium-238, plutonium-238, plutonium-239/240, and americium-241.

- Activation products from the graphite reactor core, other reactor components, and fuel cladding could be picked up by the cooling water. Significant radioactive species included tritium, carbon-14, cobalt-60, nickel-63, europium-152, and europium-154.

- Fuel element fission products such as strontium-90 and cesium-137, and transuranics such as plutonium-239, plutonium-240, and americium-241, were introduced into the cooling water in the event of fuel cladding failures.

***Cooling Water Effluent.*** Water discharged from the reactors was near boiling. The cooling water was transferred from the B and C Reactor Buildings through the effluent lines to the 107-B and 107-C Retention Basins, respectively, for cooling and decay of short-lived radionuclides. In Figure 1-10, steam is visible rising from the 116-C-1 Process Trench at left and the 107-B and 107-C Retention Basins at right. The 1904-C Outfall structure is visible to the left, and 1904-B2 Outfall structure is visible to the right.

**Figure 1-10. River Effluent Outfall Structures during Operations**

The retention time for effluent within the retention basins varied at the different reactor areas from 1.5 to 4 hours for flow rates occurring during the last 3 years of operation. Holding times fluctuated based on the flow rates through the reactors. A study conducted between 1950 and 1953, in which samples of the effluent were analyzed, indicated that the effective holding time for the 107-B Retention Basin was approximately 2.8 hours, while the effective retention time in the 107-C Retention Basin was approximately 3.2 hours (*Effective Retention Time of the Hanford 107 Reactor Effluent Retention Basins* [HW-28830]). The total radioactivity in the reactor cooling water 4 hours after exiting the reactor was reported to have been in the range of 0.2 to 2.0 µCi/L during normal operations. The 107-B Retention Basin was used from 1944 until the mid-1950s when concrete cracking became a serious problem and cooling water from the B Reactor was diverted to the 107-C Retention Basin. The 107-C Retention Basin was used from 1952 until 1969.

From the respective retention basins, the water was transferred through the 1904-B1, 1904-B2, or 1904-C Outfall structures to pipes that discharged at the bottom of the Columbia River near the middle of

the channel (*Radiological Characterization of the Retired 100 Areas* [UNI-946]). Overflow from the outfall structures could also discharge directly to the shore of the river through adjoining spillways. Although most water was disposed to the river, some was disposed to the ground. Radioactively contaminated cooling water was discharged to the 107-B Liquid Waste Disposal Trench between 1946 and 1955 and to the 107-C Liquid Waste Disposal Trench between 1952 and 1968.

Substantial evidence exists that the retention basins and effluent lines leaked, releasing cooling water to the area in and around the basins, lines, and shore at a rate as high as several thousand gal/min (*Radiological Characterization of the Retired 100 Areas* [UNI-946]). This evidence includes observations of water pooling over large areas of the ground adjacent to the 107-B Retention Basin. Several warm seeps with elevated beta activity were observed along the Columbia River shoreline below the 107-B Retention Basin (*Divisions Report on 100 and 300 Areas for the Period February 1 - 28, 1949* [HW-12732]; 100-BC-1 Work Plan [DOE/RL-90-07]).

***Sodium Dichromate—Corrosion Prevention.*** Cooling water treatment accounted for the great majority of sodium dichromate used. Bulk sodium dichromate salt and high-concentration sodium dichromate solutions were used as stock material to make 10 to 15 percent process solution batches.

Initially, dry materials were used at both water treatment plants, with the use of concentrated dichromate liquid phased in over time (*Summary of 100 B/C Reactor Operations and Resultant Wastes, Hanford Site* [WHC-SD-EN-RPT-004]). High-concentration (greater than 70 weight percent) liquid sodium dichromate solutions were used as the stock material after 1957 at the C Reactor and starting in 1960 at the B Reactor, until closure of the reactors. A 10 to 15 percent concentration solution was metered into the cooling water stream downstream of the flocculation/sedimentation basin as the water was prepared for use in the reactor, as described previously.

Complete conversion to a liquid sodium dichromate feed system was implemented at the B Reactor by April 1960, and earlier at the C Reactor, between 1957 and 1959 (*Irradiation Processing Department Monthly Record Report March, 1960* [HW-64555]; "Historical Information for 100-D/DR Area Uses of Chromic Acid and Sodium Dichromate: Supplement to IOM 129547" [Schwab, 2008]). Pipelines and other plant modifications required to stage and transfer sodium dichromate liquid included modifying an existing underground soft water pipeline between the 183-C Head House and the 183-B Filter Plant Pump House. This line was modified in 1960 to transfer sodium dichromate solution from an external 132,450 L (35,000 gal) storage tank at the 183-C Head House to feed tanks in the 183-B Filter Plant Pump House.

Initially, the C Reactor coolant water had a sodium dichromate concentration of about 1.8 ppm. The sodium dichromate concentrations were reduced to 1.0 ppm in 1960 and to 0.5 ppm in late 1967. All reactors were down to 1.0 ppm sodium dichromate additions by 1964 (*Quarterly Report Contamination Control—Columbia River April – June 1968* [DUN-4847]).

Delivery of the 70 percent solution into the storage tank at 183-C (*Discharge of Sodium Dichromate Solution Compliance with Executive Order 11258* [DUN-1818]) was not completely efficient, and discharges to the surrounding soils are known to have occurred, although the exact mass lost is not known. These transfers also resulted in a one-time significant release of concentrated sodium dichromate to the river in 1966. A transfer pump was inadvertently left running overnight, resulting in an overflow of approximately 54,055 L (14,280 gallons) to the 183-C process sewers, which discharged directly to the river (*Chemicals Discharged to the Columbia River from DUN Facilities Fiscal Year 1967* [DUN-3032]; *Douglas United Nuclear, Inc. Monthly Report September, 1966* [DUN-1295]).

### 1.2.2.6 Radioactivity Sources

Radioactivity was introduced into the cooling water at several stages of the production process. The reactors contributed the most radioactivity to the cooling water through the fuel elements and the resulting discharge of cooling water to various storage facilities.

***Fuel Elements and Failures.*** An operating system was devised to prevent both the bulk effluent and the water from the affected process tube from being discharged directly to the river during fuel failures. Both systems involved discharging the liquid to subsurface soil via trenches and cribs (e.g., 116-B-1 and 116-C-1 Process Effluent Trenches, and 116-B-3 and 116-C-2A Pluto Cribs). Each retention basin was originally constructed with two compartments that were filled sequentially. In the case of 107-B, the concrete reservoir was divided down the middle, and at 107-C, the retention basin consisted of two separate tanks. This allowed cooling water to be diverted and segregated in the second empty compartment if elevated contamination levels were indicated by the monitoring equipment. The segregated cooling water was then transferred to one of two trenches (116-B-1 and 116-C-1) excavated east of the basins for high-volume liquid waste disposal. The practice continued until the mid-1950s, when increased flows and structural stresses resulting from the temperature difference between the full and empty sides necessitated using both sides of the basins in parallel, and segregation was no longer possible.

The 107-B retention basin was used from 1944 until the mid-1950s when cracking of the concrete became a serious problem and cooling water from the B Reactor was diverted to 107-C. The 107-C retention basin was used from 1952 until 1969. These retention basins were documented to have leaked on a regular basis (*Radiological Characterization of the Retired 100 Areas* [UNI-946]). Evidence of leakage includes observations of water pooling over large areas of ground adjacent to the 116-B-11 retention basin and over the effluent lines (*Summary of Environmental Contamination Incidents at Hanford 1952-1957* [HW-54636]). Leakage rates from 107-B were as high as 18,925 to 37,850 L/min (5,000 to 10,000 gal/min) (100-BC-1 Work Plan [DOE/RL-90-07]), with the highest leakage rates on the northeast side of the basin (*Radiological Characterization of the Retired 100 Areas* [UNI-946]). Radioactivity associated with the 107-B and 107-C retention basins was documented in 1958 as having a total inventory of about $10^2$ curies of total radioactive inventory in, underneath, and adjacent to the individual retention basin (*Radiological Characterization of the Retired 100 Areas* [UNI-946]).

During reactor operations, fuel-cladding failures sometimes occurred while the fuel elements were in the process tubes. The first such failure at B Reactor occurred in 1948, the first failure at C Reactor occurred in 1953. Fuel failures for both the B and C Reactors are documented in *Fuel-Element Failures in Hanford Single-Pass Reactors, 1944-1971* (PNWD-2161 HEDR). When fuel cladding failed, the cooling water in the affected process tube became highly contaminated. Elevated radiation levels were observed in the cooling water exiting the reactor core, which was then diverted to the trenches.

Most of the irradiated fuel elements were shipped to the 200 Area for chemical processing, but some metallurgical studies on irradiated fuel and tritium production and separation were performed in the 100 Area. Approximately 44 kg (97 lb) of spent nuclear fuel was recovered from the 118-B-1 and 118-C-1 Burial Grounds during interim remedial action. In addition, during production, fuel element failures and infrastructure failures (e.g., pipe leaks) led to losses of contaminated materials to the environment.

Two systems were initially used to divert reactor-cooling water in the event of a fuel failure: "pluto cribs" were used to divert water upstream of the retention basins, and process trenches were used to divert water from the retention basins. The pluto cribs (116-B-3 and 116-C-2A) were constructed east of each reactor and used for a limited time. The purpose of the pluto cribs was to receive the highly contaminated water that was flushed directly from the process tube affected by the fuel cladding failure. The term "pluto crib"

refers to the type of cap used to accomplish the highly contaminated tube flushing and does not refer to plutonium. Later in production, as fuel failures increased, pluto cribs were replaced by process trenches. Both pluto cribs and process trenches relied on the cationic adsorption characteristic of Hanford soils (*Properties of Soils of the Hanford Project* [HW-53218]) to remove the fission products and transuranics. Pluto cribs were generally for low volume/flow rates (e.g., a single process tube flow of 30 to 60 gal/min), whereas trenches were for high-volume, high-flow rates.

***Fuel Storage Basin.*** The FSBs directly adjoined each reactor and served as collection, storage, and transfer facilities for irradiated fuel elements. The fuel elements were kept under a water shield 4.9 m (16 ft) deep. Reactor coolant-grade water was used to fill the fuel storage pool. The effluent from the FSBs was disposed to trenches close to the reactors.

Fuel element failure would occasionally cause the FSB shielding water to become highly contaminated with radionuclides. In 1946, a fuel element was accidently cut in half in the FSB at the B Reactor, which caused the shielding water to become highly contaminated. The resulting shielding water was contaminated with tritium, cobalt-60, nickel-63, strontium-90, cesium-137, and plutonium-239/240, and was subsequently discharged to the single-use 116-B-2 Trench located east of the reactor building (100-BC-1 Work Plan [DOE/RL-90-07]).

Between December 1984 and October 1985, the C Reactor FSB was cleaned out and stabilized. The B Reactor FSB was cleaned out and stabilized between 1984 and 1986. Approximately 2,720,000 L (720,000 gal) of shielding water was removed from both FSBs (100-BC-2 Work Plan [DOE/RL-91-07]). The FSB walls were washed with a high-pressure water jet as the water was drained and the walls and floor were coated with an asphalt emulsion. The washwater was combined with the shielding water and processed through a filtration system and treatment system that removed entrained sediment and radiological contaminants. It is unknown where the residues were disposed. The treated water was analyzed to verify that it met allowable residual contamination level release criteria, and then discharged to unlined percolation ponds. Cooling water from the C Reactor was disposed to the 116-C-6 Pond, located east of the C Reactor building (100-BC-2 Work Plan [DOE/RL-91-07]), and water from the B Reactor was disposed to the 116-B-15 Pond, located approximately 300 m (1,000 ft) east of the FSB (100-BC-2 Work Plan [DOE/RL-91-07]).

Miscellaneous debris, including equipment and hardware in the basins, was removed, packaged, and disposed of as appropriate. The C Reactor FSB facility served as a temporary storage area for suspect fuel elements removed from other reactors. Suspect fuel elements were subsequently transferred to the N Reactor for identification (100-BC-2 Work Plan [DOE/RL-91-07]). Approximately 17 $m^3$ (600 $ft^3$) of sludge and sediment totaling about 50,000 kg (55 tons) were transferred from each storage basin and consolidated in the fuel transfer pit located adjacent to the storage basin (100-BC-2 Work Plan [DOE/RL-91-07]; 100-BC-1 Work Plan [DOE/RL-90-07]). The transfer pits were then shielded with a cap, and for the C Reactor, the walls above the sludge were coated with an asphalt emulsion (*Radionuclide Inventory and Source Terms for the Surplus Production Reactors at Hanford* [UNI-3714]; 100-BC-2 Work Plan [DOE/RL-91-07]).

#### 1.2.2.7 Radioactive Waste Streams

Wastes resulting from supporting production operations were similarly disposed in each area according to phase (liquids or solids), quantity (high/low mass or volume), radioactivity (high level or low level), and composition (e.g., chemical or septic). Thus, liquid and solid waste disposal locations were constructed and waste management practices were developed to handle these materials.

***Radioactive Sludge and Solid Wastes.*** Several thousand tons of radioactive sludge were generated during reactor operations and accumulated in pipes in the cooling water effluent system, in the 107-B and 107-C Retention Basins, and in the reactor FSBs. Smaller volumes of sludge also collected in water traps located in the 115-B/C Gas Recirculation Facility, the 117-B Exhaust Filter Building, and the 117-C Exhaust Filter Building. The sludge consisted of diatomaceous earth periodically used to scour the reactor process tubes, and fine particulate matter that originated from dissolved and suspended solids in river water, pipe slag, rust, failed fuel elements, graphite powder, and other undefined solids. The sludge was contaminated with radionuclides and various chemical contaminants.

The bulk of the sludge accumulated in the 116-C-2A Pluto Crib system, the 107-C Retention Basin, or the 107-B Retention Basin. At least twice during the B Reactor operations, an unknown quantity of sludge was removed from the 107-B Retention Basin to two unlined trenches, 116-B-13 and 116-B-14. No record of a similar cleanout of the 107-C Retention Basin exists.

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

- The Ball 3X Project, in which the liquid boron system for emergency reactor control was modified to a system using solid boron steel and carbon steel balls
- The tube replacement project, in which nearly 4,000 aluminum process tubes from the B Reactor were replaced between 1956 and 1965 (100-BC-1 Work Plan [DOE/RL-90-07])

Reactor modifications at the C Reactor included the Ball 3X system and overboring of process channels. The overboring of some process channels for larger process tubes at the C Reactor produced contaminated graphite solid waste and contaminated aluminum process tubes (Hazards Summary Report [HW-74094 VOL 3]). Activities in the 111-B Building, used from 1950 to 1968, were also a source of radioactive solid wastes. The building was originally used as a fuel examination station, with two underground fuel examination pits. After a short time, it evolved into an equipment decontamination facility and shop for working on low-level contaminated reactor components. Wastes were generally not as highly contaminated as those disposed directly from the 105-B Reactor building (100-BC-1 Work Plan [DOE/RL-90-07]).

It is likely that other facilities associated with the B and C Reactors and waste management activities generated radioactive solid wastes. Examples are the air filters in the 117-C Exhaust Air Filter Building, equipment used in connection with the cooling water effluent system, and contaminated soil removed from near the effluent lines. The primary disposal area for the B Reactor was the 118-B-1 Burial Ground, and for the C Reactor, the primary disposal area was the 118-C-1 Burial Ground.

***Decontamination Solutions.*** During reactor operations and reactor shutdowns, large quantities of decontamination solutions were used routinely to remove radionuclides from reactor equipment and facility surfaces. Decontamination activities took place at the B and C Reactor dummy decontamination

facility (DDF) wash pad, which was adjacent to the B Reactor FSB. The B Reactor facilities are identified as the 108-B Building Decontamination Pad and the 111-B Decontamination Building/Repair Shop.

Known decontamination solutions at 100-BC included chromic acid, citric acid, oxalic acid, nitric acid, sulfamic and sulfuric acids (neutralized with sodium carbonate before disposal), and sodium fluoride. Other chemicals, including organic solvents, also were used for some decontamination processes. These solutions were generally disposed in cribs, trenches, or French drains near the building where they were used. For the B Reactor, specific disposal locations for the decontamination solutions are not specified (100-BC-1 Work Plan [DOE/RL-90-07]). At the C Reactor, the spent decontamination solutions from the C Reactor were presumably discharged to the 116-C-2A Crib (100-BC-2 Work Plan [DOE/RL-91-07]), but may also have been discharged to the cooling water process effluent sewers.

The solutions contained both radionuclide and chemical contaminants. Some of the compounds used in the decontamination solutions, such as oxalate and organic complexants, may have dissolved and transported radionuclides and metals. The quantities of decontamination solutions, as well as other disposal locations, are not precisely known (*100-B Area Technical Baseline Report* [WHC-SD-EN-TI-220]; 100-BC-2 Work Plan [DOE/RL-91-07]; 100-BC-1 Work Plan [DOE/RL-90-07], and *Process Standards – Water Plant* [HW-27155]).

***Tritium Recovery Facility Wastes.*** The 108-B Building was originally designed as a chemical pump house to receive, store, and prepare chemical solutions and slurries for the 105-B Reactor operations. In 1949, it was converted to a laboratory to extract tritium from special targets containing lithium-3 after they had been irradiated in one of the reactors (105-B, 105-F, 105-H, or 105-DR). The 108-B Building was used from 1949 to 1954. This tritium production project was conducted under the alias "P-10 Project." There were two tritium recovery campaigns, one using a stainless steel line and one using a glass line. The major contaminants from tritium recovery were tritium and mercury. The mercury was generated as a result of using mercury vapor pumps. The 104-B2 Building (and 116-B-9 French Drain) was constructed circa 1950 near 108-B as part of the P-10 Project. The floor of the building was designed to store special containers of the tritium extracted in 108-B, as shown in Figure 1-11.

The tritium recovery process was discontinued in 1954, and the 108-B Building was subsequently used as an aluminum process tube examination facility. Decontamination wastes were generated by the examination facility and by the decontamination pad located at the 108-B Building.

Liquid tritium wastes from the extraction process with an activity of less than 1 μCi/mL of tritium were discharged to the 116-B-5 Crib located north of the building (*Unconfined Underground Radioactive Waste and Contamination* [HW-27337]; 100-BC-1 Work Plan [DOE/RL-90-07]). Solid wastes such as aluminum target cans and lead target melting pots, used during the second tritium extraction campaign, were disposed in the 118-B-6 Burial Ground located southeast of the 108-B Building. In addition, this burial ground contained high-level liquid tritium wastes sealed in 3-in.-diameter iron pipe (*Unconfined Underground Radioactive Waste and Contamination* [HW-27337]; 100-BC-1 Work Plan [DOE/RL-90-07]), and small quantities of mercury. Tritium recovery process wastes and equipment were also disposed at the primary 118-B-1 Burial Ground. Low-level liquid radioactive wastes from the tube examination facility and decontamination activities were discharged to the 116-B-10 Dry Well, located immediately east of the building.

**Figure 1-11. Tritium Storage Cells at 104-B2 Building**

The 108-B Tube Examination cell, process equipment, some room wall surfaces, ductwork, piping, and the exhaust stack became contaminated during operation of the facility. After decontamination of the building, any residual contamination that remained existed in a thin layer on the inner concrete surfaces at levels not presenting an unacceptable risk of exposure. The 108-B Building was then demolished and uncontaminated rubble was buried under 1 m (3 ft) of clean fill (*Waste Site Reclassification Form,* Operable Unit 100-BC-1, Waste Site 132-B-1 [WSRF 2003-44]).

### *1.2.2.8 Nonradioactive Waste Streams*

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

***Sanitary Liquid Wastes.*** Sanitary wastes were produced in the various buildings equipped with sanitary facilities. These wastes were routed by sewer lines to septic tanks and tile drain fields located within

100-BC. Nonsanitary wastes such as detergents, cleaning compounds, and solvents likely entered some of these sewer systems. No record exists of radiological wastes being disposed of to these sewer systems; however, laboratory wastes containing low levels of both radioactive and hazardous chemical contaminants may have been disposed of via the sanitary sewers.

***Nonradioactive Liquid Wastes.*** Nonsanitary, nonradioactive liquid chemicals that were used at 100-BC potentially contributed to contamination. These include hazardous wastes and hazardous substances. Contamination from liquids, including gasoline, diesel fuel, solvents, and other chemical compounds, would be expected near aboveground or underground storage tanks and their piping systems and in areas where these materials were used or stored. Releases could have resulted from leakage, spillage, or disposal. The following activities may have resulted in the generation of nonradioactive liquid wastes (100-BC-1 Work Plan [DOE/RL-90-07]; 100-BC-2 Work Plan [DOE/RL-91-07]):

- Water treatment chemicals (alum, sulfuric acid, chlorine, sodium dichromate) were used and stored near the 108-B, 183-B, 183-C, 185-B, 190-B, 190-C Buildings, and 1713-BA Essential Material Warehouse.
- Wet-type electrical transformers and hydraulic machinery containing oil contaminated with polychlorinated biphenyls (PCBs) were used at several locations within 100-BC (e.g. the 151-B electrical yard). Fluids contaminated with PCBs may have been released or disposed of during operation, equipment repair, or decommissioning and demolition (D&D) activities.
- Boiler water treatment chemicals for the 184-B Powerhouse included sodium sulfate, trisodium phosphate, and chromates (trivalent chromium cations). These chemicals were used to treat the boiler water and ended up in the boiler sludge. Disposal methods for this sludge are not well-documented; however, it is assumed that this waste was directed to the process sewer.
- Three zeolite water softeners were located in the 184-B Powerhouse where filtered water was treated before use in the heat exchangers. Sodium chloride solutions were used to regenerate the zeolite beds in the water softener tanks. The salt was delivered in railcar lots to brine pits located adjacent to railroad tracks just north of the powerhouse. The disposal of the waste from this process is not wel-documented; however, it is assumed the waste solution was directed to the sewer, and no records of leaks or spills exist.
- Emergency electrical power for instrumentation in both the B and C Reactor buildings consisted of two backup systems: a 10-kVA gasoline engine generator for the station in general, and a set of batteries for the Ball 3X system. Fuel for the generators was stored outside the reactor building in tanks placed on tall concrete saddles for gravity feed to the system. The 120-B-1 Battery Acid Sump, located immediately northwest of the 105-B Reactor building, was used as a battery acid neutralization pit that used limestone to neutralize used battery acid (sulfuric) before discharging to the process sewer.
- Oils, paints, and solvents were stored or used at the 1715-B, 1717-B, and 1722-B Buildings.
- Automotive repair and service was performed at the 1716-B Building.
- Essential materials including sodium dichromate bags/drums were stored at the 1713-BA Essential Material Warehouse.

***Nonradioactive Solid Waste.*** Nonradioactive solid waste generated in 100-BC primarily included miscellaneous materials such as paper, trash, pieces of metal, plastic parts, etc., generated in the facilities. Several burn pits have been identified and remediated under interim actions in the 100-BC-1 and 100-BC-2 OUs, including the 128-B-2, 128-B-3, and 128-C-1 waste sites (100-BC-1 Work Plan [DOE/RL-90-07]).

Other solid waste consisted of relatively uncontaminated concrete, metal parts, and other materials generated during D&D activities. Asbestos, chemical waste, and contaminated solids were removed from the area during the decontamination/decommissioning work. Building materials that were not considered contaminated were either buried in place or taken to the former 184-B coal storage yard and buried. Some of these materials may have had low-level radiological contamination.

### 1.2.3 Previous Investigations and Remediation

This subsection summarizes the significant investigation and remediation activities for facilities, waste sites, and groundwater at 100-BC. Since the beginning of reactor operations, investigations were conducted to determine impacts to the environment, including the Columbia River. With the issuance of the Tri-Party Agreement in 1989 (Ecology et al., 1989a), activities transitioned to cleanup activities, which have been ongoing continuously under CERCLA to determine how best to protect HHE within the River Corridor, including 100-BC. These overall River Corridor activities supplement specific activities that continue to be conducted at 100-BC.

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

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

The various 100-K decision documents are summarized in Table 1-3. Appendix B presents an annotated bibliography of CERCLA documentation for the River Corridor.

Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| *Radiological Characterization of the Retired 100 Areas* | UNI-946; 1978 | Radiological characterization of select waste sites was conducted in the mid-1970s to establish radionuclide inventories and contaminant distribution. Radiological contaminants were generally detected to the maximum extent of the investigation 11.6 m (38 ft) bgs. Data from this report were also used to prepare the LFI Reports for the 100-BC-1 and 100-BC-2 OUs. Radiological inventory estimates are presented in the report. |
| *Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and the Snake River Confluence* | PNL-3127; 1980 | The radiological survey results in this 1980 report documented the magnitude and distribution of radioactive contamination on the exposed shorelines of the Columbia River along and downstream from the Hanford Site. The average exposure rate was 11±3 µR/h compared to a background of 7±1 µR/h. A maximum exposure rate of 45 µR/h was detected at the Hanford Townsite. The report indicated that cobalt-60, cesium-137, and europium-152 were detected in soil and vegetation samples. |
| *In Situ Vitrification of a Mixed-Waste Contaminated Soil Site: The 116-B-6A Crib at Hanford* | PNL-8281; 1992 | A large-scale mixed-waste demonstration of ISV was performed in 1990 at the 116-B-6A Crib. About 550 megawatts per hour of electrical energy was consumed and an 850-ton block of vitrified soil was created. At least 99.98% of the chromium (total), lead, and cesium-137 present in the demonstration area soils were retained within the vitrified mass. |
| *Sampling and Analysis of 100 Area Springs* | DOE/RL-92-12; 1992 | Shoreline seeps, seep-associated sediments, and Columbia River water were sampled for chemicals and radionuclides in 1991. The results of these analyses show that radiological and chemical contaminants were entering the Columbia River via seeps from the retired reactor areas of the 100 Area. The concentrations of contaminants in river water samples were generally below analytical detection limits. At locations where concentrations were above detection limits, the concentrations were significantly lower than drinking water standards. Seep and river water samples collected near the Hanford Townsite showed no detectable quantities of radionuclides, and the general chemistry of the river water was good. The primary contaminants in the seeps were strontium-90, tritium, and chromium (total). |
| *Remedial Investigation/Feasibility Study Work Plan for the 100-BC-5 Operable Unit, Hanford Site, Richland, Washington* | DOE/RL-90-08; 1992 | The RI work plan proposed investigations into site vadose zone, geology, hydrogeology, surface water, and sediments. A subsequent LFI report (*Limited Field Investigation Report for the 100-BC-5 Operable Unit* [DOE/RL-93-37]) presented the results of those investigations. A geologic investigation compiled existing data and collected new data during installation of new monitoring wells. A groundwater investigation studied the nature and extent of contamination in order to determine the need for an interim remedial action. Ten new wells were installed and sampled. Nine of the wells monitored the top of the unconfined aquifer, and the geology of deeper sediment was not characterized. The tenth well, 199-B2-12, was screened in a confined unit of the Ringold Formation. |

**Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions**

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| *100 Area Columbia River Sediment Sampling* | WHC-SN-EN-TI-198; 1993 | This report concluded that chemical and radiological contamination was present in Columbia River sediments. The nonradiological contaminants exceeding the 95% UCL for site background soils in sediments were arsenic, chromium (total), copper, lead, and zinc. Of these contaminants, zinc and lead were most commonly found. Arsenic, lead, and zinc were also detected upstream of the Hanford Site, suggesting an offsite source. Man-made radionuclides were detected in nearly all the locations sampled. Most of the radionuclides detected were <1 pCi/g. Cesium-137 and europium-152 were the most frequently detected, with maximum activities of 4.6 and 1.8 pCi/g, respectively. Cobalt-60 and uranium isotopes were also detected. |
| *Geophysical Investigation of the 118-B-1 Burial Grounds, 100 B/C Area, Hanford Site, Washington* | WHC-SD-EN-TI-137; 1993 | GPR and electromagnetic induction were used in this investigation to locate debris, metallic waste, and trenches within the 118-B-1 Burial Ground. Reflective materials indicative of anomalies were identified and mapped. The maximum depth of investigation using these geophysical methods was about 5.5 m (18 ft) bgs. |
| *Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River* | PNL-8789; 1993 | The levels of radionuclides and trace metals along the Hanford Reach were measured and reported. The work was conducted as part of the Surface Environmental Surveillance Project. The survey consisted of measuring exposure rates and soil samples at locations within the Hanford Reach where elevated rates are known or expected to be present based on *An Aerial Radiological Survey of the Hanford Site and Surrounding Area, Richland, Washington* (EGG-10617-1062).<br><br>Background rates measured at Vernita ranged from 4 to 11 μR/h, and from 8 to 28 μR/h at the White Bluffs Slough area. Sampling indicated that areas with elevated (compared to background) soil concentrations of major radioactive constituents include 100-D island, shoreline of the Hanford Townsite, and the White Bluffs Slough area. No results regarding the distribution of radionuclides along the remaining areas of the Hanford Reach were discussed.<br><br>The report concluded that several areas along the Hanford Reach still show impacts from Hanford Site operations. No short-lived radionuclides were detected, and no significant variation among trace metal concentrations was found. |
| *Limited Field Investigation Report for the 100-BC-5 Operable Unit* | DOE/RL-93-37; 1994 | This LFI was conducted to assess the applicability of interim remedial measures (IRMs) for reducing human and environmental risk within the 100-BC-5 Groundwater OU. COPCs were identified and samples were collected and analyzed to support the assessment. Tritium and strontium-90 were identified as COCs because their activities exceeded potential applicable relevant and appropriate requirements. The qualitative risk assessment (QRA) concluded that the human health risk is low for all site groundwater contaminants. Based on the low risk, IRMs were not recommended for the OU. Continued groundwater monitoring was recommended, in addition to the assessment of risk after sources are remediated. |

**Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions**

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| *Limited Field Investigation Report for the 100-BC-1 Operable Unit* | DOE/RL-93-06; 1994 | Soil sampling and analysis were conducted at waste sites to determine the need for IRMs. Cobalt-60, strontium-90, cesium-137, europium-152, europium-154, plutonium-239/240, and americium-241 were the primary radionuclides of concern. The maximum contaminant concentrations detected within the upper 4.6 m (15 ft) of the site surface were evaluated in a QRA. The QRA identified cobalt-60, cesium-137, europium-152, and europium-154 as the main contributors to overall human health risks via the direct exposure pathway. Metals also contributed to elevated human health risk at the 116-C-5 Retention Basin. In addition, five sites exceeded ecological hazard quotients. Overall, 16 waste sites were recommended for IRM. |
| *Limited Field Investigation Report for the 100-BC-2 Operable Unit* | DOE/RL-94-42; 1994 | This LFI was performed to determine the need for IRMs. Analytical results showed that radionuclides were the primary concern in the OU. Radiological activities were highest at the 116-C-2C Crib. The QRA showed that the major risk drivers for human health were cobalt-60, cesium-137, and europium-152. The major ecological risk driver was strontium-90. Fourteen waste sites were recommended for IRM. |
| *118-B-1 Excavation Treatability Test Plan* | DOE/RL-94-43; 1994 | The treatability test plan was implemented to support the development of a proposed plan and ROD for the 118-B-1 Burial Ground remediation, to provide engineering information on waste generated during removal actions, and to provide critical performance and cost information. |
| *100 Area Source Operable Unit Focused Feasibility Study* | DOE/RL-94-61; 1995 | The FFS provided information and rationale to evaluate high-priority source waste sites selected for IRMs in the 100 Area. The analysis was conducted using several human health exposure scenarios and known characteristics specific to OU waste sites. Six remedial alternatives were retained: no action; institutional control; containment; removal/disposal; in situ treatment; and RTD. Each alternative was evaluated using CERCLA threshold, balancing, and state and community acceptance criteria. |

**Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions**

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| *Qualitative Risk Assessment for the 100-BC-1 Source Operable Unit* | WHC-SD-EN-RA-003 1994 | This QRA evaluated risk based on two human health exposure scenarios (frequent-use and occasional-use) and four exposure pathways (soil ingestion, fugitive dust inhalation, inhalation of volatile organics from soil, and direct radiation exposure). Limited ecological and groundwater evaluations were performed. Twenty-two high-priority waste sites were evaluated. Two sites had no evidence of contamination, six sites had high human health risk (that is, incremental cancer risk $>10^2$ potential under the frequent-use scenario), and two sites had high human health risk potential under the occasional-use scenario. In general, the primary exposure pathway was direct exposure to radionuclides. The key radionuclide risk drivers were cesium-137, cobalt-60, europium-152, and europium-154. Strontium-90 was the major ecological contributor to radiological dose exceeding 1 rad/day. For chemicals, "no-observable-effect-levels" were exceeded for antimony, barium, chromium (total), lead, mercury, and pentachlorophenol. In addition, the report indicated that some 100-BC-1 waste sites had the potential to impact groundwater. |
| *Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington* | EPA/ROD/R10-95/126; 1995 | This document, also referred to as the Liquid Effluent Waste Sites ROD, presents the selected interim remedial actions for portions of the DOE Hanford 100 Area, Hanford Site, Benton County, Washington, which were chosen in accordance with CERCLA, as amended by the SARA, and to the extent practicable, the NCP. Specifically, the selected remedial actions initially addressed 37 high-priority waste sites that received liquid radioactive effluent discharges in the 100-BC-1, 100-DR-1, and 100-HR-1 OUs, as well as adjacent contaminated sites within the area required for remediation. The major components of the selected remedy included removing contaminated soil, structures, and debris using the observational approach; treatment by soil washing and/or as needed to meet waste disposal criteria; and disposal of contaminated materials at the ERDF and backfill of excavated areas followed by revegetation.<br>A subsequent amendment to this ROD, in 1997, expanded the scope of the remedy to include 34 additional sites in other OUs. This ROD amendment also eliminated soil washing as a treatment option based on pilot-scale treatability studies. |
| *Measurement of Environmental Radiation Exposure Rates from Vernita, Hanford Reach, and Richland Area Shores* | PNL-8789, Addendum 1; 1995 | This report presents additional radiation survey results and a statistical analysis of the previous 1993 investigation.<br>The 1994 radiation exposure measurements from the Vernita area (14 sites) ranged from 8 to 11 μR/hr, Hanford Reach area (19 sites) measurements ranged from 8 to 15 μR/h, and Richland area measurements (16 sites) ranged from 7 to 10 μR/h.<br>The report summarizes the statistical differences between the areas measured. Significant differences were only identified when the Hanford Reach results were compared to the Richland area results. |

Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| *100-B/C Demonstration Project Final Report* | BHI-00752; 1996 | The 100-BC Demonstration Project was planned for initiating remedial action in the 100 Area and addressing nine remedial design/remedial action uncertainties. Uncertainties were identified by the Tri-Parties in a 1995 "Streamlined Approach for Environmental Restoration Workshop." An action memorandum for an expedited response action was prepared for Waste Sites 116-B-4, 116-B-5, and 116-C-1 and issued on June 28, 1995, to address the uncertainties. Remedial action (for example, remove, treat, and dispose) commenced June 26, 1995. Uncertainties identified by the Tri-Parties are summarized and addressed based on efforts at the three waste sites. Results provided a framework for future remedial actions in the 100 Area. |
| *100 Area River Effluent Pipelines Risk Assessment* | BHI-01141; 1998 | This report evaluated current (1998) and future risks to HHE associated with the 100 Area Reactor effluent pipelines in the Columbia River along the Hanford Site. Radionuclides and metals in the pipelines presented no current risk to human health because there was no human exposure pathway. The concentration of mercury and chromium (total) posed minimal risk to fish using the pipe as habitat. |
| *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)* | EPA/ROD/R10-99/039; 1999 | This document, also referred to as the 100 Area Remaining Sites ROD, presents the select interim remedial actions for portions of the DOE Hanford 100 Area. This ROD included three types of sites: those with contaminated media and sufficient information to indicate that remediation was needed to protect HHE; those with potentially contaminated media but insufficient information to determine if remediation was warranted; and hazardous and radioactively contaminated equipment and debris from various 100 Area Reactor buildings.<br>The selected remedy included removing contaminated media, treatment as required to meet waste acceptance criteria, and disposal at the ERDF. For those sites where sufficient information was not available to establish a need for remediation, a candidate site process was established whereby the sites would be evaluated and could then be "plugged-in" to the selected remedy. This ROD also established that any sites discovered in the future could be similarly "plugged in." Explanations of significant difference for this ROD in 2004 and 2009 identified additional waste sites that had been addressed under the selected remedy. |
| *Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, WA* | EPA/ROD/R10-00/121; 2000 | This document, also referred to as the 100 Area Burial Grounds ROD, presents the selected interim remedial actions for the 100 Area Burial Grounds. The selected remedy included removing contaminated media, treatment as required to meet waste acceptance criteria, and disposal at the ERDF, followed by backfill and revegetation of excavated areas. |

Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| *RCBRA Stack Air Emissions Deposition Scoping Document* | DOE/RL-2005-49; 2005 | This report provides historical information regarding Hanford Site stack emissions and soil investigations to assess stack-related deposition in the 100 and 300 Areas. The report reaches the following conclusions:<br>• There is no evidence that waste sites should exist in the River Corridor as a result of historical air emission deposition<br>• Recent Hanford Site radiological surveys and recent onsite and offsite vegetation and soil studies have not identified any areas of elevated contamination caused by historical air emissions.<br>• The evaluation of known air emissions and nonradionuclide contaminants included in Hanford Site processes shows that deposition of hazardous or toxic materials from air emissions have been negligible. |
| *100-B/C Pilot Project Risk Assessment Report* | DOE/RL-2005-40; 2006 | The purpose of this report was to develop a process to evaluate the protectiveness of CERCLA remedial actions performed in 100-BC. An assessment of remediated waste sites, the riparian shoreline, and the nearshore Columbia River (adjoining the 100-BC Reactor area) was performed. A number of human health exposure scenarios were evaluated, including rural residential, industrial worker, national monument/refuge worker, avid hunter, and avid angler. The rural residential scenario includes the most complete exposure pathway, assumes land use is not restricted, and receptors reside within these areas for 30 years. Radionuclides and metals (aluminum, antimony, mercury, thallium, nickel-63, uranium-234, and uranium-238) detected in deep-zone soils were identified as COCs based on soil concentrations protective of groundwater. Tritium, strontium-90, antimony, Cr(VI), and nitrate were present in groundwater, had excess lifetime cancer risks greater than $10^{-4}$, and their concentrations exceeded federal drinking water maximum contaminant levels. |
| *An Aerial Radiological Survey of the Hanford Reservation Richland Washington: Date of Survey: February 29 to March 21, 1996* | DOE-0335; 2007 | An aerial radiological survey of the Hanford Site was conducted in 1996. The results of the survey are reported as contours of the terrestrial exposure rate extrapolated to 1 m (3 ft) above ground level; contours of the man-made gross count activity, which is characteristic of all long-lived man-made radionuclides that emit gamma radiation with energies less than 1,400 keV; and contours of cesium-137 activity. Excluding cosmic radiation (3.7 μR/h), implied exposure rates for background areas (areas undisturbed by Hanford Site radiological activities) ranged from 3 to 7 μR/h at 1 m (3 ft) above ground level. In radiologically disturbed areas, implied exposure rates in excess of background levels (as high as 500 μR/h in some cases) were observed. Typical disturbed areas were the nine deactivated reactors in the 100 Area, the Columbia Generating Station (Unit No. 2 Reactor; Energy Northwest [Washington Public Power Supply System in 1996]), and the facilities and radioactive storage sites within the 200 East/West and 300 Areas. |

Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| *River Corridor Baseline Risk Assessment, Volume II: Human Health Risk Assessments* | DOE/RL-2007-21, Draft C; 2010 | Potential health impacts were estimated for humans who may use the Hanford Site along the Columbia River. Risk at remediated waste sites associated with soil, groundwater, and fish ingestion pathways under various exposure scenarios (Recreational, Industrial/Commercial, Resident National Monument/Refuge, Rural Resident, and Native American) were evaluated. The risk assessment results for individual waste sites sometimes exceeded protective thresholds for the exposure scenarios and health effects evaluated. |
| *Explanation of Significant Difference for the Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR2, 100-FR-2, 100-HR-2, and 200-KR-2 Operable Units (100 Area Burial Grounds) October 2007* | EPA et al., 2007 | This document provides public notice on significant changes to the *Interim Remedial Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-2, 100-HR-2, and 100-KR-2 Operable Units, Hanford Site (100 Area Burial Grounds), Benton County, Washington* (EPA/ROD/R10-00/121) in accordance with Section 117(c) CERCLA and 40 CFR 300.435(c)(2)(1), "National Oil and Hazardous Substances Pollution Contingency Plan," "Remedial Design/Remedial Action, Operation and Maintenance." This ESD is specifically applicable to the 118-B-1 Burial Ground to allow for consideration of eight balancing factors to determine the extent of excavation. At the 118-B-1 Burial Ground, tritium concentrations in the soil column below 4.6 m (15 ft) did not achieve the RAOs of the 100 Area Burial Grounds ROD (EPA/ROD/R10-00/121). Based on an evaluation of the balancing factors, additional excavation of the remaining tritium-contaminated soil was not required. Institutional controls were required to achieve protection of groundwater and the Columbia River. |
| *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* | PNNL-17674; 2008 | The major objectives of this study were to determine the leaching characteristics of Cr(VI) from sediments collected from 100 Area spill sites, elucidate possible Cr(VI) mineral and/or chemical associations that may be responsible for Cr(VI) retention in 100 Area soil, and provide information to construct a conceptual model of Cr(VI) geochemistry in the 100 Area vadose zone. Results from column experiments indicated that most of the Cr(VI) traveled quickly through the column sediments and appeared in the effluent. Calculated retardation coefficients are close to one.<br>Calcium polysulfide solutions readily reduced Cr(VI) to trivalent chromium in column experiments. However, a significant amount of the Cr(VI) was mobilized prior to the polysulfide solution front. The experiments suggested that it would be difficult to design a remedial measure using infiltration of liquid phase reductants without increasing Cr(VI) transport toward the water table.<br>The microscopic characterization results were consistent with the column studies. Cr(VI) was found as ubiquitous coatings on sediment grain surfaces. |

**Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions**

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| | | This study also indicated that small, higher-concentration Cr(VI) sites were generally associated with secondary clay mineral inclusions with occasional barium chromate minerals, and the Cr(VI) was reduced to trivalent chromium in association with iron oxides that are most likely magnetite primary minerals. Within the restricted access domains of the sediment matrix, ferrous iron could also diffuse from in situ, high-surface-area minerals to cause the reductive immobilization of chromate. This process may be favored at micro-scale geochemical zones where ferrous iron could be supplied. |
| *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* | DOE/RL-2008-11; 2008 | This work plan presents an approach for investigating Hanford Site releases to the Columbia River. Samples sediment (shallow, shoreline, and cores), island soil, river water, pore water, and six species of fish will be collected and analyzed to identify Hanford Site-related contaminants that are present in the Columbia River. The sample collection area begins upriver from the Hanford Site above the Wanapum Dam and continues to McNary Dam, with some additional limited sediment core sampling in the vicinity of Bonneville Dam (upriver of Portland, Oregon). The results are being used to estimate the risk to humans, select wildlife, and select plants, and determine whether additional response actions or study are needed for the areas evaluated. |
| *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling* | WCH-380; 2010 | The field summary report documents the field sampling activities conducted under the *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* (DOE/RL-2008-11), described previously. The work was conducted from 2008 through 2010 throughout an approximately 64 km (40 mi) section of the Columbia River where contaminated groundwater was known or suspected. The work included preliminary mapping and measurement of Hanford Site contaminants in sediment, pore water, and surface water located in areas where groundwater upwelling was found. Results of the sampling are presented. |
| *100-BC Area Orphan Sites Evaluation Report* | OSR-2007-0001; 2009 | The OSE process is a systematic approach to review land parcels and identify potential waste sites not listed in CERCLA decision documents. Nine orphan sites were identified in the 100-BC OSE process. These sites were evaluated according to TPA-MP-14 (*Tri-Party Agreement Handbook Management Procedures* [RL-TPA-90-0001]) for consideration as waste sites. |
| *Hanford Site Environmental Report for Calendar Year 2008* | PNNL-18427; 2009 | This report is prepared annually and 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, Native American tribes, public officials, regulatory agencies, and Hanford Site contractors. |

Table 1-3. Summary of Selected Previous Investigations and Remedial Action Decisions

| Document Title | Document Number; Date | Summary of Observations and Conclusions |
|---|---|---|
| *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* | DOE/RL-2010-11; 2010 | This report is prepared annually and describes groundwater monitoring adjacent to the Columbia River in the River Corridor. |
| *Hanford Site Groundwater Monitoring for 2010* | DOE/RL-2011-01 | This report is prepared annually and describes groundwater monitoring adjacent to the Columbia River in the River Corridor. |

### 1.2.3.1 Previous Facility Demolition Activities

Seventy-six facilities were used or constructed in 100-BC. Figure 1-12 (1966) and Figure 1-13 (2010) contrast the condition of 100-BC during production versus the recent status of facilities and waste sites. Facilities and waste sites have been largely removed at 100-BC, and landscape scarring from past construction and remedial activities is evident in both photos. Table 1-4 lists the documents that guided removal actions.

Removal activities were conducted under two separate Action Memorandums (Table 1-4).

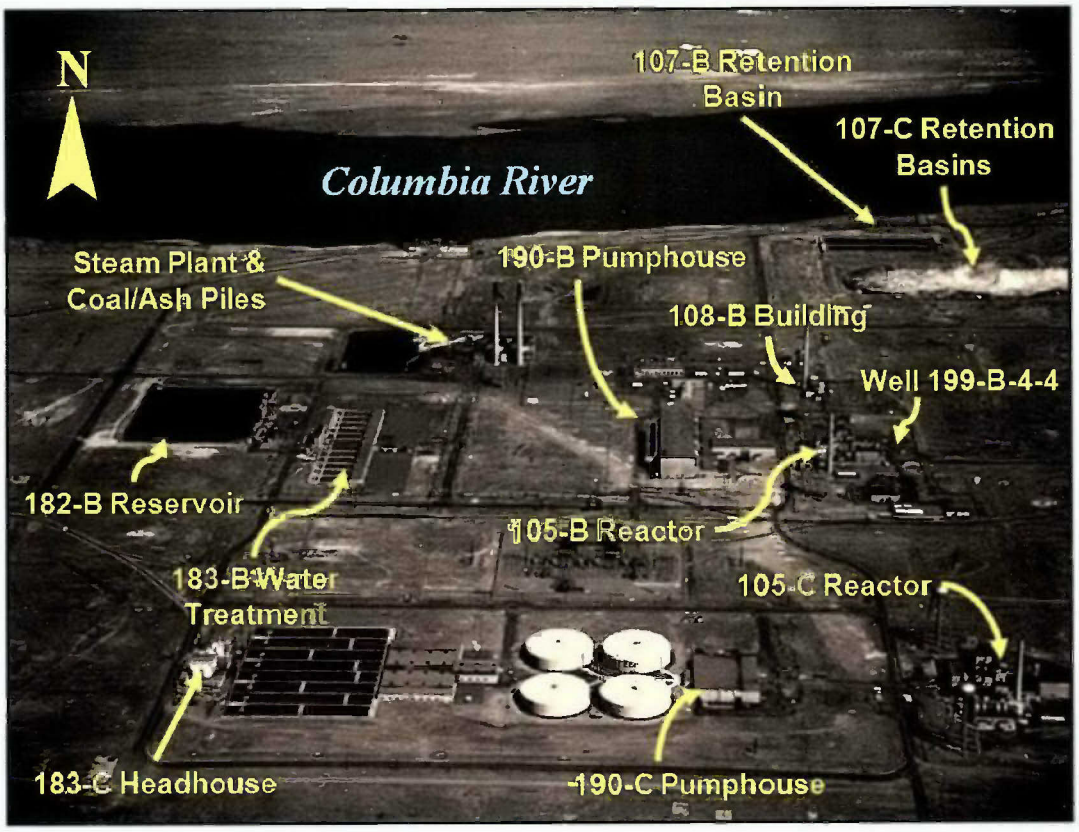


**Figure 1-12. 100-BC Major Features during Reactor Operations in 1966**

Figure 1-13. Conditions at 100-BC in April 2010

Table 1-4. Summary of Removal Action Documents at 100-BC

| Document Number | Date | Document Title |
|---|---|---|
| EPA and DOE, 1997 | 1/29/1997 | *Approved Action Memorandum for the 100 B/C Area Ancillary Facilities and the 108-F Building Removal Action* |
| EPA and DOE, 2001 | 12/2001 | *Action Memorandum for the Hanford 100 Area NPL 105-B Reactor Facility, Hanford Site, Benton County, Washington* |

The facilities have a status of active, inactive, removed, or demolished. Table 1-5 summarizes the status of facilities within 100-BC. Appendix E contains a description and history of each facility.

**Table 1-5. Summary Information on the Status of 100-BC Facilities (June 2012)**

| Total Number of Facilities | Reclassification Status | | | |
|---|---|---|---|---|
| | Demolished | Removed | Active | Inactive |
| 76 | 59 | 8 | 3 | 5 |

Notes: Does not include mobile offices or contractor trailer.

Status Definitions:

Active: Facility is occupied and/or in use (supports Hanford Site missions).

Inactive: Facility is no longer in use and is pending decommissioning and demolition.

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

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

Facilities that were used during operation of the reactor make up most of the demolished and removed facilities. These structures consist of the retention basins, reactor stacks, office and storage building, maintenance shops, process plants, electric substations, storage tanks, and pump stations. Active facilities include an electric substation (151-B), pump station (181-B), and process reservoir (182-B) that supplies water to the 200 Area. The inactive facilities at 100-BC are the 105-B Reactor Building (currently slated as a museum), 105-C Reactor Building safe storage enclosure (ISS), 116-B Exhaust Stack, 119-B Sample Building, 1608-B Pump Station, and 188-B Coal Ash Pit.

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

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

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

### 1.2.3.2 Previous Vadose Zone and Waste Site Investigations and Remediation

Information regarding the behavior of contaminants in the soil column has been an important consideration in Hanford Site operations (e.g., *Underground Waste Disposal at Hanford Works: An Interim Report Covering the 200 West Area* [HW-9671]; *The Underground Disposal of Liquid Wastes at the Hanford Works, Washington* [HW-17088]), but was not well understood at the inception of plant operations in the 1940s. Despite this, issues related to waste disposal at injection wells, shallow burial cribs, and surface ponds were considered, as well as groundwater monitoring to evaluate the rate of migration through the vadose zone and in the aquifer. Monitoring in the 200 Area primarily targeted radionuclides; however, groundwater monitoring around the 107-F waste disposal trench and then the 108-B crib reported chemicals present. Wells permitting geophysical logging were occasionally placed within these disposal sites to assess radionuclide movement through the aquifer. Continued disposal to these sites was based on the vertical migration of contaminants and ceased when contamination reached certain concentrations at the associated well(s).

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

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

Vadose zone contaminant (radiological and nonradiological) characterization studies started at 100-K in 1975 to evaluate contaminant inventories, concentrations, and distribution at inactive solid and liquid waste sites, reactors, and associated facilities. In the early 1990s, LFIs assessed the nature and extent of effluent discharges to the vadose zone at high-priority waste sites. Several column leaching studies assessed Cr(VI) transport from contaminated vadose zone material to groundwater. Based on the LFI and column leaching results, moisture characteristic curves have been calculated for 100-K, which are summarized in *100-KR-4 Remedial Process Optimization Modeling Data Package*, hereinafter called 100-KR-4 Remedial Process Optimization (RPO) Mod Data Package (SGW-41213). Because of the

presence of Cr(VI) in the groundwater, Cr(VI) source identification investigations were performed at 100-K.

***Initial Vadose Zone Radiological Characterization—1975.*** The purpose of this investigation was to establish approximate radionuclide inventories, distribution, and concentrations at inactive solid and liquid waste sites, reactors, and associated facilities. The focus of the sampling activities was liquid waste receiving sites and retention basins. Shallow boreholes were drilled in and adjacent to waste site boundaries, as presented in Table 1-6.

**Table 1-6. Summary of Sites Investigated in the Initial Radiological Characterization—1975**

| Waste Site | Media | Maximum Depth of Investigation | |
|---|---|---|---|
| | | m bgs | ft bgs |
| 116-B-11 (107-B) Retention Basin | Soil | 12 | 38 |
| 116-B-1 Trench | Soil | 6 | 20 |
| 116-C-5 (107-C) Retention Basin | Soil | 7 | 23 |
| 116-C-1 Trench | Soil | 11 | 35 |
| 100-B Junction Box Leak | Soil | 9 | 30 |
| 100-B Effluent Line Leak | Soil | 11 | 35 |
| 116-B-2 Trench | Soil | 8 | 25 |
| 116-B-3 Crib | Soil | 5 | 15 |
| 116-B-5 Crib | Soil | 7 | 22.5 |
| 116-B-6-1 Crib | Soil | 7 | 22.5 |
| 116-C-2 Crib | Soil | 15 | 50 |
| 116-C-2-1 Effluent Line Leak | Soil | 9 | 30 |
| 116-C-2-2 Crib | Soil/Sludge/Concrete | 9 | 30 |
| 118-B-1 Burial Ground | Soil | 10 | 33 |

Samples were analyzed for the following constituents, all of which were detected at levels greater than 1 pCi/g:

- Carbon-14
- Cobalt-60
- Cesium-134
- Cesium-137
- Europium-152
- Europium-154
- Europium-155
- Nickel-63
- Plutonium-238
- Plutonium-239/240
- Strontium-90
- Tritium
- Uranium (isotope not specified)
- Americium-241

This early study was narrow in its scope in that only concentrations and inventories of the selected radionuclides were reported, and no chemical contaminants were assayed. In particular, nickel-63, which is generally present at activities on the same order of magnitude as cobalt-60, was reported for only some samples and technetium-99 was not evaluated (100-BC-1 Work Plan [DOE/RL-90-07]). Sample boreholes drilled through the floor of the 107-B and 107-C Retention Basins indicated that the majority of

contamination was within a few meters of the basin floor (*Radiological Characterization of the Retired 100 Areas* [UNI-946]).

An additional component of this study involved collecting samples from retention basin sludge and concrete, and from effluent line scale and sludge. The samples were analyzed for radionuclides and the inventories of radionuclides for the facilities and sites were calculated.

***100-BC Vadose Zone Limited Field Investigations.*** LFIs were performed in the 100-BC-1 and 100-BC-2 OUs in the early 1990s. Results of these investigations are presented in *Limited Field Investigation Report for the 100-BC-1 Operable Unit* (DOE/RL-93-06) and *Limited Field Investigation Report for the 100-BC-2 Operable Unit* (DOE/RL-94-42). The primary purpose of the LFI reports was to recommend the high-priority sites that should, or should not, remain candidates for interim remedial measures (IRMs). The LFI findings were based on data compilation, intrusive investigation at selected sites, nonintrusive investigations, summarization of existing 100 Area aggregate studies, and data evaluation. The LFI reports summarized the data collection and analysis activities; and identified contaminant- and location-specific ARARs and their respective qualitative site-specific risk assessments that support the IRM candidate identification.

The LFIs performed in the early 1990s identified high-priority waste sites in 100-BC (Table 1-7). Of these sites, most were identified as candidates for the IRM through the LFI. Most IRM sites have since undergone remedial action, which removed material contaminated above cleanup levels. Waste sites that did not undergo remedial action underwent further evaluation to determine if residual contamination was protective of future land uses.

**Table 1-7. High-Priority Waste Sites and IRM Candidates Identified by LFIs in 100-BC with Subsequent Remedial Action Decision.**

| Waste Site | IRM Candidate | Remedial Action Taken | Waste Site | IRM Candidate | Remedial Action Taken |
|---|---|---|---|---|---|
| 116-B-1 Liquid Waste Disposal Trench | Yes | Yes | 116-C-1 Process Effluent Trench | Yes | Yes |
| 116-B-2 Fuel Storage Basin Trench | No | Yes | 116-C-2A Pluto Crib | Yes | Yes |
| 116-B-3 Pluto Crib | No | Yes | 116-C-2B Pluto Crib Pump Station | Yes | Yes |
| 116-B-4 Dummy Decontamination French Drain | Yes | Yes | 116-C-2C Pluto Crib Sand Filter | Yes | Yes |
| 116-B-5 Crib | Yes | Yes | 116-C-5 Retention Basin | Yes | Yes |
| 116-B-6A Crib | No | Yes | 118-C-4 Horizontal Control Rod Cave | Yes | Yes |
| 116-B-6B Crib | No | Yes | 126-B-2 Clear Wells | No | No |
| 116-B-7 Outfall Structure | Yes | Yes | 128-B-3 Burn Pit | No | Yes |
| 116-B-9 French Drain | Yes | Yes | 128-C-1 Burn Pit | Yes | Yes |

**Table 1-7. High-Priority Waste Sites and IRM Candidates Identified by LFIs in 100-BC with Subsequent Remedial Action Decision.**

| Waste Site | IRM Candidate | Remedial Action Taken | Waste Site | IRM Candidate | Remedial Action Taken |
|---|---|---|---|---|---|
| 116-B-10 Dry Well | Yes | Yes | 132-B-4 Filter Building | Yes | No |
| 116-B-11 Retention Basin | Yes | Yes | 132-B-5 Gas Recirculation Facility | Yes | No |
| 116-B-12 Crib | Yes | Yes | 132-B-6 Outfall Structure | Yes | Yes |
| 116-B-13 South Sludge Burial Trench | Yes | Yes | 132-C-1 Reactor Exhaust Stack Site | Yes | No |
| 116-B-14 North Sludge Burial Trench | Yes | Yes | 132-C-2 Outfall Structure | Yes | Yes |
| 100-B-8 Process Effluent Pipes | Yes | Yes | 132-C-3 117-C Filter Building | Yes | No |
| 100-C-6 Process Effluent Pipes | Yes | Yes | | | |
| Solid waste burial grounds: 118-B-1, 118-B-2, 118-B-3, 118-B-4, 118-B-5, 118-B-6, 118-B-7, 118-B-10, 118-C-1, 118-C-2 | | | | Yes | Yes, except 118-B-7 |

Six of the high-priority sites listed in Table 1-7 were selected for intrusive investigation using cable tool drilling of boreholes or backhoe excavation of test pits to support the LFI findings (Table 1-7). Additional LFI investigations included surface soil sampling in, and adjacent to, selected waste sites, and vadose zone soil/sediment collection from monitoring well boreholes outside of sites. Geophysical logging was also performed. Table 1-8 shows the vadose zone borehole and test pit sampling conducted at 100-BC under the LFI. Boreholes and test pits were decommissioned and backfilled.

**Table 1-8. Summary of 100-BC LFI Intrusive Vadose Zone Characterization within Selected Waste Sites**

| Waste Site | Number of Boreholes | Maximum Depth of Investigation | | Analyte List | |
|---|---|---|---|---|---|
| | | m | ft | | |
| 116-B-1 Trench | 1 | 8 | 27 | ICP/AA Metals<br>Mercury<br>VOC<br>SVOC<br>PCBs<br>Pesticides<br>Gross alpha<br>Gross beta<br>Tritium | Strontium-90<br>Technetium-99<br>Carbon-14<br>Alpha Spectroscopy<br>Total activity<br>Fluoride<br>Sulfate<br>Nitrate |
| 116-B-2 Trench | 1 | 7 | 23 | | |
| 116-B-3 Crib | 1 | 5 | 17 | | |
| 116-B-5 Crib | 1 | 5 | 17 | | |
| 116-C-5 Retention Basin | 1 | 6 | 20 | | |
| 116-C-2A Crib | 1 | 17 | 57 | | |

**Table 1-8. Summary of 100-BC LFI Intrusive Vadose Zone Characterization within Selected Waste Sites**

| Waste Site | Number of | Maximum Depth of Investigation | | Analyte List | |
|---|---|---|---|---|---|
| 116-C-1 Trench* | Test Pits (2) | 7 | 22 | Gamma Spectroscopy | Nitrite |

* Two test pits were excavated and sampled up to 22 ft bgs in 116-C-1 to collect material for bench-scale soil washing treatability tests. Samples were composited and divided into greater than, and less than, 2 mm size fractions prior to analysis and testing. Analytical results related to these test pit data were obtained from these samples.

ICP = inductively coupled plasma

The LFI report concluded that the radiological contamination of vadose zone soil was the primary concern. The following are the principal radionuclides detected in soil samples collected during the LFI:

- Americium-241
- Europium-154
- Strontium-90
- Carbon-14
- Plutonium-238
- Europium-152
- Cesium-137
- Plutonium-239
- Tritium
- Cobalt-60
- Uranium-238
- Uranium-233/234
- Thorium-228*
- Radium-226*

* These are naturally occurring radionuclides that were not increased by 100-BC processes.

The principal metals detected in soil samples during the LFI are chromium, barium, mercury, zinc, and iron. Volatile organic compounds (VOCs) and semivolatile organic compounds (SVOCs) detected in LFI samples include the following:

- benzo(k)fluoranthene
- fluoranthene
- di-n-butylphthalate*
- benzo(a)anthracene
- chrysene
- diethylphthalate*
- benzo(b)fluoranthene
- pentachlorophenol
- acetone*

* Commonly detected analytical laboratory contaminants and assumed not associated with 100-BC soil.

Contaminant concentrations and locations generally confirmed historical information documented in *Radiological Characterization of the Retired 100 Areas* (UNI-946). These waste sites represented worst-case conditions based on effluent volumes discharged, sample data, or both. Of the waste sites that were determined to be high priority and/or IRM candidates in the LFI, most are remediated and contaminated material disposed. Of those waste sites that were not remediated, site-specific evaluations of alternate decisions were documented and approved.

***Previous Studies and Treatability Tests.*** In April 1990, a treatability test using in situ vitrification (ISV) was conducted at the 116-B-6A Crib site. ISV is a thermal treatment process that converts contaminated soil into a chemically inert and stable glass and crystalline product (*In Situ Vitrification of a Mixed-Waste Contaminated Soil Site: The 116-B-6A Crib at Hanford* [PNL-8281]). This test was a technology demonstration to determine the feasibility of the technology, rather than a remedial action to stabilize waste. The ISV melt at this site reached 4.3 m (14 ft) bgs and produced a block of vitrified material

between 10.7 and 12.2 m (35 to 40 ft) in diameter, approximately 3.8 m (12 ft) high, and weighing between 726 and 816 metric tons (800 and 900 tons). Data indicated that the retention in the vitrified block of chromium, lead, and cesium-137 was greater than 99 percent. The vitrified material was removed during later remediation of the 116-B-6A/116-B-16 site and was disposed to the ERDF (*Cleanup Verification Package for the 116-B-6A Crib and 116-B-16 Fuel Examination Tank* [CVP-99-00011]). Further treatment using ISV has not been performed.

Remediation alternatives were developed and screened in 1993 in the *100 Area Feasibility Study Phases 1 and 2* (DOE/RL-92-11). As a result, a need for treatability data was identified. The *Treatability Study Program Plan* (DOE/RL-92-48) outlined the treatability studies to support remediation, including the 118-B-1 Solid Waste Burial Ground treatability study (*118-B-1 Excavation Treatability Test Plan* [DOE/RL-94-43]). The excavation treatability test plan outlined procedures for selecting trenches for excavation, data collection, overburden removal and stockpiling, and trench closure. During the treatability study, approximately 1,529 $m^3$ (2,000 $yd^3$) of waste was excavated and then returned to the 118-B-1 Burial Ground (*118-B-1 Burial Ground Excavation Treatability Test Report* [DOE/RL-95-34]). During the study, excavation methods, material identification, and material handling methods were tested and observations noted on the expected versus the actual materials in the trench and the actual trench size. Test pit excavation locations were selected based on geophysical survey results (*Geophysical Investigation of the 118-B-1 Burial Grounds, 100 B/C Area, Hanford Site, Washington* [WHC-SD-EN-TI-137]). Using these surveys to guide excavation provided positive results for identifying waste anomalies and excavation boundaries in a few locations. It was also determined that only one of the three proposed excavation approaches was feasible and safe.

***Waste Site Remediation.*** Initial remediation of vadose zone waste sites at 100-BC began in 1995 under the 100-BC Demonstration Project and 116-C-1 Investigation. The 100-BC Demonstration Project was planned for initiating remedial action in the 100 Area and addressing uncertainties in remedial design and remedial action identified by the Tri-Parties (*100-B/C Demonstration Project Final Report* [BHI-00752]). An expedited limited remedial action was initiated for the 116-B-4, 116-B-5, and 116-C-1 waste sites to commence remediation and address uncertainties. Remediation at these three sites was ultimately completed under the *Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington* (EPA/ROD/R10-95/126), including significant additional investigation performed at the 116-C-1 waste site.

The 116-C-1 Process Effluent Trench received an estimated 700 million liters (184 million gallons) of contaminated cooling water during its operation in addition to 40 billion liters (10.6 billion gallons) of high-temperature reactor cooling water in 1967 over a 150-day period. After remediation of the trench, eight contaminated soil plumes extending beyond the 116-C-1 engineered structure were identified during the subsequent field screening and sampling efforts. After the soil plume remedial excavation was completed, a 7.3 m (24 ft) test pit was excavated from the bottom of the excavation (approximately 5.0 m [16 ft] bgs) to groundwater (approximately 13.0 m [43 ft] bgs) to further characterize the subsurface (*Cleanup Verification Package for the 116-C-1 Process Effluent Trench* [CVP-98-00006]).

The test pit was centered at an area of elevated activity (identified by radionuclide field surveys) near the 116-C-1 inlet pipes. For each of the eight, 1 m (3 ft) test pit lifts, soil was obtained from each quadrant of the test pit and composited to create the sample. Results from eight test pit sample depths showed elevated radionuclide and metal concentrations continued through the first three to five lifts from 1.8 to 4.6 m (6 to 15 ft) below the existing excavation floor, at a total depth of 6.7 to 9.4 m (22 to 31 ft) bgs. The samples collected from lower lifts showed a significant decrease in concentration with increasing depth for all analytes.

This preliminary remediation evolved into formal remediation under subsequent interim action RODs (*Interim Remedial Action Record of Decision for the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington* [EPA/ROD/R10-95/126]; 100 Area Remaining Sites ROD [EPA/ROD/R10-99/039]; 100 Area Burial Grounds ROD [EPA/ROD/R10-00/121]). These interim remediation activities consist mainly of removal, treatment (as necessary), and disposal of contaminated soil, debris, and other waste material, plus backfilling and revegetating excavated areas. Approximately 1.19 million metric tons (1.31 million U.S. tons) of contaminated soil and debris have been removed from 100-BC by interim remedial actions and primarily disposed at the ERDF. Following remediation of a waste site, the remaining underlying soil is sampled, analyzed, and the data evaluated to assess the risks associated with residual contamination. Waste site sample results evaluation to date has verified that the interim remediation objectives and goals were met, thus ensuring the protection of HHE. Waste site remediation at 100-BC will continue until final remedies are selected and implemented.

***Waste Sites Status Summary.*** Table 1-9 summarizes the classification/reclassification status of 100-BC waste sites as of June 2012. These consist mainly of inactive past-practice waste sites described as trenches, ditches, cribs, ponds, French drains, burial grounds, and unplanned releases. Waste sites are listed by name under their assigned classification/reclassification status for the 100-BC-1 OU in Table 1-10 and for the 100-BC-2 OU in Table 1-11. Appendix A provides maps of the waste site locations.

**Table 1-9. Summary Information on 100-BC Sites (June 2012)**

| Operable Unit | Total Number of Sites[a] | Closed Out[b] | Interim Closed Out[c] | No Action[d] | Not Accepted[e] | Accepted[f] | Discovery[g] | Rejected[h] |
|---|---|---|---|---|---|---|---|---|
| 100-BC-1 | 93 | 2 | 47 | 22 | 6 | 8 | 0 | 8 |
| 100-BC-2 | 47 | 0 | 32 | 4 | 6 | 3 | 0 | 2 |
| **Total 100-B/C** | **140** | **2** | **79** | **26** | **12** | **10** | **1** | **10** |

a. Summary metrics are based on accounting for subsites as individual sites.

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

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

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

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

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

g. Discovery—An initial classification status indicating evidence of a potential waste site; assessments not yet complete. This is the classification of a newly discovered WIDS site.

h. Rejected—A reclassification status indicating a waste site does not require remediation under CERCLA based on qualitative information such as a review of historical records, photographs, drawings, walk downs, GPR scans, and shallow test pits. Such investigations do not include quantitative measurements.

1

**Table 1-10. Classification/Reclassification Status of 100-BC-1 Waste Sites (June 2012)**

| Status | Waste Sites | Totals |
|---|---|---|
| Closed Out | 1607-B3, 1607-B4 | 2 |
| Interim Closed Out | 100-B-5, 100-B-8:1, 100-B-8:2 100-B-12, 100-B-14:1, 100-B-14:2, 100-B-16, 100-B-18, 100-B-19, 100-B-20, 100-B-21:2, 100-B-21:3, 100-B-21:4, 100-B-22:2, 100-B-25, 100-B-27, 100-B-28, 100-B-32, 100-B-33, 116-B-1, 116-B-2, 116-B-3, 116-B-4, 116-B-5, 116-B-6A, 116-B-6B, 116-B-7, 116-B-9, 116-B-10, 116-B-11, 116-B-12, 116-B-13, 116-B-14, 116-B-16, 118-B-5, 118-B-10, 120-B-1, 126-B-3, 128-B-2, 128-B-3, 132-B-6, 1607-B2:1, 1607-B2:2, 1607-B7, 116-C-1, 116-C-5, 132-C-2 | 47 |
| No Action | 100-B-2, 100-B-3, 100-B-10, 100-B-11, 100-B-14:3, 100-B-14:4, 100-B-14:5, 100-B-14:6, 100-B-14:7, 100-B-21:1, 100-B-22:1, 100-B-24, 100-B-26, 116-B-15, 118-B-9, 126-B-2, 132-B-1, 132-B-3, 132-B-4, 132-B-5, 1607-B1, 600-230 | 22 |
| Not Accepted | 100-B-4, 100-B-7, 100-B-29, 128-B-1, 600-231, 600-253 | 6 |
| Accepted | 100-B-15, 100-B-34, 118-B-8:1, 118-B-8:2, 118-B-8:3, 132-B-2, 1607-B5, 1607-B6 | 8 |
| Discovery | None | 0 |
| Rejected | 100-B-17, 118-B-7, 126-B-1, 126-B-4, 600-34, 600-56, 600-67, 600-264 | 8 |

2

**Table 1-11. Classification/Reclassification Status of 100-BC-2 OU Waste Sites (June 2012)**

| Status | Waste Sites | Totals |
|---|---|---|
| Closed Out | None | 0 |
| Interim Closed Out | 100-B-1, 100-B-23, 100-B-31, 118-B-1, 118-B-2, 118-B-3, 118-B-4, 118-B-6, 1607-B8, 1607-B9, 1607-B10, 1607-B11, 100-C-3, 100-C-6:1, 100-C-6:2, 100-C-6:3, 100-C-6:4, 100-C-9:1, 100-C-9:2, 116-C-2A, 116-C-2B, 116-C-2C, 116-C-3, 116-C-6, 118-C-1, 118-C-2, 118-C-3:2, 118-C-3:3, 118-C-4, 128-C-1, 600-232, 600-233 | 32 |
| No Action | 100-C-9:3, 100-C-9:4, 132-C-1, 132-C-3 | 4 |
| Not Accepted | 100-B-30, 100-C-2, 100-C-4, 100-C-5, 124-C-4, 600-252 | 6 |
| Accepted | 100-C-7, 100-C-7:1, 118-C-3:1 | 3 |
| Discovery | None | 0 |
| Rejected | 100-C-8, 600-33 | 2 |

3 ***Interim Remedial Actions.*** Remediation began under the *Interim Remedial Action Record of Decision for*
4 *the 100-BC-1, 100-DR-1, and 100-HR-1 Operable Units, Hanford Site, Benton County, Washington*
5 (EPA/ROD/R10-95/126). Remediation and characterization of the burial grounds and "remaining sites"
6 was initiated later under the respective interim action RODs (100 Area Burial Grounds ROD

[EPA/ROD/R10-00/121] and 100 Area Remaining Sites ROD [EPA/ROD/R10-99/039]). These interim remediation activities consist mainly of removal, treatment, and disposal (RTD) (as necessary), of contaminated soil, debris, and other waste material, plus backfilling and revegetating excavated areas. Remediation waste has been primarily disposed of at the ERDF. Characterization is included as a component of waste site remediation and consists primarily of sample collection and analysis to assess the nature and extent of contamination, guide remediation decision making, and verify achievement of interim RAOs.

Radioactive liquid effluent waste sites were targeted first by interim remediations as primary contributors to contamination at 100-BC. Field data from previous investigations indicated that contaminant concentrations at high-volume liquid waste disposal sites (for example, lead, cesium-137, and plutonium-239/240) were highest at the bottom of the former disposal facility and generally decreased with depth in underlying soil. Waste sites that received small amounts of liquid were generally found to contain soil contamination extending limited distances into the vadose zone beneath the waste sites. Figure 1-14 shows the primary liquid waste disposal sites during interim remediation. Table 1-12 and Figure 1-15 identify all of the liquid effluent waste sites targeted by initial remedial actions at 100-BC. Most of these high-priority liquid waste sites in 100-BC were remediated by 2004, followed by the remediation of burial grounds and other remaining site types.

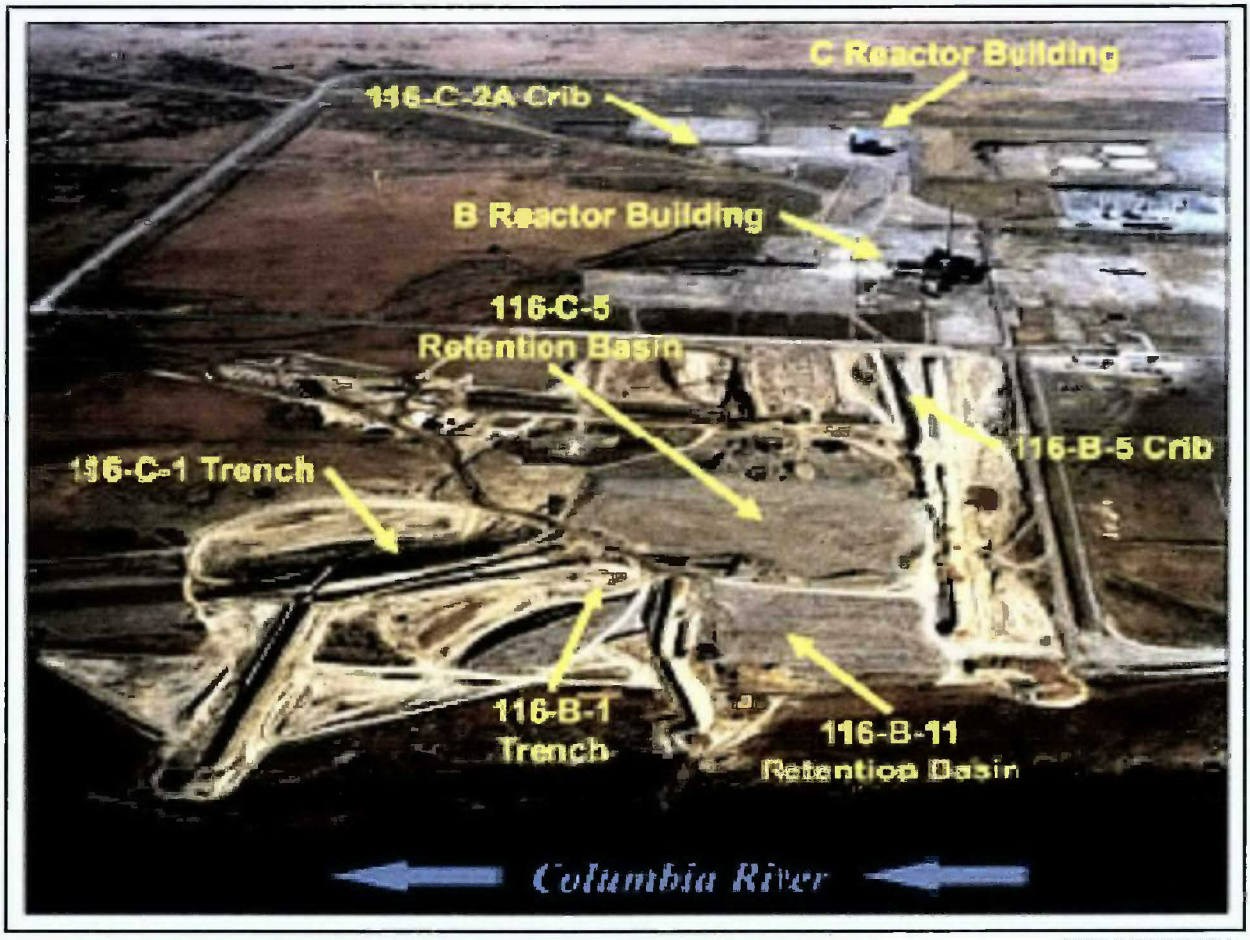


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**Figure 1-14. Southern View of 100-BC Showing Primary Liquid Waste Disposal Features (April 2002)**

**Table 1-12. 100-BC High-Priority Radioactive Liquid Effluent Disposal Sites**

| Site Code | Description |
|---|---|
| 100-B-8 | The 105-B Reactor Effluent Pipelines. |
| 116-B-1 | Liquid waste disposal trench that received effluent routed from the 107-B Retention Basin. |
| 116-B-2 | Trench was used to receive 4.16 million L (1.1 million gal) of storage basin water that had been contaminated when a fuel rod was accidentally cut in half in the 105-B FSB. |
| 116-B-3 | Wooden pluto crib received 105-B cooling water wastes that had been contaminated by cladding ruptures of fuel elements. |
| 116-B-4 | Crib received spent acid and rinse water from the 105-B DDF (fuel element spacers and reactor hardware). |
| 116-B-5 | Crib received liquid wastes from the 108-B Building. |
| 116-B-6A | Crib received radioactive liquid wastes from fuel element spacer decontamination, and equipment decontamination performed in the 111-B Building. |
| 116-B-6B | Crib received radioactive liquid wastes from fuel element spacer decontamination, and equipment decontamination performed in the 111-B Building. |
| 116-B-9 | French drain received wastewater from the P-10 Storage Building drain. |
| 116-B-10 | Quench tank was used to collect liquid decontamination wastes from the 108-B Tube Examination and Experimental Facility. |
| 116-B-11 | 107-B Retention Basin that was used to hold the 105-B Reactor cooling water effluent to allow for thermal cooling and radioactive decay prior to release to the Columbia River. |
| 116-B-12 | Crib received drainage from the confinement system in the 117-B Building seal pits. |
| 116-B-13 | Trench received low-level sludge waste from the bottom of the 107-B Retention Basin. |
| 116-B-14 | Trench received low-level sludge waste from the bottom of the 107-B Retention Basin. |
| 100-C-6 | Pipelines include the 105-C Reactor cooling water effluent pipelines. |
| 116-C-1 | Trench received effluent overflow from the 107-C Retention Basin during reactor outages because of ruptured fuel elements. |
| 116-C-2A/B/C | 105-C Pluto Crib (116-C-2A) and associated lift station and sand filter. |
| 116-C-5 | 107-C Retention Basins that received cooling water effluent from the 105-B and 105-C Reactors for radioactive decay and thermal cooling prior to release to the Columbia River. |

Notes: Based on the Radioactive Liquid Effluent Waste Sites Interim Action ROD (*Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 100-FR-1, 100-FR-2, 100-HR-1, 100-HR-2, 100-KR-1, 100-KR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)* [EPA/ROD/R10-99/039]).

Under the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039), not all waste sites were identified as requiring remediation. Sites for which a remedial action determination could not be made at the time of ROD issuance were termed as "candidate sites" or "confirmatory sites" under the interim action framework. A process was established whereby these sites and any future newly discovered waste sites could undergo confirmatory evaluation to determine if remedial action was warranted. If required, those

sites were then remediated under the existing RTD remedy using a "plug-in" mechanism established in the 100 Area Remaining Sites ROD (EPA/ROD/R10-99/039). Application of the plug-in remedy mechanism for candidate sites and new waste sites is documented in subsequent explanations of significant difference (ESDs) and annual fact sheets.

All waste sites considered for interim remedial action or evaluation, with the exception of 100-C-7 and 1607-B5, had been remediated and/or characterized and dispositioned according to the applicable interim action ROD and TPA-MP-14. The 100-C-7 waste site, including the 100-C-7:1 subsite, is currently under active remediation. The 1607-B5 septic system is overlain by active utilities for the 181-B Pumphouse.

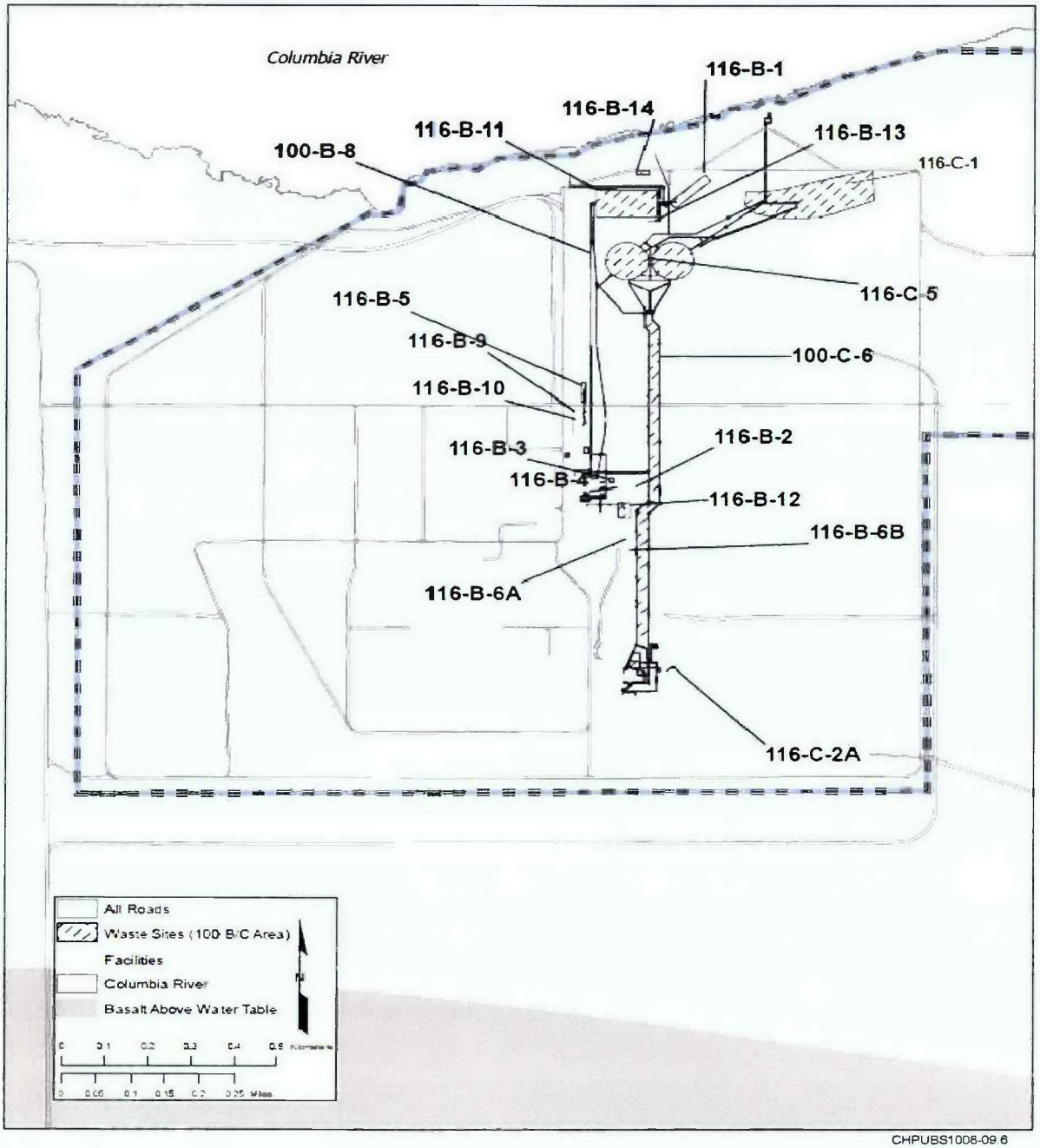


**Figure 1-15. 100-BC High-Priority Radioactive Liquid Effluent Disposal Sites**

***Waste Site Cleanup Documentation.*** Following completion of the interim remedial actions at a waste site in accordance with the applicable interim action ROD, a cleanup document is prepared. This document contains verification information that the attainment of interim remedial action goals (RAGs) and interim RAOs have been achieved. These RAOs are contained in the interim action RODs listed in Table 1-3. This documentation usually includes a description of the interim remedial action conducted, sampling results, disposal information, and a chronology of events.

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

***Waste Site Consideration in the RI/FS.*** All 100-BC waste sites were considered in this RI/FS process to determine if site conditions are protective of HHE. Although the unique factors of each site were considered individually, the process can be described generally based on waste site classification/reclassification status:

- Sites with a "closed out" status were reviewed to confirm that this determination has been made under appropriate regulatory authority. Where a closed out status was appropriate, no further review of site information was performed, and the site was not considered further within the RI/FS process.

- Sites with a "rejected" or "not accepted" status were reviewed to determine whether new information was available that contradicts the existing documented basis for rejection or non-acceptance. Where the existing classification/reclassification was appropriate, the site was not considered further within the RI/FS process. Those sites where the existing classification/reclassification was determined to be potentially inappropriate will be addressed further within the RI/FS process. The existing determinations are documented for each site in accordance with *Tri-Party Agreement Handbook Management Procedures*, Guideline Number TPA-MP-14, "Maintenance of the Waste Information Data System (WIDS)" (RL-TPA-90-0001).

- Sites with a "no action" or "interim closed" reclassification status, based on confirmatory and/or verification data, are considered within the overall RI and have been quantitatively evaluated against preliminary remediation goals (PRGs), as described in Chapters 5, 6, and 7. Sites with a no action or interim closed reclassification, with a basis other than direct data (for example, historical decommissioning data), were considered on a site-by-site basis.

- Few sites with no reclassification beyond "accepted" status remain at 100-BC. However, these sites are addressed in one of two general ways:

  - Sites where an interim remedial action requirement has been identified in interim decision documents, but for which interim remedial action has not yet been completed (via an approved waste site reclassification). These sites (100-C-7, 100-C-7:1, and 1607-B5) were considered within the RI from the standpoint that a remedial action determination has already been made. Further consideration is based on the expectation for how complete interim remedial actions will be at the time of issuance of a ROD.

- "Accepted" sites with unique considerations. These sites (100-B-15, 100-B-34, 118-B-8:1, 118-B-8:2, 118-B-8:3, 118-C-3:1, 132-B-2, and 1607-B6) are considered individually on a site-by-site basis.

- Any new discovery sites will be addressed through an appropriate CERCLA decision.

Subsites were considered individually, because different subsites within a parent site may have subsite-specific circumstances that distinguish how they are handled through the RI/FS process. Metrics reported for "sites" in this document generally account for subsites rather than parent waste sites alone. For example, 100-B-21:1, 100-B-21:2, 100-B-21:3, and 100-B-21:4 are accounted for as four sites rather than one waste site. The current classification/reclassification statuses for 100-BC sites are summarized in Tables 1-9 and 1-10.

***Waste Sites Requiring No Further Consideration at 100-BC.*** Waste sites with a "closed out," "rejected," or "not accepted" classification/reclassification status were reconsidered to determine if there was an existing adequate basis for this determination because these have final classification/reclassification status. Those sites for which the existing basis was sufficient will not be addressed further in this RI/FS process, and are identified in Table 1-13. In addition to these sites, some sites with interim classification/reclassification statuses and site-specific factors will not be addressed further in this RI/FS process. These sites are also listed in Table 1-13, with additional explanation provided below. However, all 100-BC waste sites identified in Appendix C of the *Hanford Federal Facility Agreement and Consent Order Action Plan* (hereinafter called Tri-Party Agreement Action Plan [Ecology et al., 1989b]) will be included in a ROD for the final remedy decision to be documented, even if no further remedial activities are needed.

**Table 1-13. 100-BC Sites That are Not Considered Further in the RI/FS**

| Classification/ Reclassification Status | Waste Sites |
|---|---|
| Closed Out | 1607-B3, 1607-B4 |
| Rejected | 100-B-17, 118-B-7[a], 126-B-1, 126-B-4, 100-C-8, 600-33, 600-34, 600-56, 600-67, 600-264 |
| Not Accepted | 100-B-4, 100-B-7, 100-B-29, 100-B-30, 128-B-1, 100-C-2, 100-C-4, 100-C-5, 124-C-4, 600-231, 600-252, 600-253 |
| Accepted | 1607-B6, 118-C-3:1 |
| No action | 100-B-2, 100-B-3, 100-B-10, 100-B-14:4, 100-B-21:1, 100-B-24, 126-B-2, 600-230 |
| Interim Closed Out | 100-B-12 |

Notes:

a. The 118-B-7 waste site was reclassified as rejected based on the absence of any burial ground solid wastes in exploratory excavations made at potential locations of the suspect burial ground. However, soil samples collected from these exploratory excavations have been considered in the soil risk evaluations in subsequent chapters.

***1607-B3 & 1607-B4.*** These sites are septic systems that have been abandoned in place per "Wastewater and Reclaimed Water Use Fees" (WAC 246-272) requirements and reclassified as closed out per TPA-MP-14 (RL-TPA-90-0001).

***100-B-17, 118-B-7, 126-B-1 126-B-4, 100-C-8, 600-33, 600-34, 600-56, 600-67, and 600-264.*** These sites have been reclassified as rejected in accordance with TPA-MP-14 (RL-TPA-90-001).

***100-B-4, 100-B-7, 100-B-29, 100-B-30, 128-B-1, 100-C-2, 100-C-4, 100-C-5, 124-C-4, 600-231, 600-252, and 600-253.*** These sites were not accepted as waste sites at the discovery phase of TPA-MP-14 (RL-TPA-90-001). No new or conflicting information was identified to suggest that these sites should be reconsidered as waste management units.

***100-B-2.*** The 100-B-2, 181-B Backwash Trench, site started operation in 1975, to receive backwash filter backflush from the 181-B Pump House. The trench was fed by a single 30 cm (12 in.) diameter pipeline that originated at the backwash filter. The pipe is approximately 0.9 m (3 ft) below grade and enters the trench from the west. This site previously was reclassified as "no action," based on a qualitative determination that no hazardous or radioactive contaminants were included in the filter backwash process. This determination remains appropriate for final remedy purposes.

***100-B-3.*** At the 100-B-3, Hot Thimble Burial Ground, original documentation explained that a radioactively contaminated vertical control rod thimble was buried in 1952, and removed before 1956. Any contamination remaining at the site when the thimble was removed was short-lived radionuclides and would have since decayed. A geophysical survey showed no evidence of a buried thimble or the conclusive location of an old burial site. The site reclassification to "no action" is appropriate for final remedy purposes

***100-B-10.*** The 100-B-10, 107-B Basin Leak and Warm Springs site, was created to address a warm spring reported below the 116-B-11, 107-B Retention Basin in February 1949. Although wastes were not disposed or spilled, groundwater potentially contaminated from the 116-B-11 Retention Basin emerged from the riverbank at this site. This spring no longer exists, and the precise location of the former spring is undocumented. The site was previously reclassified as "no action" based on the remediation of the 116 B-11 waste site and associated plumes. This site will not be addressed further separately from the 116-B-11 waste site and the 100-BC-5 Groundwater OU.

***100-B-12.*** The 100-B-12, Filter Box Radiological Materials Area (RMA), consisted of legacy waste residing within a RMA. The RMA contained filters in four metal boxes that rested on shoring on bare soil, and an additional six filter frames, labeled as having fixed contamination, resting directly on the soil. All waste materials were removed and disposed to the ERDF. Radiological surveys completed after the removal met the requirements for downposting the RMA. This site was reclassified as "interim closed out" and will not be considered further in the RI/FS based on complete removal of the waste forms.

***100-B-14:4.*** The 100-B-14:4 subsite consists of former pipelines in underground tunnels between the 190-B Pump House and the 105-B Reactor. These pipelines were removed and the tunnels collapsed in 1993, during deactivation and decommissioning of the 190-B Pump House. No history of radiological contamination is associated with the cooling water tunnels and contamination was not detected during tunnel decommissioning. The site was reclassified to "no action" based on prior removal of the pipelines and absence of any known releases. This determination remains appropriate for final remedy purposes.

***100-B-21:1.*** The 100-B-21:1 subsite consists of two pipeline segments discovered during remediation of other waste sites. This subsite was previously reclassified as "no action" based on process knowledge that the pipelines were not associated with any known hazardous waste processes. Since that determination, one of the pipelines was incidentally removed during remediation of the 100-B-21:3 subsite, and the remaining pipeline was determined to connect to a known service water supply pipeline in the (not accepted) 100-C-5 site. The 100-B-21:3 subsite is considered further within this RI/FS, but the remaining

100-B-21:1 pipeline will not be considered further on the basis that it is part of the former service water pipeline network.

***100-B-24.*** The 100-B-24, 1904-B1 Spillway (Flume), was an alternate potential discharge location for the 116-B-7 (1904-B1) Outfall Structure. The site was reclassified as "no action" based on samples collected from concrete in the flume, which showed only trace radionuclide concentrations and metals concentrations inherent to the concrete matrix.

***126-B-2.*** The 126-B-2, 183-B Clearwells, consists of two intact underground concrete reservoirs, or clearwells. The clearwells are separated in the center by the remains of a demolished pump room. Based on process knowledge, historical documents, historical drawings, and site visits, the clearwells were determined not to be a potential source of contamination and were reclassified as "no action." This determination remains appropriate for final remedy purposes.

***1607-B6.*** The 1607-B6 Septic Tank System is located south of the 182-B Reservoir and Pump House and is currently in active use. Following cessation of use, this system will be abandoned in accordance with WAC 246, Department of Health, requirements. This site need not be addressed further under the CERCLA RI/FS process.

***118-C-3:1.*** The 118-C-3:1 subsite addresses the remaining safe storage enclosure and is discussed further in Section 1.2.4.1.

***600-230.*** The 600-230 Dumping Area is located near the edge of the upper terrace above the Columbia River. The debris consists primarily of household items, some of which had fallen or been windblown down slope. A cultural resource review concluded that the site was the result of pre-Manhattan Project dumping activities. The site was reclassified as "no action" after removal of the only noted suspect hazardous material, a single battery. This "no action" determination based on the absence of remaining potentially hazardous solid waste remains appropriate for final remedy purposes.

***100-BC Waste Sites with Potentially Inadequate Existing Reclassification Basis.*** The review of existing information for all sites identified one site with unique factors that warrant further consideration through the RI/FS process:

- ***100-B-22:1.*** The 100-B-22:1 subsite consists of pipelines that formerly carried treated process water from the 183-B to 185/190-B facilities. This subsite was previously reclassified on the basis that the pipelines were used only to transport raw and treated water prior to sodium dichromate addition. However, it is now believed that modifications to the 100-B water treatment train over its operational lifetime would result in sodium-dichromate-treated cooling water being transported in some of these pipelines for some time. To address this possibility, this site will be considered for future reinvestigation as a candidate for remediation under the ROD, and is addressed in the FS.

***Nonoperational Area Evaluation.*** The majority of waste sites are geographically located proximate to decommissioned reactors along the Columbia River. The majority of the River Corridor Area shows little or no indication of past or present releases of hazardous constituent(s) between the reactor areas and the Hanford Site Central Plateau, also called the nonoperational area.

Numerous existing environmental surveillance and monitoring programs have been conducted at the Hanford Site to monitor operational practices and facilities, and to identify potential, new waste sites for inclusion into the established site discovery process. Environmental sampling and analytical data have been collected during these environmental programs, and as part of CERCLA remedial response activities. These datasets are useful for better informing decision makers about conditions in the

nonoperational areas. These environmental datasets are being reviewed and analyzed to determine whether Hanford Site practices have affected this nonoperational area.

The nonoperational evaluation considers transport mechanisms, physical features, and climate conditions that could influence transport, and used surface and near surface information from a number of available sources:

- Orphan site evaluations (OSEs)
- Air emissions reports
- Environmental monitoring programs
- Statistical modeling

Appendix L describes the nonoperational evaluation process for the River Corridor, data and information used, and conclusions and recommendations. It also includes specific results and conclusions for 100-BC. The nonoperational evaluation components are presented below:

- **Orphan Site Evaluation.** OSE is a program that has been designed primarily to support cleanup and long-term stewardship activities in the River Corridor. The purpose of the OSE process is to increase confidence that features and potential waste releases outside of previously established waste sites have been identified and appropriately considered for additional investigation, remediation, restoration, or stewardship tracking. Review of historical records and imagery, combined with on-the-ground walkdowns and field investigations, provide a comprehensive evaluation of current conditions in nonoperational areas. Results from these activities are reviewed with DOE-RL and EPA. Potential "orphan" waste sites are evaluated under the TPA-MP-14 (RL-TPA-90-0001) discovery site process.

  An OSE (*100-BC Area Orphan Sites Evaluation Report* [OSR-2007-0001]) was initiated for 100-BC in April 2004. A historical review and field walkdown of 100-BC was conducted. The resulting data were compiled and evaluated by DOE and EPA, and new waste sites were established through the TPA-MP-14 discovery site process.

  The historical review included examining the construction, operation, D&D, and remedial action activities conducted in the area from 1943 to 2004. This included reviewing and evaluating reports, drawings, and photographs relevant to those activities. The initial 2004 field walkdown was supplemented during 2009 to cover 100-BC, a total of 11.54 $km^2$ (4.45 $mi^2$). Global positioning system (GPS) technology has been used to define the locations of artificial features, and these locations were digitally photographed. For select sites, GPR was also employed. Figure 1-16 presents the areas covered in the field walkdowns.

  The historical review identified five new waste sites, while the field walkdown identified three new waste sites and modified an existing waste site. The GPR activities identified one new waste site. All of these waste sites are considered within the totality of 100-BC-1 and 100-BC-2 waste sites addressed in this document. A number of sites were also identified for miscellaneous restoration or stewardship tracking, including railroad tracks, underground electrical cables, and active facilities such as the 151-B Substation and the Hanford Water Transport System (181-B River Pump House, 182-B Reservoir, and associated piping).

- **Air Emissions Reports.** Two groups of sources of Hanford Site stack air emissions had the potential to impact the River Corridor by air deposition. The first source group, where most of the Hanford Site stack air emissions occurred between 1944 and 1972, were the facilities in the 200 Area that separated plutonium and uranium from irradiated reactor fuel. The second source group, the nine production nuclear reactors in the 100 Area, had stacks to exhaust ventilation air from the working areas of the reactor facilities. These were minor sources of emissions compared to the 200 Area facilities that

separated plutonium and uranium from irradiated reactor fuel (*RCBRA Stack Air Emissions Deposition Scoping Document* [DOE/RL-2005-49]). Aerial radiation surveys of the Hanford Site and widespread sampling over many years support this conclusion (*An Aerial Radiological Survey of the Hanford Site and Surrounding Area, Richland, Washington* [EGG-10617-1062]).

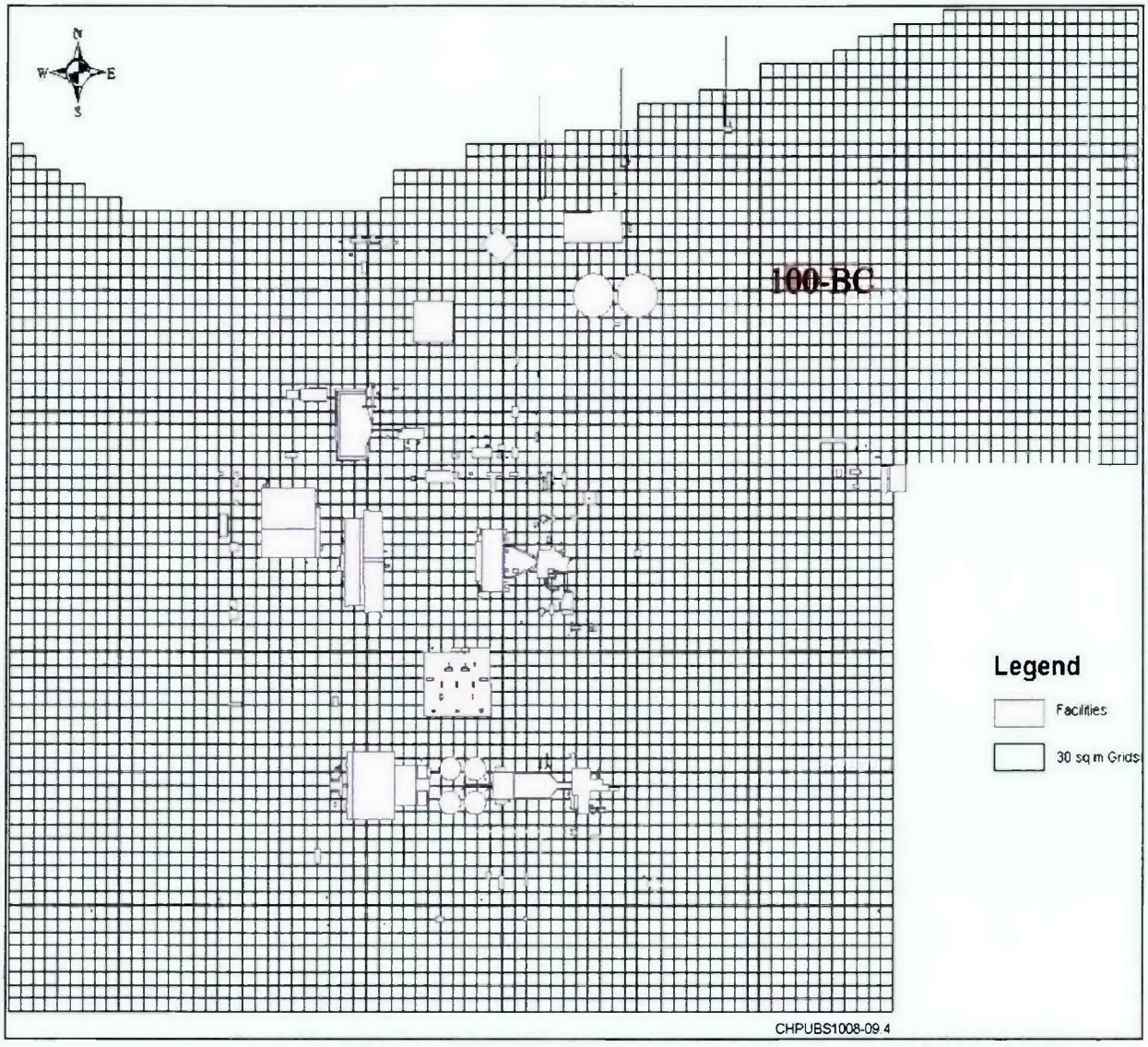


**Figure 1-16. Area Addressed by 100-BC Orphan Sites Evaluation Process**

- **Environmental Monitoring Programs.** Data from ongoing monitoring programs were also used as described in Appendix L. A number of these programs are described in Chapter 2, in sections discussing Contaminant Source Investigations and Ecological Investigations. Surveillance and monitoring programs, in combination with the OSE, have comprehensively identified all waste sites within 100-BC. In addition, the surveillance and monitoring programs have demonstrated that emissions to the air either from windblown dust or from stack emissions have not impacted nonoperational area soils with radionuclides. The surveillance and monitoring programs also have verified that biointrusion has not resulted in a spread of contamination into the nonoperational areas.

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

#### 1.2.3.3 Previous Groundwater Investigations and Remediation

There are no ongoing interim actions under CERCLA for groundwater remediation in the 100-B/C Area. Groundwater monitoring projects are established under *General Environmental Protection Program* (DOE Order 5400.1 Chg 1) to meet the requirements of *Radiation Protection of the Public and the Environment* (DOE Order 5400.5 Chg 2), which pertains to the radiation protection of the public and the environment, and federal and state regulations. The Tri-Party Agreement (Ecology et al., 1989a) is a legally binding document that is used to coordinate groundwater protection and remedial action efforts.

The earliest groundwater monitoring wells in 100-BC were installed in 1948 and 1949. Additional wells were installed in the 1990s to the present:

- Between 1948 and 1962, eight wells were installed at 100-BC. The deepest well (199-B3-2) was drilled to 241 m (790 ft) bgs. This is the only well at 100-BC to fully penetrate the suprabasalt sediments. The other wells monitor the unconfined aquifer. Four of the wells are still in use; the others have been decommissioned.

- In 1990, three monitoring wells (199-B4-5, 199-B4-6, and 199-B4-7) were installed to support an ISV test at waste site 116-B-6A (*In Situ Vitrification: Demonstrated Capabilities and Potential Applications* [PNL-SA-21706]). These wells still exist, but only 199-B4-7 is sampled routinely.

- Eleven monitoring wells were installed in 1992 for CERCLA investigations (100-BC-5 LFI [DOE/RL-93-37]). One of these wells (199-B2-12) monitors a water-producing zone in the Ringold Formation upper mud (RUM), and the others are screened at the top of the unconfined aquifer.

- Two boreholes were drilled in 2007 as part of an investigation of the 100-C-7 (including 100-C-7:1) waste site. These were completed as monitoring wells (199-B8-7 and 199-B8-8), which were decommissioned in 2010 to support waste site remediation.

- Four monitoring wells (199-B2-14, 199-B3-50, 199-B5-5, and 199-B5-6) were installed in 2009 and early 2010 in advance of the current RI/FS (*Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* [DOE/RL-2009-61]).

- Six monitoring wells were installed in 2010 as part of the current RI/FS (*Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study*, hereinafter called 100-BC SAP [DOE/RL-2009-44]).

Chapter 3 provides additional information about groundwater monitoring wells in 100-BC.

Eight 100-BC wells and several nearby wells in the 600 Area have data in the Hanford Environmental Information System (HEIS) from the 1950s or 1960s. The most commonly available data for the early decades

include water levels, gross beta, tritium, and nitrate. Beginning in 1987, samples from some wells were analyzed for more comprehensive constituent lists including metals, radionuclides, and volatile organics.

The current groundwater monitoring program is based on results of the data quality objectives (DQOs) process (*Data Quality Objectives Summary Report – Designing a Groundwater Monitoring and Assessment Network for the 100-BC-5 and 100-FR-3 Operable Units* [PNNL-14287]). The monitoring program is described in *100-BC-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-38), as amended by *Change Notice for Modifying Approved Documents/Workplans In Accordance with the Tri-Party Agreement Action Plan, Section 9.0, Documentation and Records: 100-BC-5 Operable Unit Sampling and Analysis Plan, DOE/RL-2003-38 Rev 1 (as modified by TPA-CN-240, 12/08/2008)* (TPA-CN-293). New wells are sampled quarterly and older wells typically are sampled annually to biennially, depending on location. Groundwater data are used to create maps and plots that illustrate groundwater flow, water table elevations, hydrogeochemistry, and contaminant concentration trends and distribution. The results are published in the annual Hanford Site groundwater monitoring report (for example, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* [DOE/RL-2010-11]). Chapter 4 summarizes recent results of groundwater monitoring.

***Historical Groundwater Monitoring Results.*** The following paragraphs compare current levels of groundwater contaminants (Cr(VI), strontium-90, and tritium) to conditions in 1992, the year most of the wells were installed. A paucity of wells before 1992 precludes mapping contaminant plumes for earlier years.

In calendar year 2009, the Cr(VI) plume in the upper portion of the aquifer, as defined by the 20 µg/L contour, had an area of 0.91 km2 (0.35 mi2). Average concentrations in 1992 were below 20 µg/L except in two wells: 199-B5-1 in western 100-BC (22.8 µg/L), and 199-B4-5 in eastern 100-BC (35.8 µg/L). Chromium concentrations increased through the 1990s in wells in eastern and northeastern 100-BC. Between 2007 and 2009, the estimated area of the Cr(VI) plume has grown from 0.82 to 0.91 km2 (0.32 to 0.35 mi2). However, most of the apparent change is a result of better definition of the plume as new wells were installed, not actual plume growth.

The area of the strontium-90 plume, as defined by the 8 pCi/L contour, did not change noticeably between 1992 and 2009, with a plume area of 0.63 $km^2$ (0.24 $mi^2$). The southern boundary of the plume is southeast of the B Reactor, and the plume extends to wells near the Columbia River. The western and eastern boundaries of the plume were not well defined in 1992. The installation of aquifer tubes and additional monitoring wells has refined the boundaries of the plume. Maximum concentrations declined from 130 pCi/L in 1992 to 29 pCi/L in 2009.

Three tritium plumes in 100-BC had a total area of 0.23 $km^2$ (0.088 $mi^2$) in 2009, as defined by 20,000 pCi/L contours. However, the plumes were inferred from just three wells with concentrations above 20,000 pCi/L. In 1992, only one well had a tritium concentration above that level, but the location of one of the current plumes was unmonitored at that time. Tritium concentrations have varied by orders of magnitude in some 100-BC Wells.

***100-BC-5 Operable Unit Groundwater Limited Field Investigation.*** In 1992 and 1993, 100-BC monitoring wells were sampled for a comprehensive list of analytes as part of the 100-BC-5 LFI. Results are described in the 100-BC-5 LFI (DOE/RL-93-37). The LFI sampling identified the following analytes as COPCs for human health or ecological risks, with the maximum concentration detected shown:

- **VOCs and SVOCs**—Acetone (26 µg/L) (a common laboratory contaminant), trichloroethene (3 µg/L), and bis(2-ethylhexyl)phthalate (11 µg/L)

- **Inorganics and metals**—Aluminum (327 µg/L), iron (318 µg/L), and vanadium (17.8 µg/L)
- **Radionuclides**—Americium-241 (0.021 pCi/L), carbon-14 (110 pCi/L), gross beta (290 pCi/L), technetium-99 (130 pCi/L), uranium-233/234 (1.2 pCi/L), and uranium-238 (1.1 pCi/L)
- **Other analytes**—Ammonia (0.4 mg/L), chemical oxygen demand (30 mg/L), chloride (13.8 mg/L), sulfide (57.1 mg/L), total dissolved solids (283 mg/L), total organic carbon (10 mg/L), total organic halides (136 µg/L), and pH (8.3)

The LFI concluded that the only contaminants of concern (COCs) for groundwater were strontium-90 and tritium. However, at the time of the LFI, Cr(VI) was not included in the analyte list so it was not evaluated.

***Columbia River Studies.*** River Corridor studies involving groundwater (often referred to in this context as groundwater seeps, pore water or groundwater upwelling) that are pertinent to Columbia River water quality and ecological risk include the following:

- *Sampling and Analysis of 100 Area Springs* (DOE/RL-92-12)
- *Chromium in River Substrate Pore Water and Adjacent Groundwater: 100-D/DR Area, Hanford Site, Washington* (BHI-00778)
- *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling*, hereinafter called Columbia River RI Report (WCH-380)
- *Columbia River Component Risk Assessment, Volume I:Screening Level Ecological Risk Assessment and Volume II: Baseline Human Health Risk Assessment* (DOE/RL-2010-117)

The nature and extent of groundwater contaminants entering the Columbia River is of great interest, especially with regard to how it may affect water quality and aquatic plants and animals. Groundwater seeps (small water streams flowing across shoreline areas during low river stage periods) have been identified and studied in the 100 Areas (*Sampling and Analysis of 100 Area Springs* [DOE/RL-92-12]) and 300 Area. Pore water or groundwater upwelling (groundwater entering into the space between rocks and sediment of the riverbed) have also been studied in the 100 and 300 Areas. These upwelling areas have been identified using specific conductivity and/or water temperature data (riverbed locations with higher conductivities and/or warmer temperatures than the Columbia River water column are indicative of groundwater entering the bottom of the river), then subsequently characterized to determine contaminant concentrations in surface water, sediment, and pore water at those locations. Once identified, these upwelling areas can be revisited and sampled for contamination.

The first pore water (groundwater upwelling into the space between rocks and sediment of the riverbed) study in the Hanford Reach of the Columbia River was conducted in 1994 (*Chromium in River Substrate Pore Water and Adjacent Groundwater: 100-D/DR Area, Hanford Site, Washington* [BHI-00778]). It was designed to collect pore water quality/contaminant data for determining the potential exposure and risk to ecological receptors, particularly from Cr(VI) (*Preliminary Determination of Chromium Concentration Within Pore Water and Embryonic Chinook Salmon at Hanford Reach Spawning Area in Proximity to 100-HR-3 Operable Unit* [BHI-00156]). Embryonic Chinook salmon were selected as the target receptor for the study because during their early life stages (egg and sac-fry), they have limited mobility, spend most of their time within or near the river substrate, and thus could be exposed to Cr(VI) in pore water. The appropriate season for pore water sampling was determined to be Fall (during low river stage,

relatively high groundwater discharge to the river, and active salmon spawning). Salmon redds were identified by aerial surveys to establish when salmon spawning began and to determine locations where pore water samples should be collected for Cr(VI) analysis.

More recent surface water, pore water, and sediment studies were conducted in 2009 and 2010 by Washington Closure Hanford (WCH) in the River Corridor (Columbia River RI Report [WCH-380]). The sample locations for this investigation include sites adjacent to 100-K. Detailed results for the WCH study as they apply to 100-K are provided in Chapters 2 and 4 of this RI/FS.

#### *1.2.3.4 Risk Assessment*

Risk assessments have been conducted for the 100 Area to provide the foundation for establishing the need for remedial action to protect human health and the environment. Three key risk assessments, the QRAs performed in the early 1990s, the RCBRA, and the CRC are summarized below. The results of RCBRA and the CRC are described in more detail (and used) in Chapters 4, 6, and 7 of this RI/FS.

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

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

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

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

***Columbia River Component Risk Assessment.*** The CRC (DOE/RL-2010-117) provides a comprehensive HHRA and a screening-level ERA. The intent of the CRC HHRA was to complete the assessment of the "bank-to-bank" Hanford Reach and downstream areas (i.e., Lake Wallula) of the Columbia River, characterizing risk in areas not previously addressed under the RCBRA. Human exposure scenarios include an avid angler, casual user, hypothetical future resident, and a Native American (Yakama Nation) subsistence fisher. The CRC HHRA identifies fish consumption as the largest potential contribution to overall human health risks. The CRC also uses analytical chemistry collected from surface water, sediment, pore water, island soils, and fish to evaluate the potential for risk to ecological receptors including aquatic life living within the Columbia River and wildlife frequenting or inhabiting the islands within the river. Based on a screening level ERA, the CRC identifies some contaminants as contaminants of potential ecological concern (COPECs); mostly metals. The CRC further considered whether COPECs are attributable to Hanford Site-related sources. Conclusions from the CRC HHRA are discussed in Section 6.4.2 and the CRC ERA are reviewed in Section 7.5.2.

#### *1.2.3.5 Riparian and Nearshore Areas*

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

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

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

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

*Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River* (PNL-5289) identified riverbank springs and groundwater seeps along the length of the Hanford Site shoreline and presented for 100-BC analytical results for tritium detected in groundwater, riverbank springs, and adjacent surface water for samples collected in 1983. The highest concentrations of tritium were 4,770 pCi/L in groundwater, 5,900 pCi/L in springs, and 100 pCi/L in surface water.

In addition to these historical investigations, other sampling and analytical data have been collected from riparian and nearshore areas as part of the SESP. The data from the SESP are presented in Annual Environmental Reports for the Hanford Site (e.g., *Hanford Site Environmental Report for Calendar Year 2010*, hereinafter called the 2010 Sitewide Environmental Report [PNNL-20548]). Section 4.5 summarizes pertinent results from SESP sampling of riverbank springs at 100-BC.

Investigations of riparian and nearshore areas were conducted in support of the RCBRA. Riparian and nearshore areas were selected where affected media (seeps, springs, or runoff) may have created exposure pathways to biota (RCBRA SAP [DOE/RL-2005-42]). Riparian sampling locations also were identified based on radiation field survey results (RCBRA SAP [DOE/RL-2005-42], Appendix C; *DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* [BHI-01757], Appendix H).

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

Media collected in the upland and riparian zones included soil, vegetation, invertebrates, small mammals, and kingbirds (kingbirds in riparian zone only). Nearshore media included sediment, interstitial pore water, surface water, benthic macroinvertebrates, clams, and sculpin. Toxicity testing was performed on soil, sediment, and water to provide Hanford Site-specific information on the ecological effects of contaminant mixtures and contaminant bioavailability. The results of these tests are used to make informed inferences on the toxicity of contaminants to Hanford Site biota. A more detailed discussion of the results from the RCBRA (DOE/RL-2007-21) in riparian and nearshore areas is summarized in Appendix M of this RI/FS.

#### *1.2.3.6 CERCLA 5-Year Review*

Effectiveness of the above interim actions is evaluated through the CERCLA 5-year review process. This review determines whether the selected remedy(ies) remain protective of HHE. Since the issuance of the first interim ROD, there have been three 5-year reviews for the 100 Area NPL Site. The *Hanford Site Third CERCLA Five-Year Review Report* (DOE/RL-2011-56) listed no issues or recommendations for 100-BC.

### 1.2.4 Summary

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

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# 2 Study Area Investigation

The study area investigation included the vadose zone and groundwater in the 100-BC area as guided by an approved work plan. Development of the 100-BC Work Plan (DOE/RL-2008-46-ADD3) was based on review and evaluation of relevant documented information and data. The 100-BC Work Plan (DOE/RL-2008-46-ADD3) identified the additional information to support a remedial alternative evaluation and decision. This chapter describes these data gaps, the data that were collected to fill the gaps in information, and the corresponding scope of work (including field activities, tests, analyses, and data sources) that was designed and carried out in the RI/FS. Results of the RI/FS activities are presented in Chapters 3, 4, and 5. These chapters include data from previous studies and historical information to identify the nature and extent of contamination. The details of the RI/FS scope of work are documented in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) and the 100-BC SAP (DOE/RL-2009-44).

***Highlights***

- Field studies were performed in 2009 through early 2011 to provide data needed to make informed decisions about remediation of 100-BC. Data needs identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) were adequately addressed.
- Seven boreholes were drilled to characterize the vadose zone at waste sites.
- Ten new monitoring wells were installed to characterize the geology and determine the vertical and horizontal extent of groundwater contamination.
- Columbia River pore water was sampled to determine how much Cr(VI) is carried from groundwater to the river.
- Existing wells were sampled three times to determine spatial and temporal variations in groundwater contaminants.

A description of the RI/FS field activities, as well as other investigations and ongoing activities that contributed to this RI/FS, are presented in Section 2.1. These additional investigations include those with the potential to affect the development of Remedial Action Alternatives, including RCBRA Volume II (DOE/RL-2007-21), and ongoing groundwater and aquifer tube monitoring. Section 2.2 summarizes the field activity documentation. Subsequent chapters of this report describe the results of this work and integrate it with the existing information (Chapter 1) to update the CSM and to identify and evaluate options for achieving RAOs.

## 2.1 Remedial Investigation Activities

The RI field effort included boreholes, test pits, groundwater monitoring well installation, spatial and temporal groundwater monitoring, and the associated sampling and analysis for each activity. Table 2-1 summarizes the data gaps that were identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3), how they were filled, and the section of this report where the information is discussed. Table 2-1 also lists three additional tasks identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) and summarizes how they were accomplished. Table 2-2 includes the supplemental investigations identified in the Integrated Work Plan [DOE/RL-2008-46]), and other investigations that may potentially affect feasibility decisions regarding the 100-BC waste site and groundwater contamination.

The RI scope of work is described in detail in the following sections, including deviations from the 100-BC Work Plan (DOE/RL-2008-46-ADD3). Tables 2-3 and 2-4 present a summary of the field effort and Appendix C includes specific information for each borehole and sampling interval. Figure 2-1 shows the locations of the outlined field activities that were conducted specifically under this RI/FS.
The following sections present details of investigations conducted under the RI, as well as investigation activities conducted under other scopes of work, which may affect FS decisions including the *Remedial Investigation Work Plan for Hanford Site Releases to the Columbia River* (hereinafter called the Columbia River RI Work Plan [DOE/RL-2008-11]) and RCBRA Volume II (DOE/RL-2007-21).

Additional supporting information, such as data collected from boreholes installed for the design of the 100-C-7 excavation, was included in the evaluation of 100-BC for this RI/FS Report. Sampling of 100-C-7 during excavation is guided by the *100 Area Remedial Action Sampling and Analysis Plan* (hereinafter called the 100 Area SAP [DOE/RL-96-22]).

### 2.1.1 Significant Work Plan Deviations

Significant work plan deviations are as follows:

- **Vadose zone boreholes:** Borehole C7847 was initiated at 105-B, located near the FSB. This borehole was terminated after collection of samples from four intervals due to refusal. The boring was extended to a total depth of approximately 4.6 m (15 ft) bgs. At refusal, it was suspected that a pipeline was present. Soil samples were collected and analyzed. The borehole was sealed and replaced by borehole C8239, which provided the necessary information to fill the data gap.

- **Vadose zone boreholes:** Boreholes C7844 (116-C-5) and C7846 (100-B-5) were completed as temporary wells 199-B3-52 and 199-B4-15, respectively, in order to obtain a representative water sample. The temporary wells were screened at the top of the aquifer. Groundwater samples were collected after well completion. This deviation resulted in better-quality samples than would have been collected from the unfinished boreholes.

- **Soil samples:** Split-spoon samples often yielded insufficient sample volume for a full set of chemical and physical analyses, because of the unconsolidated nature of the sediments. Other factors also occasionally prevented a full set of analyses, as detailed in Appendix C. Approximately 9 percent of the soil samples required under the 100-BC SAP (DOE/RL-2009-44) were not analyzed; an additional 24 percent had at least one missing analysis. One sample was potentially affected by addition of water during drilling (Table 2-3). However, sufficient data were available to fill the data gap.

- **Test pit 118-B-8:3 location:** The test pit was relocated to approximately 12.2 m (40 ft) north of the location identified in the work plan. The relocation was necessary to minimize potential effect on samples from demolishing/accessing the interior of the pipeline by removing an entire section for direct evaluation and sampling of residual sediment/scale. The new location was also downstream of all known influent lines from the 105-B Facilities and still upstream of the connection point to the remediated 100-B-14:1 Pipeline. The new location met the requirements of the 100-BC SAP (DOE/RL-2009-44).

- **Groundwater monitoring wells:** Well 199-B5-7 (C7787), located southeast of 100-BC, was terminated at 1.8 m (5.9 ft) below ground surface because the casing would not advance. The borehole was sealed and the drill rig was moved a short distance away and Well 199-B5-8 (C8244) was drilled as a replacement. Samples from the new well provided the information needed to fill the data gap.

- **Aquifer tube sampling:** Existing aquifer tubes were scheduled for sampling in fall 2010. Because of a safety related work stoppage and competing priorities for staff, the sampling was delayed until 2011. Eight of 26 tubes were sampled in early March. Before the remaining tubes were sampled, the river rose and submerged them so they could not be sampled until fall. The tubes were sampled again between December 2011 and March 2012.

- **Spatial/Temporal groundwater sampling:** Three rounds of sampling were intended to represent high, low, and transitional river stage conditions. When the wells were sampled in May 2010, the river had not yet risen to its highest stage for the year. This deviation is not considered detrimental

because higher river stage would have the effect of lowering contaminant concentrations in wells closest to the river. Thus, the May 2010 concentrations may be conservatively high.

Table 2-1. Data Gaps and Work Conducted Under 100-BC Remedial Investigation

| Data Gap | Data Need | Scope of Work Identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) | Work Conducted/Section with Discussion | Data Gap Filled? |
|---|---|---|---|---|
| 1 | Verification data are needed (after remediation) to complete interim remedial action at 100-C-7. | Conduct verification sampling and monitoring as applicable during the excavation of this waste site to the top of the unconfined aquifer. | Sampling during excavation at 100-C-7 is guided by the 100 Area SAP (DOE/RL-96-22)<br>Section 2.1.11 Soil and Vadose Zone Investigations<br>Section 4.2, Vadose Zone Contamination | Not yet; Remediation is ongoing. |
| 2 | Data are needed to assess the nature and vertical extent of contamination beneath select remediated waste sites. | Drill boreholes into remediated waste sites as shown in Figure 2-1. Conduct test pit sampling at select remediated waste sites. Collect and analyze soil samples as described in the 100-BC SAP (DOE/RL-2009-44).<br>Waste sites with proposed boreholes are 100-B-5, 116-B-5, 116-B-14, 116-C-5, and 118-B-6.<br>Waste sites with proposed test pits are 118-B-8:3, 116-B-6B, and 116-B-9.<br>Conduct sampling to also address Data Gap 7. | Data were successfully collected from the following soil borings and test pits:<br>• Boring C7846 at 100-B-5, C7844 at 116-B-5, C7842 at 116-B-14, C7843 at 116-C-5, and C7845 at 118-B-6.<br>• Test pit 3 at 118-B-8:3, test pit 1 at 116-B-6B, and test pit 2 at 116-B-9.<br>Section 2.1.11 Soil and Vadose Zone Investigations<br>Section 4.2 Soil and Vadose Zone Contamination | Yes |
| 3 | Data are needed to determine the nature and vertical extent of contamination in the vadose zone around the 105-B and 105-C Reactor structures. | Drill boreholes near the 105-B and 105-C Reactors in locations shown in Figure 2-1. Collect and analyze soil samples as described in the 100-BC SAP (DOE/RL-2009-44).<br>Conduct sampling to also address Data Gap 7. | Data were successfully collected from soil borings C7849 near 105-C Reactor and C8239 near 105-B Reactor. The first attempted boring near the 105-B FSB (C7847) had to be abandoned following the collection of samples at four intervals because of refusal at 4.6 m (15 ft) bgs.<br>Section 2.1.11 Soil and Vadose Zone Investigations<br>Section 4.2 Soil and Vadose Zone Contamination | Yes |

Table 2-1. Data Gaps and Work Conducted Under 100-BC Remedial Investigation

| Data Gap | Data Need | Scope of Work Identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) | Work Conducted/Section with Discussion | Data Gap Filled? |
|---|---|---|---|---|
| 4 | Data are needed to identify groundwater contaminants and define the extent of contamination horizontally and vertically. | Install six new groundwater monitoring wells as follows:<br>• Well 1: A well to create a shallow/deep pair to characterize and monitor vertical distribution of contaminants.<br>• Well 2: A well to define the contaminant plumes near the river, to be placed southeast of the intake structure.<br>• Well 3: A well placed to provide information on chromium and strontium-90 distribution within the unconfined aquifer in a cluster with existing Wells 199-B3-47 (water table) and 199-B2-12 (RUM), and provide vertical hydraulic gradient data. The well will be placed where the chromium concentrations at the top of the aquifer are historically highest.<br>• Well 4: A well west of the C Reactor to define the extent of chromium strontium-90, and tritium contamination in southern 100-BC.<br>• Well 5: A well in the southeastern corner of 100-BC to define the southern extent of contamination.<br>• Well 6: A well screened in the first water-bearing unit within the RUM and paired with Well C7665 (199-B2-14) to confirm the conditions of Well 199-B2-12, which is screened in the RUM and has no contamination.<br>Sample new and existing monitoring wells for all groundwater COPCs. Details are found in the 100-BC SAP (DOE/RL-2009-44). Conduct sampling to also address Data Gap 7. | Data were successfully collected from six new groundwater monitoring wells.<br>• Well 1 is 199-B4-14 (C7786)<br>• Well 2 is 199-B2-16 (C7784)<br>• Well 3 is 199-B3-51 (C7785)<br>• Well 4 is 199-B8-9 (C7508)<br>• Well 5 is 199-B5-8 (C8244); the initial attempt to drill a well in this location (199-B5-7; C7787) was unsuccessful because the casing would not advance past 1.8 m (5.9 ft)<br>• Well 6 is 199-B2-15 (C7783)<br>New and existing wells were sampled for all groundwater COPCs.<br>Section 2.1.12 Groundwater Investigations<br>Section 4.3 Groundwater Contamination | Yes |

**Table 2-1. Data Gaps and Work Conducted Under 100-BC Remedial Investigation**

| Data Gap | Data Need | Scope of Work Identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) | Work Conducted/Section with Discussion | Data Gap Filled? |
|---|---|---|---|---|
| 5 | Data are needed to confirm results of previous pore water sampling, to observe concentration trends over time, and to better define areas of contamination under the river.<br>Data from the aquifer tube network are needed to monitor concentrations over time and with depth near the river. | Collect additional groundwater upwelling (pore water) samples in the Columbia River. Focus on sites where contamination was detected in previous pore water sampling and where specific conductance indicates groundwater upwelling (details provided in text and in the 100-BC SAP [DOE/RL-2009-44] developed for this activity).<br>Continue routine sampling of existing aquifer tubes per *Sampling and Analysis Plan for Aquifer Sampling Tubes* (DOE/RL-2000-59), or subsequent revisions.<br>Install and sample three new aquifer tube clusters to provide better coverage (*Sampling and Analysis Plan for Aquifer Sampling Tubes* [DOE/RL-2000-59]). | Data gap was filled by collection of the following pore water and aquifer tube samples.<br>• Collected pore water samples from 12 stations.<br>• Installed and sampled three new aquifer tube clusters of three tubes each: C7718, C7719, C7720; C7724, C7725, C7726; C7780, C7781, C7782.<br>• Sampled the older aquifer tubes in 2011 and early 2012.<br>Section 2.1.9 Surface Water and Sediment Investigations<br>Section 4.4 Surface Water and Sediments | Yes |
| 6 | Only one well has been completed within the RUM aquitard unit in 100-BC. Data are not available to evaluate the integrity of the aquitard unit, or fate and transport within the aquitard. | Collect split-spoon soil samples at total depth of 1.5 m (5 ft) into the RUM from the new proposed wells (Data Gap 4), and the four new wells (Wells C7505, C7506, C7507, and C7665) being installed per *Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* (DOE/RL-2009-61).<br>Drill one well (Well 6 from Data Gap 4) into the RUM to the first water-producing unit and collect soil and groundwater samples. Sampling details are listed in the 100-BC SAP (DOE/RL-2009-44). | Data gap was filled by collection of split-spoon samples from new wells, and installation of Well 199-B2-15, screened in the RUM.<br>Section 2.1.10 Geologic Investigation<br>Section 2.1.11 Soil and Vadose Zone Investigations<br>Section 2.1.12 Groundwater Investigations<br>Section 3.4 Geology<br>Section 3.6 Hydrogeology<br>Section 4.3 Groundwater Contamination | Yes |

Table 2-1. Data Gaps and Work Conducted Under 100-BC Remedial Investigation

| Data Gap | Data Need | Scope of Work Identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) | Work Conducted/Section with Discussion | Data Gap Filled? |
|---|---|---|---|---|
| 7 | Geological characterization, physical, and hydraulic property data are needed to support modeling and analysis. | Drill and sample soil and groundwater from proposed groundwater wells and boreholes (Data Gap 4). Details are found in the 100-BC SAP (DOE/RL-2009-44).<br>Install one new well (Well 3) screened near the base of the unconfined aquifer near existing Wells 199-B3-47 (water table) and 199-B2-12 (RUM). Collect soil and water samples throughout the thickness of the unconfined aquifer and the top of the RUM. Install pressure transducers in the three wells to obtain information about vertical hydraulic gradients.<br>Install and monitor pressure transducers in selected other wells to determine horizontal hydraulic gradient and vertical gradient using wells installed as multi-depth pairs per Data Gap 4. | The data gap was filled by collection of geologic and hydrogeologic data including the following:<br>• Geologic characterization samples from new wells and boreholes.<br>• Contaminant distribution with depth in soil and groundwater (new wells, boreholes, and multi-well clusters).<br>• Hydraulic head from pressure transducers in nine wells, including two multi-depth clusters.<br>Section 2.1.10 Geologic Investigation<br>Section 2.1.11 Soil and Vadose Zone Investigations<br>Section 2.1.12 Groundwater Investigation<br>Sections 3.4 Geology<br>Section 3.6 Hydrogeology | Yes |
| 8 | Groundwater chemistry data are needed to reduce uncertainty in determining risks resulting from groundwater contamination. | Collect and analyze groundwater samples from 18 groundwater monitoring wells (see text) at three river stages (high, low, and transitional) to characterize the spatial and temporal extent of groundwater contamination. Details are found in the 100-BC SAP (DOE/RL-2009-44). | Sampled the 18 wells three times in 2010.<br>Section 2.1.12 Groundwater Investigations Spatial and Temporal Groundwater Sampling<br>Section 4.3 Groundwater Contamination<br>Chapter 6 Human Health Risk Assessment<br>Chapter 7 Ecological Risk Assessment | Yes |

Table 2-1. Data Gaps and Work Conducted Under 100-BC Remedial Investigation

| Data Gap | Data Need | Scope of Work Identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) | Work Conducted/Section with Discussion | Data Gap Filled? |
|---|---|---|---|---|
| **Task** | **Additional Tasks Identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3)** | | **Work Conducted/Section with Discussion** | |
| 1 | Opportunistic groundwater sampling. | | Groundwater samples were collected during drilling activities for each borehole. Two boreholes were completed as temporary wells.<br>Section 2.1.12 Groundwater Investigation<br>Section 4.2 Groundwater Contamination | |
| 2 | Develop potential remedial technologies. | | Remedial technologies were developed and screened<br>Chapter 8 | |
| 3 | Update bathymetry data for the river adjacent to 100-BC to support calculations of contaminant transport to the river and ecological receptors. | | Current bathymetry was evaluated.<br>Section 2.1.10.2 Bathymetric Evaluation<br>Section 3.4 Geology | |

COPC = contaminants of potential concern

**Table 2-2. Supplemental Investigations and Other Primary Investigations**

| Scope of Work Identified | Section with Discussion |
|---|---|
| Evaluating and developing approaches to obtain data that will demonstrate compliance with ambient water quality standards in the river for ROD decisions. In April 2008, a technical review panel was convened to evaluate groundwater interactions with the Columbia River (*Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area* [SGW-39305]). The panel suggested that the current mixing/dilution conceptual model should be re-evaluated. In addition, data may be needed to show representativeness of contaminant concentrations for compliance. Therefore, evaluation will include determination of whether 1:1 dilution assumption for groundwater entering the river is valid, and may include evaluation of whether data from aquifer tube samples are representative. Data collected as part of the RI for site releases to the Columbia River may be useful in this evaluation. | Section 2.1.9 Surface Water and Sediment Investigations |
| Collecting data and developing River Corridor background values in soil for antimony, boron, molybdenum, and selenium. Site-specific background values for these constituents may be needed to determine final soil RAG values where calculated risk-based concentrations and/or ecological protection concentrations are less than background. Interim remedial actions have used Washington State background values for antimony and selenium; interim soil RAGs for boron and molybdenum are above expected site-specific background values. | Section 2.1.14, River Corridor Supplemental Investigations |
| Re-evaluate soil cleanup level for Cr(VI) to support the ROD. The lowest soil RAG for Cr(VI) under the interim RODs is 2.0 mg/kg. However, the calculated "Model Toxics Control Act—Cleanup," "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747(3)(a)) (2007) soil RAG value may be below the current limits of analytical quantitation in environmental samples, depending on the soil-partitioning value and groundwater-to-river dilution attenuation factor used, and final soil cleanup values may default to the limits of quantitation. Because there is uncertainty in analytical detection and quantitation of Cr(VI) near the limits of detection, it may be necessary to consider the realistic capabilities of analytical performance in determination of a final soil cleanup value. | Section 2.1.14, River Corridor Supplemental Investigations |
| Determining a site-specific soil-partitioning value for antimony. This value is necessary for calculation of "Model Toxics Control Act—Cleanup," "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747(3)(a)) soil RAG values for antimony. Antimony is not a significant contaminant in the River Corridor, and determination will include review of scientific literature, which suggests antimony soil-partitioning values in the range of 1.4 to 45 ml/g. | Section 2.1.14, River Corridor Supplemental Investigations |

**Table 2-2. Supplemental Investigations and Other Primary Investigations**

| Scope of Work Identified | Section with Discussion |
|---|---|
| Re-evaluate soil cleanup levels for arsenic to support the ROD. The soil RAG for arsenic under the interim RODs is 20 mg/kg, based on the Tri-Party Agreement (Ecology et al., 1989a) to use the "Model Toxics Control Act—Cleanup," "Unrestricted Land Use Soil Cleanup Standards" (WAC-173-340-740(2)) (1996) Method A value (*Remedial Design Report/Remedial Action Work Plan for the 100 Area* [DOE/RL-96-17]). The "Model Toxics Control Act—Cleanup," "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(2)) Method A value is also 20 mg/kg. The "Model Toxics Control Act—Cleanup," "Unrestricted Land Use Soil Cleanup Standards" (WAC 173-340-740(3)) Method B and "Model Toxics Control Act—Cleanup," "Deriving Soil Concentrations for Groundwater Protection" (WAC 173-340-747(3)(a)) soil values for arsenic are below the site arsenic background of 6.5 mg/kg. Selection of a final soil cleanup level for arsenic in the River Corridor will be accomplished through development of RODs. | Section 2.1.14, River Corridor Supplemental Investigations |
| **Other Primary Investigations that Potentially Affect Feasibility Study Decisions for Waste Sites and Groundwater Contamination** | |
| Columbia River Pore Water Remedial Investigation. | Section 2.1.9 Surface Water and Sediment Investigation<br>Sections 3.6.4 Zone of Surface Water/ Groundwater Interaction<br>Section 4.4 Columbia River Surface Water and Sediments |
| River Corridor Baseline Risk Assessment (RCBRA). | Section 4.4 Columbia River Surface Water and Sediments |
| Annual Groundwater Monitoring. | Section 2.1.12 Groundwater Investigation<br>Sections 4.3 Groundwater Contamination |
| Ongoing Aquifer Tube Sampling. | Section 2.1.12 Groundwater Investigation<br>Section 4.3 Groundwater Contamination |

Sources:

*Sampling and Analysis Plan for Aquifer Sampling Tubes* (DOE/RL-2000-59).

*Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-44).

*Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* (DOE/RL-2009-61).

*Hanford Federal Facility Agreement and Consent Order* (Ecology et al., 1989a).

RAG = remedial action goal ROD = Record of Decision

Table 2-3. Summary of Soil Samples Collected for 100-BC

| Well ID | Well Name | Soil Chemistry | | Physical Properties | | Deviations from 100-BC SAP (DOE/RL-2009-44)[a] |
|---|---|---|---|---|---|---|
| | | No. Planned | No. Taken | No. Required | No. Taken | |
| **Monitoring Wells** | | | | | | |
| C7505[b] | 199-B5-5 | 8 | 11 | 9 | 9 | No physical properties 1.5 m (5 ft) below Hanford/Ringold contact; physical properties limited on 2 other samples because of sample condition. |
| C7506[b] | 199-B3-50 | 8 | 9 | 11 | 10 | No physical properties 1.5 m (5 ft) above the water table; physical properties limited on 4 other samples because of sample condition. |
| C7507[b] | 199-B5-6 | 8 | 10 | 11 | 11 | No physical properties 1.5 m (5 ft) above Hanford/Ringold contact; physical properties limited on 5 other samples because of sample condition. |
| C7665[b] | 199-B2-14 | 8 | 8 | 8 | 8 | Physical properties limited on two samples because of sample condition. |
| C7508 | 199-B8-9 | 8 | 8 | 12 | 6 | Three physical property samples not collected because Hanford/Ringold contact not identified in field; Insufficient sample recovery for some other samples. |
| C7783 | 199-B2-15 | 10 | 10 | 10 | 10 | None. |
| C7784 | 199-B2-16 | 8 | 7 | 9 | 7 | Insufficient sample recovery for some intervals. Approximately 7.5 L (2 gal) of water added at 3 m (10 ft) bgs to aid recovery of archive sample. Physical property or chemical analysis not required at that depth. |
| C7785 | 199-B3-51 | 7 | 6 | 11 | 4 | Physical property intervals relating to Hanford/Ringold contact not collected because contact higher than anticipated and not identified in the field. Insufficient sample recovery for physical property analyses on all samples. |

Table 2-3. Summary of Soil Samples Collected for 100-BC

| Well ID | Well Name | Soil Chemistry | | Physical Properties | | Deviations from 100-BC SAP (DOE/RL-2009-44)[a] |
|---|---|---|---|---|---|---|
| | | No. Planned | No. Taken | No. Required | No. Taken | |
| C7786 | 199-B4-14 | 0 | 0 | 0 | 0 | No characterization sampling required. Approximately 7.5 L (2 gal) of water added at 3 m (10 ft) bgs to aid recovery of archive sample. |
| C7787 | 199-B5-7 | 0 | 0 | 0 | 0 | Borehole terminated at 5.9 ft because casing would not advance. Replaced by C8244. |
| C8244 | 199-B5-8 | 8 | 11 | 11 | 12 | Physical property sample from 1.5 m (5 ft) above Hanford/Ringold contact not collected. Insufficient sample recovery for physical property analyses on some intervals. |
| **Vadose Boreholes** | | | | | | |
| C7842 | N/A | 10 | 10 | 1 | 0 | Insufficient recovery at the two planned intervals precluded collection of physical property samples. |
| C7843 | 199-B3-52[c] | 10 | 10 | 1 | 0 | Insufficient recovery at the two planned intervals precluded collection of physical property samples. |
| C7844 | N/A | 14 | 14 | 1 | 0 | Insufficient recovery at the two planned intervals precluded collection of physical property samples. |
| C7845 | N/A | 13 | 13 | 1 | 1 | 6.4 m (21 ft) sample not collected; no recovery |
| C7846 | 199-B4-15[c] | 12 | 12 | 1 | 0 | Insufficient recovery at the two planned intervals precluded collection of physical property samples. |
| C7847 | N/A | 0 | 0 | 0 | 0 | Borehole terminated at 4.1 m (13.4 ft) because of blockage. Replaced by C8239 |
| C7849 | N/A | 22 | 22 | 1 | 1 | None |

Table 2-3. Summary of Soil Samples Collected for 100-BC

| Well ID | Well Name | Soil Chemistry | | Physical Properties | | Deviations from 100-BC SAP (DOE/RL-2009-44)[a] |
|---|---|---|---|---|---|---|
| | | No. Planned | No. Taken | No. Required | No. Taken | |
| C8239 | N/A | 21 | 21 | 1 | 0 | Insufficient recovery at the two planned intervals precluded collection of physical property samples. Water added during drilling potentially affected sample at 14.4 m (47.1 ft) bgs.[d] |
| **Test Pits** | | | | | | |
| TP1 (116 B-6B) | N/A | 2 | 2 | 2 | 2 | None |
| TP2 (116-B-9 ) | N/A | 2 | 2 | 2 | 2 | None |
| TP3 (118-B-8:3 and 100-B-14:1) | N/A | 3 | 3 | 3 | 3 | None. In addition to the two soil samples required for physical properties analyses, a physical property sample was collected of the sludge inside the pipe and analyzed. |

a. See Appendix C for more specific information.

b. Four new wells were installed as described in *Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* (DOE/RL-2009-61), and 6 new wells were installed as part of this RI as described in the *Sampling and Analysis Plan for the 100-BC-1, 100-BC-2, and 100-BC-5 Operable Units Remedial Investigation/Feasibility Study* (DOE/RL-2009-44).

c. These boreholes were completed as temporary wells.

d. *Data Quality Evaluation of Vadose Zone Soil Sampling Data Collection During RI Drilling for the 100 Area Operable Units* (ECF-100KR4-11-0166)

Table 2-4. Summary of Water Samples Collected for 100-BC

| Well ID | Well Name | 100-BC SAP (DOE/RL-2009-44) Requirement | Depths Sampled (ft) | No. Intervals Sampled | Deviations from 100-BC SAP (DOE/RL-2009-44SAP |
|---|---|---|---|---|---|
| **Monitoring Wells** | | | | | |
| C7505 | 199-B5-5 | Every 1.5 m (5 ft) from water table to top of RUM | 51.4 to 202.4 | 29 | No sample 81 ft (insufficient water) or 156 ft (heaving sand). |
| C7506 | 199-B3-50 | Every 1.5 m (5 ft) from water table to top of RUM | 81.8 to 175.5 | 20 | None |
| C7507 | 199-B5-6 | Every 1.5 m (5 ft) from water table to top of RUM | 80 to 189.7 | 23 | None |
| C7665 | 199-B2-14 | Every 1.5 m (5 ft) from water table to top of RUM | 49.9 to 144.3 | 20 | None |
| C7508 | 199-B8-9 | Every 1.5 m (5 ft) from water table to top of RUM | 100.8 to 209 | 23 | None |
| C7783 | 199-B2-15 | One sample from water-bearing zone of RUM | 157.5 | 1 | None |
| C7784 | 199-B2-16 | Every 1.5 m (5 ft) from water table to top of RUM | 46.5 to 141.8 | 16 | None |
| C7785 | 199-B3-51 | Every 1.5 m (5 ft) from water table to top of RUM | 49 to 146.8 | 21 | None |
| C7786 | 199-B4-14 | One sample from top of aquifer | 86 | 1 | None |
| C7787 | 199-B5-7 | Replaced by 199-B5-8 | 0 | 0 | See 199-B5-8 |
| C8244 | 199-B5-8 | Every 1.5 m (5 ft) from water table to top of RUM | 114 to 220 | 22 | None |
| Various | Various | Sample 18 wells three times: low, high, and transitional river stage (spatial/temporal well network; Table 3-2 of the 100-BC SAP DOE/RL-2009-44) | N/A | 1 each | May 2010 intended for high river stage actually preceded peak river levels (see Section 2.1.1). |
| **Vadose Boreholes** | | | | | |
| C7842 (116-B-14) | N/A | One sample from top of aquifer | 57.4 | 1 | None |
| C7843 (116-C-5) | 199-B3-52[a] | One sample from top of aquifer | 57.4 | 1 | None |
| C7844 (116-B-5) | N/A | One sample from top of aquifer | 76.1 | 1 | None |

Table 2-4. Summary of Water Samples Collected for 100-BC

| Well ID | Well Name | 100-BC SAP (DOE/RL-2009-44) Requirement | Depths Sampled (ft) | No. Intervals Sampled | Deviations from 100-BC SAP (DOE/RL-2009-44SAP |
|---|---|---|---|---|---|
| C7845 (118-B-6) | N/A | One sample from top of aquifer | 76.4 | 1 | None |
| C7846 (100-B-5) | 199-B4-15[a] | One sample from top of aquifer | 82.1 | 1 | None |
| C7847 (105-B) | N/A | None; Replaced by C8239 | N/A | 0 | See C8239 |
| C7849 (105-C) | N/A | One sample from top of aquifer | 103 | 1 | None |
| C8239 (105-B) | N/A | One sample from top of aquifer | 82.3 | 1 | None |
| **Aquifer Sampling Tubes[c]** | | | | | |
| C7718,19,20 | N/A | One sample from each tube | N/A | 3 | None |
| C7724,25,26 | N/A | One sample from each tube | N/A | 3 | None |
| C7780,81,82 | N/A | One sample from each tube | N/A | 3 | None |
| **Columbia River Pore Water** | | | | | |
| N/A | N/A | Sample 10 existing stations | 8 to 12 inches | 12[b] | None |

a. These boreholes were completed as temporary wells to allow for more representative groundwater samples

b. The 10 existing stations were sampled, plus two upstream stations

c. Table 2-11 provides additional information

N/A = not applicable

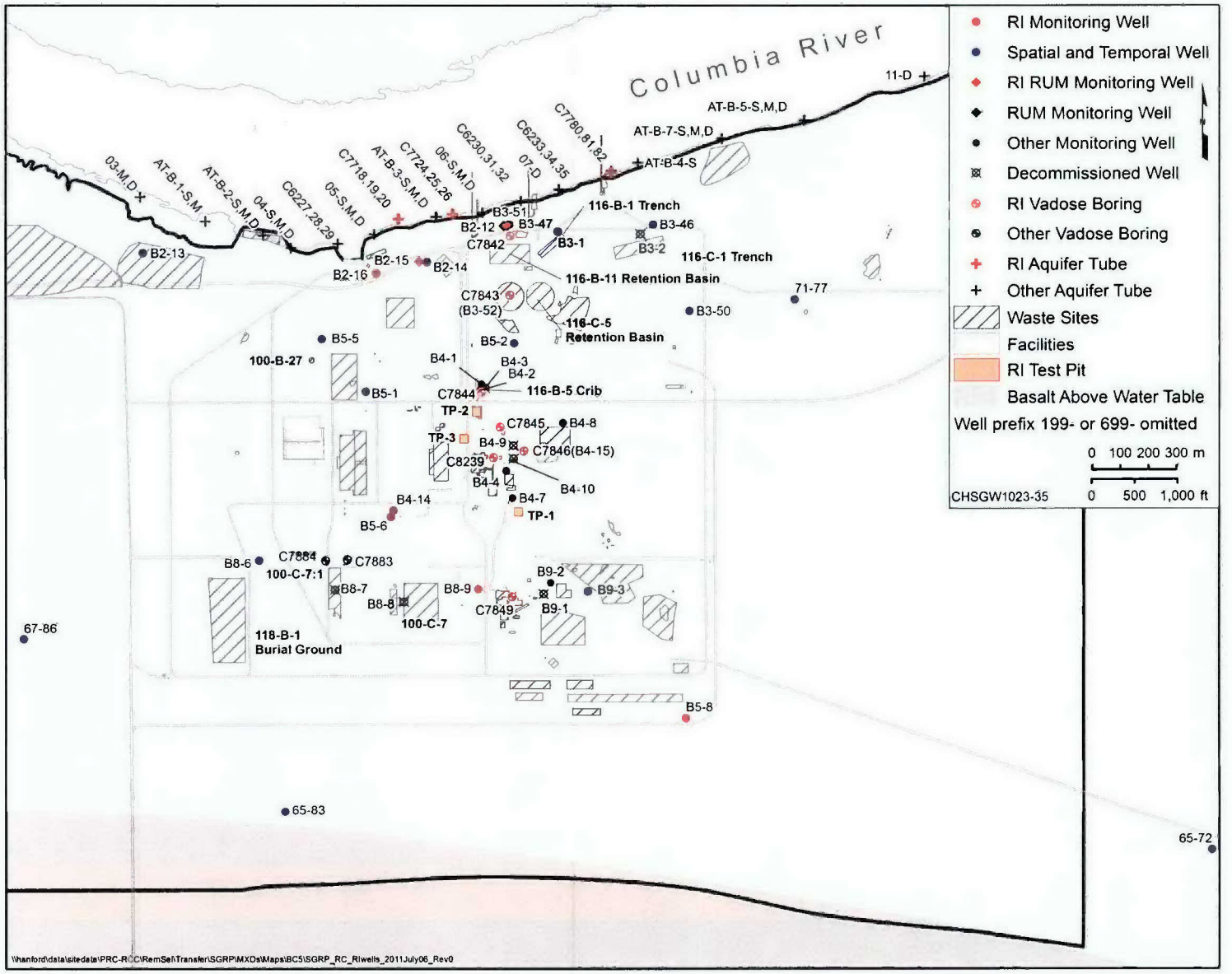



**Figure 2-1. 100-BC Field Characterization Sampling Locations**

### 2.1.2 Data Sets

Historical data as well as data collected from the RI were evaluated in this report. Additional details on the data set along with data are provided in Appendix D. The following is a list of the available data that were compiled for the RI/FS data set and evaluations:

- Waste site remediation action soil analytical data (CVP and remaining site verification package [RSVP] verification data through spring 2012). This data set was used in the evaluation of groundwater protection (Chapter 5), human health risk assessment (Chapter 6), and ecological risk assessment (Chapter 7).
- Field investigation soil analytical data (LFI data). This data set was used in the evaluation of nature and extent (Chapter 4) and considered in the evaluation of groundwater protection (Chapter 5), human health risk assessment (Chapter 6), and ecological risk assessment (Chapter 7).
- RI soil analytical data. Depth-specific soil samples collected during RI boring and well installation are used to evaluate contaminate distribution in the vadose zone and refine the CSM (Chapter 4).
- Soil physical properties (grain size, moisture content, and porosity). These data were used in the groundwater model development (Chapter 3 and Appendix F).
- Hydraulic conductivity. These data were used in the groundwater model development (Chapter 3 and Appendix F).
- Geophysical logging. The geophysical logs from the RI borings are presented in Chapter 3. These data help with the understanding of the CSM and transport of contaminants through the vadose zone.
- Groundwater analytical data. Various subsets of data were used for different purposes. (a) Data from the period January 1, 2006, to December 31, 2010 were used for statistical summaries in Chapter 4; (b) Spatial and temporal groundwater monitoring data, used for risk assessment (Chapters 6 and 7), was a subset of item a, and was limited to specific wells and sampling events specified under the 100-BC RI SAP; (c) Various data sets from 2010 through March 2012 were used to produce plume maps in Chapter 4; (d) The maximum concentration at each 100-BC well in 2009 through March 2012 was used to produce for the initial plumes for groundwater modeling (Chapter 5 and Appendix F); (e) Groundwater characterization data, collected from unfinished boreholes during drilling new wells, were used to construction vertical profiles and cross sections (Chapter 4).
- Well and borehole drilling and construction information. This data set was used in the development of the geologic cross sections (Chapter 3) and groundwater model development (Chapter 5 and Appendix F).
- Fate and transport parameters (e.g., geochemical parameters, hydrogeologic parameters, soil physical properties). This data set was used in the development of the groundwater model and fate and transport evaluations (Chapter 5 and Appendix F).
- Distribution coefficient data for metals. This data set is used in the evaluation of fate and transport of metals (Chapter 5).
- Geologic information. This data set was used in the development of the geologic cross sections (Chapter 3) and groundwater model development (Chapter 5 and Appendix F).
- Groundwater levels and River Stage. This data set was used in the development of groundwater flow maps (Chapter 3) and groundwater model development (Chapter 5 and Appendix F).

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

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

### 2.1.3 Historical Information Review

Historical information on 100-BC was researched and reviewed during the work plan preparation. This information was considered during the work plan development and those reports containing relevant or significant information are summarized in Section 1.2.3 and in the Annotated Bibliography in Appendix B.

### 2.1.4 Surface Features

Surface feature mapping, such as high-resolution topography, was conducted at 100-BC using a Light Detection and Ranging (LIDAR) mapping technology in 2008. LIDAR is an optical remote sensing technology that measures properties of scattered light to find range and/or other information of a distant target. The accuracy of the LIDAR mapping is estimated at 11 cm (4.3 in.). LIDAR data were used to create a topographic map of 100-BC for defining surface relief/elevation differences (Section 3.1). Surface topography establishes part of the framework needed to evaluate contaminant fate and transport.

### 2.1.5 Contaminant Source Investigations

The OSE process has been completed for 100-BC. The discovery site process has continued during ongoing remedial action activities (e.g., RTD excavations of known waste sites). The process was described in Section 1.2.3.2, "Previous Vadose Zone Investigations." Site discovery activities will continue during the course of remedial action.

### 2.1.6 Land and Water Use Surveys

Land and water use on the Hanford Site are limited by the controlled access to the area. Water use of the Columbia River includes irrigation, hydroelectric power generation, and recreational uses. This RI/FS does not address the various water uses of the Columbia River, but rather the potential impacts to the water quality of the river. Land or water use surveys were not conducted as part of this RI/FS or other relevant scopes of work.

### 2.1.7 Meteorological Investigations

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

### 2.1.8 Air Investigations

Hanford Site contractors monitor radionuclide airborne emissions from site facilities through several programs. The Near Facility Environmental Monitoring Program measures concentrations of radionuclides in the ambient air on the Hanford Site in or near facilities and operations. The Hanford Site Environmental Surveillance Program measures the ambient air at sitewide locations away from facilities, offsite around the site perimeter, and in nearby and distant communities. In addition, emissions from stacks, vents, or other types of point sources are monitored individually by analyzing samples extracted

from the outflow at each point of release, but these points sources are not present at 100-BC. The data collected by each program is used to assess the effectiveness of emission treatment and control systems and pollution management practices, and to determine compliance with state and federal regulatory requirements. These regulations include a radiological standard, which requires that Hanford Site emissions shall be controlled such that no member of the public in any area of unrestricted access receives greater than 10 mrem/yr total effective dose equivalent. In some cases, remedial activities are provided with project specific point source and/or ambient air sampling to assemble project specific data. DOE provides information to the Washington State and EPA clean air offices describing the emissions and resultant maximum public dose from ongoing CERCLA activities. This information addresses contributions both from point sources and from all fugitive or diffuse sources of emissions of radionuclides.

Nonradioactive air pollutants are emitted from a variety of sources at the Hanford Site. Sections 2.1.8.1 and 2.1.8.2 summarize the most recent information regarding Hanford Site air monitoring activities (2010 Sitewide Environmental Report (PNNL-20548)). Section 4.6 summarizes results of air monitoring.

### 2.1.8.1 Air Monitoring Near Facilities and Operations

Ambient air is monitored at locations on the Hanford Site near facilities and operations. Samplers are located primarily within approximately 500 m (1,640 ft) of projects or facilities having a known potential for, or history of, airborne releases of radioactive contamination. This ambient monitoring is termed near-facility environmental monitoring. Monitoring locations are associated largely with major nuclear facilities and waste storage, disposal, or cleanup activities. Occasional adjustments are made in the number or location of the monitoring stations as changes in the sources of emissions may occur. Figure 2-2 shows the 100-BC locations sampled in 2008 (*Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2008* [PNNL-18427 APP 2]. No near-facility air monitoring was performed in 100-BC in 2009 or 2010.

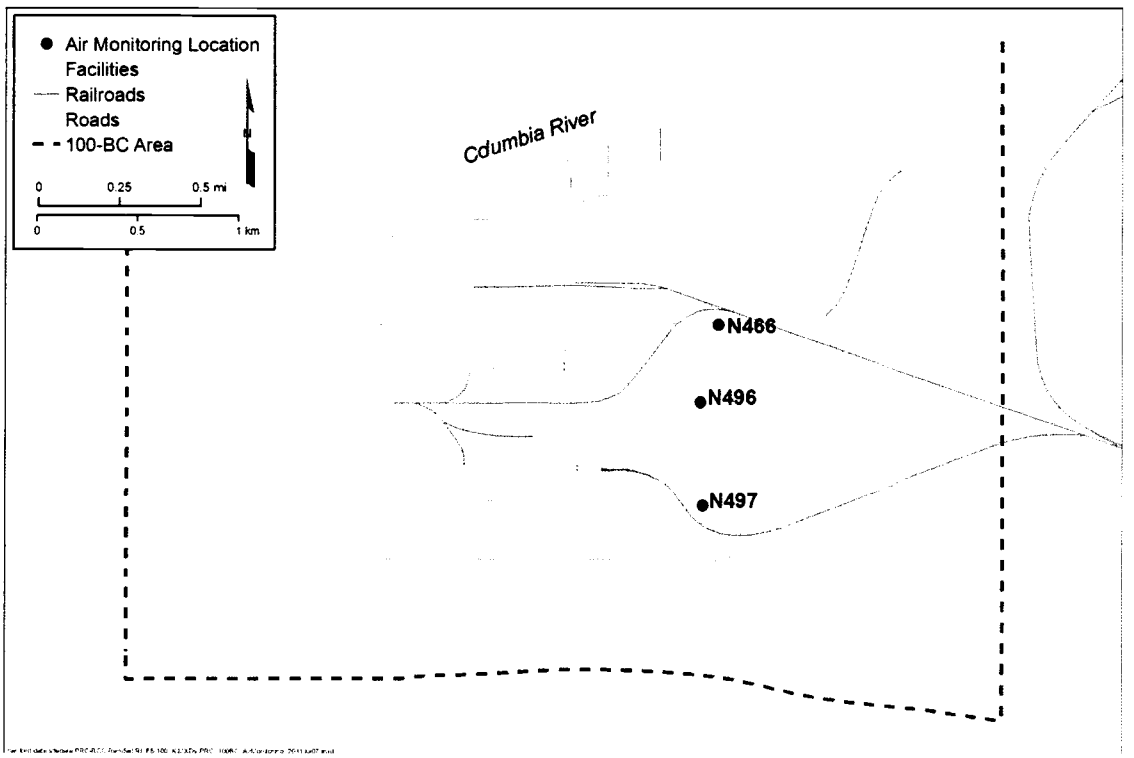



**Figure 2-2. 2008 Near-Facility Air Sampling Locations for Radionuclides at 100-BC (after *Hanford Site Near-Facility Environmental Monitoring Data Report for Calendar Year 2008* [PNNL-18427 APP 2])**

#### 2.1.8.2 Air Monitoring at Hanford Sitewide and Offsite Locations

As part of the Hanford Site Environmental Surveillance Program, 40 continuously operating air samplers on the Hanford Site collected radionuclide samples in 2010. The sampling stations were grouped into four location classifications: site-wide (onsite; 21 stations), perimeter (11 stations), nearby communities (7 stations), and distant community (1 station). No air sample locations were monitored at 100-BC in 2008 through 2010 for the Environmental Surveillance Program.

Samples are collected from known or expected air transport pathways, which are generally downwind of potential or actual airborne releases and downgradient of liquid discharges. Airborne particle samples are collected at each station biweekly and monitored for gross alpha and gross beta concentrations. Biweekly samples are combined into quarterly composite samples and analyzed for gamma emitting radionuclides. Samples of atmospheric water vapor are collected every 4 weeks and analyzed for tritium at approximately 20 locations. A detailed discussion of the air sampling and results are presented in the 2010 Sitewide Environmental Report (PNNL-20548) in Section 8.2, and Table 8.2.2 of the same report provides sample locations and a list of analyses collected at each location.

Ambient air sampling is the primary method used in monitoring fugitive emissions. Hanford Site contractors also monitor for other impacts from airborne emissions or other releases from site facilities. This is done through sampling of various environmental media besides the air, as part of the Surface Environmental Surveillance Program. Routine monitoring includes sampling of surface contamination, external radiation doses, soil, vegetation, and animals. All estimated and measured environmental doses from Hanford Site activities remain much lower than EPA and DOE standards. Chapter 4 presents a discussion of the nature and extent of air contaminants.

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

### 2.1.9 Surface Water and Sediment Investigations

Additional data related to groundwater discharge to surface water (Data Gap 5) were identified as necessary to support remedy decisions. However, some of the data were collected under programs other than the RI/FS. An investigation of pore water, surface water, and sediment was conducted to identify the nature and extent of contaminants entering the Columbia River, specifically by groundwater upwelling in the Columbia River. The following sections provide details on these investigations. Results are described in Sections 3.6 and 4.4.

#### 2.1.9.1 Pore Water, Surface Water, and Sediment Sampling

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

The nearshore groundwater conditions are directly affected by river stage. There are limited historical data available to understand groundwater flow paths, contaminant migration, and mixing in the nearshore area adequately. A wide range of mixing ratios has been observed between upwelling water at the bottom of the river and groundwater at nearshore locations (*Technical Evaluation of the Interaction of Groundwater with the Columbia River at the Department of Energy Hanford Site, 100-D Area*

[SGW-39305]). This mixing ratio represents a continuum from pure groundwater to pure river water, depending on when and where the measurement is taken.

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

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

The first phase of the Columbia River RI pore water sampling, termed Phase II(a), focused on identification of riverbed areas where groundwater was entering the Columbia River. The second phase, termed Phase II(b), returned to a subset of the Phase II(a) sample locations to collect samples of pore water for indicator contaminant analysis. For 100-BC, the indicator contaminant was Cr(VI). The third phase identified a subset of the previous sample locations for sampling and analysis of pore water, surface water, and sediment for a wide range of potential contaminants.

The objective of Phase II(a) sampling was to identify and delineate plumes of groundwater upwelling in the Columbia River adjacent to Hanford Site operations areas. Pore water data were collected using a multi-sensor water-sampling probe capable of being inserted approximately 30 cm (12 in.) into the riverbed, and measuring specific conductance and temperature in situ. Six cross-river transects, each of which had five separate sample locations, were the focus of data collection. Additionally up to 10 locations surrounding each transect were sampled. Measurements were made at 92 stations in early 2009. Chapter 3 summarizes results of this portion of the study.

Pore water sampling for Phase II(b) was conducted at a subset of the Phase II(a) locations that clearly showed groundwater upwelling based on specific conductance and temperature variances between the river and pore water, and were deemed most likely to show contamination. Figure 2-3 shows these sample locations, which were approved by the Tri-Parties. Twenty-nine stations were sampled in August and September 2009 and the samples were analyzed for Cr(VI).

Pore water samples for Phase III (Figure 2-4) were collected from established upwelling locations, with the focus on sites where the Cr(VI) was detected in the Phase II(b) pore water samples. For Phase III sampling, the Tri-Parties selected nine sample locations near 100-BC for collection of pore water, surface water, and sediment. River water was collected at approximately 0.3 m (12 in.) above the riverbed. Sediment samples were obtained as close to the pore water sample locations as reasonably possible, with a preference given to locations with sediment deposits.

Samples were analyzed for a range of radiological and non-radiological analytes as shown in Table 2-5. While samples were successfully collected at each specified location in both areas, not all media and/or analyses could be collected and/or conducted for each sample location due to site-specific sampling or sample volume constraints. Chapter 4 summarizes results of Phases IIb and III.

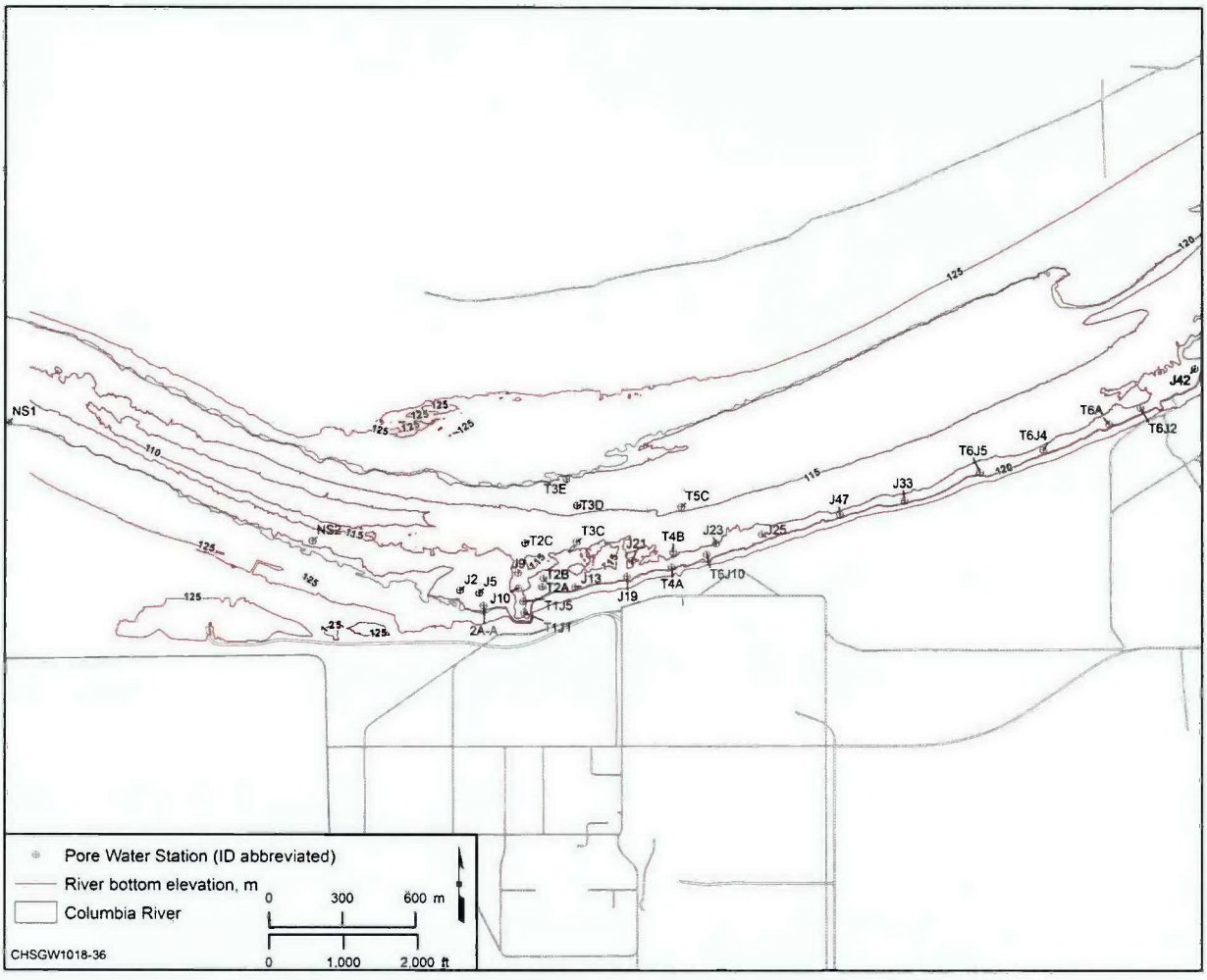
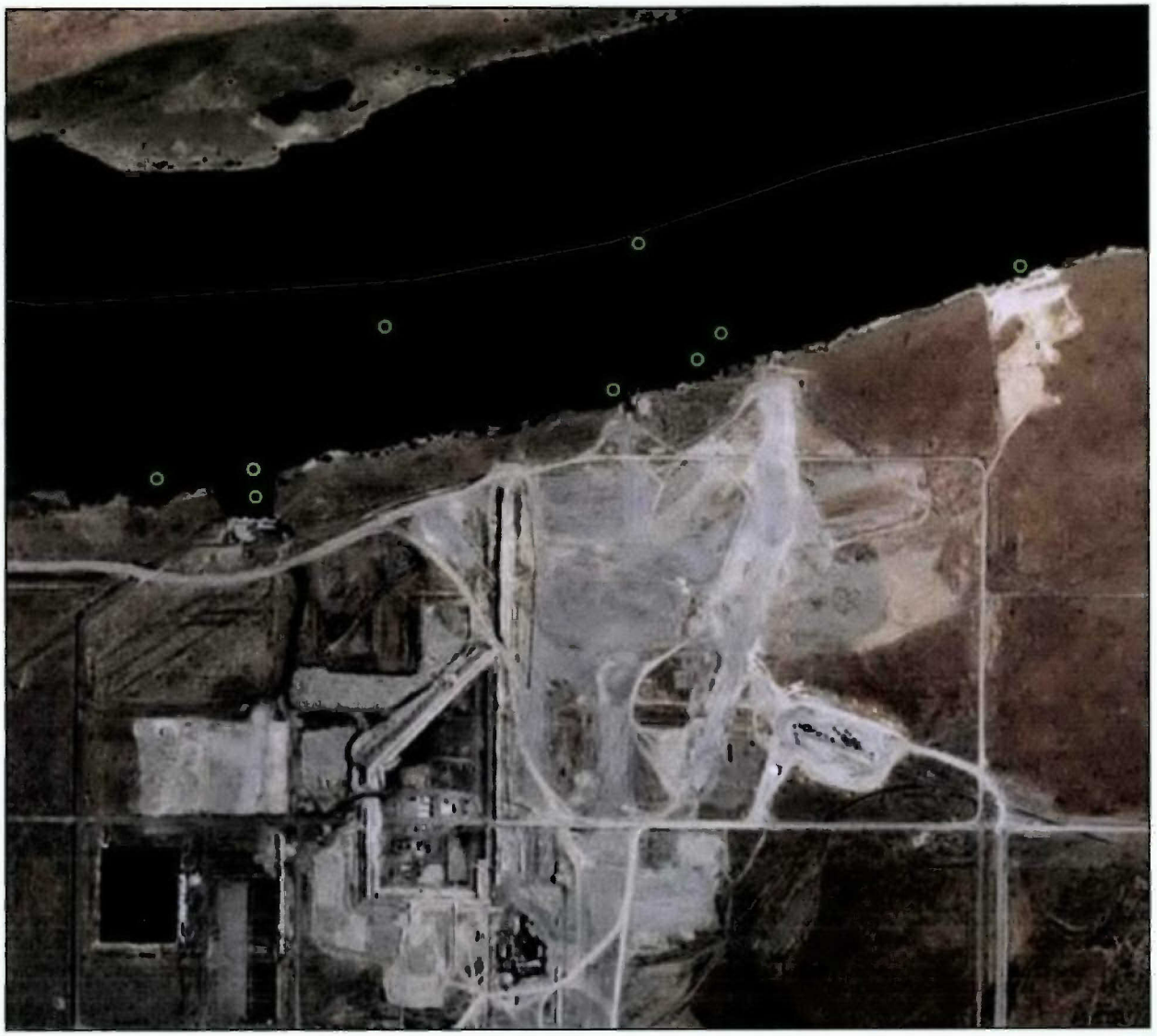



**Figure 2-3. Columbia River Pore Water Sampling Locations at 100-BC**



Source: *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling* (WCH-380).

**Figure 2-4. Remedial Investigation for Site Releases to the Columbia River—Phase III Characterization Sample Locations for 100-BC**

Supplemental pore water sampling was conducted at 100-BC in November 2010 in accordance with the 100-BC SAP (DOE/RL-2009-44). Pore water samples were collected with the Trident probe from 10 locations previously sampled during Phase II(b) and 2 additional stations. Samples were analyzed for total and Cr(VI) only. Chapter 4 summarizes results.

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

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

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

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

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

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

AVS/SEM = acid volatile sulfides/simultaneously extracted metals

TOC/TIC = total organic carbon/total inorganic carbon

### 2.1.9.2 Additional Surface Water and Sediment Sampling

In addition to the sampling described in Section 2.1.9.1, supplemental samples of surface water, sediment, and island soils samples were taken during the RI at locations described in *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, River Sediments, and Island Soils* (WCH-352), and *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (hereinafter called the Hanford Site Releases Data Summary [WCH-398]), for the purpose of identifying the nature and extent of potential releases of contaminants associated with operations at the Hanford Site. Figures 5-7 and 5-8 in the Hanford Site Releases Data Summary (WCH-398) show these sample locations near 100-BC. A sediment core taken near the 181-B River Pump Station was analyzed over three distinct elevations. A surface water sample was also taken in the area just downstream from 100-BC on the Grant County side of the river. Table 2-6 provides a summary of the number of additional samples collected.

**Table 2-6. Summary of Additional Samples Collected near 100-BC during the Columbia River Remedial Investigation**

| Media Collected | Number of Samples |
|---|---|
| Surface Water | 1 |
| Sediment* | 7 |

* Includes shoreline and core samples

#### 2.1.9.3 Routine Monitoring of Surface Water

DOE conducts routine monitoring of surface water on the Hanford Site (2010 Sitewide Environmental Report [PNNL-20548]). Samples are collected upstream of the Hanford Site at Priest Rapids Dam, downstream of the Site at the City of Richland, and at several locations on the site. A cross-river transect is sampled at the Hanford Townsite. River water is not sampled at 100-BC. Constituents of interest in Columbia River water samples collected at Priest Rapids Dam and the City of Richland include gamma-emitting radionuclides, tritium, strontium-90, technetium-99, uranium isotopes, and plutonium isotopes.

Section 4.4 discusses the results of surface water sampling.

### 2.1.10 Geologic Investigations

Geologic characterization data needs were identified to support modeling and analysis. Geologic investigations included characterization while installing and sampling new wells and boreholes, evaluating bathymetric data, and conducting geophysical logging.

#### 2.1.10.1 Geologic Characterization

Ten groundwater monitoring wells were installed to provide data for geologic and hydrogeologic investigations. Four wells were installed in 2009 and early 2010, as described in *Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* (DOE/RL-2009-61). These four wells were augmented by six additional monitoring wells that were installed as outlined in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). Geologic characterization data were also collected for seven vadose zone boreholes.

Geologic samples were collected at approximately 1.5 m (5 ft) depth intervals, and/or at discernible changes in lithology from ground surface to total depth. In general, the major stratigraphic units encountered during this project included backfill, Holocene eolian deposits, cataclysmic flood deposits of the Hanford formation, and fluvially derived Ringold Formation deposits. Drilling was terminated just below the RUM contact, with the exception of Well 199-B2-15 (C7783), which was extended approximately 15 m (50 ft) into the RUM, and Well 199-B4-14, which was only drilled to the upper portion of the aquifer. Drilling did not advance to the underlying Columbia River Basalt Group.

Screen depths and water level elevations are summarized in Table 2-7. Geologic data from the new wells were combined with data from older wells to create updated interpretations of 100-BC geology. Geologists used the data to construct geologic cross sections and maps. Section 3.4 presents detailed results of the RI/FS geologic investigations and borehole summary reports contain geologist's logs, geophysical logs, and well completion details.

#### 2.1.10.2 Bathymetric Evaluation

Contaminant flow paths from 100-BC to the Columbia River are related to the locations of geologic units both on shore and within the Columbia River. The evaluation of the near-river well geology indicates that the top of the aquitard (RUM) lies more than 15 m (49 ft) beneath the bottom of the Columbia River. This indicates that the RUM does not intersect the bottom of the Columbia River at 100-BC.

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

Table 2-7. Summary of Construction Information for New Wells and Boreholes at 100-BC

| Well Name | Well ID | Dates Drilled | Surface Elev. (m) | Drilled Depth (m) | Elev. Top Screen (m) | Elev. Bottom Screen (m) | Elev. Top RUM (m) | Water Level Elev. (m) | Water Level Date | Objective of Well (100-BC Work Plan [DOE/RL-2008-46-ADD3]) | Hydrogeologic Unit Monitored |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 199-B2-14 | C7665 | Jan. to Feb. 2010 | 134.30 | 46.4 | 121.5 | 113.9 | 90.5 | 119.62 | 4/18/2010 | Define plumes near river | Top of unconfined |
| 199-B2-15 | C7783 | Nov. to Dec. 2010 | 134.27 | 59.1 | 86.0 | 82.9 | 90.5 | 119.15 | 11/12/2010 | Monitor RUM; create well pair; vertical head | Screened in RUM |
| 199-B2-16 | C7784 | Aug. to Nov. 2010 | 133.37 | 47.3 | 99.2 | 88.5 | 88.6 | 120.10 | 8/26/2010 | Define plumes near river | Bottom of unconfined |
| 199-B3-50 | C7506 | Sep. to Dec. 2009 | 143.02 | 55.9 | 121.8 | 115.7 | 89.1 | 120.55 | 4/18/2010 | Define eastern extent of contamination | Top of unconfined |
| 199-B3-51 | C7785 | Jan. to Feb. 2011 | 134.04 | 47.6 | 91.7 | 88.6 | 88.5 | 121.5 | 2/15/2011 | Contaminant distribution; create well cluster; vertical head | Bottom of unconfined |
| 199-B3-52 | C7843 | Sep. 2010 | 134.66 | 18.3 | 121.7 | 117.1 | >TD | 119.45 | 9/21/2010 | Vadose borehole at 116-C-5[a] | Top of unconfined |
| 199-B4-14 | C7786 | Jul. 2010 | 144.97 | 29.2 | 123.0 | 116.9 | >TD | 121.74 | 7/20/2010 | Create a well pair to monitor vertical distribution | Top of unconfined |
| 199-B4-15 | C7846 | Sep. to Nov. 2010 | 144.26 | 25.7 | 122.9 | 119.2 | >TD | 121.34 | 11/5/2010 | Vadose borehole at 100-B-5[a] | Top of unconfined |
| 199-B5-5 | C7505 | Sep. to Dec. 2009 | 135.42 | 65.5 | 99.1 | 79.3 | 72.9 | 120.30 | 4/13/2010 | Define western extent of contamination; monitor 100-B-27 | Bottom of unconfined |

Table 2-7. Summary of Construction Information for New Wells and Boreholes at 100-BC

| Well Name | Well ID | Dates Drilled | Surface Elev. (m) | Drilled Depth (m) | Elev. Top Screen (m) | Elev. Bottom Screen (m) | Elev. Top RUM (m) | Water Level Elev. (m) | Water Level Date | Objective of Well (100-BC Work Plan [DOE/RL-2008-46-ADD3]) | Hydrogeologic Unit Monitored |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 199-B5-6 | C7507 | Dec. 2009 to Jan. 2010 | 144.97 | 59.6 | 94.7 | 87.1 | 86.8 | 121.08 | 4/13/2010 | Monitor 100-C-7 | Bottom of unconfined |
| 199-B5-8 | C8244 | Jan. to Feb. 2011 | 153.93 | 70.3 | 123.1 | 117.0 | 86.0 | 121.77 | 3/2/2011 | Define southern extent of contamination | Top of unconfined |
| 199-B8-9 | C7508 | Jun. to Aug. 2010 | 150.99 | 66.9 | 123.5 | 117.4 | 86.5 | 121.97 | 8/23/2009 | Define western extent of Cr(VI) near C Reactor | Top of unconfined |
| N/A | C7842 | Sep. 2010 | 133.42 | 16.8 | N/A | N/A | >TD | 119.37 | 9/14/2010 | Vadose borehole at 116-B-14 | N/A |
| N/A | C7844 | Nov. 2010 | 141.36 | 22.3 | N/A | N/A | >TD | 120.94 | 12/7/2010 | Vadose borehole at 116-B-5 | N/A |
| N/A | C7845 | Nov. 2010 | 143.1 | 24.0 | N/A | N/A | >TD | 121.28 | 11/9/2010 | Vadose borehole at 118-B-6 | N/A |
| N/A | C7847 | Nov. 2010 | | 4.1 | N/A | N/A | >TD | N/A | N/A | Aborted vadose borehole at 118-B-8. Replaced by C8329 | N/A |
| N/A | C7849 | Nov. 2010 | 151.81 | 32.8 | N/A | N/A | >TD | 121.27 | 11/22/2010 | Vadose borehole at 105-C | N/A |
| N/A | C7883 | Jul. to Aug. 2010 | 145.56 | 27.3 | N/A | N/A | >TD | 122.00 | 8/13/2010 | Vadose borehole north of 100-C-7[b] | N/A |
| N/A | C7884 | Aug. 2010 | 145.38 | 27.8 | N/A | N/A | >TD | 121.00 | 8/12/2010 | Vadose borehole north of 100-C-7[b] | N/A |

**Table 2-7. Summary of Construction Information for New Wells and Boreholes at 100-BC**

| Well Name | Well ID | Dates Drilled | Surface Elev. (m) | Drilled Depth (m) | Elev. Top Screen (m) | Elev. Bottom Screen (m) | Elev. Top RUM (m) | Water Level Elev. (m) | Water Level Date | Objective of Well (100-BC Work Plan [DOE/RL-2008-46-ADD3]) | Hydrogeologic Unit Monitored |
|---|---|---|---|---|---|---|---|---|---|---|---|
| N/A | C8239 | Dec. 2010 | 144.05 | 25.1 | N/A | N/A | >TD | 121.37 | 12/20/2010 | Vadose borehole at 105-B | N/A |

Note: Additional detail is available in borehole summary reports (*Borehole Summary Report for the Installation of Four Wells in the 100-BC-5 Operable Unit in Fiscal Year 2009* [SGW-48720]; *Borehole Summary Report for the Installation of 6 Wells in the 100-BC-5 Operable Unit to Support RI/FS [SGW-49672]; and Borehole Summary Report for the Installation of 8 Boreholes in the 100-BC Area in Support of WCH and RI/FS in FY 2010-2011* [SGW-50010]).

a. Vadose boreholes were constructed as temporary wells to obtain representative groundwater samples.

b. Installation of these boreholes was not part of an RI task.

N/A = not applicable

>TD = greater than total depth of borehole

The development of a high resolution bathymetry dataset for the Columbia River through the Hanford Reach was a continuation of FY 2009 work that focused on retrieving, assembling, and processing 66 km (41 mi) of existing bathymetry and terrestrial topographic data (*Development of a High-Resolution Bathymetry Dataset for the Columbia River through the Hanford Reach* [PNNL-19878]). At the conclusion of the FY 2009 work, it was determined that additional data were needed. The data would be collected over a 30 km (19 mi) section to supplement existing bathymetric and topographic data and would fill significant data gaps in the central portion of the Hanford Reach. In FY 2010, hydrographic surveys were conducted and the resulting data were incorporated into a multi source data fusion process to produce a single high resolution (1 m [3.3 ft]) dataset for the Hanford Reach. To complete the interpretations, key hydrogeologic unit surfaces (e.g., structure maps of the Ringold unit E and RUM, based on data from wells and boreholes) were projected beneath the footprint of the river. The river bathymetry (river bottom elevation) was then overlain onto the hydrogeologic unit structure maps. There is no intersection of the RUM surface and the river bottom in 100-BC.

#### 2.1.10.3 Geophysical Logging

To better understand the geology of the area and further address Data Gap 7, geophysical logging was conducted at each of the soil borings and groundwater monitoring wells installed under this RI. Each borehole was geophysically logged with the high-resolution, spectral gamma-ray logging system. Logging was conducted using the S.M. Stoller Corporation Spectral Gamma Logging System and Neutron-Moisture Logging System to identify natural and man-made gamma-emitting radionuclides present near the boreholes. Soil moisture was determined using a neutron logging tool. The starting point for logging, either the ground surface or top of the casing, was recorded for each well or borehole. Borehole logging was performed through the temporary casing to produce a geophysical log of the entire length of the borehole. Geophysical logs are available in borehole summary reports (*Borehole Summary Report for the Installation of Four Wells in the 100-BC-5 Operable Unit in Fiscal Year 2009* [SGW-48720]; *Borehole Summary Report for the Installation of 6 Wells in the 100-BC-5 Operable Unit to Support RI/FS [SGW-49672]*; and *Borehole Summary Report for the Installation of 8 Boreholes in the 100-BC Area in Support of WCH and RI/FS in FY 2010-2011* [SGW-50010]).

### 2.1.11 Soil and Vadose Zone Investigations

The soil borings, test pits, and waste site remediation activities provided information on the nature and extent of contaminants and the overall condition of the soil and vadose zone within 100-BC. The data were collected to address the uncertainties related to the nature and extent of contamination beneath selected waste sites, and contamination around the reactor structures, and to provide additional information on the subsurface conditions (Data Gaps 1, 2, 3, and 7). The following text describes these investigations.

#### 2.1.11.1 Ongoing Waste Site Remediation

With the exception of the 100-C-7 waste site, interim remedial actions in 100-BC have been completed. The 100-C-7 site has been largely excavated to the top of the unconfined aquifer. Contaminant concentrations in the vadose zone exceeding interim RAGs for protection of groundwater and the Columbia River are being removed during remedial action (RTD). Verification samples will confirm that the site meets the interim action ROD requirements. Excavation is complete except for the western sidewall of the 100-C-7:1 excavation. Total depth of the excavation is estimated to be approximately 26 m (85 ft). Figure 2-5 shows the extent of the excavation in spring 2011. Further discussion is provided in Chapter 4.

Figure 2-5. Remediation of 100-C-7 Waste Site, Spring 2011

### 2.1.11.2 Boreholes and Test Pits

Uncertainties were identified in the CSM related to the extent of residual contaminants at previously remediated waste sites (Data Gap 2). To determine those waste sites that may require additional characterization to address CSM uncertainties regarding the nature and extent of contamination and fate and transport, all of the area waste sites were placed into three general categories based on current site status. Site status provides an indicator of the cleanup progress and future evaluation that may be required. The selection process of the waste sites for further characterization is outlined in the 100-BC Work Plan (DOE/RL-2008-46-ADD3).

To address the uncertainty associated with Data Gap 2, five boreholes were drilled and three test pits were excavated to obtain the data needed to refine the CSM. Soil samples were collected during drilling and analyzed to assess the vertical extent of vadose zone contamination beneath the selected waste sites. Test pits were excavated to the depth of previous remediation at two locations. Soil samples were collected and analyzed to assess the nature of contamination immediately below the depth of remedial action. An additional test pit was excavated to provide access to contaminant material in and beneath a process sewer pipeline.

Additional CSM uncertainties were identified related to the presence and extent of contamination associated with the 105-B and 105-C Reactor structures. Historical information indicates that each of the 100-BC FSBs contained contaminated materials (reactor cooling water, spent fuel, and sludge) and leaked in the past. To address this uncertainty (Data Gap 3), a borehole was drilled near the 105-B Reactor FSB, and a second borehole was drilled near the 105-C Reactor FSB. Borehole samples were collected and analyzed to assess the vertical extent of contamination in the

vadose zone beneath the reactor FSBs, the most likely source of potential vadose zone contamination beneath and around the 105-B and 105-C Reactor structures.

In addition, geologic characterization and physical/hydraulic property data were collected to support modeling and analysis (Data Gap 7). Information collected to address this uncertainty included: grain-size analysis, porosity, moisture content, saturated hydraulic conductivity, bulk density, and distribution coefficients. Reactor borehole soil data were also collected and analyzed for leachable Cr(VI) and select metals per the 100-BC SAP (DOE/RL-2009-44).

Soil samples were collected and analyzed from soil borings and test pits as described in the 100-BC SAP (DOE/RL-2009-44). The locations of the boreholes and test pits are shown on Figure 2-1 and described in Table 2-8, along with the rationale for investigating the waste site. Table 2-7 lists the dates of drilling, total depth, and water table elevation of each borehole, and Tables 2-3 and 2-4 summarize the status of soil and water sampling. Additional details on soil sample depths, observations, and field screening are presented in Appendix C and in *Borehole Summary Report for the Installation of 8 Boreholes in the 100-BC Area in Support of WCH and RI/FS in FY 2010-2011* (SGW-50010).

**Table 2-8. Borehole and Test Pit Locations and Rationale for Investigation of Waste Site**

| Waste Site | Site Status | Borehole ID | Rationale for Investigation of Waste Site |
|---|---|---|---|
| 100-B-5 Trench | Interim Closed | C7846 | The 100-B-5 Trench was selected for characterization because mercury and total chromium are above screening levels for groundwater protection at a depth of 8.5 m (28 ft) bgs. No other contaminants were above screening levels for groundwater protection. Although strontium-90 and Cr(VI) were detected below screening levels for groundwater protection, this site was also selected because of its location near the two groundwater plumes. Portions of the 100-B-8 and 100-C-6 effluent pipelines are located adjacent to this site; therefore, data were also collected to characterize the process pipelines. |
| 116-B-5 Crib | Interim Closed | C7844 | The 116-B-5 Crib was selected for characterization because the list of COCs previously analyzed was limited. Results indicated that tritium, mercury, and barium were identified above screening levels for groundwater protection at a depth of approximately 4.8 m (16 ft) bgs. This site is also located near the tritium, Cr(VI), and strontium-90 groundwater plumes and the site is a likely source of the tritium groundwater contamination. Process information indicates that 10 million L (2.64 million gal) of tritiated effluent also contaminated with mercury, solvents and degreasers such as carbon tetrachloride, methanol, and trichloroethene were released to the vadose zone. The volume of effluent release was sufficient to affect the entire vadose zone beneath the waste site. No organic compounds or Cr(VI) analyses were conducted during site closeout. |

**Table 2-8. Borehole and Test Pit Locations and Rationale for Investigation of Waste Site**

| Waste Site | Site Status | Borehole ID | Rationale for Investigation of Waste Site |
|---|---|---|---|
| 116-B-14 Sludge Trench | Interim Closed | C7842 | This site received sludge from the 116-B-11 Retention Basin. No history exists of this site receiving a high-volume liquid waste stream. This site is being characterized to support CSM development of a low-volume liquid site; there is also a lack of PCB data at this site. The site is located near the Cr(VI), tritium, and strontium-90 groundwater plumes adjacent to the Columbia River. |
| 118-B-6 Burial Ground | Interim Closed | C7845 | The 118-B-6 Burial Ground was selected for characterization because the list of COCs analyzed was limited and tritium levels in the vadose zone at a depth of 7 m (23 ft) bgs are approximately 200 times the soil concentration that is protective of groundwater. This site is also located near the strontium-90 and Cr(VI) groundwater plumes. |
| 116-C-5 Retention Basin | Interim Closed | C7843 | This site was selected for characterization because Cr(VI), total chromium, lead, mercury, and nickel-63 exceed groundwater protection levels. The site is also located near the Cr(VI), tritium, and strontium-90 groundwater plumes adjacent to the Columbia River. |
| 105-B Reactor (118-B-8) | -- | C8239 | This site was selected because little or no data have been collected in the immediate vicinity of the reactor. The reactor FSB is known to have leaked and contained fuel pool water, spent fuel, and sludge. The site is also located near the Cr(VI) and strontium-90 groundwater plumes adjacent to the Columbia River. Data are needed to evaluate the vertical extent of contamination beneath and around the 105-B Reactor Museum. |
| 105-C Reactor (118-C-3) | -- | C7849 | This site was selected because the reactor FSB is known to have leaked and contained fuel pool water, spent fuel, and sludge. Data are needed to evaluate the vertical extent of contamination beneath and around the 105-C Reactor. |
| 116-B-6B Crib | Interim Closed | Test Pit TP1 | The 116-B-6B Crib was selected for characterization because it received 100 kg of sodium dichromate in 4,000 L (1,056 gal) of effluent. Based on the soil column pore volume of 198 $m^3$ (6,992 $ft^3$), the volume discharged was not sufficient to affect groundwater. Thus, the volume of effluent discharged to the soil remains in the vadose zone and may be a future source of groundwater contamination. The engineered structure was removed; however. the remedial action only extended to the bottom of the former structure, a depth of 4.6 m (15 ft) bgs. In addition, lead was the only COC analyzed for during closeout sampling. The site was also selected because of its location near the strontium-90 and Cr(VI) groundwater plumes. |

**Table 2-8. Borehole and Test Pit Locations and Rationale for Investigation of Waste Site**

| Waste Site | Site Status | Borehole ID | Rationale for Investigation of Waste Site |
|---|---|---|---|
| 116-B-9 French Drain | Interim Closed | Test Pit TP2 | This site was selected for characterization because data are not available to evaluate the concentration and distribution of tritium. The site was part of the P-10 project (an early tritium extraction program) and tritium was not included in the analysis list for the closeout data. |
| 118-B-8:3/ 100-B-14:1 Process Sewer | Accepted | Test Pit TP3 | This site was selected for characterization because the pipeline is located near the 105-B Reactor. Samples were collected from inside and below the pipe mainly to evaluate risk and contaminant concentrations below the 105-B Reactor Museum. |

***Boreholes.*** Table 2-7 includes information about the drilling of 100-BC vadose boreholes. During drilling, split-spoon soil samples were collected at the depth intervals specified in the 100-BC SAP (DOE/RL 2009-44). These intervals were typically at 1.5 m (5 ft) depth intervals from the top of native soil (i.e., the bottom of prior excavation and backfill, estimated at between 0 to 8.5 m [0 to 28 ft] bgs) to the water table, and at changes in lithology. Field screening was conducted on a continuous basis. The split-spoon samples were collected in 0.76 m (2.5 ft) long (including shoe), 10.2 cm (4 in.) diameter split-spoon samplers lined with four, 15.2 cm (6 in.) long LEXAN® or stainless-steel liners. The sampler was driven the full length or until refusal (as determined by the onsite field geologist), whichever occurred first. Overdriving the sample was avoided. One split-spoon sample was collected from the saturated zone in each borehole approximately 1.5 m (5 ft) into the unconfined aquifer.

Field conditions prevented the collection of some samples. Table 2-3 summarizes the number of soil samples collected from each borehole for chemical and physical analyses. Appendix C provides details for each required sample interval.

One filtered groundwater sample was collected from the saturated zone in each borehole. Groundwater samples were collected using a submersible pump. Before sampling, each borehole was purged of at least three borehole volumes of water and until field parameters stabilized. Boreholes C8243 and C8246 produced inadequate water for pumped samples to be successfully collected. These boreholes were completed as monitoring wells and sampled after completion. The temporary wells are built with 10 cm (4 in.) diameter polyvinyl chloride (PVC) casing and screen. The filter pack consisted of 10 to 20 mesh Colorado Silica Sand (CSS), with a layer of bentonite pellets placed immediately above the filter pack. Bentonite crumbles were placed above the bentonite pellets to approximately 1 m (3 ft) bgs. A cement grout seal was placed above the bentonite crumbles to ground surface.

Five boreholes were decommissioned immediately upon completion of sampling activities, after reaching total depth. The boreholes were backfilled to 0.6 m (2 ft) above static water level (to account for variability of the water table) with 10 to 20 mesh CSS. The remaining portion of each borehole was filled with granular bentonite to within 0.9 m (3 ft) of ground surface. A cement seal was then placed from 0.9 m (3 ft) bgs to ground surface and marked with the name and date of the decommissioned borehole.

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***116-B-6B Crib/Test Pit TP1.*** Test Pit TP1 was excavated at the 116-B-6B Crib on January 13, 2011. Boulders up to 1 m (3 ft) in diameter were encountered throughout the excavation. Samples were collected from two intervals: 5.0 to 5.6 m (16.4 to 18.4 ft) and 5.9 to 6.5 m (19.4 to 21.4 ft) in accordance with the 100-BC SAP (DOE/RL-2009-44). The test pit was backfilled the same day.

***116-B-9 French Drain/Test Pit TP2.*** Test Pit TP2 was excavated at the 116-B-9 French Drain on January 20, 2011. Remnants of the 1.2 m (4 ft) diameter concrete pipe that formed the French drain were found at approximately 1 m (3 ft) bgs and removed from the excavation for a radiological survey. The exterior of the pipe had no contamination and the interior of the pipe contained 109.9 disintegrations per minute (dpm) direct reading alpha and 1,880 dpm beta/gamma with no smearable contamination. Samples were collected from two intervals in accordance with the 100-BC SAP (DOE/RL-2009-44): 2.4 to 3.4 m (8 to 11 ft) and 3.4 to 4.0 m (11 to 13 ft). Additional demolition debris was encountered at various depths during excavation and surveyed with no further contamination found. The test pit was backfilled the same day, with the French drain pipe and debris returned to the excavation at approximately the same depths at which they were encountered.

***118-B-8:3/100-B-14:1 Process Sewer/Test Pit TP3.*** Test Pit TP3 was excavated at the 118-B-8:3/110-B-14:1 Process Sewer beginning on January 21, 2011, and completed on January 25, 2011. An abandoned 5 cm (2 in.) steel pipe was encountered just below the surface; it was determined after finding the broken ends of the pipe that it did not contain any material. The pipe was surveyed to ensure that no contamination was present and was placed aside. Excavation continued until the process sewer line was encountered at approximately 6.7 m (22 ft) bgs, with a section of the pipe removed and brought to the surface.

The interior of the pipe contained approximately 2.5 to 5 cm (1 to 2 in.) of thick sediment. Radiological readings of the pipe interior were <500 dpm total alpha (23 dpm smearable) and 40,000 dpm beta/gamma direct reading (<500 dpm smearable). Samples of the sediment were collected in accordance with the 100-BC SAP (DOE/RL-2009-44). Soil samples were collected from the bottom of the excavation at approximate depths of 6.7 and 7.0 m (22 and 23 ft) bgs in accordance with the 100-BC SAP (DOE/RL-2009-44). The pipe was returned to the bottom of the excavation and the test pit was backfilled.

### 2.1.12 Groundwater Investigations

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

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

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

To address this uncertainty (Data Gap 4), groundwater monitoring wells were installed at strategic locations within 100-BC (Figure 2-1). During field activities, groundwater and soil were sampled and analyzed to better define the vertical extent of contaminants as described in the 100-BC SAP (DOE/RL-2009-44). Table 2-7 summarizes information about the new wells and Tables 2-3 and

2-4 summarize the status of samples collected during drilling. Additional details are included in *Borehole Summary Report for the Installation of Four Wells in the 100-BC-5 Operable Unit in Fiscal Year 2009* (SGW-48720) and *Borehole Summary Report for the Installation of 6 Wells in the 100-BC-5 Operable Unit to Support RI/FS* (SGW-49672).

While drilling each borehole (for later completion as a groundwater monitoring well), groundwater samples were collected at 1.5 m (5 ft) intervals throughout the unconfined aquifer, except in boreholes that were paired with recently installed wells. At Well 199-B3-51, groundwater samples were collected from a confined aquifer within the RUM. Groundwater samples generally were collected using a submersible pump. However, if adequate water column and/or recharge were not available for a pumped sample to be successfully collected, alternative methods were used. Before collecting the sample, the borehole was bailed with a sand-pump and then purged of three borehole-volumes of water, or until dissolved oxygen readings stabilized, to ensure the representativeness of the sample. If sufficient water was not available, the borehole was purged dry and allowed to recharge before sample collection.

Figure 2-6 illustrates general well construction. All wells were constructed with Schedule 10, Type 304, 316, 304L, or 316L stainless-steel, V-slot continuous wire wrap screen atop a 0.6 m (2 ft) long sump with end cap. The sump, end cap, and riser casing are of the same schedule and grade stainless steel as the screen. Centralizers were used above and below the screen and every 12 m (40 ft) to ground surface. The casing and screen diameter of all wells except 199-B2-15 was 15 cm (6 in.). Temporary casing size in Well 199-B2-15 was reduced when the borehole was in the RUM, to prevent communication between aquifers. The permanent casing is 10 cm (4 in.) in diameter.

Where applicable, the portion of the borehole that extended below the bottom of the designed well bottom was decommissioned from total depth using 10 to 20 mesh CSS fill material to a depth that allowed for a 1.5 m (5 ft) bentonite pellet seal below the well sump. The filter pack was placed from approximately 1.5 m [5 ft] below the bottom of the screened interval to 1.5 m (5 ft) above the top of the screened interval. The filter pack consisted of 10 to 20 mesh CSS, except in Well 199-B2-15, which was screened in the RUM and used a 20 to 40 mesh sand. The typical annular seal included a 0.9 m (3 ft) layer of bentonite pellets placed immediately above the filter pack, bentonite crumbles above the pellets to approximately 3 m (10 ft) bgs, and a cement grout seal above the crumbles to ground surface. Annular seals varied on some of the wells; details are included in the borehole summary reports.

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

Following construction, wells were developed by pumping until they produced water with low turbidity (≤5 nephelometric turbidity units [NTU]) and stabilized field parameters (at least three consecutive temperature, pH, and specific conductance measurements within 10 percent of each other).

Before RI/FS investigations, the nature and extent of all COPCs had not been determined in 100-BC (Data Gap 4). Consequently, new and existing wells in 100-BC were sampled for all groundwater COPCs (100-BC SAP [DOE/RL-2009-44]). The 18 existing wells sampled to provide information on spatial and temporal variability (Data Gap 8; Section 2.1.12.4) included most of the

available wells. The six new wells installed under the RI provided additional data points. Groundwater samples are being collected from the wells installed for the RI under the scope of the 100-BC SAP (DOE/RL-2009-44) quarterly for the first year, with a reduction in frequency for subsequent years if warranted. Sampling and analysis after the first year will be conducted as part of routine sampling under the *100-BC-5 Operable Unit Sampling and Analysis Plan* (DOE/RL-2003-38).

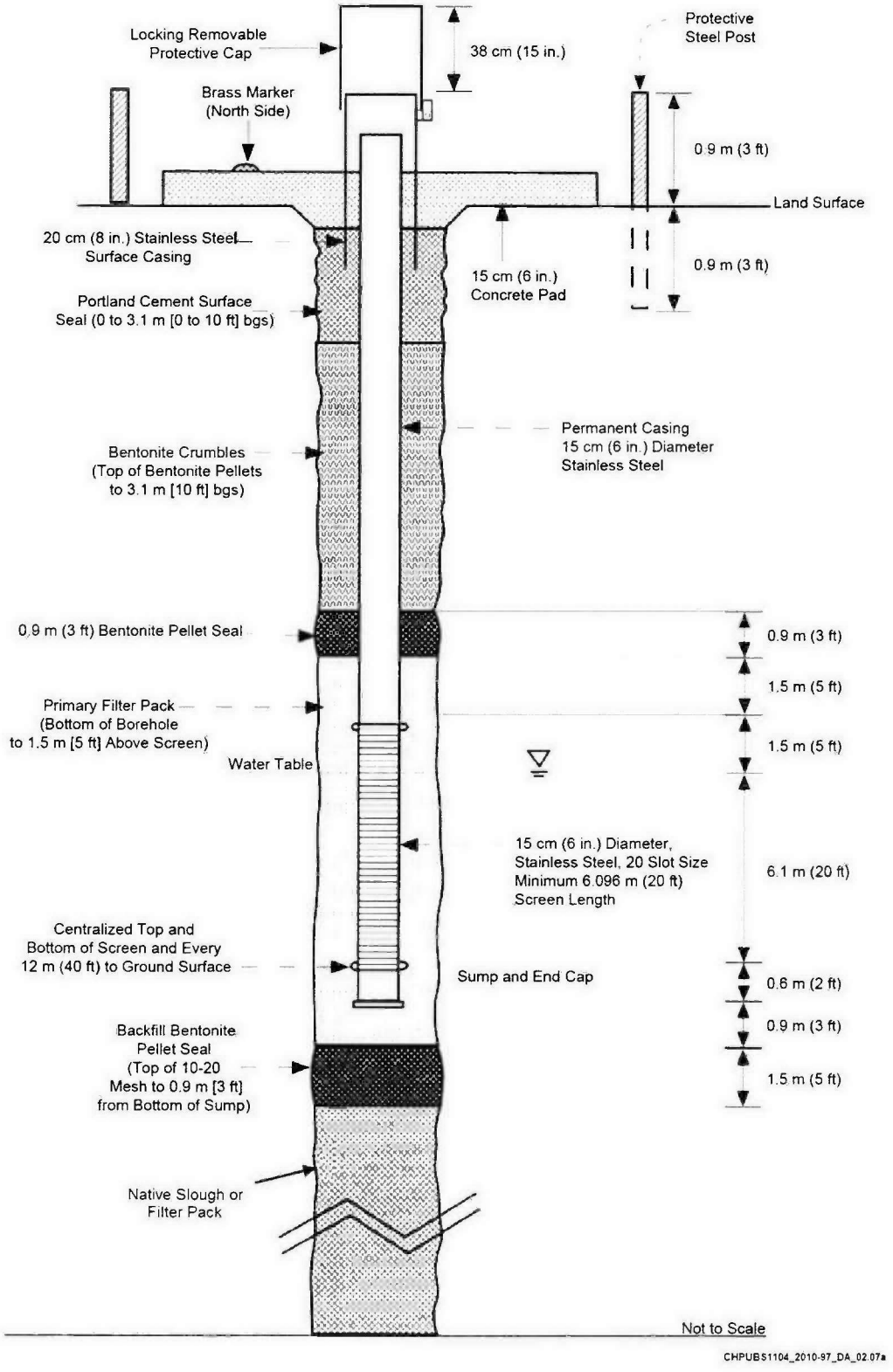


**Figure 2-6. General Well Design**

#### 2.1.12.2 Characterize Hydraulic Properties of the Aquifer and Aquitard

Knowledge of hydraulic properties is needed to help evaluate contaminant fate and transport. Data Gap 6 identified a need to evaluate the integrity of the aquitard unit (RUM), and fate and transport beneath the aquitard. Data Gap 7 called for physical and hydraulic property data from the vadose zone, unconfined aquifer, and the aquitard, to support modeling and analysis. Physical testing of sediment samples and aquifer tests provided data to fill this need. Installation and monitoring of pressure transducers provided additional data on hydraulic gradients. Section 3.6 presents results of testing for hydraulic properties.

To address the uncertainty related to soil and hydrogeologic properties, soil samples from wells were collected and analyzed for various physical characteristics including the following:

- Grain-size analysis (sieve)
- Porosity
- Sediment moisture content (unsaturated soil only)
- Saturated hydraulic conductivity
- Bulk density
- pH (saturated soil only)
- Distribution coefficient for various contaminants (per the 100-BC SAP [DOE/RL-2009-44])

Soil samples for each well were generally collected at 4.6, 3, 1.5, and 0.6 m (15, 10, 5, and 2 ft) above the water table, at the water table, 1.5 m (5 ft) below the water table, at the bottom of the unconfined aquifer, and at the total depth of drilling (1.5 m [5 ft] within the RUM), with additional samples collected at deeper Well 199-B3-51. Generally, soil samples were collected as described for soil borings, in Section 2.1.11. A grab sample was also collected from any interval where insufficient or no split-spoon sample was obtained. Two split-spoon soil samples were collected from each borehole within major formations to provide site-specific physical property values to support modeling efforts. The physical property samples were collected from lithologies representing major facies in the vadose zone. Additional physical property samples were taken 3 and 1.5 m (10 and 5 ft) above the Hanford formation/Ringold Formation contact, at the Hanford formation/Ringold Formation contact, and 1.5 m (5 ft) below the Hanford formation/Ringold Formation contact, as well as from within the RUM at Well 199-B3-51. The physical property samples were collected in conjunction with other split-spoon sample intervals, where possible.

Slug and pumping tests were conducted in 100-BC wells to determine the hydraulic conductivity in the unconfined aquifer and the RUM. Table 2-9 summarizes the tests conducted and the hydrogeologic units tested. Section 3.6 presents results of aquifer testing.

To address the uncertainty associated with variations in vertical and horizontal hydraulic gradients and their effect on contaminant mobility (Data Gap 7), pressure transducers were installed in selected 100-BC wells (Table 2-10). The new transducer systems were integrated with many other stations on the Hanford Site as part of an automated water level monitoring network. The stations measure and record hydraulic pressure hourly, and transmit the data to a central location where they are converted to water level elevations. Section 3.6 discusses results of transducer monitoring.

**Table 2-9. 100-BC Aquifer Tests**

| Well | Hydrologic Unit Tested | Type of Test |
|---|---|---|
| 199-B2-12 | RUM | Slug injection and withdrawal |
| 199-B2-14 | Ringold unit E | Slug injection and withdrawal |
| 199-B2-15 | RUM | Slug injection and withdrawal; pumping test |
| 199-B2-16 | Ringold unit E | Slug injection and withdrawal |
| 199-B3-47 | Ringold unit E | Slug injection and withdrawal |
| 199-B3-51 | Ringold unit E | Slug injection and withdrawal |
| 199-B4-14 | Hanford formation | Slug injection and withdrawal |
| 199-B5-5 | Ringold unit E | Slug injection and withdrawal |
| 199-B5-6 | Ringold unit E | Slug injection and withdrawal |
| 199-B5-8 | Hanford formation | Slug injection and withdrawal |
| 199-B8-6 | Ringold unit E | Slug injection and withdrawal |
| 199-B8-9 | Hanford formation | Slug injection and withdrawal |

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**Table 2-10. 100-BC Automated Water Level Monitoring Stations**

| Purpose | Well(s) | Screened |
|---|---|---|
| Vertical gradient between RUM and unconfined aquifer; vertical gradient within unconfined aquifer; water table in northern 100-BC for 3-point calculations | 199-B2-12 | RUM |
| | 199-B3-51 | Bottom unconfined |
| | 199-B3-47 | Water table |
| Vertical gradient within unconfined aquifer; water table in south-central 100-BC for 3-point calculations | 199-B5-6 | Bottom unconfined |
| | 199-B4-14 | Water table |
| Water table in southwestern 100-BC for 3-point calculations | 199-B8-6 | Water table |
| Water table in southeastern 100-BC for 3-point calculations | 199-B5-8 | Water table |
| Vertical gradient between RUM and unconfined aquifer; water table in northern 100-BC for 3-point calculations | 199-B2-14 | Water table |
| | 199-B2-15 | RUM |

#### 2.1.12.3 Aquifer/River Interactions

An uncertainty on the nature and extent of contamination entering the Columbia River was identified during the work plan process (Data Gap 5). Water samples were collected from among the rocky bed of the Columbia River (pore water) and from aquifer tubes adjacent to the river.

100-BC groundwater discharges to the Columbia River via seeps and upwelling to the riverbed. This groundwater flow provides a pathway for contaminant transport to the Columbia River. Rapid, periodic, or cyclic elevation fluctuations of the river occur in controlled response to flood conditions, hydroelectric production, and salmon spawning programs at a series of dams and reservoirs upriver of the site. These rapid elevation changes in the river cause periodic influences on flow conditions within the aquifer. Daily fluctuations of more than 2 m (6 ft) are common. Even greater changes (more than 4.5 m [15 ft]) are observed seasonally, with a period of high river stage in the spring or early summer and low river stage in the fall. Periods of high or low river flow affect the unconfined aquifer flow the most.

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

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

***Columbia River Pore Water Studies.*** DOE conducted sampling of pore water, river water, and sediment to investigate Hanford Site releases to the Columbia River (Columbia River RI Work Plan [DOE/RL-2008-11]). The study included three phases of pore water sample collection near 100-BC in 2009 and 2010. The 100-BC Work Plan (DOE/RL-2008-46-ADD3) identified a need for additional pore water sampling (Data Gap 5). Each of these studies was focused primarily on identifying the nature and extent of groundwater contaminants entering the Columbia River. Section 2.1.9 describes those studies.

***Aquifer Tube Installation and Monitoring***

Initial characterization of site contamination near the river relied on data from a limited number of near- river wells, contaminant plume migration predictions, and riverbank seep sampling to anticipate shoreline conditions. To resolve the uncertainty, aquifer tubes were installed along the River Corridor, including 100-BC, to assist with characterizing nearshore contaminants. The aquifer tubes are small diameter polyethylene tubes that have a screen at the lower end (Figure 2-7). The tubes were placed into the aquifer by driving temporary steel casings into the ground and inserting tubes into the casings. The end of each tube was fitted with a screened section, which acts as the sampling port. The temporary steel casing was driven by a hydraulic ram attached to a vehicle or by a hand-carried pneumatic hammer. The steel casing was then back-pulled, leaving the tube and the stainless-steel drive point in place. Water is withdrawn from the tubes using a peristaltic pump. The tubing exposed at the ground surface is of minimal length (several feet) and is protected from wildlife and the elements by PVC conduit. Figure 2-7 shows the main components of aquifer sampling tube installation.

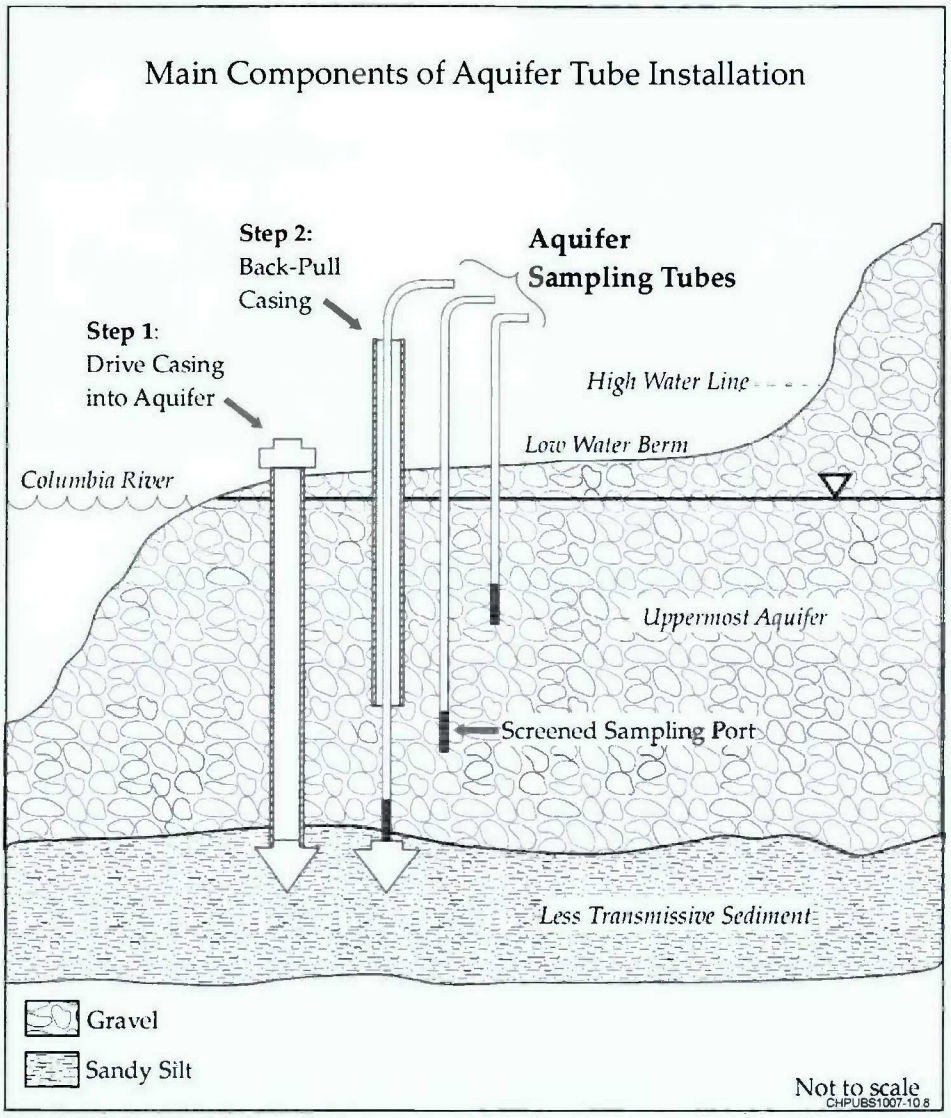



**Figure 2-7. Aquifer Tube Installation**

As part of this RI/FS, additional aquifer tubes were installed at 100-BC (Table 2-11; Figure 2-1). These aquifer tubes were added to the scope of work in the *Sampling and Analysis Plan for Aquifer Sampling Tubes* (DOE/RL-2000-59) via *Tri-Party Agreement Change Notice Form: Sampling and Analysis Plan for Aquifer Sampling Tubes DOE/RL-2000-59, Rev 1* (TPA-CN-327) to ensure consistent installation and sampling methods. The new tubes were sampled for the first time in September 2010. A larger set of 100-BC aquifer tubes was sampled between December 2011 and March 2012.

Results of aquifer tube sampling are discussed in Section 4.3.

**Table 2-11. 100-BC Aquifer Tubes Installed in 2010**

| Tube Name | Hanford River Marker | Elevation at Grade (m) | Top of Screen (ft below surface) | Top of Screen (m above sea level) |
|---|---|---|---|---|
| C7718 | 3.953 | 119.39 | 7.1 | 117.23 |
| C7719 | 3.951 | 119.40 | 12.5 | 115.60 |
| C7720 | 3.952 | 119.38 | 18.3 | 113.81 |
| C7724 | 4.063 | 119.34 | 6.3 | 117.43 |
| C7725 | 4.062 | 119.47 | 10.6 | 116.23 |
| C7726 | 4.064 | 119.45 | 15.6 | 114.70 |
| C7780 | 4.393 | 119.44 | 5.7 | 117.71 |
| C7781 | 4.394 | 119.40 | 8.5 | 116.80 |
| C7782 | 4.392 | 119.04 | 11.3 | 115.61 |

#### 2.1.12.4 Spatial and Temporal Groundwater Sampling

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

Monitoring well locations were identified to represent conditions at 100-BC without regard to the location of surface facilities, waste sites, or known groundwater plumes. To provide the number of sampling points for a monitoring well network, the average groundwater yields are used to determine the number of residences supported on one supply well. Thus, the grid size specific to each area is determined. Use of a random grid generator provides approximate locations for sampling points based on the final number of sampling points and the total area. Groundwater samples were collected so that they chemically, radiologically, spatially, and temporally represent the groundwater in the area. Eighteen monitoring wells (Figure 2-1), including 14 existing monitoring wells and four new wells installed per *Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* (DOE/RL-2009-61), were sampled and analyzed for this purpose. In addition, groundwater elevation data were collected for evaluation of groundwater and plume flow direction.

These wells were then sampled to obtain temporal representation of groundwater conditions. This sampling was intended to be conducted at high, low, and transitional river stages. Three rounds of groundwater samples were collected for analysis of all COPCs to support the RI for each contaminant. A sampling round, or event, was conducted for each seasonal high, low, and transition river stage, totaling three samples per well. Each round of monitoring in the network of

wells for this area was completed within 30 consecutive calendar days to minimize statistical variability in water levels. Table 2-12 summarizes sampling dates. Groundwater samples were collected for COPCs to provide a data set that is representative of potential releases to the groundwater. Chapters 4, 6, and 7 discuss the results and subsequent evaluation of the analysis of the data.

**Table 2-12. Dates of 100-BC Spatial/Temporal Groundwater Sampling (2010)**

| Sampling Round | Start | End | Duration (days) |
|---|---|---|---|
| Round 1 (high river) | May 10 | May 18 | 9 |
| Round 2 (transitional river) | July 27 | August 12 | 17 |
| Round 3 (low river) | September 2 | September 7 | 6 |

### 2.1.13 Ecological Investigations

DOE monitors and surveys site plant and animal resources on the Hanford Site to establish potential radiological exposures resulting from site activities; to assess the condition of endangered, threatened, or sensitive species; and to evaluate breeding locations, habitat use, and distribution of key wildlife species. Chemical analysis of biota tissues was included in the upland, riparian, and nearshore environments of 100-BC as part of the 100-BC Pilot Study, along with histopatholy analysis. Bioassays were not included as part of the 100-BC Pilot Study as was the case with other OUs addressed in the RCBRA Volume I (DOE/RL-2007-21, Rev. 0). While bioassays performed at Hanford are discussed within Chapter 7 and Appendix M of this document, no ecological investigations were conducted specifically as part of this RI/FS.

Section 3.9 summarizes the ecology of the Hanford Site and Section 4.5 summarizes results of biota monitoring.

#### *2.1.13.1 Vegetation Monitoring*

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

#### *2.1.13.2 Fish and Wildlife Monitoring*

Fish and wildlife on the Hanford Site, including fish, rabbits, deer, and elk, are monitored for site-produced contaminants. Tissue samples were analyzed for strontium-90 and gamma emitters, including cesium-137. Since the 1990s, strontium-90 and cesium-137 have been the most frequently measured radionuclides in fish and wildlife samples. In addition, liver tissues from fish and deer are monitored for trace metals.

#### *2.1.13.3 Plant Communities and Population Surveys*

Plant populations monitored on the Hanford Site include species listed by Washington State as endangered, threatened, or sensitive, and species with insufficient data to evaluate their status. Monitoring data are used to develop baseline information and to monitor for changes resulting from site operations. Surveys for rare annual species are conducted as part of annual compliance

review activities. More than 100 plants listed as endangered, threatened, sensitive, or on the view or watch list are found on the site.

#### 2.1.13.4 Wildlife Populations Surveys

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

Roadside surveys were conducted for mule deer on the site to assess age and sex ratios and the frequency of testicular atrophy in males. Testicular atrophy has been associated with an unusually large number of older deer residing on the site.

#### 2.1.13.5 Habitat and Species Characterizations

Ecological monitoring on the Hanford Site includes characterizing breeding locations, habitat use, and distribution of key wildlife species. Characterization studies focused on the Woodhouse's toad and the burrowing owl, a Washington State candidate species and federal species of concern in this region.

#### 2.1.13.6 Contaminated Biota

Animals (including insects) must be controlled when they are contaminated with radioactivity. A total of 33 contaminated animals or animal-related materials were discovered in 2008.

### 2.1.14 River Corridor Supplemental Investigations

To support information needs for the entire River Corridor, the following supplemental activities from the Integrated Work Plan (DOE/RL-2008-46) were carried out separately from the RI field investigation activities described in the 100-BC SAP (DOE/RL-2009-44):

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

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

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

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

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

  - The 0 to 40 mL/g $K_d$ range appears to be based largely on experience and general knowledge rather than on specific test results. A 1977 paper considered in establishing this range presents a $K_d$ of approximately 65 mL/g antimony desorption from soil. This appears to be one of the few references available that presents actual $K_d$ desorption data; the value supports the conclusion that desorption values are "much greater" than sorption values.

  - The 45 mL/g $K_d$ value is a calculated value based on a theoretical correlation between $K_d$ and the soil-to-plant concentration factor; it does not represent a value from experimental determination. This value is used by EPA and identified in the "Cleanup Levels and Risk Calculations" (CLARC) database (Ecology, 2009).

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

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

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

  Arsenic is a statewide concern because of historic smelter operations and pesticide use in agricultural areas (e.g., orchards). The State of Washington has established programs to

evaluate arsenic contamination continue to consider the Method A soil cleanup level of 20 mg/kg as a trigger for action. The Method A level (20 mg/kg) is proposed for continued use, which is consistent with other cleanup actions throughout the state.

## 2.2 Field Activity Documentation

As discussed in previous sections, field investigations have been conducted in 100-BC to address the data needs identified in the work plan. The results of these field investigations are summarized in a variety of documents and tables, as listed in Table 2-13. Appendix D includes soil, groundwater, and water-level data collected for 100-BC.

**Table 2-13. Field Activity Documentation**

| Field Activity | Documentation |
|---|---|
| Monitoring well installation | *Borehole Summary Report for the Installation of Four Wells in the 100-BC-5 Operable Unit in Fiscal Year 2009* (SGW-48720)<br>*Borehole Summary Report for the Installation of 6 Wells in the 100-BC-5 Operable Unit to Support RI/FS* (SGW-49672)<br>Well database (http://environet.hanford.gov/EDA) |
| Drilling of vadose boreholes | *Borehole Summary Report for the Installation of 8 Boreholes in the 100-BC Area in Support of WCH and RI/FS in FY 2010-2011* (SGW-50010)<br>Well database (http://environet.hanford.gov/EDA) |
| Characterization sampling during drilling (soil and groundwater) | Sampling paperwork in project files<br>Data in HEIS (http://environet.hanford.gov/EDA) |
| Test pit excavation | Project controlled logbook "Integrated 100 Area Remedial Investigation/ Feasibility Study Test Pit Sampling" (EL-1654)<br>Sampling paperwork in project files |
| Aquifer tube installation and sampling | Project controlled notebook<br>Data in HEIS (http://environet.hanford.gov/EDA) |
| Aquifer testing | ECF-100BC5-11-0145, *Analysis of Slug Test Data at the 100-BC-5 Operable Unit* (Appendix C)<br>*Aquifer Test Analyses for Wells 199-B2-15 and 199-F5-53* (ECF-HANFORD-11-0149) (Appendix C) |
| Pore water sampling | *Columbia River Pore Water Sampling in 100-BC Area, November 2010* (SGW-49368) |
| Collection of automated hydraulic head data | Virtual Library (automated water-level network) |
| Groundwater sampling of spatial and temporal monitoring network | Groundwater sample records in IDMS; groundwater data in HEIS (http://environet.hanford.gov/EDA) |

# 3 Physical Characteristics of the Study Area

This chapter describes the physical setting of 100-BC to establish the framework for the nature and extent of contaminants in the environment, and for contaminant fate and transport. The following site features are discussed in this chapter: surface features, meteorology, surface water hydrology, geology, soil and vadose zone, hydrogeology, artificial water systems, ecology, and cultural resources. This chapter also includes a discussion of current land use, future land use, and demography to support risk characterization efforts. Input for an assessment of risk will depend on reasonably anticipated future land use and anticipated beneficial uses of groundwater and surface water.

***Highlights***

- In 100-BC, soil in the vadose zone comprises unconsolidated gravel and sand of the Hanford formation. The water table is at a depth of up to 30 m (98 ft).
- The uppermost aquifer is unconfined and comprises the sands and gravels of Ringold unit E and, in most locations, a portion of the Hanford formation. Data from new wells were used to create maps of the contact between these geologic units and the saturated thickness of the more permeable Hanford formation.
- The unconfined aquifer is relatively thick (29 to 47 m [95 to 154 ft]). A low-permeability geologic unit in the Ringold Formation forms the bottom of the unconfined aquifer. Data from new wells show that this unit is continuous beneath 100-BC and slopes to the west.
- Groundwater flows generally to the northeast and north, and discharges to the Columbia River via springs and areas of upwelling through the riverbed.
- Data collected for the RI were evaluated to estimate the average rate of groundwater flow, which ranges from 0.07 to 0.7 m/d.
- Current land use at 100-BC consists of waste management, environmental monitoring, soil remediation, and conservation and restoration activities. The B Reactor is a National Historic Landmark and will be converted into a public museum with an interpretive center.

## 3.1 Surface Features

100-BC covers 11.5 $km^2$ (4.5 $mi^2$) and is located on the south bank of the Columbia River, upstream from the other Hanford Site reactor areas. The topography of 100-BC is relatively flat inland from the Columbia River (Figure 3-1). The area has been disturbed and graded extensively by human activity from reactor construction in the 1940s through current waste site remediation activities. Surface elevations in this region range from approximately 150 m (490 ft) above mean sea level (AMSL) at the southern border to 130 m (430 ft) in the north. The riverbank slopes steeply (10:1 grade) to the river shoreline where the elevation is approximately 122 m (400 ft) AMSL.

Significant topographic features near 100-BC include Gable Butte to the south as well as an extensive gravel beach that is exposed along the Columbia River during periods of low river stage. On the upstream end of the area, the bank is less steep and broadens into a gently sloping shoreline (50:1 grade) that is approximately 150 m (492 ft) wide (*Fiscal Year 1991 Report on Archaeological Surveys of the 100 Areas, Hanford Site, Washington* [PNL-8143]).

## 3.2 Meteorology

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

Figure 3-1. 100-BC Topography

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

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

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

Source: DOE, Hanford. Hanford Meteorological Station. Monthly and Annual Minimum Temperatures http://www.hanford.gov/page.cfm/hms/products/minmonth.

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

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

Source: DOE, Hanford. Hanford Meteorological Station. Monthly and Annual Minimum Temperatures http://www.hanford.gov/page.cfm/hms/products/maxmonth.

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

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

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

Source: Department of Energy, Hanford. Hanford Meteorological Station. Monthly and Annual Precipitation. http://www.hanford.gov/page.cfm/hms/products/totprcp.

Surface winds blow predominantly from the northwest during winter and summer and from the southwest during spring and fall. At 100-BC and along the Columbia River, local winds are strongly influenced by river topography near the river (NEPA Characterization Report [PNNL-6415]). In 100-BC, winds blow predominantly from the west and west-northwest. Table 3-4 lists Hanford Site wind speeds and directions from 1945 through 2004.[1] The prevailing wind direction at the Hanford Site is from the west-northwest or northwest, and the peak gusts are from the south-southwest, southwest, or west-southwest. The highest monthly average wind speeds occur in June. The lowest occur in December. The variability in monthly average wind speeds is much greater in the winter than during the remainder of the year.

The wind speed class with the highest frequency of occurrence is 4 to 7 mph. Winds in that category occur 37 percent of the time. The speed class with the second highest frequency is 8 and 12 mph, at 25 percent. Winds averaging more than 25 mph only occur 1 percent of the time, annually, with the highest frequency in March (1.6 percent) (*Hanford Site Climatological Summary 2004 with Historical Data* [PNNL-15160]). High-speed surface winds in the summer from the southwest can generate regional dust storms that sometimes lead to onsite work terminations. Figure 3-2, a photograph taken in approximately 1944, shows the Hanford Construction Camp during one such dust storm.

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

| Month | Prevailing Direction | Average Speed (mph)[a] | Highest Average | | Lowest Average | | Peak Gusts | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | mph | Year | mph | Year | mph | Direction | Year |
| January | NW | 6.3 | 10.3 | 1972 | 2.9 | 1985 | 80 | SW | 1972 |
| February | NW | 7.0 | 11.1 | 1999 | 4.6 | 1963 | 65 | SSW | 1999[b] |
| March | WNW | 8.2 | 10.7 | 1977[b] | 5.9 | 1958 | 70 | SW | 1956 |
| April | WNW | 8.8 | 11.1 | 1972[b] | 7.4 | 1989[b] | 73 | SSW | 1972 |

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

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

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

Note: Wind speed averages have not been published for years 2005 to present.

Source: *Hanford Site Climatological Summary 2004 with Historical Data* (PNNL-15160)

a. 1 mph = 1.61 km/hr.

b. Also in earlier years.

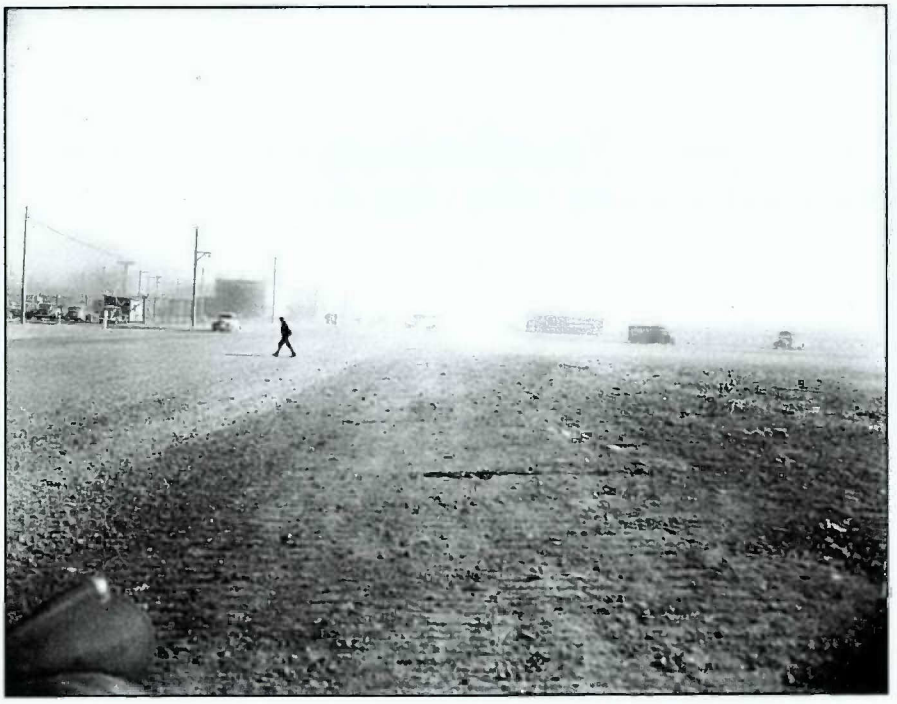


**Figure 3-2. Dust Storm at Hanford Site Construction Camp, ca. 1944**

## 3.3 Surface Water Hydrology

This section describes the Columbia River and water use at 100-BC. The Columbia River influences site hydrogeology and contaminant migration, and is used as an onsite water supply.

### 3.3.1 Columbia River

The Columbia River is the only natural surface water feature near 100-BC and forms the northern boundary of the study area (Figure 3-1). The Columbia River has played a major role in the depositional and erosional processes that helped produce the sedimentary and geologic features across the Hanford Site.

The stretch of the river that extends from Priest Rapids Dam, approximately 21 km (13 mi) upstream of 100-BC, to the headwaters of Lake Wallula, is the only free flowing portion of the Columbia River in the United States. This stretch of river, the Hanford Reach, is part of the Hanford Reach National Monument, established in June 2000 through Presidential Proclamation.

Figure 3-1 illustrates the bathymetry of the river bottom at 100-BC. The deepest portion of the river is upstream of 100-BC, with the river bottom elevation less than 105 m (344 ft) AMSL locally. At an average river stage of 120 m (394 ft), the river is up to 15 m (49 ft) deep. Adjacent to the main portion of 100-BC, the river bottom is at elevations between 112 and 114 m (367 and 374 ft) AMSL, corresponding to a water depth of approximately 8 m (26 ft).

The flow of the Columbia River at 100-BC is to the east and is controlled mainly by Priest Rapids Dam. The flow rate at Priest Rapids from 1992 through 2011 averaged approximately 3,240 $m^3$/sec (114,500 $ft^3$/sec). The highest average flow occurred in 1997 and the lowest flow in 2001 (Figure 3-3). Flow volumes are highest from April through early July because of runoff from regional and high elevation snowmelt. Flows are lowest from September through October. The width of the Columbia River through the Hanford Reach at 100-BC can vary from approximately 300 to 1,000 m (1,000 to 3,300 ft), depending on the flow rate. The elevation of the river also changes with the flow rate, resulting in wetting and drying of the shoreline area (NEPA Characterization Report [PNNL-6415]).

Since 1992, a stream gauge located in 100-BC has recorded river stage hourly. Figure 3-4 shows the location of the gauge, along with the locations of monitoring wells and borings at 100-BC. The top panel of Figure 3-5 shows daily average and annual average river stage from 1992 to 2011. The bottom panel shows river stage for 1997, a high-water year; 2001, a low-water year, and 2010, a moderate year.

High river stage can be greater than 123 m (404 ft) AMSL and generally occurs in May or June. Low river stage, approximately 118.5 m (389 ft), typically occurs in September or October. Two years of above average river stage in 1996 and 1997 caused the water table to rise and affected groundwater contaminant concentrations (Chapter 4). Diurnal fluctuations in 100-BC river stage range up to 1.5 m (5 ft). Seasonal fluctuations average 4.0 m (13 ft) over a year, and have ranged up to 5.6 m (18 ft).

The water quality of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, has been designated as Class A, Excellent, by Washington State (2010 Sitewide Environmental Report [PNNL-20548]). Class A waters are suitable for essentially all uses, including drinking water, recreation, and wildlife habitat. The suspended load in the Columbia River is typically very low. The bed load consists mainly of fine and medium sand. The river also has a low nutrient content and an absence of microbial contaminants (*Site Characterization Plan: Reference Repository Location, Hanford Site, Washington* [DOE/RW-0164]). Typical flow rates in the study area suggest that little deposition is occurring along the Hanford Reach, except along the shoreline portion of islands (Columbia River RI Work Plan [DOE/RL-2008-11]).

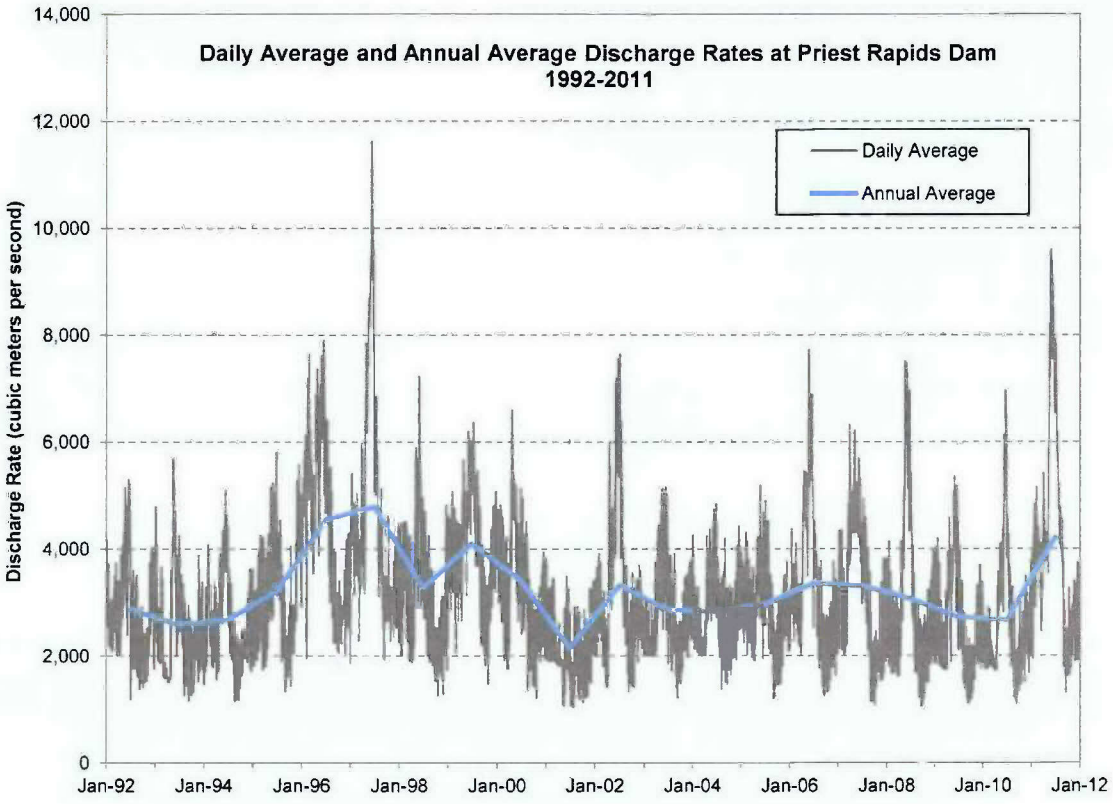



Figure 3-3. Columbia River Flow Volume at Priest Rapids Dam

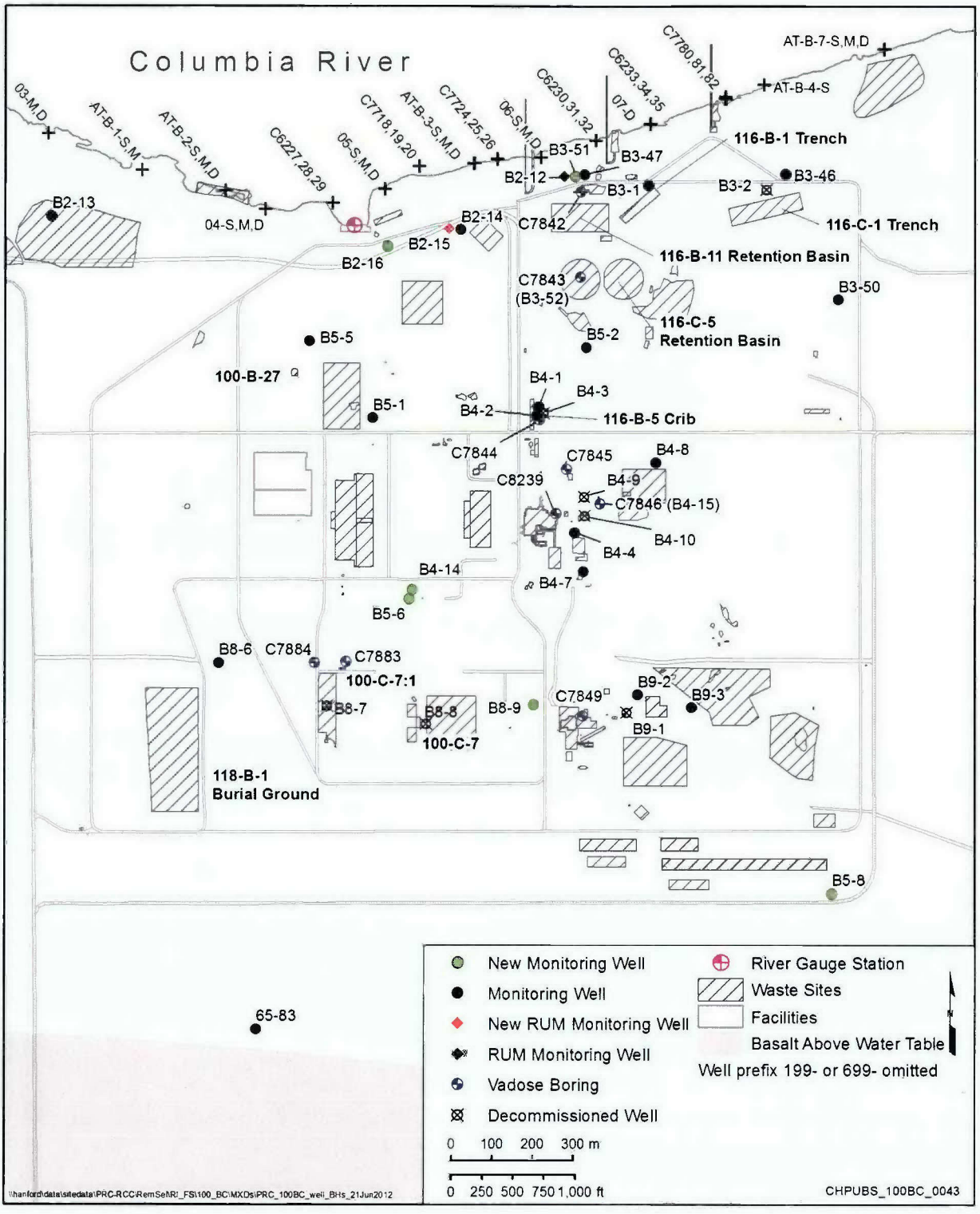
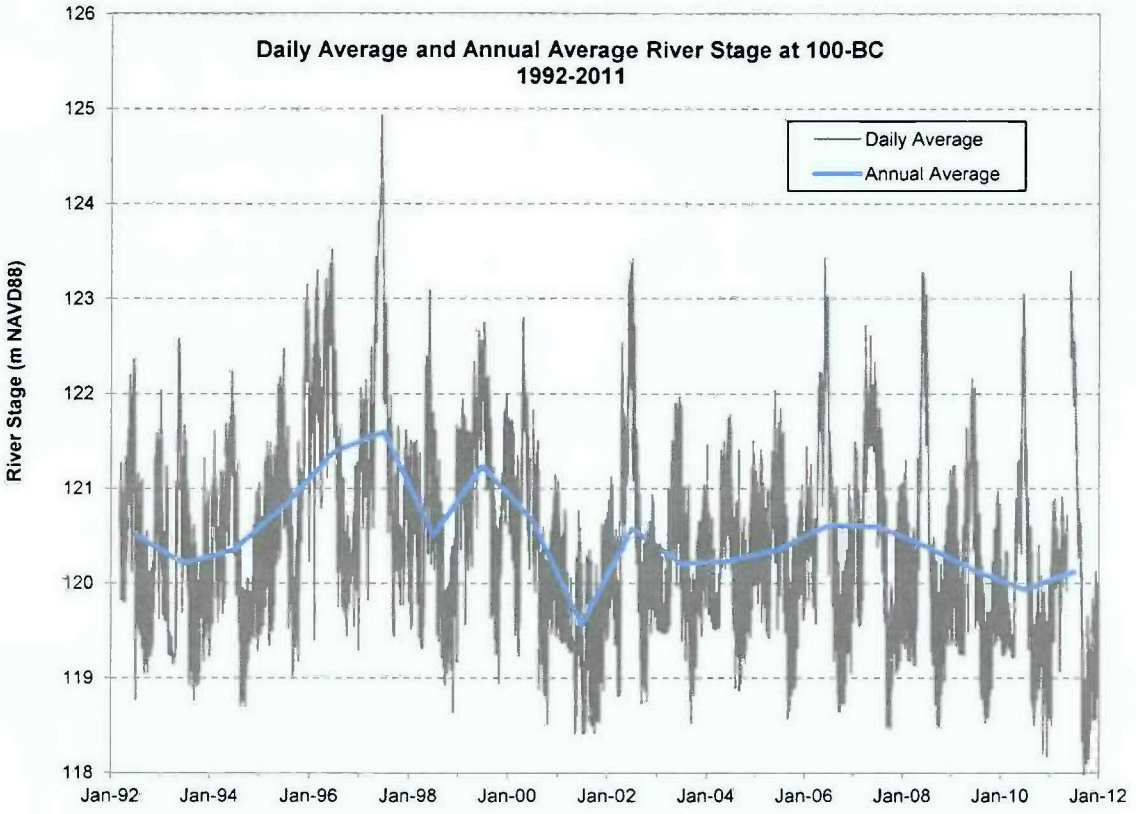



**Figure 3-4. Groundwater Monitoring Wells and Vadose Borings in 100-BC**



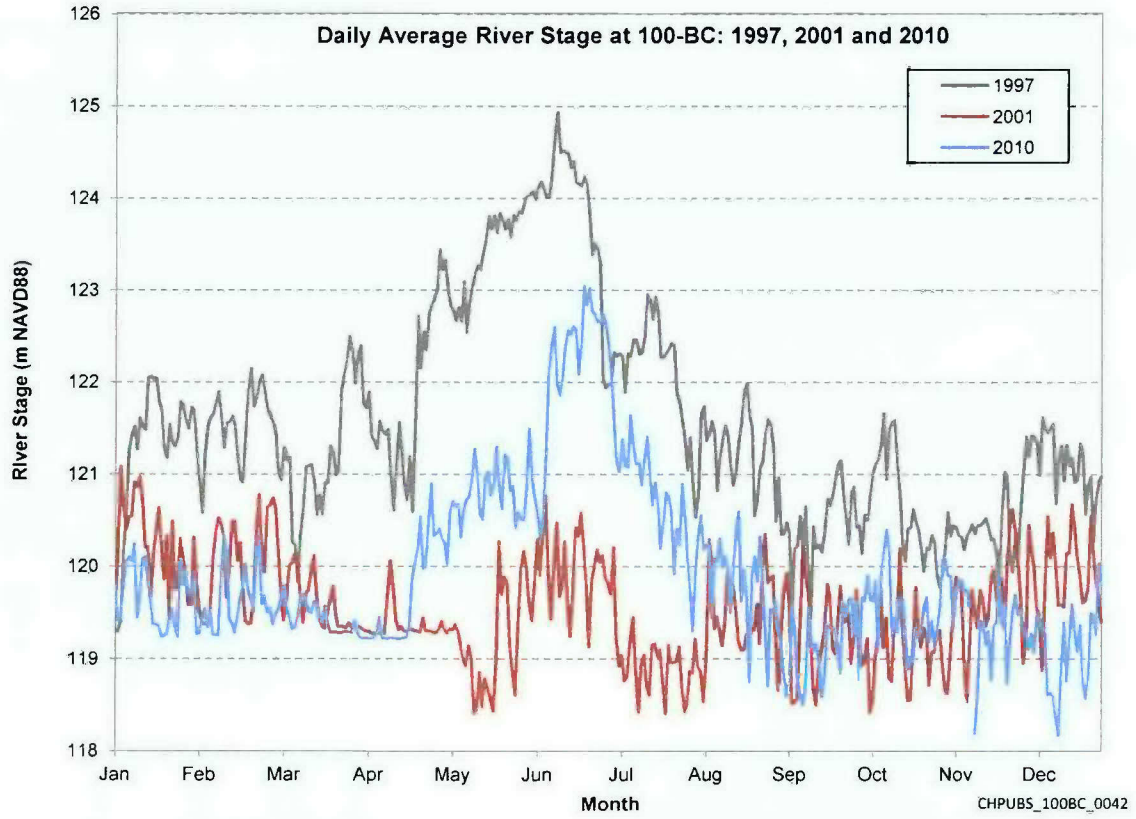




Figure 3-5. Columbia River Stage at 100-BC Gauge Station

### 3.3.2 Surface Water Use

Water is withdrawn from the Columbia River at 100-BC for Hanford Site water use. Columbia River water is pumped at the 181-B Pump House as the primary water supply for Hanford Site workers and facilities. Section 3.7 includes additional information about the water system.

## 3.4 Geology

As part of the RI, data from new wells were evaluated and combined with older data (as presented in *Geology of the 100-B/C Area, Hanford Site, South-Central Washington* [WHC-SD-EN-TI-133], *Geohydrologic Data Package in Support of 100-BC-5 Modeling* [SGW-44022]; and existing well logs), to form an updated interpretation of 100-BC geology. Geologic units from shallowest to deepest are Holocene sediments, Hanford formation, Ringold Formation, and the Columbia River Basalt Group. Environmental Calculation *100 Area Stratigraphic Database Development* (ECF-100NPL-11-0070), describes the process used to create geologic maps and cross sections presented in this section.

Geologic data from the new RI wells improved the knowledge of 100-BC stratigraphy. Prior to installation of the new wells, the Hanford/Ringold contact was defined in only a few 100-BC wells. New wells showed that the contact is deeper in southern 100-BC than previously known. The location of this contact is important because the Hanford formation is more permeable than the Ringold unit E. Eight of the 10 new wells were drilled through the entire thickness of the Ringold unit E to the uppermost fine-grained unit that defines the base of the uppermost aquifer. Previously, only two wells, both located in northeastern 100-BC, had tagged this mud unit. The mud surface appears to be continuous beneath 100-BC, and slopes toward the west.

### 3.4.1 Geologic Setting

The 100-BC Area lies on the northern flank of the Wahluke Syncline and is located adjacent the Columbia River.

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

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

### 3.4.2 Stratigraphy

Figure 3-6 shows the generalized stratigraphy of 100-BC. The area is underlain by Miocene (approximately 17 to 8.5 million years before present) basalt of the Columbia River Basalt Group and late Miocene to Pleistocene (approximately 10.5 million to 12,000 years before present) suprabasalt sediments.

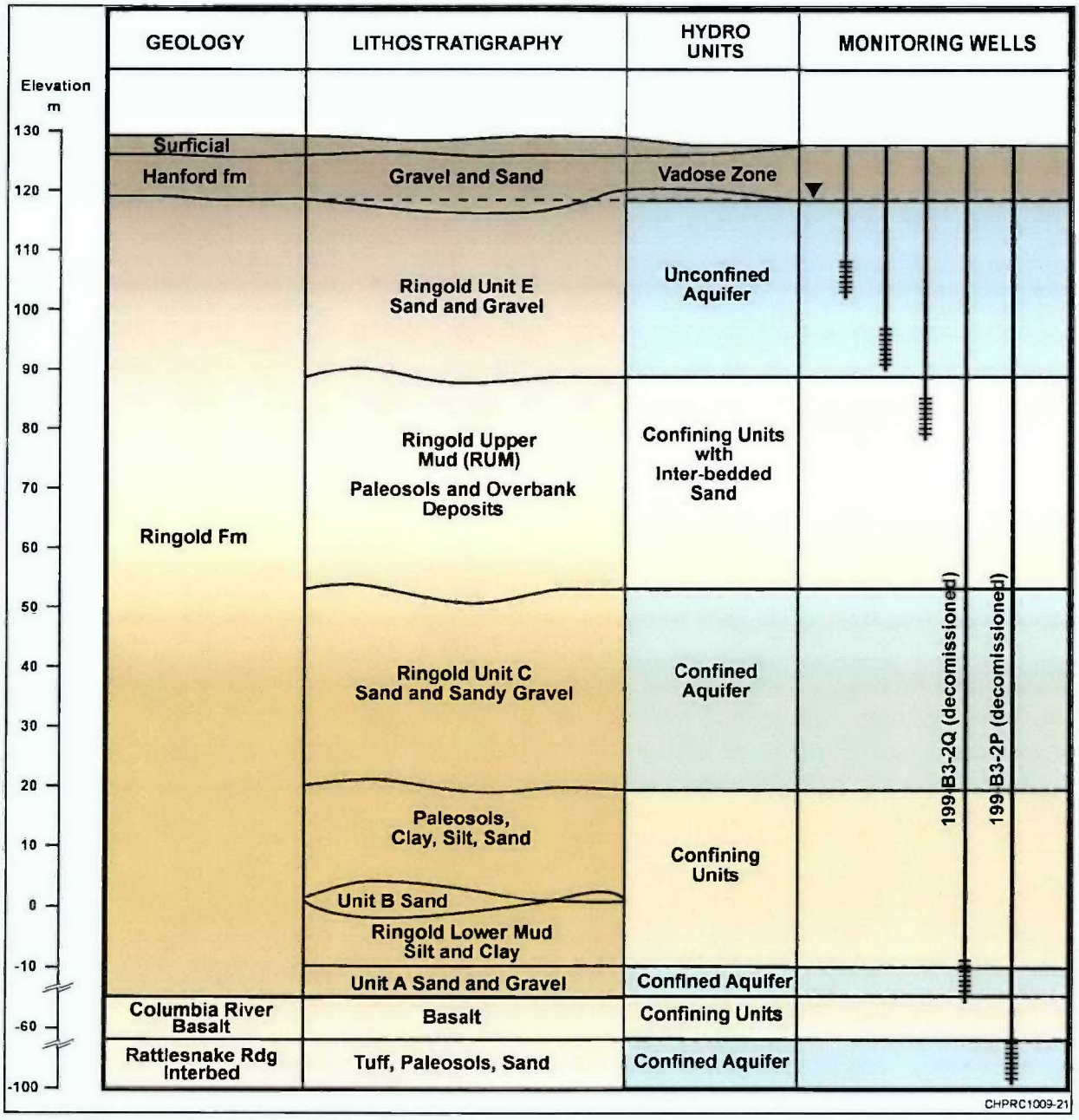



Figure 3-6. Stratigraphy and Hydrogeologic Units of 100-BC

Sediments overlying the basalts are approximately 200 m (660 ft) thick at 100-BC. Most of this sedimentary sequence can be divided into two main units: the Ringold Formation of late Miocene to middle Pliocene age (approximately 10.5 to 3 million years before present) and the Hanford formation of Pleistocene to Recent age (approximately 1 million to 12,000 years before present). Holocene surficial

deposits of silt, sand, and gravel form the veneer at the surface. Figures 3-7, 3-8, and 3-9 are geologic cross sections through 100-BC.

The sediments that overlie the basalt are divided into two primary units: the Ringold Formation of late Miocene to middle Pliocene age (approximately 10.5 to 3 million years [m.y.] before present [B.P.]) (*Sedimentology and Stratigraphy of the Miocene-Pliocene Ringold Formation, Hanford Site, South-Central Washington* [WHC-SA-0740-FP]) and the informally named Hanford formation of Pleistocene age (approximately 1 million to 12,000 B.P.) (*Geology and Ground-Water Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington* [Newcomb et al., 1972]). Holocene surficial deposits of silt, sand, and gravel form a relatively thin veneer at the surface (*Geology and Hydrology of the Hanford Site: A Standardized Text for Use in Westinghouse Hanford Company Documents and Reports* [WHC-SD-ER-TI-003]; "Long History of Pre-Wisconsin, Ice Age Cataclysmic Floods: Evidence from Southeastern Washington State" [Bjornstad et al., 2001]).

The 100-BC Area is underlain by Miocene-aged (approximately 17 to 8.5 m.y. B.P.) basalt of the Columbia River Basalt Group and late Miocene- to Pleistocene-aged sediments (Ellensburg Formation, approximately 10.5 million to 12,000 B.P.) that are interbedded with basalt flows. The basalt may exceed 3,050 m (10,000 ft) in thickness, including the interbedded sediments of the Ellensburg Formation.

The physical properties of these formations influence the distribution of contamination in the subsurface. The Hanford formation, two upper units of the Ringold Formation (Ringold unit E and RUM), and possibly backfill sediments have been contacted by contaminated fluids. The rest of the Ringold Formation consists of a lower mud unit and Ringold units A, B, and C. Contaminant migration to these lower units is very unlikely in most locations because the low hydraulic conductivity of the RUM forms an effective aquitard where it contacts the overlying Ringold unit E.

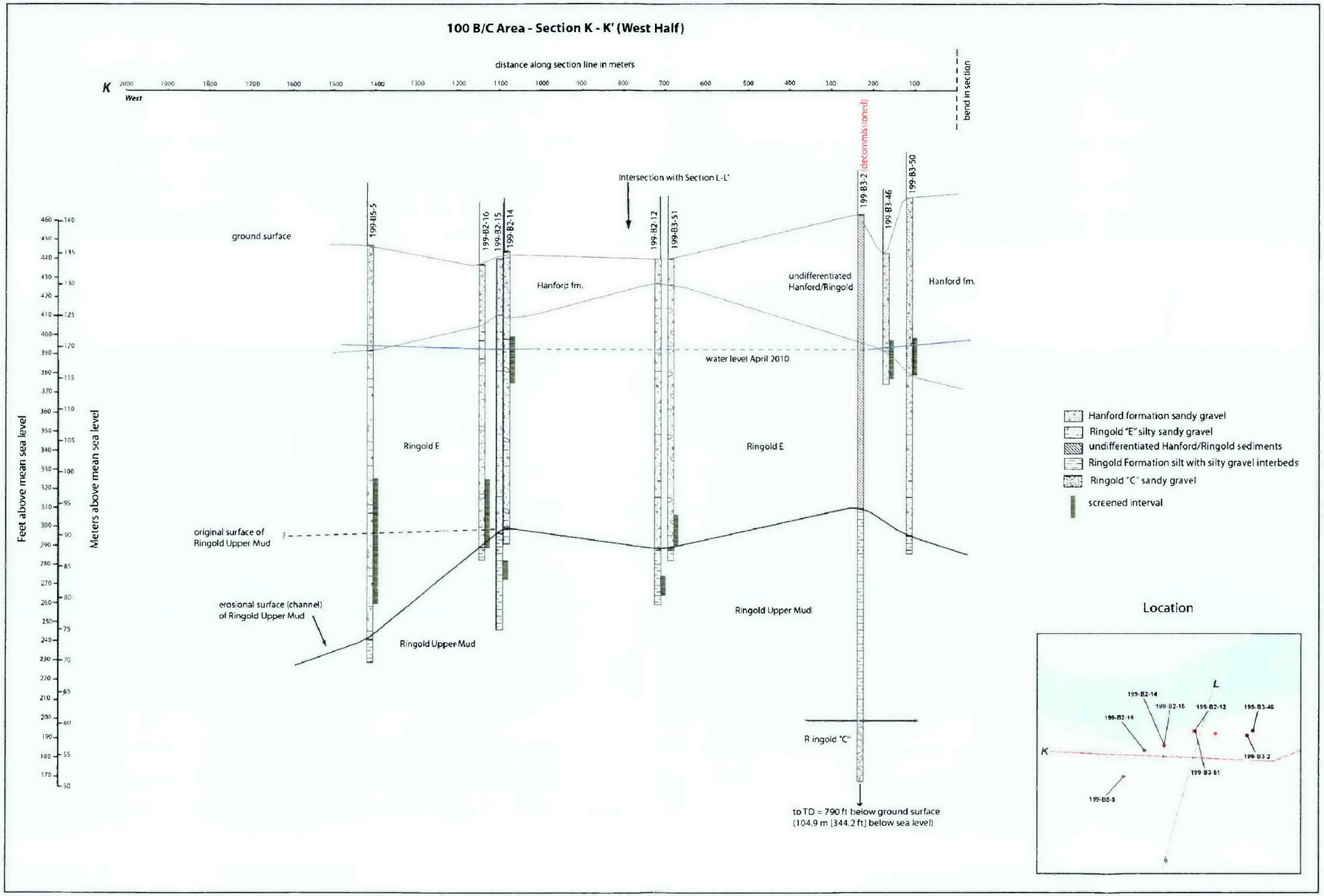
#### 3.4.2.1 Surface Deposits

Recent local, surficial deposits consist of silt, sand, and gravel. These sediments were deposited by a mix of eolian and alluvial processes during the past 10,000 years. Fill material above the Hanford formation was placed during construction of facilities and remedial action activities. Fill material typically consists of silty sandy gravel from Hanford Site borrow pits. In 100-BC, this material can be up to 4.6 m (15 ft) thick.

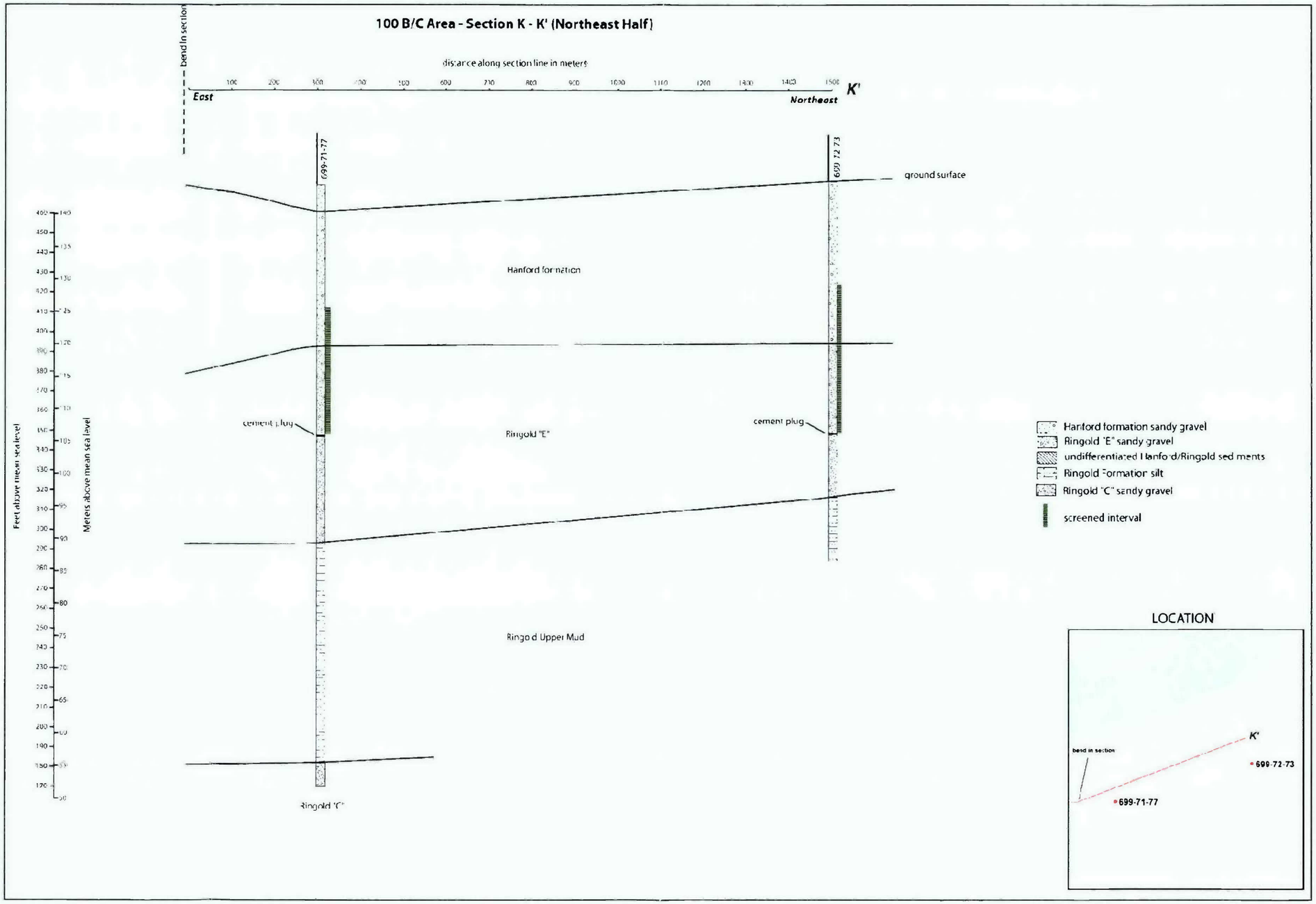
#### 3.4.2.2 Hanford Formation

The Hanford formation is an unofficial designation for a geologic unit that consists of gravel, sand, and silt deposited by cataclysmic floodwaters that drained out of glacial Lake Missoula during the Pleistocene age (*Draft Environmental Assessment: Reference Repository Location Hanford Site, Washington* [DOE/RW-0017]). The Hanford formation ranges in thickness from more than 60 m (200 ft) southeast of 100-BC to less than 15 m (50 ft) near the Columbia River (Figures 3-7, 3-8, and 3-9).

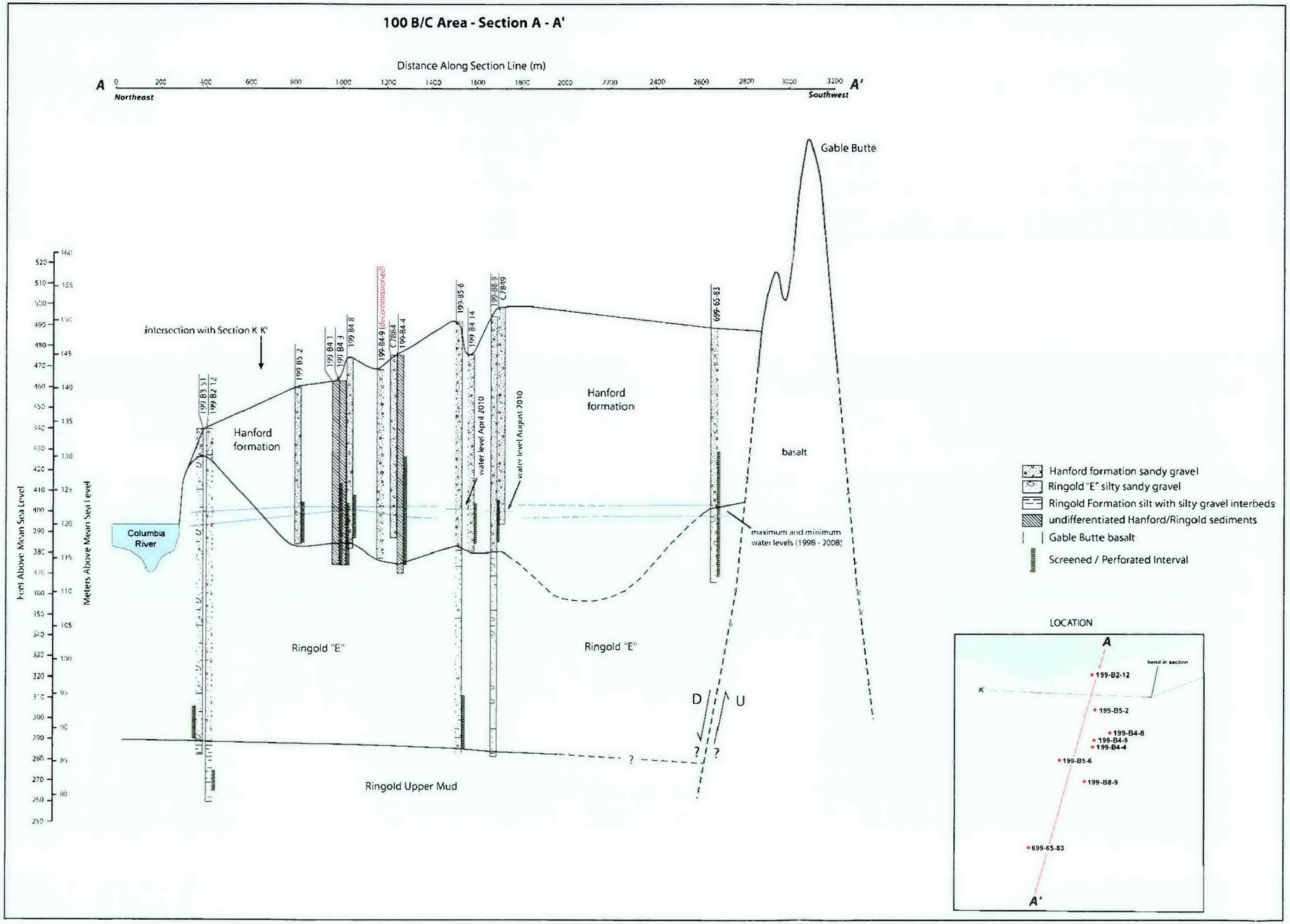
The Hanford formation is divided into three facies: gravel-dominated, sand-dominated, and silt-dominated (*Standardized Stratigraphic Nomenclature for Post-Ringold-Formation Sediments Within the Central Pasco Basin* [DOE/RL-2002-39]). While the gravel-dominated facies are observed throughout 100-BC, the sand-dominated facies were observed locally and cannot be correlated between boreholes. Silt-dominated facies are not significant in 100-BC.




Figures 3-7. Geologic Cross Section K-K' (West)




Figures 3-8. Geologic Cross Section K-K' (East)




**Figures 3-9. Geologic Cross Section A-A'**

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The Hanford formation in 100-BC is characterized by large to very large, cobble- to boulder-size clasts in open framework gravels. The formation includes discrete sand lenses with minor to no silt and clay material. The clasts typically are sub-round to round gravel and sub-angular to round in the sand grain fraction. The gravel-dominated facies typically are well stratified and contain little cementation (*Geologic Setting of the 100-HR-3 Operable Unit, Hanford Site, South-Central Washington* [WHC-SD-EN-TI-132]). Boulder gravel in the upper 6 to 15 m (20 to 50 ft) demonstrates the high-energy depositional environment created during the Missoula Floods. These deposits prove difficult to penetrate by drilling activities (*Geology of the 100-B/C Area, Hanford Site, South-Central Washington* [WHC-SD-EN-TI-133]).

#### 3.4.2.3 Hanford/Ringold Contact

The Hanford formation in 100-BC was deposited on an erosional surface of Ringold unit E. Geologists identify the contact between the Hanford formation and Ringold Formation based on characteristics such as basalt clast content, gravel content, coloration, and cementation. The Hanford formation typically is less cemented than the Ringold Formation and has greater gravel content. Hanford formation gravels typically display salt-and-pepper and gray coloring, while Ringold gravels are generally more oxidized and reddish-brown to yellow-red in color.

Because of the boulders and cobbles found in the Hanford formation and Ringold unit E, drilling of many wells was accomplished historically by "hard tooling" with a cable tool drilling rig to ensure reaching the desired depth. This method pulverizes the gravel and may wash away fine-grained sediment, making it difficult to log the characteristics that could otherwise differentiate the two formations. Even when other drilling methods are used, the contact can be difficult to identify at 100-BC. Therefore, the Hanford formation/Ringold Formation contact has not been determined in all boreholes.

The contact between Ringold unit E and the Hanford formation is important because the saturated hydraulic conductivity for the gravel-dominated sequence of the Hanford formation is one to two orders of magnitude higher than that of the more compacted and locally cemented Ringold unit E. A higher hydraulic conductivity allows for an increased flow of groundwater through the material than in those with lower conductivity. Because hydraulic conductivity varies with the formation, different groundwater level responses may occur where channels now filled with the Hanford formation have been scoured into the Ringold unit E. These buried channels could become preferential pathways for groundwater during high river stages (*Vadose Zone Hydrogeology Data Package for Hanford Assessments* (hereinafter called Vadose Zone Hydrogeology Package [PNNL-14702]), carrying contaminants where they are present.

Before the RI wells were drilled, the elevation of the geologic contact beneath 100-BC was defined in only a few wells. Data from the new wells show that beneath the former operational portion of 100-BC, the contact between the Hanford formation and Ringold unit E lies at an elevation ranging from 115 to 130 m (377 to 427 ft) AMSL (Figure 3-10). The contact is highest in 100-BC wells near the river and dips to the south. The contact is much deeper farther southeast in new Well 199-B5-8, approximately 94 m (308 ft) AMSL.

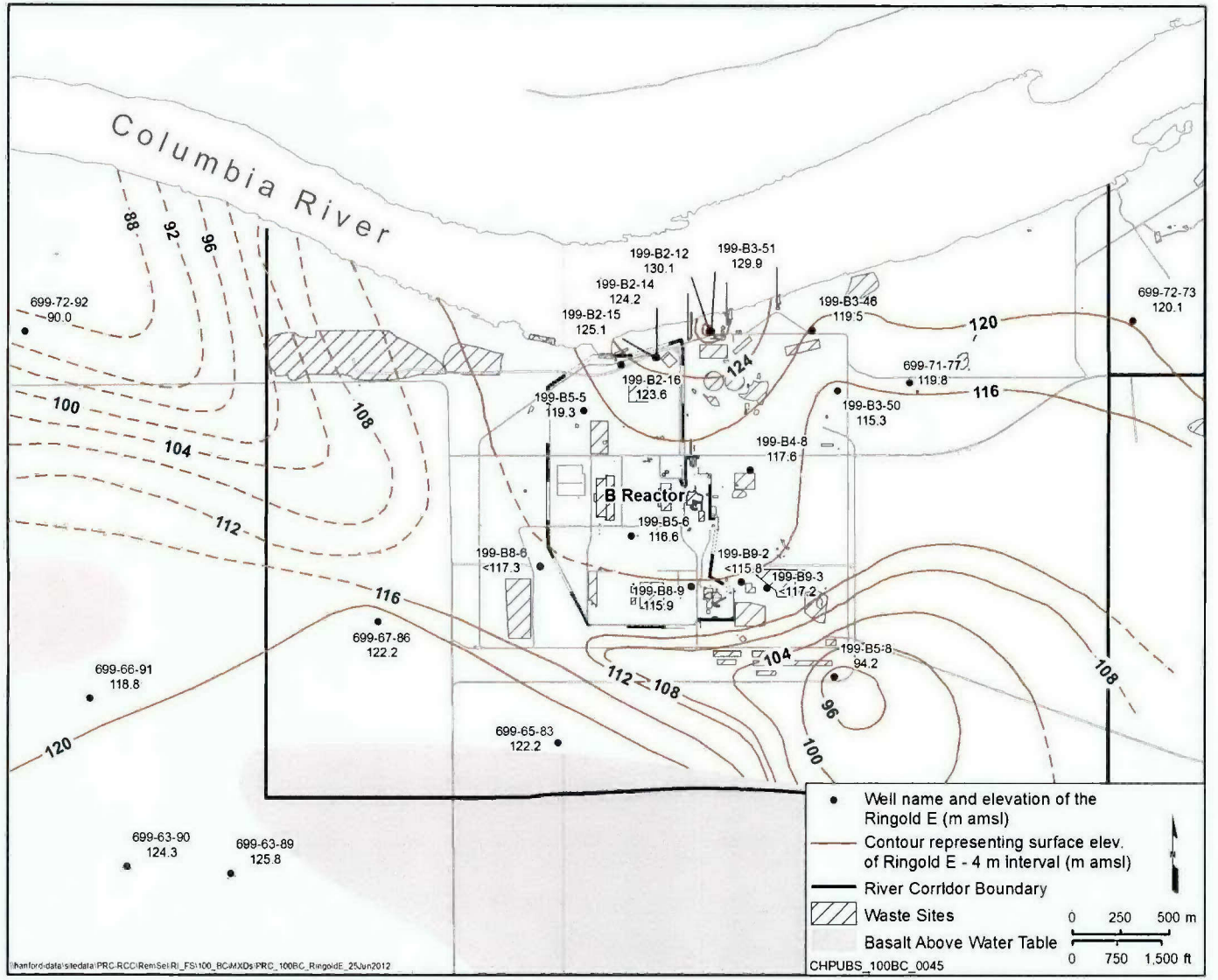


**Figure 3-10. Elevation of Top of Ringold Unit E, 100-BC (Hanford/Ringold Contact)**

#### 3.4.2.4 Ringold Formation

The Ringold Formation beneath 100-BC contains most of the units commonly encountered elsewhere at the Hanford Site. The fluvial gravel and sand units A, B, C, and E (in ascending order) are present and interbedded with fine-grained lacustrine and fluvial overbank deposits and paleosols. Only one well in 100-BC penetrated the full Ringold Formation and the upper basalt. Well 199-B3-2 was a piezometer host well in the northeastern corner of 100-BC that was decommissioned in the 1990s. Its former location is shown on Figure 3-4. The Ringold Formation is approximately 198 m (650 ft) thick at this location. The Ringold Formation is much thinner (21 m [70 ft]) at Well 699-63-89, approximately 4 km (2.5 mi) to the southwest.

The uppermost unit of the Ringold Formation in 100-BC is Ringold unit E, which comprises predominantly sandy gravel. This unit ranges from 29 to 47 m (95 to 154 ft) thick beneath the main portion of 100-BC (Figures 3-7 through 3-9). It is much thinner (6.4 m [21 ft]) southeast of 100-BC in Well 199-B5-8, where the Hanford-Ringold contact is anomalously deep.

In the 100 Area, the uppermost fine-grained Ringold sediments are informally termed the RUM unit. Distinguishing sandy, gravelly beds within the RUM unit from Ringold units C and B is not always possible. Similarly, silts and clays of the RUM unit may grade into deeper silt and clay units, making correlation of the units between boreholes difficult. In 100-BC, only Well 199-B3-2 penetrated the entire Ringold Formation. In that well, the RUM unit is interpreted to be approximately 34 m (110 ft) thick. The upper 0.5 to 4 m (2 to 13 ft) of the RUM unit in 100-BC comprises clay and silt and deeper sediments range from silty clayey gravel to silty sand.

Before the RI wells were installed in 100-BC, only two wells had been drilled through the entire thickness of Ringold unit E to reach the uppermost mud unit. Data from the new wells provided enough data to map the surface in detail (Figure 3-11). The surface of the uppermost mud unit beneath 100-BC slopes to the west. Elevations range from 72.9 m (239 ft) AMSL in Well 199-B5-5 (western 100-BC) to 89.1 m (292 ft) AMSL in Well 199-B3-50 (eastern 100-BC). In eastern 100-BC, this mud unit is interpreted to be the same RUM unit identified elsewhere in the 100 Area.

It is unclear whether the fine-grained sediments in Well 199-B5-5 and older wells farther west are the RUM or deeper Ringold mud units. West of 100-BC in Well 699-67-86, the shallowest mud unit is at an elevation of 69.2 m (227 ft) AMSL. No Ringold mud is present in Well 699-63-95, located approximately 4 km (2.5 mi) west of 100-BC. At this location, Ringold gravel overlies basalt.

Beneath the RUM, Ringold unit C comprises a coarse-grained series of silty sand to sandy gravel. In Well 199-B3-2, Ringold unit C is approximately 34 m (113 ft) thick. More layers of fine-grained units underlie Ringold unit C.

Two intervals of silty to gravelly sand are intercalated with muddy sediments. The two sandy intervals (2.4 and 1.8 m [8 and 6 ft] thick) probably correlate with Ringold unit B. Ringold unit B is thicker and better developed in the northeast and pinches out to the southwest.

The Ringold lower mud unit underlies unit B. It is approximately 44 m (143 ft) thick and consists primarily of silt and clay. The deepest Ringold unit (unit A) is approximately 18 m (60 ft) thick in Well 199-B3-2 and consists of sandy gravel, sand, and sandy silt.

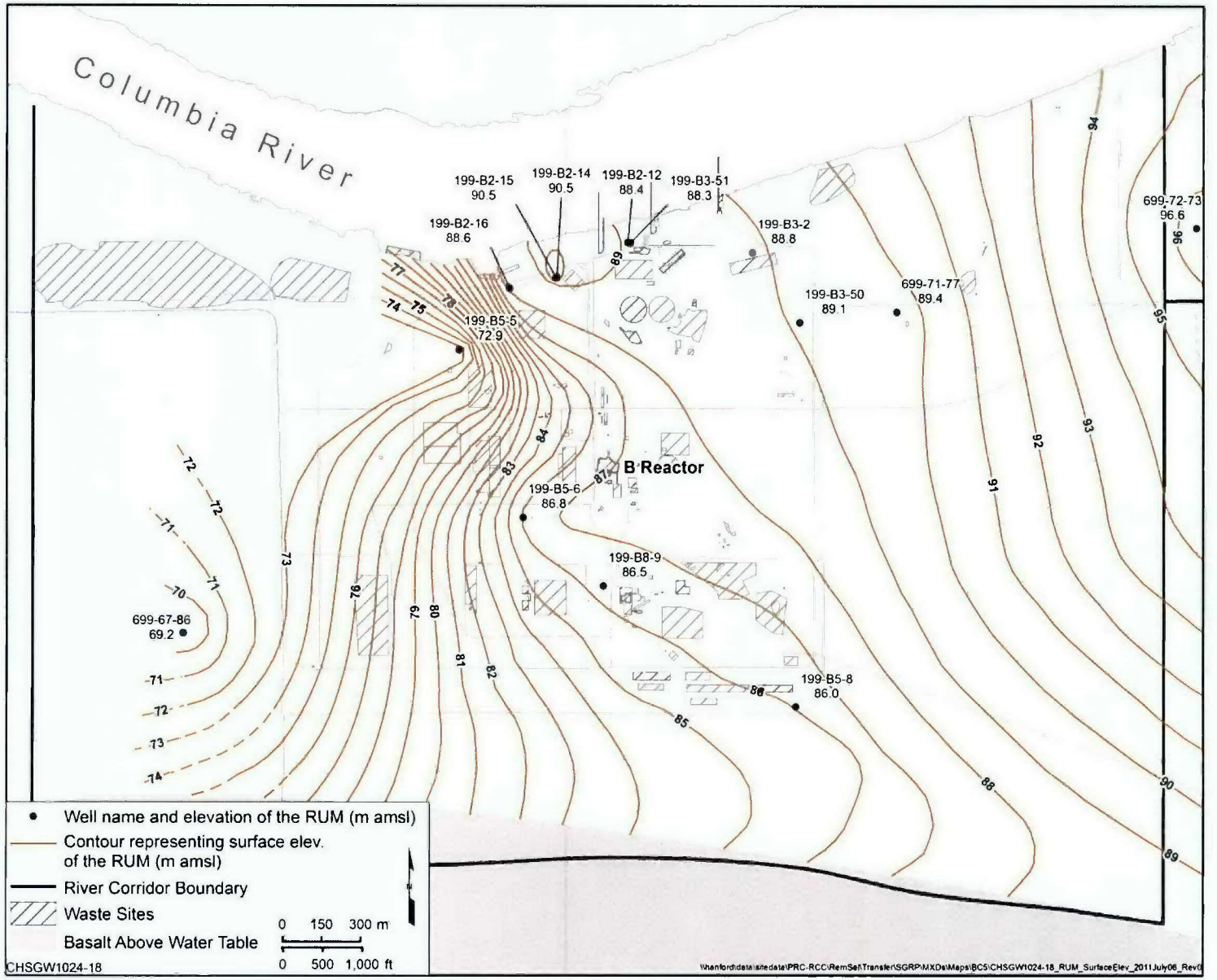


**Figure 3-11. Top of Ringold Mud, 100-BC**

#### 3.4.2.5 Columbia River Basalt Group and Ellensburg Formation

The 100-BC area is underlain by the Columbia River Basalt Group, which is greater than 3,000 m (9,800 ft) thick and forms bedrock beneath 100-BC. The Saddle Mountains Basalt Formation is the uppermost, youngest basalt in the study area.

One borehole in 100-BC (199-B3-2) and several in the nearby 600 Area (699-63-89, 699-63-90, 699-63-92, 699-63-95, and 699-66-91) were drilled to basalt. The surface of the basalt is at an elevation of 113 m (370 ft) in wells southwest of 100-BC and decreases to 65 m (213 ft) below sea level in 100-BC at Well 199-B3-2. The depth to basalt in Well 199-B3-2 is 200 m (656 ft).

Sedimentary interbeds between basalt flows are termed the Ellensburg Formation. Wells 199-B3-2 and 699-66-91 reached the Rattlesnake Ridge interbed, which comprises interbedded tuff, paleosols, and fluvial sand and gravel.

### 3.4.3 Data from New Wells and Boreholes

Table 3-5 summarizes geologic and well construction data for wells and boreholes in and near 100-BC. Geologic and geophysical logs for wells installed for the RI are included in *Borehole Summary Report for the Installation of Four Wells in the 100-BC-5 Operable Unit in Fiscal Year 2009* (SGW-48720), *Borehole Summary Report for the Installation of 6 Wells in the 100-BC-5 Operable Unit to Support RI/FS* (SGW-49672), and *Borehole Summary Report for the Installation of 8 Boreholes in the 100-BC Area in Support of WCH and RI/FS in FY 2010-2011* (SGW-50010). Figure 3-4 shows the location of wells and boreholes discussed in this chapter.

Figures 3-12 through 3-30 summarize information about new monitoring wells and vadose zone boreholes, including geology, sampled intervals, well completion, geophysics, and soil contaminants. The following subsections discuss geologic information for each well and borehole. Section 3.5.2 discusses physical properties of the vadose zone and Section 3.6.2 describes hydrogeologic properties of the aquifer and aquitard. Results of chemical analyses of sediment and groundwater samples are presented and described in Sections 4.2 and 4.3.

#### 3.4.3.1 Well 199-B2-14

Figure 3-12 summarizes information for Well 199-B2-14, located in northern 100-BC. The borehole was drilled using cable tool and a drive barrel. The well is screened in the uppermost portion of the unconfined aquifer, adjacent to Well 199-B2-15, which monitors the RUM.

The upper 2.1 m (7 ft) of sediments are characterized by gravelly silt, underlain by Hanford formation gravels with varying sand and silt content. The contact between the Hanford formation and Ringold unit E was not identified in the field. Subsequent evaluation of the borehole log places the contact at a depth of 10.1 m (33.0 ft) below ground surface (bgs) and the water table is below the contact, at about 14.6 m (45 ft) bgs. Ringold unit E is 30.2 m (99.1 ft) thick and comprises predominantly silty sandy gravel. The geologist noted repeated occurrences of "clayey cementation" throughout much of the formation. Heaving sand was noted at 33 m (110 ft) bgs. Silt content began to increase in the lower portion of Ringold unit E, and the borehole hit the RUM unit at 43.8 m (143.7 ft) bgs. The RUM unit was described as 95 percent silt and clay, 5 percent sand, very compact, with clayey cementation. Total depth of the borehole was 46.4 m (152.3 ft), which is 2.6 m (8.5 ft) into the RUM unit.

#### 3.4.3.2 Well 199-B2-15

Figure 3-13 summarizes information for Well 199-B2-15, located in northern 100-BC. The borehole was drilled using cable tool with drive barrel and hard tool. The well is screened in a water-bearing zone

beneath a silt and clay aquitard (RUM unit). Characterization samples were not collected from the Hanford formation or Ringold unit E, because these were available from adjacent Well 199-B2-14.

The lithology of the Hanford formation and Ringold unit E are as described for Well 199-B2-14. The geologist tentatively identified the Hanford formation/Ringold Formation contact at 9.6 m (31.5 ft) bgs, and subsequent evaluation of borehole data placed the contact at 9.1 m (30.0 ft) bgs. This is approximately 1 m (3 ft) higher than the contact picked in the adjacent well. The contact between Ringold unit E and the RUM unit was at the same depth as in the adjacent well. The borehole was drilled 15.3 m (50.1 ft) into the RUM unit, with sediment characterization samples collected every 1.5 m (5 ft). The geologist described the upper 3.9 m (12.8 ft) of the RUM unit as 95 percent silt/clay and 5 percent sand. Beneath this mud, the lithology changed to silty sand, and to sandy gravel. It has not been determined if the gravels represent Ringold unit C or if they are merely local zones within the RUM unit. Total depth of the borehole was 59.1 m (193.8 ft). The screen was set at a shallower depth in a silty sandy gravel.

#### *3.4.3.3 Well 199-B2-16*

Figure 3-14 summarizes information for Well 199-B2-16, located in northern 100-BC near the water intake structure. The borehole was drilled using cable tool with drive barrel and hard tool. The well is screened at the bottom of the unconfined aquifer.

The Hanford formation at this location comprises predominantly gravel, with varying amounts of sand and silt. The geologist tentatively identified the Hanford formation/Ringold Formation contact at 9.1 m (30 ft) bgs, based on increased compaction and color change. Subsequent evaluation of borehole data placed the contact at 9.8 m (32 ft) bgs. The lithology of Ringold unit E is primarily silty sandy gravel. Cementation was noted at depths below approximately 30 m (100 ft). The RUM unit was encountered as 95 percent silt and clay from 44.8 to 46.8 m (147 to 153.5 ft) bgs. This mud was underlain by gravelly silt to the total depth of the borehole at 47.3 m (155.2 ft).

#### *3.4.3.4 Well 199-B3-50*

Figure 3-15 summarizes information for Well 199-B3-50, located in eastern 100-BC. The borehole was drilled using cable tool with drive barrel and hard tool. The well is screened at the top of the unconfined aquifer.

The Hanford formation comprises silty sandy gravel and sandy gravel. The geologist identified the contact with Ringold unit E at 27.7 m (91 ft) bgs, which is approximately 5 m (16 ft) below the water table. Ringold unit E comprises predominantly sandy gravel. The RUM unit was encountered as 95 percent silt/clay at 54.3 m (178 ft) bgs. Total depth of the borehole was 55.9 m (183.3 ft), which is 1.6 m (5.3 ft) into the RUM unit.

#### *3.4.3.5 Well 199-B3-51*

Figure 3-16 summarizes information for Well 199-B3-51, located in northern 100-BC. The borehole was drilled using cable tool with drive barrel and hard tool. The well is screened at the bottom of the unconfined aquifer and is part of a multi-depth cluster with older Wells 199-B3-47 and 199-B2-12, which are screened at the water table and in the RUM unit, respectively.

Sediments are predominantly gravel with varying amounts of sand and silt. The contact between the Hanford formation and Ringold unit E cannot be distinguished with certainty at this location and the geologist did not identify the contact in the field. Evaluation of borehole logs for 199-B3-51 and the adjacent wells suggests the contact is quite shallow: 3.7 m (12 ft) bgs based on a decrease in basalt content. This would place the water table in Ringold unit E. A zone of increased cementation was noted at 39.3 to 40.2 m (129 to 132 ft) bgs. The top of the RUM unit was observed as a relatively thin layer of silt and clay at 45.6 m (149.5 ft) bgs. This was underlain by silty sandy gravel to the total depth of the borehole at 47.6 m (156.2 ft).

#### 3.4.3.6 Well 199-B4-14

Figure 3-17 summarizes information for Well 199-B4-14, located in central 100-BC. The borehole was drilled using cable tool with drive barrel. Because adjacent Well 199-B5-6 was characterized to the top of the RUM unit, Well 199-B4-14 was drilled only deep enough to be screened in the top of the unconfined aquifer.

The lithology at this location is gravel with varying amounts of sand and silt. Total depth of the borehole, which did not reach the Ringold Formation, was 29.2 m (95.8 ft).

#### 3.4.3.7 Well 199-B5-5

Figure 3-18 summarizes information for Well 199-B5-5, located in northwestern 100-BC. The borehole was drilled using cable tool with drive barrel and hard tool, and the well is screened in the lower portion of the unconfined aquifer in Ringold unit E.

The Hanford formation comprises silty gravel and sandy gravel. The geologist tentatively identified the Hanford formation/Ringold Formation contact at 16.2 m (53 ft) bgs, which would place the water table in the lower part of the Hanford formation. The borehole log shows the lithology of Ringold unit E to vary from sandy gravel to sand, but notes that the sandy samples collected while drilling with the hard tool may not represent the true formation. Traces of clay were present but little cementation was noted. An increasing amount of clay was noted at 61.9 m (203 ft) bgs and the top of a Ringold mud unit was identified at 62.5 m (205 ft) bgs, which is deeper than the RUM unit in other portions of 100-BC. Total depth of the borehole was 65.5 m (214.8 ft), which is 3.6 m (11.8 ft) below the top of the sandy clay mud.

#### 3.4.3.8 Well 199-B5-6

Figure 3-19 summarizes information for Well 199-B5-6, located in central 100-BC. The borehole was drilled using cable tool with drive barrel and hard tool. The well is screened in the lower portion of the unconfined aquifer in Ringold unit E.

The Hanford formation is made up of gravel with varying amounts of sand and silt. The geologist did not identify the contact with Ringold unit E in the field, but the contact was later identified at a depth of 28.2 m (93 ft). The water table is in the Hanford formation. Ringold unit E comprises gravel and silty sandy gravel. Some layers of cementation were noted, and drilling conditions that necessitated use of the hard tool suggest additional layers of cementation. At 58.2 m (191 ft) bgs, the borehole reached the RUM unit, which comprises 95 percent silt and clay and 5 percent sand. Total depth of the borehole was 59.4 m (195 ft), which is 1.2 m (4 ft) into the RUM unit.

#### 3.4.3.9 Well 199-B5-8

Figure 3-20 summarizes information for Well 199-B5-8, located southeast of 100-BC. The borehole was drilled using cable tool with drive barrel and hard tool. The well is screened at the top of the unconfined aquifer.

The Hanford formation is much thicker at this location than elsewhere in 100-BC, with the Ringold Formation contact at 59.7 m (196 ft) bgs. The Hanford formation and Ringold unit E comprise gravel with varying amounts of silt and sand. The borehole reached the RUM unit, described as 100 percent mud and silt, at a depth of 67.8 m (222.5 ft). Total depth of the borehole was 70.3 m (230.6 ft), which is 2.5 m (8.2 ft) into the RUM unit.

#### 3.4.3.10 Well 199-B8-9

Figure 3-21 summarizes information for Well 199-B8-9, located in southern 100-BC. The borehole was drilled using cable tool with drive barrel and hard tool. The well is screened at the top of the unconfined aquifer.

The lithology of the Hanford formation at this location is silty sandy gravel, and the geologist noted moderate cementation. The geologist did not identify the top of Ringold unit E in the field, and the contact cannot be determined with certainty. It was tentatively picked at 35.1 m (115 ft bgs), based on a change in basalt content and a decrease in drill rate. This places the water table in the Hanford formation. The borehole reached the RUM unit, described as high-plasticity mud, at 64.5 m (211.5 ft) bgs. Total depth of the borehole was 66.9 m (219.5 ft), which is 2.4 m (7.9 ft) into the RUM unit.

#### 3.4.3.11 Vadose Boreholes

Figures 3-22 through 3-30 summarize information for seven vadose zone boreholes. The boreholes were drilled to approximately 1.5 m (5 ft) below the water table. No geologic contacts were identified in the field. Subsequent evaluation of borehole geologic and geophysical logs provided additional information. Most of the boreholes were not deep enough to reach the Hanford/Ringold E contact, and sediments were consistent with the Hanford formation. A contact was identified in borehole C7843 at 8.2 m (27 ft) bgs. Borehole C7842 was also deep enough to reach the contact (based on data from nearby wells) but a contact could not be identified based on the available information.

**Table 3-5. Summary of Geologic and Well Construction Data for Wells and Boreholes in and near 100 BC**

| Well Name | Well ID | Northing (m) | Easting (m) | Year Inst. | Well Type | Well Status | Elev. Land Surface (m) | Elev. Top of Casing (m) | Casing and Screen Type | Elev. Top Screen or Perf. (m) | Elev. Bottom Screen or Perf. (m) | Drilled Depth (m) | Water Level (m) | Water Level Date | Elev. Ringold Unit E (m) | Elev. RUM (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 199-B2-12 | A4550 | 145363.68 | 565368.44 | 1992 | Well | In use | 133.93 | 134.85 | SS, screen | 83.6 | 80.6 | 54.5 | 120.53 | 2/2/2009 | 130.12 | 88.36 | Screened in RUM |
| 199-B2-13 | A4551 | 145264.56 | 564086.52 | 1992 | Well | In use | 127.69 | 128.60 | SS, screen | 123.3 | 116.9 | 12.2 | 120.86 | 3/2/2009 | X | <115.5 | |
| 199-B2-14 | C7665 | 145232.26 | 565095.99 | 2010 | Well | In use | 134.30 | 134.77 | SS, screen | 121.5 | 113.9 | 46.4 | 119.62 | 4/18/2010 | 124.2 | 90.50 | |
| 199-B2-15 | C7783 | 145230.48 | 565092.32 | 2011 | Well | In use | 134.27 | 135.01 | SS, screen | 86.0 | 82.9 | 59.1 | 119.15 | 11/12/2010 | 125.1 | 90.47 | Screened in RUM |
| 199-B2-16 | C7784 | 145190.68 | 564915.00 | 2011 | Well | In use | 133.37 | 134.15 | SS, screen | 99.2 | 88.5 | 47.3 | 120.1 | 8/26/2010 | 123.6 | 88.56 | Bottom of unconfined |
| 199-B3-1 | A4552 | 145342.08 | 565561.46 | 1953 | Well | In use | 133.97 | 134.88 | CS, perf. | 123.3 | 114.2 | 19.2 | 120.02 | 3/2/2009 | X | <114.8 | |
| 199-B3-2 | A9505 | 145326.11 | 565847.58 | 1953 | Pz Host | Decom. | 135.43 | 135.91 | CS, perf. | N/A | N/A | 240.8 | N/A | N/A | X | 88.80 | 388 ft to lower mud unit; 656 ft to basalt |
| 199-B3-2P | A9825 | 145326.11 | 565847.58 | 1953 | Pz | Decom. | 135.43 | 136.16 | unknown | -95.6 | -101.7 | N/A | N/A | N/A | X | X | Rattlesnake Ridge Interbed (depth from *Hanford Wells* [PNL-8800]) |
| 199-B3-2Q | A9808 | 145326.11 | 565847.58 | 1953 | Pz | Decom. | 135.43 | 135.98 | unknown | -57.2 | -60.2 | N/A | N/A | N/A | X | X | Depth from *Hanford Wells* (PNL-8800) |
| 199-B3-46 | A4553 | 145369.04 | 565899.57 | 1992 | Well | In use | 134.73 | 135.63 | SS, screen | 121.2 | 114.7 | 20.4 | 120.00 | 3/2/2009 | 119.49 | <114.4 | |
| 199-B3-47 | A4554 | 145368.95 | 565388.66 | 1992 | Well | In use | 133.85 | 134.77 | SS, screen | 122.2 | 115.8 | 18.6 | 119.87 | 3/2/2009 | X | <115.3 | |
| 199-B3-50 | C7506 | 145058.21 | 566028.90 | 2010 | Well | In use | 143.02 | 143.78 | SS, screen | 121.9 | 115.8 | 55.9 | 120.55 | 4/18/2010 | 115.29 | 89.07 | |
| 199-B3-51 | C7785 | 145362.36 | 565379.25 | 2011 | Well | In use | 134.04 | 134.84 | SS, screen | 91.7 | 88.6 | 47.6 | 121.5 | 2/15/2011 | 130.08 | 88.47 | Bottom of unconfined |
| 199-B3-52 | C7843 | 145115.03 | 565391.00 | 2010 | Well | Temporary | 134.66 | 134.66 | PVC | 121.7 | 117.1 | 18.3 | 118.75 | 9/21/2010 | 126.43 | <116.4 | |
| 199-B4-1 | A4555 | 144791.53 | 565289.81 | 1949 | Well | In use | 141.20 | 141.60 | CS, perf. | 126.0 | 113.8 | 27.4 | 121.42 | 3/2/2009 | X | <113.8 | |
| 199-B4-2 | A5539 | 144770.89 | 565283.84 | 1949 | Well | Decom. | 141.35 | 141.65 | CS, perf. | 122.5 | 115.1 | 27.4 | N/A | N/A | X | <113.9 | |
| 199-B4-3 | A4556 | 144771.13 | 565295.59 | 1949 | Well | Decom. | 141.31 | 141.76 | CS, perf. | 123.0 | 115.1 | 27.7 | N/A | N/A | X | <113.6 | |
| 199-B4-4 | A4557 | 144479.71 | 565377.08 | 1960 | Well | In use | 144.63 | 145.37 | CS, perf. | 129.7 | 117.2 | 32.0 | 121.59 | 3/2/2009 | X | <112.6 | |
| 199-B4-5 | A5540 | 144349.16 | 565390.51 | 1990 | Well | In use | 147.06 | 147.96 | SS, screen | 123.8 | 117.5 | 29.6 | N/A | N/A | X | <117.4 | |
| 199-B4-6 | A4558 | 144382.97 | 565388.88 | 1990 | Well | In use | 147.02 | 147.92 | SS, screen | 123.7 | 117.4 | 29.7 | N/A | N/A | X | <117.3 | |
| 199-B4-7 | A5541 | 144382.85 | 565396.86 | 1990 | Well | In use | 147.07 | 147.99 | SS, screen | 123.9 | 117.7 | 29.4 | 121.61 | 3/2/2009 | X | <117.7 | |
| 199-B4-8 | A4559 | 144653.79 | 565578.45 | 1992 | Well | In use | 144.46 | 145.37 | SS, screen | 124.7 | 118.3 | 27.6 | 121.58 | 2/2/2009 | 117.64 | <116.9 | |
| 199-B4-9 | A4560 | 144563.93 | 565395.64 | 1992 | Well | Decom. | 143.81 | 144.72 | SS, screen | 125.5 | 119.4 | 28.3 | N/A | N/A | X | <115.5 | |
| 199-B4-10 | A5542 | 144516.37 | 565396.56 | 1992 | Boring | Decom. | 144.69 | N/A | N/A | N/A | N/A | 7.2 | N/A | N/A | X | <137.5 | |
| 199-B4-14 | C7786 | 144313.98 | 564969.25 | 2010 | Well | In use | 144.97 | 145.73 | SS, screen | 123.0 | 116.9 | 29.2 | 121.74 | 7/20/2010 | <115.8 | <115.8 | |
| 199-B4-15 | C7846 | 144551.98 | 565439.68 | 2010 | Well | Temporary | 144.26 | 144.26 | PVC | 122.9 | 119.2 | 25.7 | 121.34 | 11/5/2010 | <118.6 | <118.6 | |

**Table 3-5. Summary of Geologic and Well Construction Data for Wells and Boreholes in and near 100 BC**

| Well Name | Well ID | Northing (m) | Easting (m) | Year Inst. | Well Type | Well Status | Elev. Land Surface (m) | Elev. Top of Casing (m) | Casing and Screen Type | Elev. Top Screen or Perf. (m) | Elev. Bottom Screen or Perf. (m) | Drilled Depth (m) | Water Level (m) | Water Level Date | Elev. Ringold Unit E (m) | Elev. RUM (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 199-B5-1 | A4561 | 144764.90 | 564878.15 | 1962 | Well | In use | 139.04 | 139.89 | CS, perf. | 126.8 | 108.6 | 46.0 | 121.41 | 3/2/2009 | X | <93.0 | |
| 199-B5-2 | A4562 | 144939.70 | 565405.43 | 1992 | Well | In use | 139.80 | 140.53 | SS, screen | 123.3 | 117.2 | 22.9 | 121.81 | 2/2/2009 | X | <116.9 | |
| 199-B5-5 | C7505 | 144955.22 | 564723.24 | 2010 | Well | In use | 135.42 | 136.26 | SS, screen | 99.1 | 79.3 | 65.5 | 120.30 | 4/13/2010 | 119.26 | 72.93 | Bottom of unconfined |
| 199-B5-6 | C7507 | 144316.44 | 564967.70 | 2010 | Well | In use | 144.97 | 145.60 | SS, screen | 94.7 | 87.1 | 59.6 | 121.08 | 4/13/2010 | 116.62 | 86.75 | Bottom of unconfined |
| 199-B5-8 | C8244 | 143587.69 | 566014.00 | 2011 | Well | In use | 153.93 | 154.64 | SS, screen | 123.1 | 117.0 | 70.3 | 121.77 | 3/2/2011 | 94.20 | 85.96 | |
| 199-B8-6 | A4563 | 144157.79 | 564498.83 | 1992 | Well | In use | 145.02 | 145.93 | SS, screen | 124.1 | 118.0 | 27.7 | 121.62 | 3/2/2009 | <117.3 | <117.3 | |
| 199-B8-7 | C5671 | 144045.17 | 564760.86 | 2007 | Well | Decom. | 143.02 | 143.79 | PVC | 122.6 | 116.5 | 28.0 | 121.61 | 3/2/2009 | X | <115.0 | |
| 199-B8-8 | C5672 | 144001.01 | 565006.14 | 2007 | Well | Decom. | 149.45 | 150.22 | PVC | 122.2 | 116.1 | 34.1 | 121.61 | 3/2/2009 | X | <115.3 | |
| 199-B8-9 | C7508 | 144054.45 | 565276.43 | 2010 | Well | In use | 150.99 | 151.73 | SS, screen | 123.5 | 117.4 | 66.9 | 121.97 | 8/23/2009 | 115.94 | 86.52 | |
| 199-B9-1 | A4564 | 144029.69 | 565501.96 | 1952 | Well | Decom. | 151.37 | 152.25 | CS, perf | 127.0 | 117.8 | 35.7 | N/A | N/A | X | <115.7 | |
| 199-B9-2 | A4565 | 144078.08 | 565534.79 | 1992 | Well | In use | 151.73 | 152.64 | SS, screen | 124.2 | 118.1 | 36.0 | 121.27 | 5/11/2010 | <115.8 | <115.8 | Ringold E pick uncertain |
| 199-B9-3 | A4566 | 144046.72 | 565667.36 | 1992 | Well | In use | 150.41 | 151.31 | SS, screen | 124.4 | 118.3 | 33.2 | 121.61 | 3/2/2009 | <117.2 | <117.2 | Ringold E pick uncertain |
| 199-B9-4 | A5550 | 144031.45 | 565499.75 | 1993 | Boring | Decom. | 151.33 | N/A | N/A | N/A | N/A | 17.2 | N/A | N/A | X | <134.1 | |
| C5670 | C5670 | 143840.00 | 564376.35 | 2007 | Boring | Decom. | 140.88 | N/A | N/A | N/A | N/A | 22.6 | 121.87 | 4/25/2007 | <118.3 | <118.3 | 118-B-1 borehole |
| C7842 | C7842 | 145327.43 | 565391.93 | 2010 | Boring | Decom. | 133.42 | N/A | N/A | N/A | N/A | 16.8 | 119.37 | 9/14/2010 | X | <116.0 | |
| C7844 | C7844 | 144761.31 | 565290.19 | 2010 | Boring | Decom. | 141.36 | N/A | N/A | N/A | N/A | 22.3 | 120.94 | 12/7/2010 | <119.1 | <118.2 | |
| C7845 | C7845 | 144638.85 | 565355.92 | 2010 | Boring | Decom. | 143.10 | N/A | N/A | N/A | N/A | 24.0 | 121.28 | 11/9/2010 | <119.1 | <119.8 | |
| C7847 | C7847 | 144511.79 | 565340.87 | 2010 | Boring | Decom. | 144.10 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | <140.0 | <140.0 | Unsuccessful. replaced w/ C8239 |
| C7849 | C7849 | 144026.97 | 565397.34 | 2010 | Boring | Decom. | 151.81 | N/A | N/A | N/A | N/A | 32.8 | 121.27 | 11/22/2010 | <119.0 | <120.4 | |
| C8239 | C8239 | 144527.57 | 565331.70 | 2010 | Boring | Decom. | 144.05 | N/A | N/A | N/A | N/A | 25.1 | 121.37 | 12/20/2010 | <119.0 | <119.0 | |
| C7883 | C7883 | 144161.11 | 564812.41 | 2010 | Boring | Decom. | 145.56 | N/A | N/A | N/A | N/A | 27.3 | 122.00 | 8/13/2010 | <118.2 | <118.2 | 100-C-7 borehole |
| C7884 | C7884 | 144527.57 | 565331.70 | 2010 | Boring | Decom. | 145.38 | N/A | N/A | N/A | N/A | 27.8 | 121.00 | 8/12/2010 | <117.6 | <117.6 | 100-C-7 borehole |
| 699-63-89 | A8956 | 142576.97 | 562902.06 | 1973 | Well | Decom. | 156.24 | 157.24 | CS, open | 102.0 | 89.8 | N/A | N/A | N/A | 125.76 | N/A | 178 ft to basalt. Hanford/Ringold contact based on geophysical logs. |
| 699-63-90 | A5293 | 142612.35 | 562367.22 | 1948 | Well | In use | 156.28 | 156.86 | CS, perf. | 127.3 | 111.5 | 77.1 | 122.40 | 3/2/2009 | 124.27 | N/A | 240 ft to basalt. Hanford/Ringold contact based on geophysical logs. |
| 699-63-92 | A5294 | 142637.44 | 561559.74 | 1973 | Well | In use | 151.81 | 152.63 | CS, open | 106.1 | 95.1 | 56.7 | 122.18 | 3/2/2009 | X | N/A | 150 ft to basalt |
| 699-63-95 | A8958 | 142650.82 | 560914.64 | 1980 | Well | In use | 148.33 | 148.78 | CS, open | -11.4 | -67.2 | 215.5 | 122.26 | 3/2/2009 | X | N/A | 78 ft to basalt |

**Table 3-5. Summary of Geologic and Well Construction Data for Wells and Boreholes in and near 100 BC**

| Well Name | Well ID | Northing (m) | Easting (m) | Year Inst. | Well Type | Well Status | Elev. Land Surface (m) | Elev. Top of Casing (m) | Casing and Screen Type | Elev. Top Screen or Perf. (m) | Elev. Bottom Screen or Perf. (m) | Drilled Depth (m) | Water Level (m) | Water Level Date | Elev. Ringold Unit E (m) | Elev. RUM (m) | Comments |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 699-65-72 | A5302 | 143107.92 | 567883.67 | X | Well | In use | 152.33 | 152.63 | CS, perf. | 110.6 | 104.5 | 65.8 | 121.62 | 3/13/2009 | X | N/A | |
| 699-65-83 | A5303 | 143249.09 | 564590.47 | 1967 | Well | In use | 148.12 | 149.05 | CS, perf. | 129.8 | 112.5 | 36.9 | 121.69 | 3/2/2009 | 122.21 | <111.2 | Hanford/Ringold contact based on geophysical logs |
| 699-66-91 | A5311 | 143476.80 | 562174.81 | 1973 | Well | In use | 142.62 | 143.57 | CS, open | 112.8 | 84.7 | 57.9 | 122.25 | 3/2/2009 | 118.85 | N/A | 98 ft to basalt |
| 699-67-77 | A8965 | 143896.60 | 566423.40 | X | Well | Decom. | X | 150.66 | X | N/A | N/A | N/A | N/A | N/A | X | ND | |
| 699-67-86 | A5313 | 143873.05 | 563661.65 | 1962 | Well | In use | 144.47 | 145.02 | CS, perf. | 126.2 | 114.0 | 142.3 | 121.64 | 3/2/2009 | X | 69.18 | Pzs P, Q, R, S decom. 457 ft to lower mud. |
| 699-67-98 | A5314 | 143714.66 | 559944.00 | 1960 | Well | Decom. | 139.15 | 139.84 | CS, perf. | N/A | N/A | 56.4 | N/A | N/A | X | 99.83 | Basalt at 145 ft? |
| 699-68-105 | A5315 | 144206.12 | 557803.35 | 1952 | Well | In use | 138.93 | 139.45 | CS, perf. | 125.2 | 112.1 | 28.7 | 121.38 | 3/2/2009 | X | <110.3 | |
| 699-71-77 | A5322 | 145098.61 | 566401.95 | 1962 | Well | In use | 144.23 | 144.96 | CS, perf. | 125.9 | 106.1 | 91.4 | 121.04 | 3/2/2009 | 119.85 | 89.37 | H/R contact from geophysical logs |
| 699-71-85 | A8972 | 145012.86 | 564039.81 | X | X | Decom. | X | 128.17 | X | N/A | N/A | 7.9 | N/A | N/A | X | ND | Old dug well; filled in. |
| 699-72-73 | A5323 | 145418.78 | 567551.54 | 1961 | Well | In use | 147.55 | 148.13 | CS, perf. | 129.3 | 106.4 | 61.0 | 121.08 | 3/2/2009 | 120.11 | 96.64 | |
| 699-72-88 | A5324 | 145359.93 | 563247.29 | 1980 | Well | Decom. | 132.38 | 133.10 | CS, perf. | 122.3 | 105.6 | 16.5 | N/A | N/A | X | ND | |
| 699-72-92 | A5325 | 145359.75 | 561839.42 | 1961 | Well | In use | 137.20 | 138.05 | CS, perf. | 123.8 | 109.8 | 61.0 | 121.36 | 3/2/2009 | 89.96 | <76.2 | Pzs O, P, Q Decom.. Ringold E pick uncertain. |

Note: To convert from meters to feet, multiply by 3.281

CS = carbon steel
Decom. = decommissioned
H/R = Hanford/Ringold contact
N/A = Not applicable
Perf. = perforated
PVC = polyvinyl chloride
Pz = piezometer
SS = stainless steel
X = unknown or undetermined

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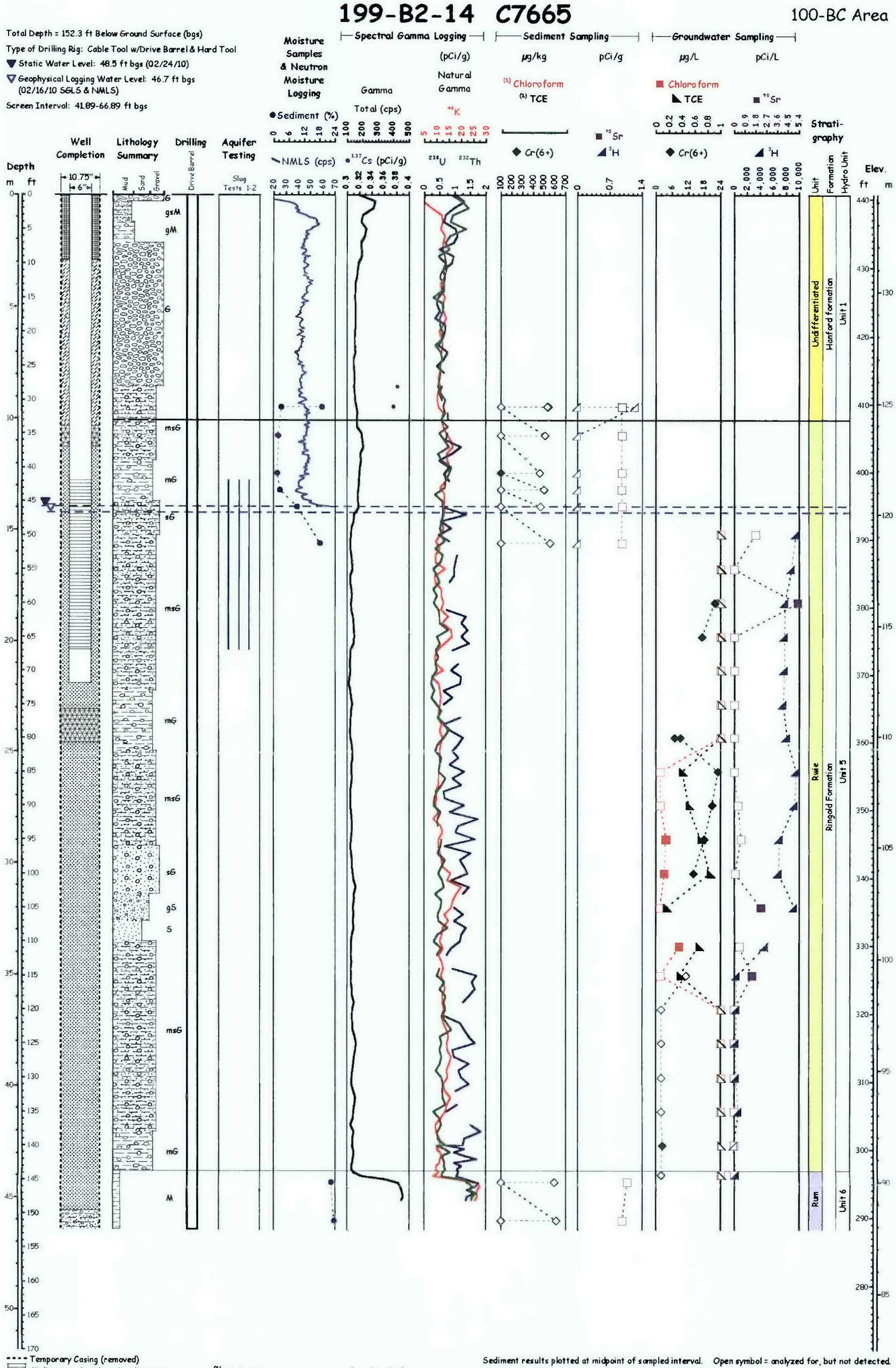



Figure 3-12. Summary of Characterization Data for Well 199-B2-14

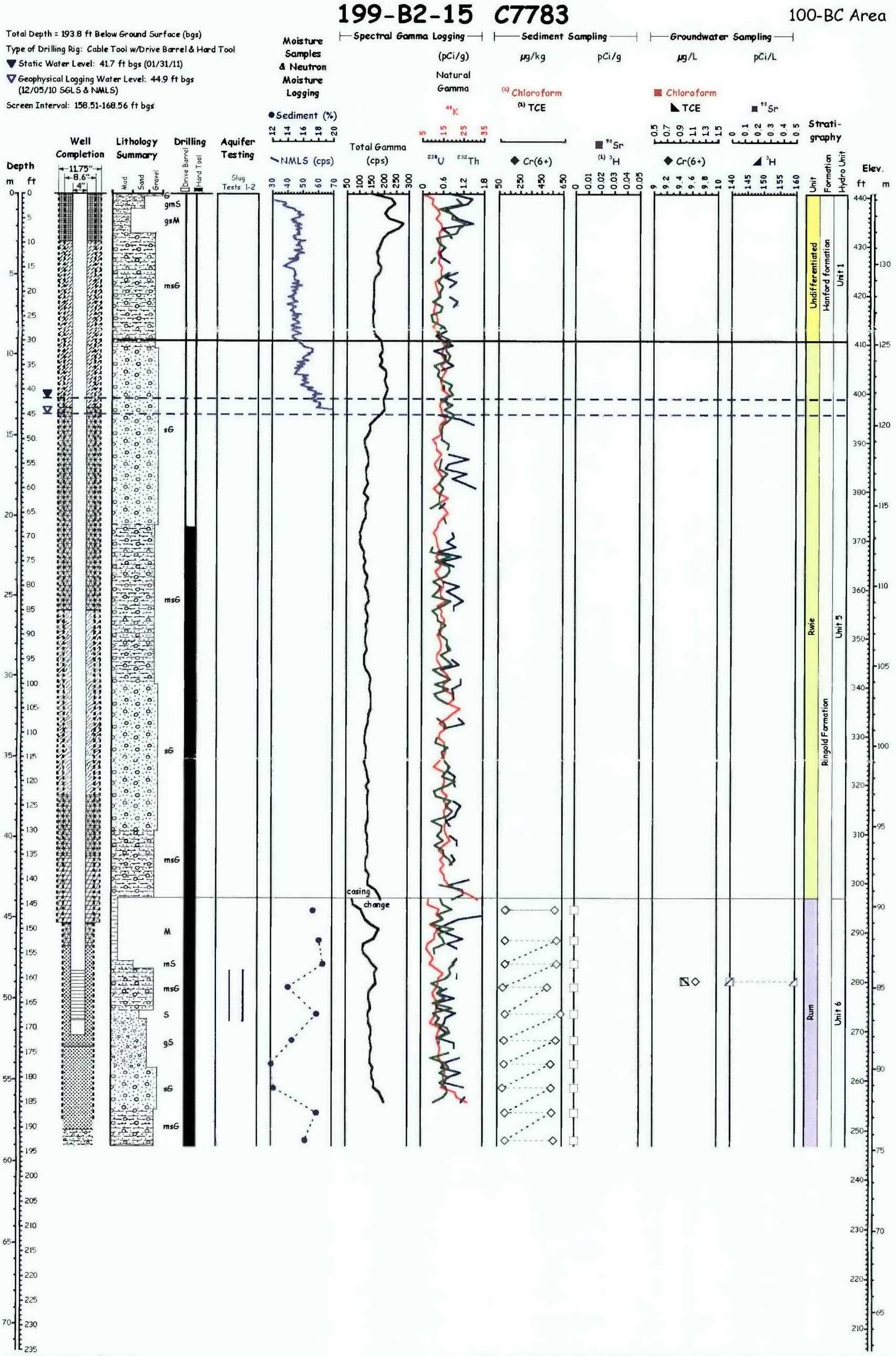
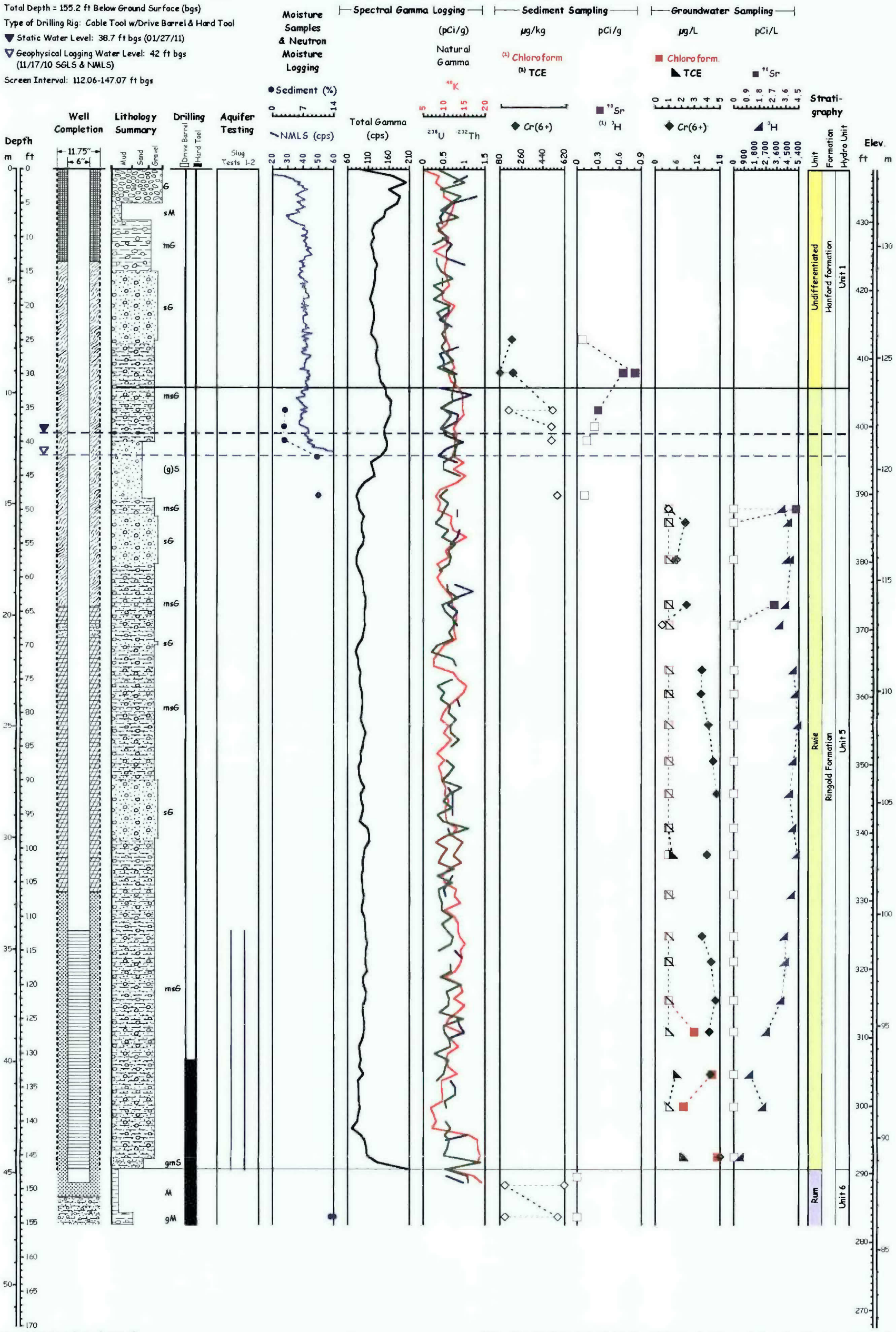



Figure 3-13. Summary of Characterization Data for Well 199-B2-15

E 564,915.00 m N 145,190.68 m NAD83(91)
Ground Surface Elevation (brass cap): 133.368 m NAVD88
Total Depth = 155.2 ft Below Ground Surface (bgs)
Type of Drilling Rig: Cable Tool w/Drive Barrel & Hard Tool
▼ Static Water Level: 38.7 ft bgs (01/27/11)
▽ Geophysical Logging Water Level: 42 ft bgs (11/17/10 SGLS & NMLS)
Screen Interval: 112.06-147.07 ft bgs

# 199-B2-16 C7784

100-BC Area




Temporary Casing (removed)
6" diameter Stainless Steel Screen
WELL SEALS
Portland Cement
Granular Bentonite
Bentonite Pellets
Bentonite Slurry
Cement Grout
10-20 Mesh Colorado Silica Sand
Natural Slough

(1) No Analysis

Lithologic scale and patterns represent size grading of dominant sediment types encountered during drilling.

Note: Borehole lithology, casing, well seals, and static water level are from C7784 Well Summary Sheet.

Increasing size of dominant fraction

| | |
|---|---|
| M | Mud |
| sM | sandy Mud |
| gM | gravelly Mud |
| S | Sand |
| (g)S | slightly gravelly Sand |
| gmS | gravelly muddy Sand |
| mG | muddy Gravel |
| msG | muddy sandy Gravel |
| sG | sandy Gravel |
| G | Gravel |

Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

| | Date | Static Water Level (ft bgs) | Slug Vol. ($ft^3$) | Screen Interval (ft bgs) | Representative Hydraulic Conductivity (m/d) |
|---|---|---|---|---|---|
| Slug Test Results | 01/28/11 | 38.62 | 1.011 | 112.06-147.07 | 6.4 |

2011-DCL-C7784-001_08-12

Figure 3-14. Summary of Characterization Data for Well 199-B2-16

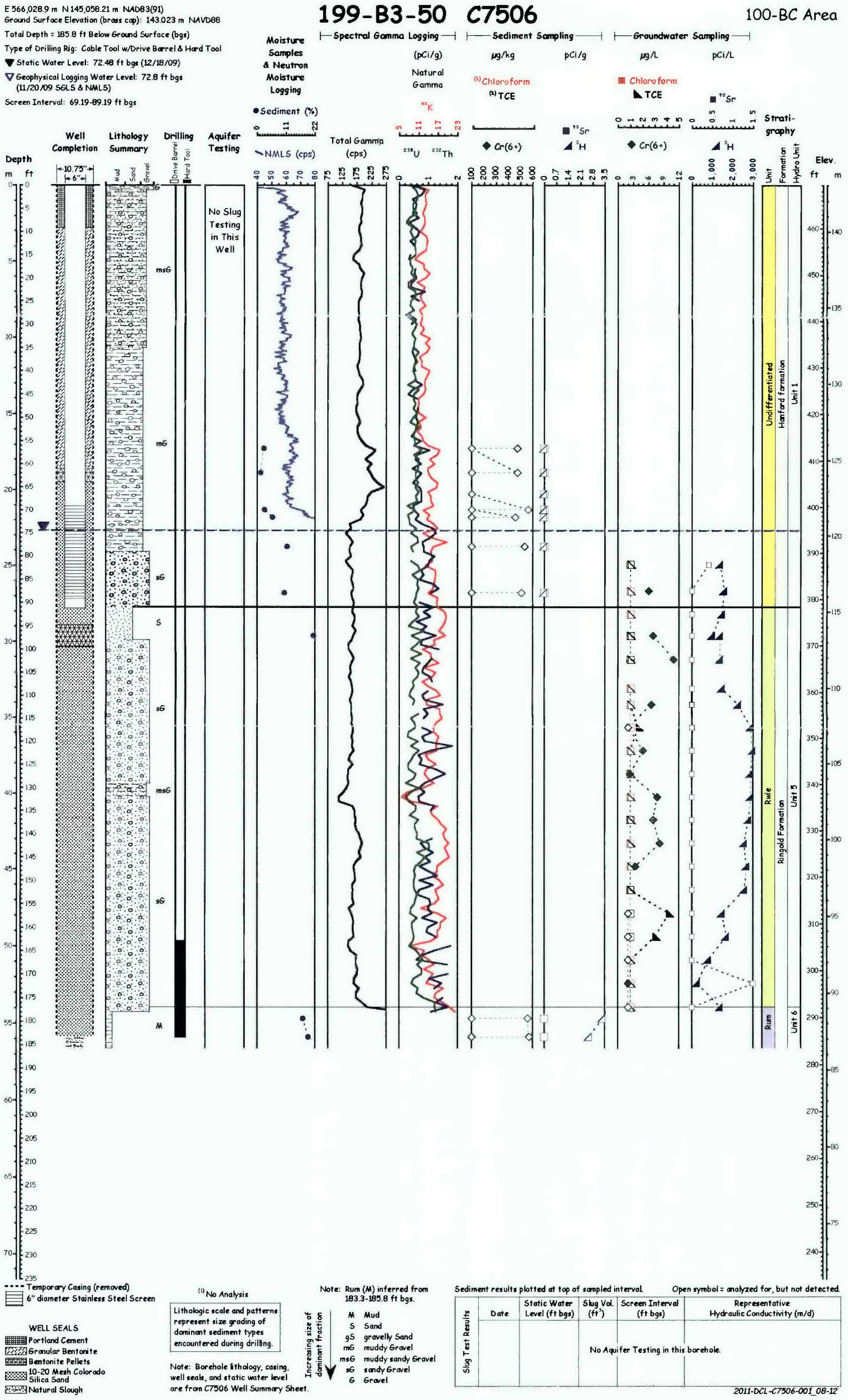
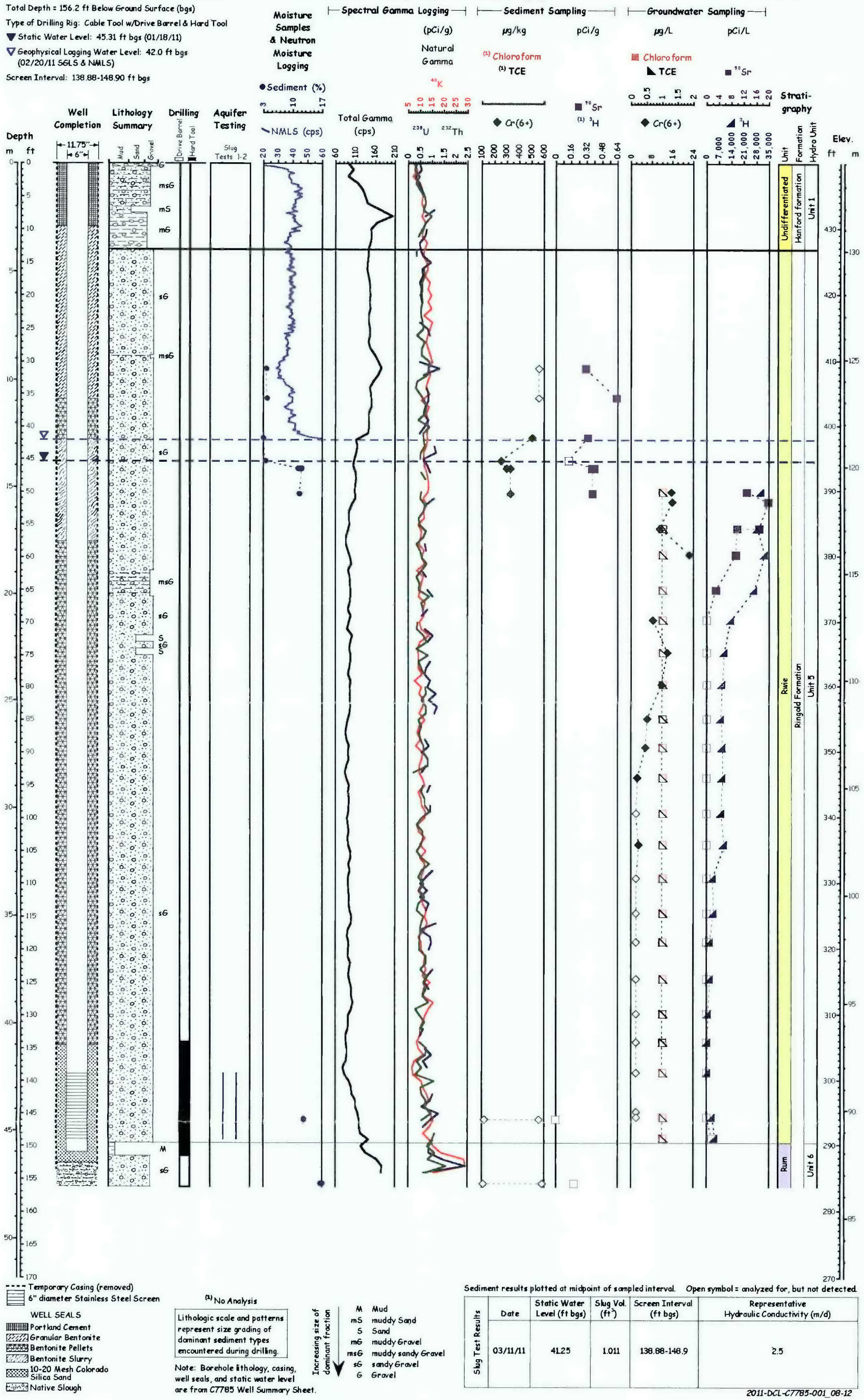



Figure 3-15. Summary of Characterization Data for Well 199-B3-50

E 565,379.25 m N 145,362.36 m NAD83(91)
Ground Surface Elevation (brass cap): 134.04 m NAVD88
Total Depth = 156.2 ft Below Ground Surface (bgs)
Type of Drilling Rig: Cable Tool w/Drive Barrel & Hard Tool
▼ Static Water Level: 45.31 ft bgs (01/18/11)
▽ Geophysical Logging Water Level: 42.0 ft bgs (02/20/11 SGLS & NMLS)
Screen Interval: 138.88-148.90 ft bgs

# 199-B3-51 C7785

100-BC Area




Temporary Casing (removed)
6" diameter Stainless Steel Screen

WELL SEALS
- Portland Cement
- Granular Bentonite
- Bentonite Pellets
- Bentonite Slurry
- 10-20 Mesh Colorado Silica Sand
- Native Slough

(1) No Analysis

Lithologic scale and patterns represent size grading of dominant sediment types encountered during drilling.

Note: Borehole lithology, casing, well seals, and static water level are from C7785 Well Summary Sheet.

Increasing size of dominant fraction

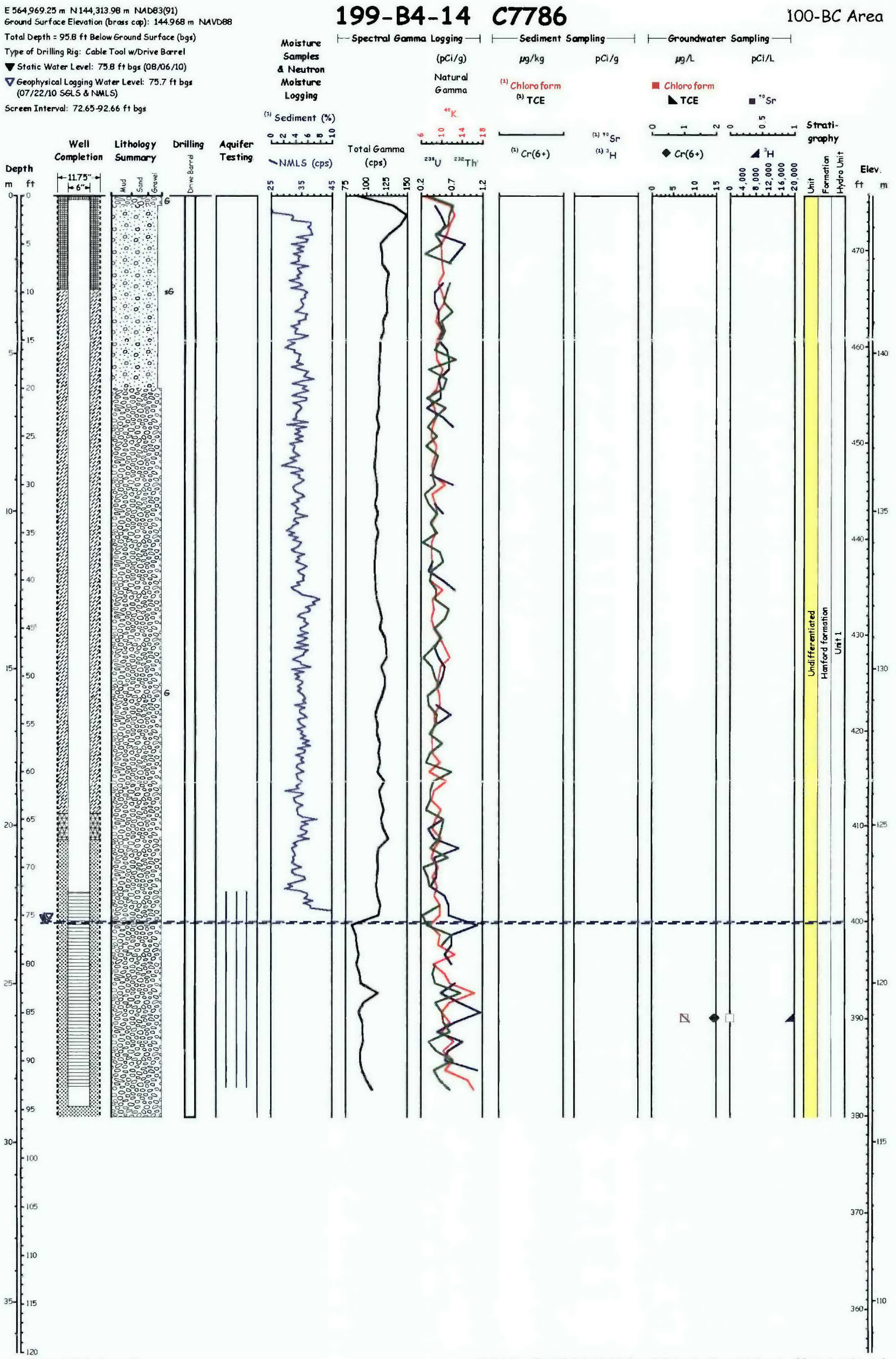
| | |
|---|---|
| M | Mud |
| mS | muddy Sand |
| S | Sand |
| mG | muddy Gravel |
| msG | muddy sandy Gravel |
| sG | sandy Gravel |
| G | Gravel |

Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

| | Date | Static Water Level (ft bgs) | Slug Vol. ($ft^3$) | Screen Interval (ft bgs) | Representative Hydraulic Conductivity (m/d) |
|---|---|---|---|---|---|
| Slug Test Results | 03/11/11 | 41.25 | 1.011 | 138.88-148.9 | 2.5 |

2011-DCL-C7785-001_08-12

Figure 3-16. Summary of Characterization Data for Well 199-B3-51



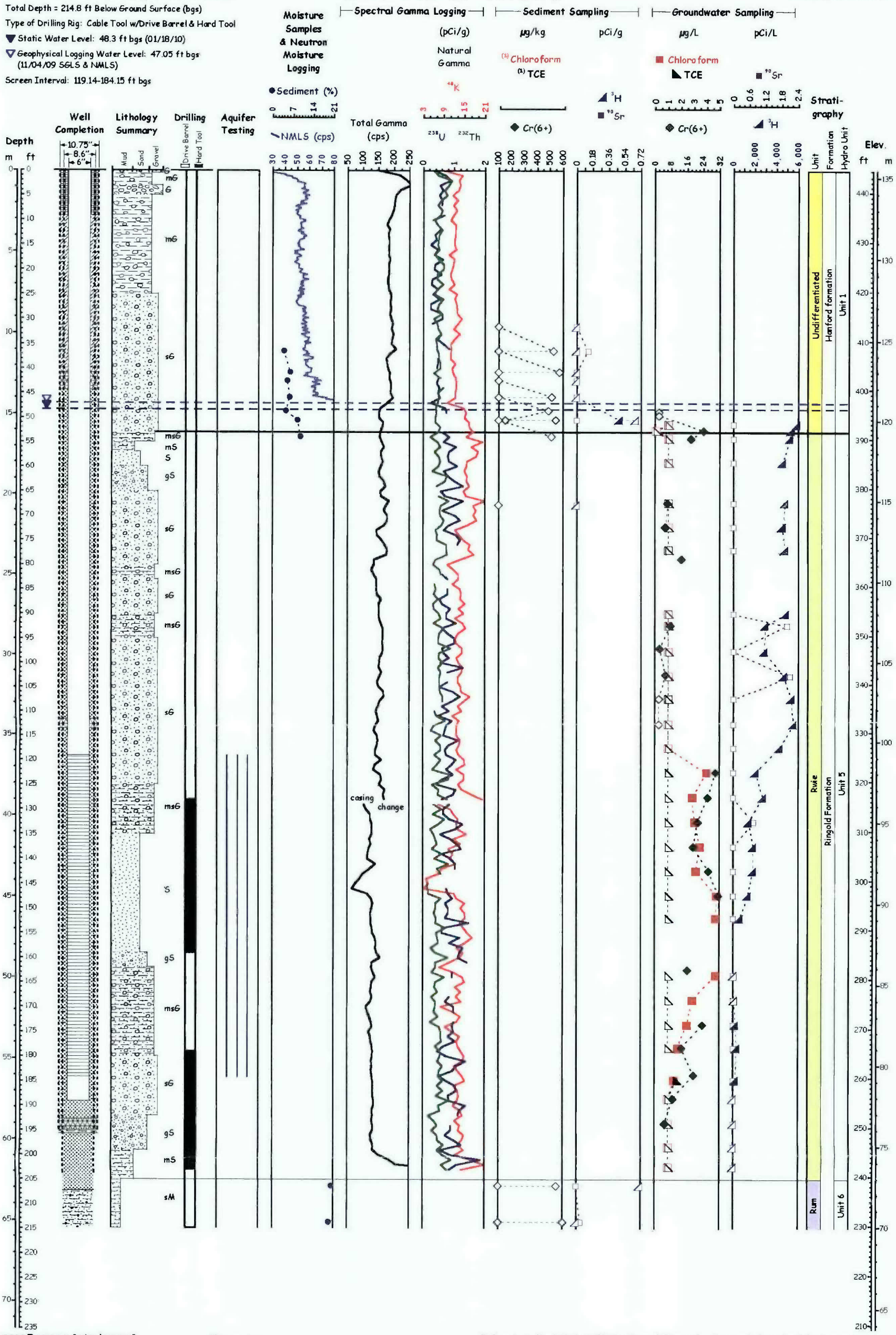

1

2 **Figure 3-17. Summary of Characterization Data for Well 199-B4-14**

E 564,721.99 m N 144,955.49 m NAD83(91)
Ground Surface Elevation (brass cap): 135.416 m NAVD88
Total Depth = 214.8 ft Below Ground Surface (bgs)
Type of Drilling Rig: Cable Tool w/Drive Barrel & Hard Tool
▼ Static Water Level: 48.3 ft bgs (01/18/10)
▽ Geophysical Logging Water Level: 47.05 ft bgs (11/04/09 SGLS & NMLS)
Screen Interval: 119.14-184.15 ft bgs

# 199-B5-5 C7505

100-BC Area




Temporary Casing (removed)
6" diameter Stainless Steel Screen

WELL SEALS
Portland Cement
Granular Bentonite
Bentonite Pellets
10-20 Mesh Colorado Silica Sand
Portland Cement Grout
Natural Slough

(1) No Analysis

Lithologic scale and patterns represent size grading of dominant sediment types encountered during drilling.

Increasing size of dominant fraction

| | |
|---|---|
| M | Mud |
| mS | muddy Sand |
| S | Sand |
| gS | gravelly Sand |
| mG | muddy Gravel |
| msG | muddy sandy Gravel |
| sG | sandy Gravel |
| G | Gravel |

Note: Borehole lithology, casing, well seals, and static water level are from C7505 Well Summary Sheet.
Rum contact and lithology from C7505 Borehole Log.

Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

| | Date | Static Water Level (ft bgs) | Slug Vol. (ft$^3$) | Screen Interval (ft bgs) | Representative Hydraulic Conductivity (m/d) |
|---|---|---|---|---|---|
| Slug Test Results | 07/21/10 | 45.98 | 0.942 | 119.14-184.15 | 15 |

2011-DCL-C7505-001_08-12

Figure 3-18. Summary of Characterization Data for Well 199-B5-5

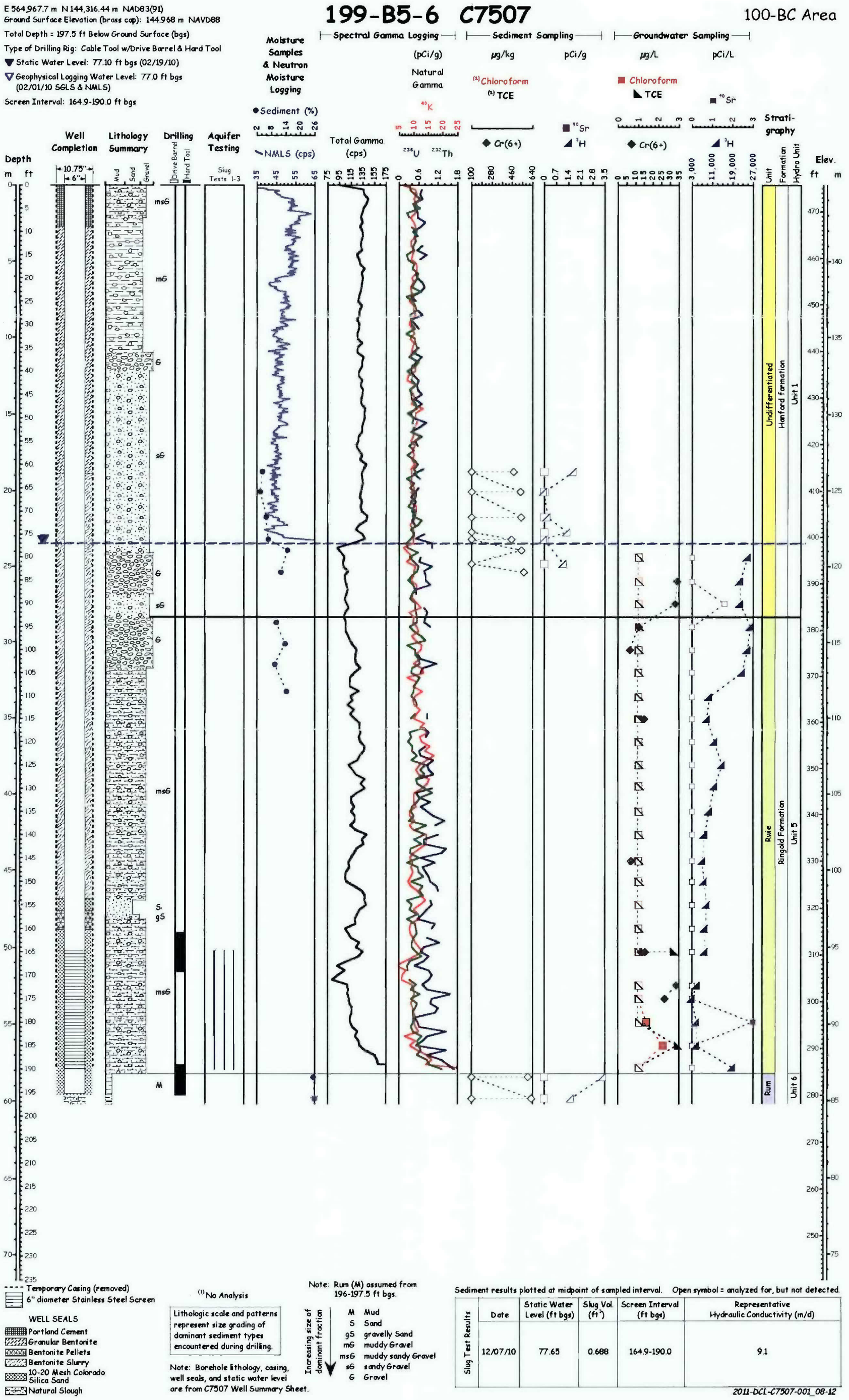
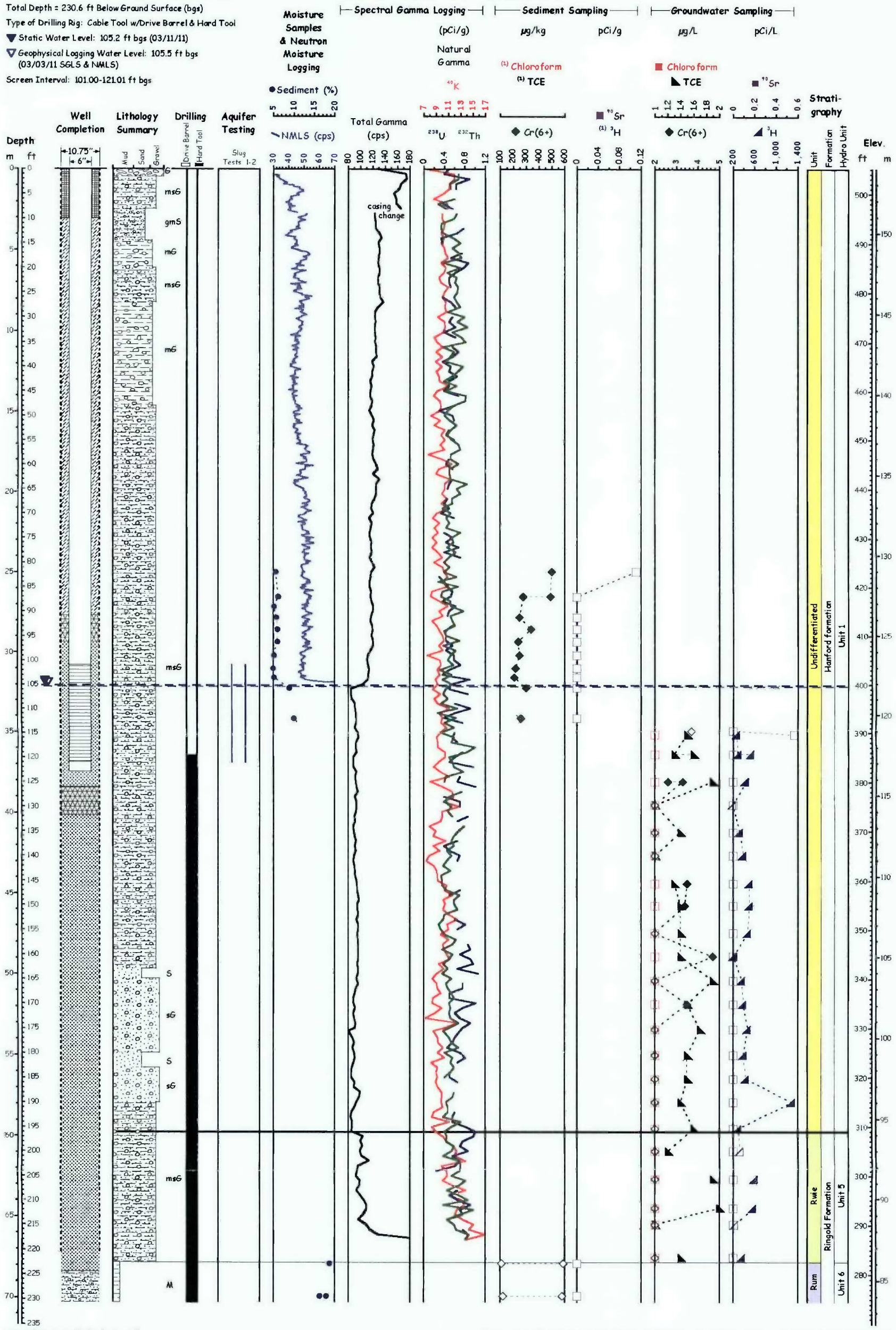



Figure 3-19. Summary of Characterization Data for Well 199-B5-6

E 566,014.00 m N 143,587.69 m NAD83(91)
Ground Surface Elevation (brass cap): 153.93 m NAVD88
Total Depth = 230.6 ft Below Ground Surface (bgs)
Type of Drilling Rig: Cable Tool w/Drive Barrel & Hard Tool
▼ Static Water Level: 105.2 ft bgs (03/11/11)
▽ Geophysical Logging Water Level: 105.5 ft bgs (03/03/11 SGLS & NMLS)
Screen Interval: 101.00-121.01 ft bgs

# 199-B5-8 C8244

100-BC Area




Temporary Casing (removed)
6" diameter Stainless Steel Screen

WELL SEALS
Portland Cement
Granular Bentonite
Bentonite Pellets
10-20 Mesh Colorado Silica Sand
6-9 Mesh Colorado Silica Sand
Natural Slough

(1) No Analysis

Lithologic scale and patterns represent size grading of dominant sediment types encountered during drilling.

Increasing size of dominant fraction

| | |
|---|---|
| M | Mud |
| S | Sand |
| gmS | gravelly muddy Sand |
| mG | muddy Gravel |
| msG | muddy sandy Gravel |
| sG | sandy Gravel |
| G | Gravel |

Note: Borehole lithology, casing, well seals, and static water level are from C8244 Well Summary Sheet.

Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

| Slug Test Results | Date | Static Water Level (ft bgs) | Slug Vol. ($ft^3$) | Screen Interval (ft bgs) | Representative Hydraulic Conductivity (m/d) |
|---|---|---|---|---|---|
| | 03/11/11 | 105.15 | 1.011 | 101.00-121.01 | Formation too permeable to interpret slug test results. |

2011-DCL-C8244-001_08-12

Figure 3-20. Summary of Characterization Data for Well 199-B5-8

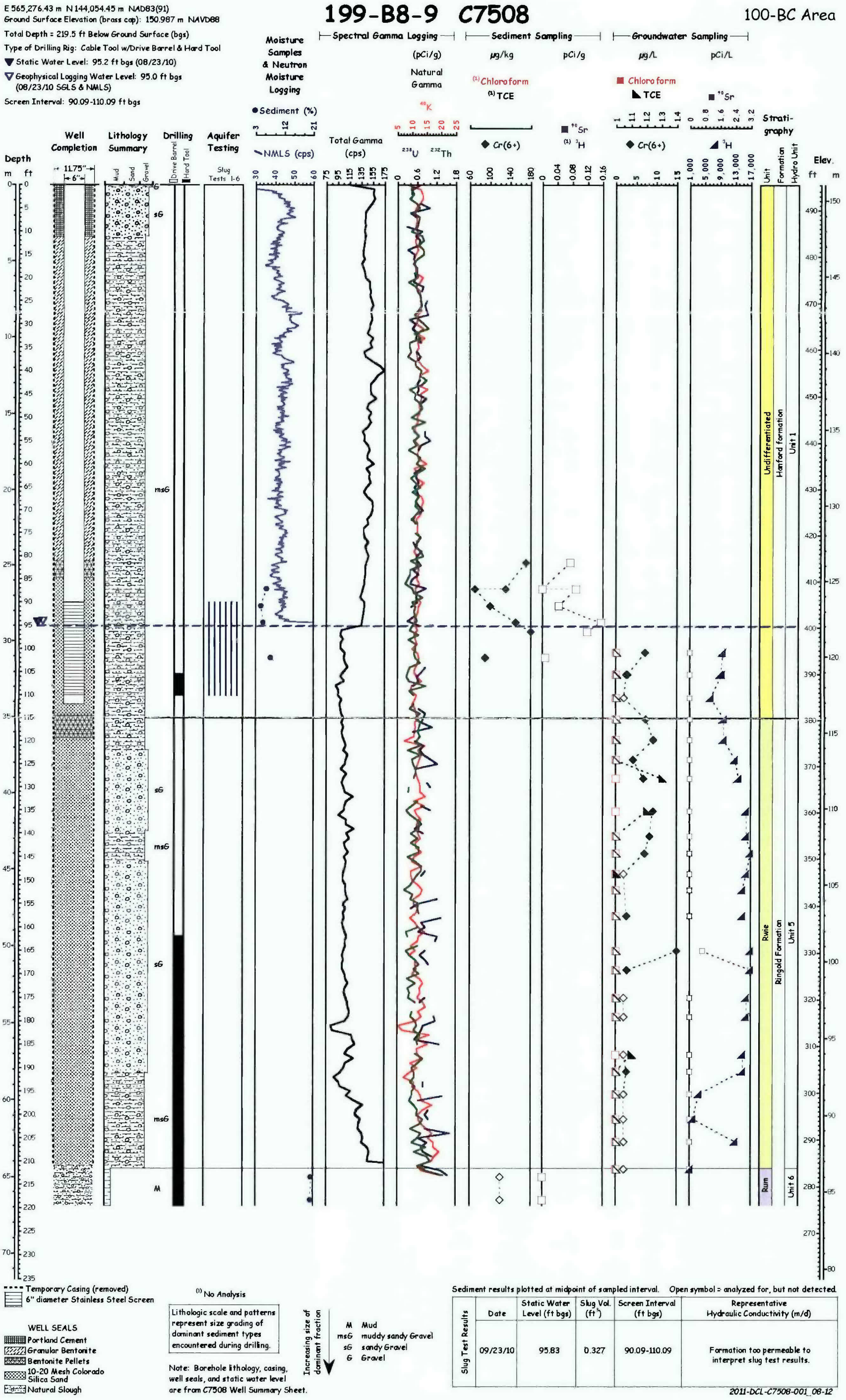



Figure 3-21. Summary of Characterization Data for Well 199-B8-9

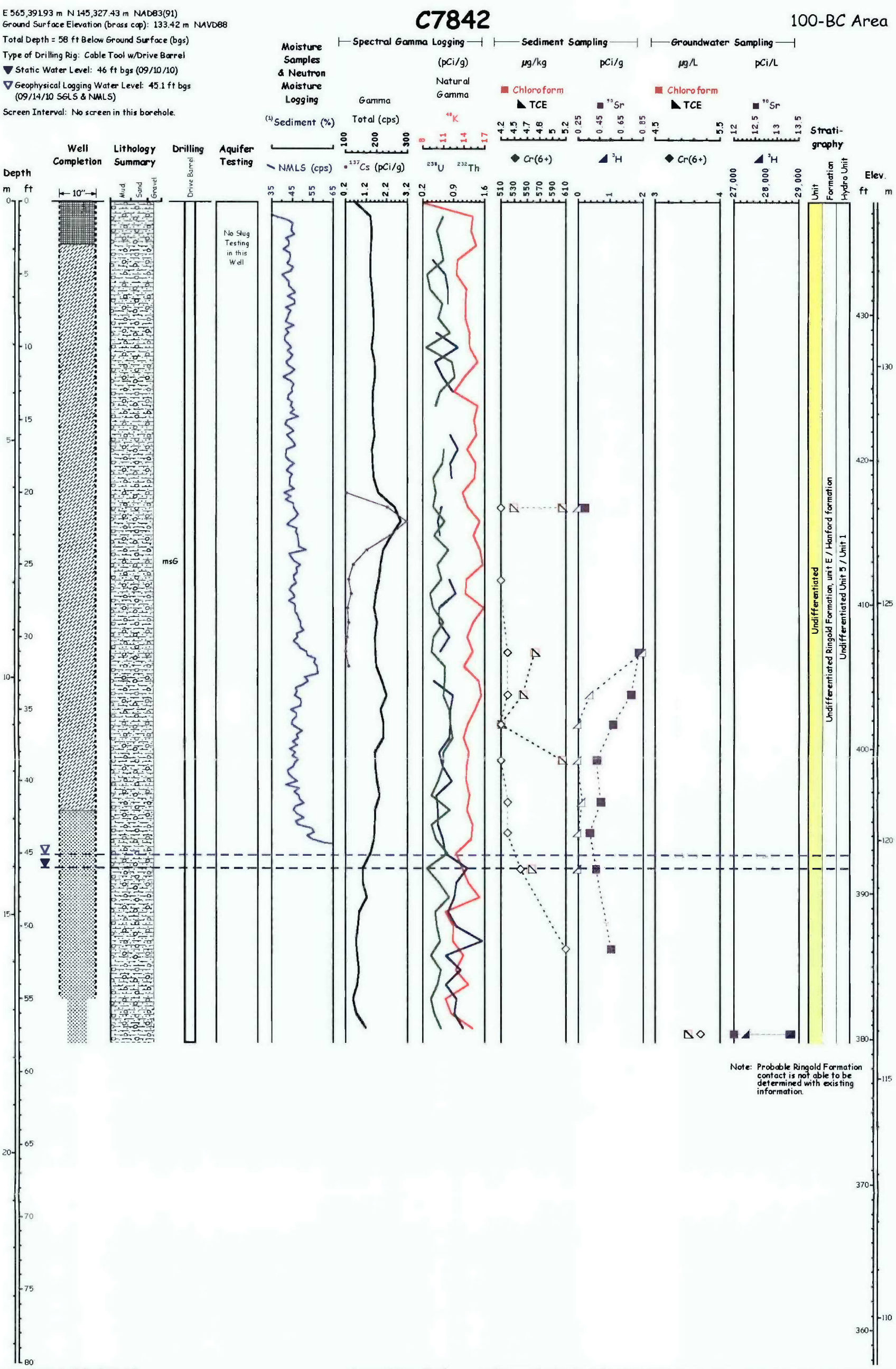



Figure 3-22. Summary of Characterization Data for Borehole C7842 at the 116-B-11 Retention Basin

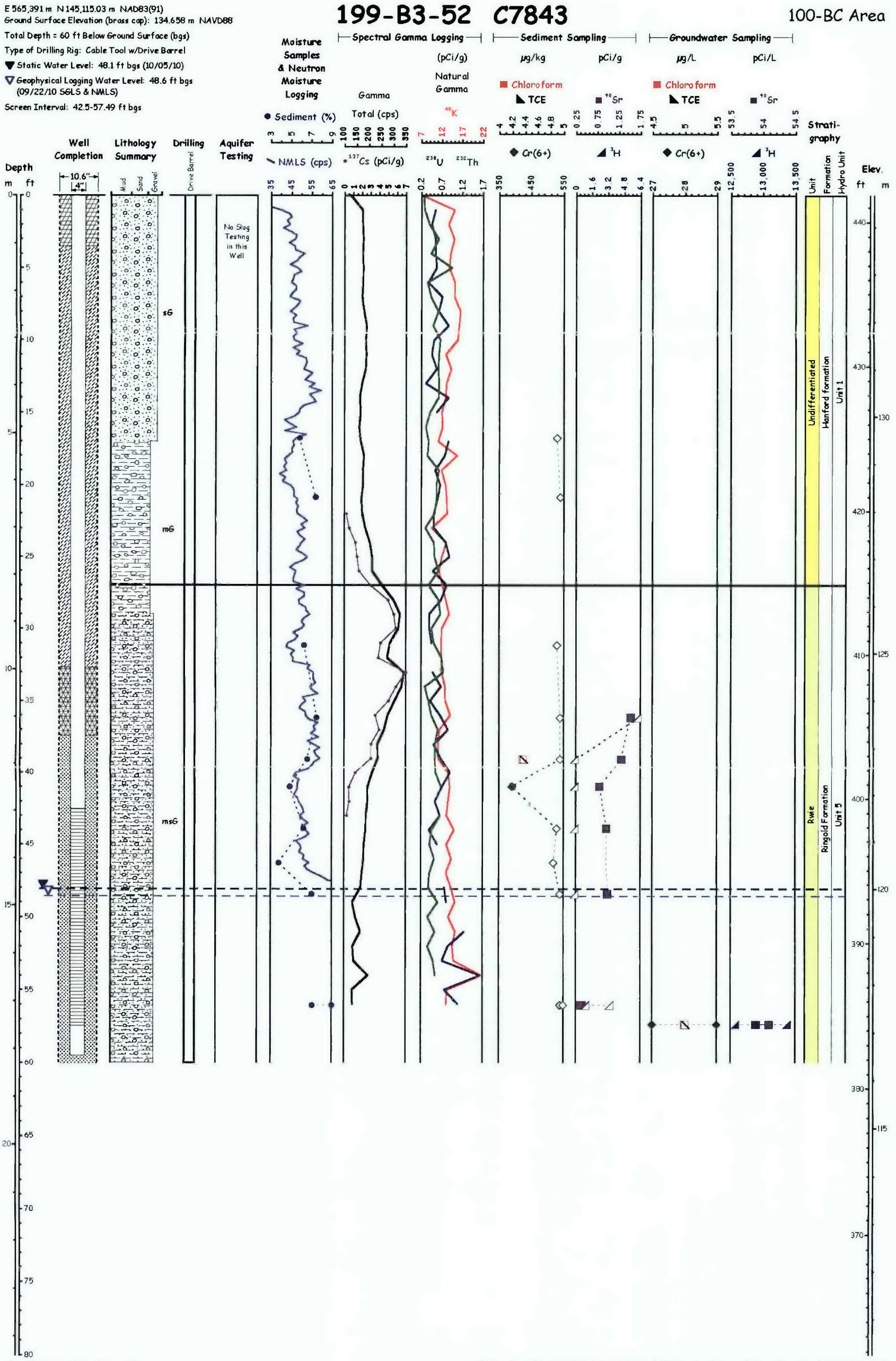



Figure 3-23. Summary of Characterization Data for Borehole C7843 (Well 199-B5-52) at the 116-C-5 Retention Basin

E 565,290.19 m N 144,761.31 m NAD83(91)
Ground Surface Elevation (brass cap): 141.36 m NAVD88
Total Depth = 74.1 ft Below Ground Surface (bgs)
Type of Drilling Rig: Cable Tool w/Drive Barrel
▼ Static Water Level: 67 ft bgs (No date recorded)
▽ Geophysical Logging Water Level: 66.0 ft bgs (12/08/10 SGLS & NMLS)
Screen Interval: No screen in this borehole.

# C7844

100-BC Area

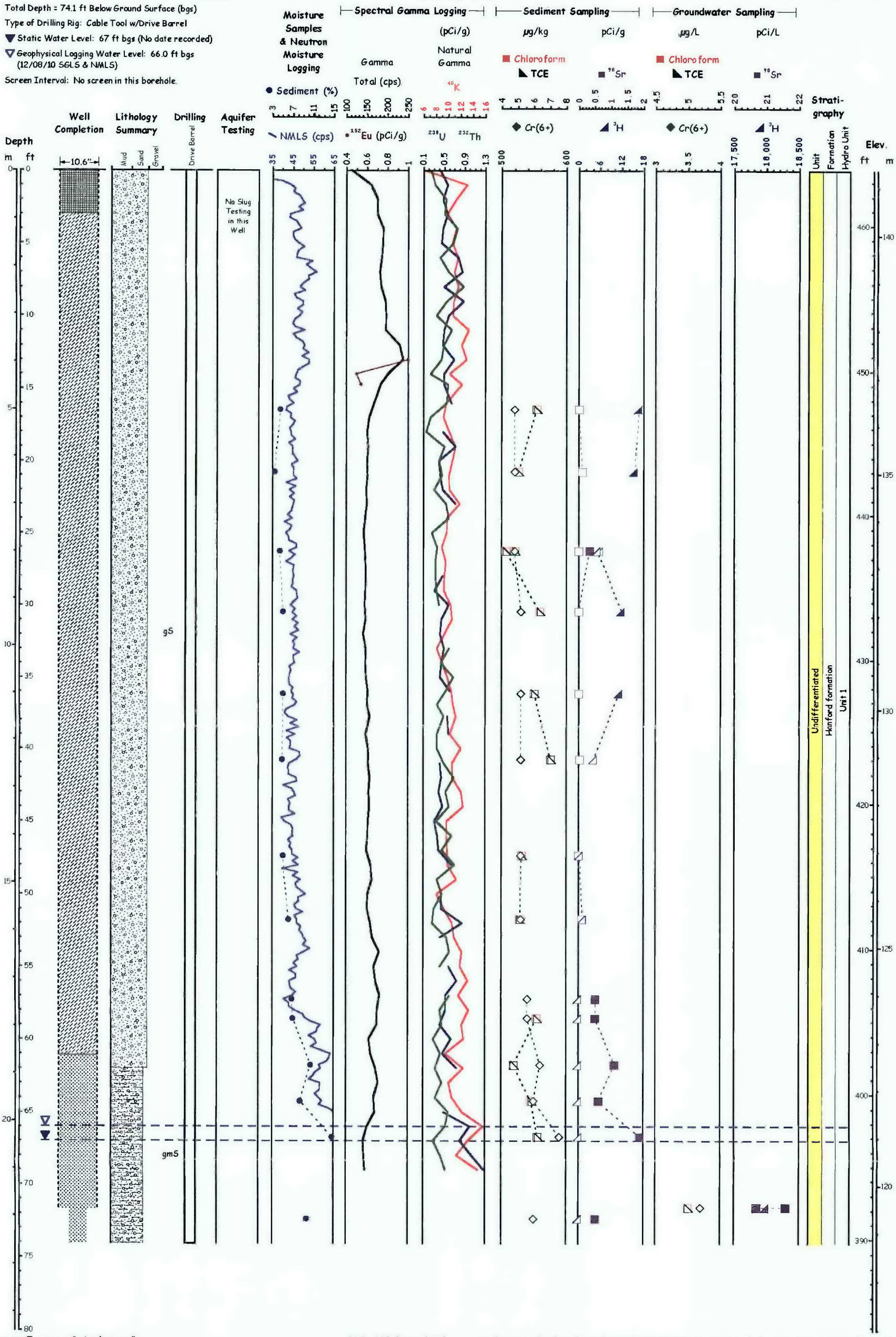



Figure 3-24. Summary of Characterization Data for Borehole C7844 at the 116-B-5 Crib

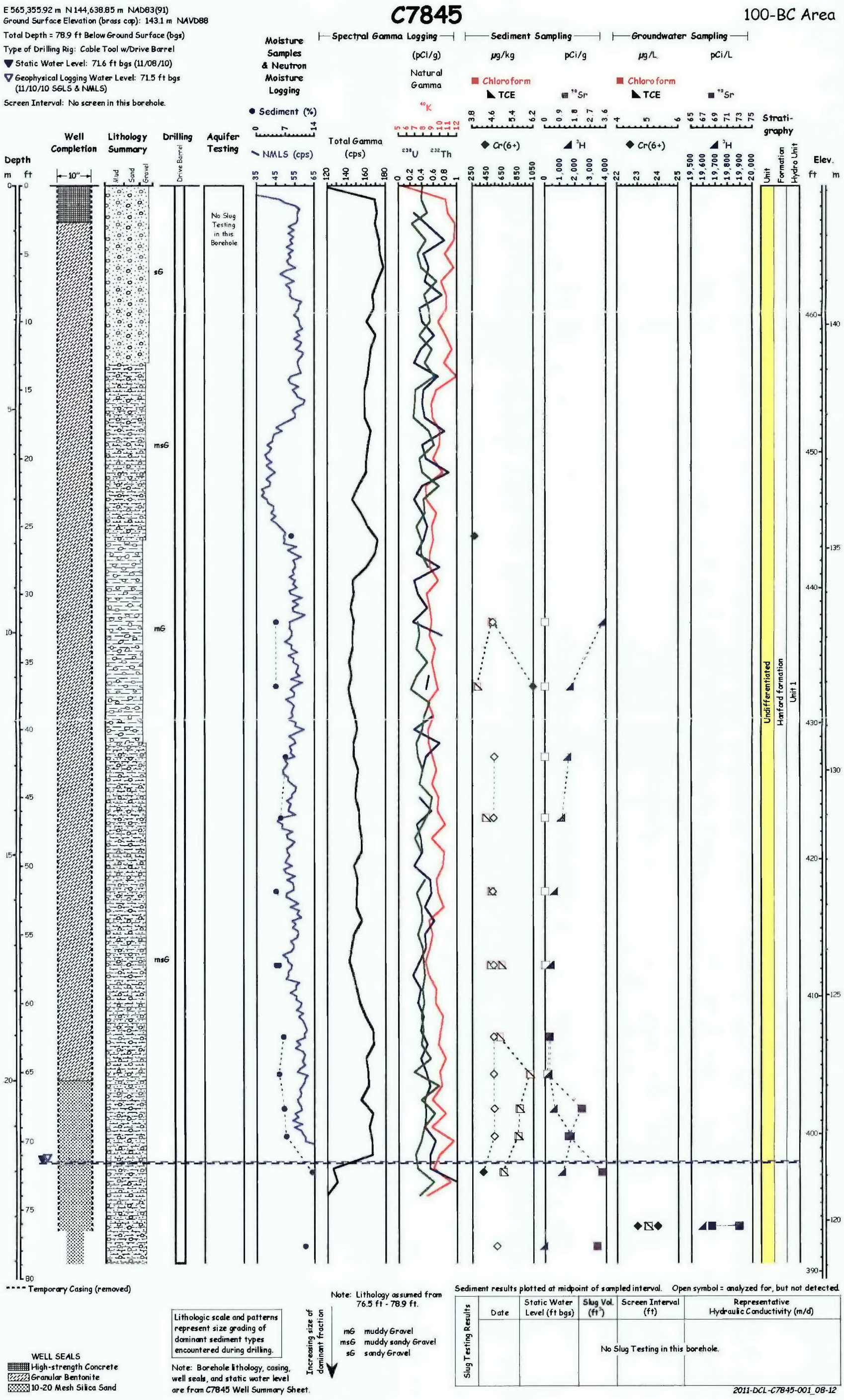
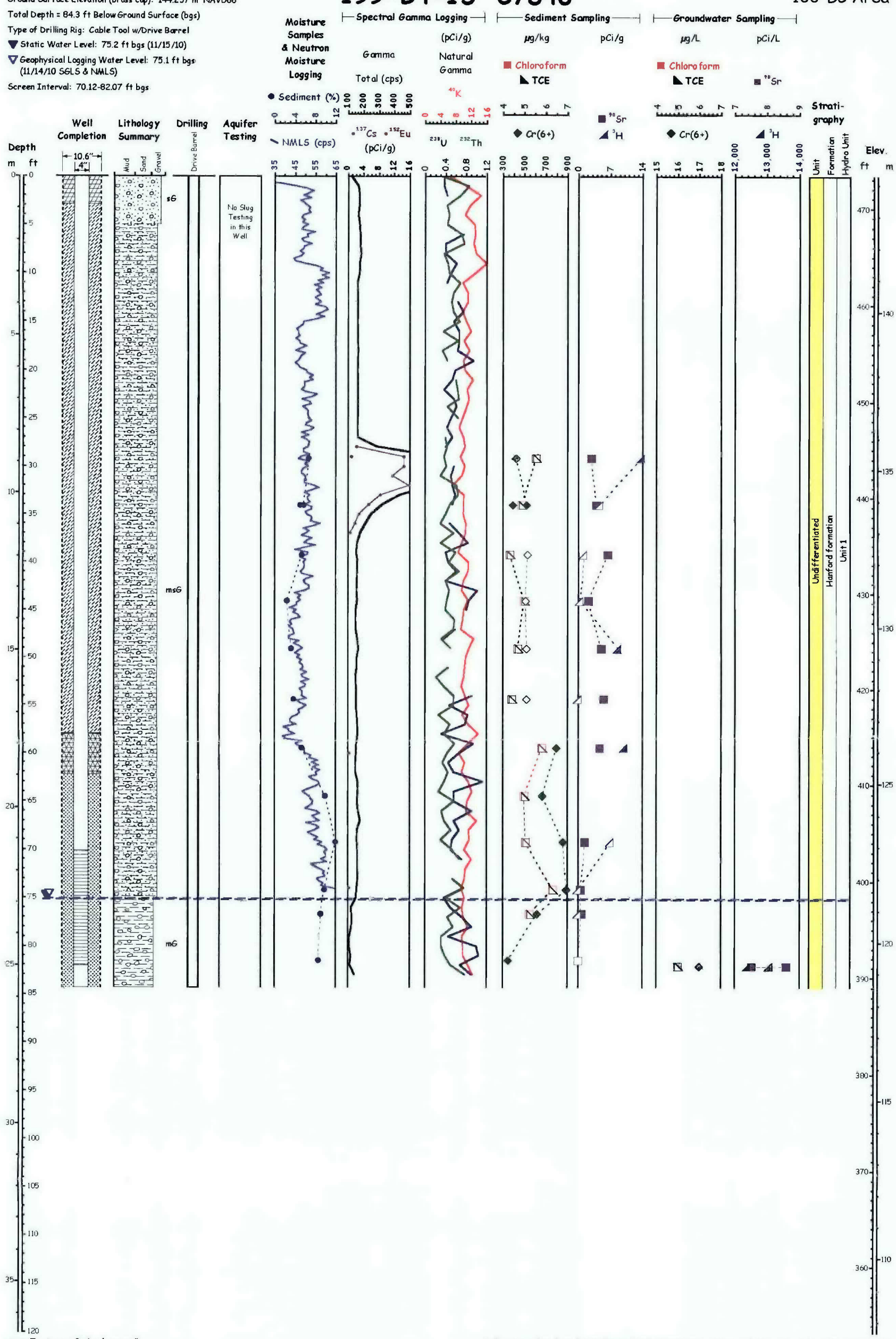



Figure 3-25. Summary of Characterization Data for Borehole C7845 at the 118-B-6 Burial Ground

E 565,439.68 m N 144,551.98 m NAD83(91)
Ground Surface Elevation (brass cap): 144.257 m NAVD88
Total Depth = 84.3 ft Below Ground Surface (bgs)
Type of Drilling Rig: Cable Tool w/Drive Barrel
▼ Static Water Level: 75.2 ft bgs (11/15/10)
▽ Geophysical Logging Water Level: 75.1 ft bgs (11/14/10 SGLS & NMLS)
Screen Interval: 70.12-82.07 ft bgs

# 199-B4-15 C7846

100-BC Area




Temporary Casing (removed)
4" diameter Stainless Steel Screen

WELL SEALS
Portland Cement Grout
Granular Bentonite
Bentonite Pellets
10-20 Mesh Colorado Silica Sand

Lithologic scale and patterns represent size grading of dominant sediment types encountered during drilling.

Note: Borehole lithology, casing, well seals, and static water level are from C7846 Well Summary Sheet.

Increasing size of dominant fraction

mG muddy Gravel
msG muddy sandy Gravel
sG sandy Gravel

Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

| SlugTest Results | Date | Static Water Level (ft bgs) | Slug Vol. ($ft^3$) | Screen Interval (ft bgs) | Representative Hydraulic Conductivity (m/d) |
|---|---|---|---|---|---|
| | No Slug Testing in this borehole. | | | | |

2011-DCL-C7846-001_08-12

Figure 3-26. Summary of Characterization Data for Borehole C7846 (Well 199-B4-15) at the 100-B-5 Trench

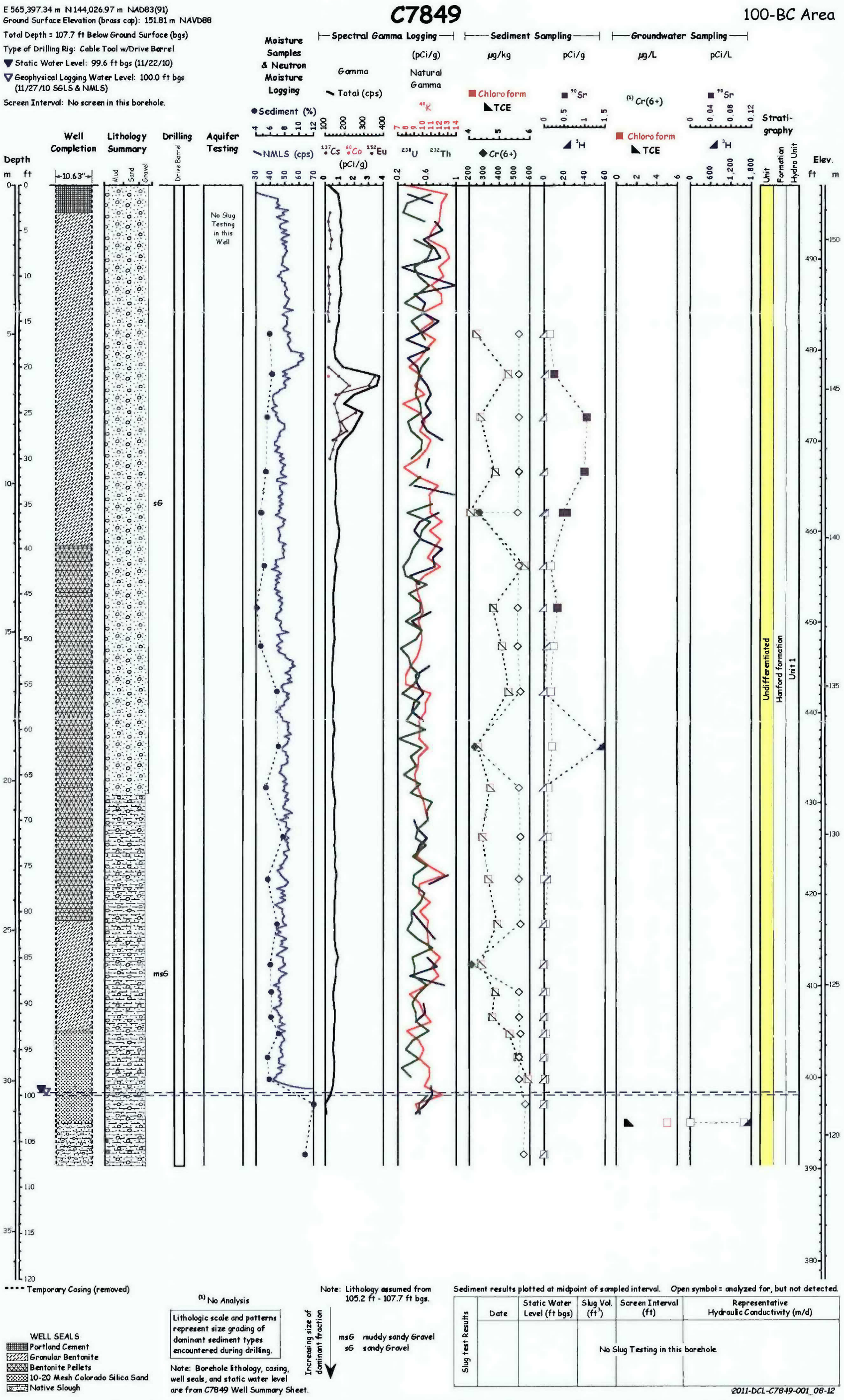
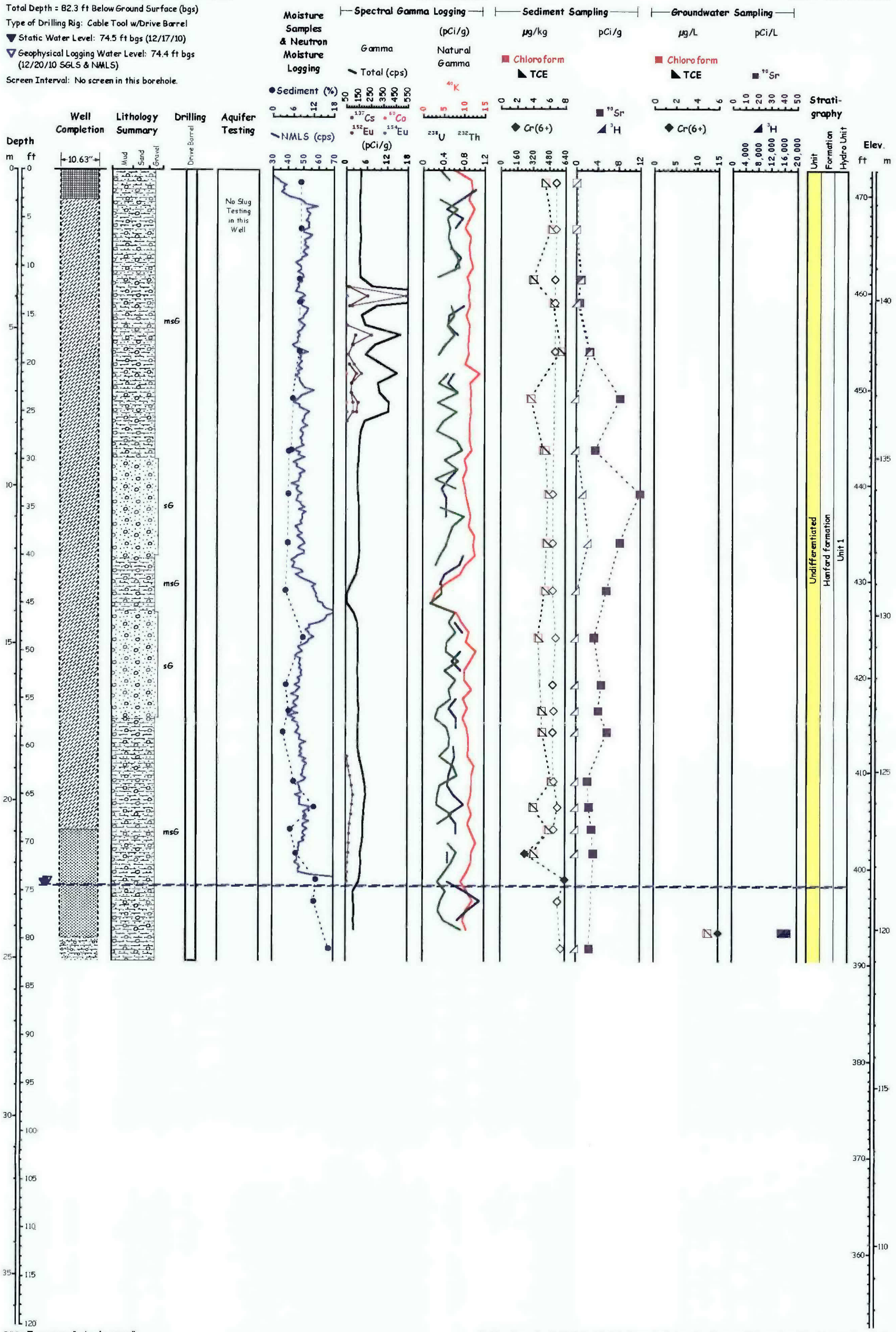



Figure 3-27. Summary of Characterization Data for Borehole C7849 at the 118-C-3 Reactor Fuel Storage Basin

E 565,331.7 m N 144,527.57 m NAD83(91)
Ground Surface Elevation (brass cap): 144.04 m NAVD88
Total Depth = 82.3 ft Below Ground Surface (bgs)
Type of Drilling Rig: Cable Tool w/Drive Barrel
▼ Static Water Level: 74.5 ft bgs (12/17/10)
▽ Geophysical Logging Water Level: 74.4 ft bgs (12/20/10 SGLS & NMLS)
Screen Interval: No screen in this borehole.

# C8239

100-BC Area




WELL SEALS
- Portland Cement
- Granular Bentonite
- 10-20 Mesh Silica Sand
- Native Slough

Lithologic scale and patterns represent size grading of dominant sediment types encountered during drilling.

Increasing size of dominant fraction

- msG muddy sandy Gravel
- sG sandy Gravel

Note: Borehole lithology, casing, well seals, and static water level are from C8239 Well Summary Sheet.

Sediment results plotted at midpoint of sampled interval. Open symbol = analyzed for, but not detected.

| Slug Test Results | Date | Static Water Level (ft bgs) | Slug Vol. ($ft^3$) | Screen Interval (ft) | Representative Hydraulic Conductivity (m/d) |
|---|---|---|---|---|---|
| | | | No Aquifer Testing in this borehole. | | |

2011-DCL-C8239-001_08-12

Figure 3-28. Summary of Characterization Data for Borehole C8239 at the 118-B-8 Reactor Fuel Storage Basin

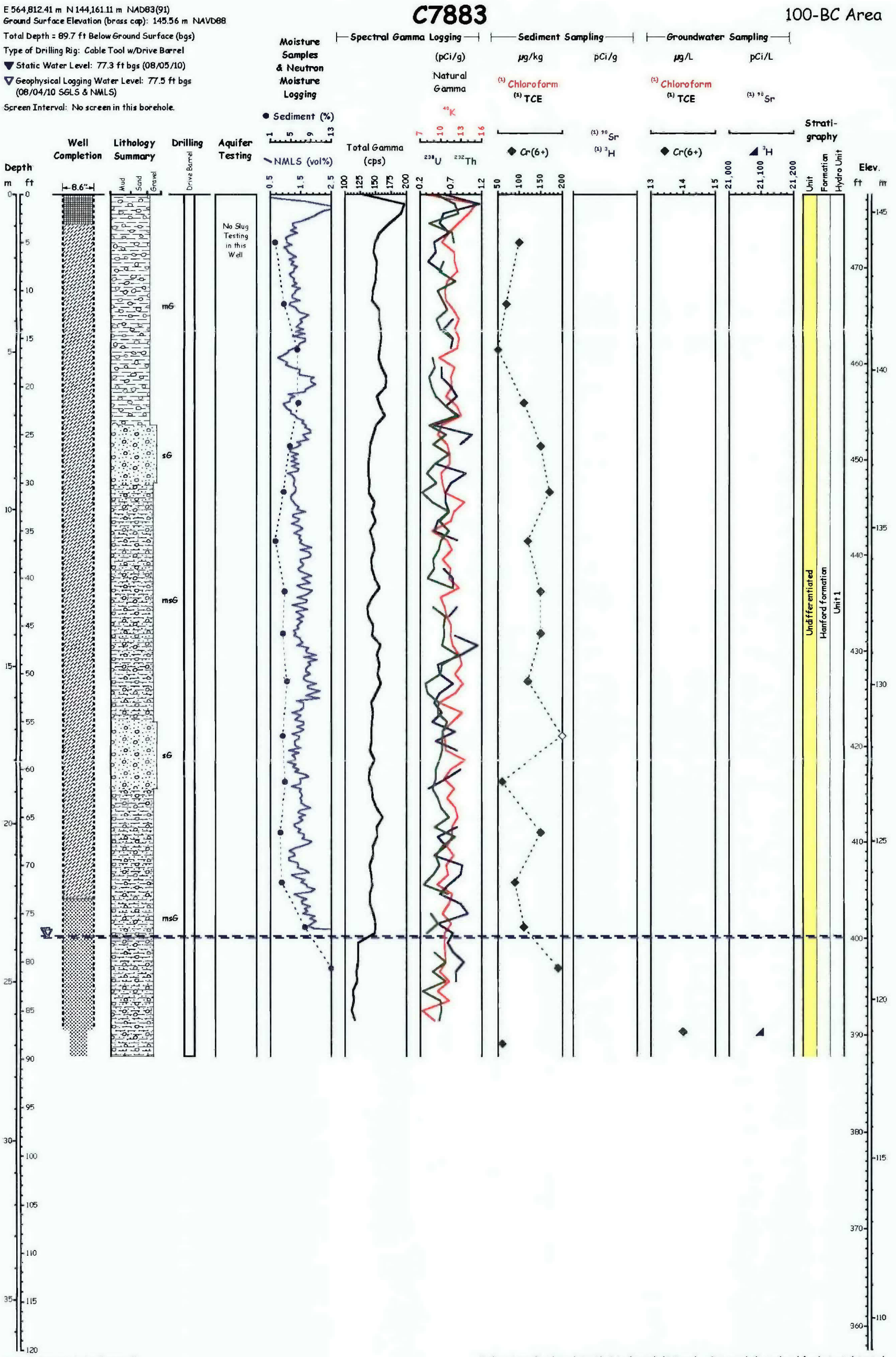



Figure 3-29. Summary of Characterization Data for Borehole C7883, North of 100-C-7

E 564,734.5 m N 144,158.1 m NAD83(91)
Ground Surface Elevation (brass cap): 145.38 m NAVD88

Total Depth = 91.1 ft Below Ground Surface (bgs)

Type of Drilling Rig: Cable Tool w/Drive Barrel

▼ Static Water Level: 80 ft bgs (08/16/10)

▽ Geophysical Logging Water Level: 79.1 ft bgs (08/13/10 SGLS & NMLS)

Screen Interval: No screen in this borehole.

# C7884

100-BC Area

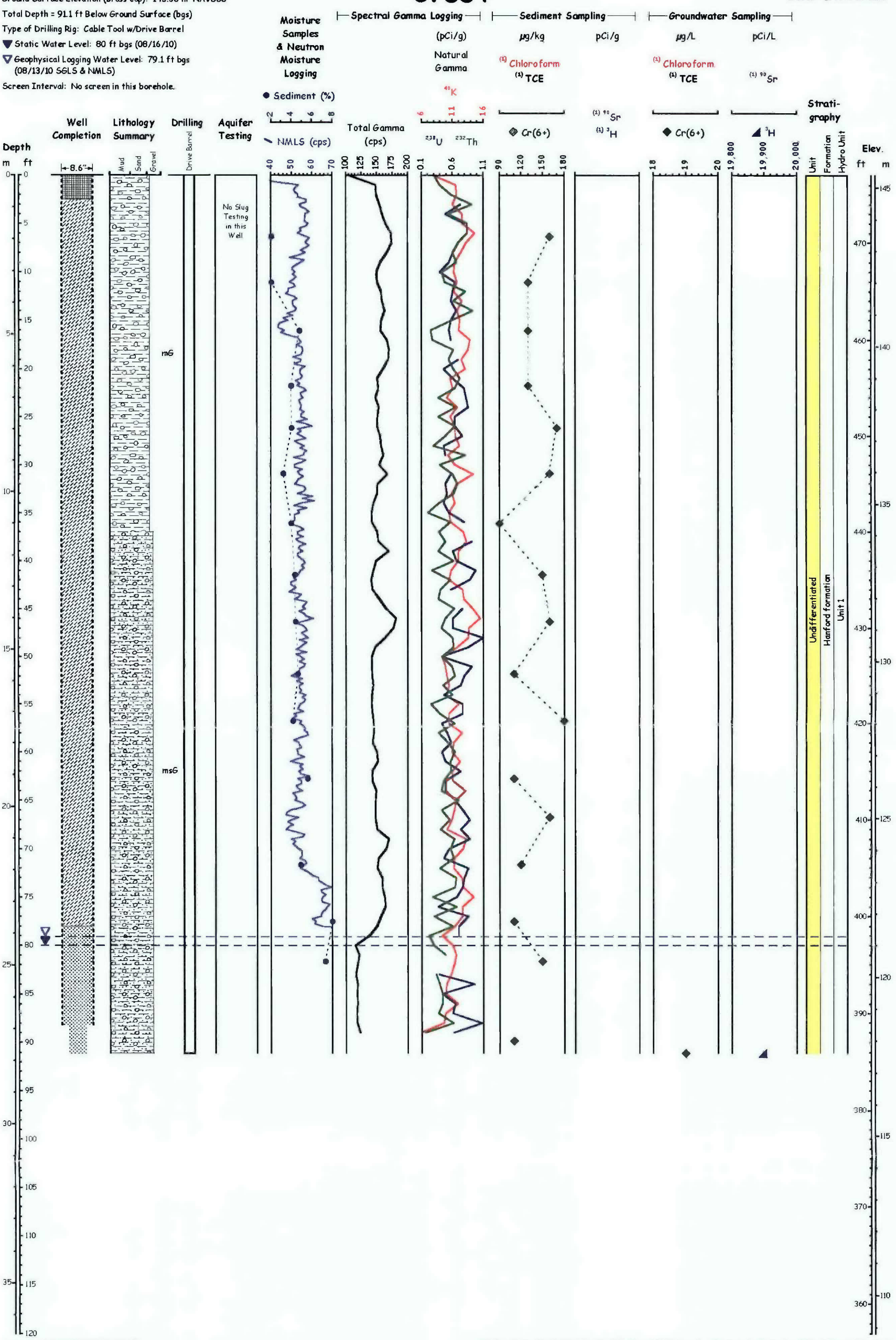



Figure 3-30. Summary of Characterization Data for Borehole C7884, North of 100-C-7

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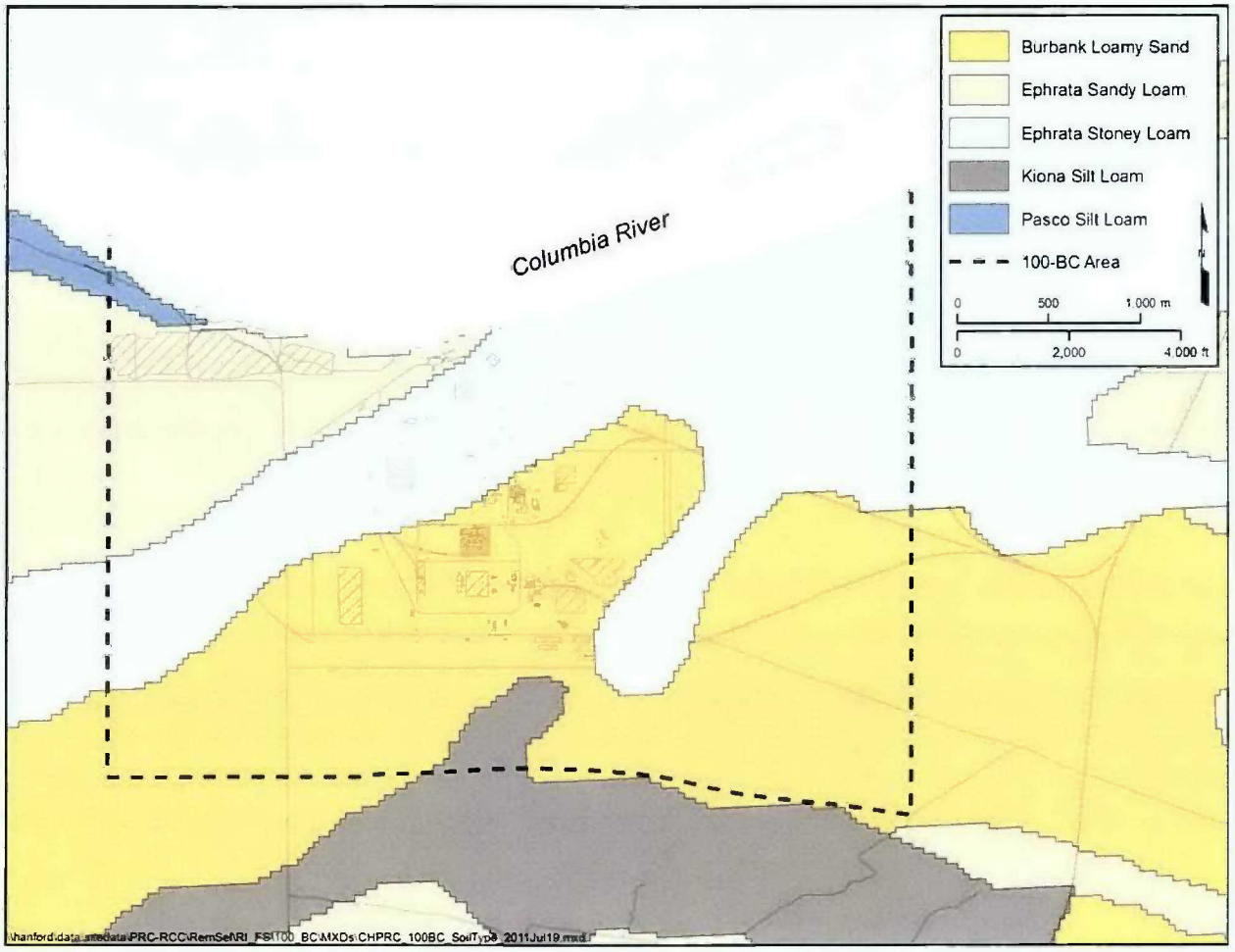
## 3.5 Soil and Vadose Zone

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

### 3.5.1 Soil

*Soil Survey Hanford Project in Benton County Washington* (BNWL-243) describes 15 soil types on the Hanford Site, 5 of which are present at 100-BC (Figure 3-31).




Source: Modified from *Hanford Site National Environmental Policy Act (NEPA) Characterization* (PNNL-6415).
Note: Does not account for remedial action efforts.

**Figure 3-31. Soil Types of 100-BC**

The soil consists of sand, sandy loam, and silty loam. The five soil types present in 100-BC are:

- Burbank Loamy Sand is a dark-colored, coarse-textured soil underlain by gravel. Its surface soil is usually about 40 cm (16 in.) thick, but may be as much as 75 cm (30 in.) thick. The gravel content of its subsoil ranges from 20 to 80 percent.
- Ephrata Sandy Loam is found on level topography on the Hanford Site. Its surface is darkly colored and its subsoil is dark grayish-brown, medium-textured soil underlain by gravelly material.

- Ephrata Stony Loam is similar to Ephrata Sandy Loam. It differs in that many large, hummocky ridges are made up of debris released from melting glaciers. Areas of Ephrata Stony Loam located between hummocks contain many large boulders.

- Kiona Silt Loam occupies steep slopes and ridges. Its surface soil is very dark grayish-brown, about 10 cm (4 in.) thick, and has dark brown subsoil containing basalt fragments that are 30 cm (12 in.) and larger in diameter. Many basalt fragments are found in its surface layer and basalt rock outcrops are often present.

- Pasco Silt Loam is poorly drained, very dark grayish-brown soil formed in recent alluvial material. Its subsoil is variable, consisting of stratified layers. A small area of Pasco Silt Loam is found located in low areas adjacent to the Columbia River.

### 3.5.2 Vadose Zone

The vadose (unsaturated) zone at 100-BC comprises primarily Hanford formation gravels. In northern 100-BC the vadose zone includes the upper portion of Ringold unit E gravels. The vadose zone is 0 to 30 m (0 to 98 ft) thick.

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

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

Data collected from the vadose zone as part of this RI confirm that soil moisture is low and porosity is high. Vertical hydraulic conductivity data were highly variable.

Table 3-6 lists particle size, percent moisture, bulk density, and calculated porosity for soil samples collected from the vadose zone and just below the water table. Particle size analysis was performed in accordance with *Standard Test Method for Particle-Size Analysis of Soils* (ASTM D422-63). Sediment moisture content was determined in accordance with *Standard Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass* (ASTM D2216-05). Density was determined in accordance with *Standard Test Method for Density of Soil in Place by the Drive-Cylinder Method* (ASTM D2937-04) and is reported both as bulk density and as dry density. Porosity is a calculated value determined by the following equation and reported as a percent:

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

For purposes of calculating porosity, normal particle density is assumed to be 2.65 g/cm$^3$ (165.434 lb/ft$^3$).

Table 3-6. Physical Property Results for Samples Collected in the Vadose Zone

| Site | Interval | Depth (ft)[a] | Geologic Unit | Grain Size (% Passing Sieve) | | | | | | | | | | | | Classification (%) | | | Calculated Porosity (%) | Moisture (%) | Density (kg/m$^3$)[b] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 3 in. | 1.5 in. | 0.75 in. | 0.375 in. | #4 | #10 | #20 | #40 | #60 | #100 | #140 | #200 | Gravel | Sand | Silt/ Clay | | | Bulk | Dry |
| 199-B8-9 (C7508) | I-002 | 85.8 to 88.3 | Hanford | 100 | 100 | 91.7 | 81.9 | 64.3 | 33.7 | 19.1 | 9.8 | 7.0 | 5.6 | 5.0 | 4.5 | 35.7 | 59.8 | 4.5 | 17.6 | 6.39 | 2182 | 2074 |
| | I-003 | 89.5 to 92.0 | Hanford | 100 | 100 | 88.5 | 74.1 | 51.0 | 22.4 | 13.1 | 6.0 | 4.1 | 3.1 | 2.7 | 2.4 | 49.0 | 48.6 | 2.4 | 22.0 | 4.65 | 2064 | 1989 |
| | I-011 | 100.5 to 103.0 | Hanford | 100 | 84.4 | 74.3 | 60.3 | 44.5 | 28.1 | 16.5 | 10.2 | 7.8 | 6.2 | 5.5 | 4.8 | 55.5 | 39.7 | 4.8 | -1.5[c] | 7.62 | 2686 | 2539 |
| | I-006 | 105.1 to 107.6 | Hanford | 100 | 100 | 78.2 | 70.8 | 63.8 | 56.4 | 50.4 | 41.7 | 34.1 | 24.6 | 18.5 | 12.8 | 36.2 | 51.0 | 12.8 | 15.7 | 5.36 | 2232 | 1982 |
| 199-B2-16 (C7784) | I-002 | 28.5 to 31.0 | Hanford | 100 | 92.5 | 83.4 | 54.1 | 36.6 | 26.9 | 21.0 | 14.9 | 11.3 | 8.8 | 7.7 | 6.8 | 63.4 | 29.8 | 6.8 | 12.2 | 2.70 | 2323 | 2258 |
| | I-003 | 34.0 to 36.5 | Hanford | 100 | 89.2 | 69.8 | 46.8 | 36.5 | 30.3 | 27.6 | 25.7 | 22.0 | 14.0 | 10.3 | 7.5 | 63.5 | 29.0 | 7.5 | 13.0 | 2.98 | 2302 | 2266 |
| | I-004 | 36.4 to 38.9 | Hanford | 100 | 67.7 | 58.8 | 45.0 | 33.9 | 26.8 | 23.0 | 20.6 | 18.1 | 13.3 | 10.5 | 8.2 | 66.1 | 25.6 | 8.2 | 23.3 | 2.69 | 2030 | 1990 |
| | I-005 | 38.4 to 40.9 | Hanford | 100 | 90.9 | 79.5 | 65.5 | 51.3 | 40.8 | 34.9 | 31.2 | 26.2 | 18.4 | 15.4 | 12.0 | 48.7 | 39.3 | 12.0 | 20.0 | 2.74 | 2118 | 2083 |
| | I-006 | 40.9 to 43.4 | Ringold E | 100 | 87.3 | 66.5 | 47.3 | 37.6 | 31.3 | 27.4 | 23.1 | 16.2 | 8.7 | 6.7 | 5.4 | 62.4 | 32.2 | 5.4 | 17.7 | 10.2 | 2178 | 2078 |
| 199-B3-51 (C7785) | I-003 | 40.4 to 42.9 | Ringold E | 100 | 73.2 | 56.0 | 42.5 | 33.4 | 29.5 | 27.9 | 23.5 | 17.1 | 10.5 | 8.1 | 6.5 | 66.6 | 27.0 | 6.5 | 22.9 | 3.09 | 2040 | 2002 |
| | I-011 | 49.0 to 51.5 | Ringold E | 100 | 81.1 | 64.5 | 45.1 | 33.2 | 26.7 | 23.9 | 21.0 | 14.6 | 8.3 | 6.4 | 5.2 | 66.8 | 28.0 | 5.2 | 13.9 | 11.6 | 2278 | 2158 |
| 199-B5-8 (C8244) | I-002 | 85.8 to 88.3 | Hanford | 100 | 91.9 | 74.5 | 54.4 | 42.0 | 31.2 | 13.4 | 7.6 | 6.1 | 5.1 | 4.6 | 4.1 | 58.0 | 37.9 | 4.1 | 21.2 | 6.22 | 2085 | 2003 |
| | I-011 | 87.8 to 90.3 | Hanford | 100 | 90.5 | 74.7 | 60.9 | 48.4 | 37.2 | 19.4 | 12.5 | 10.0 | 8.4 | 7.7 | 6.9 | 51.6 | 41.5 | 6.9 | 16.7 | 5.24 | 2205 | 2128 |
| | I-003 | 90.0 to 92.5 | Hanford | 100 | 84.1 | 68.1 | 49.9 | 41.2 | 34.9 | 25.0 | 11.5 | 8.6 | 7.0 | 6.3 | 5.7 | 58.8 | 35.5 | 5.7 | 15.4 | 5.81 | 2240 | 2150 |
| | I-004 | 92.5 to 95.0 | Hanford | 100 | 89.8 | 72.7 | 52.0 | 38.3 | 24.5 | 14.3 | 8.2 | 6.3 | 5.1 | 4.5 | 4.1 | 61.7 | 34.3 | 4.1 | 13.4 | 6.01 | 2293 | 2213 |
| | I-006 | 97.8 to 100.3 | Hanford | 100 | 100 | 81.1 | 59.1 | 37.0 | 24.3 | 15.9 | 7.4 | 5.1 | 4.0 | 3.5 | 3.2 | 63.0 | 33.9 | 3.2 | 15.7 | 5.22 | 2232 | 2152 |
| | I-007 | 100.4 to 102.9 | Hanford | 100 | 100 | 78.1 | 61.9 | 42.8 | 28.5 | 20.2 | 10.7 | 7.5 | 6.0 | 5.4 | 5.0 | 57.2 | 37.9 | 5.0 | 16.9 | 5.06 | 2200 | 2128 |
| | I-010 | 104.5 to 107.0 | Hanford | 100 | 85.8 | 68.7 | 44.7 | 25.9 | 16.3 | 10.2 | 4.9 | 3.7 | 3.1 | 2.8 | 2.5 | 74.1 | 23.5 | 2.5 | 14.6 | 8.97 | 2261 | 2162 |
| | I-015 | 190.0 to 192.5 | Hanford | 100 | 100 | 100 | 99.6 | 96.2 | 82.1 | 64.7 | 42.8 | 22.7 | 10.4 | 6.3 | 3.9 | 3.8 | 92.3 | 3.9 | 16.8 | N/A | 2202 | 1901 |
| C7844 | I-004 | 29.2 to 31.7 | Hanford | 100 | 100 | 74.7 | 53.5 | 34.1 | 17.7 | 6.4 | 3.1 | 2.4 | 2.1 | 1.9 | 1.8 | 65.9 | 32.3 | 1.8 | 18.9 | 5.16 | 2147 | 2078 |
| C7845 | I-007 | 50.6 to 53.1 | Hanford | 100 | 61.9 | 47.1 | 36.9 | 30.0 | 22.2 | 16.0 | 11.8 | 9.9 | 8.2 | 7.3 | 6.4 | 70.0 | 23.5 | 6.4 | 21.2 | 4.67 | 2086 | 2053 |
| C7849 | I-011 | 65.2 to 67.6 | Hanford | 100 | 100 | 84.5 | 67.9 | 54.1 | 41.9 | 24.5 | 12.1 | 7.9 | 5.8 | 5.0 | 4.5 | 45.9 | 49.6 | 4.5 | 23.4 | 5.39 | 2027 | 1923 |
| TP 116-B-6B[d] | — | 16.4 to 18.4 | Hanford | 100 | 100 | 100 | 92.7 | 80.4 | 72.7 | 54.4 | 26.5 | 22.0 | 20.2 | 19.5 | 18.9 | 19.6 | 61.6 | 18.9 | 42.9 | 10.3 | 1512 | 1344 |
| | — | 19.4 to 21.4 | Hanford | 100 | 100 | 100 | 100 | 100 | 100 | 63.5 | 8.3 | 4.3 | 3.3 | 2.9 | 2.7 | 0.0 | 97.3 | 2.7 | 41.7 | 5.64 | 1544 | 1451 |
| TP 116-B-9[d] | — | 8 to 10 | Hanford | 100 | 100 | 100 | 77.4 | 53.7 | 40.7 | 34.4 | 26.7 | 23.9 | 22.0 | 21.1 | 20.1 | 46.3 | 33.6 | 20.1 | 24.0 | 8.40 | 2013 | 1808 |
| | — | 11 to 13 | Hanford | 100 | 100 | 100 | 70.1 | 30.4 | 15.2 | 14.2 | 12.5 | 11.7 | 11.0 | 10.7 | 10.4 | 69.6 | 19.9 | 10.4 | 32.9 | 6.15 | 1776 | 1598 |

Table 3-6. Physical Property Results for Samples Collected in the Vadose Zone

| Site | Interval | Depth (ft)[a] | Geologic Unit | Grain Size (% Passing Sieve) | | | | | | | | | | | | Classification (%) | | | Calculated Porosity (%) | Moisture (%) | Density (kg/m$^3$)[b] | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 3 in. | 1.5 in. | 0.75 in. | 0.375 in. | #4 | #10 | #20 | #40 | #60 | #100 | #140 | #200 | Gravel | Sand | Silt/ Clay | | | Bulk | Dry |
| TP 118-B-8:3[d] | — | Inside Pipe | N/A | 100 | 100 | 90.5 | 75.8 | 61.2 | 48.8 | 40.6 | 28.7 | 22.6 | 18.4 | 16.2 | 14.1 | 38.8 | 47.1 | 14.1 | 21.3 | 20.2 | 2083 | 1773 |
| | — | 22 | Hanford | 100 | 100 | 87.6 | 54.9 | 20.2 | 9.3 | 7.7 | 6.6 | 6.2 | 5.9 | 5.7 | 5.4 | 79.8 | 14.7 | 5.4 | 34.0 | 8.09 | 1747 | 1650 |
| | — | 23 | Hanford | 100 | 100 | 93.8 | 56.5 | 33.2 | 25.2 | 22.7 | 19.1 | 17.5 | 16.1 | 15.1 | 13.9 | 66.8 | 19.3 | 13.9 | 26.9 | 3.11 | 1936 | 1802 |

Note: Includes some samples from below the water table.

a. Depth reported in feet, as measured. To convert from feet to meters multiply by 0.3048.

b. To convert from kg/m$^3$ to lb/ft$^3$ multiply by 0.0625.

c. Anomalous bulk density resulted in negative calculated porosity.

d. Test pit samples collected from excavator bucket. Borehole samples collected with split-spoon samplers.

Physical testing of the vadose zone samples is summarized below:

- Grain size: As expected, the majority of the vadose zone soil are sandy gravels with the notable exception of Well 199-B5-8 (C8244) interval I-015, which appears to be primarily sand. This was not evident on the geologist's log, which describes the sediment at this depth as silty sandy gravel. The discrepancy may be due to a sampling anomaly or uncertainty with the geologic log. The log was based on bailed samples because this portion of the borehole was drilled with a hard tool.

- Moisture percent: The Hanford Site's arid climate keeps the vadose zone soil moisture relatively low. The water export system (182-B Reservoir) and dust suppression water are existing sources of artificial recharge. Historically, effluent discharge to the soil column increased soil moisture beneath waste sites, and it is possible that some drainage may continue in areas where large volumes of liquid waste were formerly discharged. However, RI data did not find evidence to support this. Percent moisture ranged from less than 3 percent to greater than 10 percent, with the samples collected from near the water table having higher moisture than those higher in the vadose zone.

- Bulk density: Omitting an abnormally high bulk density result for Well 199-B8-9 interval I-011, density ranged from 1,512 to 2,323 kg/m$^3$ (94.5 to 145.2 lb/ft$^3$). The lowest values were for samples from test pits, which were collected from the excavator bucket. The minimum density of a split-spoon sample from a well or borehole was 2,027 kg/m$^3$ (126.7 lb/ft$^3$).

- Calculated porosity: Porosity ranged from 12.2 to 42.9 percent, with the exception of Well 199-B8-9 (C7508) interval I-011, which had a high bulk density leading to a negative porosity value. The highest porosity values were from samples from test pits. The average porosity of samples from wells and boreholes, excluding the negative value, was 18 percent. Porosity of the three samples from Ringold Formation unit E was in the same range as the Hanford formation.

- Saturated hydraulic conductivity was determined in accordance with *Standard Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter* (ASTM D5084-03) for soil with low hydraulic conductivity (silt or a mud) or *Standard Test Method for Permeability of Granular Soils (Constant Head)* (ASTM D2434-68) for soil with high hydraulic conductivity (sand or sandy gravel). Table 3-7 summarizes results of saturated vertical hydraulic conductivity tests of split-spoon samples from wells and boreholes. These include samples from the vadose zone, aquifer, and aquitard. Hydraulic conductivity of the vadose zone samples ranged from 0.0052 to 80 m/d (0.017 to 260 ft/d), and averaged 26 m/d (86 ft/d). The large variability is probably partly a result of sample conditions, since it is difficult to get an intact sample of an unconsolidated sand or gravel. Section 3.6 discusses vertical hydraulic conductivity of the aquifer and aquitard.

Table 3-7. Vertical Hydraulic Conductivity as Determined by Laboratory Testing of Split-Spoon Samples

| Well | Depth (ft) | Depth (m) | Geology (from borehole logs) | Hydrgeologic Unit | Vertical $K_s$ (m/d) | Vertical $K_s$ (ft/d) |
|---|---|---|---|---|---|---|
| 199-B2-14 | 51.2 | 15.6 | RE: silty sandy gravel | Aquifer | 2.618 | 8.6 |
| | 146.6 | 44.7 | RUM: 95% silt/clay, 5% sand | Aquitard | 0.010 | 0.032 |
| 199-B2-15 | 147.5 | 45.0 | RUM: 95% silt/clay, 5% sand | Aquitard | 0.10 | 0.31 |
| | 153.5 | 46.8 | RUM: 95% silt/clay, 5% sand | Aquitard | 0.000019 | 0.000062 |
| | 158.3 | 48.2 | RUM: silty sandy gravel (25% silt) | Aquitard | 0.0024 | 0.0079 |
| | 163.0 | 49.7 | RUM: silty sandy gravel (25% silt) | Aquitard | 0.00086 | 0.0028 |
| | 168.4 | 51.3 | RUM: gravelly sand (10% silt); densely packed | Aquitard | 16 | 51 |
| | 173.7 | 52.9 | RUM: gravelly sand (10% silt); densely packed | Aquitard | 0.014 | 0.045 |
| | 178.5 | 54.4 | RUM: sandy gravel; cementation | Aquitard | 0.079 | 0.26 |
| | 183.3 | 55.9 | RUM: sandy gravel; cementation | Aquitard | 4.3 | 14 |
| | 188.3 | 57.4 | RUM: silty sandy gravel (5% silt); very compacted | Aquitard | 13 | 42 |
| | 193.8 | 59.1 | RUM: silty sandy gravel (5% silt); very compacted | Aquitard | 0.0016 | 0.0054 |
| 199-B2-16 | 31 | 9.4 | Hf: sandy silty gravel | Vadose | 41 | 135 |
| | 36.5 | 11.1 | Hf: sandy silty gravel | Vadose | 0.80 | 2.6 |
| | 38.9 | 11.9 | Hf: sandy silty gravel | Vadose | 1.9 | 6.2 |
| | 40.9 | 12.5 | Hf/RE contact: gravelly sand | Vadose | 0.0052 | 0.017 |
| | 43.4 | 13.2 | RE: gravelly sand | Aquifer | 4.2 | 14 |
| | 148.1 | 45.1 | RUM: 95% silt/clay | Aquitard | 0.00085 | 0.0028 |
| | 152.7 | 46.5 | RUM: 95% silt/clay | Aquitard | 0.14 | 0.45 |
| 199-B3-50 | 87.9 | 26.8 | Hf: sandy gravel | Aquifer | 0.32 | 1.0 |
| | 179.4 | 54.7 | RUM: 95% silt/clay | Aquitard | 0.00046 | 0.0015 |
| | 183.3 | 55.9 | RUM: 95% silt/clay | Aquitard | 0.0038 | 0.013 |
| 199-B3-51 | 42.9 | 13.1 | RE: sandy gravel | Vadose | 1.1 | 3.5 |
| | 51.5 | 15.7 | RE: sandy gravel | Aquifer | 0.50 | 1.6 |
| | 57.6 | 17.6 | RE: sandy gravel | Aquifer | 1.2 | 3.9 |
| | 156.9 | 47.8 | RUM: silty sandy gravel | Aquitard | 2.1 | 6.8 |

Table 3-7. Vertical Hydraulic Conductivity as Determined by Laboratory Testing of Split-Spoon Samples

| Well | Depth (ft) | Depth (m) | Geology (from borehole logs) | Hydrgeologic Unit | Vertical $K_s$ (m/d) | Vertical $K_s$ (ft/d) |
|---|---|---|---|---|---|---|
| 199-B5-5 | 51.7 | 15.8 | Hf: sandy gravel | Aquifer | 0.0020 | 0.0064 |
| | 205.0 | 62.5 | RUM: silty clayey sand | Aquitard | 0.0044 | 0.014 |
| | 214.8 | 65.5 | RUM: sandy clay | Aquitard | 0.40 | 1.3 |
| 199-B5-6 | 193.0 | 58.8 | RUM: 95% silt/clay | Aquitard | 0.00057 | 0.0019 |
| | 197.6 | 60.2 | RUM: 95% silt/clay | Aquitard | 0.0010 | 0.0033 |
| 199-B5-8 | 88.3 | 26.9 | Hf: silty sandy gravel | Vadose | 80 | 260 |
| | 90.3 | 27.5 | Hf: silty sandy gravel | Vadose | 9.5 | 31 |
| | 92.5 | 28.2 | Hf: silty sandy gravel | Vadose | 13 | 41 |
| | 95 | 29.0 | Hf: silty sandy gravel | Vadose | 7.8 | 26 |
| | 100.3 | 30.6 | Hf: silty sandy gravel | Vadose | 33 | 110 |
| | 102.9 | 31.4 | Hf: silty sandy gravel | Vadose | 13 | 41 |
| | 107.0 | 32.6 | Hf: silty sandy gravel | Aquifer | 39 | 130 |
| | 192.5 | 58.7 | Hf: silty sandy gravel | Aquifer | 8.8 | 29 |
| | 205.2 | 62.5 | RE: silty sandy gravel; slightly cemented | Aquifer | 11 | 36 |
| | 208.5 | 63.6 | RE: silty sandy gravel; cemented | Aquifer | 6.2 | 20 |
| | 224.0 | 68.3 | RUM: 100% mud/silt | Aquitard | 0.000068 | 0.00022 |
| | 230.6 | 70.3 | RUM: 100% mud/silt | Aquitard | 0.000014 | 0.000045 |
| 199-B8-9 | 88.3 | 26.9 | Hf: silty sandy gravel | Vadose | 42 | 140 |
| | 92.0 | 28.0 | Hf: silty sandy gravel | Vadose | 74 | 240 |
| | 103.0 | 31.4 | Hf: silty sandy gravel | Aquifer | 290 | 960 |
| | 107.6 | 32.8 | Hf: silty gravel | Aquifer | 0.0017 | 0.0057 |
| | 214.5 | 65.4 | RUM: mud | Aquitard | 0.000029 | 0.00010 |
| | 219.5 | 66.9 | RUM: mud | Aquitard | 0.00019 | 0.00062 |
| C7844 | 31.7 | 9.7 | Hf: gravelly sand | Vadose | 37 | 120 |
| C7845 | 53.1 | 16.2 | Hf: sandy gravel | Vadose | 36 | 120 |
| C7849 | 67.6 | 20.6 | Hf: sandy gravel | Vadose | 32 | 104 |

Table 3-7. Vertical Hydraulic Conductivity as Determined by Laboratory Testing of Split-Spoon Samples

| Well | Depth (ft) | Depth (m) | Geology (from borehole logs) | Hydrgeologic Unit | Vertical $K_s$ (m/d) | Vertical $K_s$ (ft/d) |
|---|---|---|---|---|---|---|
| **Summary** | | | | | | |
| **Geologic Unit** | | **Number of Samples** | **Minimum (m/d [ft/d])** | **Average (m/d [ft/d])** | **Maximum (m/d [ft/d])** | |
| Hanford formation | | 21 | 0.0017 (0.0056) | 38 (125) | 290 (960) | |
| Ringold unit E | | 7 | 0.0052 (0.017) | 3.3 (11) | 11 (36) | |
| Ringold muds (excluding sand and gravel) | | 15 | 0.00001 (0.00005) | 0.043 (0.14) | 0.40 (1.3) | |

Vertical hydraulic conductivity is a key parameter governing contaminant fate and transport in the vadose zone. In the late 1990s, moisture retention and unsaturated conductivity data were obtained in the laboratory for 15 soil samples from the 100 Area, including 4 from 100-BC (Table 3-7; *Far-Field Hydrology Data Package for Immobilized Low-Activity Tank Waste Performance Assessment* [HNF-4769]). These data provided estimated values for vertical saturated hydraulic conductivity. Vertical unsaturated hydraulic conductivity can, in turn, be estimated mathematically from vertical saturated hydraulic conductivity as a function of matric potential or pressure head. Estimated unsaturated hydraulic conductivities (based on saturated conductivity and the van Genuchten retention model ("A Closed-form Equation for Predicting the Hydraulic Conductivity of Unsaturated Soils"[van Genuchten, 1980]) can often differ by up to several orders of magnitude with measured conductivities. Therefore, a simultaneous fit of both laboratory-measured moisture retention and unsaturated conductivity data was used, and all five unknown parameters (residual moisture content, saturated moisture content, saturated hydraulic conductivity, and the two van Genuchten fitting parameters) were fit to the data. The van Genuchten function can be written as:

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

where:

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

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

h = matric potential (cm)

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

Vertical saturated hydraulic conductivities for three of the samples (Table 3-8) were approximately 0.0001 cm/s (0.3 ft/day). Two samples were from the Ringold Formation in Well 199-B2-12, and two samples were from the Hanford formation in Well 199-B4-9. The other sample had a lower vertical hydraulic conductivity of 0.00007 cm/s (0.2 ft/day).

In the vadose zone, the pressure head is negative under unsaturated conditions. This reflects the fact that water in the unsaturated zone is held in the soil pores under negative pressure by surface tension forces.

If the volume of water in the vadose zone equals the volume that can be retained by surface tension forces (field capacity), no water is available to migrate. As additional liquid is added to the vadose zone, it will migrate vertically under the force of gravity, because an increase in water content reduces the surface tension holding the water within the pore spaces in the vadose zone.

**Table 3-8. Van Genuchten Parameters and Fitted Vertical Saturated Hydraulic Conductivity Data for Three Sandy Gravel Soil Samples**

| Sample | Well Number | Depth (m) | Formation | % Gravel | θs | θr | α (1/cm) | n | Fitted Ks (cm/s) | Bulk Density (g/cm3) |
|---|---|---|---|---|---|---|---|---|---|---|
| 2-2663 | 199-B2-12 | 8.20 | Ringold* | 61 | 0.135 | 0.0179 | 0.0067 | 1.527 | 0.0000673 | 2.38 |
| 2-2664 | 199-B2-12 | 24.84 | Ringold | 73 | 0.125 | 0.0136 | 0.0152 | 1.516 | 0.000112 | 2.25 |
| 2-2666 | 199-B4-9 | 21.49 | Hanford | 71 | 0.138 | 0.00 | 0.0087 | 1.284 | 0.000102 | 2.10 |
| 2-2667 | 199-B4-9 | 23.93 | Hanford | 75 | 0.094 | 0.00 | 0.0104 | 1.296 | 0.000140 | 2.16 |

Source: Modified from *Far-Field Hydrology Data Package for Immobilized Low-Activity Tank Waste Performance Assessment* (HNF-4769).

* Reinterpretation of Hanford/Ringold contact depth.

$\theta_s$ = saturated moisture content (dimensionless)

$\theta_r$ = residual moisture content (dimensionless)

$\alpha$ = a fitting parameter

n = a fitting parameter (dimensionless)

Ks = saturated hydraulic conductivity

## 3.6 Hydrogeology

This section describes hydrostratigraphy, hydrogeologic properties, groundwater flow, recharge and discharge, and natural groundwater chemistry. Table 3-5 lists 100-BC monitoring wells and summarizes information about their construction. Figure 3-4 shows well locations.

RI activities resulted in an improved understanding of 100-BC hydrogeology. Geologic data from new wells helped define the hydrostratigraphy of the vadose zone, uppermost unconfined aquifer, and uppermost aquitard. Data from laboratory, slug, and aquifer tests provided additional information on aquifer properties. Automated water level data from wells screened at different depths provided information on horizontal and vertical gradients and groundwater flow. A separate study of groundwater upwelling in the Columbia River defined areas where 100-BC groundwater flows into the river.

### 3.6.1 Hydrostratigraphy

In 100-BC, the groundwater system comprises several hydrologic layers (Figure 3-6). From shallowest to deepest, these include the following:

- Vadose (unsaturated) zone
- Unconfined aquifer
- Uppermost aquitard
- Series of confined aquifers in the Ringold Formation (units C, B, and A), separated by fine-grained deposits (overbank and paleosol)
- Basalt aquitard and basalt-confined aquifers

Section 3.5 describes the vadose zone. The following subsections describe aquifers and aquitards.

### 3.6.1.1 Unconfined Aquifer

The unconfined aquifer comprises primarily the sands and gravels of Ringold unit E. Beneath most of 100-BC, the bottom portion of the Hanford formation also is saturated (Figure 3-32). The saturated Hanford formation is thickest in a region south of 100-BC where the top of unit E was eroded away. This channel was later filled with gravel and sand of the Hanford formation, creating a buried paleochannel of high-permeability sediments. For example, in Well 199-B5-8, the saturated thickness of the Hanford formation is 28 m (91 ft), because the contact between the Hanford formation and Ringold Formation is deeper. Beneath the former operational area, the saturated thickness of the Hanford formation ranges up to 6 m (20 ft) in Well 199-B8-9.

Thickness of the unconfined aquifer (that is, the saturated portion of Ringold unit E and the Hanford formation) ranges from 29 m (95 ft) near the river to 47 m (154 ft) in Well 199-B5-5, where the uppermost aquitard is deeper (Figures 3-7 through 3-9 and Figure 3-33). The aquifer is approximately 53 m (174 ft) thick in Well 699-67-86, located west of 100-BC (Table 3-5).

The Columbia River intersects the unconfined aquifer (Figure 3-9). The base of the unconfined aquifer is at an elevation approximately 20 to 30 m (66 to 98 ft) below the river channel.

### 3.6.1.2 Confining Units and Confined Aquifers

Below the unconfined aquifer, the Ringold Formation consists of a series of aquitards and water-bearing zones. The Ringold mud units have low permeability and form an aquitard at the base of the unconfined aquifer. The uppermost aquitard is encountered at elevations ranging from 73 to 90 m (240 to 295 ft) AMSL. Sandy or gravelly layers within the Ringold mud units yield enough water to produce a sample; Wells 199-B2-12 and 199-B2-15 are screened in silty sandy gravel beneath or within the shallowest mud unit.

No monitoring wells in 100-BC currently in use are screened deeper than the Ringold Formation. Former piezometers 199-B3-2P and -2Q were screened in the lower Ringold (presumably unit A) and the Rattlesnake Ridge interbed, respectively. Very little information is available about the construction of Well 199-B3-2 and its piezometers. Without documentation of an annular seal, it was concluded that the well created a potential for a vertical conduit between aquifers. It was decommissioned in 1997.

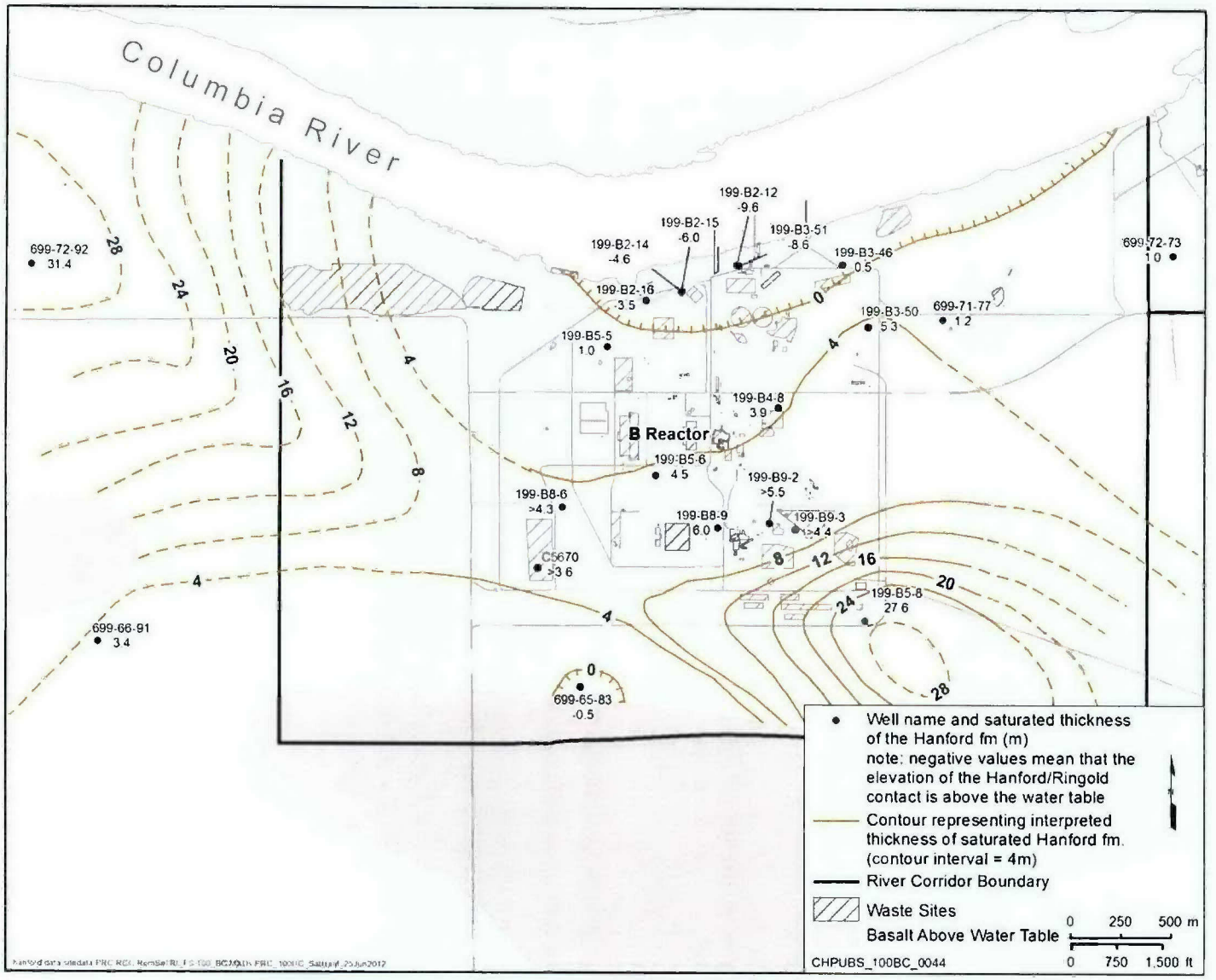



Figure 3-32. Thickness of Saturated Hanford Formation, 100-BC

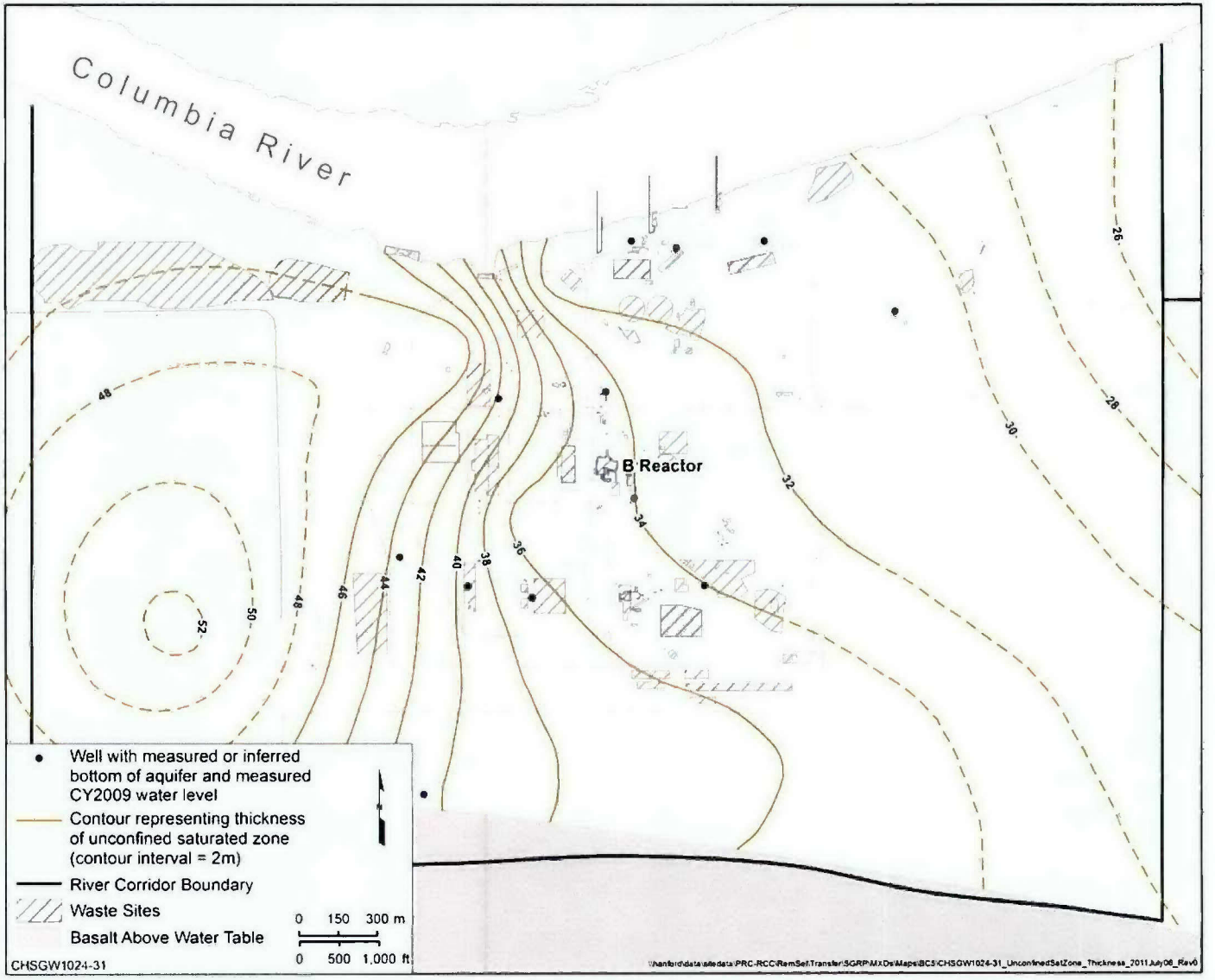



Figure 3-33. Thickness of Unconfined Aquifer, 100-BC

### 3.6.2 Hydrogeologic Properties

Selected soil samples from new monitoring wells were tested for vertical hydraulic conductivity, bulk density, and moisture content. Properties of the vadose zone and just below the water table were discussed in Section 3.5. Table 3-9 lists bulk density and percent moisture data from deeper samples, representing the unconfined aquifer and the uppermost aquitard, the RUM unit. The data set includes 5 samples from the Hanford formation, 10 from Ringold unit E, and 24 from the RUM. Fifteen of the RUM samples were primarily silt and clay and nine included varying amounts of sand and gravel.

Table 3-9. Bulk Density and Percent Moisture of 100-BC Aquifer and Aquitard, Based on Sediment Samples

| Well | Date | Depth (ft) | Depth (m) | Geology (from borehole logs) | Bulk Density Wet ($kg/m^3$) | Bulk Density Wet ($lb/ft^3$) | Percent Moisture Wet Sample |
|---|---|---|---|---|---|---|---|
| 199-B2-14 | 1/21/2010 | 51.2 | 15.6 | RE: silty sandy gravel | 2,500 | 156 | 18.1 |
| | 2/16/2010 | 146.6 | 44.7 | RUM: 95% silt/clay, 5% sand | 2,060 | 129 | 22.4 |
| | 2/16/2010 | 152.3 | 46.4 | RUM: 95% silt/clay, 5% sand | 2,100 | 131 | 23.6 |
| 199-B2-15 | 12/3/2010 | 147.5 | 45.0 | RUM: 95% silt/clay, 5% sand | 2,153 | 134 | 17.5 |
| | 12/6/2010 | 153.5 | 46.8 | RUM: 95% silt/clay, 5% sand | 2,055 | 128 | 18.3 |
| | 12/6/2010 | 158.3 | 48.2 | RUM: silty sandy gravel (25% silt) | 1,956 | 122 | 18.8 |
| | 12/7/2010 | 163.0 | 49.7 | RUM: silty sandy gravel (25% silt) | 2,137 | 133 | 14.3 |
| | 12/13/2010 | 168.4 | 51.3 | RUM: gravelly sand (10% silt); densely packed | 1,951 | 122 | 18.0 |
| | 12/13/2010 | 173.7 | 52.9 | RUM: gravelly sand (10% silt); densely packed | 2,374 | 148 | 14.8 |
| | 12/14/2010 | 178.5 | 54.4 | RUM: sandy gravel; cementation | 2,041 | 127 | 12.1 |
| | 12/14/2010 | 183.3 | 55.9 | RUM: sandy gravel; cementation | 2,124 | 133 | 12.4 |
| | 12/15/2010 | 188.3 | 57.4 | RUM: silty sandy gravel (5% silt); very compacted | 2,122 | 132 | 18.0 |
| | 12/15/2010 | 193.8 | 59.1 | RUM: silty sandy gravel (5% silt); very compacted | 2,167 | 135 | 16.5 |

Table 3-9. Bulk Density and Percent Moisture of 100-BC Aquifer and Aquitard, Based on Sediment Samples

| Well | Date | Depth (ft) | Depth (m) | Geology (from borehole logs) | Bulk Density Wet ($kg/m^3$) | Bulk Density Wet ($lb/ft^3$) | Percent Moisture Wet Sample |
|---|---|---|---|---|---|---|---|
| 199-B2-16 | 11/5/2010 | 148.1 | 45.1 | RUM: 95% silt/clay | 1,530 | 95 | X |
| | 11/5/2010 | 152.7 | 46.5 | RUM: 95% silt/clay | 1,911 | 119 | 16.3 |
| 199-B3-50 | 10/19/2009 | 87.9 | 26.8 | Hf: sandy gravel | 2,430 | 152 | 10.4 |
| | 10/21/2009 | 97.0 | 29.6 | RE: 90% sand, 10% gravel | X | 0 | 21.4 |
| | 11/19/2009 | 179.4 | 54.7 | RUM: 95% silt/clay | 2,180 | 136 | 17.5 |
| | 11/19/2009 | 183.3 | 55.9 | RUM: 95% silt/clay | 2,040 | 127 | 19.4 |
| 199-B3-51 | 1/19/2011 | 57.6 | 17.6 | RE: sandy gravel | 2,302 | 144 | X |
| | 2/15/2011 | 156.9 | 47.8 | RUM: silty sandy gravel | 2,353 | 147 | 17.0 |
| 199-B5-5 | 10/12/2009 | 50.1 | 15.3 | Hf: sandy gravel | X | X | 4.6 |
| | 10/12/2009 | 51.7 | 15.8 | Hf: sandy gravel | 2,680 | 167 | 8.6 |
| | 10/12/2009 | 55.1 | 16.8 | RE: slightly silty sand | X | X | 9.6 |
| | 12/7/2009 | 205.0 | 62.5 | RUM: silty clayey sand | 2,080 | 130 | 20.2 |
| | 12/7/2009 | 214.8 | 65.5 | RUM: sandy clay | 2,050 | 128 | 19.4 |
| 199-B5-6 | 12/29/2009 | 79.8 | 24.3 | Hf: sandy gravel | X | X | 14.7 |
| | 1/5/2010 | 84.5 | 25.8 | Hf: sandy gravel | X | X | 12.0 |
| | 1/4/2010 | 95.4 | 29.1 | RE: gravel | X | X | 10.1 |
| | 1/5/2010 | 100.0 | 30.5 | RE: gravel | X | X | 13.7 |
| | 1/6/2010 | 104.4 | 31.8 | RE: silty sandy gravel | X | X | 9.5 |
| | 1/7/2010 | 107.8 | 32.9 | RE: silty sandy gravel; tightly cemented | X | X | 14.3 |
| | 1/29/2010 | 193.0 | 58.8 | RUM: 95% silt/clay | 2,080 | 130 | 25.3 |
| | 1/29/2010 | 197.6 | 60.2 | RUM: 95% silt/clay | 2,120 | 132 | 25.8 |
| 199-B5-8 | 2/11/2011 | 205.2 | 62.5 | RE: silty sandy gravel; slightly cemented | 2,513 | 157 | X |
| | 2/15/2011 | 208.5 | 63.6 | RE: silty sandy gravel; cemented | 2,641 | 165 | X |
| | 3/2/2011 | 224.0 | 68.3 | RUM: 100% mud/silt | 2,079 | 130 | X |
| | 3/2/2011 | 230.6 | 70.3 | RUM: 100% mud/silt | 2,290 | 143 | 17.9 |
| 199-B8-9 | 8/23/2010 | 214.5 | 65.4 | RUM: mud | 1,940 | 121 | 20.2 |
| | 8/23/2010 | 219.5 | 66.9 | RUM: mud | 2,041 | 127 | 20.1 |

Bulk density of the Hanford formation and Ringold unit E ranged from 2,240 to 2,680 kg/m$^3$ (139 to 167 lb/ft$^3$) and averaged 2,500 kg/m$^3$ (155 lb/ft$^3$). Bulk density of the RUM was slightly lower.

Vertical hydraulic conductivity results varied over seven orders of magnitude (Table 3-7), and differences in lithology do not always explain the variability. For example, two adjacent samples in the RUM at Well 199-B2-16, both classified as 95 percent silt and clay, had hydraulic conductivity measurements of 0.14 and 0.00085 m/d (0.46 and 0.0028 ft/d), a difference of more than two orders of magnitude. It is likely that the condition of the samples varied considerably.

When vertical hydraulic conductivity results are considered as a whole, general patterns emerge. Figure 3-34 and the summary rows of Table 3-7 show minimum, maximum, and average results. Note that Figure 3-34 plots hydraulic conductivity on a logarithmic scale:

- The Hanford formation has the highest vertical hydraulic conductivity (average 38 m/d or 125 ft/d).
- RUM mud samples have the lowest conductivity (average 0.043 m/d or 0.14 ft/d).
- Ringold unit E has values in between the Hanford formation and the RUM (average 3.3 m/d or 11 ft/d).

In an earlier investigation (100-BC-5 LFI [DOE/RL-93-37]), calculations of vertical hydraulic conductivity from Wells 199-B2-12, 199-B4-9, and 199-B9-2 were in the lower end of the range determined in the recent samples.

Slug tests were performed in 100-BC wells in 2010 and 2011 to determine horizontal hydraulic conductivity (Table 3-10). The two wells screened in the RUM had the lowest hydraulic conductivity, approximately 1 m/d (3 ft/d). Wells screened in Ringold unit E had hydraulic conductivity ranging from 2.5 to 16 m/d (8.2 to 52 ft/d). The lowest Ringold E hydraulic conductivity (2.5 m/d or 8.2 ft/d) was in a well screened at the bottom of the aquifer. A median value of 9 m/d (30 ft/d) is used in groundwater models.

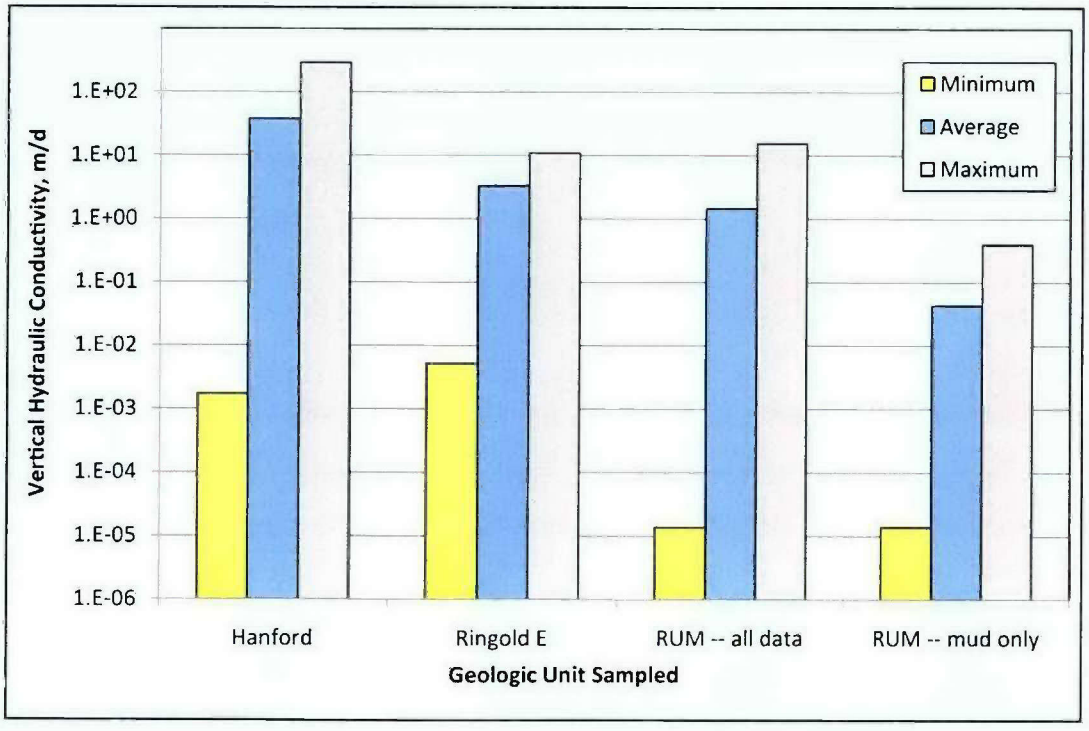



Figure 3-34. Vertical Hydraulic Conductivity of Sediment Samples from 100-BC Wells and Boreholes

Wells screened in the Hanford formation had the highest hydraulic conductivity, beyond the range suitable for determining with slug tests. The wells with the highest hydraulic conductivity based on slug tests are all located in southern 100-BC. They coincide with a postulated, high-permeability paleochannel of Hanford formation sediment between 100-BC and Gable Butte. Groundwater models use data from 100-F Area to estimate hydraulic conductivity values for the Hanford formation, with median values approximately 30 to 40 m/d (98 to 131 ft/d) and 90$^{th}$ percentile of 75 m/d (246 ft/d). Hydraulic conductivity of the paleochannel is believed to be 500 to 1,000 m/d (1,640 to 3,280 m/d).

A constant rate discharge test was conducted in RUM Well 199-B2-15 as a requirement of the 100-BC SAP (DOE/RL-2009-44). Results (Table 3-10) indicated a horizontal hydraulic conductivity of 3.0 m/d (9.8 ft/d). This estimate was slightly higher than the estimate based on slug tests (1.1 m/d or 4 ft/d).

**Table 3-10. Horizontal Hydraulic Conductivity Estimates for 100-BC Aquifer and Aquitard, Based on Slug and Pumping Tests**

| Well | Hydrogeologic Unit | Type of Test | Hydraulic Conductivity | |
|---|---|---|---|---|
| | | | (m/d) | (ft/d) |
| 199-B2-12 | Silty sandy gravel in RUM | Slug | 0.8 | 3 |
| 199-B2-14 | Top of Ringold unit E | Slug | 12 | 39 |
| 199-B2-15 | Silty sandy gravel in RUM | Slug | 1.1 | 4 |
| | | Pumping | 3.0 | 9.8 |
| 199-B2-16 | Lower part Ringold unit E (long screen) | Slug | 6.4 | 21 |
| 199-B3-47 | Top of Ringold unit E | Slug | 16 | 52 |
| 199-B3-51 | Bottom of Ringold unit E | Slug | 2.5 | 8 |
| 199-B4-14 | Hanford formation | Slug | NC | NC |
| 199-B5-5 | Lower part Ringold unit E (long screen) | Slug | 15 | 49 |
| 199-B5-6 | Bottom of Ringold unit E | Slug | 9.1 | 30 |
| 199-B5-8 | Hanford formation | Slug | NC | NC |
| 199-B8-6 | Hanford formation* | Slug | NC | NC |
| 199-B8-9 | Hanford formation | Slug | NC | NC |

Source: *Analysis of Slug Test Data at the 100-BC-5 Operable Unit* (ECF-100BC5-11-0145) for slug tests; *Aquifer Test Analyses for Wells 199-B2-15 and 199-F5-53* (ECF-HANFORD-11-0149) for pumping test (Appendix C).

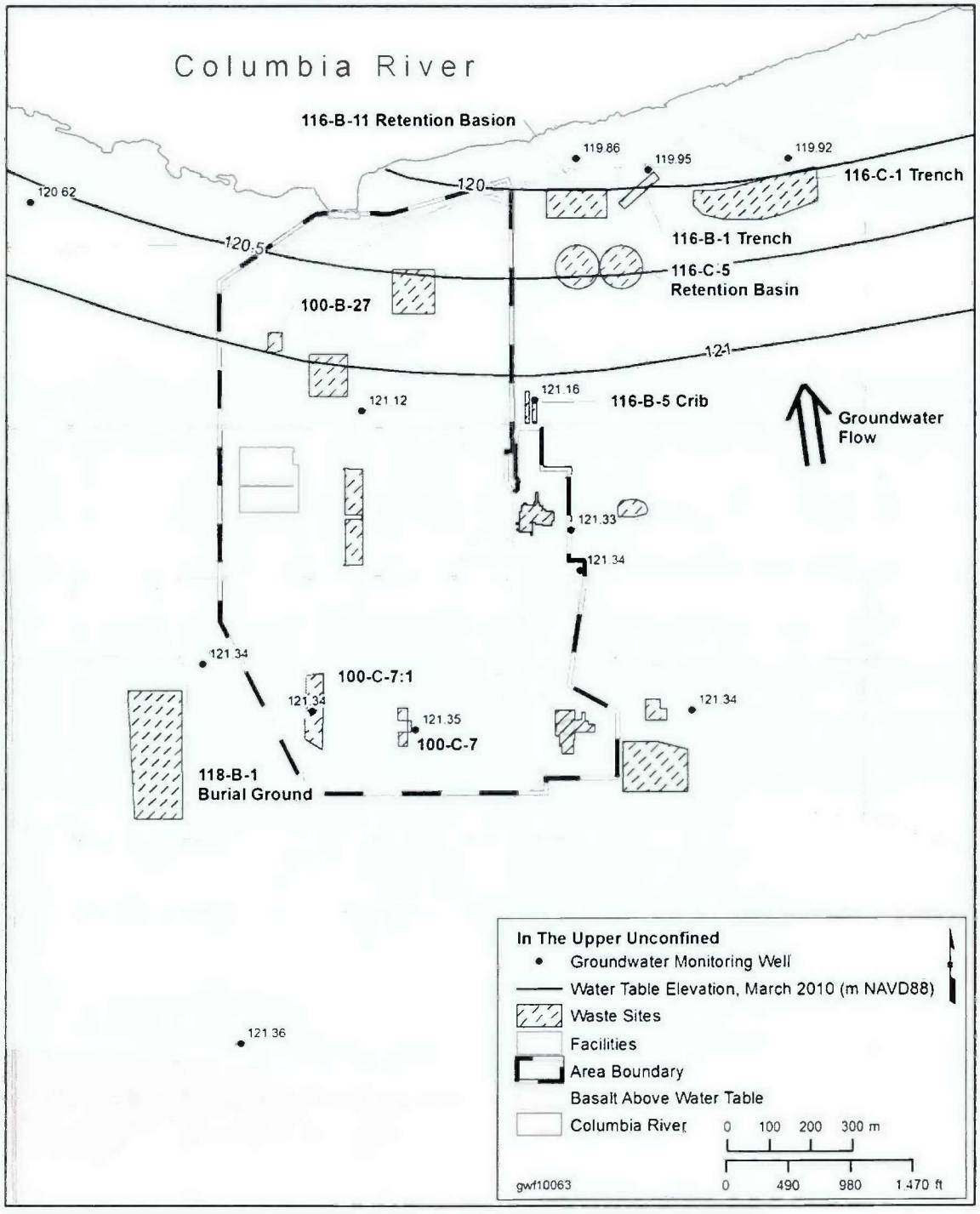
NC = Not calculated. The slug test suggests that the materials are highly permeable. A pumping test would be a better alternative to estimating the accurate value of the hydraulic conductivity at this location.

*Well 199-B8-6 was previously thought to be screened in Ringold unit E. Re-evaluation of the borehole log indicates it is screened in the Hanford formation. Its response to slug testing supports the new interpretation.

### 3.6.3 Groundwater Flow

The water table depth at 100-BC ranges from approximately 12 m (40 ft) beneath the northern bluff near the Columbia River, to approximately 30 m (100 ft) at the southern margins. Water table elevation is approximately 120 to 122 m (395 to 401 ft) AMSL, as illustrated in the water table maps for March 2010

and March 2011 (Figures 3-35 and 3-36). Groundwater flows perpendicular to the water-table contours (that is, toward the Columbia River). In some locations, groundwater discharges to the river through riverbank seeps (springs). Most discharge occurs as upwelling through the riverbed (Section 3.6.4). West of 100-BC, the river stage is approximately equal to the water table elevation, and groundwater flow is often from the river into the aquifer. Elsewhere, average flow is from the aquifer into the river.




Source: *Hanford Site Groundwater Monitoring Report for 2010* (DOE/RL-2011-01)

**Figure 3-35. Water Table beneath 100-BC, March 2010**

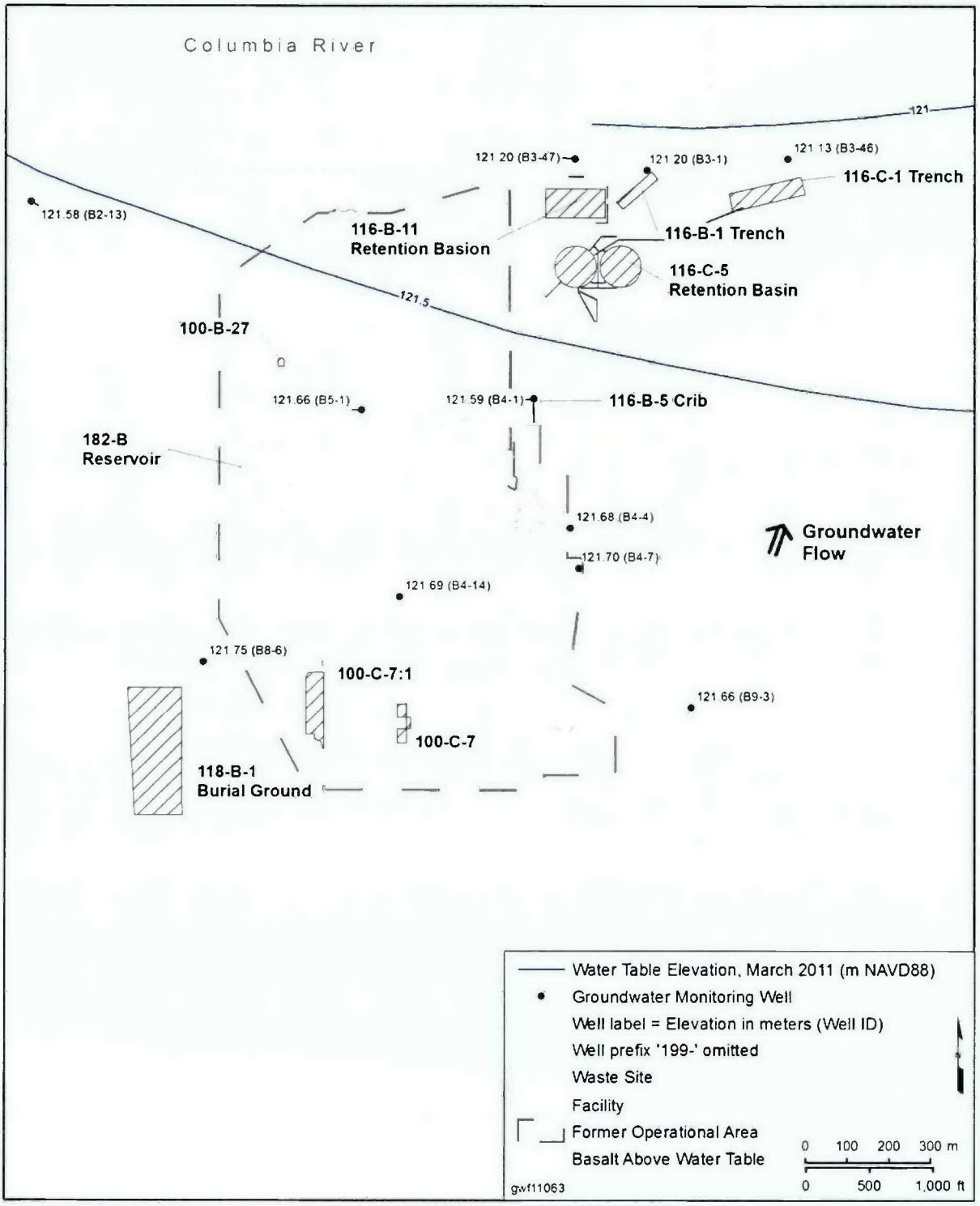



Figure 3-36. Water Table beneath 100-BC, March 2011

The water table on the north side of the Columbia River in Grant County is much higher than in 100-BC (150 to 300 m [490 to 980 ft] AMSL; Figure 2.1-2 in *Hanford Site Groundwater Monitoring for Fiscal Year 2006* [PNNL-16346]). Groundwater from Grant County and from 100-BC discharges to the Columbia River. Section 3.6.4 discusses evidence of groundwater discharge to the river.

Groundwater flows into 100-BC from the west and south, in the gaps between Umtanum Ridge, Gable Butte, and Gable Mountain. Under current flow conditions, more groundwater appears to be flowing in from the west and southwest than from the southeast. This is evident from declining contaminant concentrations in wells in western 100-BC, as uncontaminated water flows in from the west (Section 4.3.2). Wells west of 100-BC have slightly higher water level elevations than do 100-BC wells. The presence of tritium, nitrate, and technetium-99 in groundwater east of 100-BC can be traced to ources in the 200 Areas. However, this plume appears to discharge to the river east of 100-BC and not within the 100-BC Area.

Shallow groundwater beneath 100-BC receives recharge from the river along reaches to the north and northwest (*Hanford Site Groundwater Monitoring for Fiscal Year 2008* [DOE/RL-2008-66]). Additional recharge may occur by deep percolation of precipitation and rapidly melting snow. Table 3-11 lists estimated recharge rates for the dominant soil types found in 100-BC. Recharge may be as little as 1.5 mm/yr (0.059 in./yr) where mature vegetation is present, and as much as 52 mm/yr (2.0 in./hr) on disturbed soil. It is likely that leakage from the aging 182-B water reservoir (Section 3.7) is a source of artificial recharge, but this has not been quantified.

**Table 3-11. Estimated Recharge Rates for Dominant Soil Types in 100-BC**

| Major Soil Type | No Vegetation | Mature Shrub-Steppe |
|---|---|---|
| Ephrata Sandy Loam | 17 mm/yr (0.67 in./yr) | 1.5 mm/yr (0.059 in./yr) |
| Ephrata Stony Loam | 17 mm/yr (0.67 in./yr) | 1.5 mm/yr (0.059 in./yr) |
| Burbank Loamy Sand | 52 mm/yr (2.0 in./yr) | 3.0 mm/yr (0.12 in./yr) |

Source: *Vadose Zone Hydrogeology Data Package for Hanford Assessments* (PNNL-14702)

Table 3-12 summarizes groundwater flow directions and rates in 100-BC. Water-table data were evaluated by fitting a plane to the data using least squares regression, as documented in *Hydraulic Gradients in 100-BC-5, 2010 and 2011* (ECF-100BC5-12-0027). The slope of the fitted surface represents the hydraulic gradient magnitude, and the dip direction represents the hydraulic gradient direction.. This method assumes that the water table is planar. This is of course a simplification because water table contours form a varied "topography." In 100-BC, the water table is steeper in the north, where the aquifer is entirely in Ringold unit E. The water table is very flat in the south, where the top of the aquifer includes the permeable Hanford formation. To more closely meet this planar assumption, calculations were performed separately for the southern and northern 100-BC. Table 3-12 also lists estimated groundwater flow velocity based on groundwater gradients at various times of year. Velocity was estimated using a form of the Darcy equation:

$$v = Ki/n_e$$

where:

v = average velocity

$K$ = horizontal hydraulic conductivity (Table 3-12)

$i$ = hydraulic gradient

$n_e$ = effective porosity (0.18)

**Table 3-12. Hydraulic Gradient and Groundwater Flow Estimates for 100-BC**

| Date | Gradient Magnitude (m/m) | Gradient Azimuth (E of N) | Velocity Range (m/d) | |
|---|---|---|---|---|
| **Hanford Formation in Southern 100-BC** | | | | |
| May-10 | 0.000025 | 40 | 0.07[a] | 0.14[b] |
| Jul-10 | 0.00013 | 38 | 0.35[a] | 0.70[b] |
| Sep-10 | 0.000057 | 14 | 0.16[a] | 0.32[b] |
| Mar-11 | 0.000069 | 86 | 0.19[a] | 0.38[b] |
| Jun-11 | 0.00013 | 74 | 0.37[a] | 0.74[b] |
| Oct-11 | 0.000071 | 220 | 0.20[a] | 0.39[b] |
| **Ringold Unit E in Southern 100-BC** | | | | |
| Jul-10 | 0.00013 | 38 | 0.006[c] | 0.011[d] |
| Sep-10 | 0.000057 | 14 | 0.003[c] | 0.005[d] |
| Mar-11 | 0.000069 | 86 | 0.004[c] | 0.006[d] |
| Jun-11 | 0.00013 | 74 | 0.007[c] | 0.012[d] |
| Oct-11 | 0.000071 | 220 | 0.004[c] | 0.006[d] |
| **Ringold Unit E in Northern 100-BC** | | | | |
| May-10 | 0.0010 | 6 | 0.05c | 0.09d |
| Jul-10 | 0.0018 | 3 | 0.09[c] | 0.16[d] |
| Sep-10 | 0.0032 | 353 | 0.16[c] | 0.29[d] |
| Mar-11 | 0.00061 | 21 | 0.03[c] | 0.05[d] |
| Jun-11 | 0.0015 | 187 | 0.07[c] | 0.13[d] |
| Oct-11 | Insufficient data | | | |

Source: *Hydraulic Gradients in 100-BC-5, 2010 and 2011* (ECF-100BC5-12-0027)

a. Hydraulic conductivity = 500 m/d

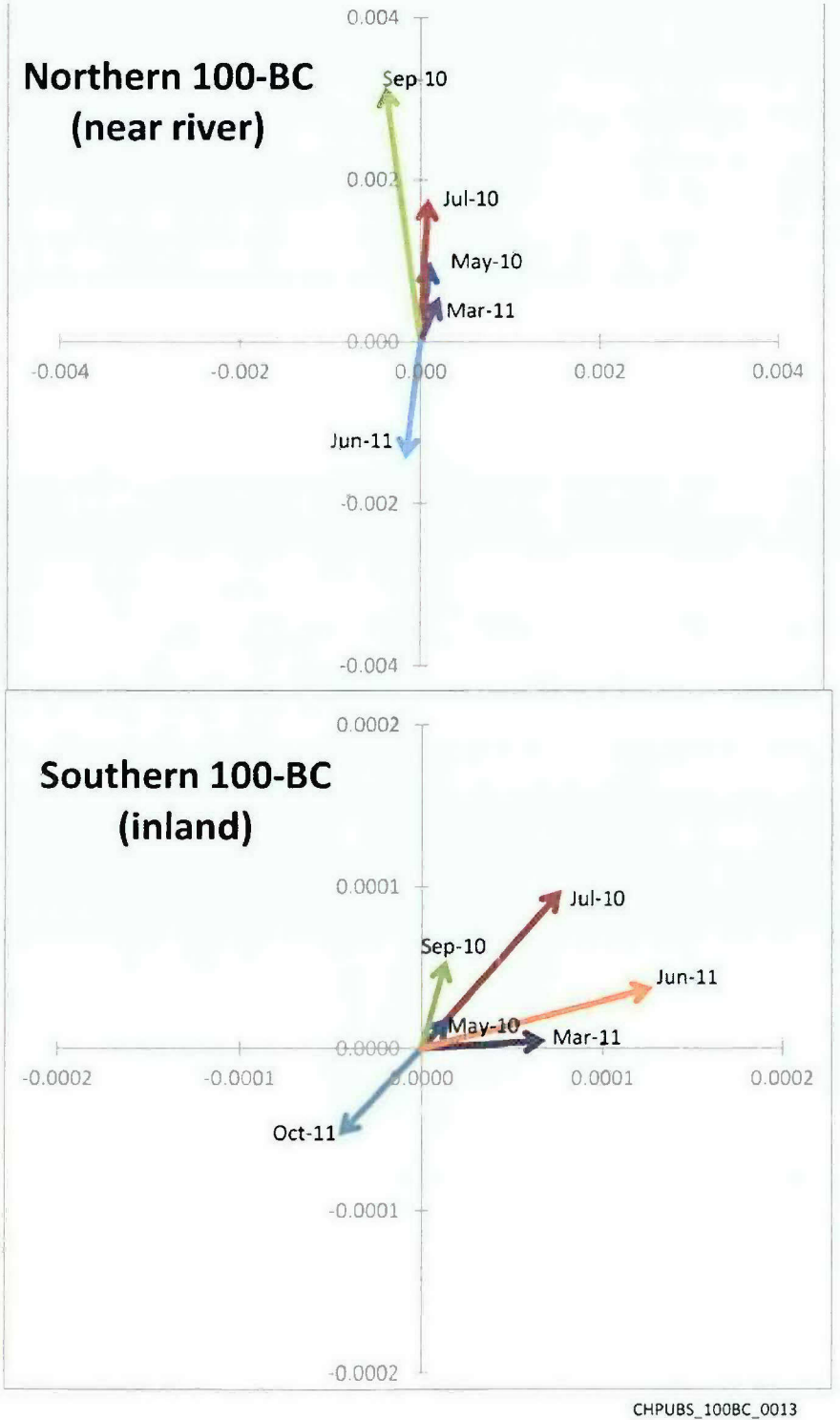
b. Hydraulic conductivity = 1,000 m/d

c. Hydraulic conductivity = 9 m/d

d. Hydraulic conductivity = 16 m/d

Figure 3-37 depicts the results of the hydraulic gradient estimates. The direction of each line indicates the calculated azimuth direction (that is, the dip of the gradient, which is the groundwater flow direction). The length of the line indicates the relative magnitude of the gradient. In northern 100-BC, the aquifer is

primarily within Ringold formation unit E and the hydraulic gradient ranged from 0.00061 to 0.0032 m/m. Except when the river stage was unusually high (June 2011), the water table sloped predominantly to the north. Velocity estimates ranged from 0.03 to 0.29 m/d. In June 2011, the high river level created a reversed gradient, with southward flow from the river into the aquifer.




Note: Scales differ for the northern and southern regions.

Figure 3-37. Hydraulic Gradients in 100-BC

In southern 100-BC, the upper part of the aquifer resides in the Hanford formation. The sediments in this region are believed to be part of a highly permeable paleochannel. The hydraulic gradient was an order of magnitude lower than in the north (0.000025 to 0.00019 m/m). The differences in head at different wells were often within measurement error, so estimates have greater uncertainty than for northern 100-BC. Flow was predominantly to the northeast except in October 2011, when the gradient was reversed (southwest). This change represented a delayed response to the high river stage of June 2011. Flow rates in the saturated Hanford formation are estimated to range from 0.07 to 0.74 m/d (0.23 to 2.4 ft/d). Flow estimates in Ringold unit E are lower (0.003 to 0.012 m/d [0.009 to 0.039 ft/d]).

Recent contaminant trends provide additional insight into groundwater flow rates in southern 100-BC. Excavation and dust-control activities at the 100-C-7 and 100-C-7:1 waste sites may have mobilized Cr(VI) contamination from the vadose zone into groundwater. If it is assumed that contaminant release occurred between February and June 2010[2], then travel time from the waste site to Well 199-B4-14 was 18 to 24 months and groundwater velocity was 0.36 to 0.47 m/d (1.2 to 1.5 ft/d; ECF-100BC5-12-0027).

RI studies included installation of automated water level recorders in selected 100-BC monitoring wells. Figure 3-38 shows water level data in these wells from April through September 2011. The top two panels illustrate water levels in two well clusters near the Columbia River. Water levels are highly variable in those wells and a strong response to rising river stage is observed. The lower left panel illustrates water levels in a well pair in central/southern 100-BC and the lower right panel illustrates water levels in single wells in southern 100-BC that monitor the top of the aquifer.

Maximum seasonal variability in water levels in 100-BC wells ranges from 1 m (3.3 ft) in southern 100-BC to over 4 m (13 ft) near the river (for example, Well 199-B3-47).

Vertical gradients within the unconfined aquifer were determined based on data from the new automated water level monitoring network (Table 3-13; Figure 3-38). Wells 199-B3-47 and 199-B4-14 monitor the top of the aquifer, and Wells 199-B3-51 and 199-B5-6 monitor the lower portion of the aquifer.

Near the river, the head in deep Well 199-B3-51 fluctuated above and below shallow Well 199-B3-47. In late April when river stage was moderate and stable, the average gradient was downward at 0.001 m/m. During a high-stage period, June, the downward gradient was stronger, 0.008 m/m. This is as expected during a period when the river was recharging the aquifer. Note that the vertical gradient is approximately the same magnitude as the horizontal gradient in northern 100-BC (Tables 3-12 and 3-13).

In southern 100-BC, the gradient was downward in late April, changed to upward in June, and reverted to downward in September. The overall average between April and September was downward at 0.001 m/m. The vertical gradient in this region is stronger than the horizontal gradient, which is barely measurable (Table 3-12).

[2] Groundwater data from now-decommissioned Well 199-B8-7, located in the 100-C-7:1 waste site, showed that Cr(VI) levels were low in January 2010. June 2010 was when deep excavation of the waste site, with associated application of dust-control water, began. If the release occurred after June 2010, actual velocity would be faster than that calculated.

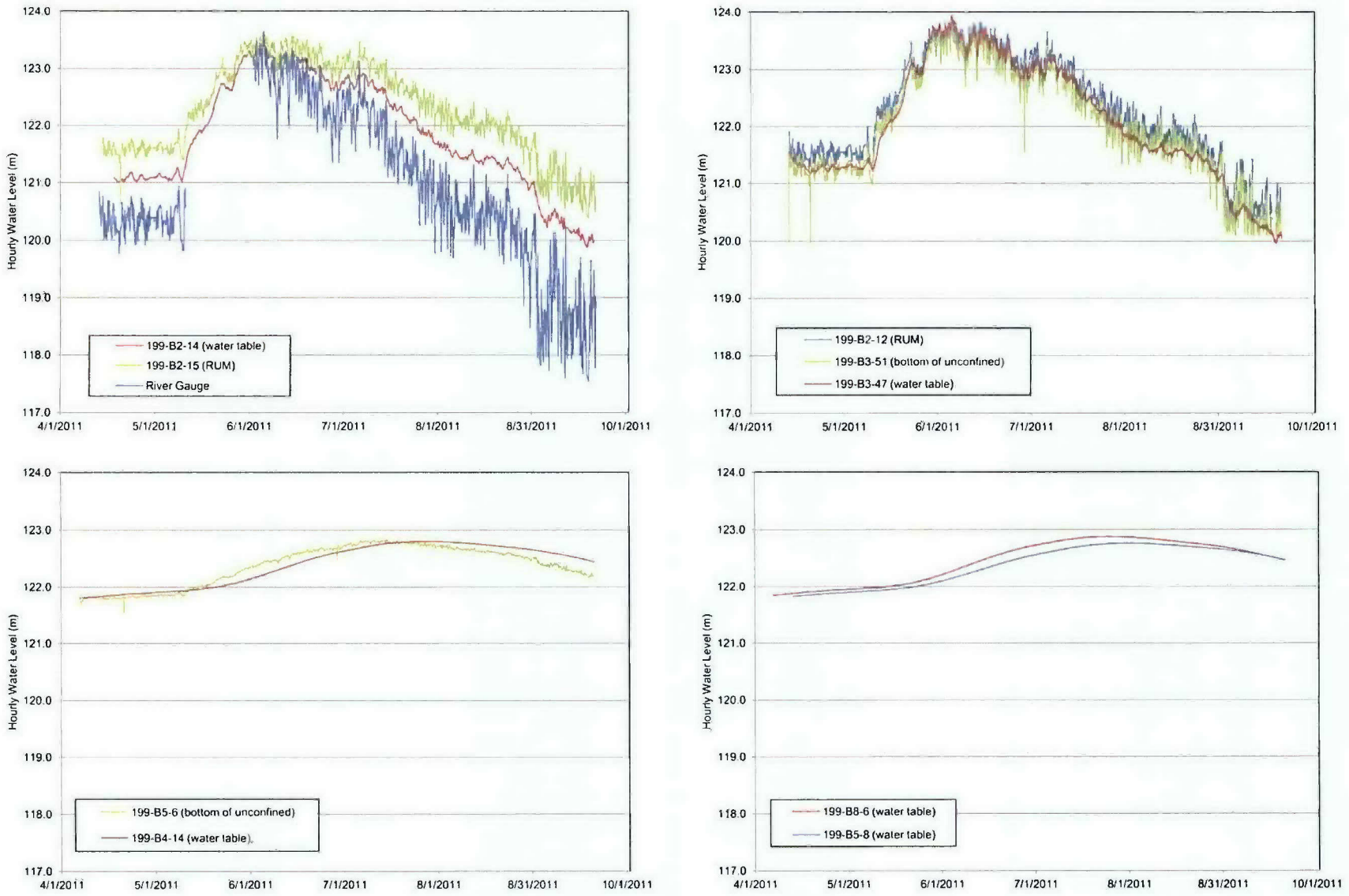



Figure 3-38. Hydrographs from Automated Water Level Network at 100-BC

Table 3-13. Vertical Hydraulic Gradients in 100-BC

| Well Group (units monitored) | Vertical Distance (m)[a] | Time Period | Average Gradient[b] (m/m) | Direction |
|---|---|---|---|---|
| **Vertical Gradient within Unconfined Aquifer** | | | | |
| 199-B3-47 (water table) and 199-B3-51 (bottom unconfined) | 27.2 | April 15 to 30, 2011 | 0.001 | Down |
| | | June 1-15, 2011 | 0.008 | Down |
| | | September 1-15, 2011 | 0.0001 | Down |
| 199-B4-14 (water table) and 199-B5-6 (bottom unconfined) | 29.8 | April 15 to 30, 2011 | 0.002 | Down |
| | | June 1-15, 2011 | 0.006 | Up |
| | | September 1-15, 2011 | 0.008 | Down |
| **Vertical Gradient between Unconfined Aquifer and RUM** | | | | |
| 199-B3-47 (water table) and 199-B2-12 (RUM) | 35.2 | April 15 to 30, 2011 | 0.007 | Up |
| | | June 1-15, 2011 | 0.001 | Down |
| | | September 1-15, 2011 | 0.008 | Up |
| 199-B2-14 (water table) and 199-B2-15 (RUM) | 30 | April 15 to 30, 2011 | 0.02 | Up |
| | | June 1-15, 2011 | 0.005 | Up |
| | | September 1-15, 2011 | 0.02 | Up |
| 199-B3-51 (bottom unconfined) and 199-B2-12 (RUM) | 8.0 | April 15 to 30, 2011 | 0.003 | Up |
| | | June 1-15, 2011 | 0.02 | Up |
| | | September 1-15, 2011 | 0.03 | Up |

a. Difference between elevation of screen bottom.

b. Average based on hourly measurements during time period shown.

Figure 3-38 includes hydrographs of wells screened in a confined aquifer of the RUM unit (199-B2-15 and 199-B2-12). Hydraulic head in the RUM unit is nearly always higher than in the overlying unconfined aquifer, with an upward gradient ranging from 0.005 to 0.03 m/m. A downward average gradient was observed between Wells 199-B2-12 and 199-B3-47 when river stage was high in late June 2011, at 0.001 m/m.

Short-term variability caused by changes in river stage is evident in many of the hydrographs on Figure 3-38. Confined RUM Wells 199-B2-12 and 199-B2-15 respond much faster and to a larger magnitude than their shallow counterparts. The response of the deep wells is consistent with much smaller storage coefficients than are applicable to the shallow wells. The response in a confined aquifer to a river stage change is due to loading. The increase or decrease in weight of the river causes an increase or

decrease in total stress in the confined aquifer. That portion of the stress borne by the aquifer water causes an increase or decrease in pressure head, which results in well water level fluctuations.

Wells 199-B3-51 and 199-B5-6, screened in the lower portion of the unconfined aquifer, also show faster, larger responses to river stage than the shallow wells. Deep portions of thick, unconfined aquifers commonly have low storage coefficients like confined aquifers ("The Effect of Tidal Fluctuation on a Coastal Aquifer in the UK" [Erskine, 1991]). In addition, the geologist's logs note the presence of cementation in Ringold unit E, which may create semi-confining conditions in the lower portion of the aquifer. The short-term variability seen in deep Well 199-B5-6 in southern 100-BC is notable since the shallow well shows virtually no short-term variability.

The time in which water levels respond to changes in river stage depends on the hydrogeologic unit monitored and distance from the river. The most rapid response was in deep wells near the river. Peak water levels in Wells 199-B2-12 (RUM), 199-B2-15 (RUM), and 199-B3-51 (deep unconfined) occurred within an hour of the peak river stage in June. Peak water levels in near-river, water-table Wells 199-B3-47 and 199-B2-14 occurred 7 and 21 hours after the peak river stage. For the inland wells, the shortest response time (40 days) was in deep unconfined Well 199-B5-6, while its shallow counterpart showed a slightly longer response time (51 days). The longest response time was 56 days in Well 199-B5-8, which is located farthest from the river.

There is no correlation between the automated water levels and barometric pressure changes. This result is unexpected for the confined wells because barometric pressure changes should also trigger a loading response. Apparently, river stage effects predominate, and mask any barometric response.

While Piezometers 199-B3-2P and 199-B3-2Q were completed and screened in the Ringold unit E and the basalt-confined aquifer, respectively, water level data from these wells sometimes were identical. This suggested leakage across the well seal material (cement) between the two piezometers (*Procedures for Ground-Water Investigations* [PNL-6894]). Therefore, their water level data were not considered dependable for estimating the vertical hydraulic gradient.

During the operational period of the 105-B and 105-C Reactors, large volumes of water were discharged to the ground. Groundwater mounds were present beneath each of the 100 Areas during the 1960s (*Hydrologic Information Summary for the Northern Hanford Site* [WHC-SD-EN-TI-023]). The 100-BC groundwater mound had a peak elevation of at least 128 m (420 ft) in 1967 and 1968, centered in northern 100-BC. At approximately 7 m (23 ft) above current conditions, this mound created the potential for radial flow and spreading of groundwater contaminants. The mound had subsided by the 1970s (Figure 3-39).

Another drop in head occurred during the 1990s as a result of a declining groundwater mound in the 200 Areas (*Hanford Site Groundwater Monitoring for Fiscal Year 2007* [DOE/RL-2008-01]). The increase in water levels in the mid 1990s, seen in the hydrograph, was a result of several years of high river stage (Section 3.3.1).

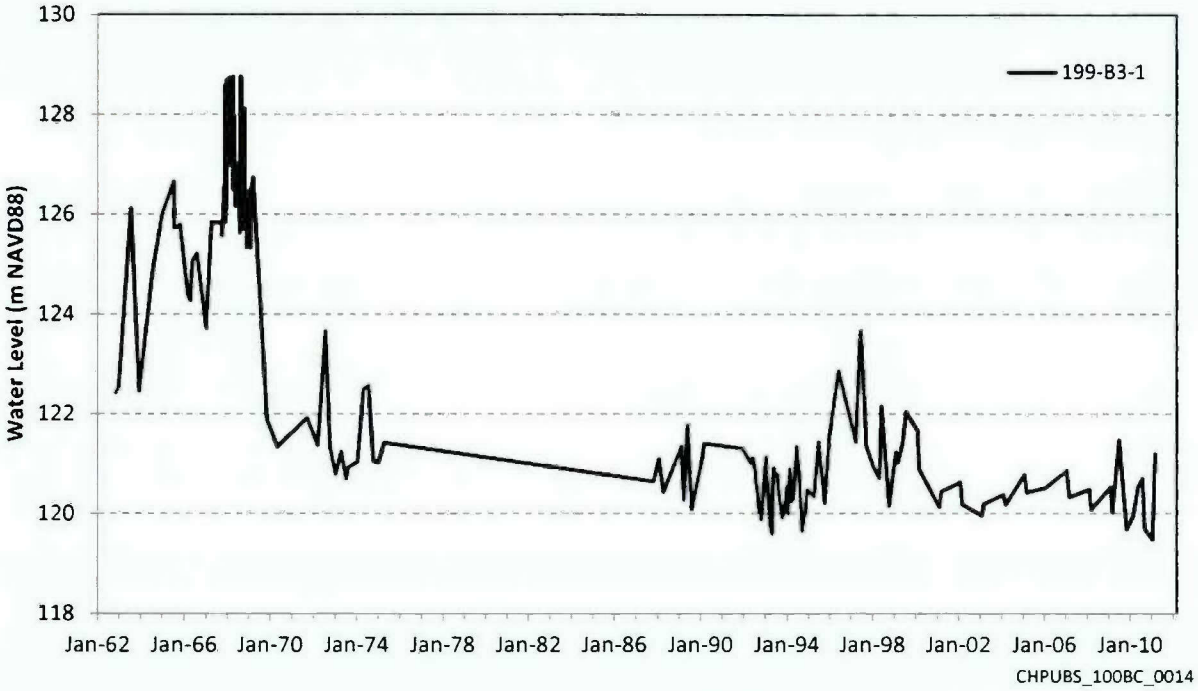
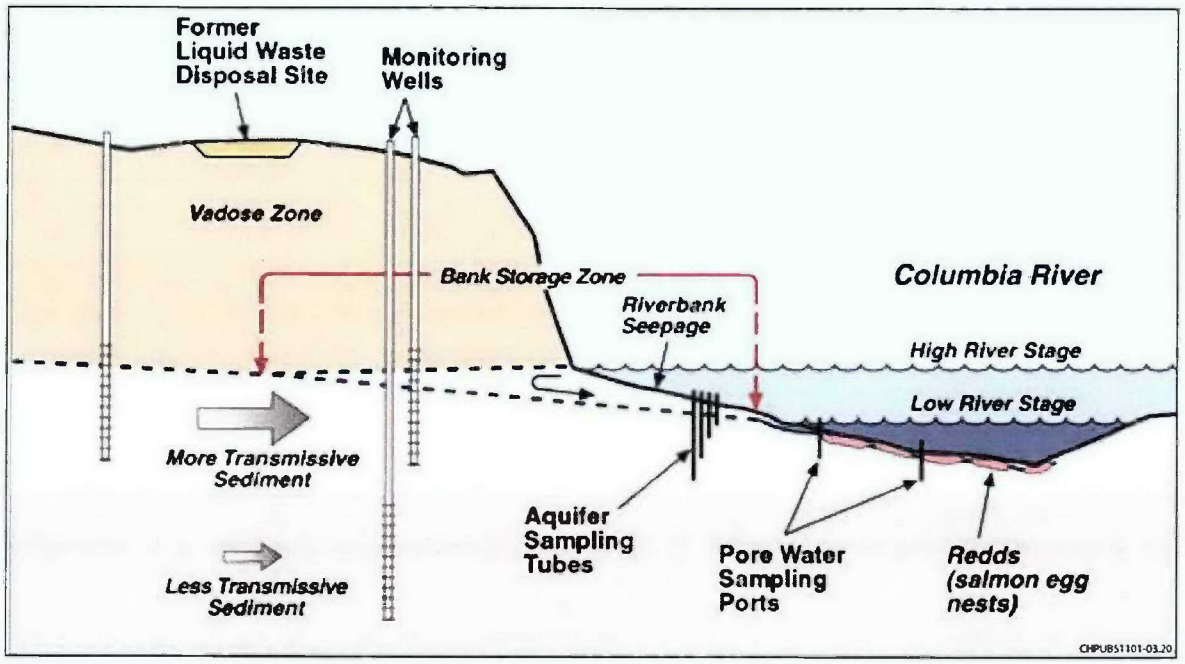



Figure 3-39. Water Levels in Well 199-B3-1, 1962 to 2011

### 3.6.4 Zone of Surface Water/Groundwater Interaction

Groundwater flow in 100-BC near the Columbia River is influenced by river stage, which is directly controlled by the upstream Priest Rapids Dam. The rise and fall of river stage creates a dynamic zone of interaction between groundwater and river water, and it influences flow patterns, transport rates, contaminant concentrations, and attenuation rates within the system (Figure 3-40; *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project* [PNNL-13674]). The Columbia River discharge and resultant river stage in the Hanford Reach vary substantially seasonally— even daily and hourly—depending on the operations of Priest Rapids Dam. At 100-BC, Columbia River elevations vary by approximately 4 m (13 ft) in a year (Section 3.3.1).

Hydrologists estimate that groundwater currently flows from the Hanford Site unconfined aquifer to the Columbia River at a rate between 0.8 and 2.8 $m^3/s$ (28 and 99 $ft^3/s$) (*Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project* [PNNL-13674]; "Hanford Site Groundwater and the Columbia River, South-Central Washington" [PNNL-SA-56038]). This rate is less than 0.001 percent of the average flow of the Columbia River, approximately 3,400 $m^3/s$ (120,000 $ft^3/s$).




Note: Modified from *Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project* (PNNL-13674)

**Figure 3-40. Illustration of Zone of Interaction and River Bank Seepage**

Physical, chemical, and biological processes that occur within the zone of interaction potentially alter the characteristics of approaching groundwater. Data suggest that physical processes are the primary influences on contaminant concentrations and fluxes where groundwater discharges into the river. Chemical processes may render contaminants less mobile as they adsorb to sediments or precipitate.

Water from the zone of interaction is a mixture of groundwater and river water. Specific conductance of groundwater in 100-BC ranges from 300 to 550 µS/cm, while that of river water averages 150 µS/cm.

Samples from deep or mid-depth aquifer tubes have specific conductance from 320 to 400 µS/cm, indicating they are primarily groundwater. Samples from some of the shallow tubes have lower conductance (less than 200 µS/cm), indicating more mixing with river water. Near-river wells indicate some influx of river water during periods of high river stage, although sampling frequency is insufficient to analyze the effects fully. In May and July 2010 when the river was moderately high, Wells 199-B2-14, 199-B3-1, 199-B3-46, and 199-B3-47 showed little or no decline in specific conductance, indicating little mixing with river water. Well 199-B3-47 was sampled in June 2011, when the river stage was much higher than usual, and specific conductance dropped to approximately 240 µS/cm, which is half the usual level.

Riverbank seeps discharging to the river are visible during low river stage. Conversely, during high river stage, the seeps are submerged as river water infiltrates the riverbanks and forms either a layered system or a mixture during interaction with approaching groundwater. Data from the seeps and along the riverbank indicate that the riverbank storage water composition oscillates dramatically from nearly completely river water during high river stage to primarily groundwater during low river stage (*Zone of Interaction Between Hanford Site Groundwater and Adjacent Columbia River: Progress Report for the Groundwater/River Interface Task Science and Technology Groundwater/Vadose Zone Integration Project* [PNNL-13674]).

Field sampling activities were conducted in 2008 through 2010 in support of an RI of Hanford Site releases to the Columbia River (Columbia River RI Report [WCH-380]). The study used a device known as the Trident Probe to measure specific conductance and temperature of pore water. Because groundwater has higher specific conductance than surface water and is warmer than surface water in winter, the data could be used to map areas of groundwater upwelling (discharge) during periods of low river stage. Relatively large temperature differences are considered indicative of relatively high groundwater discharge volumes.

Specific conductance of pore water was found to decrease when the river stage increased, indicating less groundwater discharge during periods of moderate to high river stage. A subsequent phase of the study collected and analyzed samples of pore water from 20 to 31 cm (8 to 12 in.) below the riverbed surface for Hanford Site contaminants. Sediment and surface water samples also were collected.

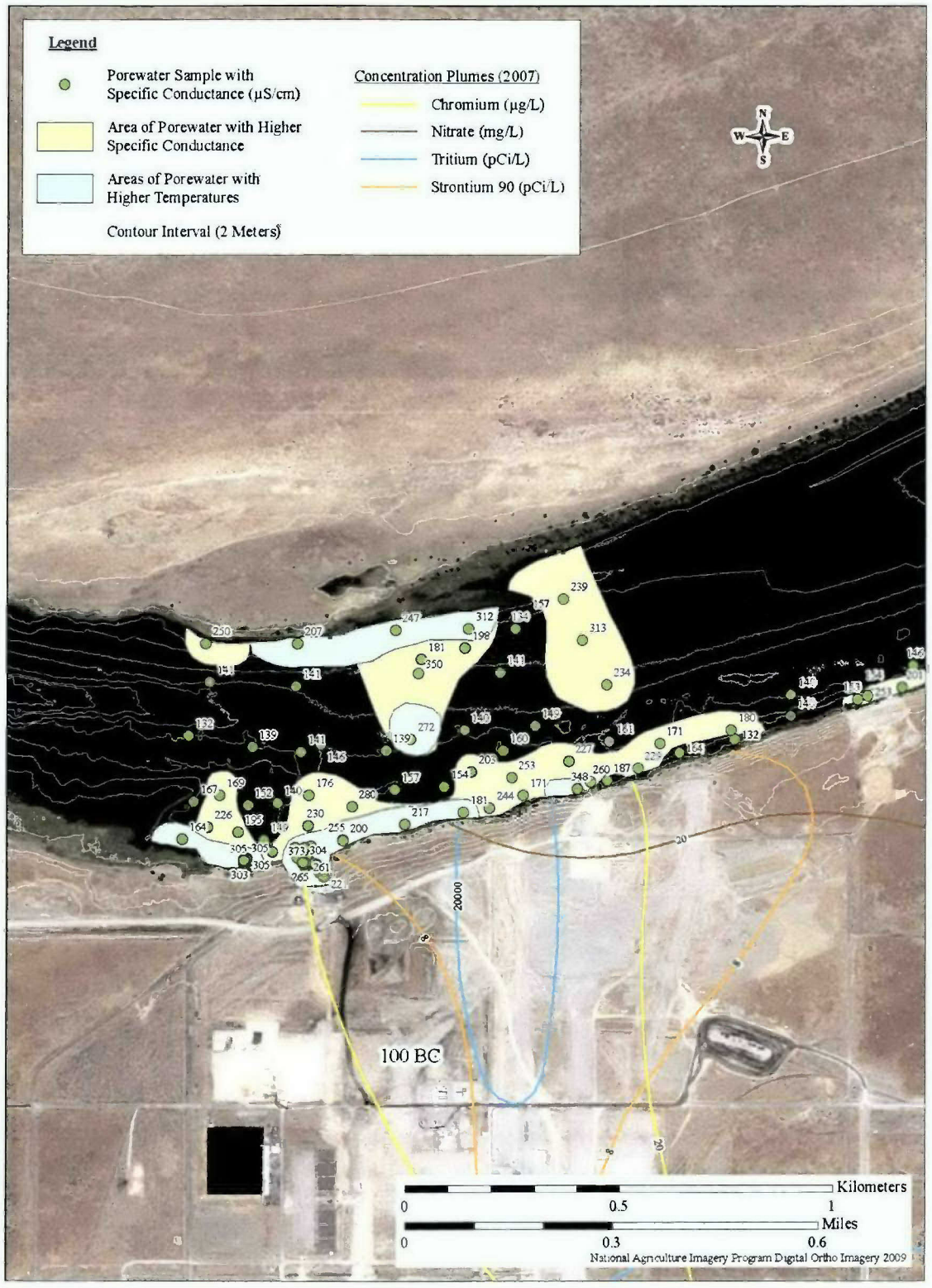
Researchers obtained 92 in situ measurements of specific conductance and temperature in the 100-BC segment of the river, and mapped areas of upwelling (Figures 3-41 and 3-42). Areas of groundwater upwelling were found along approximately 3.2 km (2 mi) of the 100-BC shoreline on the Hanford Site side of the river. Upwelling also occurs on the north side of the river where groundwater from Grant County discharges. In some areas, evidence of upwelling also was observed of the middle of the river channel.

The highest specific conductance (up to 388 µS/cm) was measured in the deep pool associated with the 100-BC water intake structure. This region also had well-defined temperature differences. These results indicate that groundwater discharges preferentially in this deep pool. Results of subsequent phases of the study (contaminants in pore water, surface water, and sediment) are summarized in Chapter 4.

### 3.6.5 Groundwater Chemistry

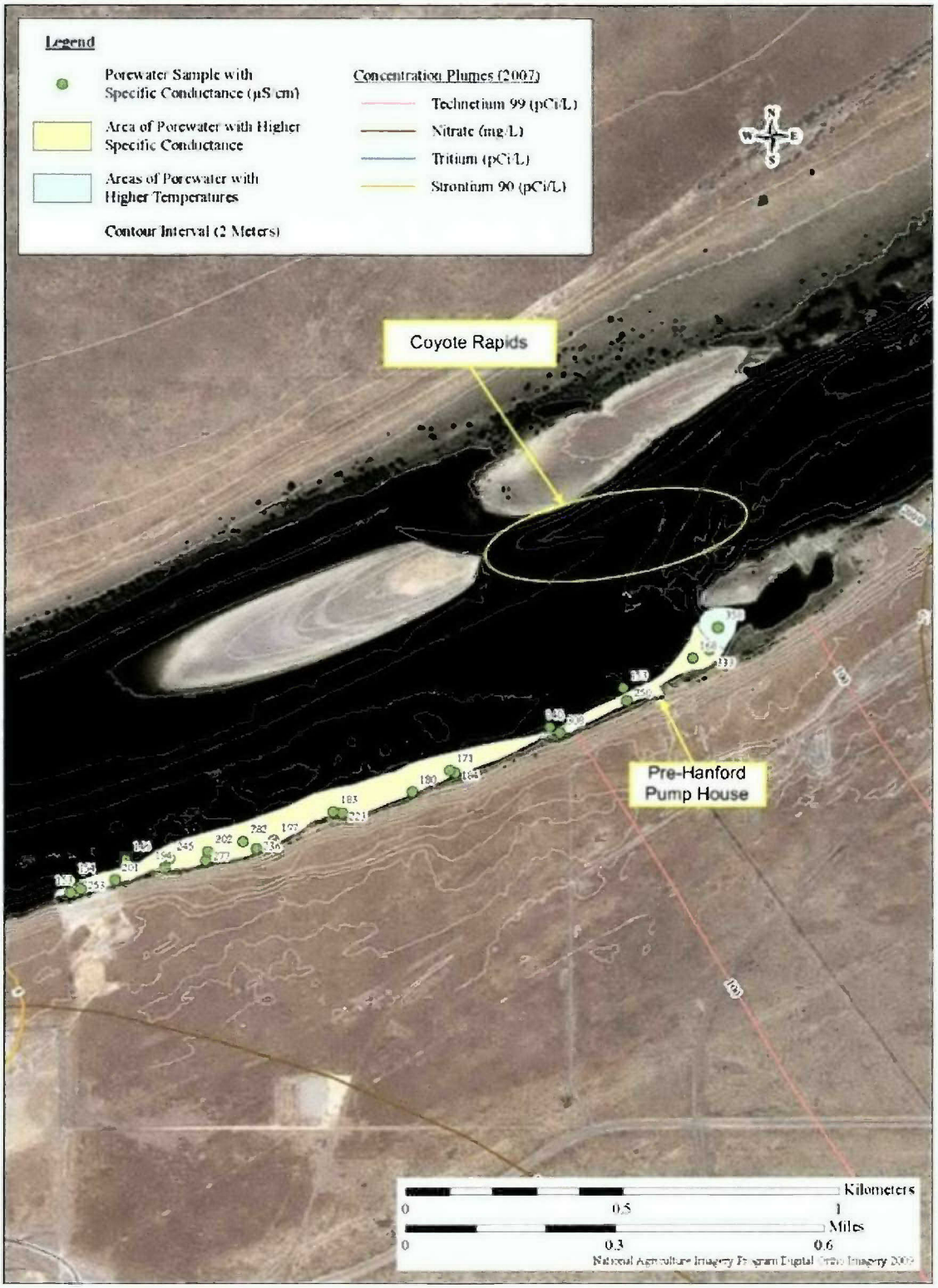
General chemistry of 100-BC groundwater is a calcium bicarbonate type. The diagrams of Figure 3-43 illustrate relative concentrations of major ions in groundwater samples collected in May 2010. Groundwater pH ranges from 7.7 to 8.0. The chemistry is similar in wells throughout the area, including Well 199-B2-12, screened in the Ringold confined aquifer. Dissolved oxygen averages about 8.0 mg/L in the unconfined aquifer. Few dissolved oxygen data are available from Well 199-B2-12; these results range from 6.0 to 6.6 mg/L.

An important addition to understanding the fate and transport of Cr(VI) is that in addition to chemical reduction, the reduction of Cr(VI) to Cr(III) can be mediated by bacteria. In "A Molecular Comparison of Culturable Aerobic Heterotrophic Bacteria and 16S rDNA Clones Derived from a Deep Subsurface Sediment," Chandler et al. (1997) described the wide variety of microbes present in the Hanford Site subsurface. Their studies focused on the vadose zone. A number of studies have been conducted on deeper Hanford Site bacteria in the groundwater. Recent studies of 100-H groundwater microbial ecology ("Physiological and Transcriptional Studies of Cr(VI) Reduction under Anaerobic and Denitrifying Conditions by an Aquifer-Derived Pseudomonad" [Han et al., 2010]) suggest that bacteria can use multiple electron donors to reduce Cr(VI), depending on whether conditions are aerobic or anaerobic. Truex et al. (2009) described results from biostimulation treatability tests at 100-D. They observed that following the injection of a carbon substrate, "…microbial activity and ability to reduce the targeted species were observed throughout the monitored zone." These general mechanisms are described in the *Chromium(VI) Handbook* (Guertin et al., 2004). Consequently, the back-and-forth motion of groundwater near the Columbia River adds nutrients from the river such as organic carbon, phosphate, and other constituents that enhance bacterial reduction of Cr(VI).




Source: *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling* (WCH-380)

**Figure 3-41. Pore Water Conductivity and Temperature Anomaly Patterns Measured during Phase IIa near the 100-BC Area, Upstream Portion**




Source: *Field Summary Report for Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington: Collection of Surface Water, Pore Water, and Sediment Samples for Characterization of Groundwater Upwelling* (WCH-380)

**Figure 3-42. Pore Water Conductivity and Temperature Anomaly Patterns Measured during Phase IIa near the 100-BC Area, Downstream Portion**

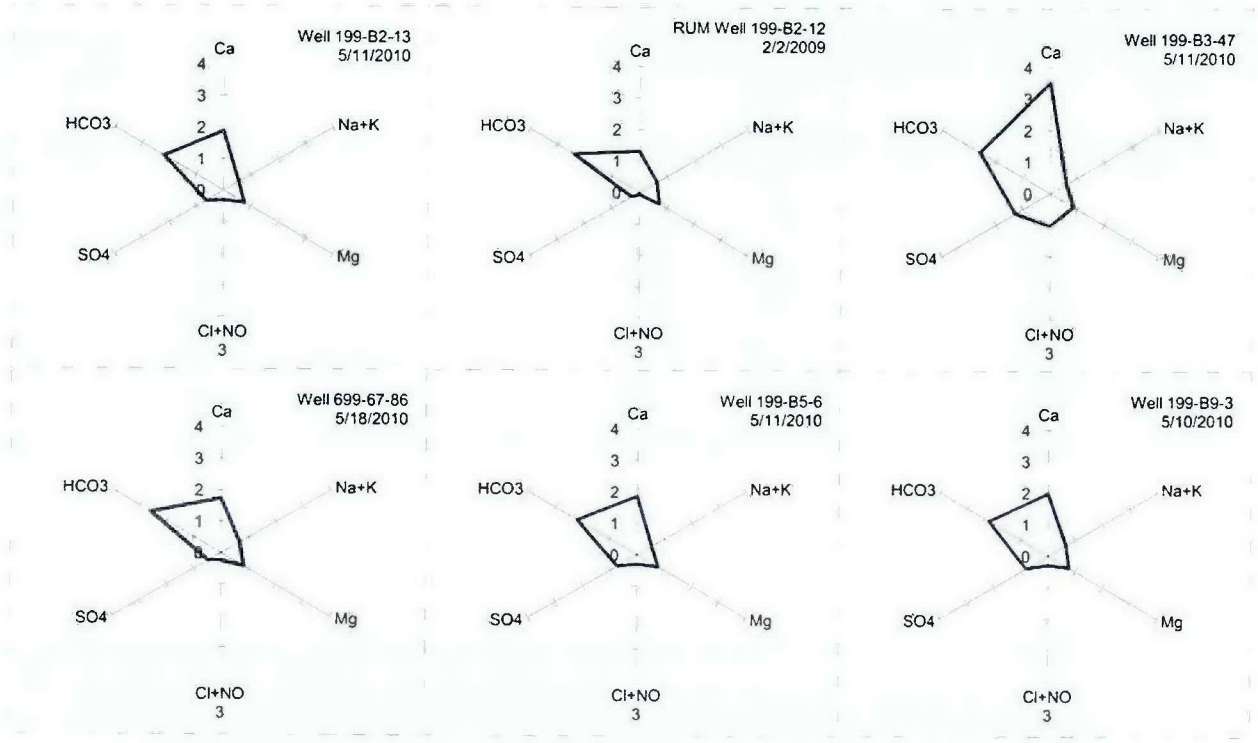



**Figure 3-43. Spider Diagrams Illustrating General Groundwater Chemistry in 100-BC**

Unconfined groundwater in 100-BC is moderately hard to hard (140 to 220 mg/L as $CaCO_3$). Hardness of water from the confined Ringold is lower (106 mg/L in Well 199-B2-12).

Groundwater contaminant chemistry is discussed in Chapter 4.Artificial Water Systems

## 3.7 Artificial Water Systems

This section discusses anthropogenic surface water features of 100-BC, including the 182-B Reservoir and related water supply features, and application of dust control water during surface remediation.

The 182-B Reservoir is a concrete structure that is 147 × 94 m (482 × 308 ft) in size and 5.5 m (18 ft) deep. The river pump house (Building 181-B) supplies water to the reservoir, which has a storage capacity of 9,500,000 L (2,500,000 gal). Because the 182-B Reservoir was constructed in the 1940s, its age and condition are of potential concern and water may leak from the reservoir. However, no data are available to document the condition of the reservoir. A leak test was conducted in 1999 that compared the volume pumped from 182-B to the 200 Area. The purpose was to determine leakage volume along the system. The test indicated leakage "within acceptable limits" for the length of the piping system. No other investigation has been conducted, and the integrity of the reservoir is unknown.

The 182-B Reservoir is part of the Export Water System (Figure 3-44). The system supplies process water, and water for fire control, dust suppression, and other nonpotable uses. The 182-B Reservoir is a primary reservoir and one of two remaining structures at the Hanford Site that is used to store large quantities of untreated, raw water. The other reservoir used for this purpose is located in 100-D and is the backup facility (*November 6 & 7 Facilitated Session and the 182D Reservoir Repair and Modification Report and Long Term Export Water Supply System Alternatives Study* [FH, 2008]).

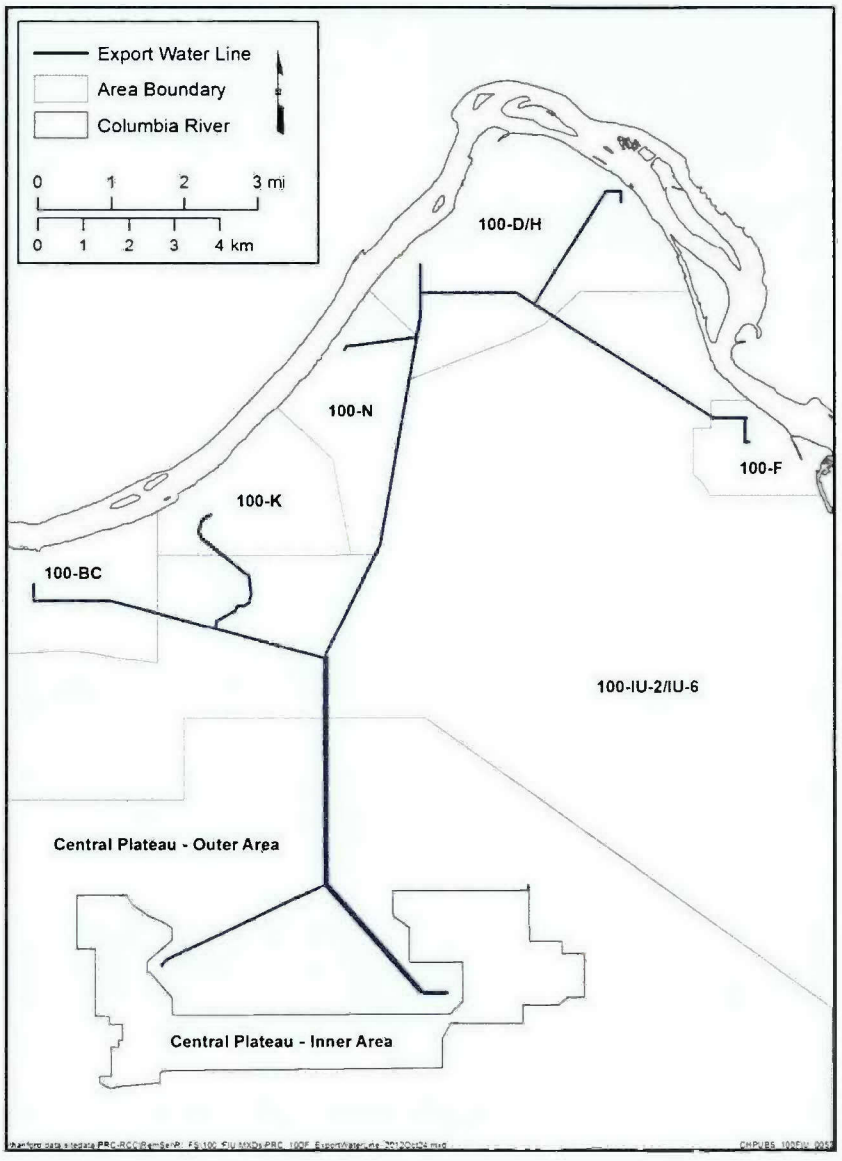



**Figure 3-44. 100-BC Export Water System**

Leaks from underground water pipes are another potential source of artificial recharge. For example, a leak from a fire hydrant affected water quality in 199-B5-1 from 2003 to 2006 (*Hanford Site Groundwater Monitoring for Fiscal Year 2006* [PNNL-16346]). Groundwater in that well became dilute, as evidenced by low specific conductance and low concentrations of contaminants and natural chemical parameters. The leak has been repaired.

Untreated (that is, raw) Columbia River water is used in 100-BC to control fugitive dust from remedial action processes. Fugitive dust consists of airborne particles from anthropogenic and natural processes. In the Hanford Site's semi-arid climate, the combination of wind and remedial action processes contribute to the generation of fugitive dust. The dust may contain hazardous waste, radioactive waste, or both.

Typical remedial action processes and site features that contribute to fugitive dust include digging, open excavations, soil stock piles, and vehicle use on dirt roads. During remedial action, it has been important to control fugitive dust primarily for contamination control, worker inhalation concerns, and offsite

perceptions. In the future, remedial actions will have less impact within 100-BC because most of the waste sites have been remediated and revegetated.

To mitigate potential impacts from airborne dust, control is maintained on haul roads, at excavation sites, and at soil storage areas (that is, stockpiles). Control is maintained by applying water and by halting remediation activities when fugitive dust cannot be controlled because of wind conditions. According to 100 Area RDR/RAWP (DOE/RL-96-17), "...use of water for dust control is minimized." This means that the quantity of water used is sufficient to control airborne emissions but excessive quantities of dust control water are not applied to minimize potential adverse impacts on groundwater.

The typical quantity of dust suppression water used in 100-BC during periods of active remediation, including the water used on haul roads, is 908,000 L/week (240,000 gal/week). Dust control water is largely removed from the soil column during waste site excavation.

## 3.8 Demography and Land Use

***Demographics.*** A detailed discussion of the population surrounding the Hanford Site, including adjacent counties and cities, is presented in the NEPA Characterization Report (PNNL-6415). The 2009 population estimate from the U.S. Census Bureau was that 47,530 people lived in the city of Richland, the closest population center to the Hanford Site. An estimated 58,650 people lived in Pasco and 67,810 people lived in Kennewick. Population groups near the Hanford Site include Native Americans and various ethnic minorities. Native American descendants living near the Hanford Site include members of the following federally recognized groups:

- Confederated Tribes and Bands of the Yakama Nations
- Confederated Tribes of the Umatilla Indian Reservation (CTUIR)
- Nez Perce Tribe
- Confederated Tribes of the Colville Reservation

Members of other unrecognized Tribes members, such as the Wanapum, also live in the area. There is no continuous human inhabitation immediately adjacent to 100-BC.

The economy in the region near the Hanford Site is driven by three major sectors: DOE and its contractors operating the Hanford Site; Energy Northwest, which operates the nuclear-powered Columbia Generating Station on land leased from DOE; and the agricultural community, including a substantial food-processing component. Additional employment sectors driving the local economy include "other major employers," such as non-DOE contractor employers in the region, tourism, and healthcare.

***Land Use.*** The Columbia River is a critical resource for the people and ecology of the Pacific Northwest. The 50-mile stretch of the Columbia River flowing through the Hanford Site is referred to as the Hanford Reach. It is the only major non-tidal, free-flowing stretch of the Columbia in the United States. The river, islands, gravel bars, sloughs, riparian areas, and dune field of the Hanford Reach provide a variety of habitats that are now rare along the Columbia River. As one of the largest rivers in North America, its waters support a multitude of uses that are vital to the economic and environmental well-being of the region. The river is particularly important in sustaining the culture of Native Americans.

Land use in the River Corridor is currently controlled by DOE and the U.S. Fish and Wildlife Service (USFWS), which jointly manage this federally-owned land to protect natural and cultural resources while conducting cleanup activities. Such management is consistent with *Final Hanford Comprehensive Land-Use Plan Environmental Impact Statement*, hereinafter called the CLUP (DOE/EIS-0222-F), and the corresponding *Supplement Analysis: Hanford Comprehensive Land-Use Plan Environmental Impact Statement* (DOE/EIS-0222-SA-01) for the site. This approach also reflects the requirements of the

USFWS management plan (*Hanford Reach National Monument: Final Comprehensive Conservation Plan and Environmental Impact Statement Adams, Benton, Grant and Franklin Counties, Washington* [USFWS, 2008]) for the Hanford Reach National Monument. Both DOE and the USFWS expect that this joint management of the Hanford Site will continue for many years and that the property will remain under federal ownership.

Interim RODs for CERCLA cleanup activities in the river corridor recognized the reasonably anticipated future land use in the river corridor had not been well defined. Since the time the RODs were prepared, DOE has issued the CLUP (DOE/EIS-0222-F), the Hanford Reach National Monument has been established, and conservation and preservation have been defined as the future use of the lands along the river. In a memorandum (Hanford Reach National Monument [Clinton, 2000]) the President directed the Secretary of Energy to consult with the Secretary of the Interior on how best to permanently protect the lands around the Hanford Reach National Monument. Much of the area contains shrub-steppe habitat and other areas of scientific and historic interests. The President specifically included the possibility of adding lands to the Hanford Reach National Monument as they are remediated. EPA and the State of Washington believe that the cleanup actions in the river corridor should also support the potential for future residential use.

When soil cleanup goals were initially established for the river corridor, the TPA signatories agreed that it was appropriate to protect for a range of potential exposures in the future so that cleanup actions did not limit future use of the site. Such a goal addressed the interests of a number of Hanford Site stakeholders, including the Future Site Uses Working Group. Interim action cleanup requirements were based upon consideration of state MTCA cleanup requirements for unrestricted surface use for chemical contaminants and a dose-based standard of 15 mrem per year for radiological constituents based on DOE guidance for a residential exposure. For the purpose of establishing final cleanup requirements for the river corridor cleanup, the TPA agencies believe it is appropriate to continue to use the interim action ROD cleanup requirements, updated to reflect revised MTCA values and excess cancer risk for radiological constituents. Final cleanup values will also be established to protect groundwater and surface water resources and address ecological risk considerations.

Because the interim action cleanup values in river corridor RODs were developed to accommodate a variety of future land use options, the resultant cleanup actions will be protective of the reasonably foreseeable land uses that DOE and the USFWS anticipate for the river corridor.

***Groundwater Use.*** Currently, 100-BC groundwater is extracted only for monitoring. No water supply wells are located in 100-BC.

***Tribal Interests.*** Tribal fishing rights are recognized on rivers within the lands ceded by treaty, including the Columbia River. In addition to fishing rights, the Tribes retain the privilege to hunt, gather roots and berries, and pasture horses and cattle on "open and unclaimed lands." It is the position of DOE that the Hanford Site, which was assembled from lands acquired from private owners and lands withdrawn from the public domain into a federal enclave with no public entry, is not open and unclaimed land. While reserving all rights to assert their respective positions, the Tribes are participants in DOE's land use planning process, and DOE considers Tribal Nation concerns in that process.

## 3.9 Ecology

The unique habitat of the Hanford Site is located in the mid-latitude, semi-arid climate of the Columbia Plateau with the last free flowing section of the Columbia River flowing through it. It supports a rich diversity of plant and animal species. Species diversity is maintained through the long-standing management practices of DOE, which leaves most of the land area relatively undisturbed. Only about 6

percent of Hanford Site land has been disturbed or is actively used by DOE for waste disposal and storage. Thus, the types of native terrestrial and aquatic ecological resources found on the Hanford Site are becoming increasingly rare throughout the Columbia Basin region. Preservation of these areas is important as agricultural, industrial, and residential development continues.

The Hanford Reach National Monument was established by presidential proclamation in 2000 to place high priority on shrub-steppe community habitat maintenance and enhancement for native species. The State of Washington has designated shrub-steppe communities as priority habitat because of their significance to a number of wildlife species and the scarcity of this habitat type. In addition, the U.S. Department of the Interior has identified native shrub and grassland steppe in Washington and Oregon as an endangered ecosystem.

Three key ecological study zones were identified: the upland, riparian, and nearshore river zones. Each ecological zone within the River Corridor supports a unique community of plants and animals.

The upland zone is the largest zone and consists of land adjacent to the main channel of the Columbia River extending inland from the river high-water mark. Terrestrial and generally dry, the upland zone is not influenced by river flow and depends on precipitation for its water supply.

The riparian zone extends from the point on the riverbank where upland vegetation is no longer dominant to the shoreline of the Columbia River. Typically narrow, the riparian zone varies in width, depending on the slope of the riverbank. The transition from the upland zone vegetation to riparian vegetation is generally abrupt. The vegetation that grows in the riparian zone along the river shoreline is thicker and taller than that in the upland area, attracting a broader range of wildlife species. The small mammals, birds, and reptiles common to the upland environment are also likely to inhabit the riparian environment (RCBRA [DOE/RL-2007-21, Volume I]).

The nearshore aquatic zone consists of a narrow band of the Columbia River adjacent to the shoreline. The nearshore aquatic zone evaluated in this report extends from the low water mark on the shoreline to roughly 1.8 m (6 ft) in depth. The Columbia River Component evaluates environmental conditions for depths greater than 1.8 m (6 ft).The aquatic vegetation found in the nearshore zone supports aquatic insect populations, benthic taxa (species and organisms that live in or on the bottom of the river), birds, and fish.

Knowledge of the ecological setting is a compilation of ecological data obtained from multiple biological inventories of plant and wildlife species, and ecological characterizations from the reports listed below:

- NEPA Characterization Report (PNNL-6415) provides a detailed summary of the ecology, biological resources, and hydrology for the entire Hanford Site, with selected information grouped by major operational areas.
- *Hanford Reach of the Columbia River: Comprehensive River Conservation Study and Environmental Impact Statement – Final* (DOI, 1994) provides general information on the riparian and aquatic environments found within the Hanford Reach.
- RCBRA Literature Review (PNNL-SA-41467) provides detailed characterization data for the 100 and 300 Areas, including comprehensive lists of plant and wildlife species occurring in or near the study area.

DOE has been conducting ecological characterization on the Hanford Site since the early 1970s, and environmental reports are produced annually (for example, 2010 Sitewide Environmental Report [PNNL-20548]). Other ecological reports pertaining to the River Corridor include Nature Conservancy surveys (*Biodiversity Inventory and Analysis of the Hanford Site: 1997 Annual Report* [Hall, 1998];

*Biodiversity Inventory and Analysis of the Hanford Site: 1994 Annual Report* [Pabst, 1995]; *Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999* [Soll et al., 1999]; *Biodiversity Inventory and Analysis of the Hanford Site: 1995 Annual Report* [Soll and Soper, 1996]) and *Vascular Plants of the Hanford Site* (PNNL-13688).

### 3.9.1 River Corridor Flora

Historically, much of the River Corridor upland zone was a native shrub-steppe habitat. The most prevalent shrub was big sagebrush (*Artemisia tridentata*), with smaller quantities of rabbitbrush (*Chrysothamnus* sp. and *Ericameria* sp.), and an understory dominated by Sandberg's bluegrass (*Poa secunda* formerly *sandbergii*). During the Euro-American settlement of the area, a large portion of the area was disturbed by farming. Construction activities for the reactor projects further disturbed the vegetation and soil in the area. These two major changes in land use resulted in changes to the native plant community, creating areas that have been kept free of vegetation and areas that have partially recovered to various levels of plant succession (RCBRA [DOE/RL-2007-21, Volume I]).

The vegetation in the River Corridor upland zone operating areas is typically sparse and consists of early successional species such as cheatgrass (*Bromus tectorum*), Russian thistle (*Salsola kali*), tumblemustard (*Sisymbrium altissimum*), and bur ragweed (*Ambrosia acanthicarpa*). Most operating areas, including waste sites, historically were maintained free of vegetation for contamination control, fire prevention, and maintenance purposes. Large areas of cheatgrass and exotic annual species present in the 100-D, 100-F, White Bluffs, and Hanford townsite areas that resulted from pre Hanford Site farming and homesteading are described as "abandoned old fields." More detailed descriptions of vegetation by reactor area can be found in the RCBRA Literature Review (PNNL-SA-41467). Distribution of vegetation types before the 2000 wildfire are presented on Figure 3-45. The fire did not reach the area within the River Corridor.

Vegetation found in riparian zones reflects the transition between aquatic and upland ecosystems. Changes to the composition of shoreline vegetation over time have been influenced by moderation in the river elevation changes controlled by the Priest Rapids Dam, approximately 18.5 km (10 mi) upstream of the Hanford Site. Because of the steepness of the shoreline, the transition from riparian to upland vegetation is abrupt. Dominant vegetation within the riparian zone includes mulberry (*Morus alba*), willow (*Salix* sp.), Siberian elm (*Ulmus pumila*), northern wormwood (*Artemisia campestris*), sweet clover (*Melilotus alba* or *M. officinalis*), and reed canarygrass (*Phalaris arundinacea*) (RCBRA [DOE/RL-2007-21, Volume I]).

Vegetation in the nearshore river zone consists of macrophytes and periphyton. Macrophytes are sparse in the Columbia River because of strong currents, the rocky bottom, and frequently fluctuating water levels. Where macrophytes are found, they commonly include duckweed (*Lemna* sp.) and the native rooted pondweeds *(Potamogeton* spp. and *Elodea canadensis*). Macrophytes provide food and shelter for juvenile fish and spawning areas for some species of warm-water game fish. Since the late 1980s, Eurasian milfoil (*Myriophyllum spicatum*), an introduced macrophyte, has increased to nuisance levels and may encourage increased sedimentation of fine particulate matter. Periphyton communities develop on suitable solid substrate wherever light is sufficient for photosynthesis and adequate currents to prevent sediment from covering the colonies.

Comprehensive lists of plants found on the Hanford Site can be found in the NEPA Characterization Report (PNNL-6415) and *Vascular Plants of the Hanford Site* (PNNL-13688).

### 3.9.2 River Corridor Fauna

Wildlife use of habitat overlaps considerably between the riparian and upland zones. Use of the riparian zone is likely higher than that of the upland zone associated with the CERCLA waste sites because of its proximity to the Columbia River. River access results in greater species diversity and the presence of

higher density and higher stature vegetation that remains productive over a longer period of time (RCBRA [DOE/RL-2007-21, Volume I]). Species lists have been compiled for the major classes of vertebrates that have been observed on the site or within the Hanford Reach of the Columbia River and include 46 species of mammals, 145 species of birds, 10 species of reptiles, 5 species of amphibians, and more than 45 species of fish (NEPA Characterization Report [PNNL-6415]). As invertebrates are concerned, a total of 1,509 species-level identifications have been completed, and the collection of 40,000 specimens has resulted in the identification of 43 new taxa and 142 new findings in the state of Washington (*Biodiversity Inventory and Analysis of the Hanford Site Final Report 1994-1999* [Soll et al., 1999]). The high diversity of insect species on the Hanford Site reflects the size, complexity, and relatively undisturbed quality of the shrub-steppe habitat. Appendix H presents an extensive list of species known or potentially occurring on the Hanford Site classified by habitat type, as well as a table with tissue sample results.

Mammals of the upland environment that might be found in and adjacent to the 100 and 300 Areas include the mule deer (*Odocoileus hemionus*), badger (*Taxidea taxus*), coyote (*Canis latrans*), Great Basin pocket mouse (*Perognathus parvus*), northern pocket gopher (*Thomomys talpoides*), black-tailed jackrabbit (*Lepus californicus*), and cottontail rabbit (*Sylvilagus nuttalii*) (*100 Areas CERCLA Ecological Investigations* [WHC-EP-0620]). The abundance of these species and the occurrence of others vary according to the soil type and vegetative community. While other large mammals, such as elk (*Cervus elaphus*), are infrequently observed in the 100 and 300 Areas upland reactor areas, the number of individual large mammals present per unit area may increase as habitat quality and shrub cover improve through natural recovery and waste site restoration. Some mammals common to the upland environment are also likely to use and inhabit the riparian environment, including the western harvest mouse (*Reithrodontomys megalotis*), Great Basin pocket mouse (*Perognathus parvus*), and deer mouse (*Peromyscus maniculatus*) (*Synthesis of Ecological Data Collected in the Riparian and Riverine Environments of the Hanford Reach* [hereinafter called the Synthesis of Riparian and Riverine Data (PNNL-14516)]).

A complete list of mammals observed and expected in all habitats of the 100 Area is provided in *100 Areas CERCLA Ecological Investigations* (WHC-EP-0620). The NEPA Characterization Report (PNNL-6415) presents a complete listing of Hanford Site wildlife species.

Several species of birds present in the upland zone rely on structures such as buildings, fences, and utility poles for some of their habitat needs. Raptors, such as red-tailed hawks (*Buteo jamaicensis*), are present and frequently nest on buildings, utility poles and towers, and trees along the river. Nonvegetated areas provide nesting habitat for nighthawks (*Chordeiles minor*) and killdeer (*Charadrius vociferus*). Canada geese (*Branta canadensis*) use open cheatgrass areas for winter grazing. Following restoration, improvements in shrub coverage will provide important habitat for native shrub-steppe bird species such as the horned lark (*Eremophila alpestris*), western meadowlark (*Sturnella neglecta*), savannah sparrow (*Passerculus sandwichensis*), loggerhead shrike (*Lanius ludovicianus*), and possibly sage sparrow (*Amphispiza belli*). Raptors will continue to be present, but as the shrubs develop and the open grassy areas shrink in size, wintering geese will likely avoid the area, preferring the cheatgrass areas associated with nearby abandoned farm fields and orchards. A list of bird species observed in the 100 Area is available in *100 Areas CERCLA Ecological Investigations* (WHC-EP-0620). A catalogue of Hanford Site avian species is presented in the NEPA Characterization Report (PNNL-6415).

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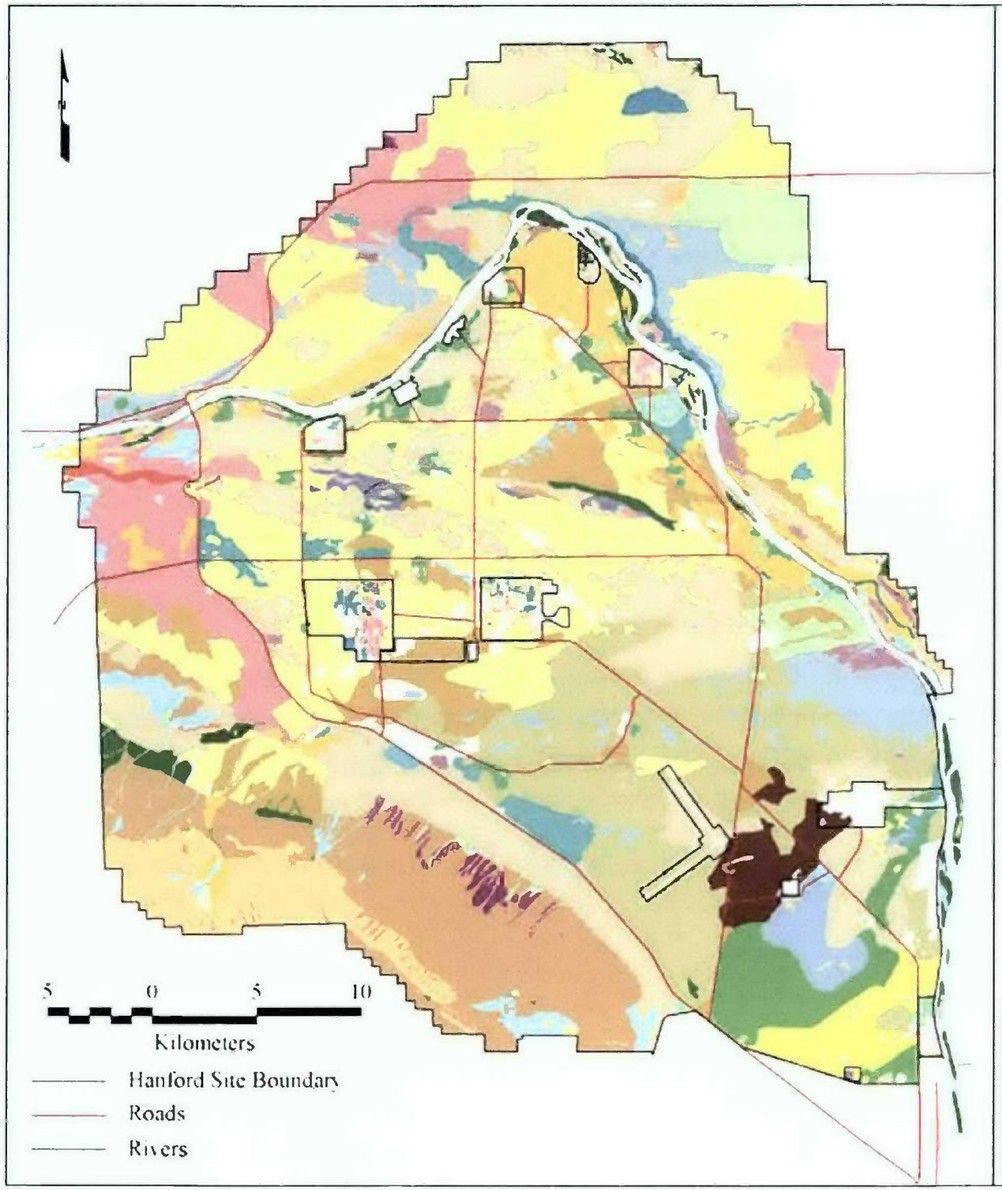


## LEGEND

- Abandoned Old Agricultural Fields
- Alkali Saltgrass - Cheatgrass
- Big Sagebrush - Bitterbrush / Bunchgrass
- Big Sagebrush - Bitterbrush / Needle-and-Thread Grass
- Big Sagebrush - Bitterbrush / Sandberg's Bluegrass
- Big Sagebrush - Rigid Sagebrush / Bunchgrass
- Big Sagebrush - Rock Buckwheat / Bunchgrass
- Big Sagebrush - Spiny Hopsage / Bunchgrass
- Big Sagebrush - Spiny Hopsage / Sandberg's Bluegrass - Cheatgrass
- Big Sagebrush / Bluebunch Wheatgrass
- Big Sagebrush / Bunchgrass
- Big Sagebrush / Needle-and-Thread Grass
- Big Sagebrush / Sand Dropseed
- Big Sagebrush / Sandberg's Bluegrass - Cheatgrass
- Bitterbrush / Bunchgrass
- Bitterbrush / Indian Ricegrass
- Bitterbrush / Needle-and-Thread Grass
- Black Greasewood / Alkali Saltgrass
- Bluebunch Wheatgrass - Needle-and-Thread Grass
- Bluebunch Wheatgrass - Sandberg's Bluegrass
- Bunchgrass - Cheatgrass
- Crested Wheatgrass
- Disturbed
- Gray Rabbitbrush - Snow Buckwheat / Bunchgrass
- Gray Rabbitbrush / Bunchgrass
- Gray Rabbitbrush / Cheatgrass
- Gray Rabbitbrush / Needle-and-Thread Grass
- Gray Rabbitbrush / Sand Dropseed
- Gray Rabbitbrush / Sandberg's Bluegrass - Cheatgrass
- Needle-and-Thread Grass - Indian Ricegrass
- Needle-and-Thread Grass -Sandberg's Bluegrass
- Non-Riverine Wetlands and Associated Deepwater Habitats
- Rabbitbrush / Bunchgrass
- Rigid Sagebrush / Sandberg's Bluegrass
- Riparian
- Riverine Wetlands and Associated Deepwater Habitats
- Sand Dropseed - Sandberg's Bluegrass - Cheatgrass
- Sandberg's Bluegrass - Cheatgrass
- Snow Buckwheat - Bitterbrush / Bunchgrass
- Snow Buckwheat / Bunchgrass
- Snow Buckwheat / Sandberg's Bluegrass - Cheatgrass
- Spiny Hopsage / Sandberg's Bluegrass - Cheatgrass
- Talus
- Threetip Sagebrush / Bunchgrass
- Thymeleaf Buckwheat / Sandberg's Bluegrass
- Vernal Pool
- White Bluffs
- Winterfat / Bunchgrass

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Figure 3-45. Distribution of Vegetation Types before the Wildfire in 2000

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The Synthesis of Riparian and Riverine Data (PNNL-14516) provides information on bird populations with respect to riparian vegetation. Location data are available in the electronic Environmental Monitoring and Compliance Project database managed by PNNL. Research efforts have assessed winter bird populations in cottonwood/willow (*Populus/Salix*) communities of the Columbia River shoreline ("A Vagrant Occurrence of the Black Phoebe in Southeastern Washington" [Rickard, 1964]; "Comparison of Winter Bird Populations After a Decade" [Rickard and Rickard, 1972]) quantified shorebird response to water fluctuations in the Columbia River nearshore environment ("Avian Interactions with Mid-Columbia River Water Level Fluctuations" [Books, 1985]), and evaluated habitat selection and use by spring migrant passerines ("Riparian Stopover Habitat Selection by Spring Transient Landbirds of South-Central Washington" [Duberstein, 1997]). The information gathered during these research efforts has been used to document the status and ecology of the Hanford Site's avian wildlife.

Common reptiles found in upland environments at the Hanford Site include the rattlesnake (*Crotalus viridis*), gopher snake (*Pituophis melanoleucus*), yellow-bellied racer (*Coluber constrictor*), and side blotch lizard (*Uta stansburiana*) (*Habitat Types on the Hanford Site: Wildlife and Plant Species of Concern* [PNL-8942]; *A Synthesis of Ecological Data from the 100 Areas of the Hanford Site* [WHC-EP-0601]). A variety of snakes common to the upland areas may also use the riparian habitat. Other reptiles that may be found in the riparian zone include the western terrestrial garter snake (*Thamnophis sirtalis*) and the painted turtle (*Chrysemys picta*) (*Herpetofauna of the Hanford Nuclear Reservation, Grant, Franklin and Benton Counties, Washington* [Hallock, 1998]; Synthesis of Riparian and Riverine Data [PNNL-14516]). Amphibians in the riparian and nearshore environments of the Hanford Reach include mostly Woodhouse's toads (*Bufo woodhousii*), but bullfrogs (*Rana catesbeiana*) and Great Basin spadefoot toads (*Scaphiopus intermontanus*) may also be present (Synthesis of Riparian and Riverine Data [PNNL-14516]).

The dominant ground dwelling invertebrate species in the upland environment are harvester ants (*Pogonomyrmex owyheei*) and darkling beetles (family *Tenebrionidae*). Harvester ants can exist on vegetated and nonvegetated soil and have been documented on waste sites (*Characterization of the Hanford 300 Area Burial Grounds: Task IV – Biological Transport* [PNL-2774]). Darkling beetles, however, rely on vegetative matter in the soil during their larval stage and therefore are not expected to occur in areas void of vegetation (*Darkling Beetle Populations (*Tenebrionidae*) of the Hanford Site in Southcentral Washington* [PNL-2465]). Areas that were not used as waste sites or have not been affected by Hanford Site operations likely have less soil disturbance and may support a more robust and diverse community of soil-dwelling fauna than previously disturbed or remediated sites.

More than 45 species of fish have been identified in the Hanford Reach of the Columbia River. Of these species, Chinook salmon (*Oncorhynchus tshawytscha*), sockeye salmon (*Oncorhynchus nerka*), Coho salmon (*Oncorhynchus kisutch*), and steelhead (*Oncorhynchus mykiss*) use the river as a migration route to and from upstream spawning areas and are of the greatest economic importance. Other fish of importance to sport anglers are the native mountain whitefish (*Prosopium williamsoni*) and white sturgeon (*Acipenser transmontanus*). Introduced species like smallmouth bass (*Micropterus dolomieui*), black crappie (*Pomoxis nigromaculatus*), channel catfish (*Ictalurus punctatus*), and walleye (*Stizostedion vitreum*) are also popular. Other large fish populations include introduced common carp (*Cyprinus carpio*) and native species such as redside shiner (*Richardsonius balteatus*) and largescale suckers (*Catostomus macrocheilus*). Smaller fish, such as sculpin (*Cottus* sp.), are associated with shoreline habitats and have small home ranges (RCBRA [DOE/RL-2007-21, Volume I]).

### 3.9.3 Threatened and Endangered Species

A variety of species are recognized by state or federal agencies as having special status based on the species' risk of extinction. Threatened and endangered species are considered at risk and, as such, these species were not identified for sacrificial sampling and subsequent analyses for the risk assessment effort.

Data for selected surrogate species were required for contaminant or biological characterization based on the guild in which the special status species were identified (Table 5-1 of *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL-2004-37]). The list of state and federally listed species of concern, including candidate, sensitive, and monitored species thought or known to occur on the Hanford Site is updated regularly in the NEPA Characterization Report (PNNL-6415). No plants, invertebrates, reptiles, amphibians, or mammals on the federal list of threatened and endangered wildlife and plants are known to occur on the Hanford Site (RCBRA Literature Review [PNNL-SA-41467]).

Two species of federally listed endangered fish, the Upper Columbia River spring-run Chinook salmon and the steelhead, occur in the Hanford Reach. The spring-run Chinook salmon do not spawn in the Hanford Reach, but use it as a migration corridor. Steelhead spawning has been observed in the Hanford Reach near 100-BC. The bull trout is listed as threatened by the National Marine Fisheries Service, but is not considered a resident species and is rarely observed in the Hanford Reach (*100-B/C Pilot Project Risk Assessment Report* [DOE/RL-2005-40]).

DOE employs the following protective measures for endangered salmon and steelhead:

- Water diversions meet state screening criteria or appropriate administrative controls, including discharges that meet National Pollutant Discharge Elimination System permit requirements. Removal of native riparian or emergent vegetation is minimized. Where possible, construction projects do not simplify shoreline structures and final construction produces banks at a 3:1 slope.

- Silt-loaded surface runoff is minimized along the shoreline, and disruptive activities in the river or on the shoreline are avoided from April to November.

Although the bald eagle has been removed from the list of federally endangered species, it is still protected under the *Bald and Golden Eagle Protection Act of 1940*. In addition, DOE continues to protect nest and roost sites on the Hanford Site under *Bald Eagle Site Management Plan for the Hanford Site, South-Central Washington* (hereinafter called the Bald Eagle Management Plan [DOE/RL-94-150]). This plan is currently under revision to account for the de-listing of the bald eagle. Changes have been made to reduce the buffer zones surrounding winter night roosts and nest sites from 800 to 400 m (2,600 to 1,400 ft). The Washington State Department of Fish and Wildlife requires protection of roosting trees for bald eagle habitat and foraging areas ("Permanent Regulations," "Bald Eagle Protection Rules" [WAC 232-12-292]).

Tables 3-14 and 3-15 list those flora and fauna species that are listed by the State of Washington as being threatened or endangered including candidate, sensitive, and monitored species thought or known to occur on the Hanford Site.

**Table 3-14. Flora Threatened and Endangered Species List**

| Scientific Name | Common Name | State Status | Federal Status |
|---|---|---|---|
| **Upland** | | | |
| *Oenothera caespitosa* ssp. *caespitosa* | Caespitose evening-primrose | SS | |
| *Orobanche californica* | California broomrape | SX | |
| *Astragalus columbianus* | Columbia milk-vetch | SS | FCo |
| *Nicotiana attenuata* | Coyote tobacco | SS | |
| *Cuscuta denticulata* | Desert dodder | ST | |

**Table 3-14. Flora Threatened and Endangered Species List**

| Scientific Name | Common Name | State Status | Federal Status |
|---|---|---|---|
| *Camissonia pygmaea* | Dwarf evening-primrose | SS | |
| *Astragalus geyeri* | Geyer's milk-vetch | ST | |
| *Cryptantha leucophaea* | Gray cryptantha | SS | FCo |
| *Aliciella leptomeria* | Great Basin gilia | ST | |
| *Lomatium tuberosum* | Hoover's desert parsley | SS | FCo |
| *Loeflingia squarrosa* var. *squarrosa* | Loeflingia | ST | |
| *Cryptantha scoparia* | Miner's candle | SS | |
| *Erigeron piperianus* | Piper's daisy | SS | |
| *Cistanthe rosea* | Rosy pussypaws | ST | |
| *Calochortus macrocarpus* | Sagebrush-mariposa lily | SE | |
| *Camissonia minor* | Small-flower evening primrose | SS | |
| *Cryptantha spiculifera* | Snake River cryptantha | SS | |
| *Ribes cereum* | Squaw currant | SE | |
| *Mimulus suksdorfii* | Suksdorf's monkey-flower | SS | |
| *Eriogonum codium* | Umtanum desert buckwheat | SE | FC |
| *Eatonella nivea* | white etonella | ST | |
| | **Riparian** | | |
| *Lipocarpha aristulata* | awned halfchaff sedge | ST | |
| *Eleocharis rostellata* | Beaked spike-rush | SS | |
| *Hypericum majus* | Canadian St. John's-wort | SS | |
| *Anagallis minima* | Chaffweed | ST | |
| *Ammannia robusta* | Grand redstem | ST | |
| *Rotala ramosior* | Lowland toothcup | ST | |
| *Rorippa columbiae* | Persistantsepal yellowcress | SE | FCo |

FE = Federal Endangered
FCo = Federal Species of Concern
FC = Federal Candidate
SE = State Endangered
SS = State Sensitive
ST = State Threatened
SX = State Possibly Extinct/Extirpated

**Table 3-15. Fauna Threatened and Endangered Species List**

| Scientific Name | Common Name | State Status | Federal Status |
|---|---|---|---|
| | **Birds** | | |
| *Pelecanus erythrorhynchos* | American white pelican | SE | |
| *Haliaeetus leucocephalus* | bald eagle | SS | FCo |
| *Athene cunicularia* | Burrowing owl | SC | FCo |
| *Gavia immer* | Common loon | SS | |
| *Buteo regalis* | Ferruginous hawk | ST | FCo |
| *Otus flammeolus* | Flammulated owl | SC | |
| *Aquila chrysaetos* | Golden eagle | SC | |
| *Centrocercus urophasianus* | Greater sage grouse | ST | FC |
| *Melanerpes lewis* | Lewis' woodpecker | SC | |
| *Lanius ludovicianus* | loggerhead shrike | SC | FCo |
| *Accipiter gentilis* | Northern goshawk | SC | FCo |
| *Falco peregrinus* | Peregrine falcon | SS | FCo |
| *Amphispiza belli* | Sage sparrow | SC | |
| *Oreoscoptes montanus* | Sage thrasher | SC | |
| *Grus canadensis* | Sandhill crane | SE | |
| *Aechmophorus occidenalis* | Western grebe | SC | |
| | **Mammals** | | |
| *Lepus californicus* | Black-tailed jackrabbit | SC | |
| *Sorex merriami* | Merriam's shrew | SC | |
| *Urocitellus townsendii (*formerly *Spermophilus townsendii)* | Townsend's ground squirrel | SC | FCo |
| *Urocitellus washingtoni* (formerly *(Spermophilus washingtoni)* | Washington ground squirrel | SC | FC |
| *Lepus townsendii* | White-tailed jackrabbit | SC | |
| | **Reptiles/Amphibians** | | |
| *Sceloporus graciosus* | Northern sagebrush lizard | SC | FCo |
| *Masticophis taeniatus* | Striped whipsnake | SC | |
| | **Aquatics** | | |
| *Salvelinus confluentus* | Bull trout | SC | FT |

**Table 3-15. Fauna Threatened and Endangered Species List**

| Scientific Name | Common Name | State Status | Federal Status |
|---|---|---|---|
| *Anodonta californiensis* | California floater (mussel) | SC | FCo |
| *SM* | Chinook salmon | SC | FE |
| *Rhinichthys falcatus* | Leopard dace | SC | |
| *Catostormus platyrhynchus* | Mountain sucker | SC | |
| *Lampetra tridentata* | Pacific lamprey | SM | FCo |
| *Oncorhynchus mykiss* | Rainbow trout (steelhead) | SC | FT |
| *Lampetra ayresii* | River lamprey | SC | FCo |
| *Fisherola nuttalli* | Shortface lanx (snail) | SC | |

### 3.9.4 River Corridor Food Web and Receptors

Consideration of ecological receptors in the risk assessment requires an understanding of relationships among biotic community members. One such relationship, trophic transfer of contaminants, is an important element in ecological risk assessments. To develop a conceptual model based on trophic guilds, EPA recommends defining the functional ecosystem components with regard to their role in the food web (*Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final* [EPA 540-R-97-006]). Given the complexity of trophic interactions, food webs are a simplification of the ecosystem showing broad relationships limited to trophic transfer. At a base level, some organisms prey on plants (herbivores), plants and animals (omnivores), or animals only (carnivores). More specific feeding classes exist with a particular trophic category. In the terrestrial environment, for example, although herbivores are pollen-feeding animals that may be relatively unimportant in terms of nutrient and energy transfer through the food web, they are important as plant pollinators. The same generalities are applicable to considerations of trophic linkages in the aquatic environment (for example, many aquatic invertebrates consume periphyton and use this autotrophic component of the aquatic food web as a refuge from predation). Ultimately, depiction of trophic-level relationships from a functional perspective allows for ready identification of the feeding guilds most at risk from ingestion of contaminated plant and animal materials (RCBRA [DOE/RL-2007-21, Volume I]).

This framework is used to describe a simplified trophic structure for the ecological community of the RCBRA (Figure 3-46).

For the most part, trophic linkages among aquatic and terrestrial biota are stronger within habitats than between habitats. In recognition of this, receptors are delineated into aquatic nearshore and terrestrial food webs. Some organisms can use both aquatic and terrestrial habitat. For example, bats and kingbirds are aerial insectivores that live on land and meet their dietary demands primarily through the consumption of emergent aquatic insects. The highest trophic level consists of avian predators that can traverse all environments.

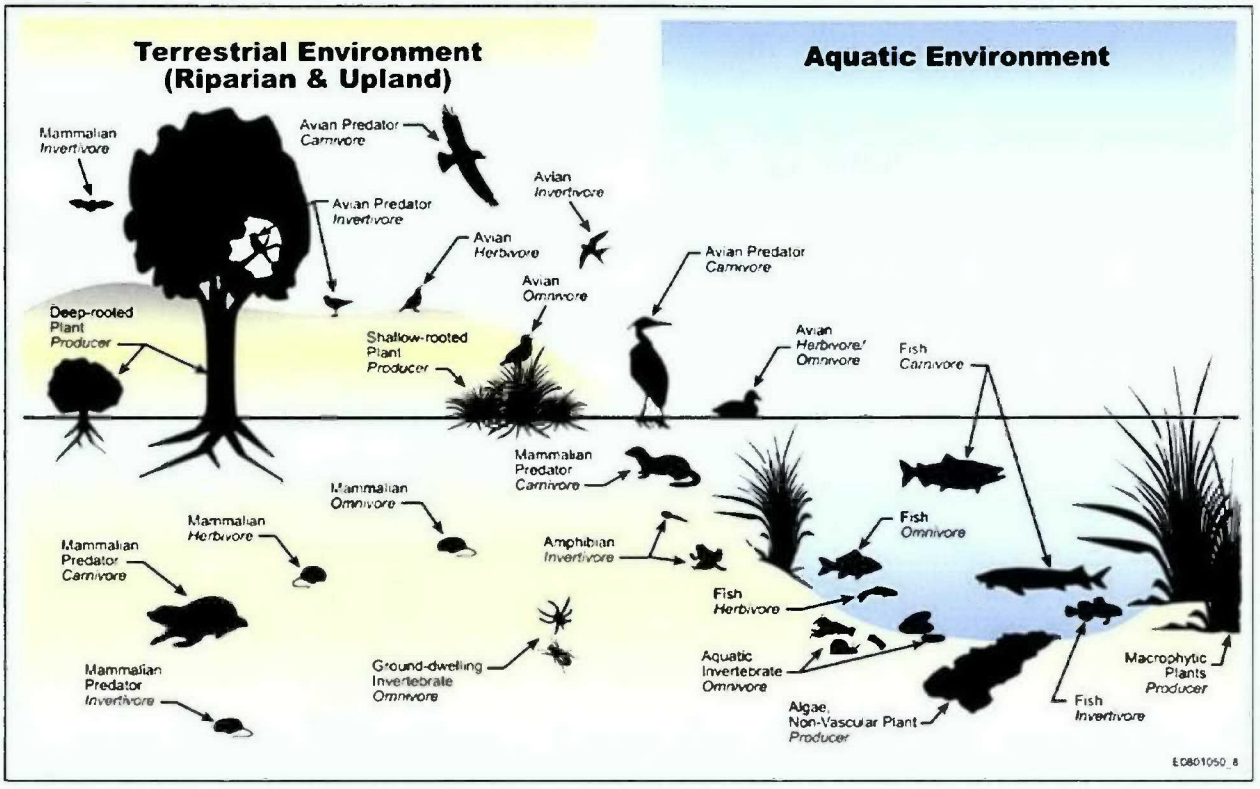


**Figure 3-46. Trophic Structure for the Ecological Community of the RCBRA**

Hanford Site-specific receptors are recommended as surrogates for the MTCA, "Terrestrial Ecological Evaluation Procedures" (WAC 173-340-7490) feeding guilds because they represent relevant ecological endpoints that also address management goals (*DQO Summary Report for the 100 Area and 300 Area Component of the RCBRA* [BHI-01757]). Receptor trophic-based guilds are representative of the upland, riparian, and nearshore environments, and include decomposers, producers, and consumers (herbivores, omnivores, insectivores, and carnivores). While categories such as omnivory and herbivory are useful constructs to simplify a complex ecosystem, it is important to note that animals do not typically restrict themselves to narrow food sources. Considerable dietary overlap exists among the middle trophic levels because all species are, to some degree, opportunists. Other species are primarily insectivorous only at times when insects are abundant (*Washington Department of Fish and Wildlife's Priority Habitat and Species Management Recommendations, Vol. IV: Birds – Sage Sparrow*, Amphispiza belli [WDFW, 2003]). Given the dietary overlap, it would be an artificial distinction to focus on a specific category; modeling specific diets (for example, strict herbivory) is done to set the exposure bounds in trophic-transfer analyses.

## 3.10 Cultural Resources

Significant cultural and historical heritage resources have been established from the riverfront environment to the ridge tops (*Addendum (Final Environmental Impact Statement): Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington* [DOE/EIS-0119F]). Some of the most important archaeological sites in the region are located at the Hanford Site. These sites are eligible to be listed on the National Register of Historic Places (NRHP) as individual sites or as archaeological districts. Cultural, environmental, and historical information of the 100 Area is provided in detail in the Integrated Work Plan (DOE/RL-2008-46). To understand impacts to cultural resources and to reduce the need to perform extensive reviews on highly disturbed areas, disturbance maps and reports

have been completed for 100-BC (NEPA Characterization Report [PNNL-6415]). Information specific to 100-BC is included in this section.

Restricted access to the Hanford Site has facilitated the preservation of these sites. Furthermore, hydroelectric and agricultural development have not destroyed these culturally significance sites, as has been experienced elsewhere in the Columbia River Basin. In addition, other natural resources and sacred sites important to the Native American communities with ancestral ties to the Hanford Site have been preserved (*Data Compendium for the Columbia River Comprehensive Impact Assessment* [PNL-9785]). Through the Cultural Resources Review process, DOE, contractor cultural resource specialists, Tribal Nation representatives, and project and site planners work together to protect resources important to the Native American community and other interested parties.

### 3.10.1 Prehistoric Archaeology

A high density of archaeological resources is associated with the Native American cultural landscape in 100-BC. Three are located partially within 100-BC, and 35 have been recorded within the immediate vicinity of 100-BC during archaeological surveys completed during 1995 (NEPA Characterization Report [PNNL-6415]).

Several archaeological sites (45BN447, 45BN446, and 45BN1422) located near 100-BC have been investigated. Test excavations conducted in 1991 at archaeological site 45BN447 revealed large quantities of deer and mountain sheep bone and projectile points dating from 500 to 1,500 years ago. Archaeological site 45BN446 is considered eligible for listing in the NRHP, in part because it may contain new information about the Frenchman Springs and Cayuse Phases of mid-Columbia prehistory. Data recovery efforts conducted at archaeological site 45BN1422 in 2006 documented a discrete activity area (dating between approximately 2,860 and 2,450 years ago) marked by three interrelated features associated with freshwater mussel shell processing.

Farther downriver, as recorded in 1968, site 45BN118 consisted of 18 to 24 house pits and associated artifacts including cobble tools and hopper mortars. The site was considered a large, open air camp or village. It was determined that this site was a contributing element to the Savage Island Archaeological District, listed on the NRHP in 1976. By 1989, surface evidence of the house pits was lacking, but fire-cracked rock, a few flakes, anvil stones, bits of fish and mammal bones, and mussel shell fragments were observed in an area extending along the shoreline. The shell layers were described as extending from 1 m (3.2 ft) to more than 2 m (6.4 ft) below the surface (*Archaeological Site Monitoring Form: 45BN118* [PNL, 1989]). By 2001, grasses and bushes had grown over the site to the extent that only two possible house pits were located, with none of the previously recorded artifacts observed (*Archaeological Site Form: 45BN118* [PNNL, 2001]).

### 3.10.2 Other Human Resources

Many sites related to hunting and religious activities are located at the west end of Gable Butte. These sites are associated with the Gable Mountain-Gable Butte Cultural District (NEPA Characterization Report [PNNL-6415]).

Three sites associated with early settlers, the Fry and Conforth Farm, Bruggerman's Warehouse, and the Coyote Rapids Hydroelectric Pumping Plant, all of which are eligible for listing on the NRHP (NEPA Characterization Report [PNNL-6415]), are located near 100-BC.

Historic archaeological resources include the remains of Haven Station, a small stop on the former Chicago, Milwaukee, St. Paul, and Pacific Railroads, located to the west of 100-BC. The only structure

associated with the Early Settlers/Farming landscape in 100-BC is the Hanford Irrigation and Power Company pumping plant built at Coyote Rapids during 1908 and located east of 100-BC.

### 3.10.3 Cold War Resources

The 105-B Reactor was the world's first full-scale plutonium production reactor. It is recognized as a National Historic Mechanical Engineering Landmark by the American Society of Mechanical Engineers (1976), a Nuclear Historic Landmark by the American Nuclear Society (1993), and a National Civil Engineering Landmark by the American Society of Civil Engineers (1994). The B Reactor has been listed on the NRHP since 1992, and was recorded by the Historic American Engineering Record (HAER) in 2000. It was named a National Historic Landmark in 2008 (NEPA Characterization Report [PNNL-6415]). Conversion of the facility into a public museum with an interpretive center is planned.

HAER documentation of the B Reactor was completed in 1999 (*Historic American Engineering Record B Reactor (105-B Building) HAER No. WA-164* [DOE/RL-2001-16]). Fourteen buildings and structures within the reactor area have been recorded on historic property inventory forms. Of that number, the following 10 were selected as representative examples of buildings and structures eligible for the NRHP as contributing properties within the Historic District and recommended for individual documentation:

- 104-B-1 Tritium Vault
- 104-B-2 Tritium Laboratory
- 105-B Reactor
- 105-B-Rod Tip Cave
- 116-B Reactor Exhaust Stack
- 117-B Exhaust Air Filter Building
- 118-B-1 Solid Waste Burial Trench
- 181-B River Pump House
- 182-B Reservoir
- Pump House

An assessment of the contents of the B Reactor was conducted to locate and identify Manhattan Project and Cold War era artifacts that may have interpretive or educational value in potential exhibits. Thirty-nine industrial artifacts were identified and tagged, with many displayed as interpretive exhibits in the reactor building. Tagged artifacts from the D and F Reactors were transferred to the B Reactor for display as interpretive exhibits (NEPA Characterization Report [PNNL-6415]).

## 3.11 Summary of Physical Setting

100-BC covers 11.5 $km^2$ (4.5 $mi^2$) and is located on the south bank of the Columbia River, upstream from the other Hanford Site reactor areas. Most of the area is relatively flat and open, but downstream of the water intake structure, the bank slopes steeply towards the river. The Columbia River flows to the east past 100-BC. Flow volume is controlled by Priest Rapids Dam, located approximately 21 km (13 mi) upstream. Flow volumes typically peak from April through June during spring runoff, and are lowest from September through October.

The vadose zone comprises unconsolidated gravel and sand of the Hanford formation. This formation in 100-BC is characterized by cobble- to boulder-size clasts in open framework gravels that include discrete sand lenses with very little silt and clay material. The vadose zone is up to 30 m (98 ft) thick beneath inland portions of 100-BC. Percent moisture in samples from new wells and boreholes ranged from less than 3 percent to more than 10 percent, with the samples collected from near the water table having higher moisture than those higher in the vadose zone. Average porosity was 18 percent.

RI activities provided data that helped characterize the uppermost aquifer and aquitard beneath 100-BC. The uppermost aquifer is unconfined and comprises primarily the sands and gravels of Ringold unit E. Beneath most of 100-BC, the bottom portion of the Hanford formation also is saturated. The saturated thickness of the Hanford formation generally increases to the south, and ranges up to 6 m (20 ft) beneath

the main portion of 100-BC. A low-permeability geologic unit in the Ringold Formation forms the bottom of the unconfined aquifer. RI data showed that this unit is continuous beneath 100-BC and slopes toward the west. Aquifer thickness ranges from 29 to 47 m (95 to 154 ft), increasing to the west.

Slug tests were performed for the RI to determine horizontal hydraulic conductivity. The two wells screened in the RUM had the lowest hydraulic conductivity, approximately 1 m/d (3 ft/d). Wells screened in Ringold unit E had hydraulic conductivity ranging from 2.5 to 16 m/d (8.2 to 52 ft/d). The lowest Ringold E hydraulic conductivity (2.5 m/d or 8.2 ft/d) was in a well screened at the bottom of the aquifer. Wells screened in the Hanford formation paleochannel had the highest hydraulic conductivity, beyond the range suitable for determining with slug tests (likely 500 to 1,000 m/d).

A constant rate discharge test was conducted in RUM Well 199-B2-15. Results indicated a horizontal hydraulic conductivity of 3.0 m/d (9.8 ft/d).

Vertical hydraulic conductivity results were highly variable. When vertical hydraulic conductivity results are considered as a whole, general patterns emerge.

- The Hanford formation has the highest vertical hydraulic conductivity (average 38 m/d or 125 ft/d).
- RUM samples have the lowest vertical conductivity (average 0.043 m/d or 0.14 ft/d).
- Ringold unit E has vertical conductivity values in between the Hanford formation and the RUM unit (average 3.3 m/d or 11 ft/d).

The water table lies at a depth of 0 m (0 ft) adjacent to the river to 30 m (98 ft) inland. The water table is nearly flat in southern 100-BC and steepens toward the Columbia River. Water-level data and contaminant migration indicate that groundwater in the Hanford formation beneath southern 100-BC flows toward the northeast at rates ranging from 0.07 to 0.7 m/d (0.23 to 2.3 ft/d). In northern 100-BC, the aquifer is in Ringold unit E, where hydraulic conductivity is lower and the hydraulic gradient is steeper. Groundwater flow rates range from 0.03 to 0.29 m/d (0.10 to 0.95 ft/d) toward the north, except when river stage is very high and the gradient is reversed.

Daily and seasonal fluctuations in river stage, which range up to 4 m (13 ft), affect groundwater flow near the river. During periods of high river stage, the hydraulic gradient flattens or reverses near the river. These changes further slow the movement of groundwater to the river. Groundwater discharges via springs and areas of upwelling through the river bed. Recent studies of the river created maps of these areas of upwelling.

Data collected for the RI provided new information about vertical hydraulic gradients. Near the river, the vertical hydraulic gradient within the unconfined aquifer is downward. In the same region, the average gradient between the confined Ringold aquifer and the unconfined aquifer is upward. In southern 100-BC, there is a downward gradient within the unconfined aquifer except when the water table is rising. The vertical gradient in southern 100-BC is stronger than the horizontal gradient.

Natural recharge to the aquifer is low because of the Hanford Site's hot, arid climate. Artificial recharge may include leakage from facilities associated with water supply. The 182-B Reservoir is part of the primary water supply system for the Hanford Site and is used to store large volumes of untreated water. Leaks from this reservoir or associated piping are a potential source of artificial recharge to groundwater. Water applied to control dust during waste site remediation is another potential source of recharge, although this is believed to be minor.

Current land use in the Hanford Site River Corridor, including 100-BC, consists of waste management, environmental monitoring, soil remediation, and conservation and restoration activities. Access is

typically restricted to Hanford Site employees and contractors. DOE's reasonably anticipated future land use is predominantly conservation (mining) in the River Corridor and 100-BC. In addition, B Reactor, the world's first full scale plutonium production reactor, is recognized as a National Historic Landmark. Conversion of the facility into a public museum with an interpretive center is planned.

100-BC is partially located in the Hanford Reach National Monument. The monument was created in part from the security buffer zone surrounding the Hanford Site, which has been untouched by development or agriculture since 1943. The predominant plant community at 100-BC is sagebrush, Sandberg's bluegrass, and cheatgrass. A relatively narrow riparian zone supports grasses, sedges, and scattered deciduous shrubs and trees.

Two species of federal listed endangered fish, the Upper Columbia River spring-run Chinook salmon and the steelhead, occur in the Hanford Reach. The spring-run Chinook salmon do not spawn in the Hanford Reach, but use it as a migration corridor. Steelhead spawning has been observed in the Hanford Reach near 100-BC.

**Looking Ahead In This Document**

Chapter 3 described the physical setting of 100-BC, including the makeup of vadose zone materials, the groundwater, and the Columbia River.

Chapter 4 describes the contaminants resulting from 100-BC operations and their current extent in the environment. Contaminants can be harmful to human health and the environment if there is contact with sufficient concentrations, mass, or radioactivity.

Chapter 5 describes and predicts fate and transport, that is, how these contaminants will migrate through the environment. The potential harm depends on specific receptors as well as exposure times and patterns that might bring receptors and contaminants into contact. The ways that the contaminants could come into contact with humans and the environment are called pathways. Chapter 6 addresses the human health pathway, and evaluates potential impacts. Chapter 7 addresses the biological receptor pathway and evaluates how plant, animal, bird, or invertebrate species might be affected.

Chapter 8 identifies technologies that could remove contaminants from the setting or interrupt these pathways. Chapter 9 develops and evaluates remedial alternatives using these technologies. Chapter 10 compares the alternatives that can best address the problem. This evaluation and comparison will support a remedial decision to implement actions to protect human health and the environment.

# 4 Nature and Extent of Contamination

The nature and extent evaluation describes the contaminant levels found in the environmental media in the study area. Contamination is determined from recently collected RI data, data from RI of the Columbia River, data available from previous field investigations, completed interim remediation, ongoing interim action remediation, and operational process information. Reported concentrations of the various analytes are compared to background concentrations to evaluate if the analyte represents a contaminant or is simply present in the environment. The discussion of analytes determined to be present below background levels is limited to Section 4.1.

Following the comparison to background levels, the contaminants are described in relation to their nature and extent. This chapter focuses principally on the COPCs that were identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) and continues to build on the CSM by adding information on contaminants into the physical setting.

This chapter also describes uncertainties associated with the data, as they relate to the nature and extent of contamination. The intent of this chapter is to provide information for determining a remedy(s) and to identify locations where the remedy(s) should be applied based on the long history of information for 100-BC and the new information collected during the RI to meet the DQOs outlined in the 100-BC Work Plan (DOE/RL-2008-46-ADD3) and 100-BC SAP (DOE/RL-2009-44). Many of the data collected during remediation that havebeen documented in CVPs and LFIs also are incorporated into the discussion of nature and extent with the understanding that DQOs for these data generally are insufficient for risk assessment purposes.

***Highlights***

- No substantive residual contaminant mass was identified in the vadose zone except in the ongoing remediation of Cr(VI) waste site 100-C-7:1.
- Low concentrations of strontium-90 were detected through the vadose zone to groundwater beneath several waste sites.
- Low concentrations of tritium were detected through the vadose to groundwater beneath the 118-B-6 burial ground. Tritium concentrations measured during the deep zone closeout sampling were elevated.
- Cr(VI) concentrations beneath remediated waste sites were generally low. The most elevated result was 1.05 mg/kg beneath 118-B-6. Low level detections of Cr(VI) in the rewetted zone and within the water table were present at 100-BC groundwater characterization wells.
- Groundwater is contaminated with Cr(VI), strontium-90, and tritium with concentrations above aquatic or drinking water standards.
- Data from a new groundwater well show that a portion of the Cr(VI) plume extends farther west than previously known.
- Cr(VI) increased sharply in a well downgradient of the 100-C-7:1 waste site in early 2012, suggesting that remediation activities have mobilized contamination.
- Cr(VI) concentrations in groundwater decrease with depth in eastern 100-BC. In western 100-BC, concentrations are highest at the top and bottom of the aquifer, and lower in between.
- Strontium-90 and tritium concentrations decline with depth in the aquifer.
- Groundwater contains trichloroethene at concentrations below the drinking water standard.
- Groundwater contamination is limited to the unconfined aquifer.
- Columbia River pore water had Cr(VI) concentrations ten times the aquatic standard in some locations in 2009. Concentrations declined in two subsequent sampling campaigns, but remained slightly above the standard at some locations.

### *Types of Waste Sites*

Figures 4-1, 4-2, and 4-3 show the locations of the former waste sites that were the primary sources of the groundwater contaminants Cr(VI), strontium-90, and tritium. The following paragraphs provide brief descriptions of the major types of waste sites and facilities that formerly were present in 100-BC:

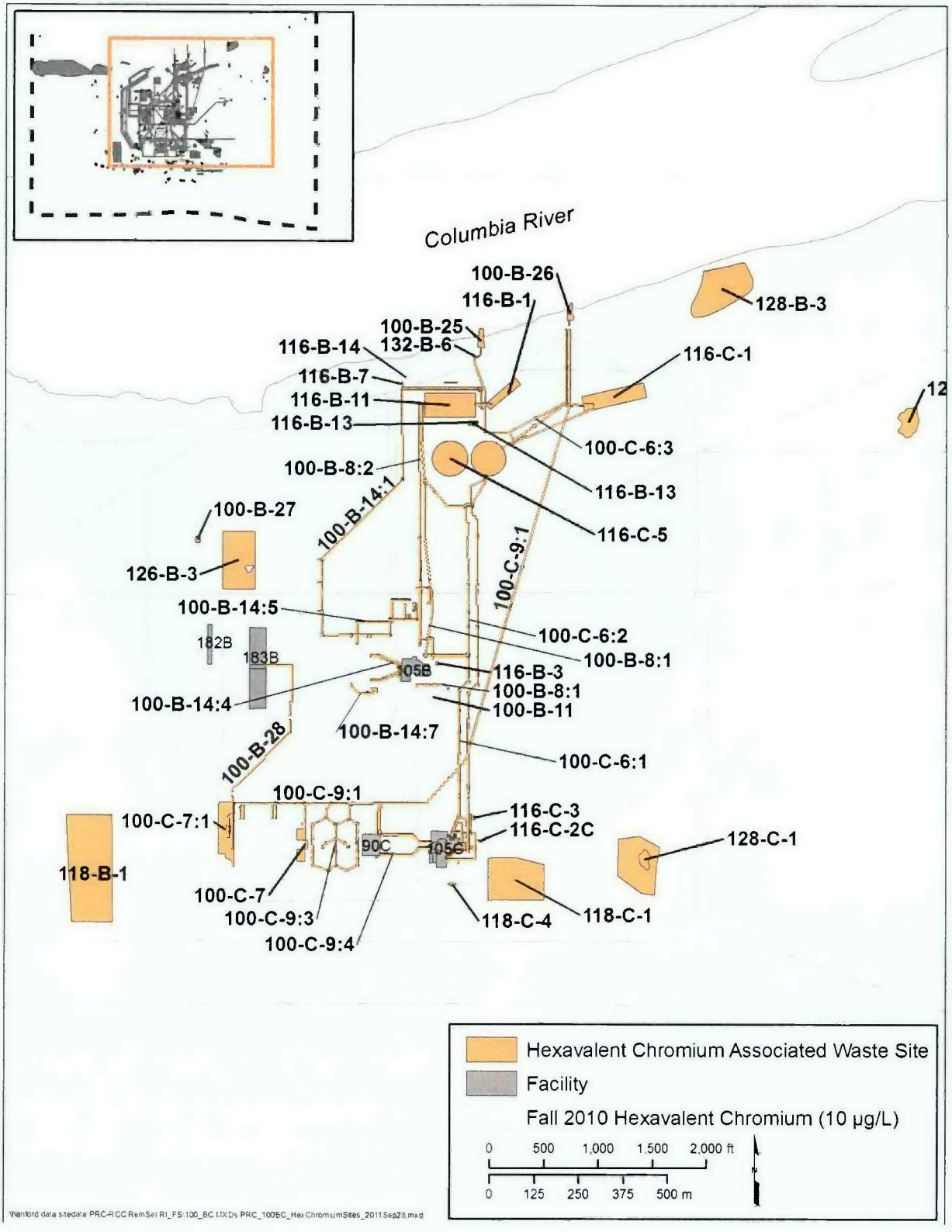


Figure 4-1. Cr(VI) Waste Sites in 100-BC

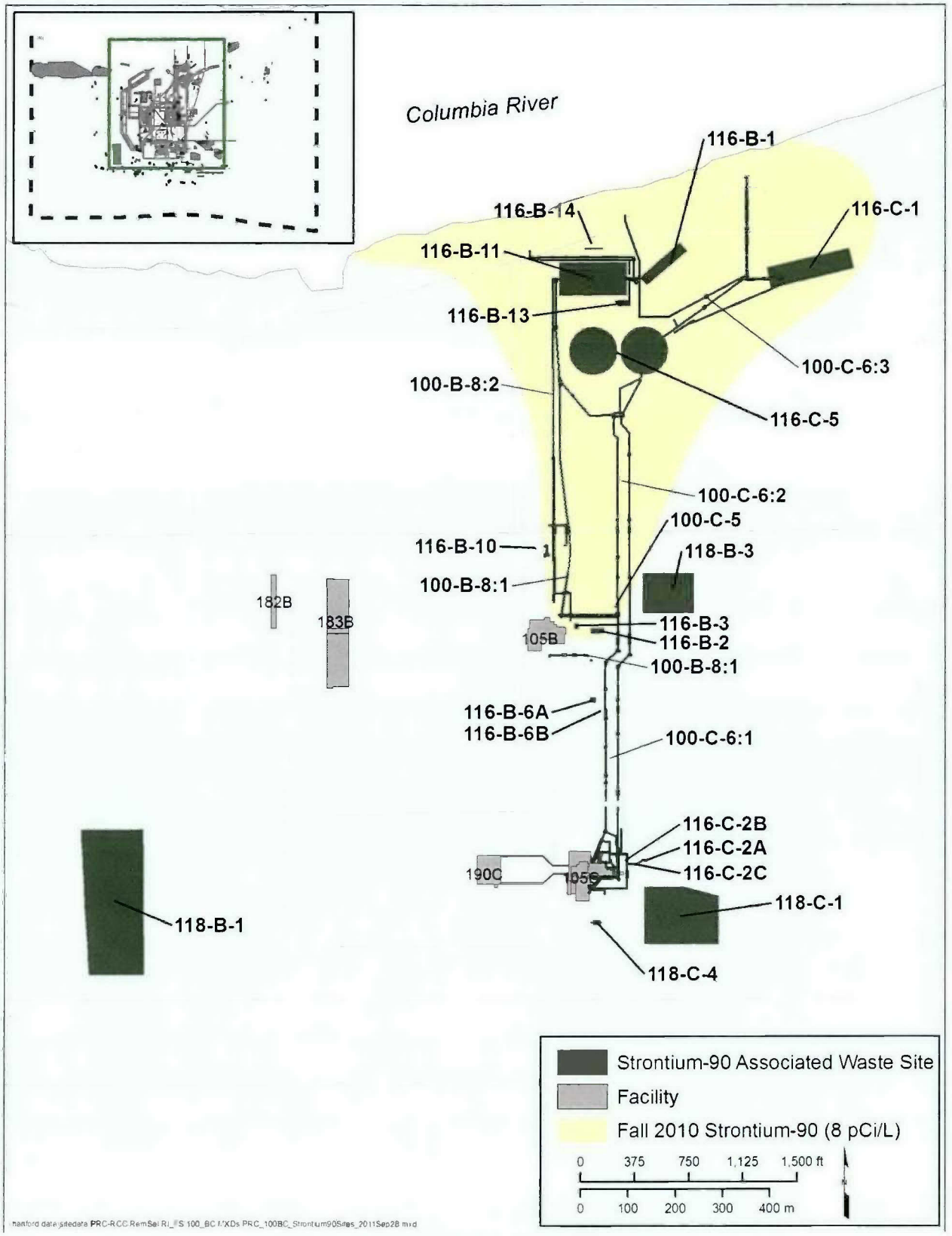


**Figure 4-2. Strontium-90 Waste Sites in 100-BC**

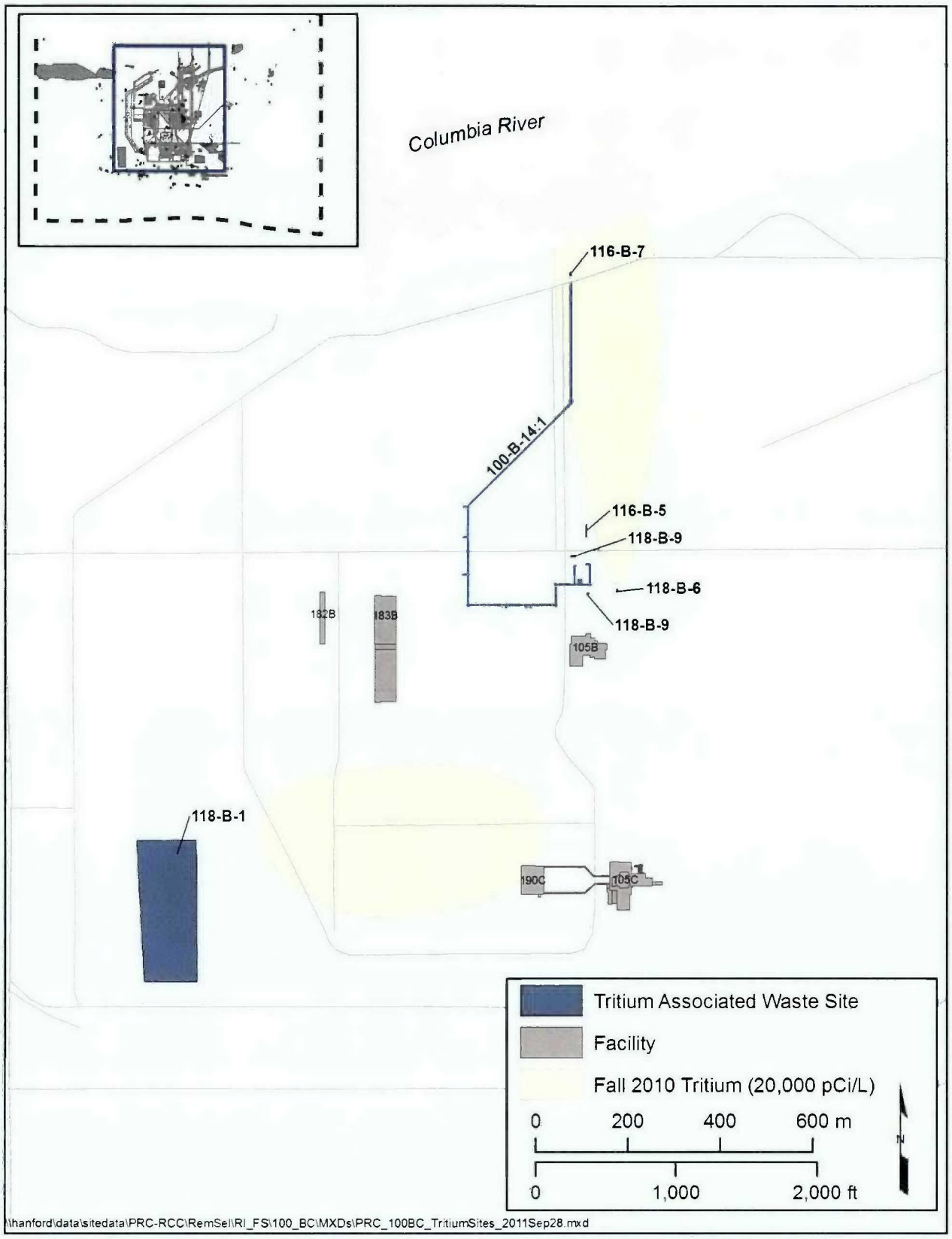


**Figure 4-3. Tritium Waste Sites in 100-BC**

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

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

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

***Solid Waste Burial Grounds*** were areas used for near-surface disposal of solid waste containing radioactive and nonradioactive hazardous substances, construction debris from reactor modifications, contaminated construction equipment, contaminated dirt, irradiated reactor parts, and low level radioactive combustible material.

**Several factors are unique to 100-BC and influence the nature and extent of contamination significantly:**

- Interim remedial action of former waste sites is nearly complete. When excavation of the large 100-C-7 waste site is finished, there will no longer be any ongoing sources of groundwater contamination in the vadose zone.
- Release of high-concentration waste appears to have been less significant in 100-BC than in some other 100 Areas. Groundwater contaminants have relatively low concentrations.
- No interim groundwater remediation systems are active in 100-BC.

***Unplanned Release Sites*** were locations where wastes unintentionally were released to the environment. Waste sites in this group typically related to liquid waste spills.

***Retention Basins*** were large, open, reinforced concrete structures designed to hold cooling water from reactor operations temporarily. After cooling and decay of short-lived radioactive contaminants, the water was discharged to the Columbia River. Although retention basins were not designed to dispose of water to the ground, they leaked substantially to the surrounding vadose zone.

***Pipelines*** were closed transfer lines between facilities or structures that were used to transfer chemicals or waste effluents. Some pipelines leaked.

***Analytical Data.*** Figures in this chapter illustrate concentrations of chemical and radiological analytes in soil and groundwater. Concentrations in sediments are reported in concentrations of mg/kg (parts per million) or picocuries/gram; contaminant concentrations in groundwater generally are reported in µg/L (parts per billion) or pCi/L. Analytical results are included in Appendix D.

Filled symbols on graphs in this chapter indicate detections during the analysis. Hollow symbols indicate that the analyte was not detected above limiting criteria. Limiting criteria are usually the method detection limit (MDL), instrument detection limit (IDL), or minimum detectable activity (MDA). For chemical constituents the results are reported as the limiting criteria and flagged with a "U." Thus, a data point reported as "1.0 U mg/kg" means "less than 1.0 mg/kg." Radionuclides are reported as a counted value corrected for background radiation.

As concentrations get closer to detection limits, precision and accuracy decline, primarily because oftwo factors: extrapolation beyond determined calibration curve boundaries and increased noise-to-signal ratios from the instrument detection system. Consequently results near the MDL/IDL are less precise and accurate than higher values. The estimated quantitation limit (EQL); sometimes referred to as the Reporting Limit [RL] or Practical Quantitation Limit [PQL]) is the lowest concentration that can be reliably quantified within specified limits of precision and accuracy under routine laboratory operating conditions. The EQL is generally 5 to 10 times greater than the MDL. The concentration range between the IDL/MDL and the EQL/RL is an analytical "grey zone" where the presence of an analyte can be detected but the analytical precision and accuracy of the values obtained are diminished. If an analyte is detected at a value less than the EQL/RL, but greater than or equal to the IDL/MDL the detected concentration is flagged ("B" for most inorganic analytes, "J" for organics) to indicate the potential for diminished precision and accuracy.

Because detection limits for a given analyte can vary depending on many factors, it sometimes happens that a detected value is reported at a lower concentration than a non-detection (U-flagged) value. It is important that any laboratory established detection be documented and reported to the best of the laboratory's capability. Not reporting the obtained value (even if potentially with a very large error bound) would be a functional corruption of the data set. Requesting/requiring the laboratory to report nondetects to routine MDLs is not technically appropriate as it would negatively bias the interpretation of actual laboratory capabilities and the results thus reported. The apparent disparity in detected values reported at lower values than non-detect values (particularly when presented as plots) does not misrepresent the accuracy or usefulness of the data. If project defined EQL/RL goals are met, this facet of the data will not negatively affect decision-making activities.

## 4.1 Background Concentrations

Background refers to substances or locations that are not influenced by the releases from a site, and are usually described as naturally occurring (present in the environment in forms that have not been influenced by human activity) or anthropogenic (natural and artificial) substances present in the environment as a result of human activities not specifically related to the CERCLA site in question. Some chemicals may be present in background because of both natural and artificial conditions, such as naturally occurring arsenic and arsenic from pesticide applications (*Guidance for Comparing Background and Chemical Concentrations in Soil for CERCLA Sites* [EPA 540-R-01-003]).

Section 4.1.1 describes pre-Hanford practices that affected background concentrations of lead and arsenic, and Section 4.1.2 describes Hanford Site soil background concentrations as determined by sampling. Groundwater background concentrations for 100-BC COPCs were derived from *Hanford Site Background: Part 3, Groundwater Background* (DOE/RL-96-61), as corrected. Section 4.3 presents groundwater background concentrations.

### 4.1.1 Historical Agricultural Activities

Co-located within the historical orchard land areas are waste sites related to releases from Hanford Site operations (Figure 4-4). The contaminants associated with these waste sites will continue to be evaluated and addressed through the RI/FS process for the various areas (100-BC, 100-K, 100-N, 100-D/H, or 100-F) where the individual waste sites are geographically located. During implementation of the selected remedy at these waste sites, contaminants present will be remediated as needed to meet the cleanup levels prescribed in the applicable ROD. Should contaminants associated with historical orchard lands (for example, lead and arsenic) be present at any particular waste site, that contamination will not be remediated beyond the waste site footprint as part of the ROD. Any contaminants remaining outside the waste site footprint will be addressed as part of the remedial investigation for the 100-OL-1 OU. This

approach will allow reclassification of individual waste sites that meet the cleanup standards (for non-orchard lands related contaminants) of the applicable decision area ROD while supporting the broad area investigation of historical orchard lands as part of the 100-OL-1 OU.

Details for the handoff of actions between the decision area RODs and the 100-OL-1 OU investigations will be established in the remedial design report/remedial action work plan (RDR/RAWP) documents associated with each decision area ROD. An example of this approach as implemented for the interim action RODs is provided by *Federal Facility Agreement and Consent Order, Modify Remedial Design Report/ Remedial Action Work Plan for the 100 Area (DOE/RL-96-17, Rev. 6) to Add Section 3.6.10 Residual Pesticides from Agriculture Use* (TPA-CN-401).

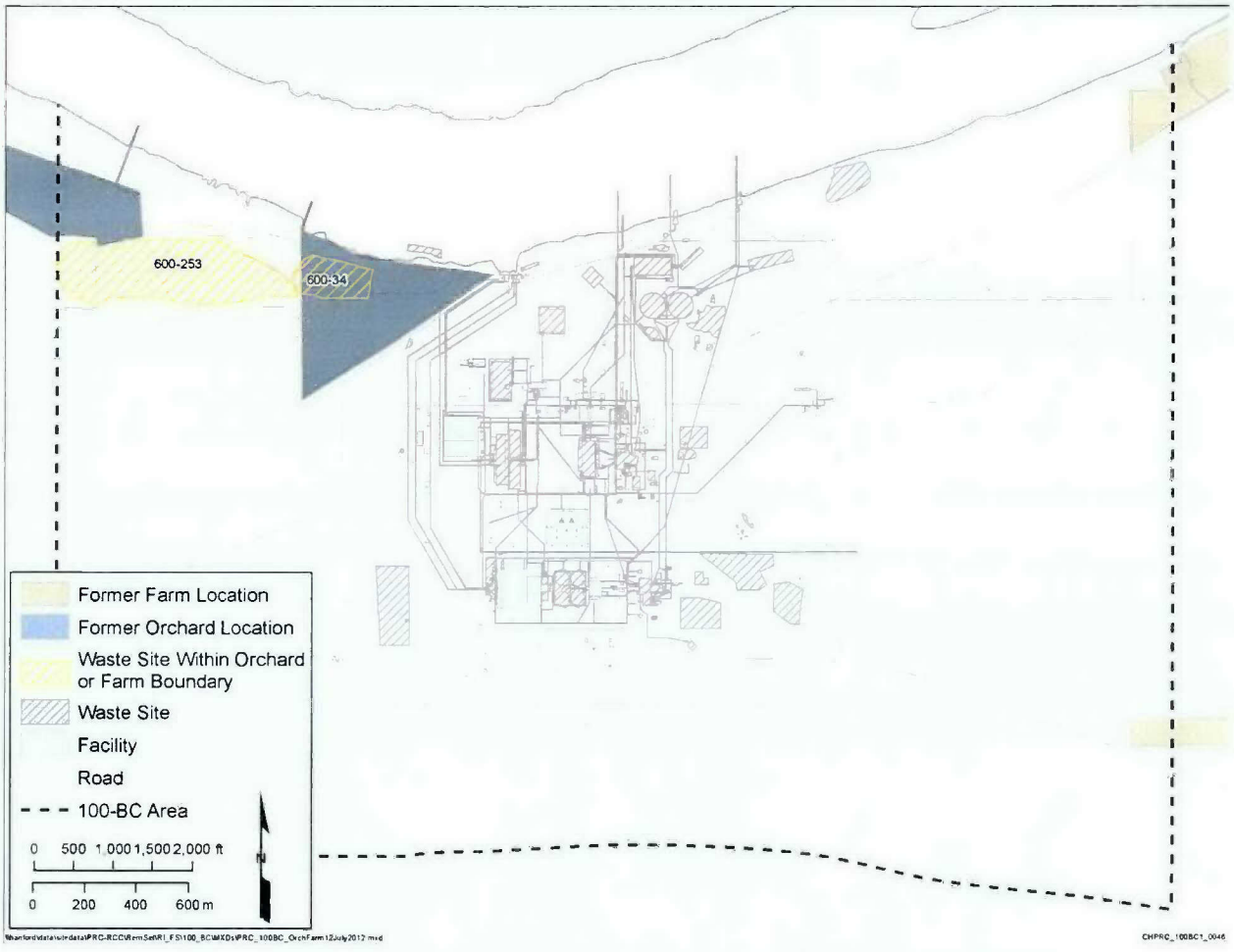


**Figure 4-4. Locations of Former Orchards, Farms, and Waste Sites in 100-BC**

### 4.1.2 Hanford Site Soil Background

The identification of background concentrations of constituents in the soil and groundwater is important in determining which waste sites may require remedial action. These concentrations are also important because calculated risk-based benchmarks (that is, human health and ecological), in some instances, are less than background levels. Where such benchmarks are less than background levels, RAGs default to background concentrations rather than the calculated values. CERCLA typically does not require cleanup to concentrations below background levels. Background soil concentrations derived for the Hanford Site are presented in Table 4-1 and are used as benchmarks to define contamination, as well as COPCs. As such, a constituent detected below background (for example, 90$^{th}$ percentile in *Hanford Site Background:*

*Part 1, Soil Background for Nonradioactive Analytes* [hereinafter called the Non-Rad Soil Background document (DOE/RL-92-24)], *Hanford Site Background: Part 2, Soil Background for Radionuclides* [hereinafter called the Rad Soil Background document (DOE/RL-96-12)]) is not considered a contaminant.

**Table 4-1. Background Concentrations in Hanford Site Soil**

| CAS Number | Analyte | Abbreviation | 90th Percentile | Reference |
|---|---|---|---|---|
| **Radionuclides (pCi/g)** | | | | |
| 10098-97-2 | Strontium-90[a] | Sr-90 | 0.178 | DOE/RL-96-12 |
| 10198-40-0 | Cobalt-60[a] | Co-60 | 0.00842 | DOE/RL-96-12 |
| 10045-97-3 | Cesium-137[a] | Cs-137 | 1.05 | DOE/RL-96-12 |
| 15585-10-1 | Europium-154[a] | Eu-154 | 0.0334 | DOE/RL-96-12 |
| 14391-16-3 | Europium-155[a] | Eu-155 | 0.0539 | DOE/RL-96-12 |
| 13966-29-5 | Uranium-233/234 | U-233/234 | 1.10 | DOE/RL-96-12 |
| 15117-96-1 | Uranium-235 | U-235 | 0.109 | DOE/RL-96-12 |
| 7440-61-1 | Uranium-238 | U-238 | 1.06 | DOE/RL-96-12 |
| 13981-16-3 | Plutonium-238[a] | Pu-238 | 0.00378 | DOE/RL-96-12 |
| 15117-48-3 | Plutonium-239/240[a] | Pu-239/240 | 0.0248 | DOE/RL-96-12 |
| **Nonradionuclides (mg/kg)** | | | | |
| 7439-14-2 | Aluminum | Al | 11800 | DOE/RL-92-24, Rev. 4 |
| 7440-36-0 | Antimony | Sb | 0.130 | ECF-HANFORD-11-0038 |
| 7440-38-2 | Arsenic | As | 6.47 | DOE/RL-92-24, Rev. 4 |
| 7440-39-3 | Barium | Ba | 132 | DOE/RL-92-24, Rev. 4 |
| 7440-41-7 | Beryllium | Be | 1.51 | DOE/RL-92-24, Rev. 4 |
| 7440-42-8 | Boron | B | 3.89 | ECF-HANFORD-11-0038 |
| 7440-43-9 | Cadmium | Cd | 0.81 | ECF-HANFORD-11-0038 |
| 7440-47-3 | Chromium (total) | Cr | 18.5 | DOE/RL-92-24, Rev. 4 |
| 7440-48-4 | Cobalt | Co | 15.7 | DOE/RL-92-24, Rev. 4 |
| 7440-50-8 | Copper | Cu | 22 | DOE/RL-92-24, Rev. 4 |
| 7439-92-1 | Lead | Pb | 10.2 | DOE/RL-92-24, Rev. 4 |
| 7439-93-2 | Lithium | Li | 13.3 | ECF-HANFORD-11-0038 |
| 7439-96-5 | Manganese | Mn | 512 | DOE/RL-92-24, Rev. 4 |
| 7439-97-6 | Mercury | Hg | 0.0131 | ECF-HANFORD-11-0038 |

**Table 4-1. Background Concentrations in Hanford Site Soil**

| CAS Number | Analyte | Abbreviation | 90th Percentile | Reference |
|---|---|---|---|---|
| 7439-98-7 | Molybdenum | Mo | 0.470 | ECF-HANFORD-11-0038 |
| 7440-02-0 | Nickel | Ni | 19.1 | DOE/RL-92-24, Rev. 4 |
| 7782-49-2 | Selenium | Se | 0.78 | ECF-HANFORD-11-0038 |
| 7440-22-4 | Silver | Ag | 0.167 | ECF-HANFORD-11-0038 |
| 7440-28-0 | Thallium | Tl | 0.185 | ECF-HANFORD-11-0038 |
| 7440-32-6 | Titanium | Ti | 2,950 | DOE/RL-92-24, Rev. 4 |
| 7440-62-2 | Vanadium | V | 85.1 | DOE/RL-92-24, Rev. 4 |
| 7440-66-6 | Zinc | Zn | 67.8 | DOE/RL-92-24, Rev. 4 |
| 14797-55-8 | Nitrate | $NO_3^-$ | 52 | DOE/RL-92-24, Rev. 4 |
| 14797-65-0 | Nitrite | $NO_2^-$ | Note[c] | DOE/RL-92-24, Rev. 4 |

Sources:

DOE/RL-92-24, Rev. 4, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes.*

DOE/RL-96-12, Rev. 0, *Hanford Site Background: Part 2, Soil Background for Radionuclides.*

ECF-HANFORD-11-0038, *Soil Background Data for Interim Use at the Hanford Site.*

a. Cesium-137, cobalt-60, europium-154, europium-155, plutonium-238, plutonium-239/240, and strontium-90 are anthropogenic radionuclides whose background values only apply to surface soil samples.

b. The 90th percentile value for selenium is estimated because the majority of detections were below the minimum quantitation limit.

As part of the RI, investigations for collecting data and developing River Corridor background values in soil for selected metals were performed. Revised, provisional background values for antimony, cadmium, mercury, selenium, silver, and thallium are presented in a calculation brief (*Soil Background Data for Interim Use at the Hanford Site* [ECF-HANFORD-11-0038]).

For anthropogenic radionuclides in soil samples at depth, including strontium-90, cobalt-60, cesium-137, europium-154, europium-155, plutonium-238 and plutonium-239/240, anthropogenic constituents were not excluded based on background concentration (that is, all detects are presented, even if below background Hanford Site soil concentrations).

Naturally occurring radionuclides include potassium-40, radium-226, thorium-232, thorium-234, and uranium-234, -235, and -238, which are present in all geologic materials that include the soil throughout the Hanford vadose zone. Anthropogenic radionuclides are radioactive isotopes that were produced or concentrated by non-Hanford related human activities (Rad Soil Background document [DOE/RL-96-12]). Most of the anthropogenic background radionuclides were produced by aboveground nuclear explosions and nuclear accidents and were subsequently deposited as global fallout from dry and wet precipitation of atmospheric particles. However, the application of Hanford background concentrations for anthropogenic radionuclides such as cesium-137, plutonium-239/240, and strontium-90 are largely restricted to soil in the upper few tens of centimeters, and can extend to deeper levels in soil affected by remobilization, transport, and depositional processes (for example, eolian processes).

In extreme cases, anthropogenic background radionuclides have been found to occur at depths up to 120 cm below the surface (*Hanford Site Radiological Background: Data Quality Objective Issues and Recommendations* [DOE/RL-94-98]).

## 4.2 Vadose Zone Contamination

This section describes the nature (that is, type and concentration) and extent (that is, distribution) of existing contamination in the vadose zone beneath 100-BC, including data collected during this remedial investigation at 10 waste sites and 10 groundwater monitoring wells in 100-BC. A diagrammatic evaluation is also presented to identify the occurrence of analytes detected above background at closed out, interim closed, and no action waste sites. Description of soil contamination is based on data collected between 1992 and 2011, and detection of constituents above background soil concentrations identified in Table 4-1. Data used to prepare this section include analytical results from the following investigations: the remedial investigation as outlined in the 100-BC Work Plan (DOE/RL-2008-46-ADD3), interim remedial actions as guided by interim action RODs, remedial action borehole sampling, and Limited Field Investigations. Radiological data are decayed through 2012 (*100-B/C Remedial Investigation Radiological Decay Calculations*, 0100X-CA-V0064 [WCH, 2011]).

The soil analytical data set applicable to RI sampling includes radionuclides constituents characterized as having short half-lives (for example, <3 years), common laboratory contaminants, essential nutrients, and other nontoxic constituents. These constituents are commonly not discussed as detections, are primarily an artifact of the sampling and analysis process, not observed above background concentrations, or not a human health concern (that is, nontoxic) per *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A): Interim Final* [EPA/540/1-89/002]). Analytes excluded from consideration in 100-BC are identified in *100-BC Target Analyte List Development for Soil* (WCH-329) and are shown in Table 4-2. Table 4-3 presents the RI investigation targets for each waste site. Appendix D contains the complete soil analytical data set.

**Table 4-2. 100-BC Soil Analytes Excluded from Further Consideration**

| Analyte | Exclusion Rationale |
|---|---|
| **Radionuclides** | |
| Cobalt-58 | Half-life less than 3 years (70.856 d), stable daughter product |
| Cesium-134 | Half-life less than 3 years (2.0662 y), stable daughter product |
| Ruthenium-106 | Half-life less than 3 years (1.0235 y), stable daughter product |
| Sodium-22 | Half-life less than 3 years (2.6036 y), stable daughter product |
| Potassium-40 | Naturally occurring background radiation not associated with 100 Area processes |
| Radium-226 | Naturally occurring background radiation not associated with 100 Area processes (insufficient in-growth time for potential introduction as decay daughter of Hanford U-234/thorium-230) |
| Radium-228 | Naturally occurring background radiation not associated with 100 Area processes (present in secular equilibrium with parent thorium-232 isotope) |

**Table 4-2. 100-BC Soil Analytes Excluded from Further Consideration**

| Analyte | Exclusion Rationale |
|---|---|
| Silver-108m | Present only as a potential trace impurity in certain irradiated materials; no confirmed detections in 100 Area samples to date |
| Thorium-228 | Naturally occurring background radiation not associated with 100 Area processes (present in secular equilibrium with parent radium-228 isotope) |
| Thorium-232 | Naturally occurring background radiation not associated with 100 Area processes |
| **Nonradionuclides** | |
| Acetone | Laboratory contaminant |
| bis[*2-Ethylhexyl*]phthalate | Laboratory contaminant |
| Di-n-butylphthalate | Laboratory contaminant |
| Methylene chloride | Laboratory contaminant |
| Toluene | Laboratory contaminant[a] |
| Calcium | Essential nutrient |
| Iron | Essential nutrient |
| Magnesium | Essential nutrient |
| Potassium | Essential nutrient |
| Sodium | Essential nutrient[b] |
| Phosphorus | Essential nutrient[b] |
| Sulfate | No toxicity information available |
| delta-BHC | No toxicity information available |

Note: List is from *100-BC Target Analyte List Development for Soil* (WCH-329), except as noted.

a. Common laboratory contaminant neither included in the master target analyte list for 100-BC nor a site-specific analyte in the 100-BC SAP (DOE/RL-2009-44).

b. Essential nutrient neither included in the master target analyte list for 100-BC nor a site-specific analyte in the 100-BC SAP (DOE/RL-2009-44).

The following sections summarize the maximum detected concentrations above background and the vertical extent of contamination at RI waste sites. Analytes that were not detected above background are not reported in these summary tables, figures, and associated text. The lateral extent of contamination at waste sites is defined by the boundary of the excavated footprint associated with soil remediation efforts (that is, RTD). Appendix A shows the original and excavated waste site footprints.

Table 4-3. Remedial Investigation Target

| Characterization Target | RI Borehole | RI Well | RI Test Pit |
|---|---|---|---|
| 100-B-5 Trench | C7846 | 199-B4-15 | - |
| 116-B-14 Trench | C7842 | - | - |
| 116-B-5 Crib | C7844 | - | - |
| 116-B-6B Crib | - | - | TP-1 |
| 116-B-9 French Drain | - | - | TP-2 |
| 116-C-5 Retention Basin | C7843 | 199-B3-52 | - |
| 118-B-6 Burial Ground | C7845 | - | - |
| 118-B-8:1 Fuel Storage Basin (B Reactor subsite) | C7847* | - | - |
| | C8239 | - | - |
| 118-B-8:3 Process Sewer (B Reactor subsite) | - | - | TP-3 |
| 118-C-3:2 Fuel Storage Basin (C Reactor Subsite) | C7849 | - | - |
| Rewetted zone (not waste site-specific) | C7508 | 199-B8-9 | - |
| | C7784 | 199-B2-16 | - |
| | C7785 | 199-B3-51 | - |
| | C8244 | 199-B5-8 | - |

* An obstruction was encountered at 4.3 m (14 ft) bgs and the borehole was relocated to C8239.

### 4.2.1 Waste Site Characterization

The 100-BC RI generated characterization data for ten waste sites. The data were considered in conjunction with data generated during previous investigations and remedial actions to enhance understanding of the lateral and vertical extent of contamination at these ten waste sites, and further refine the preliminary conceptual site model as outlined in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). Seven of the waste sites were characterized with new boreholes and three were characterized by excavation and sampling of new test pits. Data and summary information from the 100-C-7 and 116-C-1 waste sites is also presented, although no characterization activities were conducted at these sites explicitly as part of the RI investigation. Vadose zone samples were also collected at new groundwater monitoring wells, primarily to help characterize the periodically rewetted zone. Chapter 2 shows the locations of waste sites, boreholes, groundwater monitoring wells, and test pits.

For discussion of radionuclide activities, the sample values presented represent the original sample activity decayed through the year 2012.

Vertical profile figures are used here to depict analytical results relative to background concentrations, waste site structure, stratigraphy, and the water table, all presented relative to depth below ground surface. For waste sites where remedial excavation has occurred, the vertical profiles also incorporate the maximum depth of remedial excavation.

#### 4.2.1.1 Nature and Extent of Contamination—116-B-14 Trench

The 116-B-14 Waste Site was an unlined trench used to dispose of sludge removed from the bottom of the 107-B Retention Basin (116-B-11 Waste Site) during maintenance cleanout operations in 1948. Available records do not identify any other substantive waste stream. The site was taken out of service in 1948 and covered with about 1.8 m (6 ft) of soil. Remedial excavation, conducted in 1998, extended to a maximum depth of 6 m (20 ft) below the surrounding grade. Contaminants of concern for verification sampling included americium-241, cobalt-60, cesium-137, europium-152, europium-154, europium-155, plutonium-238, plutonium-239/240, strontium-90, uranium-238, total chromium, Cr(VI), mercury, and lead (*Cleanup Verification Package for the 116-B-14 North Sludge Trench* [CVP-99-00003]). Based on evaluation of the analytical results for shallow and deep zone closure verification samples, summarized in Table 4-4, the site was determined to meet interim closure requirements.

The 116-B-14 Waste Site was selected for additional characterization to support development of a CSM for low-volume liquid sites and to address the potential for PCB contamination, which was not addressed during the interim remedial action. In addition, this site is of interest because ofits location with respect to the tritium, strontium-90, and Cr(VI) groundwater plumes. This site was characterized with a single RI borehole, C7842, drilled through the center of the former trench location, to a total depth of 16.8 m (55 ft) bgs. Groundwater was encountered at 14.0 m (46 ft) bgs. Samples were collected at ten discrete depth intervals, with one interval transected by the water table and another fully within the aquifer. RI analytical results are summarized in Table 4-4 and depicted in Figure 4-5.

Cesium-137 was detected only in RI samples collected between 6.1 and 11.3 m (20 and 37 ft) bgs, with the maximum concentration, 3.39 pCi/g, occurring in the uppermost sample interval (Figure 4-15). Concentrations measured in samples below this uppermost interval decreased rapidly with depth. Low levels of strontium-90 were detected throughout the vadose zone with a maximum result of 0.778 pCi/g at 9.8 m (32 ft) bgs. Americium-241 was detected in a single sample, collected at about 13.1 m (43 ft) bgs (roughly 0.9 m (3 ft) above the water table) at a concentration of 0.747 pCi/g. Characterization data do not support a determination of its source. Uranium-233/234 and U-238 were detected in all samples, but at levels below background. No other radionuclides from the target analyte list were detected.

PCBs were not detected in any of the RI sample intervals. Cr(VI) was not detected in any of the samples while total chromium slightly above background was detected in several samples between about 8.2 m and 12.2 m (27 and 40 ft) bgs. Elevated concentrations of both total chromium and nickel observed in the sample collected at about 16.2 m (53 ft) bgs show evidence of stainless steel contamination from sampling equipment, which artificially increases the respective concentrations (Section 4.2.2). Low concentrations of lithium, mercury, and molybdenum were detected above the background established in ECF-HANFORD-11-0038 but all detections of mercury were less than the PQL. Concentrations of nonradiological analytes for which a background value is not available (for example, strontium and tin) are consistent with concentrations measured in other 100-BC RI samples.

Collectively these data suggest that there was not significant contaminant migration beyond the former low-volume liquid disposal trench and previous remediation efforts. The potential for PCB contamination at the site was identified based on the potential for PCBs in the retention basin sludge disposed to the trench, but PCBs were not detected in RI sampling. Tritium and Cr(VI) also were not detected in the underlying vadose zone, and this site is not believed to be significant relative to groundwater plumes of those contaminants. Low activity strontium-90 contamination was detected extending through the vadose zone beneath the waste site, but this site is likely not significant as a potential source of strontium-90 groundwater contamination relative to other waste sites in the vicinity that received larger volumes of liquid waste disposal. All data for this site are considered in the refinement of the conceptual site model and risk evaluation in subsequent chapters.

## Table 4-4. 116-B-14 Trench—Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Back-ground | Cleanup Verification Data[a] (1999) | | | | Remedial Investigation Borehole C7842[b] (2010) | | | |
| | | Shallow Zone[c] | | Deep Zone | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (16 m/52.8 ft bgs unless otherwise noted)[d] |
| | | Original | Decayed | Original | Decayed | Original | Decayed | | Original | Decayed |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[e]** | | | | | | | | | | |
| Americium-241 | NA | 0.182 | 0.178 | 0.036 (U) | NA | 0.749 (13 / 42.7) | 0.747 | 13 / 42.7 | U (14.4 / 47.3 ft) | U |
| Cesium-137 | NA | 0.785 | 0.582 | 5.37 | 3.98 | 3.55 (6.8 / 22.3) | 3.39 | 11.4 / 37.3 | U (14.4 / 47.3 ft) | U |
| Cobalt-60 | NA | 0.057 (U) | NA | 0.028 (U) | NA | U | NA | NA | U (14.4 / 47.3 ft) | U |
| Europium-152 | NA | 1.31 | 0.67 | 1.21 | 0.62 | U | NA | NA | U (14.4 / 47.3 ft) | U |
| Europium-154 | NA | 0.164 (U) | NA | 0.631 | 0.221 | U | NA | NA | U (14.4 / 47.3 ft) | U |
| Europium-155 | NA | 0.109 | 0.016 | 0.081 (U) | NA | U | NA | NA | U (14.4 / 47.3 ft) | U |
| Plutonium-239/240 | NA | 0.267 | 0.267 | 0.068 | 0.068 | U | NA | NA | U (14.4 / 47.3 ft) | U |
| Strontium-90 | NA | 1.14 | 0.84 | 1.35 | 0.99 | 0.816 (9.8 / 32.3) | 0.778 | 16.0 / 52.8 | 0.555 | 0.529 |
| **Nonradionuclides (mg/kg)** | | | | | | | | | | |
| Chromium | 18.5 | 31.2 | | 17.9 (<BG) | | 42.7 (16 0 / 52.8)[f] | | 16.0 /52.8 | 42.7[f] | |
| Cr(VI) | NA | 0.253 | | 0.231 | | U | | NA | U | |
| Lead | 10.2 | 18.7 | | 5.0 (<BG) | | 5.03 (<BG) (10.7 / 35.2) | | NA | 2.09 (<BG) | |
| Lithium | 13.3 | ND | | ND | | 13.9 (10.7 / 35.2) | | 10.7 / 35.2 | 4.96 (<BG) | |
| Mercury | 0.0131 | 0.03 | | 0.02 | | 0.015 (6.8 / 22.3) | | 9.8 / 32.3 | U | |
| Molybdenum | 0.470 | ND | | ND | | 1.83 (8.3 / 27.3) | | 16.0 / 52.8 | 1.82 | |
| Nickel | 19.1 | ND | | ND | | 24.2 (16.0 / 52.8)[f] | | 16.0 / 52.8 | 24.2[f] | |

## Table 4-4. 116-B-14 Trench—Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | |
|---|---|---|---|---|---|---|
| | | Cleanup Verification Data[a] (1999) | | Remedial Investigation Borehole C7842[b] (2010) | | |
| | Back-ground | Shallow Zone[c] | Deep Zone | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection Above BG (m/ft bgs) | Result at Maximum Sample Depth (16 m/52.8 ft bgs unless otherwise noted)[d] |
| Strontium | NA | ND | ND | 30.4 (12.1 / 39.8) | 16.0 / 52.8 | 24.6 |
| Tin | NA | ND | ND | 1.64 (8.3 / 27.3) | 16.0 / 52.8 | 1.62 |

a. Verification sample results represent the maximum 95% UCL concentration from the given decision unit(s). Values that are followed by (U) indicate that none of the data used for 95% UCL calculation were detected above the sample minimum detectable activity. Verification 95% UCL values were obtained from *Cleanup Verification Package for the 116-B-14 North Sludge Trench* (CVP-99-00003). The maximum depth of interim remedial action at 116-B-14 was 6 m (19.7 ft) bgs.

b. Borehole data obtained from HEIS. The water table was encountered at 46 ft. Well was drilled to 55 ft.

c. Shallow zone value represents the excavation area unless otherwise noted.

d. The maximum depth from which samples were collected is in the rewetted zone/aquifer.

e. Original radiological data presented in left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% UCL values obtained using U-flagged data sets is not decayed.

f. Results of chromium and nickel in B27FF5 collected at 16.0 m (52.8 ft) bgs indicate potential stainless steel contamination in the sample. The maximum values of chromium and nickel from the borehole excluding this sample are 24.9 and 17.1 mg/kg, respectively, at 10.7 m (35.2 ft) bgs. Concentrations of chromium and nickel are 14.6 and 15.0 mg/kg, respectively, in the sample interval above B27FF5 collected at 14.4 m (47.3 ft) bgs. See stainless steel contamination discussion in Section 4.2.2.

BG = background
NA = not applicable
ND = no data, not a contaminant of concern/contaminant of potential concern
U = undetected
UCL = upper confidence limit

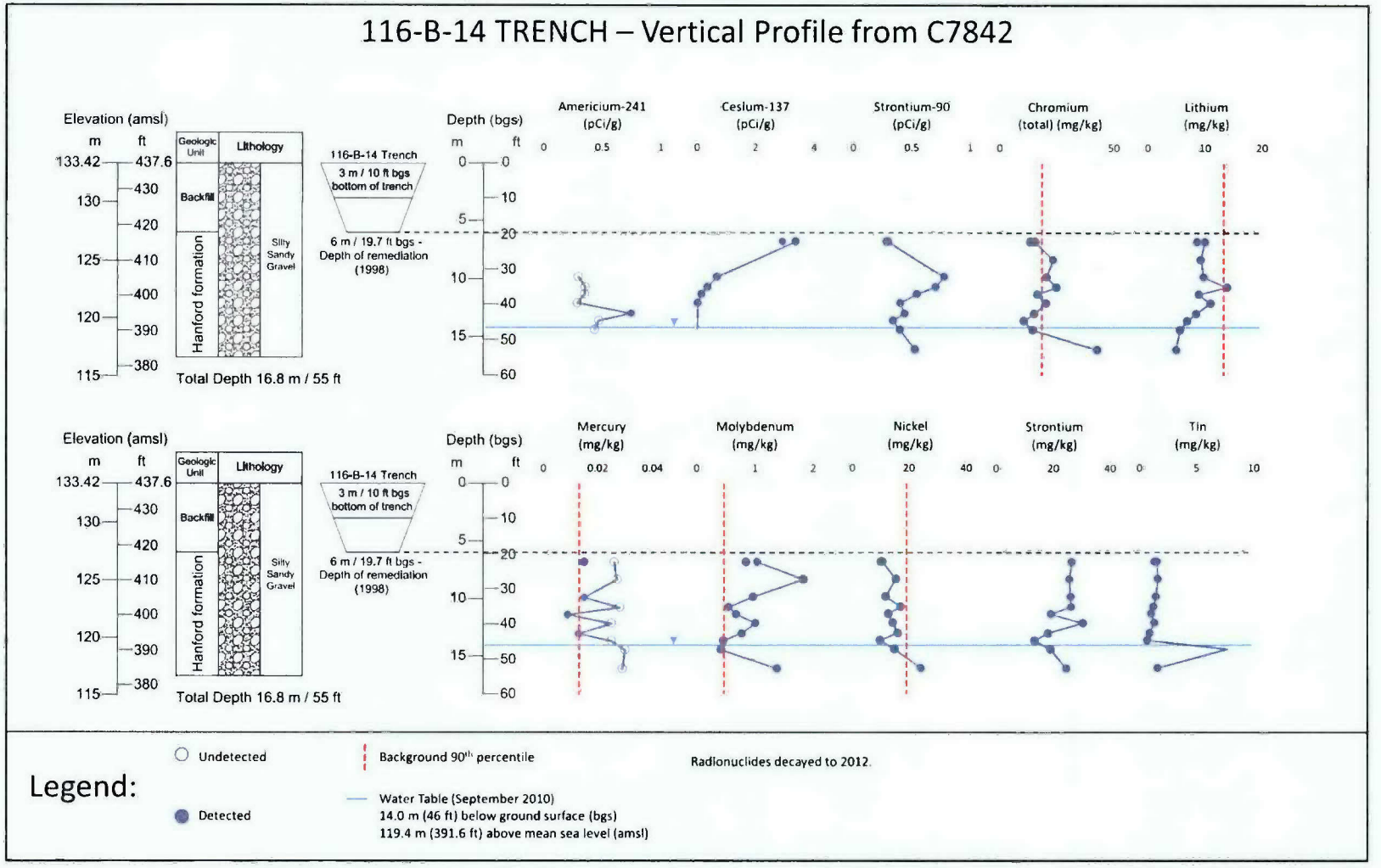


**Figure 4-5. Vertical Profile from Borehole C7842**

#### 4.2.1.2 Nature and Extent of Contamination—116-B-5 Crib

The 116-B-5 Waste Site was a 3.4 m (11 ft) deep crib that received roughly 10 million L (2.6 million gal) of tritiated effluent from the 108-B Tritium Separation Facility (132-B-1 waste site) containing hundreds of gallons of mercury. Solvents and degreasers such as carbon tetrachloride, methyl alcohol, and trichloroethylene were also reportedly discharged to the crib.

As part of a limited field investigation, conducted in 1992, Borehole 199-B5-4 was drilled through the 116-B-5 Crib to a depth of 5.2 m (17 ft) bgs. Vadose zone samples were collected at three depth intervals for laboratory analysis. Data from all three intervals are summarized in Table 4-5, and depicted in Figure 4-6, but only the deepest sample, collected at 5.5 m (18 ft) bgs, is representative of residual soil, as soil associated with the upper two intervals were removed during remedial excavation (1995). Analysis of the 199-B5-4 samples identified no substantive radionuclide contamination, and in the deepest sample, showed copper and zinc, above background. Mercury was detected above background in all three samples with the maximum detection of 2.9 mg/kg at 5.2 m (17 ft) bgs.

Remedial excavation, conducted in 1995 under the 100-BC Demonstration Project, extended to a maximum depth of about 5 m (16 ft) (*Clean Up Verification Package for the 116-B-5 Crib* [NPL-111]). COCs were cobalt-60, cesium-137, europium-152, europium-154, tritium, barium, and mercury. The site was interim closed based on verification sampling results, summarized in Table 4-5.

## Table 4-5. 116-B-5 Crib Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | LFI Borehole 199-B5-4[b] | | | | | Remedial Investigation Borehole C7844[c] | | | | |
| | Back-ground | Cleanup Verification Data[a] Shallow Zone | | Maximum Result with Corresponding Depth (m / ft bgs) | | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (5.2 m /17.0 ft bgs) | | Maximum Result with Corresponding Depth (m / ft bgs) | | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (22.3 m /73.1 ft bgs unless otherwise noted)[d] | |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[e]** | | | | | | | | | | | | | |
| | | Original | Decayed | Original | Decayed | | Original | Decayed | Original | Decayed | | Original | Decayed |
| Cesium-137 | NA | 0.23 | 0.16 | 0.132 (2.1 / 6.9) | 0.083 | 2.1 / 6.9 | U | NA | U | NA | NA | U | NA |
| Cobalt-60 | NA | 0.17 | 0.02 | 0.26 (3.4 / 11.0) | 0.019 | 5.2 / 17.0 | 0.18 | 0.013 | U | NA | NA | U | NA |
| Europium-152 | NA | 1.26 | 0.53 | 1.5 (3.4 / 11.0) | 0.55 | 3.4 / 11.0 | 1.5 (3.4 / 11.0) | 0.55 (3.4 / 11.0) | U | NA | NA | U | NA |
| Europium-154 | NA | 1.02 | 0.26 | ND | ND | ND | ND | ND | U | NA | NA | U | NA |
| Nickel-63 | NA | ND | ND | ND | ND | ND | ND | ND | 4.53 (17.8 / 58.5) | 4.47 | 17.8 / 58.5 | U | NA |
| Strontium-90 | NA | ND | ND | U | NA | NA | U | NA | 1.9 (20.7 / 68.0) | 1.8 | 22.3 / 73.1 | 0.527 | 0.502 |
| Tritium | NA | 48.48 | 18.6 | ND | ND | ND | ND | ND | 16.9 (5.4 / 17.7) | 15.1 | 11.4 / 37.4 | U | NA |
| **Nonradionuclides (mg/kg)** | | | | | | | | | | | | | |
| Antimony | 0.130 | ND | | U | | NA | U | | 0.351 (18.2 / 59.8) | | 18.2/59.8 | U | |
| Arsenic | 6.5 | ND | | 5.1 (<BG) (3.4 / 11.0) | | NA | 0.74 (<BG) | | 10.9 (19.2 / 63.0) | | 19.2/;63 | 1.46 | |
| Barium | 132 | 412.07 | | 484 (3.4 / 11.0) | | 3.4 / 11.0 | 78.6 (<BG) | | 92.4 (<BG) | | NA | 44.4 (<BG) | |
| Chromium | 18.5 | ND | | 19.6 (3.4 / 11.0) | | 3.4 / 11.0 | 6.9 (<BG) | | 306 (18.2 / 59.8)[f] | | 18.2/59.8 | 17.0 (<BG) | |

Table 4-5. 116-B-5 Crib Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | LFI Borehole 199-B5-4[b] | | | Remedial Investigation Borehole C7844[c] | | |
| | Back-ground | Cleanup Verification Data[a] Shallow Zone | Maximum Result with Corresponding Depth (m / ft bgs) | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (5.2 m /17.0 ft bgs) | Maximum Result with Corresponding Depth (m / ft bgs) | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (22.3 m /73.1 ft bgs unless otherwise noted)[d] |
| Copper | 22 | ND | 26.8 (3.4 / 11.0) | 5.2 / 17.0 | 26.1 | 66.2 (18.2 / 59.8)[f] | 18.2 / 59.8 | 9.93 (<BG) |
| Mercury | 0.0131 | 2.17 | 2.9 (5.2 / 17.0) | 5.2 / 17.0 | 2.9 | 2.06 (5.4 / 17.7) | 20.7 / 68.0 | U |
| Molybdenum | 0.470 | ND | ND | ND | ND | 51.1 (18.2 / 59.8)[f] | 22.3 / 73.1 | 1.01 |
| Nickel | 19.1 | ND | 9.6 (<BG) (2.1 / 6.9) | NA | 6.1 (<BG) | 28.8 (18.2 / 59.8)[f] | 18.2 / 59.8 | 10.3 (<BG) |
| Nitrate | 52 | ND | 122.3 (3.4 / 11.0) | 3.4 / 11.0 | 4.1 (<BG) | 72.4 (12.8 / 42.0) | 14.8 / 48.6 | U (68.0 ft) |
| Nitrate as N | 11.8 | ND | ND | ND | ND | 17.7 (12.8 / 42.0) | 14.8 / 48.6 | 0.53 (<BG) (68.0 ft) |
| Strontium | NA | ND | ND | ND | ND | 24.4 (16.2 / 53.0) | 22.3 / 73.1 | 13.5 |
| Sulfate | 237 | ND | 566 (3.4 / 11.0) | 3.4 / 11.0 | 39 (<BG) | 103 (<BG) | NA | 14.1 (<BG) (68.0 ft) |
| Thallium | 0.185 | ND | U | NA | U | 0.469 (6.7 / 22.0) | 6.7 / 22.0 | U |
| Tin | NA | ND | ND | ND | ND | 5.36 (18.2 / 59.8) | 22.3 / 73.1 | 2.59 |
| Vanadium | 85.1 | ND | 43.7 (<BG) (5.2 / 17.0) | NA | 43.7 (<BG) | 87.1 (16.2 / 53.0) | 16.2 / 53.0 | 39.1 (<BG) |
| Zinc | 67.8 | ND | 125 (5.2 / 17.0) | 5.2 / 17.0 | 125 | 113 (5.4 / 17.7) | 5.4 / 17.7 | 29.8 (<BG) |

## Table 4-5. 116-B-5 Crib Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | LFI Borehole 199-B5-4[b] | | | Remedial Investigation Borehole C7844[c] | | |
| | Back-ground | Cleanup Verification Data[a] Shallow Zone | Maximum Result with Corresponding Depth (m / ft bgs) | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (5.2 m /17.0 ft bgs) | Maximum Result with Corresponding Depth (m / ft bgs) | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (22.3 m /73.1 ft bgs unless otherwise noted)[d] |

a. Verification sample results represent the 95% UCL concentration from the shallow zone decision unit. Verification 95% UCL values were obtained from *Clean Up Verification Package for the 116-B-5 Crib* (NPL-111). Maximum depth of interim remedial action was 5 m (16.4 ft) bgs.

b. Borehole data obtained from *Limited Field Investigation Report for the 100-BC-1 Operable Unit* (DOE/RL-93-06) and HEIS. Three vadose zone soil samples taken in 1992 for LFI investigation at 2.6, 3.4, and 5.2 m (8.6, 11.2, and 17.0 ft) bgs (deeper end of interval reported). Total borehole depth was 24.6 ft bgs.

c. Borehole data obtained from HEIS. The water table was encountered at 20.4 m (67 ft) bgs. Well was drilled to 22.3 m (73.1 ft) total depth

d. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

e. Original radiological data presented with decay corrected value to year 2012 in parentheses.

f. See discussion of maximum result in 116-B-5 RI borehole C7844 associated text.

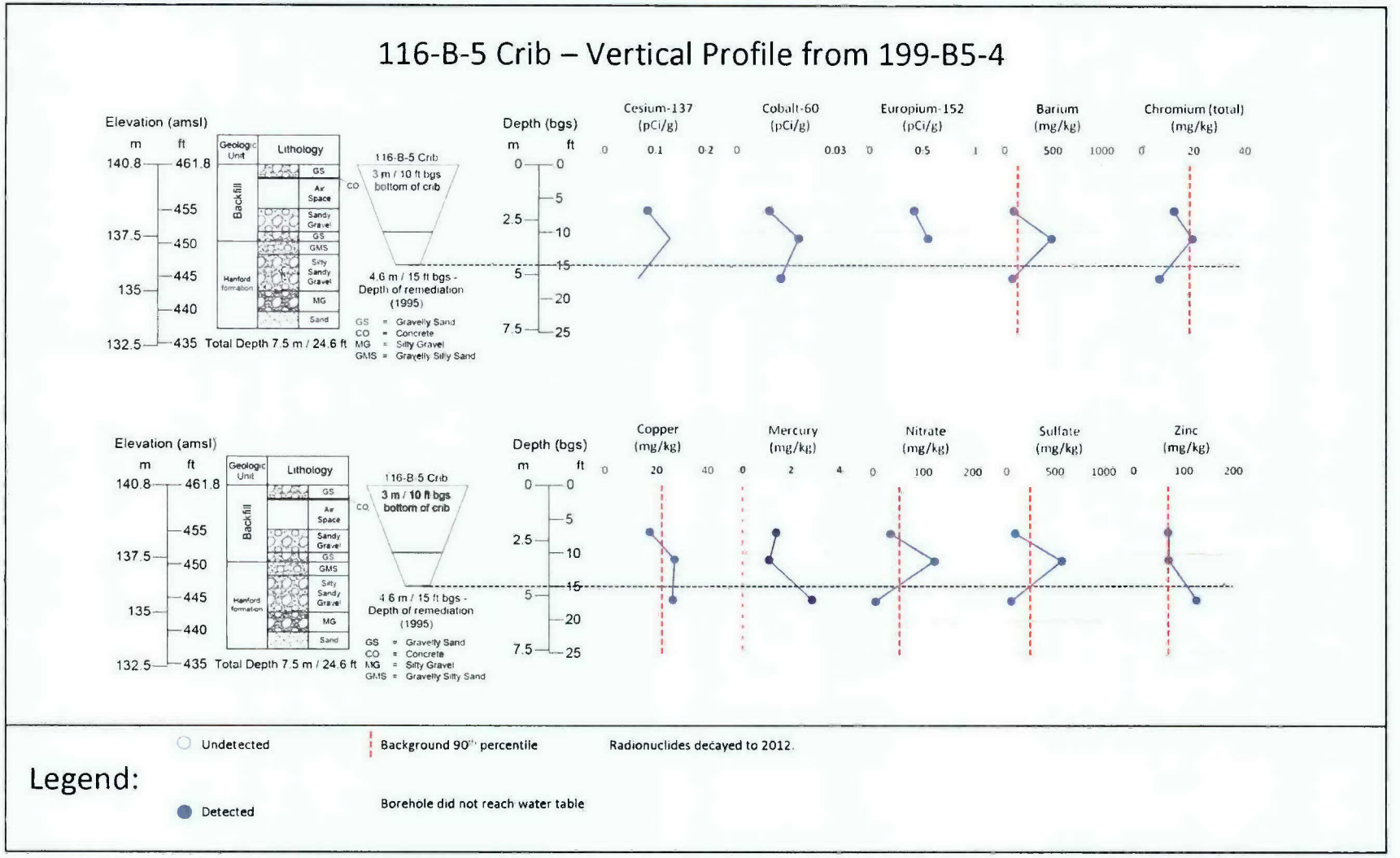


**Figure 4-6. Vertical Profile from LFI Borehole 199-B5-4**

The 116-B-5 Waste Site was selected for additional characterization under the RI because the list of COCs evaluated during the interim closure was limited and cleanup verification samples collected at 5 m (16 ft) bgs contained elevated tritium, mercury, and barium. In addition, this site is of interest because of its location with respect to the strontium-90, tritium and Cr(VI) groundwater plumes. RI borehole C7844 was drilled through soil beneath the southern half of the crib, to a total depth of 22.3 m (73 ft) bgs. Groundwater was encountered at 20.4 m (67 ft) bgs.

Analytical data from borehole C7844 show no substantive residual radionuclide mass in the upper 18.3 m (60 ft) of the vadose zone (Figure 4-7). Three radionuclides from the target analyte list were detected in this interval. Nickel-63 was detected in two samples (5.5 m and 8.2 m [18 and 27 ft] bgs), at concentrations of less than 5 pCi/g; strontium-90 was detected in one sample (8.5 m [28 ft] bgs) at 0.330 pCi/g; and tritium was detected in the five samples collected between 5.5 m and 11.3 m [18 and 37 ft] bgs, with a maximum concentration of 15.1 pCi/g at about 5.5 m (18 ft) bgs.

No target analyte radionuclides were detected in the interval between 11.6 m and 17.7 m [38 and 58 ft] bgs; however, two were identified at depth. Nickel-63 was detected in one sample at 4.47 pCi/g from 17.7 m (58 ft) bgs. Strontium-90 was detected at very low levels in all samples collected between 17.7 m and 22.3 m [58 and 73 ft] bgs, showing its highest concentration (1.81 pCi/g) in the sample collected at 20.7 m (68 ft) bgs, below the water table. Comparisons of these data are presented in Table 4-6.

One sample from C7844 was potentially affected by adding water during drilling (sample B28ND4 at 47.3 to 49.8 ft bgs), however results from this interval are consistent with results above and below this interval (Figure 4-7.)

Mercury was detected at 2.06 mg/kg in the uppermost sample (about 5.5 m [18 ft] bgs) and showed decreasing concentration with depth (Figure 4-7). This maximum concentration was measured in the sample interval just below the depth of remediation and compares well with the cleanup verification value of 2.17 mg/kg. Zinc was measured at 113 mg/kg in the uppermost sample but all other results are below background. Low concentrations of antimony and thallium were detected above the background established in ECF-HANFORD-11-0038. Cr(VI) was not detected in any of the samples and all barium results were below background. Carbon tetrachloride and trichloroethene were not detected in any samples.

Anomalous metal results for chromium (306 mg/kg), copper (66.2 mg/kg), molybdenum (51.1 mg/kg), and nickel (28.8 mg/kg) were observed in sample interval 10, collected at about 18.3 m (60 ft) bgs. While the ratio of chromium:nickel for this sample does not fall within the range observed with other samples with probable stainless steel contamination, results from interval 10 are suspect because of these elevated concentrations that are inconsistent with neighboring samples (Table 4-6).

Nitrate was measured as both the anion (nitrate) and as the element (total nitrogen). Samples collected from this borehole show low concentrations of nitrate (as nitrate), with the highest concentration, 72.4 mg/kg, detected at about 12.8 m (42 ft) bgs. Nitrate concentrations as measured by both methods drop below background values at about 14.9 m (49 ft) bgs.

Collectively, these data suggest that there was not significant contaminant migration beyond the prior extent of remediation at the crib. Mercury concentrations above background were detected beneath the base of former remediation, but decrease to background levels with depth. Low-level tritium activities were detected in several RI samples, but the low magnitudes do not suggest that this site is a significant continuing contributor to the underlying tritium groundwater plume. Barium was not detected above background levels in RI samples collected beneath the former crib. This site is not believed to have contributed to underlying Cr(VI) groundwater samples as this contaminant was not significantly

associated with disposal history at the site and it has not been detected in vadose zone soil sampling. Strontium-90 was not significantly detected in the vadose zone underlying the former crib during RI sampling except in the deepest intervals. At these depths, the vadose zone is influenced by fluctuating groundwater elevation, and these results are likely the result of minor contamination from the strontium-90 groundwater plume in the general area. The site data does not suggest that the 116-B-5 site has been a contributor to the strontium-90 groundwater plume. All data for this site are considered in the refinement of the conceptual site model and risk evaluation in subsequent chapters.

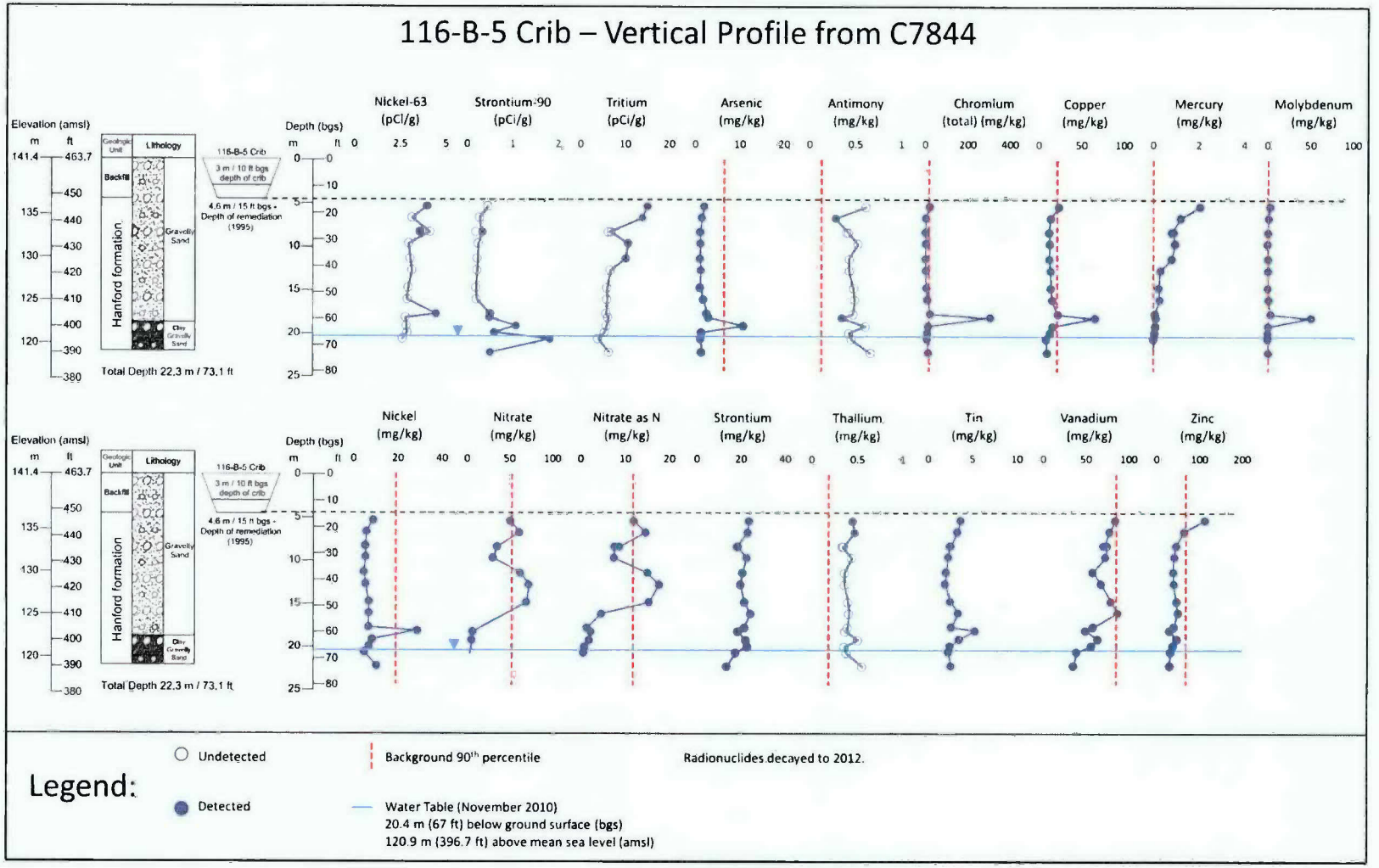


**Figure 4-7. Vertical Profile from Borehole C7844**

**Table 4-6. 116-B-5 Crib Borehole C7844, Interval 10 (Sample B27J76) Chromium, Copper, Molybdenum, and Nickel Results Relative to Neighboring Interval Sample Results**

| Interval | Sample | Sample Depth in m (ft) | Chromium (total) (BG = 18.5 mg/kg) | | Copper (BG = 22 mg/kg) | | Molybdenum (BG = 0.470 mg/kg) | | Nickel (BG = 19.1 mg/kg) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | mg/kg | Q | mg/kg | Q | mg/kg | Q | mg/kg | Q |
| C7844 (116-B-5); I-008 | B27J74 | 16.2 (53.0) | 11.8 | | 16.1 | | 1.31 | B | 6.96 | |
| C7844 (116-B-5); I-009 | B27J75 | 17.8 (58.5) | 25.5 | | 22.7 | | 3.56 | | 6.62 | |
| C7844 (116-B-5); I-010 | B27J76 | 18.2 (59.8) | 306 | | 66.2 | | 51.1 | | 28.8 | |
| C7844 (116-B-5); I-011 | B27J77 | 19.2 (63.0) | 16.5 | | 16.5 | | 1.04 | B | 8.46 | |

B = analyte detected at less than the contract required detect limit, but greater than the detection limitQ = qualifier

#### 4.2.1.3 Nature and Extent of Soil Contamination—118-C-3:2 Fuel Storage Basin

The 118-C-3:2 subsite is part of the 105-C Reactor waste site. This subsite consists of the below-grade structures and underlying soil outside the safe storage enclosure. Its primary component is the remnants of the reactor fuel storage basin and underlying soil. Interim safe storage activities for the 105-C Reactor were completed in 1998, and included cleanout of the fuel storage basin and removal of all portions of the fuel storage basin structure that were within 4.6 m (15 ft) of ground surface (*Cleanup Verification Package for the 105-C Reactor Building Below-Grade Structures and Underlying Soils* [CVP-98-00009]). The lower portion of the fuel storage basin walls and the floor were left intact, and the area was backfilled to grade with clean soil. Cleanup verification samples were collected from the remaining portions of the fuel storage basin and from multiple depth intervals in the underlying soil. COCs in the CVP included americium-241, carbon-14, cobalt-60, cesium-137, europium-152, europium-154, europium-155, nickel-63, plutonium-238 and plutonium-239/240, strontium-90, technetium-99, uranium-234, uranium-235, uranium-238, Cr(VI), lead, mercury, and PCBs. Table 4-7 summarizes analytical results for the related cleanup verification soil samples.

The 118-C-3:2 subsite was selected for further characterization because the reactor fuel storage basin contained fuel pool water, spent fuel, and sludge, and is known to have leaked, and additional data are needed to delineate subsurface contamination. RI borehole C7849 was sited to the east of the 105-C Reactor building, at a point roughly 3 m (10 ft) north of the remaining sub grade fuel storage basin structure, and was drilled to a total depth of 32.6 m (107 ft) bgs. Groundwater was encountered at 30.4 m (99.6 ft) bgs.

Sampling identified a number of radionuclides, including cesium-137, cobalt-60, europium-152, europium-154, and nickel-63 in the shallowest samples between about 5.5 and 10 m (18 and 33 ft) bgs (Table 4-7). Strontium-90 was detected between about 6.7 and 14.7 m (22 and 48 ft) bgs with a maximum result of 1.00 pCi/g at 8.2 m (27 ft) bgs. A single detection of tritium (50.8 pCi/g) occurred at about 19.2 m (63 ft) bgs. All radionuclides were found at very low activities, and at a significant distance above the water table (Figure 4-8). No significant residual radionuclide mass was identified.

A number of metals were also detected, all at very low concentrations and with their maxima found well above the water table. A single detection of arsenic at 19.8 mg/kg occurred at about 6.7 m (22 ft) bgs with no other detections above background. Total chromium above background (maximum result of 38.0 mg/kg) was detected between about 6.7 and 10 m (22 and 33 ft) bgs. Cr(VI) was detected in the samples collected at 11.3, 19.2, and 26.5 m (37, 63, and 87 ft) bgs, at concentrations less than 0.3 mg/kg.

Aroclor 1260, the only PCB detected, was found only in the sample collected at about 5.5 m (18 ft) bgs, at a concentration of 0.0075 mg/kg. A number of polycyclic aromatic hydrocarbons, including benzo(*a*)pyrene at 0.0268 mg/kg, were also detected at this same depth, all at very low concentrations. A few (benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, and pyrene) were detected at levels below the practical quantitation limit in samples collected at about 27.4 m (90 ft) bgs, roughly 3 m (10 ft) above the water table. Chrysene was detected at levels below the practical quantitation limit at 15.9 and 22.3 m (52 and 73 ft) bgs.

Motor oil-range petroleum hydrocarbons were detected in the shallowest sample, roughly 5.5 m (18 ft) bgs, at a concentration of 18.6 mg/kg, and in the sample collected below the water table, at a concentration of 4.79 mg/kg. It was not detected in any other sample.

The RI data do not show significant contaminant migration beyond the immediate vicinity of the former fuel storage basin. The elevated tritium concentration detected at approximately 19.2 m (63 ft) bgs is likely associated with the lithology change at this depth. Increased silt content could result in increased entrainment of low-activity tritiated water migrating from the former FSB, but this result suggests an

isolated occurrence, not potentially significant contribution to underlying groundwater. These data are considered collectively with previous characterization data for this site in the refinement of the conceptual site model and risk evaluation in subsequent chapters.

Table 4-7. 118-C-3:2 Fuel Storage Basin Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] (1998) Deep Zone Soil beneath FSB Floor | | Remedial Investigation Borehole C7849[b] (2010) | | | | |
| | | | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (32.8 m / 107.7 ft bgs unless otherwise noted)[c] | |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[d]** | | | | | | | | |
| | | Original | Decayed | Original | Decayed | | Original | Decayed |
| Americium-241 | NA | 2.69 | 2.63 | U | U | NA | U | U |
| Cesium-137 | NA | 171 | 124 | 1.15 (8.1 / 26.7) | 1.10 | 9.9 / 32.7 | U | U |
| Cobalt-60 | NA | 1.69 | 0.27 | 0.211 (6.7 / 22.0) | 0.16 | 6.7 / 22.0 | U | U |
| Europium-152 | NA | 9.19 | 4.48 | 2.18 (6.7 / 22.0) | 1.97 | 8.1 / 26.7 | U | U |
| Europium-154 | NA | 1.47 | 0.48 | 0.181 (6.7 / 22.0) | 0.15 | 6.7 / 22.0 | U | U |
| Nickel-63 | NA | 56.9 | 51.6 | 5.6 (6.7 / 22.0) | 5.5 | 6.7 / 22.0 | U | U |
| Plutonium-238 | NA | 0.263 | 0.235 | U | U | NA | U | U |
| Plutonium 239/240 | NA | 10.4 | 10.4 | U | U | NA | U | U |
| Strontium-90 | NA | 37.6 | 26.9 | 1.05 (8.1 / 26.7) | 1.00 | 14.6 / 47.8 | U | U |
| Technetium-99 | NA | 1.20 | 1.20 | ND | ND | ND | ND | ND |
| Tritium | NA | ND | ND | 56.8 (19.2 / 63.1) | 50.7 | 19.2 / 63.1 | U | U |
| **Nonradionuclides (mg/kg)** | | | | | | | | |
| Antimony | 0.130 | ND | | 3.82 (6.7 / 22.0) | | 6.7 / 22.0 | U | |
| Arsenic | 6.5 | ND | | 19.8 (6.7 / 22.0) | | 6.7 / 22.0 | 0.717 (<BG) | |
| Chromium | 18.5 | ND | | 38 (8.1 / 26.7) | | 9.9 / 32.7 | 2.85 (<BG) | |

Table 4-7. 118-C-3:2 Fuel Storage Basin Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] (1998) Deep Zone Soil beneath FSB Floor | Remedial Investigation Borehole C7849[b] (2010) | | |
| | | | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (32.8 m / 107.7 ft bgs unless otherwise noted)[c] |
| Copper | 22 | ND | 23.7 (6.7 / 22.0) | 6.7 / 22.0 | 13.4 (<BG) |
| Cr(VI) | NA | 0.12 | 0.27 (11.3 / 37.2) | 26.5 / 87.0 | U |
| Lead | 10.2 | 120 | 5.6 (<BG) (5.4 / 17.6) | NA | 1.48 (<BG) |
| Mercury | 0.0131 | U | 0.303 (6.7 / 22.0) | 8.1 / 26.7 | U |
| Molybdenum | 0.470 | ND | 1.96 (13.1 / 43.1) | 32.8 / 107.7 | 0.474 |
| Strontium | NA | ND | 54.1 (6.7 / 22.0) | 32.8 / 107.7 | 14.5 |
| Sulfate | 237 | ND | 278 (6.7 / 22.0) | 6.7 / 22.0 | 17.3 (<BG) |
| Tin | NA | ND | 4.55 (8.1 / 26.7) | 32.8 / 107.7 | 3.72 |
| TPH (motor oil range) | NA | ND | 18.6 (5.4 / 17.6) | 31.2 / 102.3 | 4.79 (31.2 m/ 102.3 ft) |
| Vanadium | 85.1 | ND | 86.3 (8.1 / 26.7) | 22.3 / 73.1 | 60.5 (<BG) |
| Acenaphthene | NA | ND | 0.0138 (5.4 / 17.6) | 28.3 / 92.7 | U (31.2 m/ 102.3 ft) |
| Anthracene | NA | ND | 0.00172 (5.4 / 17.6) | 5.4 / 17.6 | U (31.2m / 102.3 ft) |
| Benzo(a)anthracene | NA | ND | 0.0766 (5.4 / 17.6) | 5.4 / 17.6 | U (31.2 m/ 102.3 ft) |
| Benzo(a)pyrene | NA | ND | 0.0268 (5.4 / 17.6) | 5.4 / 17.6 | U (31.2 m/ 102.3 ft) |
| Benzo(b)fluoranthene | NA | ND | 0.0487 (5.4 / 17.6) | 26.5 / 87.0 | U (31.2 m/ 102.3 ft) |

Table 4-7. 118-C-3:2 Fuel Storage Basin Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] (1998) Deep Zone Soil beneath FSB Floor | Remedial Investigation Borehole C7849[b] (2010) | | |
| | | | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (32.8 m / 107.7 ft bgs unless otherwise noted)[c] |
| Benzo(k)fluoranthene | NA | ND | 0.0203 (5.4 / 17.6) | 26.5 / 87.0 | U (31.2 m/ 102.3 ft) |
| Chrysene | NA | ND | 0.01233 (5.4 / 17.6) | 22.3 / 73.1 | U (31.2 m/ 102.3 ft) |
| Fluoranthene | NA | ND | 0.0505 (5.4 / 17.6) | 5.4 / 17.6 | U (31.2 m/ 102.3 ft) |
| Indeno(1,2,3-cd) pyrene | NA | ND | 0.00132 (5.4 / 17.6) | 5.4 / 17.6 | U (31.2 m/ 102.3 ft) |
| Phenanthrene | NA | ND | 0.0182 (5.4 / 17.6) | 5.4 / 17.6 | U (31.2 m/ 102.3 ft) |
| Pyrene | NA | ND | 0.0897 (5.4 / 17.6) | 27.4 / 90.0 | U (31.2 m/ 102.3 ft) |
| Aroclor 1260 | NA | ND | 0.0075 (5.4 / 17.6) | 5.4 / 17.6 | U (31.2 m/ 102.3 ft) |

a. Verification values obtained from *Cleanup Verification Package for the 105-C Reactor Building Below-Grade Structures and Underlying Soils* (CVP-98-00009). The walls of the FSB were removed to 4.6 m (15 ft) bgs. The remaining walls and floor below 4.6 m (15 ft )bgs were buried in place. Verification sample results represent the maximum concentrations from the soil samples collected at multiple depth intervals beneath the remaining concrete floor of the FSB.

b. Borehole data was obtained from HEIS. The water table was encountered at 30.5 m(100 ft). Well was drilled to 32.8 m (107.7 ft).

c. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

d. Original radiological data presented in left column with decay corrected value to year 2012 in right column.

BG = background
FSB = fuel storage basin
ND = no data, not a contaminant of concern/contaminant of potential concern
TPH = total petroleum hydrocarbon
U = undetected

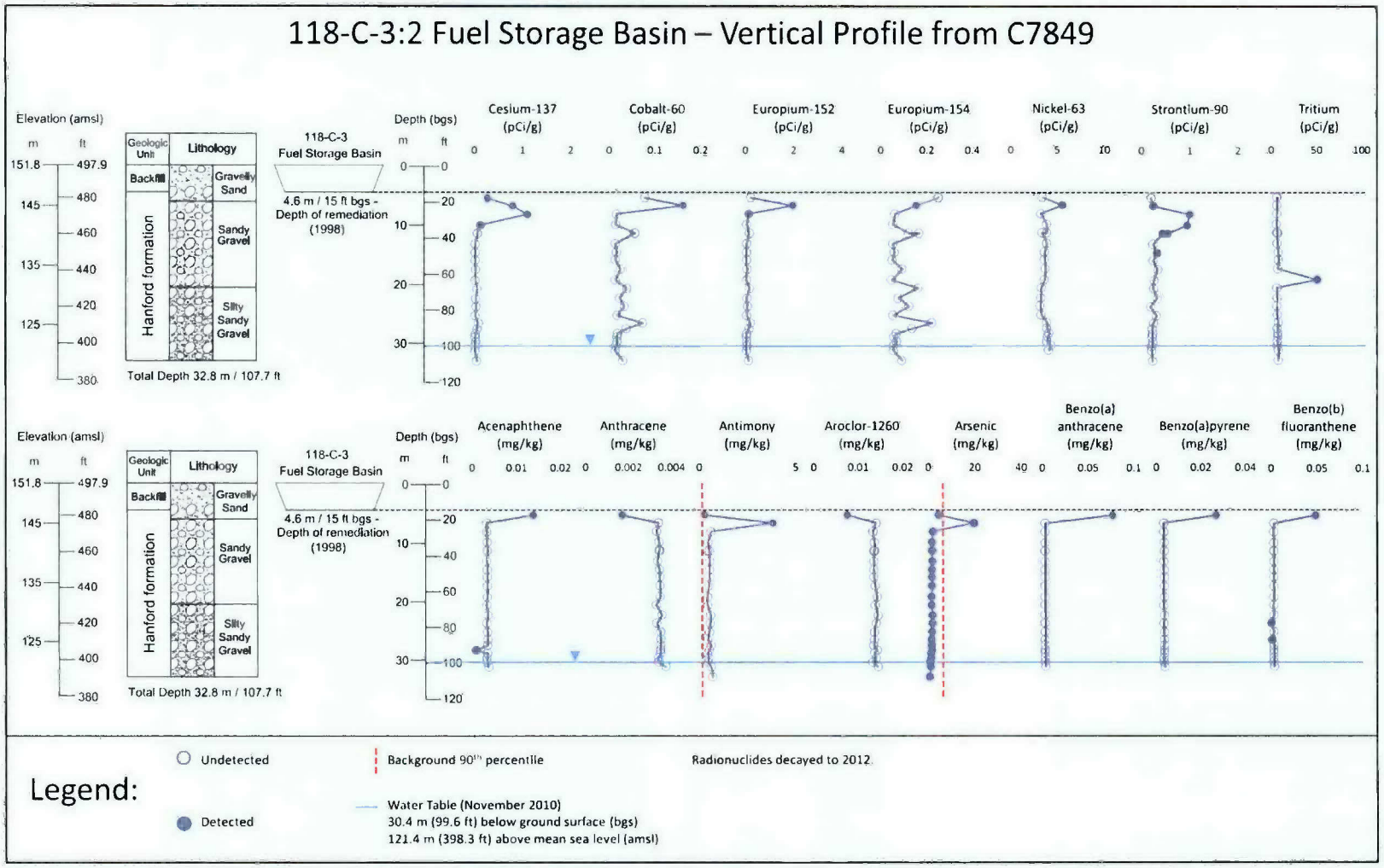


**Figure 4-8. Vertical Profile from Borehole C7849**

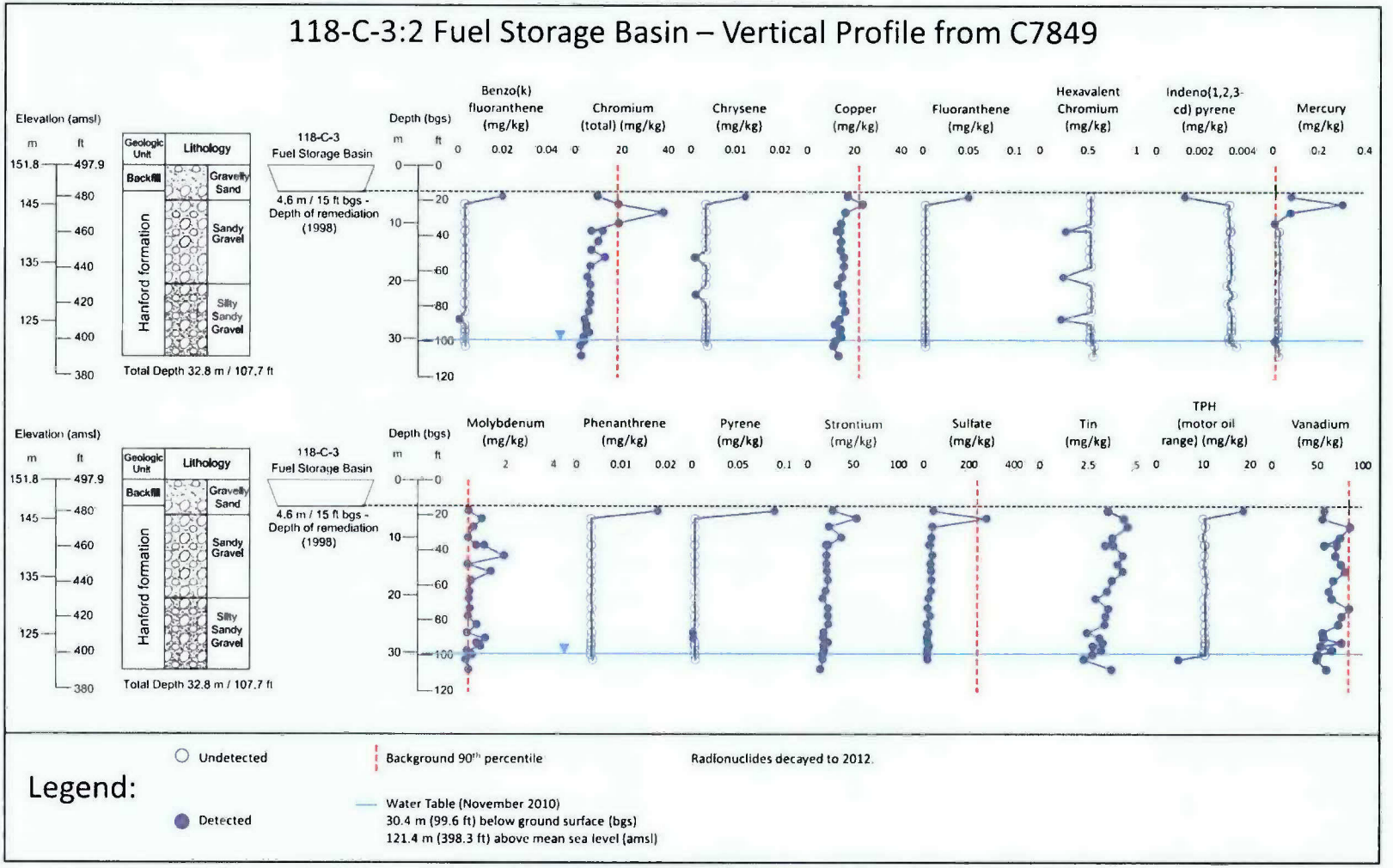


**Figure 4-8. Vertical Profile from Borehole C7849 (cont.)**

#### 4.2.1.4 Nature and Extent of Soil Contamination—100-B-5 Trench

The 100-B-5 Waste Site was not a designed waste facility. It consists of soil contaminated by multiple leaks of reactor cooling water effluent from a vent pipe associated with the 100-B-8:1 and 100-C-6:1 effluent sewers. Remedial excavation, conducted in 2003, extended to a maximum depth of 8.5 m (28 ft) bgs (*Cleanup Verification Package for the 100-B-5 Effluent Vent Disposal Trench* [CVP-2003-00014]). Remedial action COCs were americium-241, cesium-137, cobalt-60, europium-152, europium-154, europium-155, plutonium-238, plutonium-239/240, strontium-90, uranium-238, lead, mercury, total chromium, and Cr(VI). All radionuclides except americium-241 and europium-155 were detected in the deep zone closure verification samples, though uranium-238 was below background levels. All four nonradionuclides were found in the deep zone verification samples; only lead was below background. The site was interim closed based on shallow and deep zone verification sampling results, which are included in Table 4-8.

The 100-B-5 Waste Site was selected for additional characterization because cleanup verification samples collected at 8.5 m (28 ft) bgs contained mercury and total chromium at concentrations that exceeded screening levels for groundwater protection. In addition, this site is of interest because ofits location with respect to the strontium-90 and Cr(VI) groundwater plumes. The site was characterized with RI borehole C7846 (converted to Well 199-B4-15), drilled in the former location of the piping junction box that generated the leaks. The borehole was drilled to a total depth of 25.6 m (84 ft) bgs, intersecting the water table at 22.9 m (75 ft) bgs. Twelve discrete depth intervals were sampled, with one extending a few inches into the water table and two being fully within the aquifer. RI analytical results are summarized in Table 4-8 and depicted in Figure 4-9.

Analytical results indicate that essentially all cesium-137 in the vadose zone at this location is retained between 8.5 and 11.6 m (28 and 38 ft) bgs, immediately beneath the base of the 2003 remedial excavation (Figure 4-9 and Table 4-8). The maximum cesium-137 concentration identified was 17.2 pCi/g, at about 9.1 m (30 ft) bgs. Strontium-90 was detected in each vadose zone sample, as well as two of the three samples collected immediately below the water table. The strontium-90 concentration peak of 6.13 pCi/g occurred at about 12.2 m (40 ft) bgs; samples below roughly 1.8 m (6 ft) bgs showed a consistent decrease in strontium-90 concentration with depth. These results suggest that the site may be minor contributor to the groundwater strontium-90 plume. Low levels of tritium were detected intermittently in the vadose zone at a maximum of 12.3 pCi/g. Cobalt-60 was detected in only one vadose zone sample, at 0.031 pCi/g. Nickel-63 was detected at 5.97 pCi/g in the sample collected at about 22.9 m (75 ft) bgs.

Analytical results for chromium, Cr(VI), and zinc suggest that low levels of these analytes remain in the vadose zone near the base of the remedial excavation, and that the residual concentration is very low. Elevated concentrations of chromium and nickel observed in the sample collected at about 10.7 m (35 ft) bgs show evidence of stainless steel contamination from sampling equipment, which artificially increases the respective concentrations (Section 4.2.2). Chromium results were relatively constant, but elevated, in samples collected in the upper intervals and at or near the water table (Figure 4-9). Cr(VI) was detected below the PQL in the upper three sample intervals while detections measured between 0.62 and 0.89 mg/kg in the deep vadose and into the water table (from 18.6 to 23.8 m [61 to 78 ft] bgs). Given that there are several intermediate intervals where Cr(VI) is not found and total chromium is below background, there is a potential that these contaminants originated elsewhere and were transported to this location via the groundwater. Several additional metals (barium, manganese, and thallium) show a significant increase in concentration in the sample collected at 23.0 m (75.4 ft) bgs; however, higher clay content was observed at this depth. Mercury was not detected above background in RI sampling. All data for this site are considered in the refinement of the conceptual site model and risk evaluation in subsequent chapters

## Table 4-8. 100-B-5 Trench Borehole C7846 (Well 199-B4-15) Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Back-ground | Cleanup Verification Data[a] (2003) | | | | Remedial Investigation Well - 199-B4-15[a] (2010) | | | | |
| | | Shallow Zone | | Deep Zone | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (25.2 m /82.8 ft bgs unless otherwise noted)[c] | |
| Radionuclides (Original and Decayed Concentrations) (pCi/g)[d] | | | | | | | | | | |
| | | Original | Decayed | Original | Decayed | Original | Decayed | | Original | Decayed |
| Americium-241 | NA | 0.150 (U) | NA | 0.452 (U) | NA | U | NA | NA | U | NA |
| Cesium-137 | NA | 0.0507 (U) | NA | 20.3 | 16.5 | 18 (9.3 / 30.4) | 17 | 23.7 / 77.9 | 0.084 (77.9 ft) | 0.080 |
| Cobalt-60 | NA | 0.0457 (U) | NA | 1.50 | 0.46 | 0.04 (12.3 / 40.5) | 0.031 | 12.3 / 40.5 | U | NA |
| Europium-152 | NA | 0.102 (U) | NA | 14.8 | 9.3 | U | NA | NA | U | NA |
| Europium-154 | NA | 0.136 (U) | NA | 1.38 | 0.67 | U | NA | NA | U | NA |
| Europium-155 | NA | 0.103 (U) | NA | 0.292 (U) | NA | U | NA | NA | U | NA |
| Nickel-63 | NA | ND | ND | ND | ND | 6.05 (23.0 / 75.4) | 5.97 | 23.0 / 75.4 | U | NA |
| Plutonium-238 | NA | 0.0291 (U) | NA | 0.233 | 0.217 | U | NA | NA | U | NA |
| Plutonium-239/240 | NA | 0.0954 | 0.0954 | 3.08 | 3.08 | U | NA | NA | U | NA |
| Strontium-90 | NA | 0 (U) | NA | 1.86 | 1.50 | 6.43 (12.3 / 40.5) | 6.13 | 23.7 / 77.9 | U | NA |
| Tritium | NA | ND | ND | ND | ND | 13.8 (9.3 / 30.4) | 12.33 | 18.5 / 60.7 | U | NA |
| Nonradionuclides (mg/kg) | | | | | | | | | | |
| Antimony | 0.130 | ND | | ND | | 0.393 (10.8 / 35.3) | | 10.8 / 35.3 | U | |
| Barium | 132 | ND | | ND | | 170 (23.0 / 75.4) | | 23.0 / 75.4 | 98.4 (<BG) | |

Table 4-8. 100-B-5 Trench Borehole C7846 (Well 199-B4-15) Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | |
|---|---|---|---|---|---|---|
| | Back-ground | Cleanup Verification Data[a] (2003) | | Remedial Investigation Well - 199-B4-15[a] (2010) | | |
| | | Shallow Zone | Deep Zone | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (25.2 m /82.8 ft bgs unless otherwise noted)[c] |
| Chromium | 18.5 | 13 (<BG) | 280 | 87.1 (10.8 / 35.3)[e] | 23.7 / 77.9 | 8.17 (<BG) |
| Copper | 22.0 | ND | ND | 25.6 (25.2 / 82.8) | 25.2 / 82.8 | 25.6 |
| Cr(VI) | NA | 0.43 (U) | 1.8 | 0.89 (23.0 / 75.4) | 25.2 / 82.8 | 0.35 |
| Manganese | 512 | ND | ND | 2570 (23.0 / 75.4) | 23.0 / 75.4 | 424 (<BG) |
| Mercury | 0.0131 | 0.02 | 4.5 | 0.075 (9.3 / 30.4) | 21.5 / 70.5 | 0.013 (<BG) |
| Molybdenum | 0.470 | ND | ND | 1.08 (17.0 / 55.6) | 25.2 / 82.8 | 0.481 |
| Nickel | 19.1 | ND | ND | 33.5 (10.8 / 35.3)[e] | 10.8 / 35.3 | 9.12 (<BG) |
| Strontium | NA | ND | ND | 26.5 (21.5 / 70.5) | 25.2 / 82.8 | 25.8 |
| Thallium | NA | ND | ND | 1.97 (23.0 / 75.4) | 23.0 / 75.4 | U |
| Tin | NA | ND | ND | 3.52 (10.8 / 35.3) | 25.2 / 82.8 | 2.71 |
| Vanadium | 85.1 | ND | ND | 108 (13.8 / 45.3) | 17.0 / 55.6 | 50.4 (<BG) |
| Zinc | 67.8 | ND | ND | 235 (9.3 / 30.4) | 9.3 / 30.4 | 50.4 (<BG) |

## Table 4-8. 100-B-5 Trench Borehole C7846 (Well 199-B4-15) Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | |
|---|---|---|---|---|---|---|
| | | Cleanup Verification Data[a] (2003) | | Remedial Investigation Well - 199-B4-15[a] (2010) | | |
| | Back-ground | Shallow Zone | Deep Zone | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (25.2 m /82.8 ft bgs unless otherwise noted)[c] |

a. Verification sample results represent the maximum 95% UCL concentration from the excavation area unless otherwise noted. Values that show (U) indicate all data used for 95% UCL calculation were nondetects. Verification 95% UCL values obtained from *Cleanup Verification Package for the 100-B-5 Effluent Vent Disposal Trench* (CVP-2003-00014). Maximum depth of interim remedial action at 100-B-5 was 8.5 m (28 ft) bgs.

b. Borehole data obtained from HEIS. The water table was encountered at 22.9 m (75 ft). Well was drilled to 25.7 m (84.3 ft).

c. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

d. Original radiological data presented in left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% UCL values obtained using U-flagged data sets is not decayed.

e. Results of chromium and nickel in sample B27Y42 collected at 10.8 (35.3 ft) bgs indicate potential stainless steel contamination in the sample. The maximum values of chromium and nickel from the borehole excluding this sample are 35.0 and 12.1 mg/kg, at 22.7 m (74.4 ft) and 16.9 m (55.6 ft) bgs, respectively. Concentrations of chromium and nickel are 33.7 and 6.63 mg/kg, respectively, in the sample interval above B27Y42 collected at 9.3 m (30.4 ft) bgs. See stainless steel contamination discussion in Section 4.2.2.

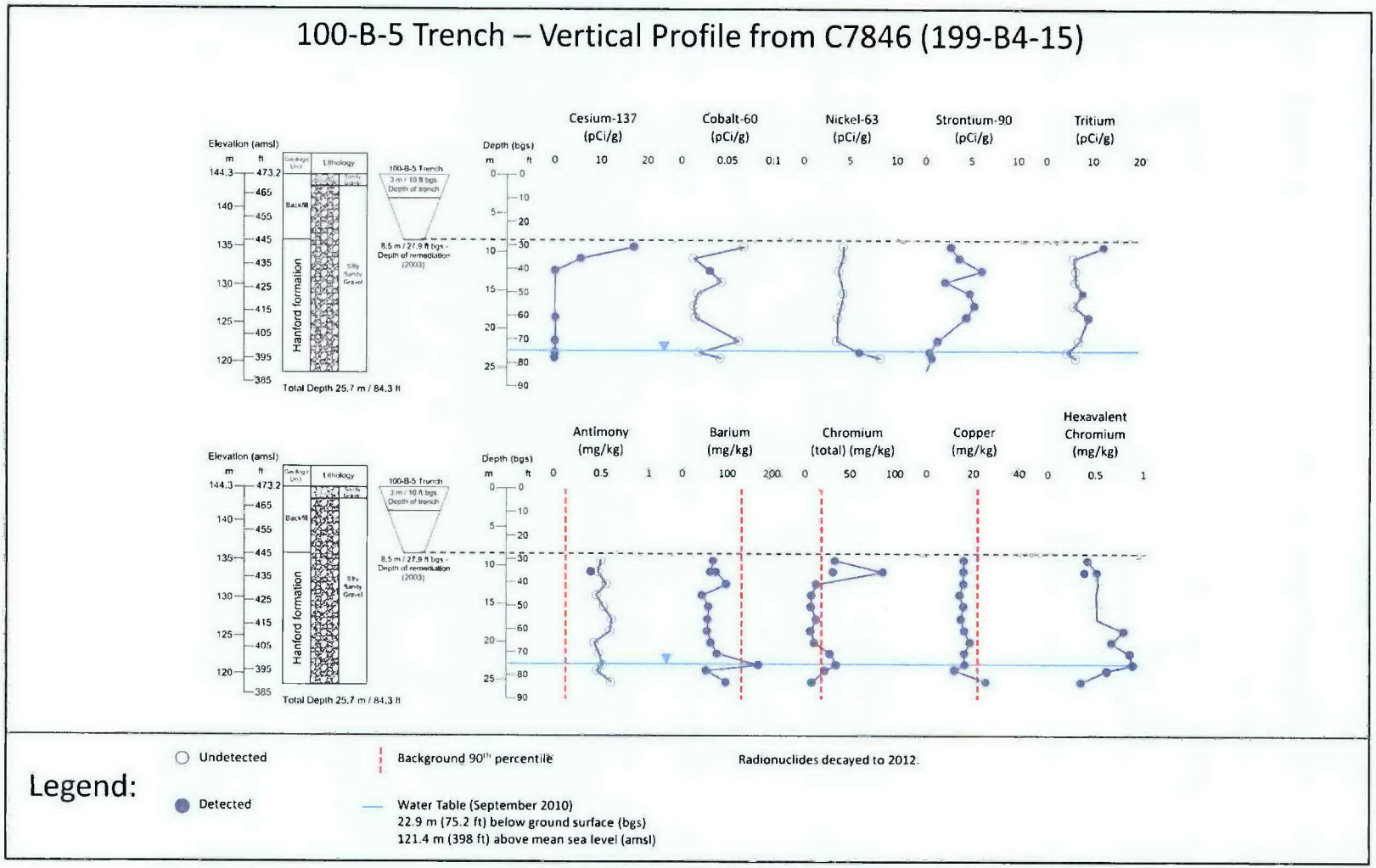


**Figure 4-9. Vertical Profile from Borehole C7846 (Well 199-B4-15)**

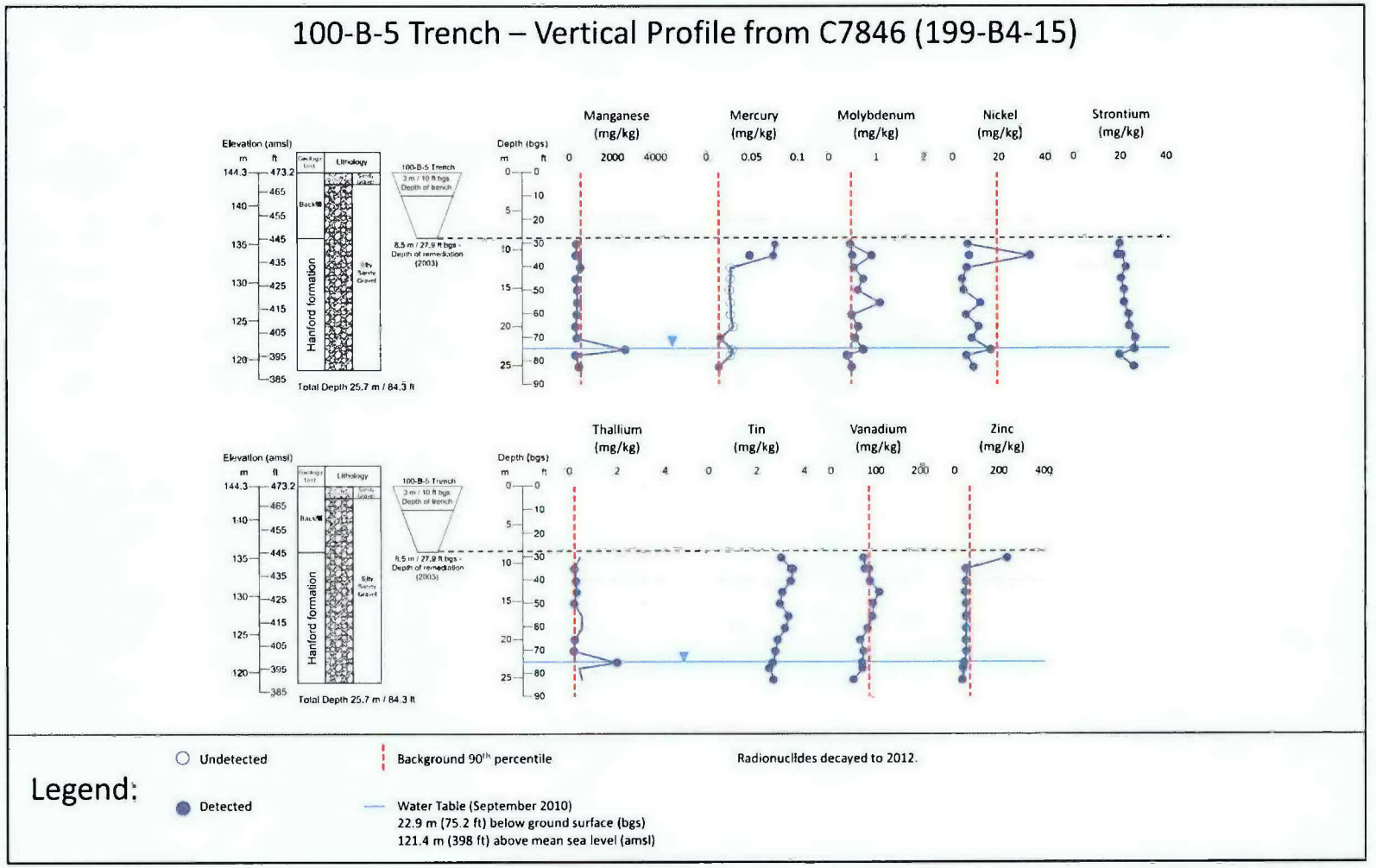


**Figure 4-9. Vertical Profile from Borehole C7846 (Well 199-B4-15) (cont.)**

#### 4.2.1.5 Nature and Extent of Soil Contamination—118-B-8:1 Fuel Storage Basin

The 118-B-8:1 Waste Site is a subsite of the 105-B Reactor that incorporates the reactor building, including subgrade structures and underlying soil. One subgrade component is the FSB, which served as an underwater collection, storage, and transfer facility for the irradiated fuel elements discharged from the reactor. The basin has been drained and cleared of debris, and an asphalt emulsion fixative has been applied to radiologically contaminated surfaces. The sludge cleaned from the basin was placed in the transfer pit, where it remains, covered by a layer of sand and a plywood cap (*Hanford B Reactor Building Hazard Assessment Report* [BHI-01282]). The FSB sludge in the transfer pit is scheduled to be removed from the 105-B facility in fiscal year 2013.

The 118-B-8:1 Waste Site was selected for characterization because subsurface data are scant near the reactor and the reactor fuel storage basin, which contained fuel pool water, spent fuel, and sludge, is known to have leaked. Additional demolition or remediation at the 105-B Reactor is not currently planned as the building is being converted into a public museum.

The RI called for a single borehole adjacent to the FSB. The initial borehole, C7847, met refusal at about 4.0 m (13 ft) bgs, and was terminated. The refusal is believed to have been the result of encountering residual process sewer systems around the FSB (these sewers are included in the 118-B-8:3 subsite). The replacement Borehole C8239 was sited 18.3 m (60 ft) northwest of C7847 and successfully reached target depth. Results for both boreholes are described below.

***RI Borehole C7847.*** This borehole was sited about 6.1 m (20 ft) west of the reactor building. It penetrated 76.2 mm (3 in.) of asphalt at about 0.3 m (1 ft) bgs, and three intervals were sampled before drilling encountered an unidentified obstruction, suspected to be a pipeline. Significant levels of radiological contamination were present at the location of the suspected pipeline. Therefore, a fourth sample was collected from this location about 4.0 m (13 ft) bgs. Because ofthe obstruction, drilling was terminated and the borehole was sealed. Analytical results for the C7847 vadose zone samples are summarized in Table 4-9 and depicted in Figure 4-10.

The only radionuclide detected in samples collected at 0.76, 2.3, and 3.8 m (2.5, 7.5, and 12.5 ft) bgs was cesium-137 at less than 2.00 pCi/g. However, analysis of material sampled at 4.0 m (13 ft) bgs identified multiple radionuclides at notably elevated activities, including americium-241 (9.06 pCi/g), carbon-14 (9.53 pCi/g), plutonium-239/240 (29 pCi/g), strontium-90 (15.8 pCi/g), cesium-137 (359 pCi/g), and nickel-63 (391 pCi/g). This is the interval where drilling was halted because of an obstruction.

Low concentrations of antimony, mercury, and molybdenum were detected above the background established in ECF-HANFORD-11-0038. Cr(VI) was detected below the analytical PQL at 0.29 mg/kg in the sample collected at 3.8 m (12.5 ft) bgs.

Various polycyclic aromatic hydrocarbons were detected in each interval sampled, but at very low concentrations. Most showed highest concentrations in the sampling interval that contained the asphalt. Benzo(a)pyrene was detected at a maximum concentration of 0.0117 mg/kg at 2.4 m (8 ft) bgs. Low concentrations of PCBs were detected in samples from about 0.9 and 4.0 m (3 and 13 ft) bgs. The maximum concentration was 0.0124 mg/kg at 4.0 m (13 ft) bgs. Total petroleum hydrocarbons (TPH) were also detected in nearly all samples, with maximum concentrations (612 and 211 mg/kg for diesel and motor oil range TPH, respectively) found in the shallow sample at approximately 0.9 m (3 ft) bgs that contained the asphalt layer.

***RI Borehole C8239.*** This borehole was sited about 18.3 m (60 ft) northwest of the terminated borehole, C7847, about 3 m (10 ft) north of the westernmost portion of the reactor building. It was drilled to a total depth of 25 m (82 ft) bgs, encountering the water table at 22.9 m (75 ft) bgs. Samples were collected at

21 discrete intervals. One sample interval was transected by the water table, and two sample intervals were entirely within the aquifer. Analytical results for the C8239 vadose zone samples are summarized in Table 4-9 and depicted in Figure 4-11.

Six radionuclides were detected, with all except strontium-90 showing peak activities at 6.1 or 9.1 m (20 or 30 ft) bgs (Figure 4-11); a few showed elevated activities. Strontium-90 was detected in all samples collected below about 2.1 m (7 ft) bgs with a maximum concentration of 11.3 pCi/g at about 35 bgs. The strontium-90 concentration decreased with depth below this maximum result. Cesium-137 was detected at very low concentrations both in shallow soil and near the water table, with a maximum concentration of 1.81 pCi/g at about 21.3 m (70 ft) bgs. Europium-152 was found at low concentrations (maximum concentration of 0.893 pCi/g at about 6.1 m (20 ft) bgs, with no detects below12.2 m (40 ft) bgs. Plutonium-239/240 was detected in only one sample at 0.196 pCi/g located 9.1 m (30 ft) bgs. Carbon-14 was detected only in the 6.1 m (20 ft) sample, at 166 pCi/g. Nickel-63, detected at relatively low concentrations at 3.7 and 4.6 m (12 and 15 ft) bgs, was measured at 23.0 pCi/g at 6.1 m (20 ft) bgs; it was not detected in deeper samples.

Cr(VI) was detected in two samples, one immediately above the water table (0.24 mg/kg) and one from the interval that intersected the water table (0.64 mg/kg). Total chromium concentrations barely exceeded background in three samples collected between 19.8 and 21.9 m (65 and 72 ft) bgs with a maximum concentration of 20.5 mg/kg at deepest interval. Several other metals exceeded background concentrations to some extent in at least one sample, including barium (178 mg/kg at 19.8 m [65 ft] bgs), copper (38.7 and 25.5 mg/kg at 7.6 and 22.9 m [25 and 75 ft] bgs, respectively), and vanadium, which was found above background between12.2 m (40 ft) bgs and the water table with a maximum concentration of 102 mg/kg at about 20.7 m (68 ft) bgs. Low concentrations of antimony, mercury, molybdenum, and thallium were detected above the background established in ECF-HANFORD-11-0038).

Polycyclic aromatic hydrocarbons (PAHs) were detected in samples collected between the ground surface and 7.6 m (25 ft) bgs, with highest concentrations of each analyte found in the shallowest interval (0 to 0.76 m [2.5 ft] bgs), collected immediately below asphalt pavement. Detections decreased in samples collected below 7.6 m (25 ft) bgs; however, several PAHs (acenaphthene, chrysene, fluoranthene, phenanthrene, and pyrene) were sporadically detected at low concentrations between 7.6 m (25 ft) bgs and the water table. Multiple PAHs, including benzo(*a*)pyrene, were detected at low concentrations at or near the water table. The benzo(*a*)pyrene concentrations were highest in the upper sample interval measuring 0.0902 at0.76 m (2.5 ft) and decreased to 0.00291 mg/kg at 7.6 m (25 ft). Benzo(*a*)pyrene was detected once below 7.6 m (25 ft) bgs (0.000931 mg/kg at 22.0 m [72.3 ft] bgs).

Total petroleum hydrocarbons were detected in samples up to 6.1 m (20ft) bgs with the maximum concentrations (277 and 669 mg/kg of diesel and motor oil range TPH, respectively) occurring in the uppermost sample. Low level detections occurred again at about 18.3 (60 ft) measuring 7.82 and 16.8 mg/kg of diesel and motor oil range TPH, respectively. Low levels of diesel range TPH (maximum concentration of 2.93 mg/kg) were detected in four of the six samples collected below 18.3 m (60 ft) bgs.

Data from both boreholes are considered in the risk evaluations in subsequent chapters and consideration of potential future actions for the area around the 105-B Reactor building.

Table 4-9. 118-B-8:1 Fuel Storage Basin —Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Back-ground | Remedial Investigation Borehole C7847[a] (2010) | | | | | Remedial Investigation Borehole C8239[b] (2010) | | | | |
| | | Maximum Result with Corresponding Depth (m / ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (4.1 m/13.4 ft bgs) | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (25.0 m / 82.2 ft bgs unless otherwise noted)[c] | |
| Radionuclides (Original and Decayed Concentrations) (pCi/g)[d] | | | | | | | | | | | |
| | | Original | Decayed | | Original | Decayed | Original | Decayed | | Original | Decayed |
| Americium-241 | NA | 9.09 (4.1 / 13.4) | 9.06 | 4.1 / 13.4 | 9.09 | 9.06 | U | NA | NA | U | NA |
| Carbon-14 | NA | 9.53 (4.1 / 13.4) | 9.53 | 4.1 / 13.4 | 9.53 | 9.53 | 166 (6.1 / 19.9) | 166 | NA | U | NA |
| Cesium-137 | NA | 376 (4.1 / 13.4) | 359 | 4.1 / 13.4 | 376 | 359 | 1.90 (21.2 / 69.8) | 1.81 | 21.2 / 69.8 | 1.22 (22.0 /72.3 ft) | 1.17 |
| Cobalt-60 | NA | 2.88 (4.1 / 13.4) | 2.21 | 4.1 / 13.4 | 2.88 | 2.21 | U | NA | NA | U | NA |
| Europium-152 | NA | 42.1 (4.1 / 13.4) | 38.0 | 4.1 / 13.4 | 42.1 | 38.0 | 0.99 (6.1 / 19.9) | 0.89 | 12.2 / 39.9 | U | NA |
| Europium-154 | NA | 3.81 (4.1 / 13.4) | 3.24 | 4.1 / 13.4 | 3.81 | 3.24 | U | NA | NA | U | NA |
| Nickel-63 | NA | 396 (4.1 / 13.4) | 391 | 4.1 / 13.4 | 396 | 391 | 23.3 (6.1 / 19.9) | 23.0 | 6.1 / 19.9 | U | NA |
| Plutonium-238 | NA | 0.49 (4.1 / 13.4) | 0.48 | 4.1 / 13.4 | 0.49 | 0.48 | U | NA | NA | U | NA |
| Plutonium-239/240 | NA | 29 (4.1 / 13.4) | 29 | 4.1 / 13.4 | 29 | 29 | 0.196 (9.2/ 30.2) | 0.196 | 9.2 / 30.2 | U | NA |
| Strontium-90 | NA | 16.6 (4.1 / 13.4) | 15.8 | 4.1 / 13.4 | 16.6 | 15.8 | 11.9 (10.6 / 34.8) | 11.3 | 25.0 / 82.2 | 2.54 | 2.42 |

## Table 4-9. 118-B-8:1 Fuel Storage Basin —Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Background | Remedial Investigation Borehole C7847[a] (2010) | | | | | Remedial Investigation Borehole C8239[b] (2010) | | | | |
| | | Maximum Result with Corresponding Depth (m / ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (4.1 m/13.4 ft bgs) | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (25.0 m / 82.2 ft bgs unless otherwise noted)[c] | |
| Tritium | NA | 6.33 (4.1 / 13.4) | 5.66 | 4.1 / 13.4 | 6.33 | 5.66 | U | NA | NA | U | NA |
| **Nonradionuclides (mg/kg)** | | | | | | | | | | | |
| Antimony | 0.130 | 0.342 (3.8 / 12.5) | | 3.8 / 12.5 | U | | 0.540 (10.6 / 34.8) | | 21.2 / 69.8 | U | |
| Barium | 132 | 70.4 (<BG) (4.1 / 13.4) | | NA | 70.4 (<BG) | | 178 (19.8 / 64.8) | | 19.8 / 64.8 | 80.0 (<BG) | |
| Chromium | 18.5 | 14.0 (<BG) (4.1 / 13.4) | | NA | 14.0 (<BG) | | 20.5 (22.0 / 72.3) | | 22.0 / 72.3 | 12.5 (<BG) | |
| Copper | 22 | 19.3 (<BG) (4.1 / 13.4) | | NA | 19.3 (<BG) | | 38.7 (7.6 / 24.8) | | 22.0 / 72.3 | 17.8 (<BG) | |
| Fluoride | 2.81 | 0.9 (<BG) (2.3 / 7.5) | | NA | 0.4 (<BG) | | 3.0 (15.2 / 49.8) | | 18.2 / 59.7 | 2.9 | |
| Cr(VI) | NA | 0.29 (3.8 / 12.5) | | 3.8 / 12.5 | U | | 0.64 (22.9 / 75.0) | | 22.9 / 75.0 | U | |
| Lead | 10.2 | 5.57 (<BG) (4.1 / 13.4) | | NA | 5.57 (<BG) | | 13.0 (2.2 / 7.3) | | 22.0 / 7.3 | 2.72 (<BG) | |
| Mercury | 0.0131 | 0.321 (4.1 / 13.4) | | 4.1 / 13.4 | 0.321 | | 0.021 (21.2 / 69.8) | | 21.2 / 69.8 | 0.041 | |
| Molybdenum | 0.470 | 0.776 (4.1 / 13.4) | | 4.1 / 13.4 | 0.776 | | 6.03 (22.0 / 72.3) | | 25.0 / 82.2 | 0.555 | |
| Strontium | NA | 32.1 (4.1 / 13.4) | | 4.1 / 13.4 | 32.1 | | 52.2 (7.6 / 24.8) | | 7.6 / 24.8 | 31.2 | |
| Thallium | 0.185 | U | | NA | U | | 0.187 (20.6 / 67.5) | | 20.6 / 67.5 | U | |
| Tin | NA | 2.86 (3.8 / 12.5) | | 4.1 / 13.4 | 2.70 | | 2.99 (18.2 / 59.7) | | 25.0 / 82.2 | 1.75 | |
| Vanadium | 85.1 | 33.1 (<BG) (3.8 / 12.5) | | NA | 66.1 (<BG) | | 102 (20.6 / 67.5) | | 22.0 / 72.3 | 61.4 (<BG) | |
| TPH–diesel range | NA | **211 (0.8 / 2.5)** | | 4.1 / 13.4 | 22.1 | | 277 (0.8 / 2.5) | | 22.9 / 75.0 | 2.04 (23.6 m/ 77.3 ft) | |
| TPH–motor oil (high boiling) | NA | 612 (0.8 / 2.5) | | 4.1 / 13.4 | 79.3 | | 669 (0.8 / 2.5) | | 22.9 / 59.7 | U | |

Table 4-9. 118-B-8:1 Fuel Storage Basin —Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | | |
|---|---|---|---|---|---|---|---|
| | Back-ground | Remedial Investigation Borehole C7847[a] (2010) | | | Remedial Investigation Borehole C8239[b] (2010) | | |
| | | Maximum Result with Corresponding Depth (m / ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (4.1 m/13.4 ft bgs) | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (25.0 m / 82.2 ft bgs unless otherwise noted)[c] |
| Aroclor 1254 | NA | 0.0124 (4.1 / 13.4) | 4.1 / 13.4 | 0.0124 | U | NA | U |
| Aroclor 1260 | NA | 0.00507 (4.1 / 13.4) | 4.1 / 13.4 | 0.00507 | U | NA | U |
| Acenaphthene | NA | 0.264 (0.8 / 2.5) | 4.1 / 13.4 | 0.0428 | 0.425 (0.8 / 2.5) | 23.6 / 77.3 | 0.00203 (77.3) |
| Acenaphthylene | NA | 0.283 (0.8 / 2.5) | 4.1 / 13.4 | 0.0167 | 0.857 (0.8 / 2.5) | 4.5 / 14.9 | U |
| Anthracene | NA | 0.00321 (2.3 / 7.5) | 4.1 / 13.4 | 0.00121 | 0.025 (0.8 / 2.5) | 7.6 / 24.8 | U |
| Benzo(*a*)anthracene | NA | 0.0223 (0.8 / 2.5) | 4.1 / 13.4 | 0.00109 | 0.110 (0.8 / 2.5) | 7.6 / 24.8 | U |
| Benzo(*a*)pyrene | NA | 0.0117 (2.3 / 7.5) | 4.1 / 13.4 | 0.00207 | 0.0902 (0.8 / 2.5) | 22.0 / 72.3 | U |
| Benzo(*b*)fluoranthene | NA | 0.154 (0.8 / 2.5) | 4.1 / 13.4 | 0.0105 | 0.201 (0.8 / 2.5) | 22.0 / 72.3 | U |
| Benzo(*ghi*)perylene | NA | 0.0052 (3.8 / 12.5) | 4.1 / 13.4 | 0.00182 | 0.121 (0.8 / 2.5) | 6.1 / 19.9 | U |
| Benzo(*k*)fluoranthene | NA | 0.0265 (0.8 / 2.5) | 4.1 / 13.4 | 0.00232 | 0.074 (0.8 / 2.5) | 4.5 / 14.9 | U |
| Chrysene | NA | 0.0132 (0.8 / 2.5) | 4.1 / 13.4 | 0.00516 | 0.0703 (6.1 / 19.9) | 20.6 / 67.5 | U |
| Dibenz[*a,h*]anthracene | NA | 0.0058 (0.8 / 2.5) | 0.8 / 2.5 | U | 0.0266 (0.8 / 2.5) | 4.5 / 14.9 | U |
| Fluoranthene | NA | 0.0573 (0.8 / 2.5) | 4.1 / 13.4 | 0.00389 | 0.957 (0.8 / 2.5) | 22.0 / 72.3 | U |
| Fluorene | NA | 0.0218 (0.8 / 2.5) | 4.1 / 13.4 | 0.00171 | 0.0457 (0.8 / 2.5) | 18.2 / 59.7 | U |
| Indeno(*1,2,3-cd*)pyrene | NA | 0.0179 (2.3 / 7.5) | 4.1 / 13.4 | 0.00461 | 0.272 (0.8 / 2.5) | 6.1 / 19.9 | U |
| Naphthalene | NA | 0.0222 (0.8 / 2.5) | 0.8 / 2.5 | U | 0.00603 (2.2 / 7.3) | 2.2 / 7.3 | U |
| Phenanthrene | NA | 0.0263 (2.3 / 7.5) | 4.1 / 13.4 | 0.00480 | 0.623 (0.8 / 2.5) | 22.0 / 72.3 | U |
| Pyrene | NA | 0.0504 (0.8 / 2.5) | 4.1 / 13.4 | 0.00377 | 0.526 (0.8 / 2.5) | 16.7 / 54.7 | U |

## Table 4-9. 118-B-8:1 Fuel Storage Basin —Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | | |
|---|---|---|---|---|---|---|---|
| | Back-ground | Remedial Investigation Borehole C7847[a] (2010) | | | Remedial Investigation Borehole C8239[b] (2010) | | |
| | | Maximum Result with Corresponding Depth (m / ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (4.1 m/13.4 ft bgs) | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (25.0 m / 82.2 ft bgs unless otherwise noted)[c] |
| Total Xylenes | NA | Not analyzed | Not analyzed | Not analyzed | 0.00305 (2.2 / 7.3) | 2.2 / 7.3 | U |

a. Borehole data obtained from HEIS. Borehole C7847 was drilled to a depth of 4.1 m (13.4 ft) at which point contamination from the 105-B FSB was encountered. A sample was taken and the borehole was relocated.

b. Borehole data obtained from HEIS. Borehole C8239 is the replacement borehole for the 118-B-8:1 site after the original borehole (C7847) encountered contamination from the 105-B FSB. The water table was encountered at 22.9 (75 ft). Well was drilled to ~25.1 m (82.3 ft).

c. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

d. Original radiological data presented in left column with decay corrected value to year 2012 in right column.

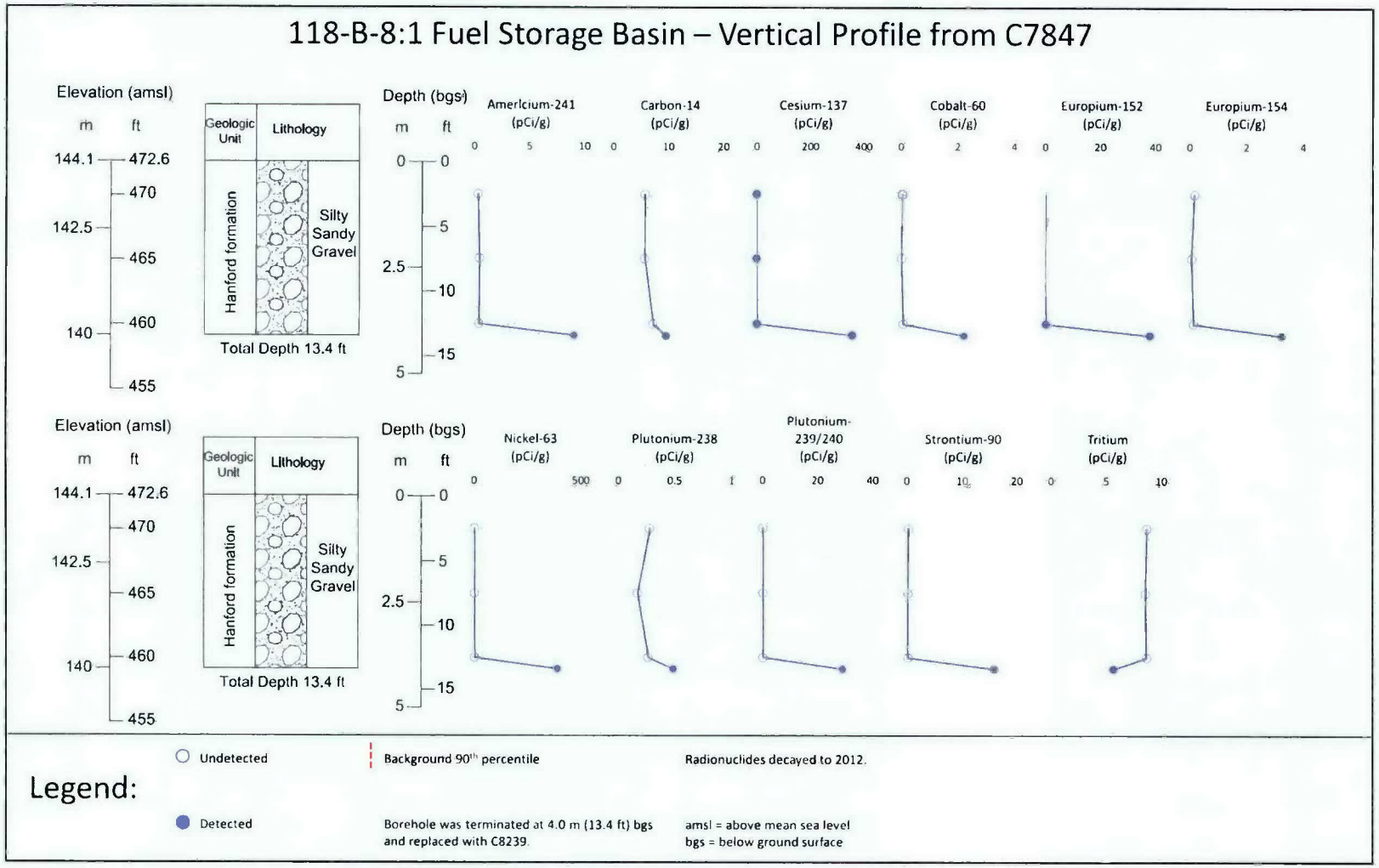


**Figure 4-10. Vertical Profile from Borehole C7847**

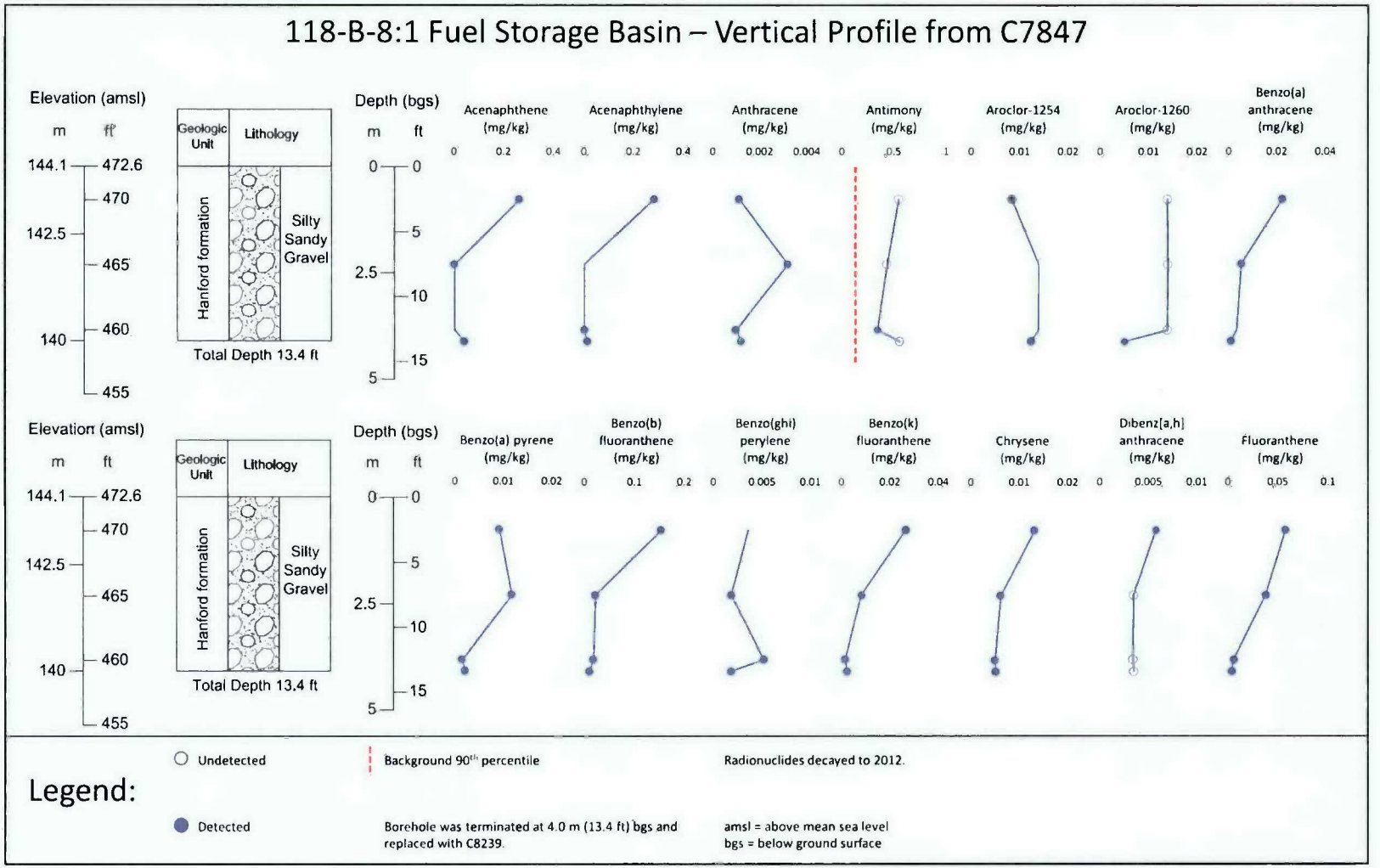


**Figure 4-10. Vertical Profile from Borehole C7847 (cont.)**

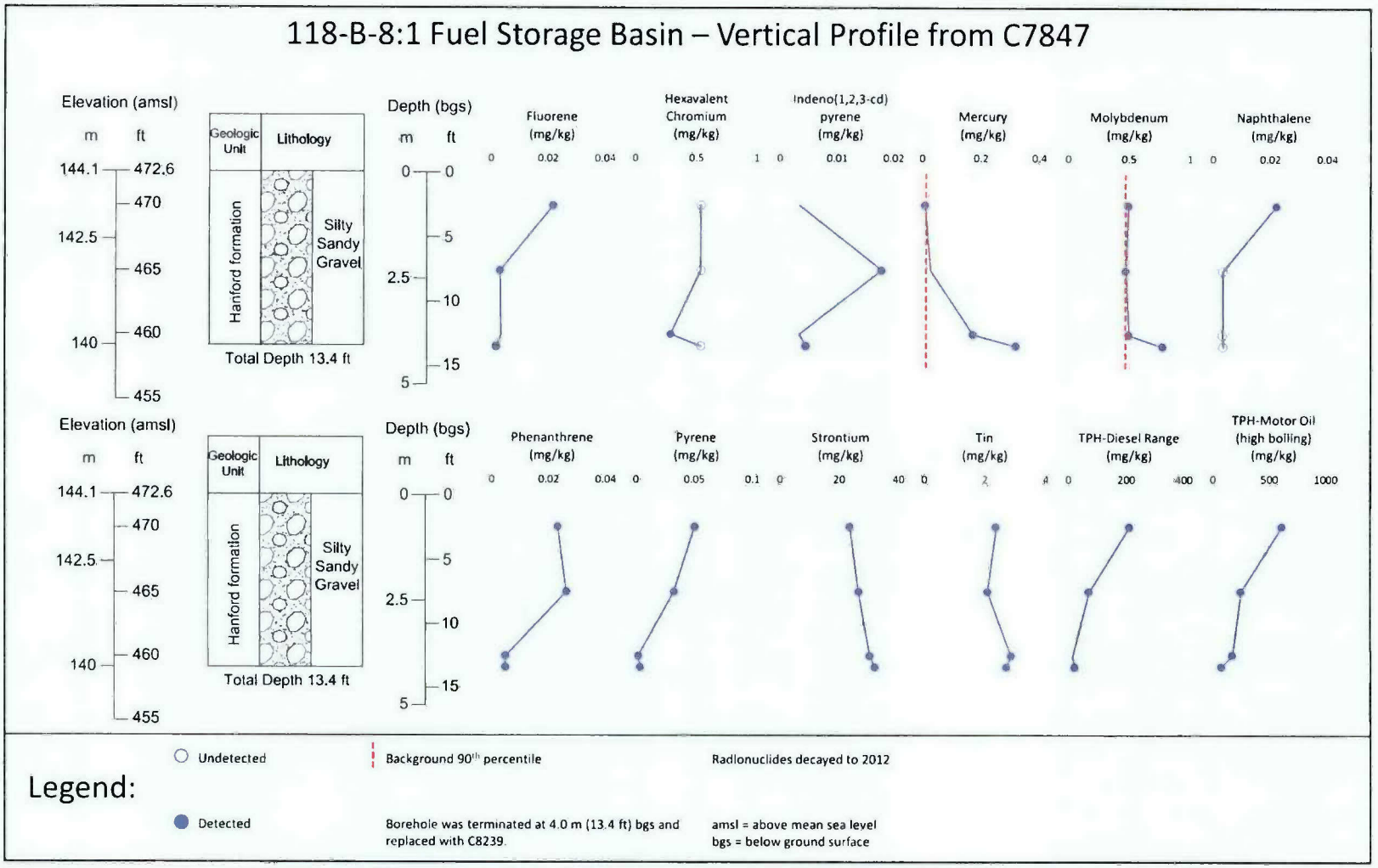


**Figure 4-10. Vertical Profile from Borehole C7847 (cont.)**

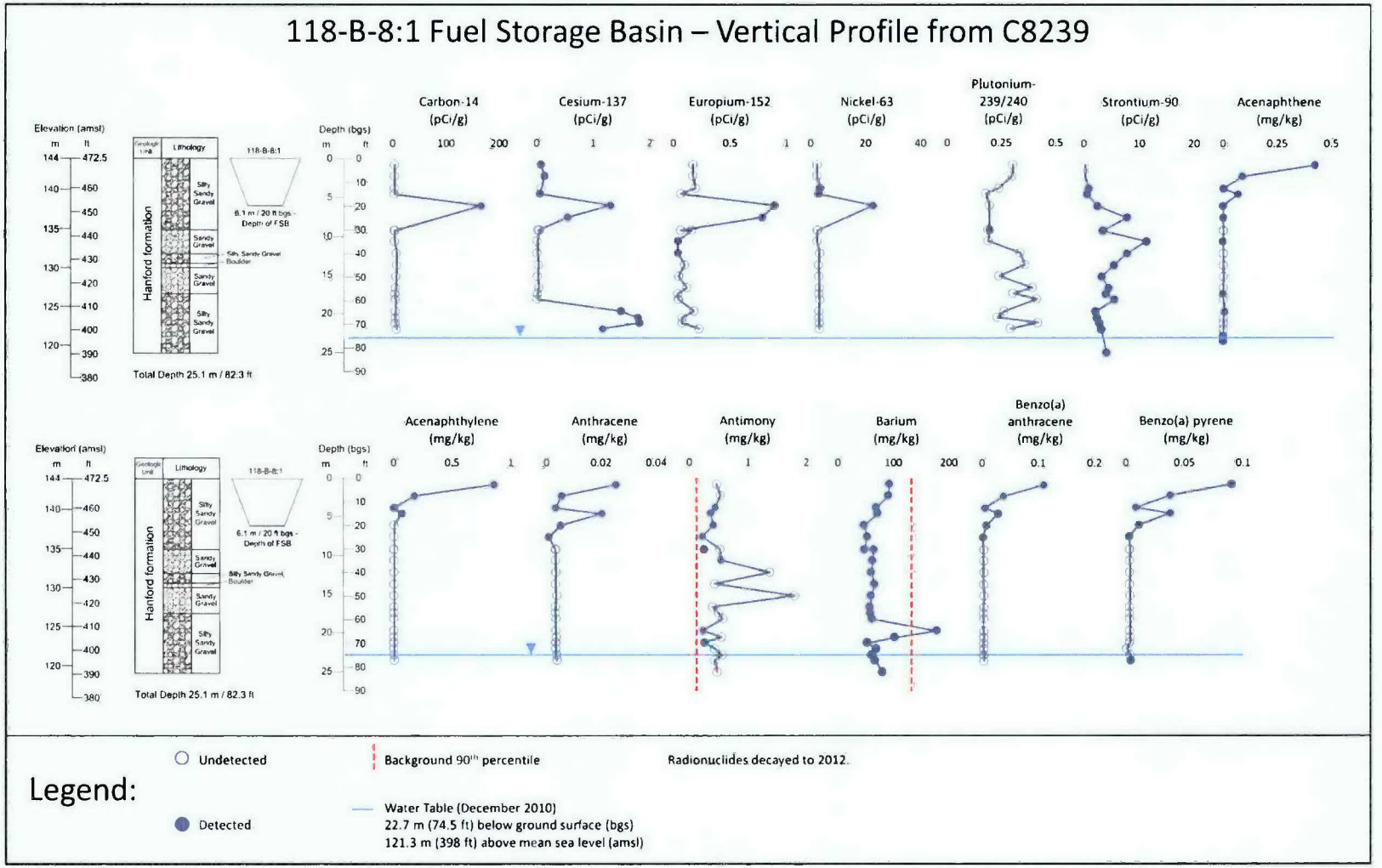


Figure 4-11. Vertical Profile from Borehole C8239

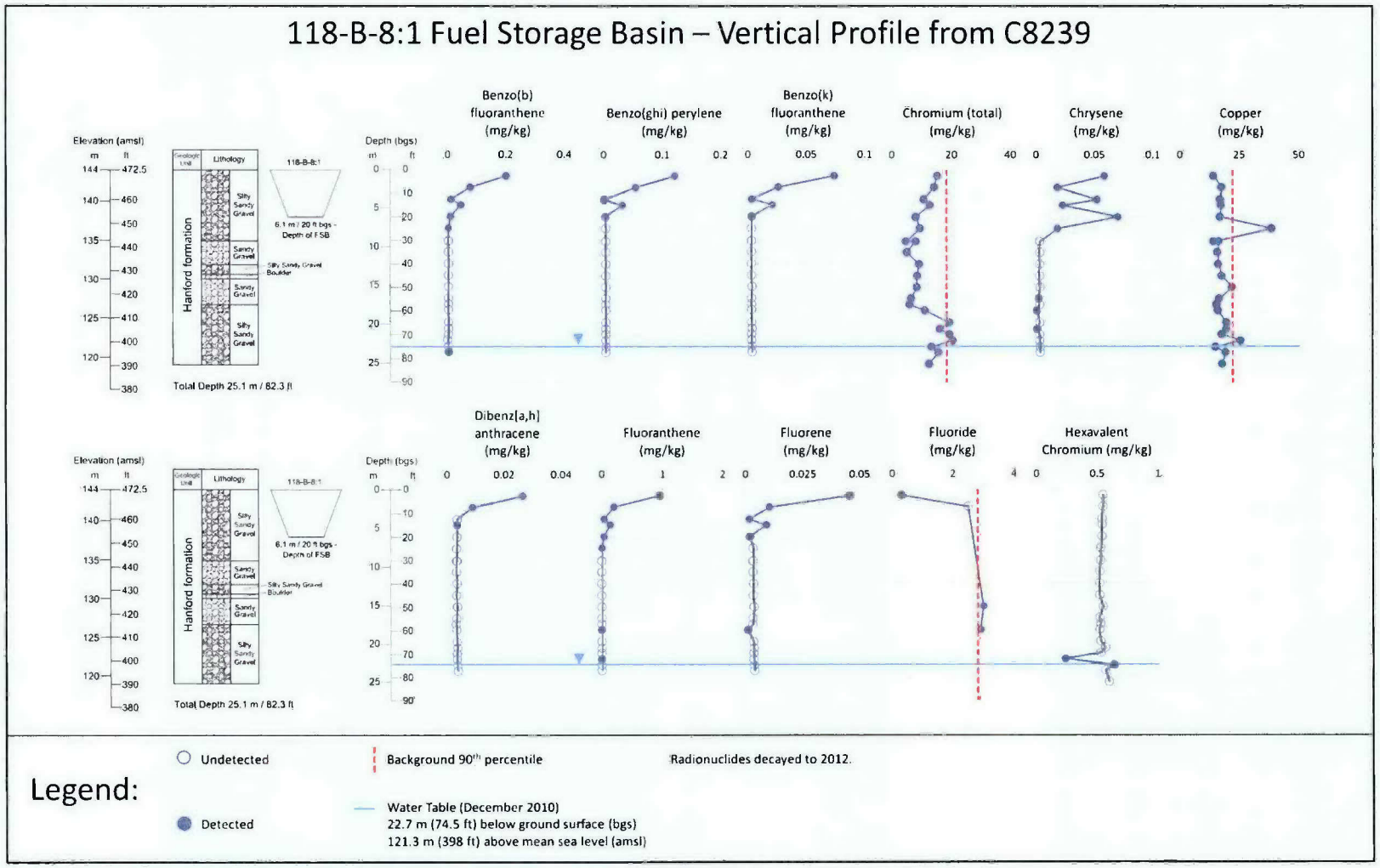


**Figure 4-11. Vertical Profile from Borehole C8239 (cont.)**

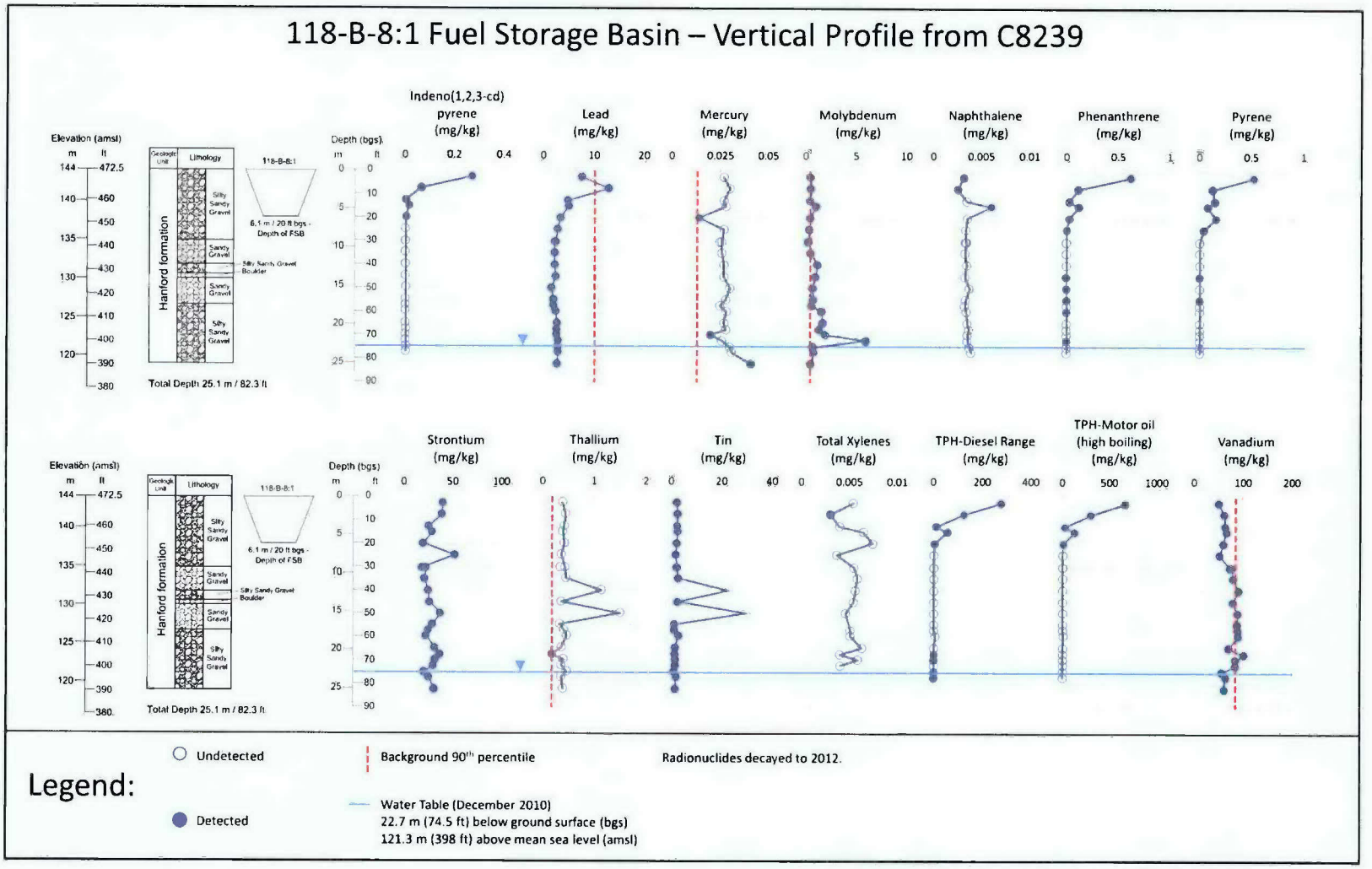


**Figure 4-11. Vertical Profile from Borehole C8239 (cont.)**

#### 4.2.1.6 Nature and Extent of Soil Contamination—118-B-6 Burial Ground

The 118-B-6 Waste Site consisted of two vertical concrete caissons that extended roughly 6.1 m (20 ft) bgs, used for disposal of tritium waste and tritium recovery process waste (aluminum target cans and lead target melting pots) from the P-10 Tritium Separation Project. Remedial excavation, conducted in 2004 and 2005, extended to a maximum depth of roughly 7 m (23 ft) bgs. COCs for the interim remedial action were tritium, lead, and mercury (*Cleanup Verification Package for the 118-B-6, 108-B Solid Waste Burial Ground* [CVP-2006-00002]). A summary of the verification sampling results is provided in Table 4-10.

The 118-B-6 Waste Site was selected for characterization under the RI because the list of COCs analyzed was limited and tritium levels were elevated at the deepest point of the remedial excavation. This site is also of interest because of its location with respect to the stontium-90, tritium and Cr(VI) groundwater plumes.

RI borehole C7845 was sited to investigate the vadose zone beneath the northernmost caisson, to a total depth of about 21.1 m (79 ft) bgs. Groundwater was encountered at 21.9 m (72 ft) bgs. No vadose zone material was recovered from the shallowest planned sampling interval, at 7.3 m (24 ft) bgs. Only partial recovery was achieved in the next interval, at 7.9 m (26 ft) bgs, requiring a reduced set of analyses that did not include the target radionuclides.

Radionuclides assessed in the remainder of the samples were iodine-129, strontium-90, and tritium. Iodine-129 was not detected in any samples. Strontium-90 was detected only in the deepest samples (Figure 4-12), with the first detection being 0.267 pCi/g at 19.2 m (63 ft) bgs. The highest strontium-90 activity, 3.23 pCi/g, was found in the sample collected immediately below the water table at 22.3 m (73 ft) bgs. Tritium was present in all samples, with the highest activity, 3,410 pCi/g, found in the shallowest analyzed sample, from 10.0 m (33 ft) bgs. Tritium shows a consistent decrease in activity with increasing depth, until it approaches the water table, where increased activity was noted. Samples collected below the water table reflected decreasing tritium activities.

Two metals, chromium and cobalt, were detected at concentrations slightly exceeding background (Table 4-10). Chromium was found at a concentration of 19.3 mg/kg at a depth of 20.1 m (66 ft) bgs. Cobalt was found at a concentration of 20.8 mg/kg at 17.7 m (58 ft) bgs; analysis of a duplicate sample from 17.7 m (58 ft) bgs identified a cobalt concentration of 7.48 mg/kg. Cr(VI) was detected at 1.05 mg/kg at 11.4 m (37.5 ft) bgs. However, the corresponding total chromium result at this depth (6.84 mg/kg) is very low. Two other Cr(VI) detections occurred at low concentrations: 0.28 and 0.39 mg/kg at 7.9 and 22.3 m (26 and 73 ft) bgs, respectively. The deepest detection came from a sample collected immediately beneath the water table at 22.3 m (73 ft) bgs. Low concentrations of antimony and molybdenum were detected above the background established in ECF-HANFORD-11-0038.

Collectively, the site data and process history do not suggest that the site contributed to the underlying Cr(VI) groundwater plume in the area. The site history does not suggest significant potential for strontium-90 contamination, and the RI data confirms this. The low activities of strontium-90 detected in the deepest vadose zone intervals are most likely the result of contamination from fluctuating contaminated groundwater; strontium-90 activities in sediment increase slightly further in RI samples from the aquifer. While tritium activity levels decrease rapidly with depth beneath the former remediation, the RI data suggest that this site was a historic source of tritium contamination in groundwater. The potential for a continuing source and potential further remedial action in the vadose zone is considered further in subsequent chapters.

Table 4-10. 118-B-6 Burial Ground—Summary of Contaminant Soil Data

| Contaminants | Concentration and Distribution | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] (2005) | | | | Remedial Investigation Borehole—C7845[b] (2010) | | | | |
| | | Shallow Zone | | Deep Zone | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (24.1 m/78.9 ft bgs)[c] | |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[d]** | | | | | | | | | | |
| | | Original | Decayed | Original | Decayed | Original | Decayed | | Original | Decayed |
| Strontium-90 | NA | ND | ND | ND | ND | 3.39 (22.4/73.5) | 3.23 | 24.1 / 78.9 | 3.08 | 2.94 |
| Tritium | NA | 238[e] | 160 | 1,996 | 1,345 | 3,820 (10.0 / 32.9) | 3,413 | 24.1 / 78.9 | 28.4 | 25.4 |
| **Nonradionuclides (mg/kg)** | | | | | | | | | | |
| Antimony | 0.130 | ND | | ND | | 0.280 (21.6 / 70.9) | | 24.1 / 78.9 | 0.273 | |
| Cobalt | 15.7 | ND | | ND | | 20.8 (17.8 / 58.5) | | 20.2 / 66.4 | 6.26 (<BG) | |
| Chromium | 18.5 | ND | | ND | | 19.3 (20.2 / 66.4) | | 22.4 / 73.5 | 12.8 (<BG) | |
| Cr(VI) | NA | ND | | ND | | 1.05 (11.4 / 37.5) | | 24.1 / 78.9 | U | |
| Mercury | 0.0131 | 0.08 | | U | | U | | NA | U | |
| Molybdenum | NA | ND | | ND | | 3.14 (24.1 / 78.9) | | 24.1 / 78.9 | 3.14 | |
| Strontium | NA | ND | | ND | | 32.2 (10.0 / 32.9) | | 24.1 / 78.9 | 18.5 | |
| Tin | NA | ND | | ND | | 4.25 (16.2 / 53.1) | | 24.1 / 78.9 | 1.94 | |

**Table 4-10. 118-B-6 Burial Ground—Summary of Contaminant Soil Data**

a. Verification sample results represent the maximum 95% UCL concentration from the excavation area unless otherwise noted. At 118-B-6, 95% UCL values were determined for three shallow zone decision units: excavation area, staging pile footprint, and overburden stockpile. Values that show (U) indicate all data used for 95% UCL calculation were nondetects. Verification 95% UCL values obtained from *Cleanup Verification Package for the 118-B-6, 108-B Solid Waste Burial Ground* (CVP-2006-00002). Maximum depth of interim remedial action at 118-B-6 was 7 m (23 ft) bgs.

b. Borehole data obtained from HEIS. The water table was encountered at 72 ft. Well was drilled to ~78.9 ft.

c. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

d. Original radiological data presented in left column with decay corrected value to year 2012 in right column.

e. The maximum 95% UCL for tritium among the shallow zone decision units at 118-B-6 is from the overburden.

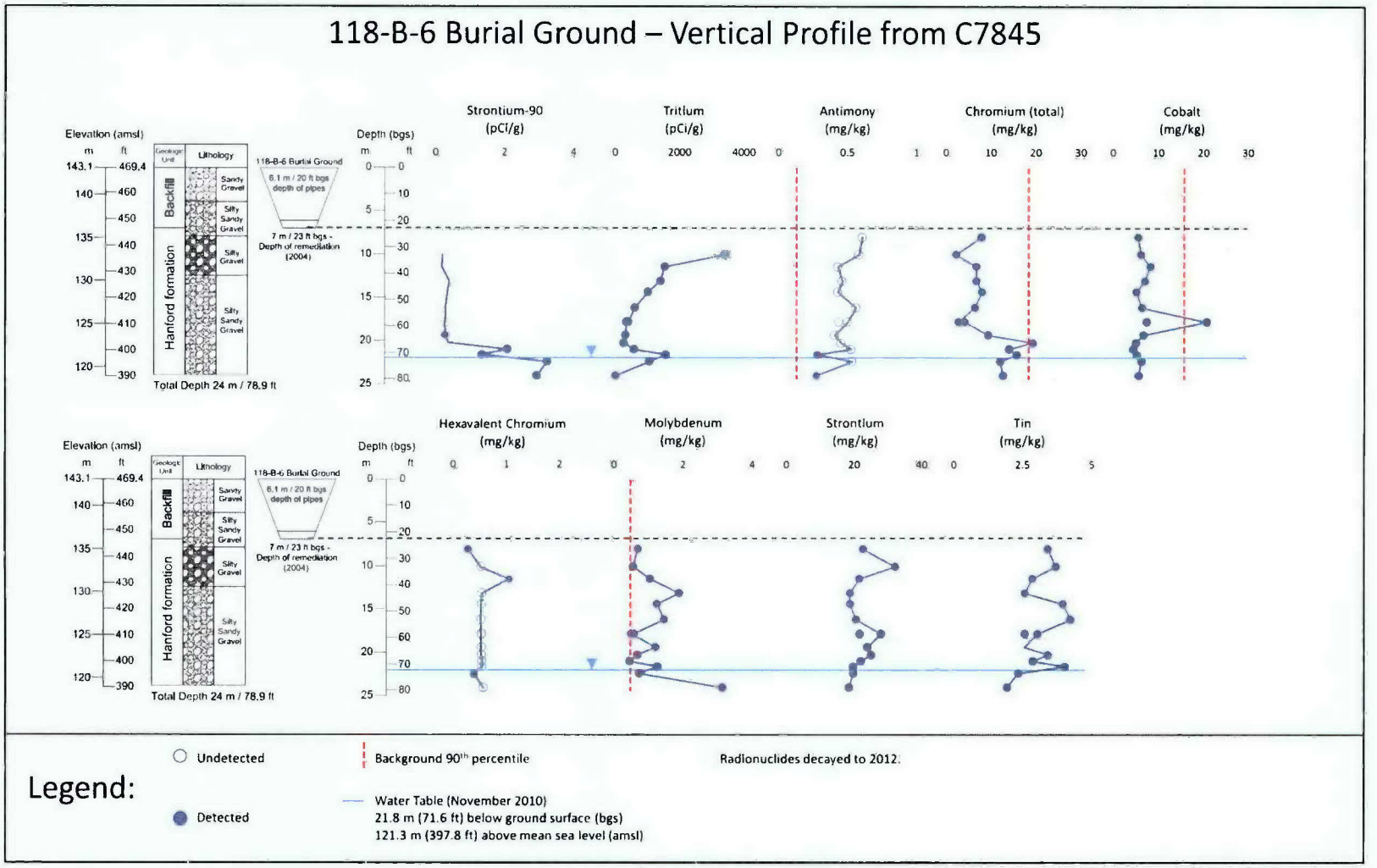


**Figure 4-12. Vertical Profile from Borehole C7845**

#### 4.2.1.7 Nature and Extent of Soil Contamination—116-C-5 Retention Basin

The 116-C-5 Waste Site encompasses the former 107-C Retention Basins and underlying soil. The basins were constructed in 1952 to hold cooling water effluent from the 105-C Reactor to allow for thermal cooling and radioactive decay before release to the Columbia River. The site received cooling water from 1952 until 1969. In 1992, as part of an LFI, test pit samples were collected to a depth of 6.1 m (20ft) bgs. Six of the seven radionuclides detected in the test pit samples had maximum concentrations at 1.5 m (5 ft) bgs. Four of those radionuclides (cesium-137, cobalt-60, europium-152, and europium-154) were also detected at very low activities (less than 0.05 pCi/g) at 6.1 m (20ft) bgs. The LFI test pit data are summarized in Table 4-11 and depicted in Figure 4-13.

Remedial action was conducted between 1996 and 1998 and extended to a depth of 4.6 m (15 ft) bgs. Contaminants of concern included americium-241, cesium-137, cobalt-60, europium-152, europium-154, europium-155, nickel-63, plutonium-238, plutonium-239/240, strontium-90, uranium-238, total chromium, Cr(VI), mercury, and lead (*Cleanup Verification Package for the 116-C-5 Retention Basin* [CVP-99-00004]). Based on evaluation of the analytical results for shallow and deep zone closure verification samples, summarized in Table 4-11, the site was determined to meet interim closure requirements.

The 116-C-5 Waste Site was selected for further characterization under the RI because Cr(VI), total chromium, lead, mercury, and nickel-63 were all elevated in the deep zone verification soil samples. This site is also of interest because of its location with respect to the Cr(VI), tritium, and strontium-90 groundwater plumes adjacent to the Columbia River.

RI borehole C7843 (converted to Well 199-B3-52) was drilled at a location formerly occupied by the western retention basin. It was advanced to a total depth of 18.3 m (60 ft) bgs, encountering the water table at 14.9 m (49 ft) bgs. Vadose zone material to a depth of 4.6 m (15 ft) bgs was assumed clean fill. Samples were collected at ten discrete depth intervals. Analytical results are summarized in Table 4-11 and depicted in Figure 4-14.

RI vadose zone samples collected between 5.5 and 10 m (18 and 33 ft) bgs were not of sufficient volume to allow laboratory analysis for radionuclides. Thus, assessment of radiological contamination in that depth interval relies on cesium-137 data generated using a borehole spectral gamma logging system, as documented in *C7843 Log Data Report* (HGLP-LDR-518), and strontium-90 data generated during interim closure.

Cesium-137 was detected in all samples collected between 11.3 and 15.2 m (37 and 50 ft) bgs, with a maximum concentration of 6.59 pCi/g at 11.3 m (37 ft) bgs. Cesium-137 activity decreased with increasing depth. Borehole data generated with a spectral gamma logging system indicate elevated concentrations of cesium-137 from about 6.7 and 11.3 m (22 to 37 ft) bgs at concentrations up to 8 pCi/g, which agrees well with concentrations identified through laboratory analysis (Figure 4-14). Strontium-90 was detected in all RI samples from 11.3 to 17.4 m (37 ft to 57 ft) bgs, with a maximum concentration of 1.46 pCi/g occurring at 11.3 m (37 ft) bgs. The CVP deep zone verification sampling value for strontium-90 was 3.75 pCi/g. No other radionuclides from the target analyte list were detected above background.

Total chromium exceeded background from 9.8 to 15.2 m (32 to 50 ft) bgs with a maximum concentration of 68.3 mg/kg occurring at 11.3 m (37 ft) bgs. Cr(VI) was detected in only one sample at 0.39 mg/kg (below the analytical PQL) at 12.8 m (42 ft) bgs. Mercury was detected in several samples with the most elevated concentration (0.359 mg/kg) from the sample interval at the water table (15.2 m [50 ft] bgs). Copper was detected at 39.3 mg/kg (above background) in a duplicate sample taken at about

17.4 m (57 ft) bgs (below the water table). However, copper in the associated primary sample was measured at 20.1 mg/kg (below background). Low concentrations of molybdenum and thallium were detected above the background established in ECF-HANFORD-11-0038.

Petroleum hydrocarbons in the motor oil range were detected in samples collected between 9.1 and 12.2 m (30 and 40 ft) bgs, at approximately 5 mg/kg, and again at 4.31 mg/kg in the sample collected 2.4 m (8 ft) below the water table. Acenaphthene was detected at low levels (less than 0.010 mg/kg) in samples from both 9.8 and 17.4 m (32 and 57 ft) bgs. No other organic constituents were detected in the samples.

Collectively, these data show that contamination has migrated to significant depth beneath the former retention basin, though this is not inclusive of all potential site contaminants. While elevated total chromium was detected at depth by RI sampling, significant residual Cr(VI) was not observed. Low-activity strontium-90 contamination was observed extending through the vadose zone to groundwater, suggesting that this site has historically had a contributing influence on the groundwater plume. Mercury concentrations in the underlying vadose zone were only nominally above background, and other contaminants of specific interest for the RI (lead, tritium, and nickel-63) were not detected above background at depth. All data for this site are considered in the refinement of the conceptual site model and risk evaluation in subsequent chapters.

## Table 4-11. 116-C-5 Retention Basin (Well 199-B3-52) —Summary of Contaminant Soil Data

| Contaminants | Background | Concentration and Distribution | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Cleanup Verification Data[a] (1999) | | | | LFI Test Pit Soil Data[b] (1992) | | | | | Remedial Investigation Borehole C7843[c] (2010); Well 199-B3-52 | | | | |
| | | Shallow Zone[d] | | Deep Zone | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (6.0 m/20 ft bgs) | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (17.4 m/57.2 ft bgs)[e] | |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[f]** | | | | | | | | | | | | | | | |
| | | Original | Decayed | Original | Decayed | Original | Decayed | | Original | Decayed | Original | Decayed | | Original | Decayed |
| Americium-241 | NA | 0.256 | 0.251 | 5.11 | 5.01 | 0.13 (1.5 / 5) | 0.13 | 1.5 / 5 | U | NA | U | NA | NA | U | NA |
| Cesium-137 | NA | 1.12 | 0.20 | 114 | 85 | 9.8 (1.5 / 5) | 6.2 | 6.1 / 20 | 0.03 | 0.02 | 6.9 (11.4 / 37.4) | 6.6 | 15.2 / 49.7 | U | NA |
| Cobalt-60 | NA | 0.145 | 0.108 | 21.4 | 3.87 | 3.2 (1.5 / 5) | 0.23 | 6.1 / 20 | 0.03 | 0.002 | U | NA | NA | U | NA |
| Europium-152 | NA | 1.59 | 0.82 | 135 | 69 | 13 (1.5 / 5) | 4.7 | 6.1 / 20 | 0.07 | 0.03 | U | NA | NA | U | NA |
| Europium-154 | NA | 0.244 | 0.086 | 23.8 | 8.3 | 2.0 (1.5 / 5) | 0.4 | 6.1 / 20 | 0.09 | 0.02 | U | NA | NA | U | NA |
| Europium-155 | NA | 0.066 (U) | NA | 0.71 | 0.107 | ND | ND | ND | ND | ND | U | NA | NA | U | NA |
| Nickel-63 | NA | 7.52 | 6.87 | 677 | 618 | ND | ND | ND | ND | ND | U | NA | NA | U | NA |
| Plutonium-238 | NA | 0.029 | 0.026 | 0.19 | 0.17 | U | NA | NA | U | NA | U | NA | NA | U | NA |
| Plutonium-239/240 | NA | 0.192 | 0.183 | 5.1 | 5.1 | 0.21 (1.5 / 5) | 0.21 | 1.5 / 5 | U | NA | U | NA | NA | U | NA |
| Strontium-90 | NA | 0.37 | 0.27 | 5.11 | 3.75 | 1.3 (1.5 / 5) | 0.8 | 1.5 / 5 | U | NA | 1.53 (11.4 / 37.4) | 1.46 | 17.4 / 57.2 | 0.399 | 0.38 |
| **Nonradionuclides (mg/kg)** | | | | | | | | | | | | | | | |
| Barium | 132 | ND | | ND | | 260 (1.5 / 5) | | 1.5 / 5 | 113 (<BG) | | 123 (<BG) (12.3 / 40.3) | | NA | 52.1 (<BG) | |
| Boron | NA | ND | | ND | | ND | | ND | ND | | 0.897 (5.5 / 18.0) | | 17.4 / 57.2 | 0.490 | |
| Chromium | 18.5 | 12.9 | | 43.2 | | 16.6 (<BG) (6.1 / 20) | | NA | 16.6 (<BG) | | 68.3 (11.4 / 37.4) | | 14.5 / 47.5 | 8.54 (<BG) | |
| Copper | 22 | ND | | ND | | 22.9 (6.1 / 20) | | 6.1 / 20 | 22.9 | | 39.3 (17.4 / 57.2) | | 17.4 / 57.2 | 39.3 | |
| Cr(VI) | NA | 0.239 | | 2.28 | | ND | | ND | ND | | 0.39 (12.9 / 42.2) | | 12.9 / 42.2 | U | |
| Lead | 10.2 | 7.3 | | 20.9 | | 12.6 (1.5 / 5) | | 1.5 / 5 | 7.0 (<BG) | | 3.42 (<BG) (45.3) | | NA | U | |
| Mercury | 0.0131 | 0.04 | | 1.47 | | 0.15 (<BG) (1.5 /5) | | NA | 0.14 | | 0.359 (15.2 / 49.7) | | 15.2 / 49.7 | U | |
| Molybdenum | 0.470 | ND | | ND | | ND | | ND | ND | | 2.31 (15.2 / 49.7) | | 17.4 / 57.2 | 1.25 | |
| Silver | 0.167 | ND | | ND | | 1.9 (6.1 / 20) | | 6.1 / 20 | 1.9 | | U | | NA | U | |
| Strontium | NA | ND | | ND | | ND | | ND | ND | | 29.1 (12.3 / 40.3) | | 17.4 / 57.2 | 19.6 | |
| Thallium | 0.185 | ND | | ND | | U | | NA | U | | 0.284 (11.4 / 37.4) | | 15.2 / 49.7 | U | |
| Tin | NA | ND | | ND | | ND | | ND | ND | | 2.09 (12.3 / 40.3) | | 17.4 / 57.2 | 1.47 | |
| Acenaphthene | NA | ND | | ND | | ND | | ND | ND | | 0.00962 | | 17.4 / 57.2 | 0.00403 | |
| TPH–Motor oil (high boiling) | NA | ND | | ND | | ND | | ND | ND | | 5.0 (9.9 / 32.4) | | 17.4 / 57.2 | 4.31 | |

a Verification sample results represent the maximum 95% UCL concentration from the excavation area. Values that show (U) indicate all data used for 95% UCL calculation were nondetects. Verification 95% UCL values obtained from *Cleanup Verification Package for the 116-C-5 Retention Basin* (CVP-99-00004). The maximum depth of interim remedial action at 116-C-5 was 5 m (16.4 ft) bgs.

**Table 4-11. 116-C-5 Retention Basin (Well 199-B3-52) —Summary of Contaminant Soil Data**

| Contaminants | Background | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cleanup Verification Data[a] (1999) | | LFI Test Pit Soil Data[b] (1992) | | | Remedial Investigation Borehole C7843[c] (2010); Well 199-B3-52 | | |
| | | Shallow Zone[d] | Deep Zone | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (6.0 m/20 ft bgs) | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (17.4 m/57.2 ft bgs)[e] |

b. LFI test pit data obtained from *Limited Field Investigation Report for the 100-BC-1 Operable Unit* (DOE/RL-93-06) and HEIS. Five soil samples were taken at 0.5, 1.5, 3.1, 4.6, and 6.1 m (1.5, 5, 10, 15, and 20 ft) bgs during test pit excavation in 1992 for LFI investigation. The test pit was located on the northwest perimeter of the west retention basin to evaluate effluent leakage contamination.

c. Borehole data obtained from HEIS. The water table was encountered at 15 m (49 ft). Well was drilled to 18.3 m (60 ft).

d. Shallow zone value represents the excavation area unless otherwise noted.

e. The maximum depth from which samples were collected is in the rewetted zone/aquifer.

f. Original radiological data presented in left column with decay corrected value to year 2012 in right column. Data from closeout sampling 95% UCL values obtained using U-flagged data sets is not decayed.

1

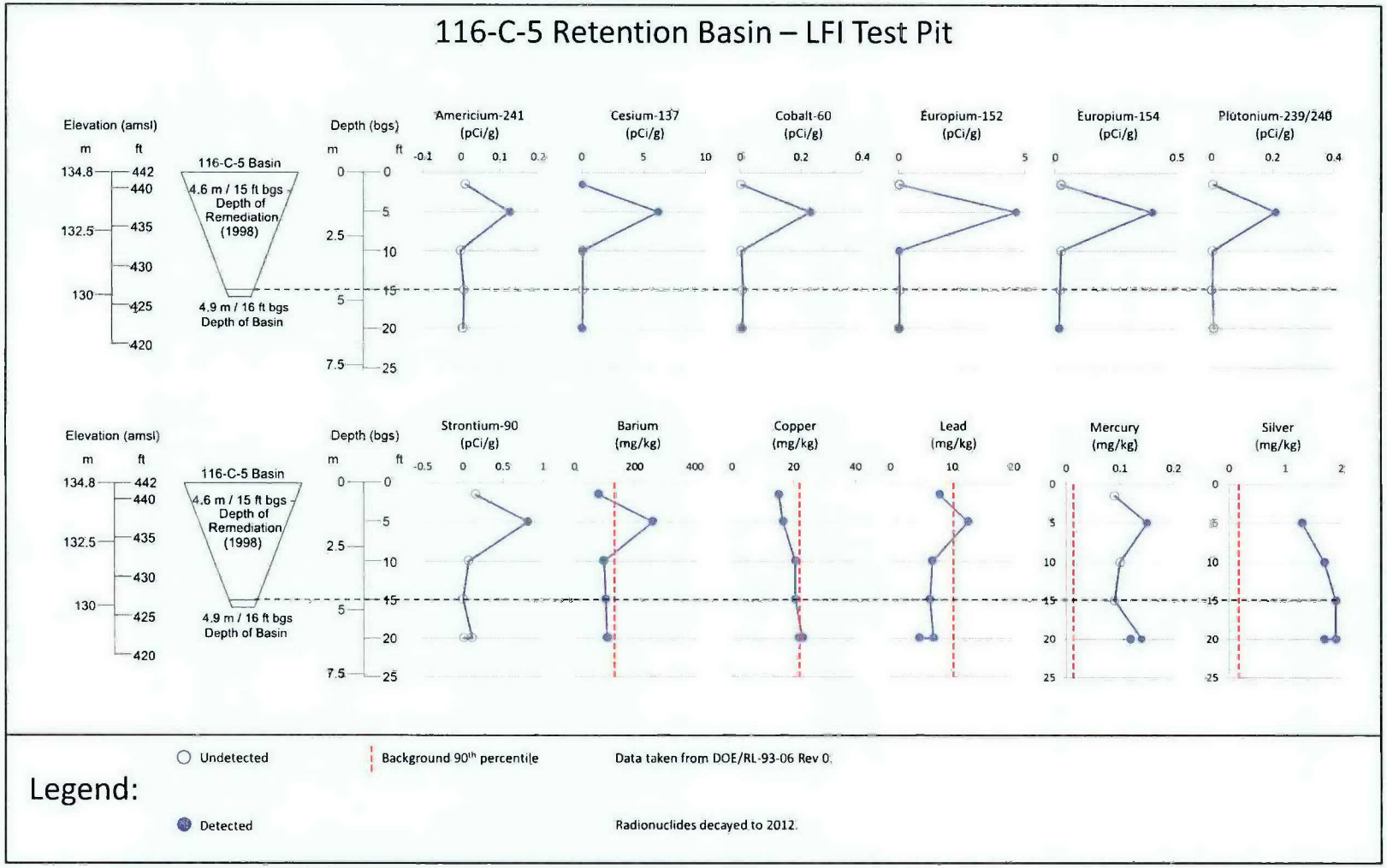


**Figure 4-13. Vertical Profile from LFI Test Pit**

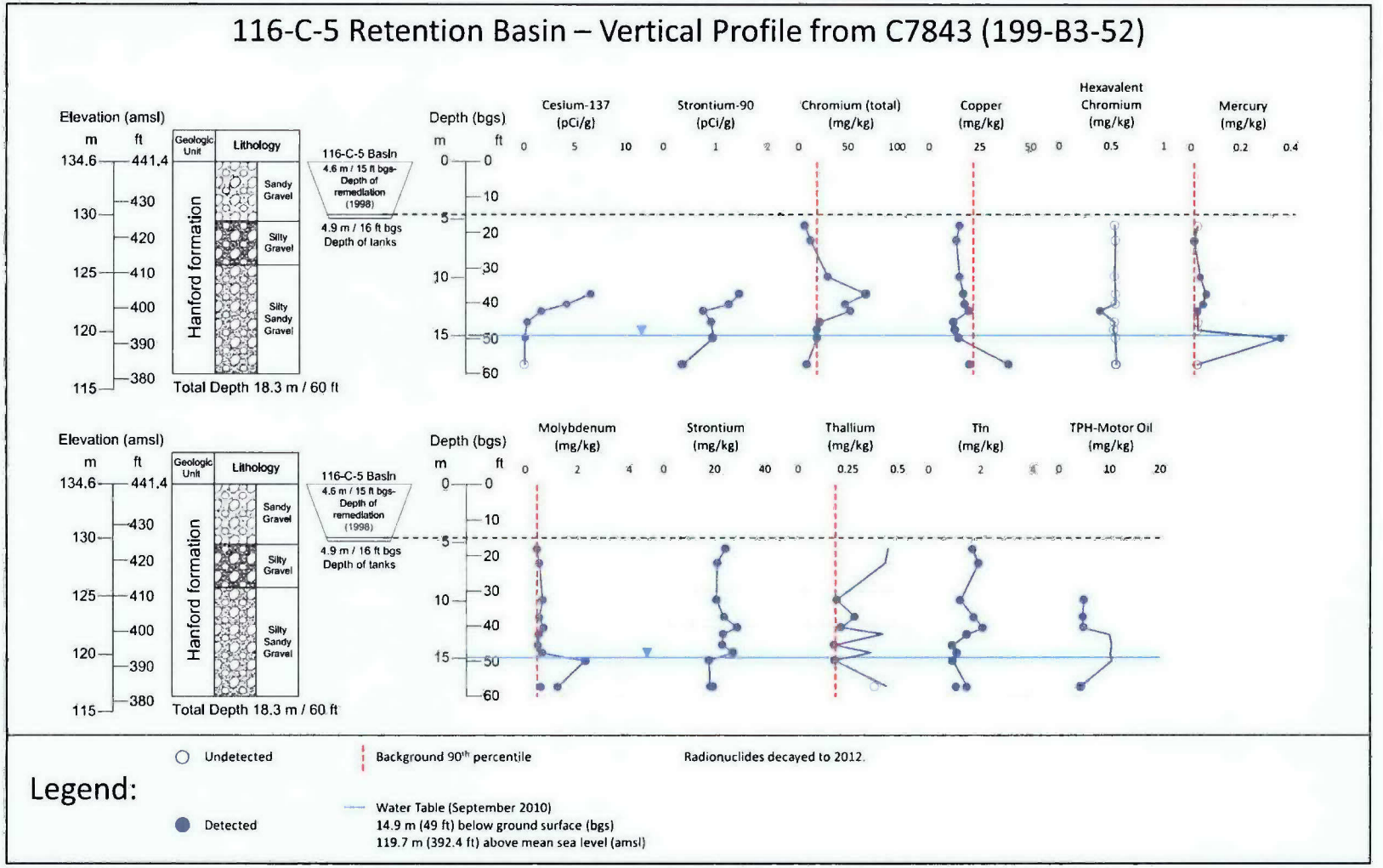


**Figure 4-14. Vertical Profile from Borehole C7843 (Well 199-B3-52)**

#### 4.2.1.8 Nature and Extent of Soil Contamination—116-B-6B Crib

The 116-B-6B Waste Site was a 1.8 m (6 ft) deep unlined crib that received about 5,000 L of radioactive process effluent from equipment decontamination performed in the 111-B decontamination station, as well as liquid wastes from the decontamination of fuel element spacers. The site was remediated in 1999 by excavating to a maximum depth of 3 m (10 ft) bgs (*Cleanup Verification Package for the 116-B-6B Crib* [CVP-99-00017]). Lead, the only COC for cleanup verification sampling, was not detected above background in any of the closeout verification samples.

The 116-B-6B waste site was identified in Data Gap 2 of the 100-BC Work Plan (DOE/RL-2008-46-ADD3) for test pit characterization because of discharges of sodium dichromate to the crib and the lack of radionuclide analytical data from cleanup verification sampling. Test pit sampling occurred in 2011 at 5.6 and 6.4 m (18.4 and 21.0 ft) bgs, as described in the 100-BC SAP (DOE/RL-2009-44).

No radionuclides were detected in either test pit sample. Lead concentrations were below background in both samples and Cr(VI) was not detected in either sample (Table 4-12). Low concentrations of mercury, molybdenum, and silver were detected above the background established in ECF-HANFORD-11-0038. Figure 4-15 shows the vertical profiles for these constituents. These data do not suggest significant residual contamination beyond the boundaries of the former remediation at this site, and these RI data are considered with the previous remediation verification data in the risk evaluation in subsequent chapters.

Table 4-12. 116-B-6B Crib Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] Shallow Zone | Remedial Investigation Test Pit 116-B-6B[b,c] | | |
| | | | Maximum Result with Corresponding Depth (m / ft bgs) | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (6.5 m/ 21.4 ft bgs) |
| **Nonradionuclides (mg/kg)** | | | | | |
| Molybdenum | NA | ND | 0.531 (5.6 / 18.4) | 6.5 / 21.4 | 0.479 |
| Silver | 0.167 | ND | 0.299 (5.6 / 18.4) | 5.6 / 18.4 | U |
| Strontium | NA | ND | 24.3 (5.6 / 18.4) | 6.5 / 21.4 | 16.7 |
| Tin | NA | ND | 2.26 (5.6 / 18.4) | 6.5 / 21.4 | 1.53 |

a. Verification sample results representing the maximum 95% UCL concentration from the excavation area were obtained from *Cleanup Verification Package for the 116-B-6B Crib* (CVP-99-00017). Lead was the only contaminant of concern for 116-B-6B closeout sampling and was not detected above background. The maximum depth of interim remedial action at 116-B-6B was 3.0 m (9.8 ft) bgs.

b. Two soil samples were collected from the 116-B-6B test pit at 5.6 m (18.4 ft) and 6.5 m (21.4 ft) bgs.

c. Test pit data obtained from HEIS.

ND = no data, not a contaminant of concern/contaminant of potential concern

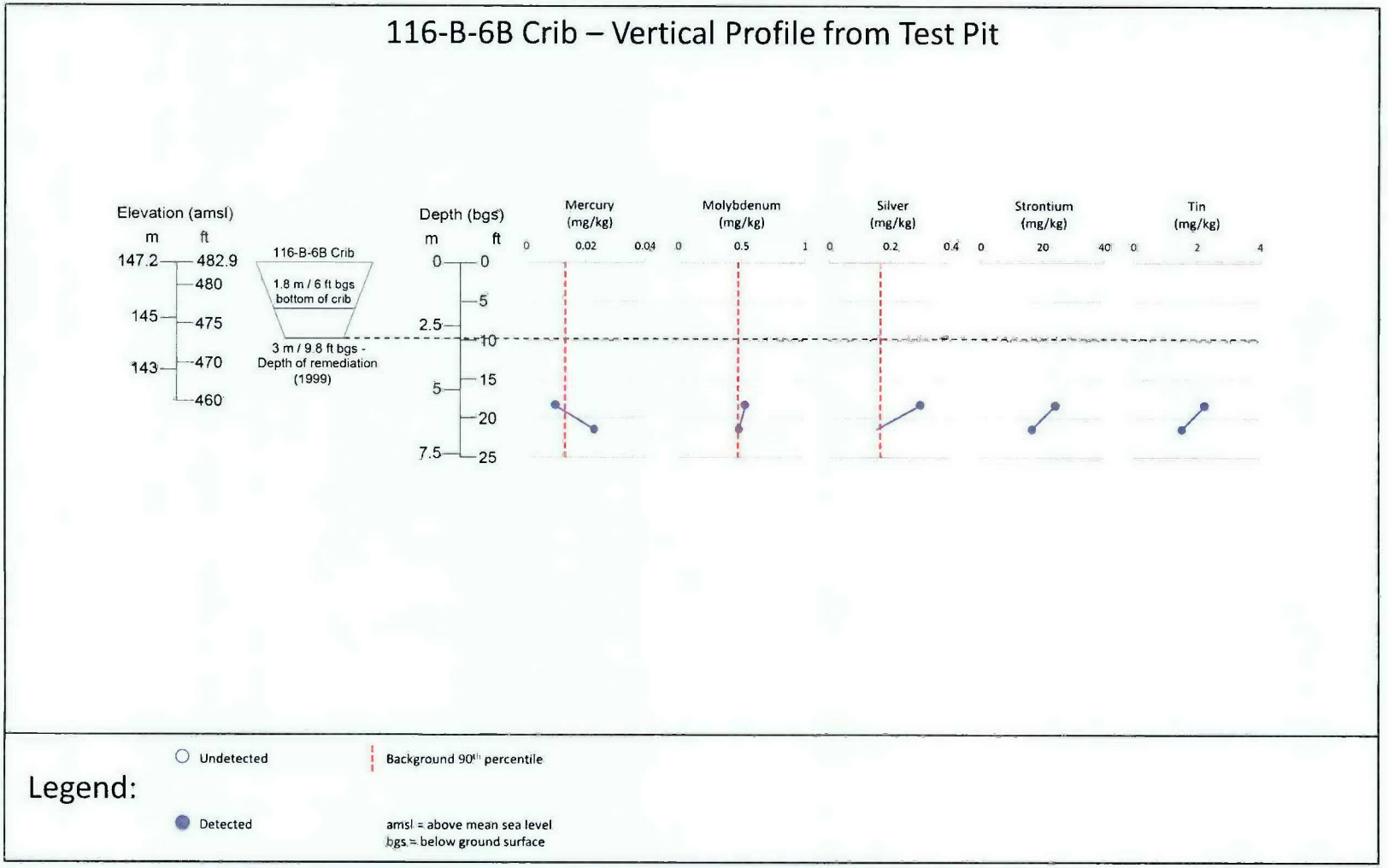


**Figure 4-15. Vertical Profile for Test Pit at 116-B-6B**

#### 4.2.1.9 Nature and Extent of Soil Contamination—118-B-8:3 Process Sewer

The 118-B-8:3 Waste Site is a subsite of the 105-B reactor and consists of miscellaneous pipe segments associated with and immediately around the reactor. Remediation of the 118-B-8:3 pipeline segments has not been planned or performed, as the B Reactor is being converted into a public museum and excavation of these pipelines would potentially undermine the facility. Characterization sampling under the 100-BC Work Plan (DOE/RL-2008-46-ADD3) was conducted to evaluate risk and contaminant concentrations for some of the remaining pipelines.

A test pit was excavated along a north-south pipe run, about 39.6 m (130 ft) northwest of the 105-B Reactor Building. This pipeline segment was upstream of the remediated 100-B-14:1 process sewer pipelines. The (adjacent to) the pipe at 6.7 m (22 ft) bgs and beneath the pipe at 7.0 m (23 ft) bgs. The pipe was opened, and a third sample was collected from the 25.4 to 50.8 mm (1 to 2 in.) of sediment found within.

As shown in Table 4-13, radionuclides were identified in the pipe sediment, and to a lesser extent, in the sample collected adjacent to the pipe, but were not detected in the samples collected below the pipe. Ten radionuclides were detected in the pipe sediment, including cesium-137 at 153 pCi/g, carbon-14 at 38.0 pCi/g, europium-152 at 10.6 pCi/g, strontium-90 at 20.2 pCi/g, and tritium at 38.3 pCi/g). The sample collected adjacent to the pipe contained detectable amounts of only seven radionuclides, with cesium-137 at 0.78 pCi/g and no detectable carbon-14 or tritium. As expected, radionuclides in soil samples collected below the pipe were found at concentrations at approximately an order of magnitude lower than measured in the pipe sediment with some radionuclides not detected in soil. The exception to this trend is nickel-63, which measured 63.2 pCi/g in soil, compared to 46.0 pCi/g in the pipe sediment.

Nonradionuclides identified in the pipe sediment at levels above background include multiple metals (antimony, barium, boron, cadmium, chromium, copper, lead, mercury, molybdenum, and zinc), TPH in the diesel and motor oil range, PCBs, and a number of PAHs (Table 4-13). The same contaminants were detected in previous characterization of sediments in the downstream 100-B-14:1 pipeline, although residual downstream concentrations were up to an order of magnitude higher.

Of the metals quantified in pipe sediment, only mercury was detected in soil. The mercury soil result was 0.18 mg/kg, which is 100 times less than the pipe sediment result of 20 mg/kg. Soil samples collected adjacent to and beneath the pipe showed no PCBs, and fewer detectable organics with concentrations up to 1000 times lower than that measured in the pipe sediment. Cr(VI) was detected below the analytical PQL in a duplicate sample collected from 6.7 m (22 ft) bgs. Low levels of TPH were measured in both soil samples, with the maximum concentration of 14.5 mg/kg from the deeper sample. Low levels of multiple PAHs were also measured in the sample collected beneath the pipe. Figure 4-16 shows the vertical profiles for the constituents. These data are considered in evaluation of potential future actions for the area around the 105-B Reactor building in subsequent chapters.

## Table 4-13. 118-B-8:3 Process Sewer Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Background | Remedial Investigation Test Pit Soil Samples[a,b] (2011) | | | | | Remedial Investigation Test Pit Pipe Sediment Sample (2011) (6.7 / 22.0 ft bgs)[a,b] | |
| | | Maximum Result with Corresponding Depth (m /ft bgs) | | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (7.0 m / 23.0 ft bgs) | | | |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[c]** | | | | | | | | |
| | | Original | Decayed | | Original | Decayed | Original | Decayed |
| Americium-241 | NA | U | NA | NA | U | NA | 3.2 | 3.2 |
| Carbon-14 | NA | U | NA | NA | U | NA | 38 | 38 |
| Cesium-137 | NA | 0.801 (6.7 / 22.0) | 0.783 | 6.7 / 22.0 | U | NA | 157 | 153 |
| Cobalt-60 | NA | 0.650 (6.7 / 22.0) | 0.570 | 6.7 / 22.0 | U | NA | 1.91 | 1.67 |
| Europium-152 | NA | 3.01 (6.7 / 22.0) | 2.86 | 6.7 / 22.0 | U | NA | 11.2 | 10.6 |
| Europium-154 | NA | U | NA | NA | U | NA | 1.39 | 1.28 |
| Nickel-63 | NA | 63.6 (6.7 / 22.0) | 63.2 | 6.7 / 22.0 | U | NA | 46.3 | 46.0 |
| Plutonium-239/240 | NA | 0.266 (6.7 / 22.0) | 0.266 | 6.7 / 22.0 | U | NA | 6.33 | 6.33 |
| Strontium-90 | NA | 2.25 (6.7 / 22.0) | 2.20 | 6.7 / 22.0 | U | NA | 20.7 | 20.2 |
| Tritium | NA | U | NA | NA | U | NA | 40.5 | 38.3 |
| **Nonradionuclides (mg/kg)** | | | | | | | | |
| Antimony | 0.130 | U | | NA | U | | 0.352 | |
| Barium | 132 | 67.6 (<BG) (6.7 / 22.0) | | NA | 56.8 (<BG) | | 156 | |
| Boron | 3.89 | 0.928 (<BG) (6.7 /22.0) | | 6.7 / 22.0 | 0.403 | | 4.17 | |
| Chromium | 18.5 | 15.2 (<BG) (6.7 / 22.0) | | NA | 9.45 (<BG) | | 31.7 | |
| Copper | 22 | 15.5 (<BG) (6.7 / 22.0) | | NA | 15.3 (<BG) | | 32.8 | |
| Cr(VI) | NA | U | | NA | U | | 2.91 | |

## Table 4-13. 118-B-8:3 Process Sewer Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | Background | Remedial Investigation Test Pit Soil Samples[a,b] (2011) | | | Remedial Investigation Test Pit Pipe Sediment Sample (2011) (6.7 / 22.0 ft bgs)[a,b] |
| | | Maximum Result with Corresponding Depth (m /ft bgs) | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (7.0 m / 23.0 ft bgs) | |
| Lead | 10.2 | 4.43 (<BG) (6.7 / 22.0) | NA | 2.02 (<BG) | 126 |
| Mercury | 0.0131 | 0.18 (<BG) (6.7 / 22.0) | NA | U | 20 |
| Molybdenum | 0.470 | 0.267 (<BG) (6.7 / 22.0) | 6.7 / 22.0 | U | 1.21 |
| Strontium | NA | 28.9 (6.7 / 22.0) | 7.0 / 23.0 | 8.42 | 144 |
| Tin | NA | 1.67 (6.7 / 22.0) | 7.0 / 23.0 | 1.07 | 4.76 |
| Zinc | 67.8 | 45.8 (<BG) (6.7 / 22.0) | NA | 16.8 (<BG) | 421 |
| TPH—Diesel range | NA | 4.34 (7.0 / 23.0) | 7.0 / 23.0 | 4.34 | 153 |
| TPH—Motor oil (high boiling) | NA | 14.5 (7.0 / 23.0) | 7.0 / 23.0 | 14.5 | 279 |
| Aroclor 1254 | NA | U | NA | U | 0.304 |
| Aroclor 1260 | NA | U | NA | U | 0.191 |
| Acenaphthene | NA | 0.00182 (7.0 / 23.0) | 7.0 / 23.0 | 0.00182 | 1.45 |
| Acenaphthylene | NA | U | NA | U | 0.305 |
| Anthracene | NA | 0.00117 (7.0 / 23.0) | 7.0 / 23.0 | 0.00117 | 0.201 |
| Benzo(*a*)anthracene | NA | 0.0131 (7.0 / 23.0) | 7.0 / 23.0 | 0.0131 | 0.965 |
| Benzo(*a*)pyrene | NA | 0.0153 (7.0 / 23.0) | 7.0 / 23.0 | 0.0153 | 1.27 |
| Benzo(*b*)fluoranthene | NA | 0.0161 (7.0 / 23.0) | 7.0 / 23.0 | 0.0161 | 1.53 |
| Benzo(*ghi*)perylene | NA | 0.0135 (7.0 / 23.0) | 7.0 / 23.0 | 0.0135 | 1.40 |
| Benzo(*k*)fluoranthene | NA | 0.00799 (7.0 / 23.0) | 7.0 / 23.0 | 0.00799 | 0.802 |

## Table 4-13. 118-B-8:3 Process Sewer Summary of Contaminant Soil Data

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | Background | Remedial Investigation Test Pit Soil Samples[a,b] (2011) | | | Remedial Investigation Test Pit Pipe Sediment Sample (2011) (6.7 / 22.0 ft bgs)[a,b] |
| | | Maximum Result with Corresponding Depth (m /ft bgs) | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (7.0 m / 23.0 ft bgs) | |
| Chrysene | NA | 0.00758 (7.0 / 23.0) | 7.0 / 23.0 | 0.00758 | 0.546 |
| Dibenz[*a,h*]anthracene | NA | U | NA | U | 0.229 |
| Fluoranthene | NA | 0.0238 (7.0 / 23.0) | 7.0 / 23.0 | 0.0238 | 2.02 |
| Fluorene | NA | U | NA | U | 0.0862 |
| Indeno(*1,2,3-cd*) pyrene | NA | 0.00846 (7.0 / 23.0) | 7.0 / 23.0 | 0.00846 | 1.13 |
| Phenanthrene | NA | 0.00873 (7.0 / 23.0) | 7.0 / 23.0 | 0.00873 | 1.01 |
| Pyrene | NA | 0.0202 (7.0 / 23.0) | 7.0 / 23.0 | 0.0202 | 1.18 |

a. Three samples were collected from the 118-B-8:3 test pit. The 118-B-8:3 pipe was located at approximately 6.7 m (22.0 ft) bgs and sediment within was sampled. Soil samples were collected at the depth of the pipe (6.7 m [22.0 ft]) and from below the pipe 7.0 m (23.0 ft).

b. Test pit data obtained from HEIS.

c. Original radiological data presented in left column with decay corrected value to year 2012 in right column.

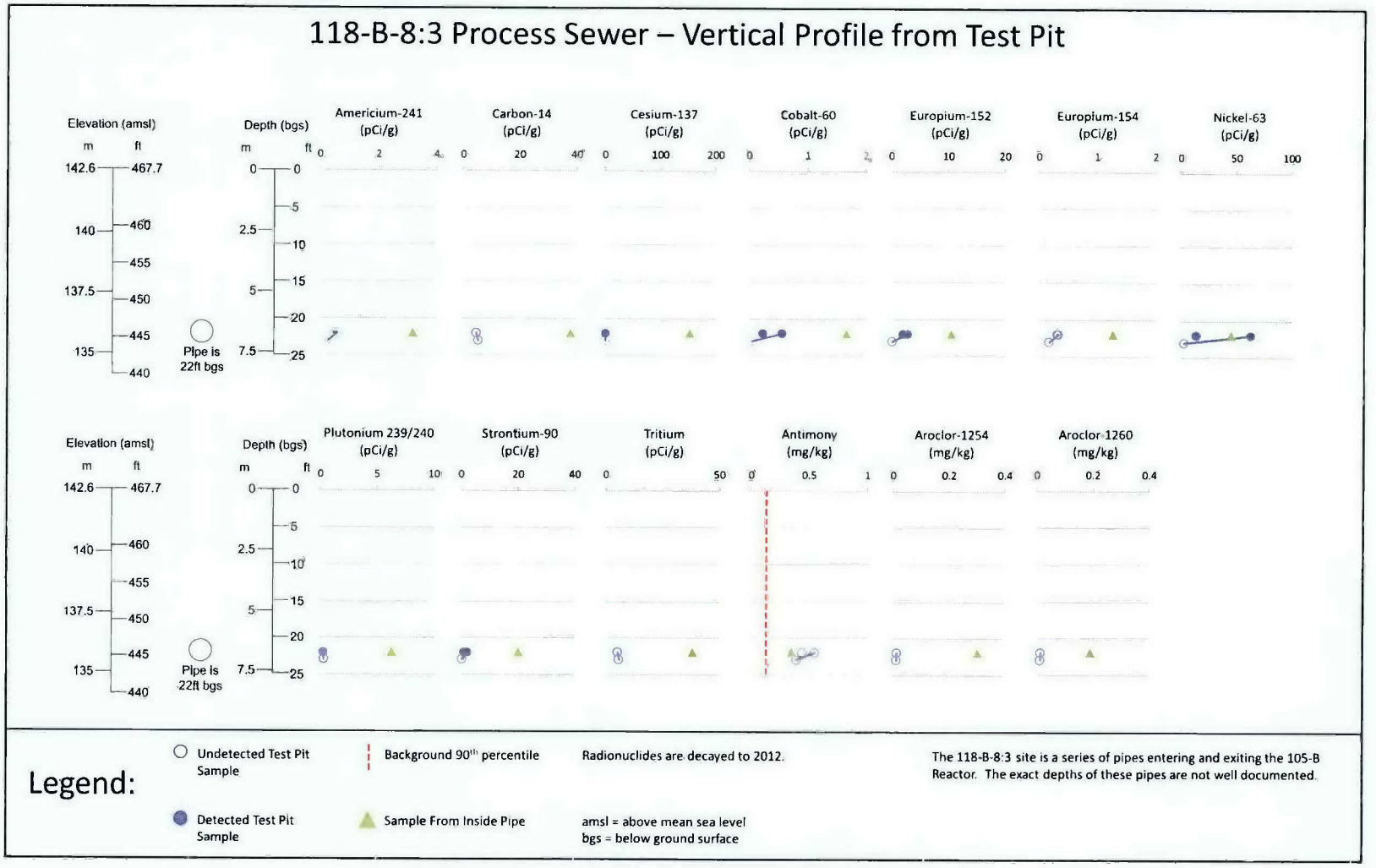


**Figure 4-16. Vertical Profile from Test Pit 118-B-8:3**

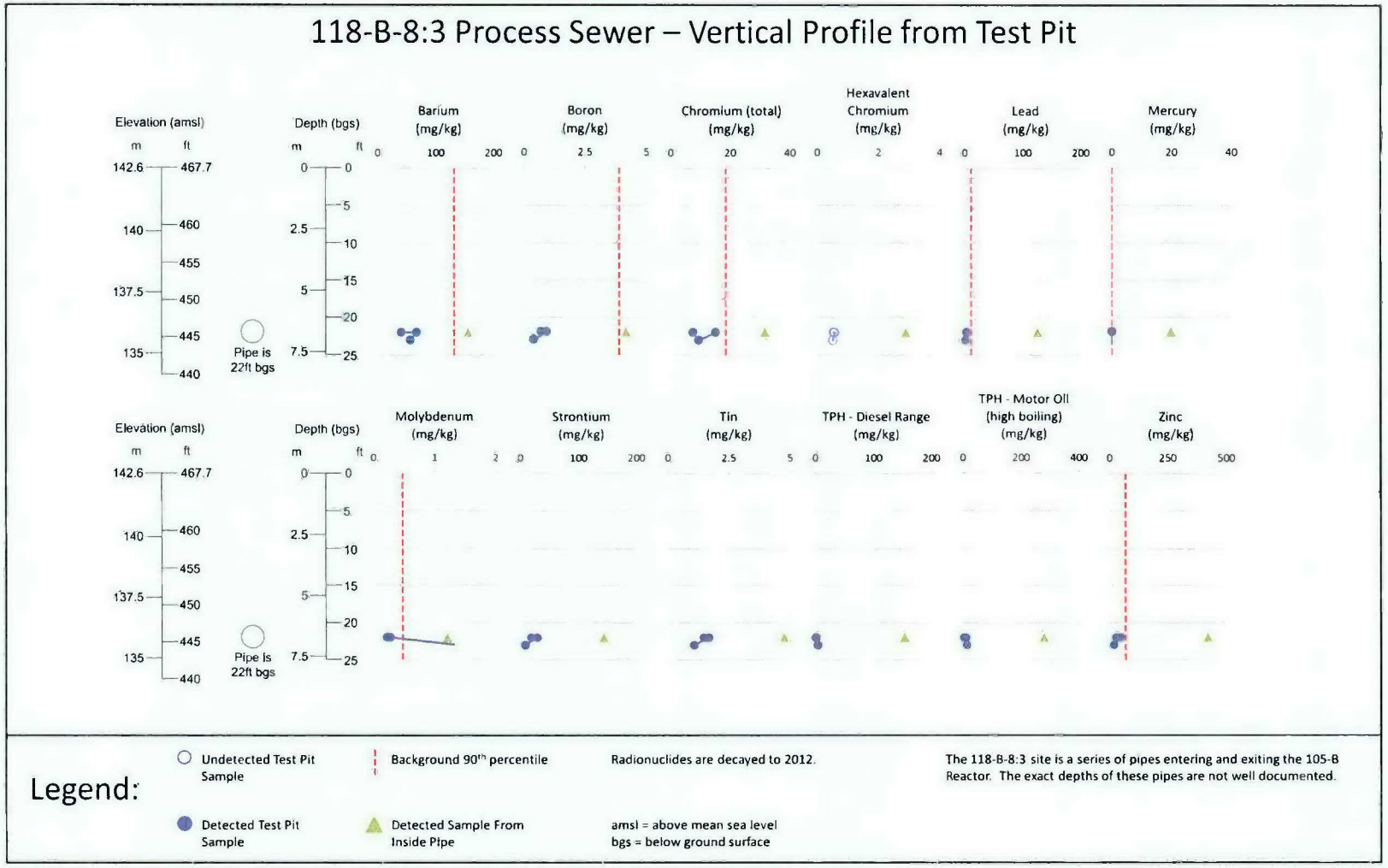


**Figure 4-16. Vertical Profile from Test Pit 118-B-8:3 (cont.)**

#### 4.2.1.10 Nature and Extent of Soil Contamination—116-B-9 French Drain

The 116-B-9, 104-B-2 French Drain, waste site received waste from the 104-B-2 Tritium Laboratory, which supported the P-10 (tritium production) project. The site was remediated (remedial excavation) in 1999 to a maximum depth of 2.4 m (8 ft) bgs. Contaminants of concern for cleanup verification sampling included cobolt-60, cesium-137, europium-152, and strontium-90, but not tritium. None of the COCs was detected in closeout samples. Because of the omission of tritium as a COC, the 116-B-9 Waste Site was identified in Data Gap 2 of the 100-BC Work Plan (DOE/RL-2008-46-ADD3) for test pit characterization to evaluate the concentration and distribution of tritium at the site.

The 116-B-9 site was characterized in 2011 by test pit sampling at 3.0 and 3.9 m (10 and 13 ft) bgs, as described in the 100-BC SAP (DOE/RL-2009-44). No radiological analytes, including tritium, were detected in the samples (Table 4-14). Several nonradiological target analytes were detected at concentrations slightly above background. Figure 4-17 shows the vertical profiles for these constituents. These data do not suggest significant residual contamination beyond the boundaries of the former remediation at this site, and this RI data is considered with the previous remediation verification data in the risk evaluation in subsequent chapters.

**Table 4-14. 116-B-9 French Drain Summary of Contaminant Soil Data**

| Constituent | Concentration and Distribution | | | | |
|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] Shallow Zone | Remedial Investigation Test Pit 116-B-9[b,c] | | |
| | | | Maximum Result with Corresponding Depth (m / ft bgs) | Extent of Detection above BG (m / ft bgs) | Result at Maximum Sample Depth (3.9m / 13.0 ft bgs) |
| Chromium | 18.5 | ND | 22.3 (3.9 / 13.0) | 3.9 / 13.0 | 22.3 |
| Copper | 22 | ND | 25.4 (3.9 / 13.0) | 3.9 / 13.0 | 25.4 |
| Cr(VI) | NA | ND | 0.30 (3.9 / 13.0) | 3.9 / 13.0 | 0.30 |
| Magnesium | 7,060 | ND | 8590 (3.9 / 13.0) | 3.9 / 13.0 | 8,590 |
| Manganese | 512 | ND | 521 (3.9 / 13.0) | 3.9 / 13.0 | 521 |
| Nickel | 19.1 | ND | 20.5 (3.9 / 13.0) | 3.9 / 13.0 | 20.5 |
| Strontium | NA | ND | 49.2 (3.0 / 10.0) | 3.9 / 13.0 | 37.9 |
| Tin | NA | ND | 1.74 (3.0 / 10.0) | 3.9 / 13.0 | 1.61 |

a. Verification sample results representing the maximum 95% UCL concentration from the 116-B-9 excavation area were obtained from *Cleanup Verification Package for the 116-B-9 French Drain* (CVP-99-00009). The maximum depth of interim remedial action at 116-B-9 was 2.4 m (8.0 ft) bgs.

b. Two soil samples were collected from the 116-B-9 test pit at 3 and 3.9 m (10.0 and 13.0 ft) bgs.

c. Test pit data obtained from HEIS.

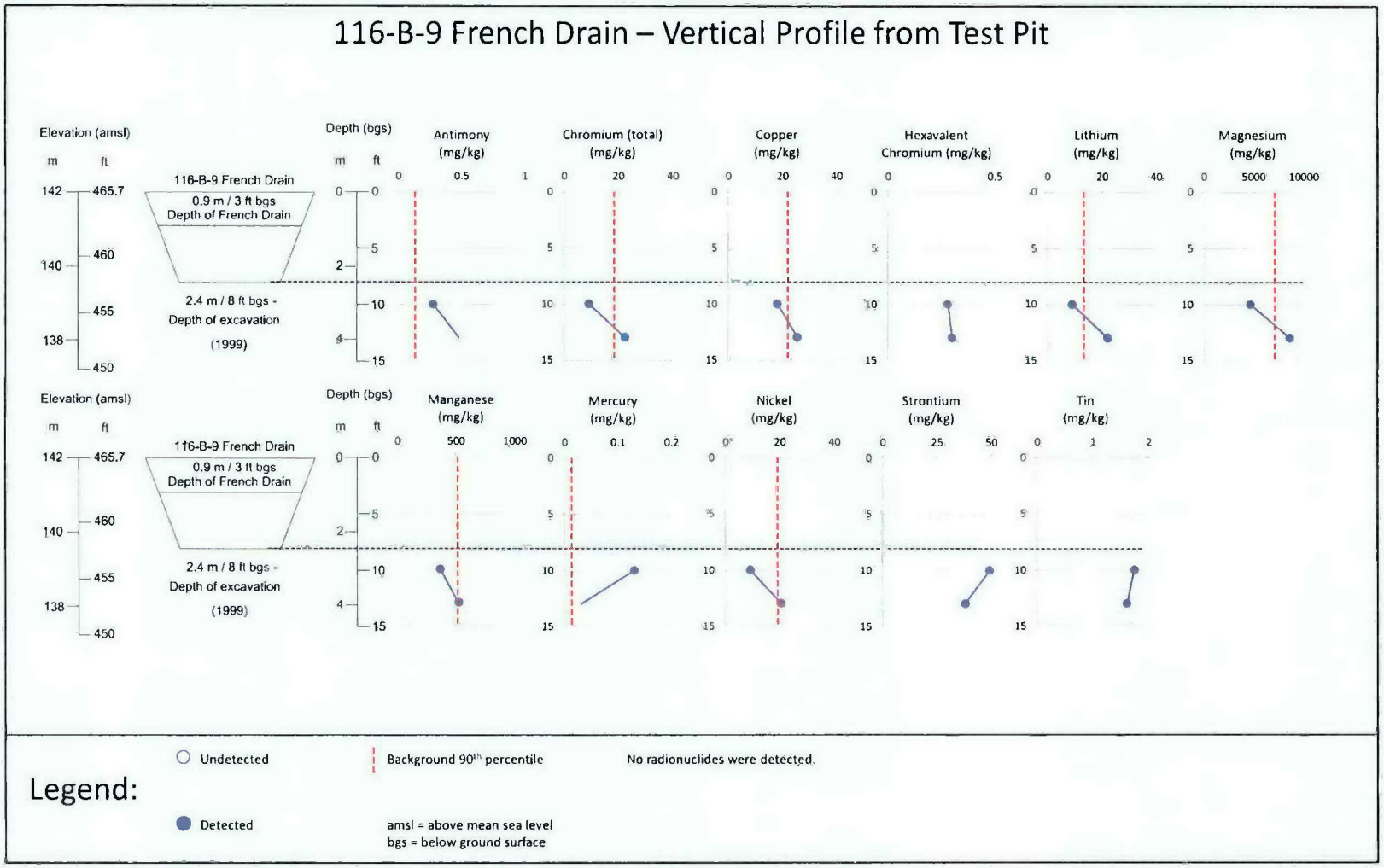


**Figure 4-17. Vertical Profile from Test Pit 116-B-9**

#### 4.2.1.11 Nature and Extent of Soil Contamination—100-C-7

The 100-C-7 waste site is one of the few 100-BC sites where interim remedial actions have not yet been completed. Interim remediation will continue at this site, and is expected to be complete before issuance of a ROD. However, a brief summary of the current state and data for this site, as of May 2012, is provided here to support an understanding of the nature of releases at this site and on-going remediation efforts.

The 100-C-7 waste site is located in the southwestern portion of 100-BC, at the footprint of the former 183-C Filter Building. The site consists of contaminated residual structures and soils associated with the former facility, most notably a significant volume of Cr(VI)-contaminated soil. The 100-C-7 site includes both the 100-C-7:1 subsite and an area that has not been assigned to a separate site. Significant characterization and remediation have been performed at both of these areas to date, including disposal of over 670,000 metric tons (740,000 tons) of contaminated soil and debris at ERDF.

***100-C-7.*** This area is associated with the former pump room on the eastern side of the 183-C Filter Building, where sodium dichromate was injected into cooling water as it was pumped to the 183-C Clearwells to the east. Releases of sodium dichromate solution are known to have occurred within the facility, such as a 1966 event when approximately 54,050 L (14,280 gal) of concentrated solution overflowed from the feed tank (*Radiation Protection Records Contamination Release to the Environs 9/23 – 24/66* [Battelle-Northwest, 1997]; *Chemicals Discharged to the Columbia River from DUN Facilities Fiscal Year 1967* [DUN-3032]; *Douglas United Nuclear, Inc. Monthly Report September, 1966* [DUN-1295]). The majority of releases within this facility would be expected to drain to the process sewer system and ultimately to the Columbia River, but significant releases to the soil underlying the facility also occurred.

Initial remediation at this site in 2005 confirmed that the side of the residual concrete foundation was contaminated with Cr(VI) that extended into soil. This initial effort removed contaminated concrete and soil to a maximum depth of approximately 6 m (20 ft). A characterization borehole (C5672; well 199-B8-8) completed at the location in 2007 did not detect Cr(VI) greater than 6 m (20 ft) bgs. Total chromium concentrations were below background levels except for a detection of 310 mg/kg at 17 m (56 ft) bgs ("100-C-7 and 100-B-27 Test Pit and Borehole Data Summary Report" [ Blakley, 2008]). Further demolition and removal of remaining 183-C facility structural components was performed in 2010 and soil remediation resumed in early 2011, following an observational approach to remove contaminated material. As of May 2012, remediation has extended to approximately 26 m (85 ft) below original ground surface, extending to the local groundwater table. Preliminary verification sampling results for the excavation indicate that interim remedial action objectives for the vadose zone have been attained, with no detections of Cr(VI) in soil samples from the excavation footprint.

***100-C-7:1.*** This subsite is associated with an area of contaminated soil on the western side of the former 183-C facility, generally north of the former headhouse area. This area was associated with receiving, handling, and storage of concentrated sodium dichromate solutions and other water treatment chemicals.

Initial remediation at this subsite in 2005 removed contaminated soil to a depth of 4.6 m (15 ft), with visibly contaminated soil still present at the base of the excavation. A characterization test pit was excavated in one location to a total depth of approximately 10 m (33 ft) below original ground surface. Analytical samples detected 1,620 mg/kg Cr(VI) at the base of this test pit. Further characterization was performed by completing two boreholes (C5671 and C4947) and eight additional test pits later in 2005 and in 2007. These characterization efforts showed Cr(VI) contamination extending to the groundwater table, with up to 37.9 mg/kg detected at 24.4 m (80 ft) bgs. Significantly higher concentrations were detected in shallower samples--up to 1,290 mg/kg Cr(VI) at 5.5 m (18 ft) below original ground surface

("100-C-7 and 100-B-27 Test Pit and Borehole Data Summary Report" [Blakley, 2008]). The characterization samples also generally showed total chromium concentrations only slightly higher than corresponding results for Cr(VI), suggesting that some reduction to trivalent chromium had occurred, but that the majority of the contaminant mass was still present as Cr(VI). Slightly acidic pH values (down to 5.0) were also observed at several characterization locations, compared to typically slightly basic results (pH 8.1 to 8.9) at most locations. Sulfuric acid was also received and stored at this location for use in water treatment, and it is possible that releases of this chemical also occurred. However, mercury results were not significantly elevated, as has been observed for other locations of sulfuric acid releases at 100-BC.

Further demolition and removal of the headhouse and other remaining 183-C facility structural components were performed in 2010, and additional characterization was performed to the north of the site to support relocation of the export water line. Cr(VI) was quantified below PQLs in these boreholes (C7883 and C7884), but there were not significant detections. Soil remediation resumed in early 2011. As of May 2012, remediation has extended to approximately 26 m (85 ft) below original ground surface, encountering the local groundwater table. During this remediation, an additional area of unexpected Cr(VI) contamination was also discovered slightly farther to the west. It is suspected that this contamination may be related to former temporary storage tanks in the area, and remediation is expanding to address this contamination following the observational approach.

#### 4.2.1.12 Nature and Extent of Soil Contamination—116-C-1 Process Effluent Trench

The 116-C-1 Process Effluent Trench received an estimated 700 million L (184 million gal) of contaminated cooling water during its operational use. In addition, 40 billion L (10.6 billion gal) of high temperature reactor cooling water was discharged to the trench over a 150-day period in 1967. Remediation at 116-C-1 consisted of the 100-BC Demonstration Project (southwest portion of the trench) and remedial action of the remaining trench in 1995-1996 to a maximum depth of 16.4 ft bgs. The purpose of the 100-BC Demonstration Project (BHI-00752) was to initiate a limited remedial action in the 100 Areas to address uncertainties in remedial design and planning. At 116-C-1, a 38 x 38 m (125 x 125 ft) area of the southwest end of the trench was chosen for remediation under this project. The chosen area included the inlet pipes for the trench. Contaminants of concern for cleanup verification sampling included americium-241, cesium-137, cobalt-60, europium-152, europium-154, europium-155, nickel-63, plutonium-238, plutonium-239/240, strontium-90, chromium, Cr(VI), lead, and mercury (*Cleanup Verification Package for the 116-C-1 Process Effluent Trench* [CVP-98-00006]). Analytical results for the related cleanup verification soil samples are summarized in Table 4-15.

After remediation of the trench and associated soil contamination plumes were completed, a 7.3 m (24 ft) test pit was excavated at the base of remediation in December 1997 and January 1998 to further characterize the deep zone. The test pit was conservatively located at an area of elevated activity as identified by radionuclide field surveys near the 116-C-1 inlet pipes. For each of the eight, 1 m (3 ft) test pit lifts, soil was obtained from each quadrant of the test pit and composited to create the sample. The test pit encountered groundwater at approximately 12.3 m (40.3 ft) bgs.

Results from eight test pit samples showed elevated radionuclide and metal concentrations continued below the trench excavation floor (Figure 4-18). Multiple radionuclides were detected through the vadose zone. For all radionuclides except strontium-90, peak activity was measured at 8.0 m (26.2 ft) bgs and decreased significantly below this point. Isotopes with maximum activity at this depth included americium 241 (80.5 pCi/g), cesium-137 (4,030 pCi/g), cobalt-60 (16 pCi/g), europium-152 (518 pCi/g), europium-154 (43 pCi/g), nickel-63 (11,430 pCi/g), plutonium-238 (3.54 pCi/g), and plutonium 239/240 (136 pCi/g). The maximum activity of strontium-90 (62.8 pCi/g) was measured at 9.4 m (31 ft) bgs. Both

cesium-137 and strontium-90 were detected in all test pit samples, with concentrations of 0.352 and 4.88 pCi/g, respectively at the final depth of 12.3 m (40.3 ft) bgs.

The 116-C-1 test pit was located at an area of elevated radiological activity and sample results showed that contaminant concentrations were elevated relative to the deep zone statistical data set values (95 percent UCL values). Therefore, the deep zone was divided into three levels (Levels I, II, and III) for site-specific modeling (*Cleanup Verification Package for the 116-C-1 Process Effluent Trench* [CVP-98-00006]). Table 4-15 presents the closeout values from each deep zone level. Test pit sample results from the upper four lifts were used in conjunction with the statistical data values to determine the upper deep zone cleanup value. The maximum activities of radionuclides within the test pit were up to 2.5 times greater than the deep zone Level I closeout value. However, the test pit was specifically located in a worst-case location to acquire information on the most contaminated soil to support site-specific contaminant transport modeling. Contaminant levels in deep zone Levels II and III were determined solely from results from the lower four test pit lift sample results.

Several metals showed elevated concentrations in the upper test pit sample intervals with decreasing concentration with depth. CrVI was detected in all samples with a maximum concentration of 1.80 mg/kg measured at 7.0 m (23.0 ft) bgs. Concentrations decreased with depth with 0.44 mg/kg CrVI detected in the deepest sample at 12.3 m (40.3 ft) bgs. Cadmium (0.80 to 2.3 mg/kg), lead (28.9 to 48.5 mg/kg), and zinc (279 to 464 mg/kg) were measured above background between 6.0 and 10.0 m (19.7 and 32.8 ft) bgs but all analytes were below background or not detected in deeper samples. Copper (30.4 to 26.5 mg/kg) was above background from 7.0 to 9.0 m (23.0 to 29.5 ft) bgs but less than background in all deeper samples. Chromium (43.4 to 148 mg/kg) was above background between 6.0 and 10.0 m (19.7 and 32.8 ft) bgs, with results from deeper samples at or below background. Concentrations of antimony and mercury were above the background values established in ECF-HANFORD-11-0038 in all samples with maximum detections of 5.9 and 11.8 mg/kg, respectively. A single detection of silver above background (0.89 mg/kg at 9.0 m [29.5 ft]) was reported. As with the radionuclide data, the non-radionuclide statistical data set values (95% UCL values) were used with results from the test pit to divide the deep zone into 3 levels (Table 4-15). This served to conservatively increase the value used for cleanup verification in deep zone Level 1, while values used for Levels II and III were based on data from the deeper test pit lifts.

Table 4-15. 116-C-1 Process Effluent Trench - Summary of Contaminant Soil Data

| Contaminants | Background | Concentration and Distribution | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Cleanup Verification Data[a] | | | | Remedial Action Test Pitb | | | | |
| | | Shallow Zone[c] | | Deep Zone (Level I/ Level II/ Level III)[d] | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth 12.3 m (40.3 ft bgs) | |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)[e]** | | | | | | | | | | |
| | | Original | Decayed | Original | Decayed | Original | Decayed | | Original | Decayed |
| Americium-241 | NA | 0.041[f] | 0.040 | 29.3/0.663/0.035 | 28.6/0.647/0.034 | 82.5 (8.0/26.2) | 80.7 | 11.0/36.1 | U | U |
| Cesium-137 | NA | 0.803 | 0.569 | 2120/407/3.91 | 1503/288/2.77 | 5690 (8.0/26.2) | 4126 | 12.3/40.3 | 0.485 | 0.352 |
| Cobalt-60 | NA | 0.076[f] | 0.011 | 62.7/3.34/0.015 | 8.7/0.46/0.002 | 115 (8.0/26.2) | 18 | 10.0/32.8 | U | U |
| Europium-152 | NA | 0.755[f] | 0.350 | 759/33.4/0.032 | 351/15.5/0.015 | 1120 (8.0/26.2) | 546 | 10.0/32.8 | U | U |
| Europium-154 | NA | 0.258 | 0.077 | 91.1/1.84/0.047 | 27.2/0.55/0.014 | 144 (8.0/26.2) | 47 | 9.0/29.5 | U | U |
| Europium-155 | NA | 0.084 | 0.009 | 3.32/0.286/0.060 | 0.37/0.032/0.007 | U | U | NA | U | U |
| Nickel-63 | NA | 4.96[f] | 4.47 | 1140/131/0.905 | 1027/118/0.816 | 1590 (8.0/26.2) | 1443 | 11.0/36.1 | U | U |
| Plutonium-238 | NA | 0.017 | 0.015 | 1.40/0.535/0.082 | 1.2/0.475/0.073 | 3.99 (8.0/26.2) | 3.57 | 12.0/39.4 | U | U |
| Plutonium-239/240 | NA | 0.215 | 0.215 | 52.0/0.998/0.011 | 52.0/0.998/0.011 | 136 (8.0/26.2) | 136 | 11.0/36.1 | U | U |
| Strontium-90 | NA | 0.345 | 0.241 | 50.8/44.6/7.98 | 35.5/31.2/5.58 | 87.7 (10.0/32.8) | 58.4 | 12.3/40.3 | 6.81 | 4.88 |
| **Nonradionuclides (mg/kg)** | | | | | | | | | | |
| Antimony | 5 | ND | | ND | | 5.9 (10.0/32.8) | | 10.0/32.8 | 0.3 (<BG) | |
| Cadmium | 0.81 | ND | | ND | | 2.9 (7.0/23.0) | | 9.0/29.5 | U | |
| Chromium | 18.5 | 12.3 | | 119/45.8/16.9 | | 148 (8.0/26.2) | | 12.3/40.3 | 19.0 | |
| Copper | 22 | ND | | ND | | 30.4 (7.0/23.0) | | 9.0/29.5 | 8.8 (<BG) | |
| Cr(VI) | 0 | 0.210[f] | | 1.15/0.073/0.034 | | 1.80 (7.0/23.0) | | 12.3/40.3 | 0.44 | |
| Lead | 10.2 | 4.41 | | 33.9/6.45/3.63 | | 48.5 (7.0/23.0) | | 9.0/29.5 | 5.5 (<BG) | |
| Mercury | 0.33 | 0.030 | | 5.53/0.255/0.025 | | 11.8 (8.0/26.2) | | 10.0/32.8 | 0.02 (<BG) | |
| Silver | 0.78 | ND | | ND | | 0.89 (9.0/29.5) | | 9.0/29.5 | U | |
| Zinc | 67.8 | ND | | ND | | 464 (7.0/23.0) | | 9.0/29.5 | 20.8 (<BG) | |

**Table 4-15. 116-C-1 Process Effluent Trench - Summary of Contaminant Soil Data**

| Contaminants | Concentration and Distribution | | | | | |
|---|---|---|---|---|---|---|
| | Background | Cleanup Verification Data[a] | | Remedial Action Test Pitb | | |
| | | Shallow Zone[c] | Deep Zone (Level I/ Level II/ Level III)[d] | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth 12.3 m (40.3 ft bgs) |

a. Verification sample results represent the maximum cleanup verification value from the given decision unit(s). For the shallow zone, the value represents the 95% UCL from *Cleanup Verification Package for the 116-C-1 Process Effluent Trench* (CVP-98-00006). The maximum depth of interim remedial action at 116-C-1 was 4.9 m (16 ft) bgs.

b. Test pit data obtained from *Cleanup Verification Package for the 116-C-1 Process Effluent Trench* (CVP-98-00006) and HEIS. The test pit was excavated at the base of the remedial action excavation at an area of elevated radiological activity and extended to groundwater. Soil samples were collected from each of eight, 0.9 m (3 ft) lifts. Groundwater was encountered at approximately 12.3 m (40.3 ft) bgs.

c. Shallow zone value represents the excavation area unless otherwise noted.

d. As described in *Cleanup Verification Package for the 116-C-1 Process Effluent Trench* (CVP-98-00006), the 116-C-1 deep zone was divided into 3 levels for site specific modeling. Cleanup verification data combined results from deep zone verification sampling and data from the test pit focused in an area of elevated radiological activity. The cleanup value from deep zone Level I was the most elevated as it contained data from the statistical verification data set (95% UCL value) and sample results from the upper four test pit lifts. Deep zone levels II and III cleanup values were conservatively determined based on data from the lower four test pit lifts.

e. Original radiological data presented in left column with decay corrected value to year 2012 in right column.

f. Shallow zone value is from overburden sampling result.

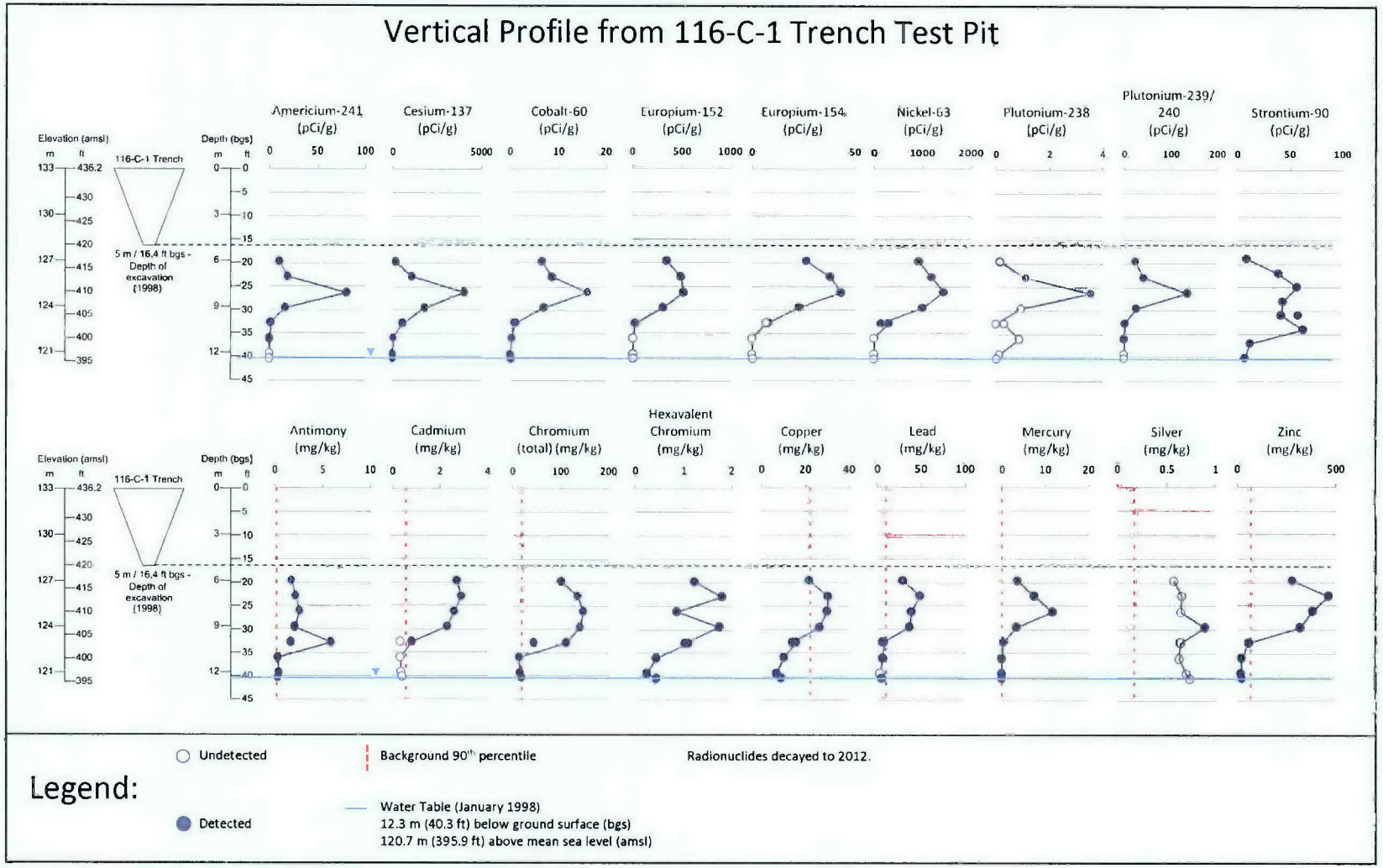


**Figure 4-18. Vertical Profile from 116-C-1 Process Effluent Trench**

### 4.2.2 Potential Stainless Steel Contamination of 100-BC RI Samples

Upon review of the analytical data from the vadose zone soil samples, some of the chromium and nickel results appear anomalous when compared to other results from neighboring intervals in the same boring and duplicate sample results. This trend of elevated chromium and nickel results occurs primarily in a ratio between 1.5 to 2.2, chromium:nickel. The ratio between the metals generally decreases as the analytical result approaches background values of chromium (18.2 mg/kg) and nickel (19.1 mg/kg). In some cases, concentrations of other metals, such as molybdenum, are anomalous. Table 4-16 presents data for the corresponding wells and intervals in 100-BC boreholes that show the elevated chromium and nickel results potentially attributable to stainless steel contamination, and the relative ratios of chromium:nickel in these samples.

**Table 4-16. Elevated Metal Concentrations in 100-BC Area RI Samples**

| Well ID | Interval | Sample | Chromium (mg/kg) | Nickel (mg/kg) | Ratio Chromium: Nickel |
|---|---|---|---|---|---|
| C7842 | I-010 | B27FF5 | 42.7 | 24.2 | 1.76 |
| C7846 | I-002 | B27Y42 | 87.1 | 33.5 | 2.60 |

The ratio of chromium:nickel in C7846, sample B27Y42, is greater than that above identified ratio of 1.5 to 2.2 for a sample contaminated with stainless steel. This is explained by evidence that the soil in sample B27Y42 had an existing chromium concentration greater than background in addition to stainless steel contamination.

As shown in Table 4-17, the total chromium concentration from the C7846 interval I-001 (collected 1.5 m [5 ft] above interval I-002; sample B27Y42) indicates chromium above background (33.7 mg/kg; sample B27Y38). The chromium concentration in the duplicate sample associated with C7846, interval I-002 (31.5 mg/kg; sample B27Y45) is consistent with the result from interval I-001. The nickel concentration in sample B27Y42 (33.5 mg/kg) argues that the sample was contaminated by stainless steel. Nickel concentrations in samples B27Y38 (interval I-001), B27Y45 (interval I-002 duplicate), and B27Y49 (interval I-003) are 6.63, 7.23, and 6.11 mg/kg, respectively, indicating contamination from stainless steel has artificially increased the nickel concentration by a factor of 5 in B27Y42. Assuming the chromium concentration in interval I-002 is likely near that measured in the duplicate (31.5 mg/kg; sample B27Y45), it is reasonable that the ratio of chromium:nickel in sample B27Y42 is higher than would be expected from a sample without an existing elevated chromium concentration in the soil. In summary, it is probable that the chromium concentration in B27Y42 is greater than background, but the analytical result of 87.1 mg/kg is elevated because of contamination by stainless steel.

The discussion of elevated concentrations of the other metals in the presence of chromium is predicated on the fact that these metals are all components of various alloys of steel. The shoes that are used on the split spoons are made of 4140 alloy steel, the split spoons are DOM 520 steel, and the stainless steel liners that are periodically used are 304 stainless. The use of steel to drill and collect subsurface soil is the only method available to obtain analytical samples, and with it, poses the potential of introducing some contamination attributable to the sampling approach.

Given that the DOM 520 steel does not contain any chromium, molybdenum, or nickel, it can be discounted as a source of the elevated concentrations. The 4140 alloy steel contains between 0.80 and

1.10 percent by weight of chromium and 0.15 to 0.25 percent molybdenum. For the 304 stainless, chromium is much more prevalent ranging from 18 to 20 percent and contains nickel at 8 to 12 percent.

**Table 4-17. C7846, Interval 2 (Sample B27Y42), Chromium and Nickel Results Relative to Neighboring Intervals and Duplicate Sample Results**

| Interval | Sample | Sample depth m (ft) | Chromium (total) | | Nickel | |
|---|---|---|---|---|---|---|
| | | | mg/kg | Q | mg/kg | Q |
| C7846 (100-B-5); I-001 | B27Y38 | 9.3 (30.4) | 33.7 | | 6.63 | |
| C7846 (100-B-5); I-002 | B27Y42 | 10.8 (35.3) | 87.1 | | 33.5 | |
| C7846 (100-B-5); I-002 DUP | B27Y45 | 10.8 (35.3) | 31.5 | | 7.23 | |
| C7846 (100-B-5); I-003 | B27Y49 | 12.3 (40.5) | 12.8 | | 6.11 | |

As seen with C7846, Interval I-002 (Table 4-16), results from C7842, Interval I-010, also show an unexpected increase in chromium and nickel concentrations potentially due to stainless steel contamination (Table 4-18). Sample B27FF5 (Interval I-010) is the only sample from the borehole with nickel above background (19.1 mg/kg) and has a concentration of total chromium nearly two times that of any of the upper intervals. This supports the assertion that the results from Interval I-010 are questionable because of potential contamination by stainless steel.

**Table 4-18. C7842, Interval 10 (Sample B27FF5), Chromium and Nickel Results Relative to Upper Interval Sample Results**

| Interval | Sample | Sample Depth m (ft) | Chromium (total) | | Nickel | |
|---|---|---|---|---|---|---|
| | | | mg/kg | Q | mg/kg | Q |
| C7842 (116-B-14); I-001 | B27FC4 | 6.8 (22.3) | 13.5 | | 10.2 | |
| C7842 (116-B-14); I-001 Dup | B27FC6 | 6.8 (22.3) | 15.6 | | 10.7 | |
| C7842 (116-B-14); I-002 | B27FC9 | 8.3 (27.3) | 23.4 | | 15.4 | |
| C7842 (116-B-14); I-003 | B27FD2 | 9.8 (32.3) | 20.6 | | 11.8 | |
| C7842 (116-B-14); I-004 | B27FD4 | 10.7 (35.2) | 24.9 | | 17.1 | |
| C7842 (116-B-14); I-005 | B27FD6 | 11.4 (37.3) | 16.5 | | 12.8 | |
| C7842 (116-B-14); I-006 | B27FD8 | 12.1 (39.8) | 20.3 | | 14.2 | |
| C7842 (116-B-14); I-007 | B27FF0 | 13.0 (42.7) | 15.2 | | 16.1 | |
| C7842 (116-B-14); I-009 | B27FF4 | 13.7 (44.8) | 10.6 | | 9.85 | |
| C7842 (116-B-14); I-008 | B27FF2 | 14.4 (47.3) | 14.6 | | 15.0 | |
| C7842 (116-B-14); I-010 | B27FF5 | 16.1 (52.8) | 42.7 | | 24.2 | |

### 4.2.3 Contaminants above Background at Remediated Waste Sites

Analytical data used to reclassify waste sites in 100-BC to "Closed Out," "Interim Closed Out," and "No Action" were evaluated to document the occurrence of analytes detected above background. Contaminants detected above background at each reclassified waste site are identified in Appendix E. Data from waste sites previously evaluated in this section were not evaluated.

### 4.2.4 Nature and Extent of Contamination in Soil Samples from Monitoring Wells

As part of the 2010-2011 RI/FS, 6 groundwater wells were drilled and constructed in 100-BC to examine the lateral and vertical extent of the groundwater contamination. These groundwater wells are not affiliated with any particular waste site. The RI activities are outlined in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). Sections 4.2.4.1 through 4.2.4.4 summarize soil contaminant data for 4 of the 6 wells. Characterization samples were not required for two of the wells because they were located adjacent to previously-characterized wells.

Four additional wells were drilled before onset of the RI fieldwork under *Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* (DOE/RL-2009-61) to allow for modification of future RI work, as needed. Data from these wells are summarized in Section 4.2.4.5.

#### *4.2.4.1 Well 199-B2-16*

Borehole C7784 (RI Well 2—199-B2-16) was located near the river, about 61 m (200 ft) southeast of the 181-B River Pumphouse. Based on the location of this borehole adjacent to the river, extensive flux in the groundwater table would occur throughout the year, leading to a significantly sized rewetted zone.

Samples were collected between 7.9 and 14.6 m (26 and 48 ft) bgs, with the water table encountered at about 13.4 m (44 ft) bgs. Strontium-90 was detected between 9.4 and 11.1 m (31 and 36.5 ft) bgs, at a maximum concentration of 0.775 pCi/g. No other radionuclides were detected (Table 4-19).

Cr(VI) was detected at levels below the practical quantitation limit (less than 0.20 mg/kg) in the shallowest samples, collected at about 7.9 and 9.4 m (26 and 31 ft) bgs, but was not detected in the deeper vadose zone samples or in the sample collected 1.2 m (4 ft) below the water table.

Between about 9.1 m and 11 m (30 and 36 ft) bgs, total chromium and nickel showed elevated concentrations. The highest concentration of total chromium (51.0 mg/kg at11.3 m [37 ft] bgs) also corresponds with an elevated molybdenum result (7.32 mg/kg), which is at least seven times greater than other molybdenum results in the borehole. However, the nickel results are all near background levels with 20.4 mg/kg at the11.3 m [37 ft] bgs sample. Figure 4-19 shows the vertical profiles for these constituents.

**Table 4-19. Well 199-B2-16—Summary of Contaminant Soil Data**

| Contaminants | Concentration and Distribution | | | | | |
|---|---|---|---|---|---|---|
| | Back-ground | Remedial Investigation Borehole C7784 (Well 199-B2-16)[a] (2010) | | | | |
| | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (14.7 m/48.3 ft bgs)[b] | |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)** | | | | | | |
| | | Original | Decayed | | Original | Decayed |
| Stronium-90 | NA | 0.813 (9.4 / 31.0) | 0.775 | 11.1 / 36.5 | U | NA |
| **Nonradionuclides (mg/kg)** | | | | | | |
| Chromium | 18.5 | 51.0 (11.1 / 36.5) | | 11.1 / 36.5 | 7.45 (<BG) | |
| Cr(VI) | NA | 0.19 (9.4 / 31.0) | | 9.4 / 31.0 | U | |
| Molybdenum | 0.470 | 7.32 (11.1 / 36.5) | | 11.1 / 36.5 | 0.489 | |
| Nickel | 19.1 | 24.8 (9.4 / 31.0) | | 11.1 / 36.5 | 7.81 (<BG) | |
| Strontium | NA | 27.4 (8.0 / 26.1) | | 14.7 / 48.3 | 19.4 | |
| Tin | NA | 7.82 (9.4 / 31.0) | | 14.7 / 48.3 | 1.24 | |

Note: Well 2 was located southeast of the intake structure to characterize contaminant plumes near the Columbia River. See Data Gap 4, Table 4-4 (100-BC Work Plan [DOE/RL-2008-46-ADD3]).

a. Borehole data obtained from HEIS. The water table was encountered at 13.4 m(44 ft). Well was drilled to 47.3 m (155.2 ft).

b. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

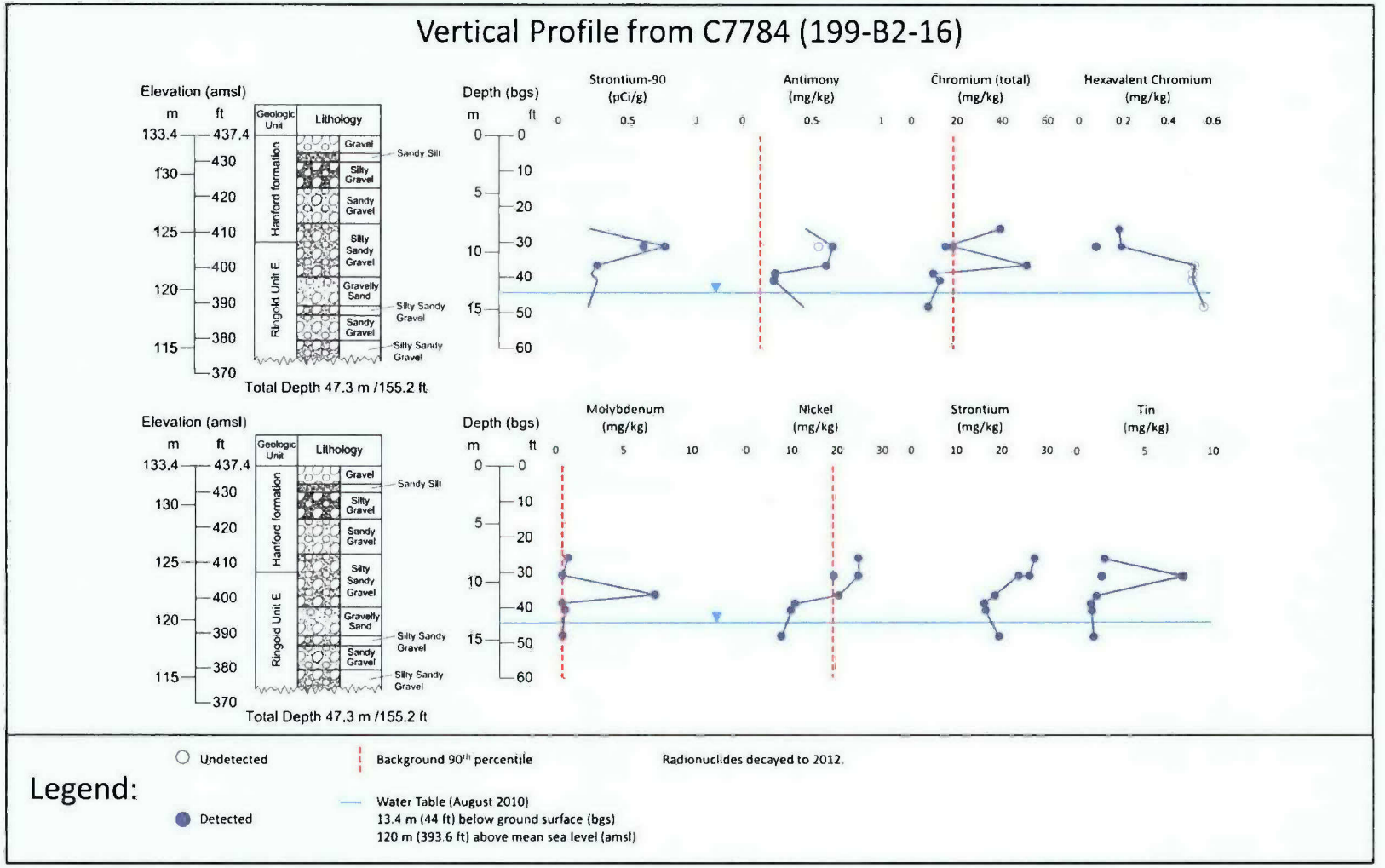


Figure 4-19 Vertical Soil Profile from Well 199-B2-16 (Borehole C7784)

#### 4.2.4.2 Well 199-B3-51

Borehole C7785 (RI Well 3—199-B3-51) was sited based on groundwater characterization needs, as opposed to waste site characterization needs. It is located near the river, about 61 m (200 ft) north of the former 107-B Retention Basin (116-B-11 waste site), to support characterization of groundwater contaminant plumes, particularly strontium-90 and chromium near the river. Based on the location of this borehole adjacent to the river, significant flux in the ground water table would occur throughout the year leading to a significantly sized rewetted zone.

Samples were collected between 9.8 and 15.5 m (32 and 51 ft) bgs, with the water table encountered at about 13.7 m (45 ft) bgs during sampling. Strontium-90 was detected in six of the seven samples at activities less than 0.7 pCi/g. No other radionuclides were detected (Table 4-20).

Cr(VI) was only detected in samples collected immediately above or within the upper portion of the unconfined aquifer. The highest concentration was 0.47 mg/kg, found in the sample collected at 13.1 m (42.9 ft) bgs, just above where the water table was encountered during drilling.

Chromium exceeded its background concentration (18.5 mg/kg) in most of the rewetted zone samples, with a maximum concentration of 37.3 mg/kg detected at about 14.6 m (48 ft) bgs (0.76 m [2.5 ft] below the water table). While there is a trend of elevated total chromium, the actual concentration at 14.6 m (48 ft) bgs may be significantly lower as the duplicate sample result was below background at 13.3 mg/kg. The nickel concentration in the sample, 23.9 mg/kg, also exceeded background while the duplicate was below background at 11.5 mg/kg. The molybdenum concentration was elevated (9.91 mg/kg) in the sample collected at about 13.1 m (43 ft) bgs (immediately above the water table). While total chromium is also elevated at about 13.1 m (43 ft) bgs (35.2 mg/kg), nickel was below background at 16.1 mg/kg. Figure 4-20 shows the vertical profiles for these constituents.

**Table 4-20. Well 199-B3-51—Summary of Contaminant Soil Data**

| Contaminants | Concentration and Distribution | | | | | |
|---|---|---|---|---|---|---|
| | Back-ground | Remedial Investigation Borehole C7785 (Well 199-B3-51)[a] (2011) | | | | |
| | | Maximum Result with Corresponding Depth (m/ft bgs) | | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (15.7 m/51.5 ft bgs)b | |
| **Radionuclides (Original and Decayed Concentrations) (pCi/g)** | | | | | | |
| | | Original | Decayed | | Original | Decayed |
| Stronium-90 | NA | 0.628 (11.1 / 36.5) | 0.613 | 15.7 / 51.5 | 0.379 | 0.370 |
| **Nonradionuclides (mg/kg)** | | | | | | |
| Boron | NA | 0.934 (13.1 / 42.9) | | 15.7 / 51.5 | 0.673 | |
| Chromium | 18.5 | 37.3 (14.5 / 47.6) | | 14.5 / 47.6 | 13.7 (<BG) | |
| Cr(VI) | NA | 0.47 (13.1 / 42.9) | | 15.7 / 51.5 | 0.30 | |
| Molybdenum | NA | 9.91 (13.1 / 42.9) | | 15.7 / 51.5 | 0.339 | |
| Nickel | 19.1 | 23.9 (14.5 / 47.6) | | 14.5 / 47.6 | 13.9 (<BG) | |
| Strontium | NA | 24.3 (32.3) | | 15.7 / 51.5 | 13.8 | |
| Tin | NA | 1.82 (47.0) | | 15.7 / 51.5 | 1.72 | |

Note:

Well 3 was located in the unconfined aquifer near Wells 199-B3-47 and 199-B2-12 in area where chromium concentrations at the upper aquifer are highest. Intent of well to provide information on chromium and strontium-90 distribution in the unconfined aquifer. See Data Gap 4, Table 4-4 (100-BC Work Plan [DOE/RL-2008-46-ADD3]).

a. Borehole data obtained from HEIS. The water table was encountered at 13.7 m (45 ft). Well was drilled to 47.6 m (156.2 ft).

b. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

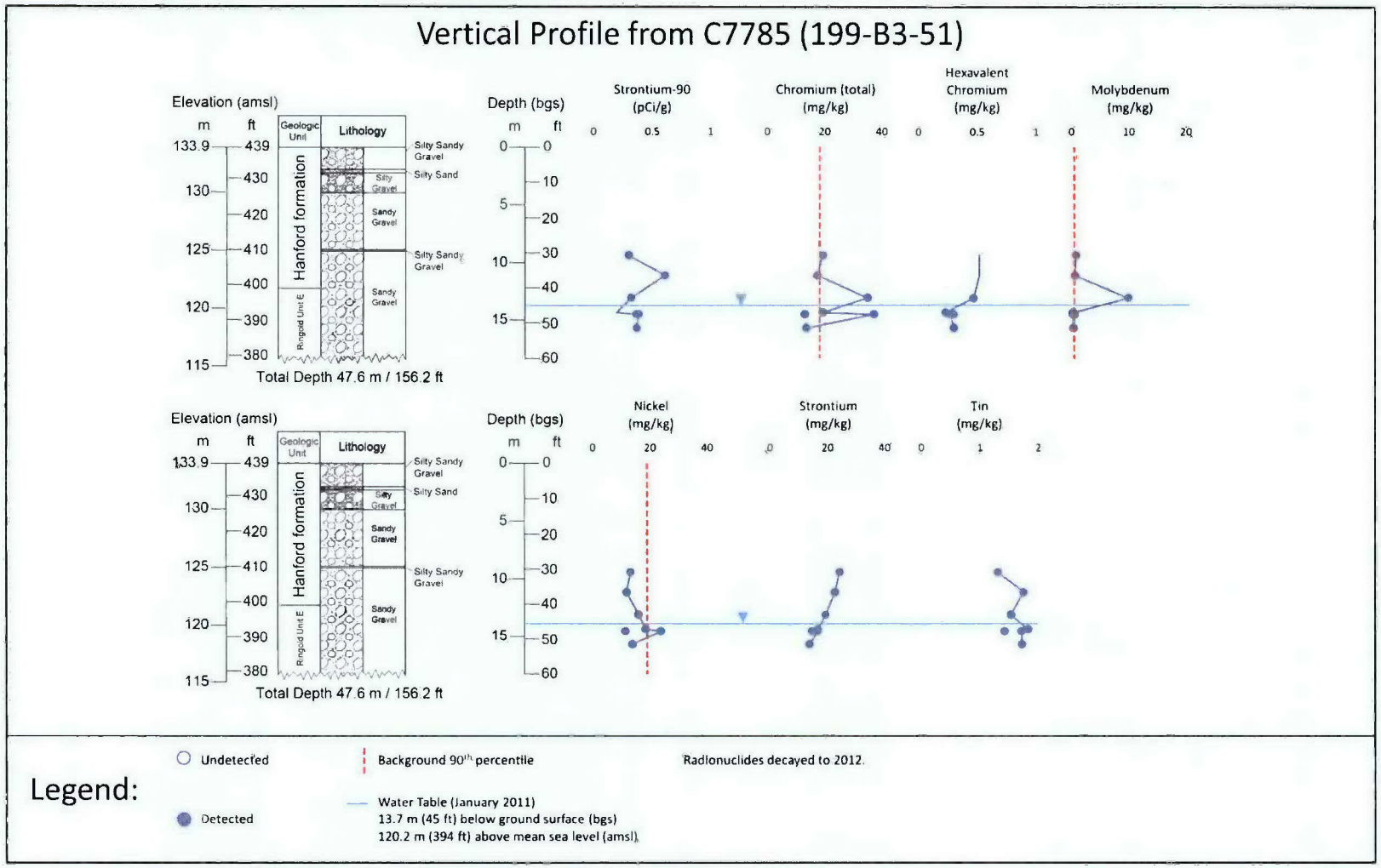


**Figure 4-20. Vertical Soil Profile from Well 199-B3-51 (Borehole C7785)**

### 4.2.4.3 Well 199-B8-9

Borehole C7508 (RI Well 4 – 199-B8-9) was sited roughly 76.2 m (250 ft) west-northwest of the 105-C Reactor Building and was drilled to a total depth of 65.5 m (215 ft) bgs. Samples were collected at six different intervals between 25.3 and 31.4 m (83 and 103 ft) bgs, with one being immediately above the water table (encountered at 29.3 m [96 ft] bgs), and two being below the water table.

The target analyte list for these samples consisted of radionuclides and metals. None of the target radionuclides was detected. Only one metal, vanadium, was found at a concentration that exceeded background; it was identified in a single sample, collected at 26.8 m (88 ft) bgs, at a concentration essentially equivalent to background (Table 4-21). Cr(VI) was detected at very low levels in all the rewetted zone samples with a maximum value of 0.18 mg/kg. Molybdenum results were above the background established in ECF-HANFORD-11-0038 in nearly all samples with a maximum detection of 0.900 mg/kg (Figure 4-21).

**Table 4-21. Well 199-B8-9—Summary of Contaminant Soil Data**

| Contaminants | Concentration and Distribution | | | |
|---|---|---|---|---|
| | Background | Remedial Investigation Borehole C7508 (Well 199-B8-9)[a] | | |
| | | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (31.1 m 102 ft bgs)[b] |
| **Nonradionuclides (mg/kg)** | | | | |
| Cr(VI) | NA | 0.18 (29.7 / 97.5) | 31.4 / 103 | 0.09 |
| Molybdenum | 0.470 | 0.892 (28.0 / 92.0) | 31.4 / 103 | 0.505 |
| Strontium | NA | 24.3 (26.9 / 88.3) | 31.4 / 103 | 20.0 |
| Tin | NA | 3.43 (26.9 / 88.3) | 31.4 / 103 | 2.62 |
| Vanadium | 85.1 | 85.3 (26.9 / 88.3) | 26.9 / 88.3 | 59.4 (<BG) |

Note: Well 4 was located west of 105-C Reactor to define the western extent of contamination. See Data Gap 4, Table 4-4 (100-BC Work Plan [DOE/RL-2008-46-ADD3]).

a. Borehole data obtained from HEIS. The water table was encountered at 29.3 m (96 ft). Well was drilled to 66.9 m (219.5 ft).

b. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

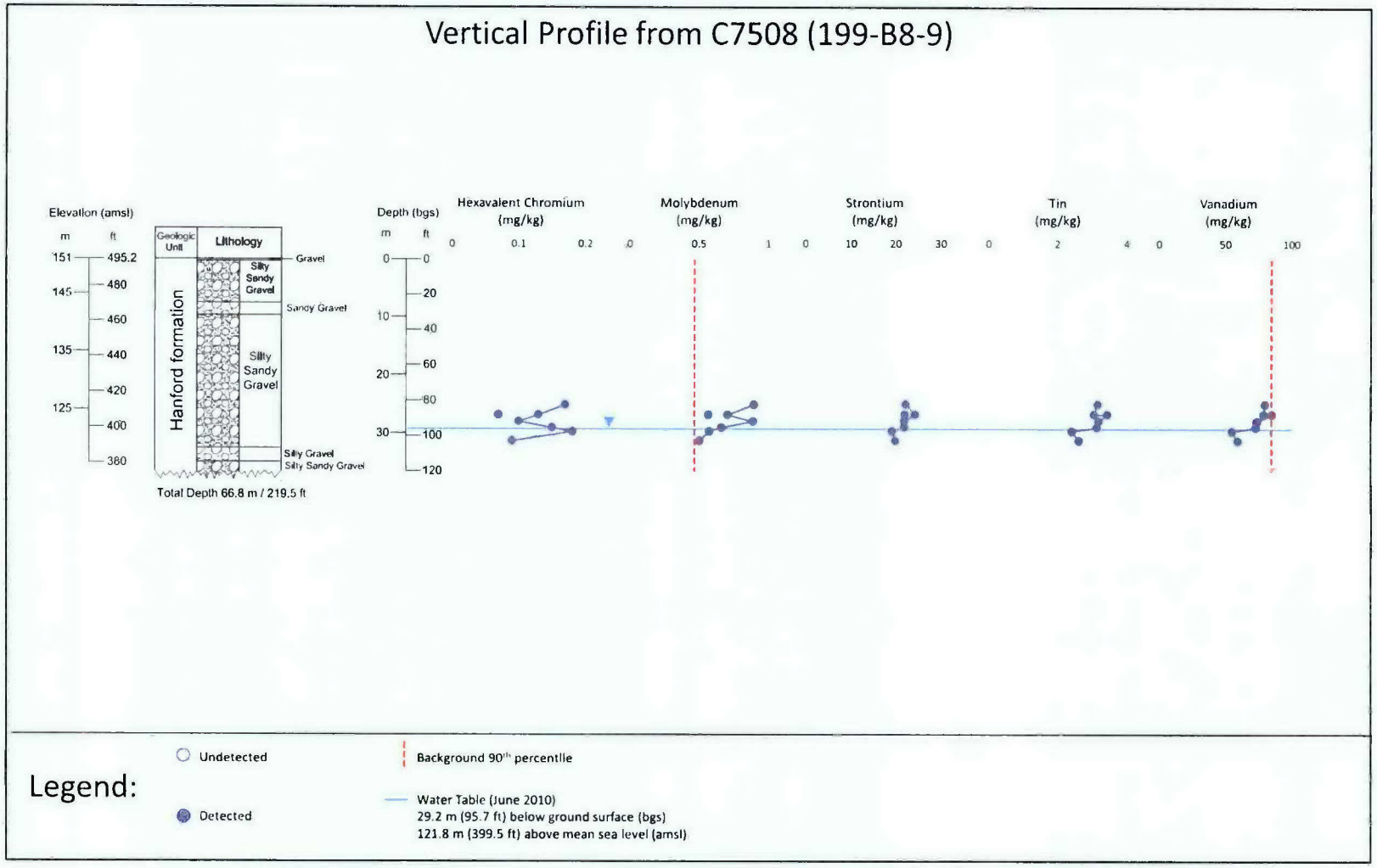


**Figure 4-21. Vertical Soil Profile from Well 199-B8-9 (Borehole C7508)**

#### 4.2.4.4 Well 199-B5-8

Borehole C8244 (RI Well 5 – 199-B5-8) was drilled in the southeast corner of 100-BC to a total depth of 70.4 m (231 ft) bgs; groundwater was encountered at 29.3 m (96 ft) bgs. Samples discussed in the vadose zone section were collected at 10 different intervals between 25.3 and 35.1 m (83 and 115 ft) bgs, 6 of those being below the water table.

The target analyte list for borehole C8244 consisted of a limited number of radionuclides and metals. Analytical results are summarized in Table 4-22. None of the target radionuclides was detected. Only one metal, vanadium, was found at a concentrations that slightly exceeded background, being found at levels slightly exceeding background in the rewetted zone (above and below the water table) (Figure 4-22). Cr(VI) was detected at low levels in all samples, with a maximum result of 0.50 mg/kg detected at 25.3 m (83 ft) bgs, about 4 m (13 ft) above the water table. Molybdenum results were above the background established in ECF-HANFORD-11-0038 in nearly all samples with a maximum detection of 2.20 mg/kg.

**Table 4-22. Well 199-B5-8—Summary of Contaminant Soil Data**

| Contaminants | Concentration and Distribution | | | |
|---|---|---|---|---|
| | Background | Remedial Investigation Borehole C8244 (Well 199-B5-8)[a] | | |
| | | Maximum Result with Corresponding Depth (m/ft bgs) | Extent of Detection above BG (m/ft bgs) | Result at Maximum Sample Depth (34.5 m/113.3 ft bgs)[b] |
| **Nonradionuclides (mg/kg)** | | | | |
| Cr(VI) | NA | 0.50 (25.4 / 83.2) | 34.5 / 113.3 | 0.26 |
| Molybdenum | 0.470 | 2.2 (25.4 / 83.2) | 34.5 / 113.3 | 0.331 |
| Strontium | NA | 27.9 (28.2 / 92.5) | 34.5 / 113.3 | 16.7 |
| Tin | NA | 3.52 (26.9 / 88.3) | 34.5 / 113.3 | 2.22 |
| Vanadium | 85.1 | 92.0 (26.9 / 88.3) | 29.7 / 97.5 | 51.2 (<BG) |

Note: Well 5 was located southeastern end of 100-BC to define the southern extent of contamination. See Data Gap 4, Table 4-4 (100-BC Work Plan [DOE/RL-2008-46-ADD3]).

a. Borehole data obtained from HEIS. The water table was encountered at 29.3 m (96 ft). Well was drilled to 70.3 m (230.6 ft).

b. The maximum depth from which soil samples were collected is in the rewetted zone/aquifer.

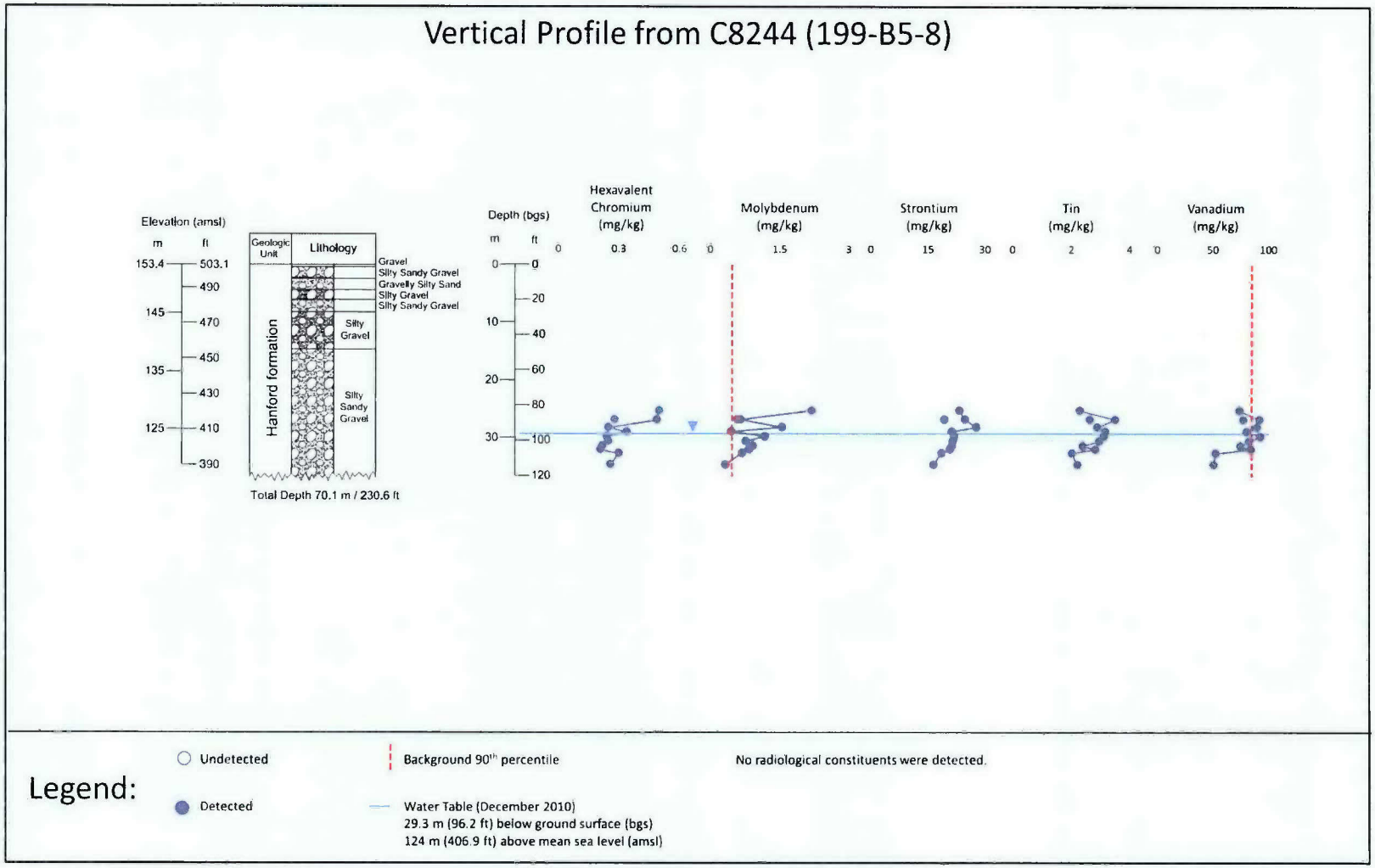


**Figure 4-22. Vertical Soil Profile from Well 199-B5-8 (Borehole C8244)**

#### 4.2.4.5 Pre-RI Wells

Four wells were installed in 2009 and early 2010 under *Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* (DOE/RL-2009-61). Table 4-23 and Figures 4-23 through 4-26 summarize COPC results that were above background levels.

Well 199-B2-14 (C7665) is located near the Columbia River and helps define the Cr(VI), strontium-90, and tritium plumes. Soil samples were collected from 9.4 to 16.4 m (31 to 53.8 ft), with the water table at 14.0 m (46 ft). Cobalt-60, detected in one sample, was the only radionuclide present at a level above background (Table 4-23; Figure 4-23). Cr(VI) was detected in one sample at 100 µg/kg, which is the detection limit. Nickel exceeded background in four of six samples. Total chromium, lead, selenium, and zinc were detected above background in one or more samples.

Well 199-B3-50 (C7506) is located in northeastern 100-BC and helps delimit the Cr(VI) plume. Soil samples were collected between 17.3 and 24.5 m (56.6 and 80.4 ft), with the water table at 22.6 m (74 ft). No radionuclide COPCs were detected. Cr(VI) also was undetected. Antimony, total chromium, lead, nickel, and zinc were detected at levels above background in one or more samples (Table 4-23; Figure 4-24).

Well 199-B5-5 (C7505) is located in northwestern 100-BC, north of the 100-B-27 waste site. Soil samples were collected between 9.2 and 21.1 m (30.2 and 69.1 ft), with the water table at 14.9 m (49 ft). No radionuclide COPCs were detected. Cr(VI) also was undetected. Copper, nickel, vanadium, and zinc exceeded background levels in one or more samples (Table 4-23; Figure 4-25).

Well 199-B5-6 (C7507) is located in central 100-BC, north of the 100-C-7:1 waste site. Soil samples were collected from 18.3 to 25.8 m (60.2 to 84.5 ft), with the water table at 23.5 m (77 ft). No radionuclide COPCs were detected. Cr(VI) also was undetected. Total chromium, nickel, selenium, vanadium, and zinc exceeded background levels in one or more samples (Table 4-23; Figure 4-26).

**Table 4-23. Summary of Vadose Zone Contaminant Data from Pre-RI Monitoring Wells**

| COPC | Units | Background | Maximum | Depth of max. (m) |
|---|---|---|---|---|
| **199-B2-14** | | | | |
| Chromium | ug/kg | 18,500 | 26,900 | 10.76 |
| Cobalt-60 | pCi/g | 0.00842 | 0.028 | 13.96 |
| Hex. Chromium | ug/kg | N/A | 100 | 12.44 |
| Lead | ug/kg | 10,200 | 12,200 | 9.45 |
| Nickel | ug/kg | 19,100 | 43,800 | 10.76 |
| Selenium | ug/kg | 780 | 960 | 9.45 |
| Zinc | ug/kg | 67,800 | 68,200 | 9.45 |
| **199-B3-50** | | | | |
| Antimony | ug/kg | 130 | 2660 | 21.28 |
| Chromium | ug/kg | 18,500 | 68,500 | 21.79 |
| Lead | ug/kg | 10,200 | 20,000 | 21.28 |
| Nickel | ug/kg | 19,100 | 43,200 | 18.84 |
| Zinc | ug/kg | 67,800 | 72,400 | 21.28 |
| **199-B5-5** | | | | |
| Copper | ug/kg | 22,000 | 22,800 | 12.86 |
| Nickel | ug/kg | 19,100 | 200,000 | 14.33 |
| Vanadium | ug/kg | 85,100 | 112,000 | 14.33 |
| Zinc | ug/kg | 67,800 | 83,000 | 12.86 |
| **199-B5-6** | | | | |
| Chromium | ug/kg | 18,500 | 234,000 | 22.1 |
| Nickel | ug/kg | 19,100 | 25,700 | 23.59 |
| Selenium | ug/kg | 780 | 2070 | 23.1 |
| Vanadium | ug/kg | 85,100 | 99,900 | 22.1 |
| Zinc | ug/kg | 67,800 | 93,800 | 23.59 |

Soil COPCs: antimony, arsenic, beryllium, cadmium, cesium-137, chromium, cobalt-60, copper, europium-152, Europium-154, Cr(VI), lead, manganese, nickel, selenium, silver, strontium-90, thallium, vanadium, and zinc (*Sampling and Analysis Plan for Four Groundwater Monitoring Wells in the 100-BC Decision Unit* [DOE/RL-2009-61]).

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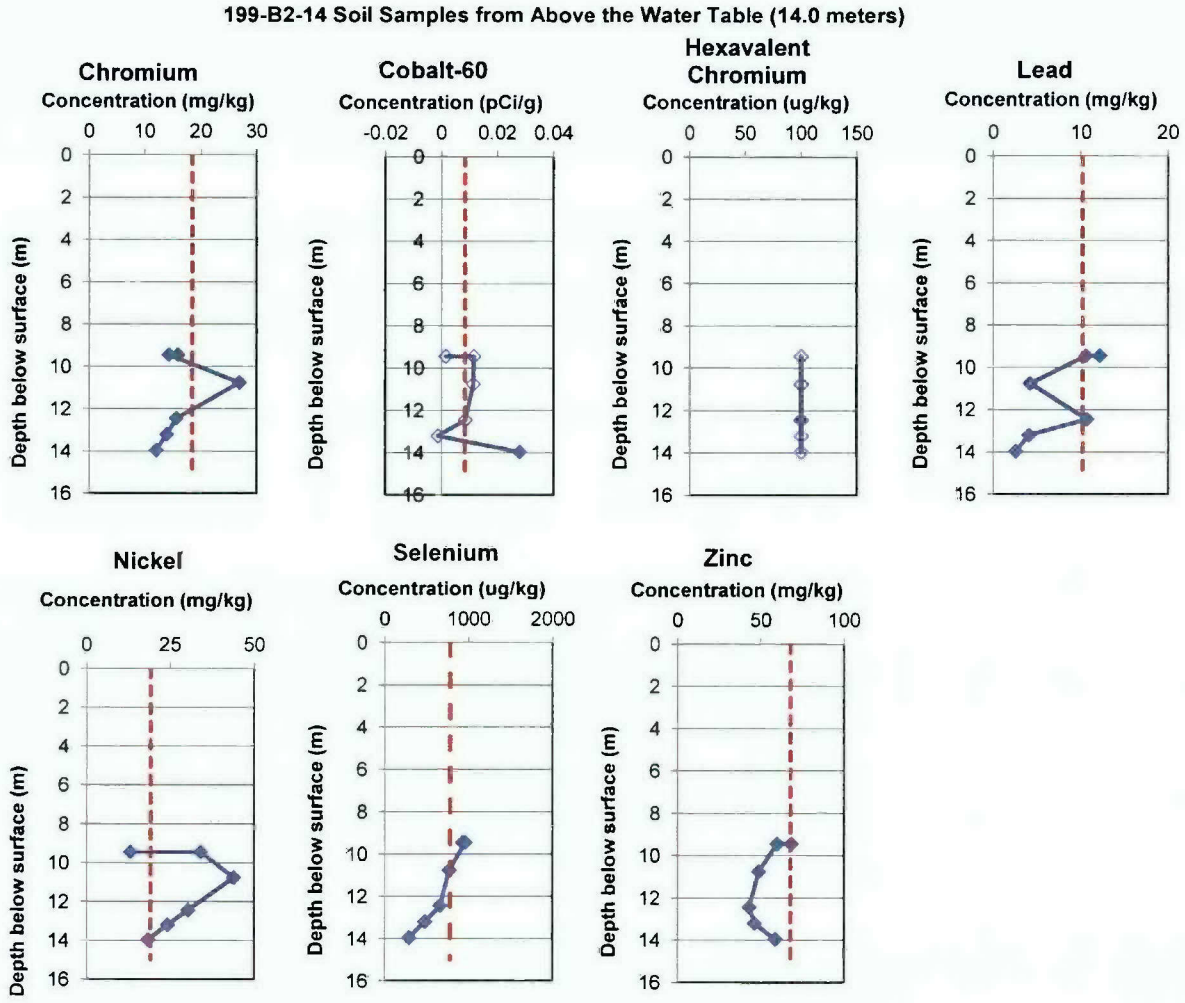


Figure 4-23. Vertical Soil Profiles for Well 199-B2-14

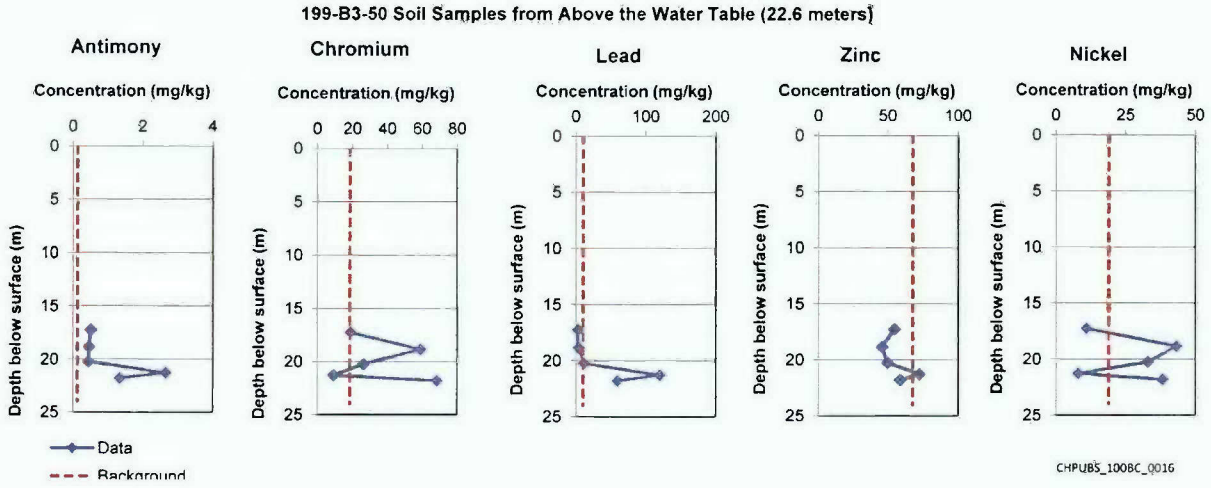


Figure 4-24. Vertical Soil Profiles for Well 199-B3-50

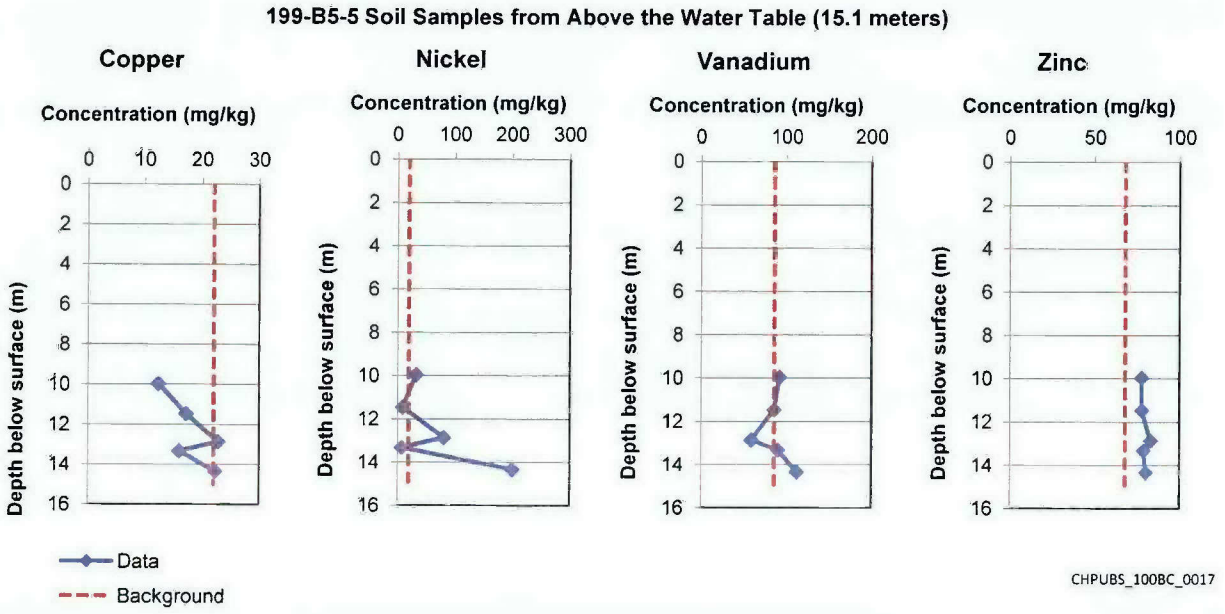


Figure 4-25. Vertical Soil Profiles for Well 199-B5-5

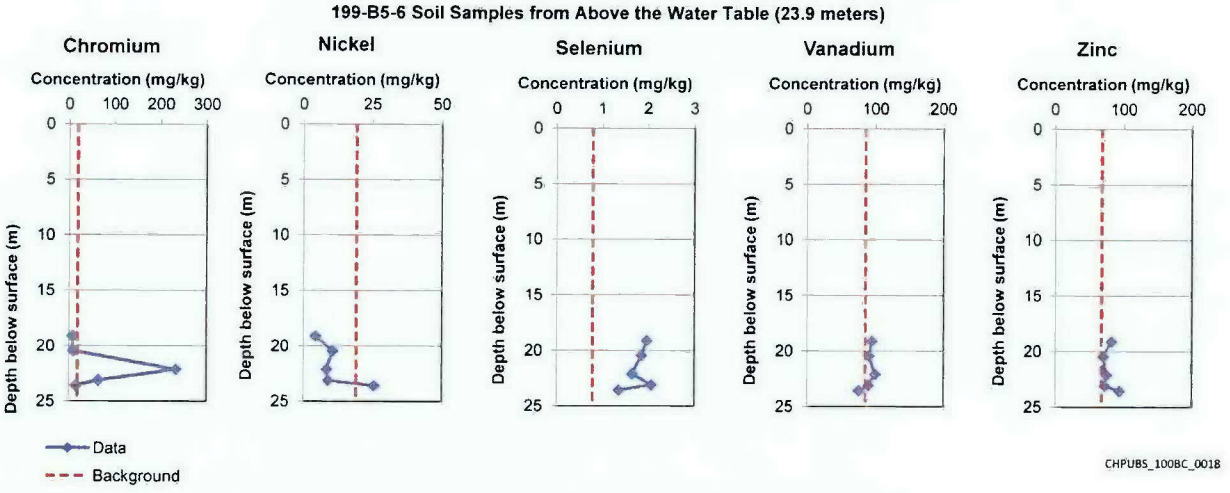


Figure 4-26. Vertical Soil Profiles for Well 199-B5-6

### 4.2.5 100-BC Vadose Zone Constituent Summary

Table 4-24 lists constituents detected at concentrations above background in one or more samples from RI vadose zone characterization activities at 100-BC. There were low concentrations of strontium-90 detected through the vadose zone to groundwater beneath several waste sites. In addition, there were low concentrations of tritium detected through the vadose to groundwater beneath the 118-B-6 burial ground. Tritium concentrations measured during the deep zone closeout sampling were elevated beneath the 118-B-6 burial ground as well. The data indicate Cr(VI) concentrations beneath remediated waste sites are generally low. The highest concentration was 1.05 mg/kg beneath the 118-B-6 burial ground. Low level detections of Cr(VI) in the rewetted zone and within the water table were present at 100-BC groundwater characterization wells.

**Table 4-24. Constituents Detected Above Background in RI Vadose Zone Characterization Samples**

| Radionuclides | Metals (cont.) | Organic Compounds (cont.) |
|---|---|---|
| Americium-241 | Lead | Acenaphthylene |
| Carbon-14 | Magnesium | Anthracene |
| Cesium-137 | Manganese | Aroclor 1254 |
| Cobalt-60 | Mercury | Aroclor 1260 |
| Europium-152 | Molybdenum | Benzo(*a*)anthracene |
| Europium-154 | Nickel | Benzo(*a*)pyrene |
| Nickel-63 | Selenium | Benzo(*b*)fluoranthene |
| Plutonium-238 | Silver | Benzo(*ghi*)perylene |
| Plutonium-239/240 | Strontium | Benzo(*k*)fluoranthene |
| Strontium-90 | Thallium | Chrysene |
| Tritium | Tin | Dibenz[*a,h*]anthracene |
| **Metals** | Vanadium | Fluoranthene |
| **Antimony** | Zinc | Fluorene |
| Arsenic | **Anions** | Indeno(*1,2,3-cd*)pyrene |
| Barium | Fluoride | Naphthalene |
| Boron | Nitrate | Phenanthrene |
| Chromium | Nitrate as N | Pyrene |
| Cobalt | Sulfate | Total Xylenes |
| Copper | **Organic Compounds** | TPH—Diesel range |
| Cr(VI) | Acenaphthene | TPH—Motor oil (high boiling) |

### 4.2.6 Summary of LFI Data not associated with 100-BC RI

Vadose zone characterization was conducted as part of several 100-BC LFI efforts in the early 1990s. Several LFI data sets have been presented as part of the vadose zone contamination at remedial investigation sites. This section summarizes LFI contaminant data that is not linked to data gaps and waste sites efforts identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). Soil data from the following LFI sampling locations was obtained from HEIS and reviewed:

- 199-B2-12
- 199-B3-46
- 199-B3-47
- 199-B3-48
- 199-B4-8

- 199-B4-9
- 199-B4-10
- 199-B5-2
- 199-B5-3
- 199-B9-2
- 199-B9-3
- 199-B9-4
- Surface samples at various 100-BC locations (identifiers: 4847, 4849, 4851, 4853, 4855, 4856, 4858, 4859, 4861, 4862, 4862, 4864)

Tables 4-25 through 4-27 present the maximum radionuclides, metals, organic compounds, and anion concentrations detected above background in the vadose zone from the associated samples. Depth information is provided to describe the vertical extent of vadose zone contamination. Each contaminant detected above background is evaluated further in Chapters 5 and 6 to assess impact to groundwater and risk as appropriate. Radionuclide results are decayed through December 2012.

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**Table 4-25. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100-BC Radionuclides (Table 1 of 2)**

| Waste Site | Sample Location | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Americium-241 | | | Carbon-14 | | | Cesium-137 | | | Cobalt-60 | | | Europium-152 | | | Europium-154 | | |
| NA | 199-B4-9 | 0.35 | 0.34 | 5.5 / 18 | -- | -- | -- | 14.3 | 8.83 | 21.0 / 69 | 8.97 | 0.57 | 5.5 / 18 | -- | -- | -- | 2.91 | 0.54 | 5.5 / 18 |
| 116-B-1 | 199-B3-48 | 0.0503 | 0.0486 | 6.7 / 22 | 6.18 | 6.16 | 5.8 / 19 | 43.85 | 27.08 | 8.2 / 27 | 4.167 | 0.263 | 6.7 / 22 | 121.9 | 41.5 | 8.2 / 27 | 9.90 | 1.82 | 6.7 / 22 |
| 116-B-2 | 199-B4-10 | 0.366 | 0.654 | 5.5 / 18 | -- | -- | -- | 91.32 | 56.39 | 3.7 / 12 | 0.1351 | 0.0085 | 3.6 / 12 | 10.36 | 3.52 | 3.6 / 12 | 0.5639 | 0.1038 | 3.6 / 12 |
| 116-B-3 | 199-B5-3 | 0.0835 | 0.0807 | 2.9 / 9.5 | -- | -- | -- | 78.58 | 48.53 | 5.2 / 17 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B3-46 | -- | -- | -- | -- | -- | -- | 0.154 | 0.095 | 11.3 / 37 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B3-47 | -- | -- | -- | -- | -- | -- | 0.440 | 0.278 | 12.9 / 43 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B4-8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B5-2 | -- | -- | -- | -- | -- | -- | 1.46 | 0.923 | 20.3 / 67 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B9-3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

a. Value represents the maximum radiological result decay corrected through 2012.

-- = not applicable

Table 4-25. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100-BC Radionuclides (Cont.)

| Waste Site | Sample Location | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs | Maximum Result (pCi/g) | Decayed (pCi/g)[a] | Vertical Extent (m/ft) bgs |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Plutonium-238 | | | Plutonium-239/240 | | | Strontium-90 | | |
| NA | 199-B4-9 | -- | -- | -- | 1.1 | 1.1 | 5.5 / 18 | 1.8 | 1.1 | 21.0 / 69 |
| 116-B-1 | 199-B3-48 | -- | -- | -- | 0.269 | 0.269 | 8.2 / 27 | 13.2 | 8.0 | 8.2 / 27 |
| 116-B-2 | 199-B4-10 | -- | -- | -- | 0.0497 | 0.0497 | 5.5 / 18 | 64.1 | 38.9 | 6.7 / 22 |
| 116-B-3 | 199-B5-3 | 0.0346 | 0.0293 | 2.9 / 9.5 | 0.791 | 0.791 | 4.0 / 13 | 39.2 | 23.8 | 5.2 / 17 |
| NA | 199-B3-46 | -- | -- | -- | -- | -- | -- | 7.8 | 4.7 | 11.4 / 17.4 |
| NA | 199-B3-47 | -- | -- | -- | -- | -- | -- | 1.2 | 0.7 | 16.0 / 52.5 |
| NA | 199-B4-8 | -- | -- | -- | -- | -- | -- | 0.11 | 0.07 | 23.8 / 78 |
| NA | 199-B5-2 | -- | -- | -- | -- | -- | -- | 2.9 | 1.8 | 20.3 / 67 |
| NA | 199-B9-3 | -- | -- | -- | -- | -- | -- | 0.073 | 0.044 | 30.5 / 100 |

[a] Value represents the maximum radiological result decay corrected through 2012.

-- = not applicable

Table 4-26. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Metals (Table 1 of 2)

| Waste Site | Sample Location | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Antimony | | | Barium | | | Cadmium | | | Chromium | | | Copper | | | Lead | | |
| 116-B-1 | 199-B3-48 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 18.5 | 33 | 6.7 / 22 | 22.0 | 23.7 | 5.2 / 17 | -- | -- | -- |
| 116-B-2 | 199-B4-10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 18.5 | 20.2 | 3.7 / 12 | 22.0 | 27.8 | 6.7 / 22 | -- | -- | -- |
| 116-B-3 | 199-B5-3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 18.5 | 44.5 | 5.2 / 17 | -- | -- | -- | -- | -- | -- |
| 116-C-2A | 199-B9-4 | 0.130 | 4.6 | 8.2 / 27 | 132 | 484 | 3.4 / 11 | 0.563 | 3.2 | 8.2 / 27 | 18.5 | 629 | 8.2 / 27 | 22.0 | 29.3 | 8.2 / 27 | -- | -- | -- |
| NA | 199-B4-9 | -- | -- | -- | | | | -- | -- | -- | 18.5 | 257 | 21.0 / 69 | -- | -- | -- | -- | -- | -- |
| NA | 199-B4-8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B5-2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | 18.5 | 33.1 | 67 / 20.3 | -- | -- | -- | -- | -- | -- |
| NA | 199-B9-3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B2-12 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 10.2 | 14.2 | 49.1 / 161 |

-- = not applicable

Table 4-26. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Metals (Table 2 of 2)

| Waste Site | Sample Location | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | BG mg/kg | Maximum Result mg/kg | Vertical Extent (m/ft) bgs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mercury | | | Nickel | | | Silver | | | Zinc | | |
| 116-B-1 | 199-B3-48 | -- | -- | -- | 19.1 | 24.5 | 6.7 / 22 | -- | -- | -- | 67.8 | 128 | 5.2 / 17 |
| 116-B-2 | 199-B4-10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 116-B-3 | 199-B5-3 | -- | -- | -- | -- | -- | -- | 0.167 | 3.0 | 4.0 / 13 | -- | -- | -- |
| 116-C-2A | 199-B9-4 | -- | -- | -- | 19.1 | 21.3 | 8.2 / 27 | 0.167 | 1.1 | 11.3 / 37 | 67.8 | 198 | 8.2 / 27 |
| NA | 199-B4-9 | 0.0131 | 2.49 | 8.5 / 28 | 19.1 | 117 | 19.2 / 63 | -- | -- | -- | -- | -- | -- |
| NA | 199-B4-8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B5-2 | -- | -- | -- | -- | -- | -- | 0.167 | 2.7 | 67 / 20.3 | -- | -- | -- |
| NA | 199-B9-3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B2-12 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

-- = not applicable

Table 4-27. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Organic Compounds and Anions (1 of 4)

| Waste Site | Sample Location | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1,1,1-Trichloroethane | | 1,1,2-Trichloroethane | | 1,1,2,2-Tetrachloroethane | | 1,1-Dichloroethane | | 1,1-Dichloroethene | | 1,2-Dichloroethane | | 1,2-Dichloroethene (Total) | | 1,2-Dichloropropane | | 2-Butanone | |
| 116-B-2 | 199-B4-10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 116-B-3 | 199-B5-3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B4-9 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 |
| NA | 199-B4-8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B5-2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B2-12 | 0.005 | 46.6 / 153 | 0.005 | 46.6 / 153 | | | 0.005 | 46.6 / 153 | 0.005 | 0.005 | 46.6 / 153 | 0.005 | 46.6 / 153 | | | 0.005 | 46.6 / 153 | 0.005 |
| NA | 199-B3-46 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B3-47 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4849 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4851 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4853 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4855 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4856 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4858 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4859 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4861 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4862 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4864 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

-- = not applicable

Table 4-27. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Organic Compounds and Anions (2 of 4)

| Waste Site | Sample Location | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 4-Methyl-2-pentanone | | Benzene | | Benzo(a)anthracene | | Bromo-dichloromethane | | Bromoform | | Butylbenzyl-phthalate | | Carbon disulfide | | Carbon tetrachloride | | Chlorobenzene | |
| 116-B-2 | 199-B4-10 | 0.011 | 3.7 / 22 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 116-B-3 | 199-B5-3 | 0.003 | 4.0 / 13 | 0.001 | 2.9 / 10 | 0.16 | 2.9 / 10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B4-9 | -- | -- | 0.005 | 8.5 / 28 | -- | -- | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | -- | -- | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 |
| NA | 199-B4-8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B5-2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B2-12 | -- | -- | 0.005 | 46.6 / 153 | -- | -- | 0.005 | 46.6 / 153 | 0.005 | 46.6 / 153 | -- | -- | 0.005 | 49.1 / 161 | 0.005 | 46.6 / 153 | 0.005 | 46.6 / 153 |
| NA | 199-B3-46 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.048 | 11.3 / 37 | -- | -- | -- | -- | -- | -- |
| NA | 199-B3-47 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.086 | 13.0 / 43 | -- | -- | -- | -- | -- | -- |
| NA | 4849 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4851 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4853 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4855 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4856 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4858 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4859 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4861 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4862 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4864 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

-- = not applicable

Table 4-27. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Organic Compounds and Anions (3 of 4)

| Waste Site | Sample Location | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Chloroform | | cis-1,3-Dichloropropene | | Dibromo-chloromethane | | Diethylphthalate | | Ethyl acetate | | Ethylbenzene | | Hexane | | n-Nitroso-diphenylamine | | Pyrene | |
| 116-B-2 | 199-B4-10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.11 | 3.7 / 12 | -- | -- |
| 116-B-3 | 199-B5-3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B4-9 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.22 | 19.2 / 63 | -- | -- | 0.005 | 8.5 / 28 | -- | -- | -- | -- | 0.005 | 8.5 / 28 |
| NA | 199-B4-8 | -- | -- | -- | -- | -- | -- | 0.11 | 23.8 / 78 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B5-2 | -- | -- | -- | -- | -- | -- | 0.39 | 16.8 / 55 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B2-12 | 0.005 | 51.8 / 170 | 0.005 | 46.6 / 153 | 0.005 | 46.6 / 153 | -- | -- | 0.030 | 51.8 / 170 | 0.005 | 46.6 / 153 | -- | -- | -- | -- | 0.005 | 46.6 / 153 |
| NA | 199-B3-46 | -- | -- | -- | -- | -- | -- | 6.4 | 17.4 / 57 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B3-47 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4849 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4851 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4853 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4855 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4856 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4858 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4859 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4861 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4862 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4864 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

-- = not applicable

Table 4-27. Summary of LFI Data Above Background from Non-Remedial Investigation Sample Locations - 100- BC Organic Compounds and Anions (4 of 4)

| Waste Site | Sample Location | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs | Maximum Result mg/kg | Vertical Extent (m/ft) bgs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Styrene | | Tetrachloroethene | | trans-1,3-Dichloropropene | | Trichloroethene | | Xylenes (total) | | Aroclor-1254 | | Aroclor-1260 | | Fluoride | |
| 116-B-2 | 199-B4-10 | 0.039 | 3.7 / 12 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 116-B-3 | 199-B5-3 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B4-9 | -- | -- | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | 0.005 | 8.5 / 28 | -- | -- | -- | -- | -- | -- |
| NA | 199-B4-8 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.4 | 23.8 / 78 |
| NA | 199-B5-2 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B2-12 | -- | -- | 0.005 | 46.6 / 153 | 0.005 | 46.6 / 153 | 0.005 | 46.6 / 153 | 0.005 | 46.6 / 153 | -- | -- | -- | -- | 3.9 | 46.6 / 153 |
| NA | 199-B3-46 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 199-B3-47 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| NA | 4849 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.021 | 0.2 / 0.5 | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4851 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.19 | 0.2 / 0.5 | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4853 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.89 | 0.2 / 0.5 | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4855 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.029 | **0.2 / 0.5** | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4856 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.19 | **0.2 / 0.5** | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4858 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.50 | **0.2 / 0.5** | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4859 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6.4 | **0.2 / 0.5** | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4861 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.7 | **0.2 / 0.5** | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4862 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.42 | **0.2 / 0.5** | 0.007 | 0.2 / 0.5 | -- | -- |
| NA | 4864 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.34 | 0.2 / 0.5 | -- | -- |

-- = not applicable

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## 4.3 Groundwater Contamination

Remedial Investigation tasks have produced additional data to help refine knowledge of the nature and extent of contaminants in 100-BC groundwater and aquifer sediments. Section 4.3.1 evaluates the nature and extent of groundwater contamination based on comprehensive sampling results for all groundwater COPCs identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3). The analysis narrows down the list to three final COPCs (Cr(VI), strontium-90, and tritium) and one additional analyte of interest (trichloroethene). Section 4.3.2 presents further information about the distribution and trends in these four contaminants.

Groundwater data discussed in this section are available via the Hanford Environmental Dashboard application (http://environet.hanford.gov/eda) and included in Appendix D.

### 4.3.1 Groundwater Contaminant Statistics

Data Gap 4, identified in the 100-BC Work Plan (DOE/RL-2008-46-ADD3), stated, "The nature and extent of contamination in the unconfined aquifer above cleanup standards has not been defined in select areas or for all COPCs." To fill the second part of this data gap, wells were sampled for all groundwater COPCs. This section provides an overview of the results of COPC sampling. Chapter 6 presents the results of a formal evaluation of the COPCs and determination of final COPCs.

This evaluation of the nature and extent of contamination in groundwater was based on samples collected between January 5, 2006, and January 26, 2011. The nature and extent evaluation uses a subset of data from the work plan as well as all spatial and temporal wells considered in the groundwater risk assessment. A total of 32 wells, including the 18 spatial and temporal wells, were considered; 24 of the 32 wells considered had analytical data available during the time period considered. Figure 4-27 provides the locations of the wells considered in the nature and extent evaluation. Groundwater data for 100-BC were compiled and statistically analyzed and the results are presented in Table 4-28. This table presents the summary statistics for each analyte identified as a COPC in the work plan and lists the background concentrations in Hanford Site groundwater (*Hanford Site Background: Part 3, Groundwater Background* [DOE/RL-96-61]) where available, and the lowest chemical-specific ARAR for each analyte.

The evaluation presented in this section focuses on the following:

- Analytes that are identified as COPCs in the groundwater risk assessment provided in Section 6.3 that warrant further evaluation in the FS
- Analytes of interest that were identified as COPCs in the work plan as a result of uncertainties because of limitations in the analytical data (inadequate method detection limits or anomalous results), but do not warrant further evaluation in the FS, after considering data from a larger population of wells and a longer sampling timeframe as well as the groundwater risk assessment data in Section 6.3

Section 4.3.1.1 addresses the final groundwater COPCs ), Section 4.3.1.2 discusses additional analytes of interest, and Section 4.3.1.3 presents conclusions.

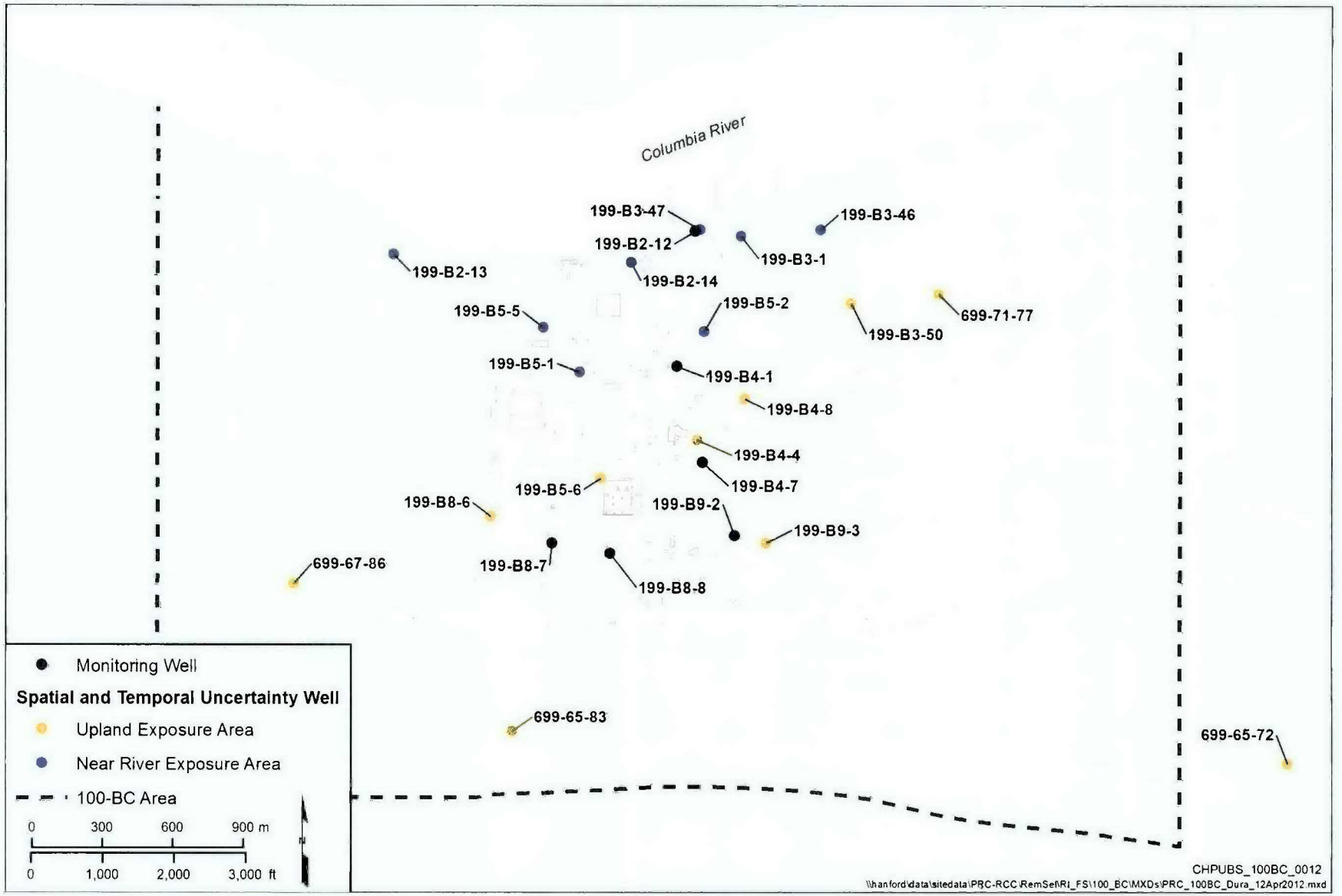


Figure 4-27. Groundwater Monitoring Wells Used in Statistical Evaluation

Table 4-28. Groundwater Summary Statistics for 100-BC

| Analyte Name | Filtered | Units | Number of Results | Number of Detects | Frequency of Detects (%) | Min Non-Detect | Max Non-Detect | Min Detect | Max Detect | Mean Detect | Median Detect | Background 90th Percentile | No. of Detects > Background | Action Level | No. of Detects > Action Level | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Anions** | | | | | | | | | | | | | | | | |
| Nitrate | N | ug/L | 127 | 127 | 100 | -- | -- | 708 | 44,200 | 10,281 | 7,840 | 26,871 | 7 | 45,000 | -- | 40 CFR 141 - Federal MCL |
| **Radionuclides** | | | | | | | | | | | | | | | | |
| Carbon-14 | N | pCi/L | 54 | 0 | 0 | -5.0 | 7.6 | -- | -- | -- | -- | -- | -- | 2,000 | -- | 40 CFR 141 - Federal MCL |
| Cesium-137 | N | pCi/L | 54 | 1 | 1.9 | -2.2 | 1.7 | 2 | 2 | 2 | 2 | 8.6 | -- | 200 | -- | 40 CFR 141 - Federal MCL |
| Cobalt-60 | N | pCi/L | 54 | 0 | 0 | -2.1 | 2.4 | -- | -- | -- | -- | 0.023 | -- | 100 | -- | 40 CFR 141 - Federal MCL |
| Europium-155 | N | pCi/L | 54 | 0 | 0 | -3.2 | 2.5 | -- | -- | -- | -- | 5.9 | -- | 600 | -- | 40 CFR 141 - Federal MCL |
| Gross alpha | N | pCi/L | 117 | 26 | 22 | -32.0 | 2.5 | 1 | 9.6 | 3 | 2 | -- | -- | 15 | -- | 40 CFR 141 - Federal MCL |
| Gross beta | N | pCi/L | 117 | 115 | 98 | 2.7 | 3.2 | 3.6 | 110 | 21 | 12 | 3.1 | 115 | 4 mrem/year | -- | 40 CFR 141 - Federal MCL |
| Iodine-129 | N | pCi/L | 54 | 0 | 0 | -0.33 | 0.24 | -- | -- | -- | -- | 9.00E-07 | -- | 1 | -- | 40 CFR 141 - Federal MCL |
| Nickel-63 | N | pCi/L | 54 | 0 | 0 | -3.4 | 3.2 | -- | -- | -- | -- | -- | -- | 50 | -- | 40 CFR 141 - Federal MCL |
| Radium-228 | N | pCi/L | 54 | 0 | 0 | -4.0 | 1.7 | -- | -- | -- | -- | -- | -- | 5 | -- | 40 CFR 141 - Federal MCL |
| Strontium-90 | N | pCi/L | 105 | 50 | 48 | -8.4 | 1.8 | 0.52 | 49 | 20 | 18 | 0.001 | 50 | 8 | 38 | 40 CFR 141 - Federal MCL |
| Technetium-99 | N | pCi/L | 69 | 31 | 45 | -11 | 6.4 | 5.9 | 26 | 12 | 9.7 | 0.83 | 31 | 900 | -- | 40 CFR 141 - Federal MCL |
| Tritium | N | pCi/L | 154 | 137 | 89 | -130 | 212 | 190 | 125,000 | 15,650 | 9,000 | 119 | 137 | 20,000 | 42 | 40 CFR 141 - Federal MCL |
| **VOCs** | | | | | | | | | | | | | | | | |
| 1,1,2,2-Tetrachloroethane | N | ug/L | 54 | 0 | 0 | 0.10 | 0.10 | -- | -- | -- | -- | -- | -- | 0.17 | -- | Clean Water Act -- Human Health Water + Organism |
| 1,1-Dichloroethene | N | ug/L | 54 | 0 | 0 | 0.08 | 0.08 | -- | -- | -- | -- | -- | -- | 0.057 | -- | 40 CFR 131 -- Human Health Water + Organism |
| Benzene | N | ug/L | 54 | 0 | 0 | 0.06 | 0.06 | -- | -- | -- | -- | -- | -- | 0.80 | -- | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Carbon tetrachloride | N | ug/L | 54 | 0 | 0 | 0.12 | 0.12 | -- | -- | -- | -- | -- | -- | 0.23 | -- | Clean Water Act -- Human Health Water + Organism |
| Chloroform | N | ug/L | 54 | 42 | 78 | 0.10 | 0.10 | 0.11 | 3.0 | 0.53 | 0.31 | -- | -- | 1.4 | 6 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Tetrachloroethene | N | ug/L | 54 | 0 | 0 | 0.18 | 0.18 | -- | -- | -- | -- | -- | -- | 0.08 | -- | WAC 173-340-720(4)(b)(iii)(A) and (B) |

Table 4-28. Groundwater Summary Statistics for 100-BC

| Analyte Name | Filtered | Units | Number of Results | Number of Detects | Frequency of Detects (%) | Min Non-Detect | Max Non-Detect | Min Detect | Max Detect | Mean Detect | Median Detect | Background 90th Percentile | No. of Detects > Background | Action Level | No. of Detects > Action Level | Action Level Basis |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trichloroethene | N | ug/L | 54 | 40 | 74 | 0.21 | 0.25 | 0.23 | 3.3 | 1.0 | 0.88 | -- | -- | 0.49 | 28 | WAC 173-340-720(4)(b)(iii)(A) and (B) |
| Vinyl chloride | N | ug/L | 54 | 0 | 0 | 0.08 | 0.08 | -- | -- | -- | -- | -- | -- | 0.025 | -- | Clean Water Act -- Human Health Water + Organism |
| **Metals** | | | | | | | | | | | | | | | | |
| Aluminum | N | ug/L | 54 | 23 | 43 | 5.0 | 10 | 7.1 | 72 | 24 | 21 | 7.1 | 22 | 50 | 1 | 40 CFR 141 - Federal MCL |
| Aluminum | Y | ug/L | 54 | 5 | 9 | 5.0 | 10 | 12 | 30 | 19 | 19 | 7.1 | 5 | 50 | -- | 40 CFR 141 - Federal MCL |
| Antimony | N | ug/L | 109 | 0 | 0 | 0.30 | 60 | -- | -- | -- | -- | 55 | -- | 5.6 | -- | Clean Water Act -- Human Health Water + Organism |
| Antimony | Y | ug/L | 127 | 0 | 0 | 0.30 | 60 | -- | -- | -- | -- | 55 | -- | 5.6 | -- | Clean Water Act -- Human Health Water + Organism |
| Arsenic | N | ug/L | 54 | 51 | 94 | 0.80 | 0.80 | 0.82 | 3.9 | 2.3 | 2.3 | 7.9 | -- | 0.018 | 51 | Clean Water Act -- Human Health Water + Organism |
| Arsenic | Y | ug/L | 54 | 50 | 93 | 0.80 | 1.0 | 0.84 | 18 | 2.6 | 2.3 | 7.9 | 1 | 0.018 | 50 | Clean Water Act -- Human Health Water + Organism |
| Beryllium | N | ug/L | 109 | 1 | 0.9 | 0.050 | 4.0 | 0.13 | 0.13 | 0.13 | 0.13 | 2.3 | -- | 4.0 | -- | 40 CFR 141 - Federal MCL |
| Beryllium | Y | ug/L | 127 | 3 | 2.4 | 0.050 | 4.0 | 0.061 | 0.24 | 0.14 | 0.12 | 2.3 | -- | 4.0 | -- | 40 CFR 141 - Federal MCL |
| Cadmium | N | ug/L | 109 | 0 | 0 | 0.055 | 4.0 | -- | -- | -- | -- | 0.92 | -- | 0.25 | -- | Clean Water Act -- Freshwater CCC |
| Cadmium | Y | ug/L | 127 | 1 | 0.8 | 0.10 | 4.0 | 0.06 | 0.06 | 0.06 | 0.06 | 0.92 | -- | 0.25 | -- | Clean Water Act -- Freshwater CCC |
| Chromium | N | ug/L | 109 | 95 | 87 | 13 | 14 | 4.5 | 69 | 22 | 19 | 2.4 | 95 | 65 | 1 | Clean Water Act -- Freshwater CCC |
| Chromium | Y | ug/L | 127 | 111 | 87 | 1.9 | 14 | 3.1 | 56 | 21 | 17 | 2.4 | 111 | 65 | -- | Clean Water Act -- Freshwater CCC |
| Cobalt | N | ug/L | 109 | 8 | 7.3 | 0.050 | 5.0 | 0.054 | 7.9 | 1.8 | 0.18 | 0.92 | 2 | 2.6 | 2 | WAC 173-340-730(3)(b)(iii)(A) and (B) |
| Cobalt | Y | ug/L | 127 | 21 | 17 | 0.050 | 5.0 | 0.059 | 9.4 | 1.8 | 0.28 | 0.92 | 7 | 2.6 | 6 | WAC 173-340-730(3)(b)(iii)(A) and (B) |
| Copper | N | ug/L | 109 | 24 | 22 | 0.20 | 6.0 | 0.12 | 5 | 0.7 | 0.50 | 0.81 | 2 | 9.0 | -- | Clean Water Act -- Freshwater CCC |
| Copper | Y | ug/L | 127 | 21 | 17 | 0.10 | 6.0 | 0.11 | 4.1 | 0.6 | 0.39 | 0.81 | 1 | 9.0 | -- | Clean Water Act -- Freshwater CCC |
| Cr(VI) | N | ug/L | 129 | 124 | 96 | 2.0 | 2.0 | 2.4 | 64 | 21 | 17 | -- | -- | 10 | 98 | WAC 173-201A |
| Cr(VI) | Y | ug/L | 94 | 87 | 93 | 2.0 | 5.0 | 2.4 | 58 | 22 | 21 | -- | -- | 10 | 73 | WAC 173-201A |
| Iron | N | ug/L | 109 | 52 | 48 | 9.0 | 38 | 9.2 | 347 | 70 | 43 | 570 | -- | 300 | 1 | 40 CFR 141 - Federal MCL |