

Remedial Investigation/Feasibility Study for the 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units

J. J. Virgin
CH2M HILL Plateau Remediation Company

Date Published
June 2014

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

By Lee Ann Snyder at 12:36 pm, Jun 04, 2014

Release Approval

Date

**Approved for Public Release;
Further Dissemination Unlimited**

TRADEMARK DISCLAIMER

Reference herein to any specific commercial product, process, or service by tradename, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof or its contractors or subcontractors.

This report has been reproduced from the best available copy.

Printed in the United States of America

Appendix L
Riparian/Nearshore Evaluation

This page intentionally left blank.

Contents

L1	Introduction	L-1
L1.1	Background	L-1
L1.2	Description of the 100-F/IU Area.....	L-2
L1.3	Review of Previous Riparian/Nearshore Studies	L-4
L1.3.1	100-F Area Historical Studies	L-4
L1.3.2	100-IU-2 Area (White Bluffs) Historical Studies	L-5
L1.3.3	100-IU-6 Area (Hanford Town Site) Historical Studies	L-6
L1.3.4	Surface Environmental Surveillance Program	L-8
L1.3.5	Groundwater and Aquifer Tube Monitoring Programs.....	L-8
L1.4	Approach to CSM Development	L-9
L2	Evaluation of Riparian and Nearshore Exposure Pathways.....	L-11
L2.1	Sources	L-11
L2.1.1	Waste Sites and Soils	L-11
L2.1.2	Groundwater	L-17
L2.2	Contaminant Release and Transport Mechanisms.....	L-17
L2.2.1	Overland Transport from Waste Sites.....	L-17
L2.2.2	Contaminant Leaching from Waste Site Soils to Groundwater	L-17
L2.2.3	Transport in Groundwater.....	L-18
L2.3	Exposure Points in Seeps, Surface Water, Sediments, and Riparian Soils.....	L-19
L2.3.1	100-F	L-19
L2.3.2	100-IU-2/IU-6	L-20
L2.3.3	100-F.....	L-21
L2.3.4	100-IU-2/IU-6.....	L-21
L2.4	Routes of Potential Exposure and Receptors.....	L-21
L2.4.1	Riparian Zone Exposure Pathways	L-21
L2.4.2	Nearshore Aquatic Zone Exposure Pathway.....	L-24
L2.4.3	100-F/IU-2/IU-6 River Effluent Pipeline Investigations	L-25
L3	Data Evaluation	L-26
L3.1	Data Sources and Data Processing	L-27
L3.1.1	Laboratory and Data Validation Flags	L-27
L3.1.2	Analytes Reported by Numerous Analytical Methods.....	L-27
L3.1.3	Field Duplicate and Field Split Results.....	L-33
L3.2	Identification of Ecological Screening Levels	L-33
L3.2.1	Ecological Screening Levels for Water	L-33
L3.2.2	Ecological Screening Levels for Soil.....	L-34
L3.2.3	Ecological Screening Levels for Sediment	L-35

L3.3	Identification of Contaminants of Interest - Water.....	L-35
L3.3.1	Apply Exclusion Criteria	L-35
L3.3.2	Identify Nondetected Analytes.....	L-35
L3.3.3	Identify Analytes with Maximum Detected Concentrations Less Than ESLs.....	L-36
L3.3.4	Identify Analytes with Maximum Detected Concentrations Greater Than ESLs	L-36
L3.3.5	100-FR-3 Groundwater OU	L-36
L3.3.6	100-IU-2/IU-6 Groundwater OU	L-43
L3.4	Identification of Contaminants of Interest – Riparian Soil.....	L-51
L3.4.1	Apply Exclusion Criteria	L-51
L3.4.2	Identify Nondetected Analytes.....	L-51
L3.4.3	Identify Analytes with Maximum Detected Concentrations Less Than ESLs.....	L-51
L3.4.4	Identify Analytes with Maximum Detected Concentrations Greater Than ESLs	L-51
L3.5	Identification of Contaminants of Interest – Nearshore Sediment	L-53
L3.5.1	Apply Exclusion Criteria	L-53
L3.5.2	Identify Nondetected Analytes.....	L-53
L3.5.3	Identify Analytes with Maximum Detected Concentrations Less Than ESLs.....	L-53
L3.5.4	Identify Analytes with Maximum Detected Concentrations Greater Than ESLs	L-53
L3.6	Data Evaluation Summary.....	L-54
L4	Summary of Ecological Risks.....	L-54
L4.1	Risks to Terrestrial Plants.....	L-54
L4.2	Risks to Aquatic Plants.....	L-55
L4.3	Risks to Terrestrial Invertebrates.....	L-57
L4.4	Risks to Aquatic Invertebrates	L-57
L4.4.1	Abiotic Media Concentrations Compared to Literature Values.....	L-57
L4.4.2	Direct Toxicity Measures.....	L-64
L4.4.3	Community Structure Measures.....	L-64
L4.4.4	Measures of Exposure.....	L-64
L4.4.5	Weight of Evidence.....	L-64
L4.5	Risk to Riparian Wildlife	L-65
L4.6	Risk to Fish.....	L-67
L4.7	Evaluation of Risks in the Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C	L-69
L4.7.1	Benthic Invertebrates	L-71
L4.7.2	Terrestrial Plants and Invertebrates.....	L-85
L4.7.3	Risk to Wildlife.....	L-85
L4.7.4	Final Conclusion for 100-F-59.....	L-87
L4.8	Conclusions for 100-F/IU2/IU6	L-87
L5	References	L-88

Figures

Figure L-1.	Environmental Zones in the Riparian/Nearshore Area	L-10
Figure L-2.	Photograph Depicting the Environmental Zones	L-10
Figure L-3.	100-F Waste Sites of Interest.....	L-12
Figure L-4.	100-IU-2/100-IU-6 Waste Sites of Interest.....	L-13
Figure L-5.	Conceptual Model of Groundwater-Surface Water Interaction at the Hanford Site.....	L-19
Figure L-6.	Ecological Conceptual Exposure Model for the Aquatic Environment (Combined Riparian and Aquatic Nearshore Zones).....	L-22
Figure L-7.	Summary of Endpoints and Measures Evaluated in the Riparian Environment	L-23
Figure L-8.	Sampling Locations in 100-F and Identifiers for Samples in the Riparian/Nearshore Area Conceptual Model.....	L-28
Figure L-9.	Sampling Locations in 100-IU-2/IU-6 and Identifiers for Samples in the Riparian/Nearshore Area Conceptual Model.....	L-29
Figure L-10.	Sampling Locations in 100-IU-2/IU-6 and Identifiers for Samples in the Riparian/Nearshore Area Conceptual Model.....	L-30
Figure L-11.	Sampling Locations in 100-IU-2/IU-6 and Identifiers for Samples in the Riparian/Nearshore Area Conceptual Model.....	L-31
Figure L-12.	Chromium Samples Collected at the 100-F-59 Waste Site.....	L-61
Figure L-13.	Chromium Samples in the Slough South of the 100-F-59 Waste Site.....	L-62
Figure L-14.	Example Boxplot Diagram Displaying a Graphical Representation of Underlying Data Distribution	L-66
Figure L-15.	Distribution of Bioaccumulation Factor and Total Chromium in Sediment and Tissue...	L-66
Figure L-16.	View of 100-F-59 Area C	L-69
Figure L-17.	Maximum Aquifer Tube and Nearshore Groundwater Well Measurements of Cr(VI) in the Vicinity of 100-F-59 (2007 to 2011)	L-75

Tables

Note: Tables referenced throughout the text are recorded on the attached compact disk.

Table L-1.	Summary of Near Shore Wells and Aquifer Tubes for the 100-FR-3 Groundwater Operable Unit
Table L-2.	Summary of Near Shore Wells and Aquifer Tubes for the 100-IU-2/IU-6 Groundwater Area
Table L-3.	Surface Water NOECs for Aquatic Biota and Amphibians
Table L-4.	Summary of Ecological Soil Preliminary Remediation Goals
Table L-5.	Summary of Sediment Ecological Screening Levels
Table L-6.	Summary of Groundwater Analytes Without Ecological Screening Levels for the 100-F Source Area
Table L-7.	Summary of Aquifer Tube Analytes Without Ecological Screening Levels for the 100-F Source Area
Table L-8.	Summary of Seep/Spring Analytes Without Ecological Screening Levels for the 100-F Source Area

- Table L-9. Summary of Surface Water Analytes Without Ecological Screening Levels for the 100-F Source Area
- Table L-10. Summary of Groundwater Analytes Without Ecological Screening Levels for the 100-IU-2/IU-6 Source Area
- Table L-11. Summary of Aquifer Tube Analytes Without Ecological Screening Levels for the 100-IU-2/IU-6 Source Area
- Table L-12. Summary of Pore Water Analytes Without Ecological Screening Levels for the 100-IU-2/IU-6 Source Area
- Table L-13. Summary of Aquifer Tube Analytes Without Ecological Screening Levels for the 100-IU-2/IU-6 Source Area
- Table L-14. Summary of Surface Water Analytes Without Ecological Screening Levels for the 100-IU-2/IU-6 Source Area
- Table L-15. Summary of Groundwater Analytes That Were Not Detected for the 100-F Source Area
- Table L-16. Summary of Aquifer Tube Analytes That Were Not Detected for the 100-F Source Area
- Table L-17. Summary of Seep/Spring Analytes That Were Not Detected for the 100-F Source Area
- Table L-18. Summary of Surface Water Analytes That Were Not Detected for the 100-F Source Area
- Table L-19. Summary of Groundwater Analytes That Were Not Detected for the 100-IU-2/IU-6 Source Area
- Table L-20. Summary of Aquifer Tube Analytes That Were Not Detected for the 100-IU-2/IU-6 Source Area
- Table L-21. Summary of Pore Water Analytes That Were Not Detected for the 100-IU-2/IU-6 Source Area
- Table L-22. Summary of Seep/Spring Analytes That Were Not Detected for the 100-IU-2/IU-6 Source Area
- Table L-23. Summary of Surface Water Analytes That Were Not Detected for the 100-IU-2/IU-6 Source Area
- Table L-24. Summary of Groundwater Analytes That Do Not Exceed an Ecological Screening Level for the 100-F Source Area
- Table L-25. Summary of Aquifer Tube Analytes That Do Not Exceed an Ecological Screening Level for the 100-F Source Area
- Table L-26. Summary of Seep/Spring Analytes That Do Not Exceed an Ecological Screening Level for the 100-F Source Area
- Table L-27. Summary of Surface Water Analytes That Do Not Exceed an Ecological Screening Level for the 100-F Source Area
- Table L-28. Summary of Groundwater Analytes That Do Not Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-29. Summary of Aquifer Tube Analytes That Do Not Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-30. Summary of Pore Water Analytes That Do Not Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-31. Summary of Seep/Spring Analytes That Do Not Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area

- Table L-32. Summary of Surface Water Analytes That Do Not Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-33. Summary of Groundwater Analytes That Exceed an Ecological Screening Level for the 100-F Source Area
- Table L-34. Summary of Aquifer Tube Analytes That Exceed an Ecological Screening Level for the 100-F Source Area
- Table L-35. Summary of Seep/Spring Analytes That Exceed an Ecological Screening Level for the 100-F Source Area
- Table L-36. Summary of Surface Water Analytes That Exceed an Ecological Screening Level for the 100-F Source Area
- Table L-37. Comparison of Contaminants of Interest to Ecological Screening Levels for the 100-F Source Area
- Table L-38. Summary of Groundwater Analytes That Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-39. Summary of Aquifer Tube Analytes That Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-40. Summary of Pore Water Analytes That Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-41. Summary of Seep/Spring Analytes That Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-42. Summary of Surface Water Analytes That Exceed an Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-43. Comparison of Contaminants of Interest to Ecological Screening Levels for the 100-IU-2/IU-6 Source Area
- Table L-44. Summary of Riparian Soil Analytes Without a Plant/Invertebrate Ecological Screening Level for the 100-F Area
- Table L-45. Summary of Riparian Soil Analytes Without a Plant/Invertebrate Ecological Screening Level for the 100-IU-2/IU-6 Area
- Table L-46. Summary of Riparian Soil Analytes Without a Wildlife Ecological Screening Level for the 100-F Area
- Table L-47. Summary of Riparian Soil Analytes Without a Wildlife Ecological Screening Level for the 100-IU-2/IU-6 Area
- Table L-48. Summary of Riparian Soil Analytes With Plant/Invertebrate Ecological Screening Level that Were Not Detected for the 100-F Area
- Table L-49. Summary of Riparian Soil Analytes With Plant/Invertebrate Ecological Screening Level that were Not Detected for the 100-IU-2/IU-6 Area
- Table L-50. Summary of Riparian Soil Analytes With Wildlife Ecological Screening Level that were Not Detected for the 100-F Area
- Table L-51. Summary of Riparian Soil Analytes With Wildlife Ecological Screening Level that were Not Detected for the 100-IU-2/IU-6 Area
- Table L-52. Summary of Riparin Soil Analytes That Do Not Exceed the Lowest Generic Plant/Invertebrate Ecological Screening Level for the 100-F Area
- Table L-53. Summary of Riparin Soil Analytes That Do Not Exceed the Lowest Generic Plant/Invertebrate Ecological Screening Level for the 100-IU-2/IU-6 Area

- Table L-54. Summary of Riparian Soil Analytes That Do Not Exceed the Lowest Generic Wildlife Ecological Screening Level for the 100-F Area
- Table L-55. Summary of Riparian Soil Analytes That Do Not Exceed the Lowest Generic Wildlife Ecological Screening Level for the 100-IU-2/IU-6 Area
- Table L-56. Summary of Riparian Soil Analytes That Exceed the Lowest Generic Plant/Invertebrate Ecological Screening Level for the 100-F Area
- Table L-57. Summary of Riparian Soil Analytes That Exceed the Lowest Generic Wildlife Ecological Screening Level for the 100-F Area
- Table L-58. Summary of Riparian Soil Analytes That Exceed the Lowest Generic Wildlife Ecological Screening Level for the 100-IU-2/IU-6 Area
- Table L-59. Summary of Sediment Analytes Without a Lower Threshold Ecological Screening Level for the 100-F Area
- Table L-60. Summary of Sediment Analytes Without a Lower Threshold Ecological Screening Level for the 100-IU-2/IU-6 Area
- Table L-61. Summary of Sediment Analytes That Were Not Detected for the 100-F Source Area
- Table L-62. Summary of Sediment Analytes That Were Not Detected for the 100-IU-2/IU-6 Source Area
- Table L-63. Summary of Sediment Analytes With Concentrations That Do Not Exceed a Lower Threshold Ecological Screening Level for the 100-F Source Area
- Table L-64. Summary of Sediment Analytes With Concentrations That Do Not Exceed a Lower Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-65. Summary of Sediment Analytes With Concentrations Greater than a Lower Threshold Ecological Screening Level for the 100-F Source Area
- Table L-66. Summary of Sediment Analytes With Concentrations Greater than an Upper Threshold Ecological Screening Level for the 100-F Source Area
- Table L-67. Summary of Sediment Analytes With Concentrations Greater than a Lower Threshold Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-68. Summary of Sediment Analytes With Concentrations Greater than an Upper Threshold Ecological Screening Level for the 100-IU-2/IU-6 Source Area
- Table L-69. Chromium Sediment and Tissue Data from the RCBRA Used to Estimate Hanford Specific BAFs
- Table L-70. Results of Grubb's Outlier test on Chromium Sediment and Tissue Data from the RCBRA
- Table L-71. Comparison of 100-F/IU OUs Riparian Soil/Sediment Concentrations to Lower and Upper Threshold Sediment ESLs
- Table L-72. Comparison of 100-FIU Decision Area Riparian Soil/Sediment Concentrations to Soil and Sediment Reference Concentrations
- Table L-73. Comparison of 100-FIU Decision Area Estimated Porewater Concentrations to Surface Water Screening Values
- Table L-74. Soil Concentrations from 100-F-59 and surrounding Area Versus Ecological Screening Levels for Plants and Invertebrates
- Table L-75. Chromium Concentrations in the 100-F-59 Area C, Near Waste, North Shore, and Slough Sub-areas
- Table L-76. Soil Concentrations from 100-F-59 and surrounding Area Versus Ecological Screening Levels for Avian and Mammalian Receptors

Table L-77. Comparison of Vanadium Concentrations in 100-F-59 to Hanford Site Background Concentrations

Table L-78. Sediment Concentrations from 100-F-59 and surrounding Area Versus Ecological Screening Levels for Omnivorous Birds

Table L-79. Sediment Concentrations from 100-F-59 and surrounding Area Versus Ecological Screening Levels for Herbivorous Birds

Table L-80. Refined Evaluation for Terrestrial Insectivorous Birds Feeding Near the 100-F-59 Waste Site

Table L-81. Refined Evaluation for Aquatic Omnivorous Birds Feeding Near the 100-F-59 Waste Site

Table L-82. Refined Evaluation for Aquatic Herbivorous Birds Feeding Near the 100-F-59 Waste Site

This page intentionally left blank.

Terms

AUF	area use factor
BAF	bioaccumulation factor
bgs	below ground surface
CERCLA	<i>Comprehensive Environmental Response, Compensation, and Liability Act of 1980</i>
COEC	contaminant of ecological concern
COI	contaminant of interest
COPC	contaminant of potential concern
COPEC	contaminant of potential ecological concern
CRC	Columbia River Component
Cr(VI)	hexavalent chromium
CSM	conceptual site model
CTE	central tendency estimate
DOE	U.S. Department of Energy
EMC	Ecological Monitoring and Compliance
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ESL	ecological screening level
FS	feasibility study
GAF	gut absorption factor
HHE	human health and the environment
HEIS	Hanford Environmental Information System
HQ	hazard quotient
HRM	Hanford River Marker
kcf/s	thousand cubic feet per second
K_d	partitioning coefficient
LOAEL	lowest observed adverse effect level
LOEC	lowest observed effect concentration
MDL	method detection limit

MTCA	“Model Toxics Control Act—Cleanup” (WAC 173-340)
MIS	MULTI INCREMENT [®] sampling
NOEC	no observed effect concentration
OHWM	ordinary high water mark
ORNL	Oak Ridge National Laboratory
OU	operable unit
PCB	polychlorinated biphenyl
PNL	Pacific Northwest National Laboratory
ppm	parts per million
PRG	preliminary remediation goal
QC	quality control
RAG	remedial action goal
RCBRA	River Corridor Baseline Risk Assessment
RDR/RAWP	Remedial design report/remedial action work plan
RI	remedial investigation
SAP	sampling and analysis plan
SESP	Surface Environmental Surveillance Program
SSL	soil screening level
SUF	site use factor
TPH	total petroleum hydrocarbon
TRV	toxicity reference value
UCL	upper confidence limit
UTL	upper threshold limit

L1 Introduction

This appendix presents a conceptual site model (CSM) of the riparian and nearshore environment along 100-F/IU-2/IU-6 at the Hanford Site. The 100-F/IU-2/IU-6 Area is located along the Columbia River and includes the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 Source Operable Units (OUs); the 100-FR-3 Groundwater OU; and the adjacent surface water, saturated sediment, and aquatic biota. This CSM has been developed to evaluate concentrations of nonradiological substances and radionuclides detected in soil, water, and sediments further, and to determine if potential transport pathways exist to these media from Hanford Site sources. The supporting evaluation of analytical data also determines whether there is the potential for exposure to aquatic receptors. The data tables compiled for this appendix are recorded on the attached compact disk.

L1.1 Background

Remediation of waste sites in the 100-F/IU-2/IU-6 Area has been ongoing since 1999 (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* [DOE/RL-2008-46-ADD4]) based on *Interim Action Record of Decision for the 100-BC-1, 100-BC-2, 100-DR-1, 100-DR-2, 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]) remedial action goals (RAG) for protection of human health and protection of groundwater and the Columbia River (*Remedial Design Report/Remedial Action Work Plan for the 100 Area* [DOE/RL-96-17], hereinafter called 100 Area RDR/RAWP). A final record of decision has not yet been developed for the 100-F/IU-2/IU-6 OUs, and active groundwater remediation has not occurred. One key component needed to support development of final remedies is a baseline risk assessment.

The River Corridor Baseline Risk Assessment (RCBRA) was initiated in 2004 to characterize current and potential threats to human health and the environment (HHE) (*Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* [DOE/RL-2004-37]; *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment* [DOE/RL-2007-21], hereinafter called RCBRA). In addition to waste sites located in upland areas and groundwater, the RCBRA (DOE/RL-2007-21) evaluated soil, sediment, and water located in riparian and nearshore areas. The RAGs used in the interim actions addressed risks to human health from direct contact with soil and threats to groundwater from leaching from soil, but did not directly address risks to ecological receptors. The ecological risk assessment conducted as part of the RCBRA (DOE/RL-2007-21) addresses residual contaminant concentrations at remediated waste sites in the upland zones and the transport of contaminants from waste sites to the Columbia River riparian and nearshore zones (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan* [DOE/RL-2008-46], hereinafter called the Integrated Work Plan).

The RCBRA (DOE/RL-2007-21) evaluated ecological risks at representative riparian study sites across the River Corridor located adjacent to, or where they may be directly affected by, known contaminated media (groundwater seeps, soil, or sediment). The RCBRA (DOE/RL-2007-21) concluded that 6 of the 22 contaminants of potential ecological concern (COPEC) (arsenic, chromium, lead, mercury, zinc, and total petroleum hydrocarbon [TPH]-diesel) identified for the riparian environment may present some level of risk for one or more of the assessment endpoint entities, based on soil bioassays, comparison of COPEC concentrations to plant or terrestrial invertebrate toxicity benchmarks, or the results of wildlife exposure analyses. The RCBRA (DOE/RL-2007-21) evaluated ecological risks at nearshore study sites potentially affected by contamination from Hanford Site sources in comparison to reference sites. Study sites were selected in areas where known contaminated groundwater plumes enter the Columbia

River and in areas between the plumes. The RCBRA (DOE/RL-2007-21) concluded that five of the 22 COPECs (cadmium, chromium, hexavalent chromium [Cr(VI)], manganese, and uranium) identified for the nearshore environment might present some level of risk for one or more of the assessment endpoint entities. Relevant risk results are comparisons of COPEC concentrations to toxicity benchmarks or the results of wildlife exposure analyses (RCBRA [DOE/RL-2007-21]).

The five contaminants of ecological concern (COEC) identified by the RCBRA (DOE/RL-2007-21) in riparian and nearshore media mostly were metals and TPH-diesel. With few exceptions (notably chromium and Cr(VI)), there are ambient sources for the constituents in soil, sediment and water that are unrelated to the Hanford Site. The CSM describes the interrelationships between sources, transport mechanisms, exposure pathways and receptors. When the principal threat constituents in soil and groundwater at the 100-F/IU-2/IU-6 Area were compared with the contaminants identified by the RCBRA (DOE/RL-2007-21) as posing ecological risk in riparian and nearshore media, additional work was warranted to better understand the CSM in the riparian and nearshore environment.

L1.2 Description of the 100-F/IU Area

The 100-F/IU-2/IU-6 is located in the northern portion of the Hanford Site adjacent to the Columbia River. The 100-F Area contains one water-cooled, graphite moderated, plutonium production reactor. The IU-2/IU-6 Area contains burial grounds, landfills, cribs, storage facilities, dumping area, and storage tanks (*Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment* [PNNL-SA-41467], hereinafter called RCBRA Literature Review).

The topography changes are greatest in the vicinity of the river. Away from the river, the topography varies widely. The region is relatively flat with areas of sand dunes, but also includes Gable Butte and Gable Mountain. The operational area within the perimeter fence has been disturbed and graded extensively by human activity since reactor construction began in the 1950s through present-day waste site remedial activities (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Unit* [DOE/RL-2008-46-ADD4]).

The entire River Corridor, which includes the 100-F/IU-2/IU-6 Area, has been divided in three environmental zones for purposes of investigation (RCBRA [DOE/RL-2007-21]; Integrated Work Plan [DOE/RL-2008-46]): the upland, riparian, and nearshore aquatic zones. Summary definitions of these environmental zones are presented in Section L1.4.

The upland environment within the boundary of the 100-F Area contains graveled areas adjacent to buildings and facilities; however, significant portions of the 100-F Area are vegetated. The main vegetation cover type throughout the central and northeastern portions is gray rabbit brush/cheatgrass. This cover type extends beyond the perimeter fence in the northeastern corner to form a narrow band between the 100-F fenced area and the riparian zone to the northeast. Within the western edge of the 100-F Area, Sandberg's bluegrass and cheatgrass compose the dominant vegetation cover with small patches of big sagebrush and gray rabbitbrush occurring within this type in the southwestern corner. The southeastern corner is dominated by big sagebrush/Sandberg's bluegrass-cheatgrass. The area to the south and west beyond the perimeter fence consists primarily of two vegetation cover types: big sagebrush/bunchgrass mosaic and abandoned old agricultural fields (now primarily Sandberg's bluegrass and cheatgrass). From the eastern perimeter fence eastward to edge of the riparian zone are areas of big sagebrush/Indian ricegrass and bitterbrush/Indian ricegrass. North of the perimeter fence, the upland environment is narrow and consists primarily of abandoned old agricultural fields and the narrow band of gray rabbitbrush/cheatgrass mentioned above (spatial data available from the Ecological Monitoring and Compliance [EMC] databases).

The riparian environment immediately adjacent to the northeastern boundary of the 100-F Area occupies a narrow, steep bank slope no wider than 25 m (82 ft) adjacent to the upland communities. The exotic weeds (knapweed, Russian thistle) occupy a portion of the upper slope. The dominant cover type on the bank slope and along the Columbia River edge is a sparse low shrub/forb/cobble association. Just downstream from the narrow, steep section and to the east of the perimeter fence, the riparian zone becomes significantly broader with a diverse association of vegetation cover. The riparian zone also widens to approximately 125 m (410 ft) north of the northwestern corner of the 100-F Area. Riparian habitats found on these broad benches include wormwood/perennial grass, wormwood/riparian wheatgrass, sand dropseed grass association, low shrub/forb/cobble association, riparian wheatgrass association, wild rye association, willow, reed canary grass, exotic weed, and occasional small areas of emergent wetland. A series of tree clumps is found approximately 0.5 km north of the northwestern corner. Each clump encompasses from 0.7 to 1.5 hectares (1.7 to 3.7 ac) (spatial data available from EMC database).

The upland environment near the 100-IU-2 Area (also identified as the White Bluffs area) has been subject to disturbances because of farming and traffic. The types of vegetation cover found there are primarily Sandberg's bluegrass-cheatgrass, gray rabbitbrush/Sandberg's bluegrass-cheatgrass vegetation cover types where cheatgrass and other exotic annuals may be the dominant species. The upland habitats surrounding the White Bluffs area are described in the vegetation mapping for the site as "abandoned old fields".

The riparian environment immediately adjacent to the White Bluffs boat launch is highly disturbed and degraded in some areas. The 100-IU-2 Area was a populated area and used extensively by humans. Tree groves remain adjacent to the launch area, and exotic annuals dominate much of the understory. Along the shoreline, the riparian vegetation consists of mostly low shrub/forb/cobble association. Upstream of the launch area, a backwater slough extends north into a broader expanse of riparian vegetation extending nearly to the edge of the White Bluffs boat launch. Riparian habitats found on the broad bench include the following: wormwood/perennial grass, sand dropseed grass association, low shrub/forb/cobble association, wormwood/riparian wheatgrass association, and areas of both on persistent emergent wetland and emergent wetland. Several areas are dominated by reed canary grass in this area, and several clumps of trees are present as well. A small topographic rise within this bench supports upland shrub steppe vegetation.

The upland environment at the 100-IU-6 (also identified as the Hanford town site) has been radically changed and disturbed by settlement, farming, and construction. The vegetation types found there are primarily Sandberg's bluegrass-cheatgrass, gray rabbitbrush/Sandberg's bluegrass-cheatgrass vegetation cover types where cheatgrass and other exotic annuals may be the dominant species. Some upland habitats surrounding the Hanford town site area are described in the vegetation mapping for the site as "abandoned old fields." The town site differs from other upland vegetation cover types because it contains trees scattered along the remains of roadways and walkways associated with previous homesteads, the town itself, and the Hanford Construction Camp. The trees present along old streets of the town/construction camp are not captured as features of the vegetation cover type mapping. However, they provide important habitat for a number of mammals and birds.

The riparian environment immediately adjacent to the Hanford town site is composed of a relatively narrow strip ranging from 75 to 150 m (246 to 492 ft) in width for most of the shoreline. Just to the north and upstream of the area previously occupied by the construction camp, a backwater slough exists, and a broad expanse of riparian vegetation is associated with the peninsula and bench along the river. Along the narrower and steeper region of the riverbank, the riparian vegetation consists of mostly low shrub/forb/cobble association adjacent to the river. This vegetation grades into a narrower band inhabited

by either wormwood/perennial grass, or wormwood/riparian wheatgrass association, or perennial grasses. Clumps and linear stands of trees are scattered along the steep bank throughout the shoreline in this area. Above the backwater slough, the riparian habitats found on the broad bench include the following: wormwood/perennial grass, wormwood/riparian wheatgrass association, riparian wheatgrass association, sand dropseed grass association, low shrub/forb/cobble association, reed canary grass, and emergent wetland. Several stands of willows (willow complex) are located adjacent to the backwater slough and along the shoreline. A small topographic rise within this bench supports upland wild rye association (spatial data available from EMC database) (RCBRA Literature Review [PNNL-SA-41467]).

L1.3 Review of Previous Riparian/Nearshore Studies

Investigations, which were historically conducted in the riparian and nearshore areas of the 100-F and 100-IU-2/IU-6 Areas, are summarized below and detailed in the RCBRA Literature Review (PNNL-SA-41467). Most recently, investigations of riparian and nearshore areas were conducted as part of the RCBRA (DOE/RL-2007-21); *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan* [DOE/RL-2005-42], hereinafter called RCBRA Sampling and analysis Plan [SAP]).

L1.3.1 100-F Area Historical Studies

Approximately 66 km (41 mi) of Hanford Site shoreline were evaluated, and 115 riverbank spring and groundwater seepage areas were identified in *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River* (PNL-5289). Riverbank spring water was analyzed for tritium, uranium (primarily in the 300 Area), and nitrate, with selected samples analyzed for strontium-90, technetium-99, and gross beta. In addition, at some locations Columbia River water samples were collected 2 to 4 m (6.6 to 13.1 ft) from the shoreline. In general, elevated concentrations of radionuclides and nitrate were reported for river water samples collected in the vicinity of riverbank springs with elevated concentrations of contaminants. The report is an excellent source for locating historic riverbank spring discharges and provides valuable contaminant data for environmental conditions along the Hanford shoreline in the early 1980s. Contaminant data specific to the 100-F Area riverbank springs are provided, with slightly elevated concentration of nitrates reported (maximum concentration of 1.77 parts per million [ppm]). Maximum tritium concentrations ranged from 1,900 pCi/L in monitoring wells to 270 pCi/L in springs and 130 pCi/L in river water. Maximum strontium-90 concentrations in river water were <1 pCi/L, and maximum gross beta analysis from spring samples was 12 pCi/L.

1988 Hanford Riverbank Springs Characterization Report (PNL-7500) characterized the concentrations of radionuclides and chemicals in riverbank springs (i.e., groundwater seepage) entering the Columbia River along the Hanford Site. The 100-F Area shore was not considered a major source of groundwater discharge, and riverbank springs were not observed during three attempts to collect samples.

In 1991, samples of Columbia River water, riverbank springs, and riverbank spring sediment were collected from 26 locations from the 100-B Area to the upriver portion of the Hanford town site (Hanford River Marker [HRM] 25.2) (*Sampling and Analysis of 100 Area Springs* [DOE/RL-92-12]). The samples were analyzed for radiological and chemical contaminants. Two riverbank springs (187-1 and 190-4) at the F Reactor and four riverbank springs downriver from the reactor (207-1, 211-1, 213-1, and 216-1) were located and sampled. Concentrations of contaminants in riverbank spring water from these locations were at or below the detectable levels for all constituents except for strontium-90 (2.5 to 40 pCi/L). Columbia River water collected in the vicinity of these riverbank springs were below the detectable levels for all constituents. Samples of riverbank spring sediment from the 100-F Area had detectable concentrations of strontium-90, cesium-137, europium-155, cobalt-60, radium-226, thorium-228, and thorium-232.

Environmental Monitoring of Columbia River Sediments: Grain-Size Distribution and Contaminant Association (PNL-10535) reported concentrations of radionuclide, metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls (PCB), and pesticides in sediment from Priest Rapids Dam, the Hanford Reach, and McNary Dam. In addition, sediment samples were analyzed for sediment grain size and total organic carbon content. Contaminant data specific to the 100-F Area slough are provided.

Sediment samples collected between 1997 and 1999 were analyzed for metals, simultaneously extracted metals/acid volatile sulfide, total organic carbon, and sediment grain size analysis from the 100-F Slough (*Simultaneously Extracted Metals/Acid-Volatile Sulfide and Total Metals in Surface Sediment from the Hanford Reach of the Columbia River and the Lower Snake River* [PNNL-13417]). On a molar basis, zinc was the dominant metal present. In general, sediment from the Hanford Reach had lower metal concentrations compared to sediment from Priest Rapids Dam. For Hanford Reach samples, there was sufficient acid volatile sulfide to limit bioavailability of most divalent metals (cadmium, copper, mercury, nickel, and lead), except zinc, which had similar levels as the available sulfide. Sediment at the 100-F Slough was composed primarily of medium sand and fine sand.

Eight sediment samples were collected at five locations in the 100-F slough in 1991 and analyzed for radionuclides and metal concentrations (*100 Area Columbia River Sediment Sampling* [WHC-SD-EN-TI-198]). All concentration levels for potassium-40 were less than the reference level at Vernita. Two samples had cobalt-60 concentrations above the detection limit; the highest concentration was 0.36 pCi/g. Seven of the eight samples had detectable cesium-137 concentrations; the highest concentration was 0.83 pCi/g. Europium-152, uranium-233/234, and uranium-238 sediment concentrations generally exceeded those from sediment at Vernita with maximum concentrations of 0.92 pCi/g, 1.6 pCi/g, and 2.0 pCi/g, respectively. Other radionuclide concentrations, europium-154 (maximum 0.16 pCi/g), radium-226 (maximum 1.7 pCi/g), thorium-228 (maximum 4.4 pCi/g), and thorium-232 (maximum 3.2 pCi/g), were generally below the concentrations found in Vernita sediment.

Sediments collected in 1991 (*100 Area Columbia River Sediment Sampling* [WHC-SD-EN-TI-198]) in the 100-F slough¹ were analyzed for chromium, copper, lead, and zinc concentrations and compared to an upper threshold limit (UTL) from the 95 percent confidence interval of the 95th percentile of the Hanford Site soil background data set (95 percent UTL). Of the eight chromium samples, only two samples exceeded the 95 percent UTL, with a maximum concentration of 45.7 µg/g. Copper concentrations in five of the eight samples exceeded the 95 percent UTL, with a maximum concentration of 69.6 µg/g. Lead levels also generally exceeded the 95 percent UTL (six of eight samples), with a maximum concentration of 55.7 µg/g. The maximum lead concentration was, however, less than reported for Vernita (57.7 µg/g). All but one zinc level was above the 95 percent UTL and the maximum concentration was 335 µg/g.

L1.3.2 100-IU-2 Area (White Bluffs) Historical Studies

Approximately 66 km of Hanford Site shoreline were evaluated, and 115 riverbank spring and groundwater seepage areas were identified in *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River* (PNL-5289). Riverbank spring water was analyzed for tritium, uranium (primarily in the 300 Area), and nitrate, with selected sample analyzed for strontium-90, technetium-99, and gross beta. In addition, at some locations Columbia River water samples were collected 2 to 4 m (6.6 to 13.1 ft) from the shoreline. In general, elevated concentrations of radionuclides and nitrate were reported for river water samples collected in the vicinity of riverbank springs with elevated concentrations

¹ Note these samples are from what is known as the 100-F-Slough, which is not the same as the seasonally inundated slackwater slough located just downstream of 100-F-59, described in detail in Section L4.7. Samples from the 100-F Slough are found in Figure L-10.

of contaminants. No springs were found in the White Bluffs area (HRM 16 to 18), and tritium levels from the river were generally below detection (maximum concentration 395 pCi/L). Nitrate levels in the area were near background levels (maximum concentration of 0.66 ppm).

A preliminary study of PCBs in aquatic habitats and great blue herons was conducted on the Hanford Site (*A Preliminary Survey of Polychlorinated Biphenyls (PCBs) in Aquatic Habitats and Great Blue Herons on the Hanford Site* [PNL-5685]). Water, fish, and sediment from the White Bluffs slough were analyzed for PCBs. When detected, the PCB levels in water were reported as over 1 ng/L, but less than 20 ng/L. These values were similar to levels reported in other freshwater environments during that time. PCBs were detected in the fat of fish from the White Bluffs slough. Concentrations of PCBs in sediment samples from the Hanford Site were generally lower than levels reported from other areas of the nation during that time period.

Environmental Monitoring of Columbia River Sediments: Grain-Size Distribution and Contaminant Association (PNL-10535) reported concentrations of radionuclide, metals, polycyclic aromatic hydrocarbons, PCBs, and pesticides in sediment from Priest Rapids Dam, the Hanford Reach, and McNary Dam. In addition, sediment samples were analyzed for sediment grain size and total organic carbon content. Contaminant data specific to the White Bluffs slough were provided.

Sediment samples collected between 1997 and 1999 were analyzed for metals, simultaneously extracted metals/acid volatile sulfide, total organic carbon, and sediment grain size (*Simultaneously Extracted Metals/Acid-Volatile Sulfide and Total Metals in Surface Sediment from the Hanford Reach of the Columbia River and the Lower Snake River* [PNNL-13417]). On a molar basis, zinc was the dominant metal present. In general, sediment samples from the Hanford Reach had lower metal concentrations compared to samples from Priest Rapids Dam. Additionally, for the Hanford Reach samples, there was sufficient acid volatile sulfide to limit the bioavailability of most divalent metals (cadmium, copper, mercury, nickel, and lead), except for zinc which had a concentration similar to the available sulfide. Sediment at the White Bluffs slough was composed primarily of medium sand and fine sand, with a small amount (<10% dry weight) of very fine sand and silt/clay.

L1.3.3 100-IU-6 Area (Hanford Town Site) Historical Studies

Approximately 66 km of Hanford Site shoreline were evaluated, and 115 riverbank springs and groundwater seepage areas were identified in *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River* (PNL-5289). Riverbank spring water was analyzed for tritium, uranium (primarily in the 300 Area), and nitrate, with selected sample analyzed for strontium-90, technetium-99, and gross beta. In addition, at some locations, Columbia River water samples were collected 2 to 4 m (6.6 to 13.2 ft) from the shoreline. In general, elevated concentrations of radionuclides and nitrate were reported for river water samples collected in the vicinity of riverbank springs with elevated concentrations of contaminants. The report is an excellent source for locating historic riverbank spring discharges and provides valuable contaminant data for environmental conditions along the Hanford shoreline in the early 1980s. Contaminant data specific to the Hanford town site riverbank springs and Columbia River water are provided. Maximum concentrations of tritium (wells: 230,000 pCi/L, springs 110,000 pCi/L, and river 107 pCi/L), nitrate (16.6 ppm from a spring), technetium-99 (43 pCi/L), iodine-129 (0.062 pCi/L), and gross beta (9.8 pCi/L) were reported.

1988 Hanford Riverbank Springs Characterization Report (PNL-7500) characterized the concentrations of radionuclides and chemicals in riverbank springs (i.e., groundwater seepage) entering the Columbia River along the Hanford Site. The Hanford town site is a major discharge location for the plume of contaminated groundwater flowing from the 200 Areas. A number of springs were sampled in the vicinity of HRM 28. The maximum tritium concentration (155,000 pCi/L) in Hanford town site riverbank springs

was nearly 8 times the ambient water quality criteria of 20,000 pCi/L. In addition, elevated concentrations of gross beta (maximum concentration 69.9 pCi/L) and technetium-99 (maximum concentration 350 pCi/L) were also reported for riverbank spring water at the Hanford town site.

In 1991, samples of Columbia River water, riverbank springs and riverbank spring sediments were collected from 26 locations from the 100-B Area to the upriver portion of the Hanford town site (HRM 25.2) (*Sampling and Analysis of 100 Area Springs* [DOE/RL-92-12]). The samples were analyzed for radiological and chemical contaminants. Two riverbank springs (241-1 and 247-1) at the Hanford town site were located and sampled. Concentrations of contaminants in riverbank spring water from these locations were at or below the detectable levels for all constituents. Columbia River water collected in the vicinity of these riverbank springs was below the detectable levels for all constituents. However, these riverbank springs are located upriver from the shoreline where the 200 Area contaminated groundwater plume intersects the Columbia River, whereas most other studies have collected samples approximately 5 km downriver; thus direct comparison to results from other studies (e.g., *1988 Hanford Riverbank Springs Characterization Report* [PNL-7500]) are not possible. Samples of riverbank spring sediment from the Hanford town site had detectable concentrations of cesium-137, europium-152, europium-155, cobalt-60, radium-226, thorium-228, thorium-232, and total uranium.

The *1988 Hanford Riverbank Springs Characterization Report* (PNL-7500) summarized radiological monitoring of Columbia River water along the Hanford Reach from 1980 through 1989. Concentrations of radionuclides in river water are reported for samples collected primarily at Priest Rapids Dam, the 300 Area water intake, and the city of Richland's water intake. The Columbia River water concentrations of tritium and iodine-129 are reported for a series of samples collected in 1982 at the Hanford town site.

Columbia River sediment was collected in 1991 at three locations in the Hanford town site area (*100 Area Columbia River Sediment Sampling* [WHC-SD-EN-TI-198]). Two samples were collected at each location and analyzed for radionuclide and metal concentrations. Concentrations of radionuclides were similar to those reported for samples from Vernita, except for a sample from the north end of the Hanford Slough. In that sample, concentrations of cobalt-60 (0.056 pCi/g), cesium-137 (1.0 pCi/g), europium-152 (0.82 pCi/g), and europium-155 (0.17 pCi/g) were above background. For inorganic constituents, only a single sample and a single constituent exceeded the 95 percent UTL (UTL from 95 percent confidence interval of the 95th percentile of the Hanford Site soil background data set). Again, the sample came from the north end of the Hanford slough, and the constituent was zinc. The maximum concentration of zinc was 293 µg/g compared to the 95 percent UTL concentration of 79 µg/g.

Environmental Monitoring of Columbia River Sediments: Grain-Size Distribution and Contaminant Association (PNL-10535) reported concentrations of radionuclide, metals, polycyclic aromatic hydrocarbons, PCBs, and pesticides in sediment from Priest Rapids Dam, the Hanford Reach, and McNary Dam. In addition, sediment samples were analyzed for sediment grain size and total organic carbon content. Contaminant data specific to the Hanford Townsite Slough were provided.

Sediment samples collected between 1997 and 1999 were analyzed for metals, simultaneously extracted metals/acid volatile sulfide, total organic carbon, and sediment grain size (*Simultaneously Extracted Metals/Acid-Volatile Sulfide and Total Metals in Surface Sediment from the Hanford Reach of the Columbia River and the Lower Snake River* [PNNL-13417]). On a molar basis, zinc was the dominant metal present. In general, sediment samples from the Hanford Reach had lower metal concentrations compared to samples from Priest Rapids Dam. Additionally, for the Hanford Reach samples, there was sufficient acid volatile sulfide to limit the bioavailability of most divalent metals (cadmium, copper, mercury, nickel, and lead), except for zinc, which had a concentration similar to the available sulfide.

Sediment at the White Bluffs slough was composed primarily of medium sand and fine sand, with a small amount (<10% dry weight) of very fine sand and silt/clay.

There has been minimal contaminant monitoring efforts at the White Bluffs town site and no surveillance activity in upland zones. The groundwater program classifies this area as within the 600 Area, which includes all areas of the Hanford Site not associated with reactor or processing facilities. There is minimal data collection within the 600 Area. Most of the available data is associated with the White Bluffs slough and was collected in support of site-wide surveillance objectives. Plutonium isotopes, cobalt-60, cesium-137, strontium-90, and europium isotopes were detected in slough sediment with maximum concentrations below 1 pCi/g. Existing metal and organic data are also minimal.

Groundwater migrates into the Hanford town site region from the west and contains contaminants that were released to the environment in the 200 East Area (*Hydrogeologic Controls on Ground-Water and Contaminant Discharge to the Columbia River Near the Hanford Townsite* [PNL-8167]). The town site region has recently been included in the 200-PO-1 OU, which includes the site-wide tritium plume. Although numerous chemical and radiological constituents were discharged to the ground at waste disposal sites in the 200 East Area, only a few are sufficiently mobile in groundwater to have migrated to the river. Contaminants of potential concern (COPC) in groundwater at the Hanford town site are identified in *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit* (DOE/RL-2003-04). For the far-field portions of the site-wide plume, they are iodine-129, nitrate, and tritium.

L1.3.4 Surface Environmental Surveillance Program

In addition to the historical investigations stated above, other sampling and analytical data have been collected from riparian and nearshore areas as part of the Surface Environmental Surveillance Program (SESP). The SESP is responsible for site-wide and offsite environmental surveillance at the Hanford Site. Surface environmental surveillance at the Hanford Site is a multimedia environmental monitoring effort conducted to assess onsite and offsite human health exposures to radionuclides and chemicals and to evaluate the impact of Hanford Site operations on the environment.

Under the SESP, Columbia River water, shoreline spring water, and sediment sampling are conducted along the 100-F and 100-IU-6 Area. In addition Columbia River water samples are also collected at three additional location that bracket the 100-F Area and four additional locations that bracket the 100-IU-6 Area. Sediment sampling is conducted along the 100-IU-2 Area. The SESP does not monitor Columbia River water or riverbank spring water in the vicinity of the 100-IU-2 Area.

The trends in metals concentrations in spring samples are reported to have been consistent over the past several years. With the exception of chromium, concentrations of metals in spring samples in 100-F/IU were below Washington State chronic ambient surface water quality criteria in “Water Quality Standards for Surface Waters of the State of Washington” (WAC 173-201A). Concentrations of radionuclides detected in springs in 2009 were reported to be similar to those in previous years. Potassium-40 (natural background), cesium-137, and uranium isotopes were the only radionuclides reported above minimum detectable concentrations. Concentrations of radionuclides and metals in 100-F/IU sediments were similar to levels detected in previous years (*Hanford Site Environmental Report for Calendar Year 2009* [PNNL-19455]).

L1.3.5 Groundwater and Aquifer Tube Monitoring Programs

U.S. Department of Energy (DOE) monitors groundwater at the Hanford Site to fulfill a variety of state and federal regulations, including the *Atomic Energy Act of 1954*, *Resource Conservation and Recovery Act of 1976*, *Comprehensive Environmental Response, Compensation, and Liability Act of 1980*

(CERCLA), and “Model Toxics Control Act—Cleanup” (WAC 173-340), hereinafter called MTCA. The groundwater monitoring data relevant to the 100-F/IU-2/IU-6 riparian and nearshore environment are discussed further in Section 3 of this appendix.

DOE monitors groundwater quality along the Columbia River by collecting samples from aquifer tubes and riverbank seeps (springs). The rise and fall of the Columbia River create a zone of interaction that influences contaminant concentrations and groundwater flow patterns. Water samples from aquifer tubes and riverbank seeps nearly always represent a mixture of river water and approaching groundwater. In general, the degree of dilution by river water decreases with depth in the aquifer near the river shoreline. The degree of dilution also varies by location and with seasonal river cycles (*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 aquifer tube and seep data relevant to the 100-F/IU-2/IU-6 riparian and nearshore environment are discussed further in Section L3 of this appendix.

L1.4 Approach to CSM Development

As described previously, the objective for developing this CSM is to provide a tool for evaluating the potential for contaminants in riparian and nearshore media to be associated with releases from Hanford-related sources. The foundation for developing the CSM begins with the definition of environmental zones presented in the RCBRA (RCBRA [DOE/RL-2007-21]). They are:

- **Nearshore aquatic zone:** the nearshore aquatic zone includes the surface water of the Columbia River from the area that is permanently inundated by river water (i.e. the low-water mark, commonly referred to as the “green line,” where the periphyton remain green year-round) up to the riparian zone.
- **Riparian zone:** the riparian zone is a transition area between the aquatic environment in the nearshore zone and the upland zone. The riparian zone extends from the shoreline of the Columbia River to the point on the riverbank where upland vegetation becomes dominant. The riparian zone typically is narrow and varies in width depending on the slope of the riverbank.
- **Upland zone:** the upland zone consists of land that extends inland from the riparian zone situated approximately 3 m (10 ft) above the river high-water mark. The upland zone generally is dry and not readily influenced by river flow. Recharge to groundwater in this zone occurs largely from precipitation. The upland zone includes operational areas in the 100 Area decision areas and generally is where waste sites are located.

These environmental zones are depicted in Figures L-1 and L-2.

Potential exposure pathways from source OUs and the underlying groundwater OU located in the upland zone have been traced to media in the riparian and nearshore zones. An exposure pathway can be described as the physical course that a contaminant takes from the point of release to a receptor. The route of exposure is the means by which a contaminant encounters a receptor. For an exposure pathway to be complete, all of the following components must be present:

- A source
- A mechanism of contaminant release and transport
- An exposure point
- An exposure route
- A receptor or exposed population
- An environmental transport medium

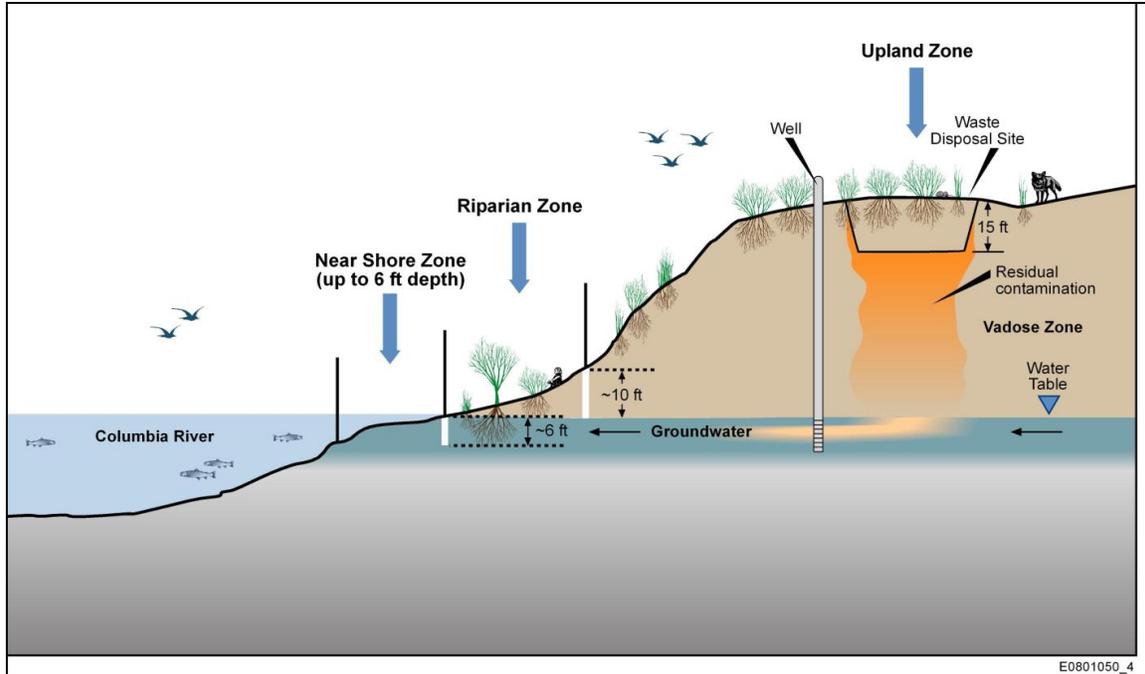


Figure L-1. Environmental Zones in the Riparian/Nearshore Area

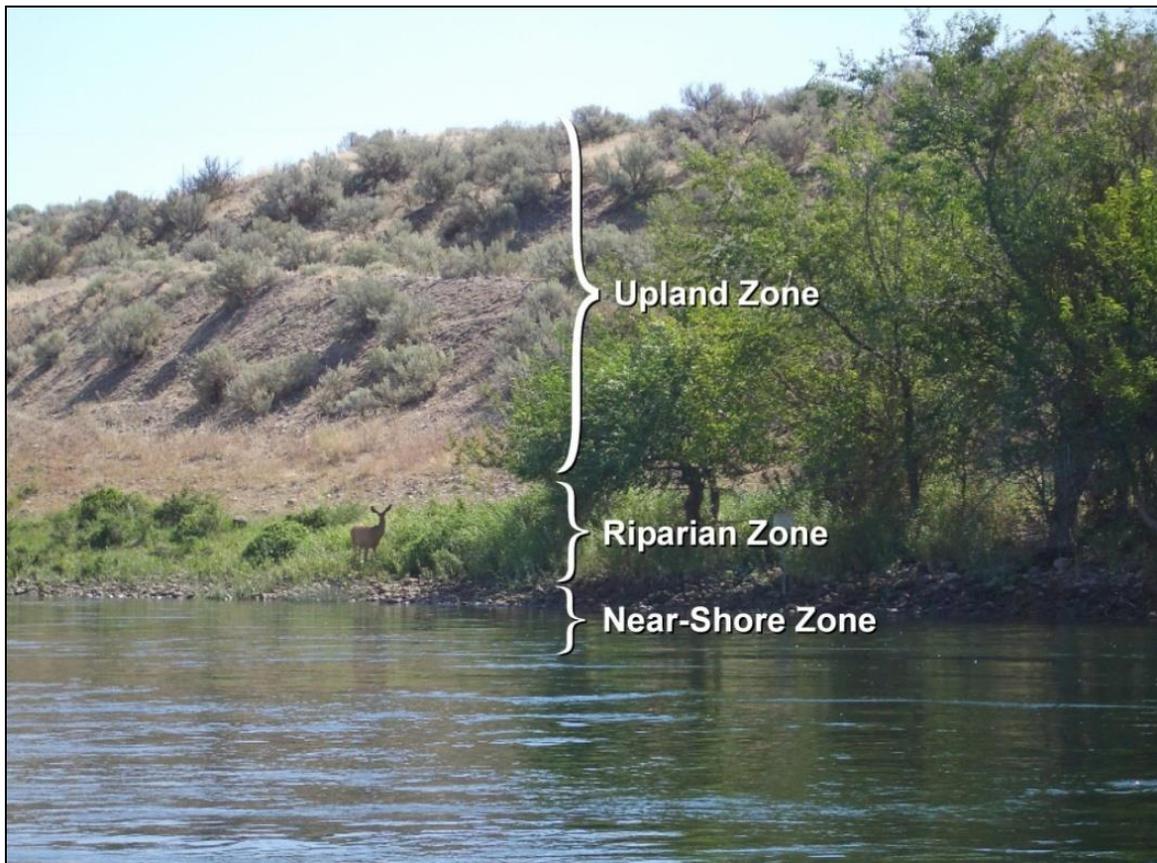


Figure L-2. Photograph Depicting the Environmental Zones

In the absence of any one of these components, an exposure pathway is considered incomplete and, therefore, creates no risk or hazard.

An additional consideration for contaminants detected in riparian and nearshore zones is a contaminant source, or sources, unrelated to Hanford Site operations, that have been transported and deposited via the river. These other sources also are discussed as part of this CSM. Identification of potential exposure pathways in the riparian and nearshore zones is described in Section L2.

Once the potential exposure pathways are identified and described, sampling and analytical data from various media are evaluated. The objectives for this evaluation include depicting the relative concentrations in the various riparian and nearshore media and evaluating data quality. Media in the riparian and nearshore areas that have been sampled include groundwater, pore water, seeps/springs, surface water, sediments, biota, and soil. The results from this data evaluation are combined with the exposure pathway information (described previously) to determine if contaminant concentrations located at exposure points are potentially associated with Hanford Site activities. The data evaluation is described in Section L3.

An evaluation of potential ecological risks in riparian and nearshore zones was conducted as part of the RCBRA (DOE/RL-2007-21). The results from this evaluation are summarized in Section L4. These results, which identified COECs, are compared with the results from the data evaluation in Section L3 to determine if those COECs might be associated with Hanford Site activities.

L2 Evaluation of Riparian and Nearshore Exposure Pathways

This section describes the sources, release and transport mechanisms, environmental media through which contaminant transport occurs and exposure points in the riparian and nearshore zones. This section provides the framework for the data evaluation that is presented in Section L3.

L2.1 Sources

A total of 259 waste sites are found in the 100-F/IU-2/IU-6 Area, located principally in the upland zone (*Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units* [DOE/RL-2008-46-ADD4]). As described in the RCBRA Literature Review (PNNL-SA-41467), the riparian environment immediately adjacent to the 100-F Area occupies a narrow, steep bank slope no wider than 25 m (82 ft) adjacent to the upland communities. The riparian area immediately adjacent to the 100-IU-6 Area is composed of a relatively narrow strip ranging from 75 to 150 m (246 to 492 ft) in width for most of the shoreline. A limited number of the 100-F/IU-2/IU-6 waste sites are of interest with regard to the riparian/nearshore CSM. In addition to these waste sites, groundwater in the 100-FR-3 OU is potentially a source for contaminant release to riparian and nearshore media.

L2.1.1 Waste Sites and Soils

The waste sites located close to the riparian zone in the 100-F/IU-2/IU-6 Area OU are presented in Figures L-3 and L-4. Brief descriptions of these sites are presented in the following paragraphs. The nature and extent of contamination has been characterized, or is currently being characterized for these waste sites. While it is not known if there are potential releases or exposure pathways from these sites, their proximity to the riparian area makes them candidates for consideration as potential sources in this evaluation.

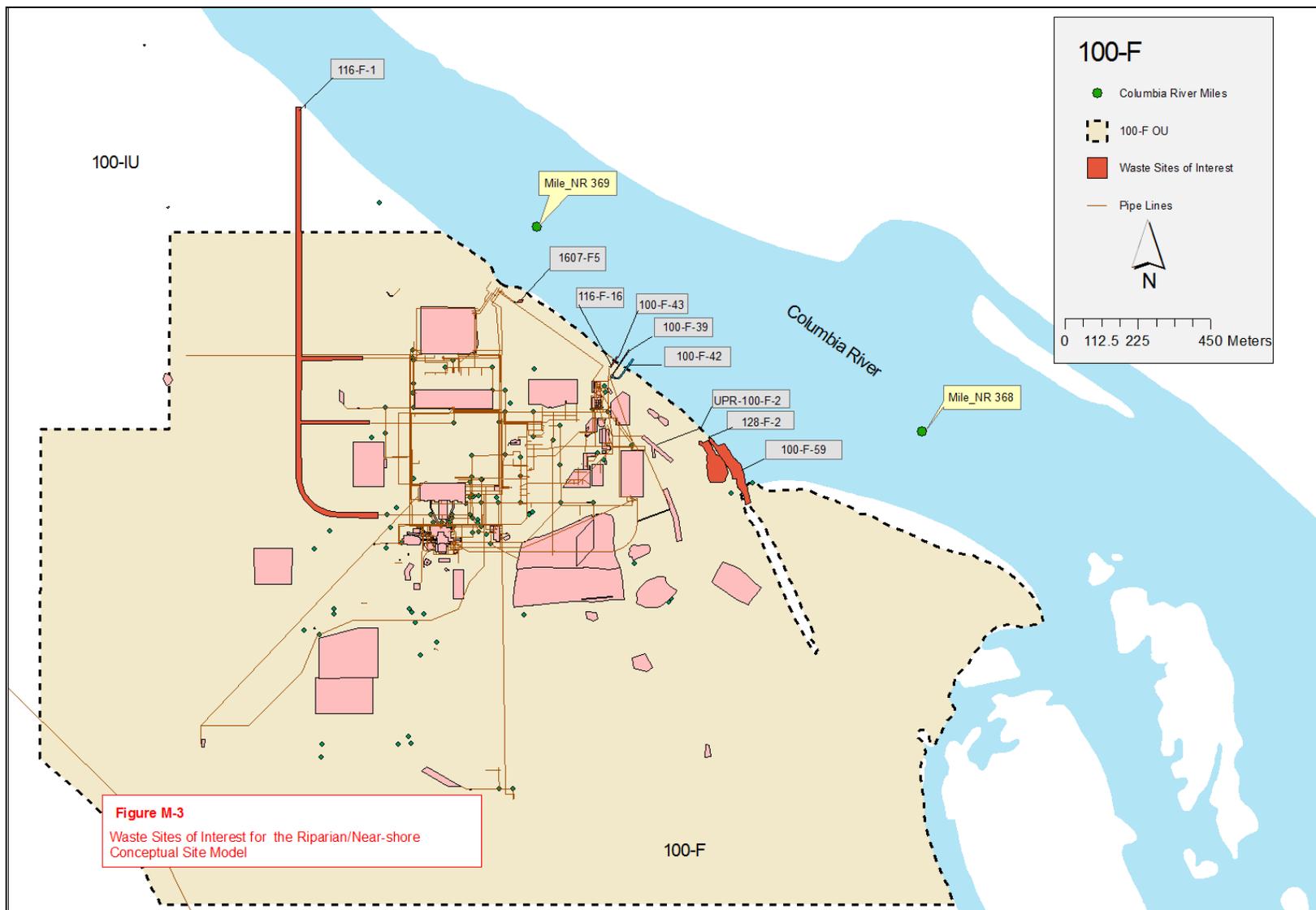


Figure L-3. 100-F Waste Sites of Interest

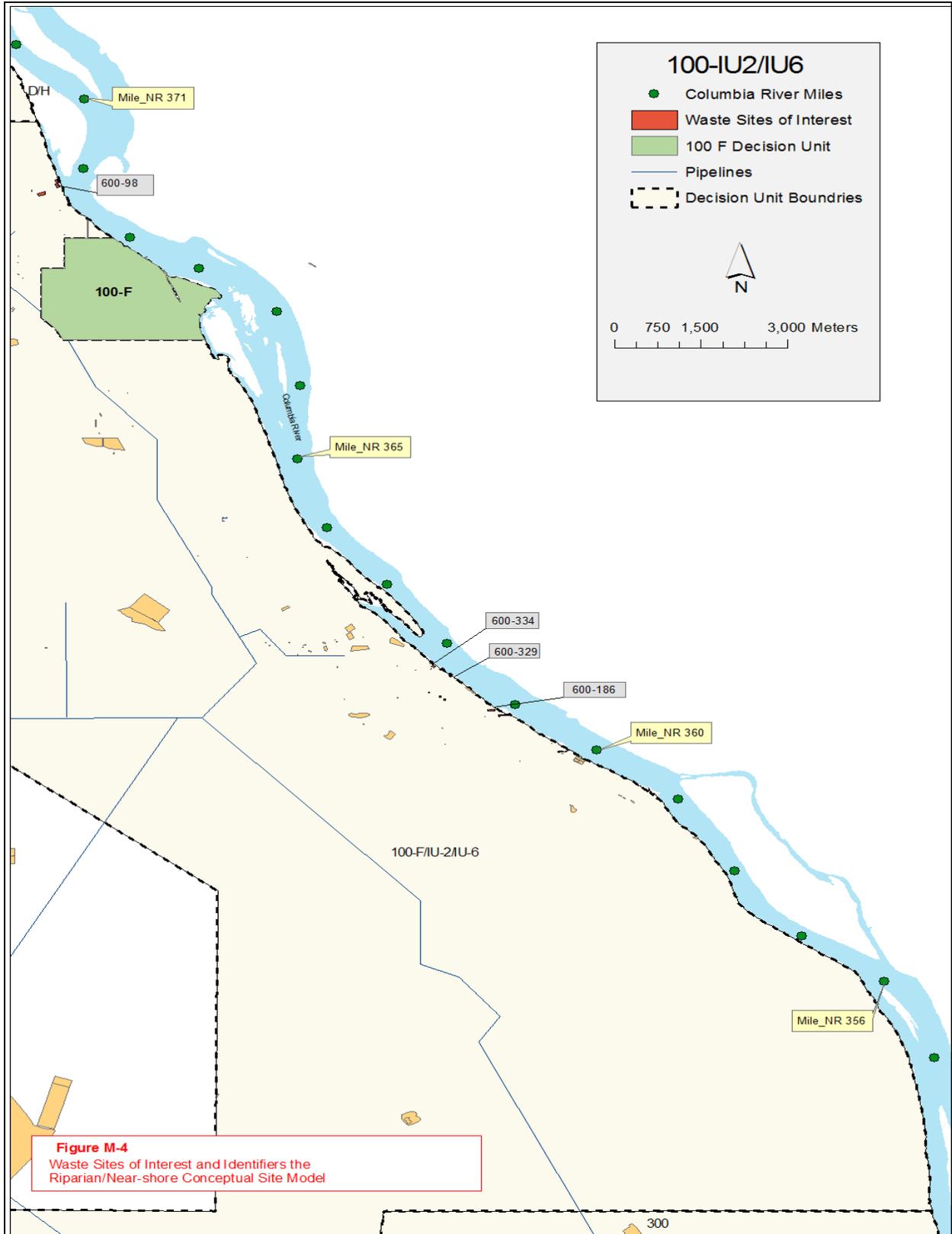


Figure L-4. 100-IU-2/100-IU-6 Waste Sites of Interest

L2.1.1.1 100-F Area

100-F-39 (100F River Effluent Pipelines). This site consists of the river effluent pipelines (river lines) that extend from 1904-F Outfall (116-F-8) in the 100-F Area into the main channel of the Columbia River. The river lines are located in the Columbia River, adjacent to the 100-F Area. These river effluent pipelines extend from, and are perpendicular to, the discharge (river side) face of the 116-F-8 Outfall structure for 91 m (300 ft) into the main channel of the river. This site is associated with the 116-F-8 Outfall, the Pacific Northwest Laboratory (PNL) spillway (100-F-43), and the 100-F-42 Spillway. This site is classified as interim closed out and is inactive.

100-F-42 (1904-F Spillway). This site, a spillway, is located approximately 214 m (700 ft) north of the 116--F-14 Retention Basin. The upper end of the spillway began at the west face of the outfall and terminated in the river. This site consisted of a reinforced concrete spillway (also referred to as a flume) and extended from the 116-F-8 Outfall to the Columbia River shoreline and into the river. The site was associated with the 100-F-39, 100-F River Effluent Pipelines, the 116-F-8 Outfall Structure, the 116-F-16 Outfall, and 100-F-43 Spillway. An engineered erosion barrier composed of heavy riprap was constructed at the discharge end of the concrete structure. The spillway was designed to prevent excessive backwater at the 107-F Retention Basin during high water or in the event of a blockage of the outfall lines. This site is classified as interim closed out and is inactive.

100-F-43 (116-F-16 PNL Outfall). This site is located approximately 670 m (2,200 ft) northeast of the 105-F Reactor Building and about 15 m (50 ft) upstream of the 116-F-8 Outfall. It was connected to the 116-F-16 PNL Outfall face and extends into the river. The 100-F-43 spillway (also referred to as a "flume") was constructed of reinforced concrete, and extended from the 116-F-16 PNL Outfall to the Columbia River shoreline and into the river. An engineered erosion barrier composed of heavy riprap was constructed at the discharge end of the concrete structure. The site was associated with 100-F-29 (100-F EAF Process Sewer Pipelines), 100-F-9, 100-F Reactor Cooling Water Effluent Underground Pipelines, Contaminated Underground Lines, Effluent Water System, 1904-F Process Sewer, the 116-F-8 (1904-F) Outfall structure, the 100-F-42 (1904-F) Spillway, and the 116-F-16 PNL Outfall. The site has been remediated and has been classified interim closed with an inactive status.

100-F-45 (Buried River Effluent Pipelines). This site is located on a steep riverbank approximately 10 m (33 ft) from the Columbia River, 670 m (2,200 ft) northeast of the 105-F Reactor building and about 15 m (50 ft) upstream from the 116-F-16 PNL outfall. The site consists of a piece of pipeline that was buried in the riverbank after it floated loose from the river effluent pipe. The suspected pipeline section is believed to have resulted from the failure of one of the 100-F-39, 100-F River effluent pipelines, which are also co-located with the 116-F-8 outfall structure and the 100-F-42, 1904-F spillway/flume. This site has been classified as accepted and is inactive.

100-F-59 (Riparian Area Contamination Originating from 128-F-2). This site is located in the northeast corner of the 100-F Area; approximately 30.5 m (100 ft) east of the northeast corner of the 100-F Area perimeter road, which runs along the riverbank and directly east of the 107-F Retention Basin, and along the Columbia River, in the nearby riparian area which is occasionally underwater. The site consists of two areas known to contain contaminants above soil RAGs.

The first area was originally part of the 128-F-2 Burning Pit waste site located adjacent to the Columbia River. This portion of the site was remediated to an elevation below the ordinary high water mark (OHWM) of the river, but sampling showed that metal contamination in excess of soil RAGs was present. The second area was located in riparian areas east and southeast of the 128-F-2 waste site. In January 2008, sampling of riparian areas surrounding the 128-F-2 waste site was conducted to determine the nature and extent of contamination. This site has been classified as accepted with a current status of inactive.

116-F-1 (Lewis Canal). This site is located approximately 160 m (525 ft) west-northwest of the 105-F Building, then turned north to the Columbia River. The 116-F-1 Trench was commonly known as the Lewis Canal. The 105-F Reactor cooling water was diverted to the Columbia River via this trench and flowed west from the headwall, turned northward where it intersected with the Columbia River. Two additional ditches entered the main trench laterally from the east. The north lateral ditch was 194.5 m (638 ft) long. The south lateral ditch was 219 m (718 ft) long. Once at the Columbia, the water entered the river from the main trench without an outfall structure across a cobble-covered beach.

The total length of the main ditch, including the lateral trenches, was 1,743.5 m (5,720.5 ft). This site has been remediated with a classification of closed out and a status of inactive.

116-F-8 (1904-F Outfall Structure). This site is located approximately 214 m (700 ft) northeast of the 107-F Retention Basin, near the shore of the Columbia River. The site consisted of an open-topped, compartmentalized, reinforced concrete outfall structure, a 183 cm (72 in.) diameter steel retention basin pipeline; and two 107 cm (42 in.) pipelines that exited the north face into the Columbia River. The site is associated with the 116-F-14 (107-F Retention Basin) and the 116-F-16 PNL Outfall structure and discharged effluent to the 100-F-39 River Effluent Pipelines and/or 100-F-42 Flume. The site has been remediated with a classification of interim closed and a status of inactive.

116-F-16 (PNL Outfall). This site is located approximately 670 m (2200 ft) northeast of the 105-F Reactor Building and about 15 m (50 ft) upstream of 116-F-8 Outfall. The site consisted of an open-topped, compartmentalized, reinforced concrete outfall structure that contained animal sewage and low-level contamination resulting from various experimental animal farm projects, which was then pumped to the Columbia River via the 116-F-16 Outfall structure and associated 100-F-43 Spillway. The site was associated with 100-F-29 (100-F Experimental Animal Farm Process Sewer Pipelines), 100-F-9, 100-F Reactor Cooling Water Effluent Underground Pipelines, Contaminated Underground Lines, Effluent Water System, 1904-F Process Sewer, the 116-F-8 Outfall structure, 100-F-43 Flume, and 100-F-39 River Lines. Most of this unit has been backfilled, with only a small portion visible near the shoreline. The site has been remediated with a classification of interim closed and is inactive.

128-F-2 (100-F Burning Pit). This site is located approximately 30.5 m (100 ft) east of the northeast corner of the 100-F Area perimeter road, which runs along the riverbank and is directly east of the 107-F Retention Basin. Originally, the pit was an irregularly shaped depression that was used for burning wastes. The site has been covered and appears as a flat surface with no sign of the burn pit or its contents. During Hanford Site cleanup operations in the late 1970s, unknown quantities of debris were removed from the burn pit, and the site was backfilled. Historical documentation suggested that multiple burn pits were present at the site. According to documentation, the waste site was 46 by 18 m (151 by 60 ft) and was situated on a steep grade near the shoreline of the Columbia River. During remediation activities of the burn pit, the waste site footprint was expanded because additional areas requiring remediation were discovered. An area of contamination from this site was designated as a new site, 100-F-59 Riparian Area Contamination, for later remediation. This site has been classified as interim closed out and is in inactive status.

1607-F5 (1607-F5 Septic Tank). This site consisted of a septic tank, drain field, and an associated pipeline. The site was located approximately 122 m (400 ft) east of the northeast corner of the old 182-F Reservoir, with the drain field portion located just southeast of the septic tank. This site received effluent from the 181-F pump house. Historical documentation placed the septic tank at about N 136/E1 20, with the drain field positioned about 15 m (49 ft) east southeast of the tank. Documentation also shows an inlet pipe coming into the tank from the northwest and a pipe exiting the tank to the southeast for a few meters and

then turning to the east into a drain field. The site has been remediated with a classification of interim closed out and is in inactive status.

UPR-100-F-2 (107-F Basis Leak Ditch). This site ran northeast from the corner of the 107-F Retention Basin to the bank of the Columbia River. The site was associated with the 107-F Retention Basin and the 116--F--9, Animal Waste Leaching Trench. This Basin Leak Ditch was formed in 1955 following an overflow of the 107-F Retention Basin and was enlarged by repeated overflows from an effluent manhole located near the north end of the 107-F Retention Basin. The site has been remediated with a classification of interim closed out and is in inactive status.

L2.1.1.2 100-IU-2/IU-6 Area

600-98. This waste site is divided up into two sections: 600-98 East (the eastern most site along the river), and 600-98 West (the western most site, which was roughly 300 m to the west of 600-98 East). The East White Bluffs Dump is located approximately 150 m (492 ft) north of the White Bluffs Ferry Landing. Both sites were used to dispose of industrial and domestic wastes common to the time that it was being used. Surface debris found around the East White Bluffs Dump included cans, glass, and wood. Surface debris found the West White Bluffs Dump included wood, metallic, domestic (pots, bowls, and glassware), and industrial debris (cables and plywood sheets). The sites contain no known radioactive constituents. Following operational use, these sites were backfilled and are classified as No action and are in inactive status.

600-186 (Hanford Construction Camp Septic Tanks and Sewage Treatment Plants). This site consists of septic tanks that were scattered throughout the Camp Area at required locations for the retention of sewage. These septic tanks were related to waste treatment facilities where sewage was collected, treated and disposed. The sewage treatment plants were located on the river side of A Avenue between 4th and 6th Streets East and at 10th Street East. Two of the treatment plants are located near the east end of 5th Street East. The southernmost treatment plant is located near the intersection of 10th Street East and A Avenue, approximately 216 m (709 ft) north of Well #A8744.

The northernmost site is the largest and deepest and appears as a trench that begins at a group of trees and extends to the river, cutting into the river bank. Small pieces of concrete, concrete pipe, vitrified clay pipe, and wood were observed around the trench. The bottom of the trench has fine soil that did not appear to be sludge derived from sewage. The second trench, just south of the first trench is shallower and not as obvious. Small pieces of concrete were observed surrounding the trench. A layer of sludge-0like material was observed on the east side of the trench. The southernmost trench was obscured by blown-in tumbleweeds. The outline of a foundation was found on the north side of the most southern trench. One septic tank was found between this trench and the turn off to the Honey Dump site. The site has been classified as Accepted and is in inactive status.

600-334 (CMX Building). This site is located next to the Columbia River approximately 275 m (902 ft) upstream of the Hanford town site former ferry landing at the end of Division Street (C-127). This site consists of four areas divided into two sub sites: CMX Building and Surface Anomalies, and Burn area near CMX Building; both are located in the vicinity of the former CMX Building.

The first sub site (CMX Building and surface anomalies) consisted of a raised footprint where the 145 Building Complex was once located, a 16- by 16-ft depression that is approximately 1.5 m (5 ft) deep, and on the riverbank side three open-ended outfall pipes that protrude horizontally from what appears to have been the middle of the CMX Building. Two of these pipes are vitrified clay pipe, and the southernmost is stainless steel. These were originally thought to have carried contaminants from experimental procedures to the Columbia River. The second sub site (Burn Area near the CMX Building),

consists of a 4.6 m (15.1 ft) diameter burn area of unknown origin found off the northwest corner of the former CMX Building complex. This site is located next to the bank of the Columbia River approximately 275 m (902 ft) upstream of the Hanford town site former ferry landing at the end of Division Street (C-127). This site has been classified as Accepted with an inactive status.

600-329 (Concrete Outfall Structure). The site is an unknown concrete structure at the high water line, near the construction shop of the Hanford Town-site operations. The location of this site is approximately 2 km northwest of the intersection of Route 2 North and Route 11A. This site consists of a concrete structure protruding from the riverbank. The site has been classified as Accepted with an inactive status.

L2.1.2 Groundwater

The 100-FR-3 OU includes groundwater beneath the former F Reactor along the Columbia River. The principal groundwater issues are related to the disposal of both solid and liquid wastes associated with the operation of the F Reactor from 1945 to 1965. The principal contaminants of concern in 100-FR-3 groundwater are nitrate, strontium-90, tritium, trichloroethene, uranium, gross alpha, and Cr(VI). Waste sites that received high volumes of effluent included cribs and pipelines near the former reactor building (e.g., 116-F-5 Crib) and the major retention basins, trenches, and cribs near the Columbia River (e.g., 116-F-14 retention basins, 116-F-2 Trench, and 116-F-9 Trench). Most of the groundwater contamination is associated with these facilities (*Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2* [DOE/RL-2010-11]).

Groundwater beneath the 100-IU-2/IU-6 Area originates from upgradient groundwater OUs on the Central Plateau (200-BP-5, 200-PO-1, and 200-ZP-1) and the 100-FR-3 Groundwater OU.

L2.2 Contaminant Release and Transport Mechanisms

Release and transport mechanisms potentially most likely associated with the occurrence of Hanford Site contaminants in riparian and nearshore zones are overland transport from waste sites, and contaminant leaching from the vadose zone to underlying groundwater, followed by lateral transport in groundwater.

L2.2.1 Overland Transport from Waste Sites

Hazardous and radioactive substances that are in surface materials can be transported away from facilities or known waste sites by surface runoff following precipitation events. Overland flow is water flow over the ground surface that occurs from precipitation (rainfall or snowmelt), that is greater than combined interception, evapotranspiration, and infiltration. In addition, overland flow can occur from the spillage of process effluent that historically had been discharged into liquid waste disposal units. Overland flow potentially results in the transport of contaminated sediments or water away from a waste site into other areas such as the riparian or nearshore locations. Factors that affect overland flow include slope of the ground surface, soil texture, and vegetative cover and the frequency of precipitation.

There are relatively few examples of overland flow potentially from 100-F/IU-2/IU-6 sites into riparian or nearshore areas. Contamination of riparian and nearshore media would likely be more associated with historical releases from outfall structures from the reactors and retention basins.

L2.2.2 Contaminant Leaching from Waste Site Soils to Groundwater

Contaminated wastes released from reactor support facilities, cooling water processing facilities, underground piping, liquid waste disposal sites, solid waste disposal sites, and surface spills were primary sources of contamination in 100-F/IU-2/IU-6 during operations; secondary sources may have developed in vadose zone and aquifer materials. The potential for transport of contaminants within the vadose zone and aquifer at 100-F/IU-2/IU-6 is affected by the impacts of historical high volume liquid waste disposal

during operations on vadose zone moisture and the water table, the development of secondary sources of contamination in the vadose zone material, groundwater/surface water interactions, and the effect of Columbia River stage fluctuations on contaminant transport. The fate and transport of contaminants detected in vadose zone and groundwater above applicable criteria is discussed in detail in Chapter 5 of the Remedial Investigation/Feasibility Study (RI/FS) report.

One concept important to understanding contaminant fate and transport in 100-F/IU-2/IU-6 is the difference between site conditions during Hanford operations (1955 to 1971) and the current site conditions, which have developed since reactor operations ended.

L2.2.3 Transport in Groundwater

The groundwater system is highly dynamic, being influenced by regional groundwater conditions, the local site remediation efforts, and the daily and seasonal variations of river stage. The main features of the current conceptual model follow:

- Flow under the site and near the banks is generally assumed to be perpendicular to the river.
- Deeper geologic formations are assumed not to contribute to shallow groundwater or observed river exchanges along the riverbank.
- The daily variability of river stage creates a complex zone of mixing within the near-bank groundwater system.
- Springs observed on the riverbanks are attributed to bank storage of river water and site groundwater discharging to the river when river stage drops.
- Site groundwater generally discharges to the banks via springs and through the bottom of the Columbia River immediately adjacent to the Site.

The site conceptual model clearly needs to include the transient nature of water exchange in this setting at multiple time scales (Figure L-5). For example, a daily 3 m (9.8 ft) change in river levels superimposed with seasonal changes or alterations of site groundwater flows by remediation efforts likely causes seasonal shifts in the regional groundwater flow system that will consequently impact groundwater-surface water exchange locations and rates. The complex geologic setting, aquifer heterogeneity, and transient nature of the surface water and groundwater results in a complex groundwater flow system. During major spring discharge events, river water may enter the banks and the adjacent groundwater system upstream of the Site and move laterally parallel to the river for some distance before discharging back into the 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 RCBRA (DOE/RL-2007-21) showed a cross section of the river that defined the study zones to be the upland zone, the riparian zone, nearshore aquatic zone, and aquatic zone as a vertical panel that extends down from the surface into the subsurface to some undetermined depth when, in reality, they are three-dimensional zones that change size over time. In particular, it is the vertical distribution of the receptors beneath the river and in the deposits adjacent to the river that potentially (i.e., the depth to which they are found, or bottom of the system) have the greatest implications for remedial actions because the mechanisms of dilution and mixing of groundwater may not be as effective at greater depths, and so there is greater potential for exposure to contaminants from groundwater.

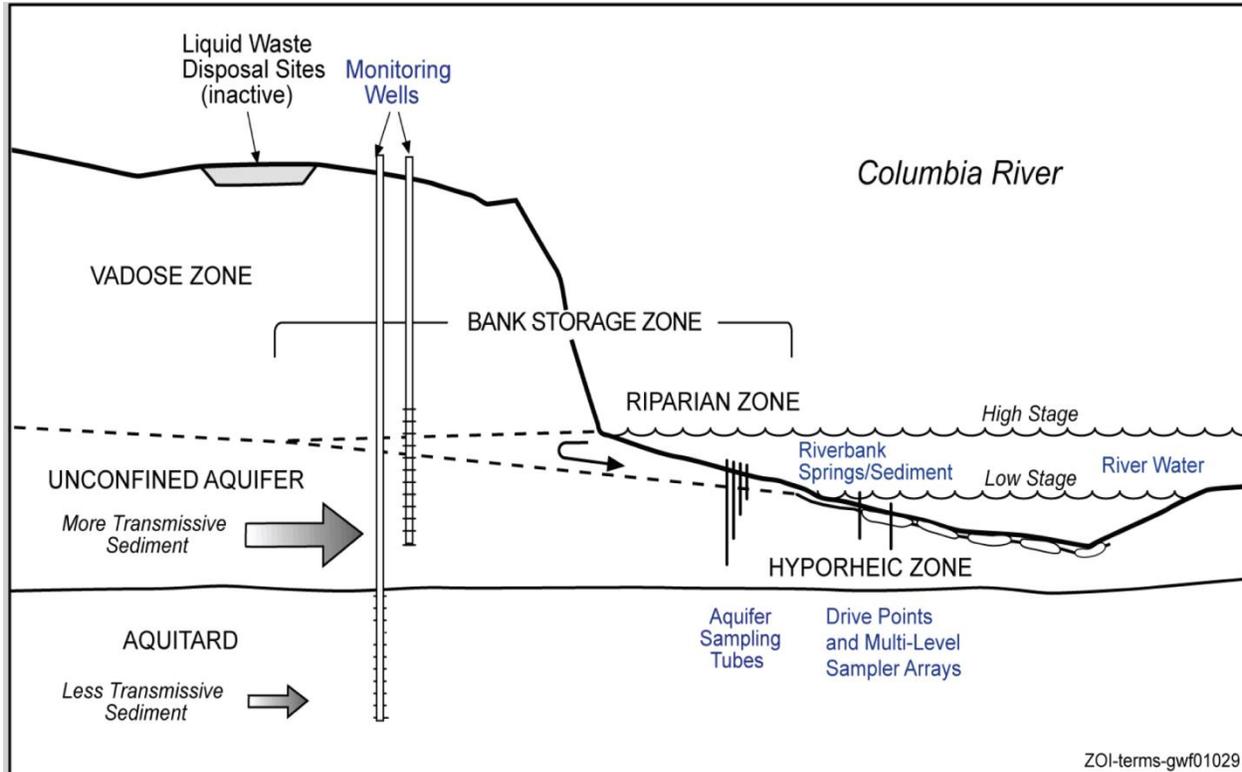


Figure L-5. Conceptual Model of Groundwater-Surface Water Interaction at the Hanford Site

L2.3 Exposure Points in Seeps, Surface Water, Sediments, and Riparian Soils

In the studies of the Columbia River at the Hanford Site, the term hyporheic zone has been used as a general term to describe the zone of all groundwater and surface water mixing. Receptors in the riverbed and benthic and hyporheic zones can be exposed to contaminated (1) groundwater, (2) groundwater surface-water mixtures, or (3) surface water. These distinctions become important when identifying from analytical results in groundwater and surface water COPECs that are related to Hanford Site operations.

Investigation of riparian area soils was conducted as part of the RCBRA (DOE/RL-2007-21). The riparian assessment evaluated ecological risks at 18 study sites potentially affected by contamination from Hanford Site sources. Eleven study sites were selected from locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, sediment). These sites were located along the Columbia River shoreline near the operating areas (e.g., 100-B/C, 100-K, and 300 Area) and included six sites with relatively elevated contaminant concentrations and five sites with relatively low contaminant concentrations. Historic data and radiation surveys were used to determine the general contaminant levels at each site. Two of these riparian study sites were located near the 100-F decision area, and seven of these riparian study sites were located near the 100-IU-2/IU-6 decision area. This site is described as follows:

L2.3.1 100-F

Riparian 2I. This site was located in the third-largest backwater region adjacent to the Hanford Site, commonly known as the 100-F slough, and located ~2 km (1.2 mi) downstream of the 100-F Area. The site consists of large flat bench surrounded by a backwater channel of the river. The width was generally 100 m (328 ft) and encompassed ~20,000 m² (22,400 yd²) of shoreline habitat. The substrate is

a mixture of cobbles and coarse sands, largely from deposited material that is transported through the river from a sand dune (“the black sands”) area when river flows exceed ~180 kcfs (thousand cubic feet per second). The vegetation is a diverse mixture of grasses and forbs. There are no trees.

Riparian #7. Located immediately adjacent to the 100-F Area, this site was positioned near the receiving corner of a large bend in the river where sediment deposits were common. The site, however, was scoured regularly from a river channel that develops over the site each year when river flows exceed ~180 kcfs, flushing the water and resuspending sediment down the backside of the peninsula and emptying into the 100-F Slough. The width of the site was relatively varied, ranging between 4 m (13 ft) near the upriver end and 27 m (89 ft) near the downriver end. The site encompassed approximately 2,300 m² (2,760 yd²) of shoreline. The site was densely vegetated with predominantly reed canary grass and short-statured mulberry trees. Old metal debris (e.g., bolts and barrel straps) was common throughout the site.

L2.3.2 100-IU-2/IU-6

Riparian 4a. This site was located ~5 km (3 mi) downstream of the old Hanford town site on a gentle, sloping bench covered in medium- to large-sized cobbles. The site was typically ~30 m (98 ft) wide and encompassed ~6,600 m² (7,260 yd²) of shoreline habitat. Sediment deposits were scarce in between the rock surfaces, but increased as distance from the river shoreline increased. The site was bounded by a steep inactive embankment that was heavily covered with a vine. The site is located in a prominent groundwater upwelling area, and vegetation along the steep bank appeared to be highly dependent on the shallow groundwater sources there. Reed canary grass was the dominant vegetation covering the cobble substrate, and there were very few trees on the investigation area.

Riparian 3b. This site was located along the leeward side of the old Hanford town site peninsula. It was located in a wide and flat riparian area that is inundated when flows exceed ~120 kcfs. The width of site ranged from ~50 to ~100 m, (164 to 328 ft) and it encompassed about 16,000 m² (17,600 yd²) of riparian habitat. Located ~1 km (0.6 mi) back into the old Hanford town site slough, the site is typically protected from fast-moving water; however, a small river channel develops on the upstream end of the peninsula when flows are greater than about 200 kcfs. The substrate consisted of small- to medium-size cobble that was heavily embedded with sediment. The site had very dense vegetation consisting of grasses and forbs, with very few small trees. This site also contained a substantial stand of willows, being a more sediment-dominated area.

Riparian 2j. This site was located in one of the largest backwater regions in the Hanford Reach, commonly known as the White Bluffs slough. The site was relatively steep and narrow, being no more than about 10 m (33 ft) wide and encompassing ~2,500 m² (2,750 yd²) (of shoreline habitat). The substrate consisted of small to medium cobbles heavily embedded with sediment. Reed canary grass was the predominant vegetation in this investigation area, and there were very few trees except for a large stand of black locust near the high elevation boundary that ran parallel to the shoreline.

Soil samples were collected from study sites and from reference sites using MULTI INCREMENT[®] sampling (MIS) methodology. This method was designed to obtain representative estimates of the average contaminant concentrations in the study site and control the sampling fundamental error and the grouping and segregation errors associated with measuring soil concentrations. Soil MIS represents surface soils of the 0 to 15 cm (0 to 6 in.) depth interval using a systematic random design across a 200 m (656 ft) long investigation area. The contaminants detected in these soil samples include inorganics (metals), organic compounds including PCB aroclors, polycyclic aromatic hydrocarbons, phthalates and chlorinated pesticides, and radionuclides. Biota sampling conducted in these sites is described in detail in the RCBRA (DOE/RL-2007-21). Assessment of ecological risks based on the soil and biota sampling is described further in Section L4 of this appendix.

Nearshore study sites sampled as part of the RCBRA in 2005 were located within three key contaminant plumes originating from Hanford Site operations (Cr(VI) at 100-K and 100-D, strontium-90 at 100-N, and uranium at the 300 Area) (RCBRA SAP [DOE/RL-2005-42]). Ten additional study sites sampled in 2006 were located in selected regions where Hanford's legacy materials were known or suspected to have been deposited. Study sites located in proximity to 100-F/IU-2/IU-6 are summarized in the following subsections.

L2.3.3 100-F

Nearshore Site 4a. This site was located about 5 km (3 mi) downstream of the old Hanford town site next to a bench of land covered in medium- to large-sized cobbles. The aquatic site was located in a prominent groundwater upwelling area. The river was symmetric and relatively shallow. The area was generally scoured during high river flow conditions, but contained a matrix of sediment in the immediate vicinity of the aquatic study station. This site did not contain suitable salmonid spawning habitat.

L2.3.4 100-IU-2/IU-6

Nearshore Sites 2j, 2l, and 3b. Nearshore sites 2j, 2l, and 3b were located in the three largest backwater regions in the Hanford Reach, and are commonly known as the White Bluffs slough, 100-F slough, and the Hanford town site slough respectively. The substrate primarily consisted of deep sediment, with some exposed small to medium-cobbles that were heavily embedded with sediment. These areas contain some of the highest densities of macrophytic vegetation and freshwater mussels known to exist in the Hanford Reach. None of these sites contained suitable salmonid spawning habitat.

Sediment, pore water, and surface water samples were collected from these sites. Further discussion of these data is incorporated into the data evaluation presented below in Section L3. Biota sampling performed at these sites is described in the RCBRA (RCBRA [DOE/RL-2007-21]). Assessment of ecological risks based on the biota sampling results is described in Section L4. Contaminants detected principally in the sediment, pore water, and surface water samples were inorganics (metals and anions) and radionuclides.

L2.4 Routes of Potential Exposure and Receptors

A range of terrestrial and aquatic plant, invertebrate and wildlife species were considered in the ecological risk assessment, conducted as part of the RCBRA (DOE/RL-2007-21), and are discussed in detail in that ecological risk assessment. A conceptual model depicting the exposure pathways is provided in Figure L--6 followed by a depiction in Figure L-7 of the measurement endpoints used to evaluate those pathways to the receptors identified. These measures are discussed in Sections L3 and L4. The measures of abiotic environmental media (e.g., groundwater or soil) are compared to effects levels presented in Section L3.2. Biotic measures and a weight of evidence are discussed in Section L4.

L2.4.1 Riparian Zone Exposure Pathways

The boundaries of the riparian zone are defined as extending from the water line of the Columbia River to the upper edge of the riverbank where upland vegetation becomes dominant. The riparian zone along the shoreline of the Columbia River is typically narrow because of the steep riverbank. Potential sources of contamination include seep water (upwelling of groundwater in the riparian zone) and associated sediment. Additionally, contaminants originating from past releases in operational areas could have been transported through several release mechanisms affecting the soil surface within the riparian zone.

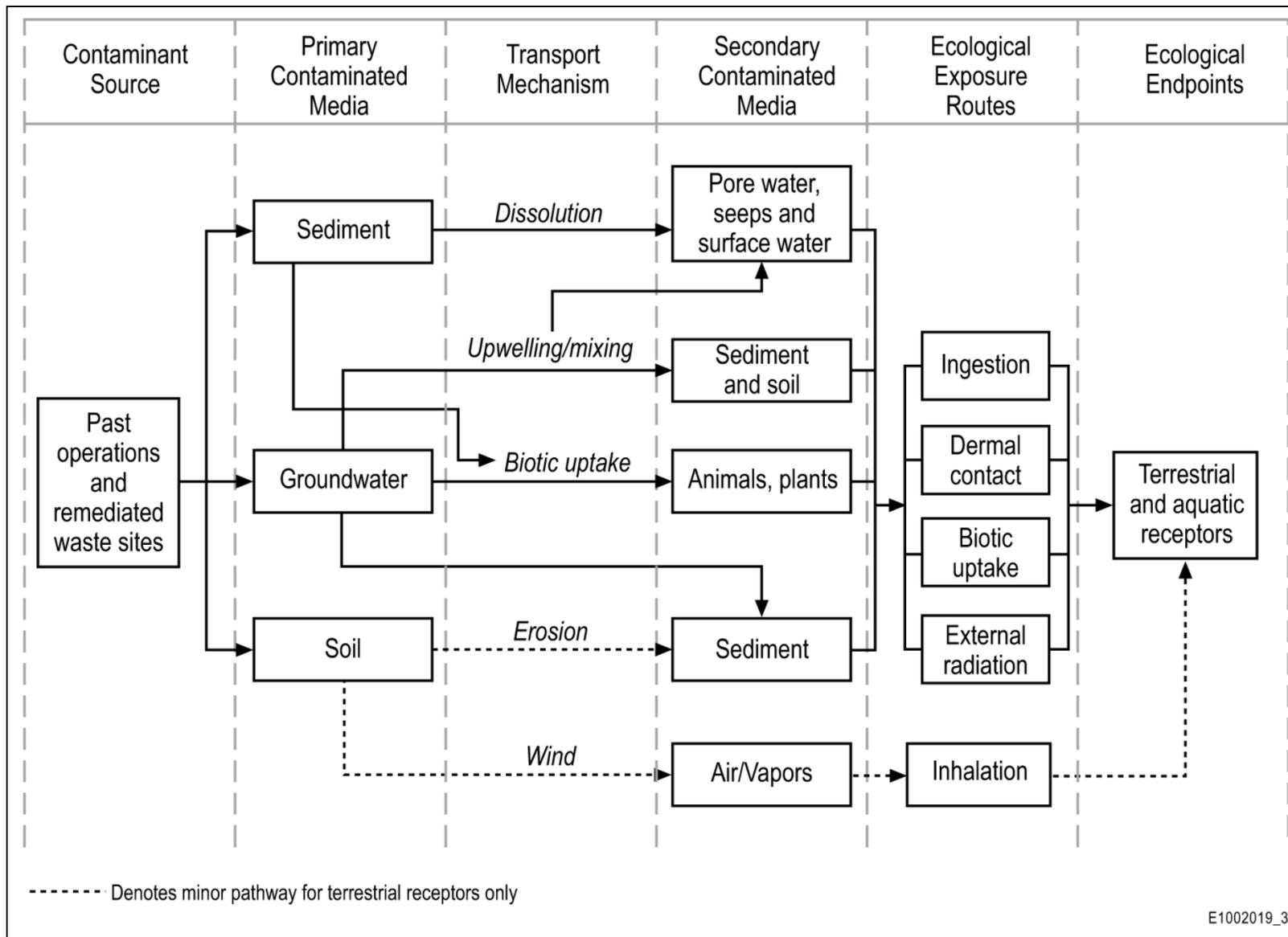


Figure L-6. Ecological Conceptual Exposure Model for the Aquatic Environment (Combined Riparian and Aquatic Nearshore Zones)

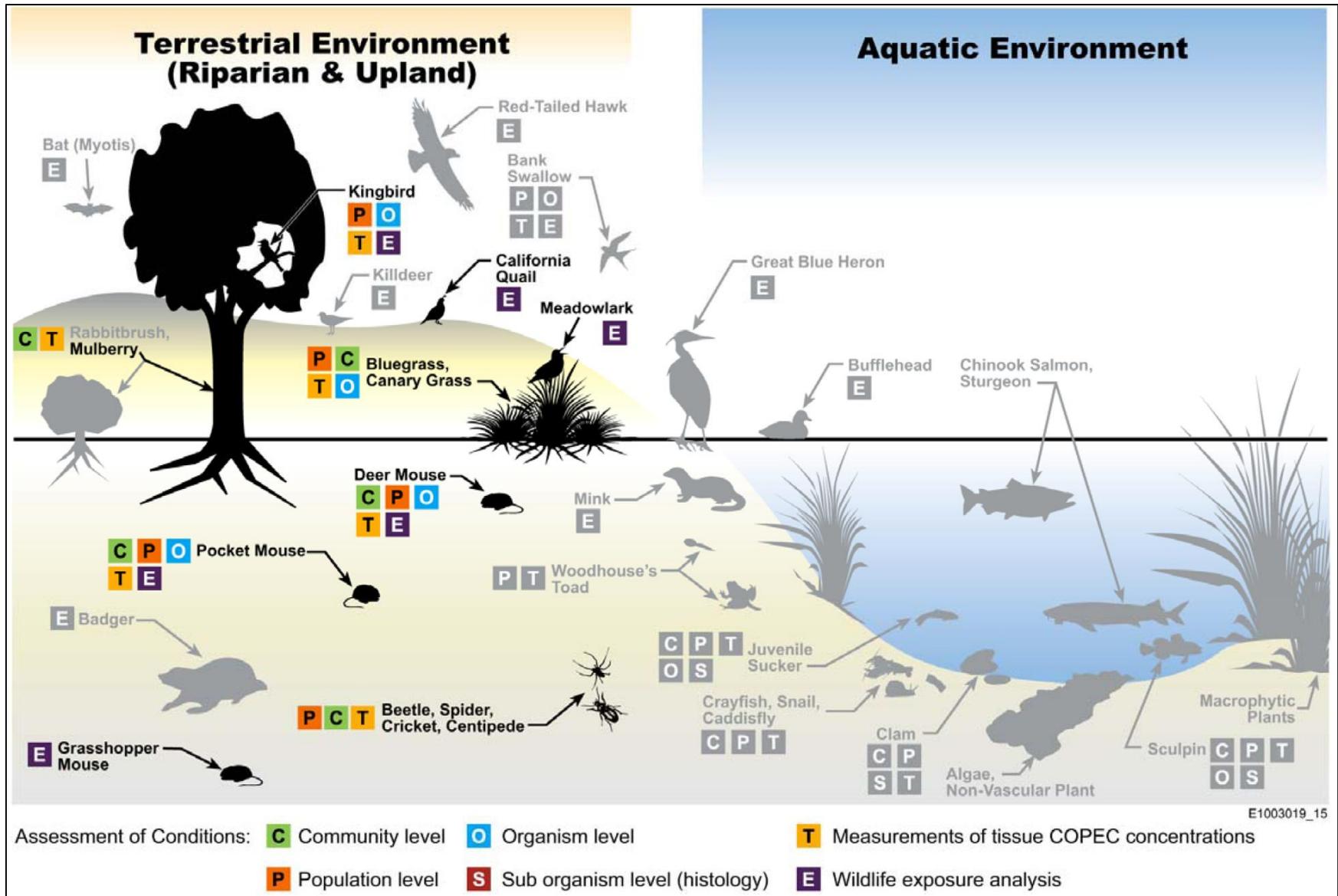


Figure L-7. Summary of Endpoints and Measures Evaluated in the Riparian Environment

Contaminants could have been transported to the riparian zone through surface drainage from the following:

- Precipitation contacting surface soil or waste and running off of the associated waste site
- Landslides or slumping of contaminated soil from upland operational areas into the riparian zone
- Fugitive dust transported through wind or work activities on the waste sites

The primary exposure pathways and release mechanisms in the riparian zone transporting the contaminants from the source, via environmental media, to potential receptors include the following:

- External radiation from contaminated surface soil or sediment
- Generation of dust emanating from surface soil to ambient air from wind
- Volatilization of chemicals emanating from surface soil or sediment to ambient air at the site
- Transport of contaminants in groundwater to release locations in the riparian area (i.e., seeps)
- Shoreline seeps/springs containing contaminants

Sampling locations were selected near historical operating areas and in areas likely to have been affected by contaminated source media such as surface soil, shoreline seeps, or groundwater plumes. The sampling locations were generally selected to optimize the potential for detecting contaminants and effects.

Through transport pathways (e.g., upwelling of groundwater in a riverbank seep), secondary media (such as plants) may become contaminated through root uptake from soil or groundwater/seeps. These secondary contaminated media, in turn, may be consumed by receptor species contributing to exposure.

The following ecological exposure routes were identified for the riparian zone:

- Incidental or intentional ingestion of contaminated soil, sediment, water, or biota
- Dermal contact with contaminated soil, sediment, water, or biota
- Exposure of terrestrial and aquatic vertebrates, invertebrates, and plants to external radiation emitted by contaminated soil or foodstuffs
- Uptake or absorption of soil-, sediment-, or water-bound contaminants
- Inhalation of contaminated dust or volatilized contaminants

The riparian ecological exposure routes that were evaluated in the ecological risk assessment include ingestion of contaminated soil, seep water, and biota. Exposure from external radiation was considered by comparing soil radioactivity to radionuclide-specific biota concentration guidelines. While there is a potentially complete exposure pathway via inhalation of fugitive dust and dermal contact with chemicals, these are generally considered minor exposure routes for ecological receptors (*Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55]).

L2.4.2 Nearshore Aquatic Zone Exposure Pathway

The nearshore aquatic zone is defined as the area that is permanently inundated by river water, extending from the seasonal low-water mark (i.e., a “green line” where the periphyton [sessile algae] remains green year round) into the river to a water depth of about 2 m (6 ft). A nearshore study boundary depth of 2 m (6 ft) was selected to optimize the ability to measure potential influence of emergent groundwater and other potential Hanford Site contaminant sources within the Columbia River. Potential sources of contamination within the nearshore aquatic zone include contamination along the Columbia River shoreline at riverbank seeps/springs and other submerged locations where upwelling groundwater mixes with the river water.

The primary release mechanisms transporting the contaminants from the source, via environmental media, to potential receptors include the following:

- Transport of contaminants in groundwater to mixing areas in the nearshore area.
- Seeps containing contaminants that flow into the river.
- External irradiation from surface sediment containing contaminants (receptor irradiation from sediment replaces release and transport).
- Sampling locations were selected near historical operating areas and in areas likely to have been affected by contaminated source media such as surface soil, shoreline seeps, or groundwater plumes. The sampling locations were generally selected to optimize the potential for detecting contaminants and effects.

Secondary media such as surface or pore water, sediment, or biota may become contaminated through transport pathways such as biotic uptake or upwelling of groundwater. These secondary contaminated media, in turn, may be contacted or consumed by receptor species, contributing to exposure.

The following ecological exposure routes were identified for the nearshore zone:

- Incidental or intentional ingestion of contaminated sediment, pore water, surface water, or biota.
- Dermal contact with contaminated sediment, biota, pore water, or surface water.
- Exposure of aquatic vertebrates, invertebrates, and plants to external radiation emitted by contaminated sediment or biota.
- Uptake or absorption of sediment- or water-bound contaminants.

The nearshore ecological exposure routes that were quantified in the ecological risk assessment include ingestion of contaminated sediment, surface water, and biota. Exposure from external radiation was considered by comparing contaminated sediment and water to radionuclide-specific biota concentration guidelines. While there is a potentially complete exposure pathway via dermal contact with chemicals, this is generally considered a minor exposure route for ecological receptors (*Guidance for Developing Ecological Soil Screening Levels* [OSWER Directive 9285.7-55]).

L2.4.3 100-F/IU-2/IU-6 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, one inactive 100-F effluent pipeline remains in its original location 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. The RCBRA (DOE/RL-2007-21) provided a summary of the previous characterization efforts and risk assessment for these pipelines in Section 8.2.2.

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. Because the half-lives of all of these radionuclides is less than 30 years, the activity levels have declined by a factor of two to five and are no longer expected to be ecological risk drivers.

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. 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.

In 1995, pipe scale and sediment from the interior of the effluent pipelines from the 100-BC and 100-D Areas were sampled and physically characterized using a robotic transporter (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]). Analytical data from these two pipelines were intended to complement the 1984 radionuclide data (*River Discharge Lines Characterization Report* [UNI-3262]) and were expected to represent "worst case" conditions with respect to radiological contamination. This assumption was based on the long years of pipeline service and the volume of effluent known to have been discharged from the 105-B and 105-D/DR Reactors.

Evaluations of human health and ecological risk have been performed for the river effluent pipelines, as they are today, located on or beneath the river channel bottom, and for a scenario in which a pipeline section breaks away from the main pipeline and is washed onto the shore of the river. Both the 1996 risk assessment effort (*100 Area River Effluent Pipelines Characterization Report* [BHI-00538]) and the 1998 risk assessment effort (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) relied on data collected from the 1984 and 1995 characterization work. The evaluation of human health and ecological risk performed in 1998 (*100 Area River Effluent Pipelines Risk Assessment* [BHI-01141]) concluded that the concentrations of chromium and mercury in the scale and sediment within the pipelines pose minimal ecological risk because they have been in contact with river water without dissolving since the reactors were shut down. The 1998 risk evaluation results indicated pipelines present no unacceptable risks and, therefore, no remediation requirements under CERCLA. This is supported by the following:

- Minimal deteriorated condition of the pipelines
- Continued decrease of radionuclide concentrations because of decay
- Inaccessible location
- Unavailability of significant contaminants to affect HHE

Accordingly, no further action is considered for below river effluent pipeline waste site 100-F-39 in this RI/FS.

L3 Data Evaluation

Analytical data collected from the riparian and nearshore zones were evaluated to focus on the COPECs that could be related to Hanford Site operations. This data evaluation encompassed groundwater (characterized by near river wells and aquifer tubes), seeps/springs, surface water, sediments, and riparian soil data, obtained from a range of Hanford Site sources. These sources included groundwater-monitoring activities documented in the Annual Groundwater Monitoring reports, sampling of sediments, seeps and surface water conducted as part of the SESP, and sampling of sediments, pore water, surface water, and riparian soils conducted as part of the RCBRA (DOE/RL-2007-21). Locations are presented in Figures L-8 through L-11.

These analytical results were compared with ecological benchmarks and criteria to confirm if they should be identified as COPECs. Analytical data quality, in particular filtered versus unfiltered analyses of water samples, was taken into consideration in making the comparisons with benchmarks and criteria. The spatial relationships of contaminant concentrations in surface water, pore water and groundwater were evaluated to address considerations of whether or not detected contaminants were related to Hanford Site operations (i.e., originated from upland groundwater sources) or reflected ambient background conditions.

L3.1 Data Sources and Data Processing

The data set used in this evaluation consisted of sampling and analysis data collected from 6 nearshore monitoring wells, 41 aquifer tubes, 3 seep/spring location, and 13 surface water locations within the boundaries of the 100-FR-3 OU, and 3 nearshore monitoring wells, 17 aquifer tubes, 10 seep/spring location, 3 pore water locations, and 33 surface water locations within the boundaries of the 100-IU-2/IU-6 Groundwater Area. A list of the nearshore wells and aquifer tubes used in this evaluation are provided in Table L-1 and L-2. Seep/spring, pore water and surface water sampling locations are based on sampling locations identified in the RCBRA (DOE/RL-2007-21). Figure L-5 shows the sampling locations for each type of water media, riparian soil, and sediment.

The data set was obtained from the Hanford Environmental Information System (HEIS) and included the following types of information:

- Analytical results from both unfiltered and filtered samples
- Data qualification and data validation flags, including rejected results
- Results for a given analyte reported by more than one analytical method
- Parent, field duplicate, and field split sample results

The analytical data were processed to eliminate unusable results and thus identify one set of results per sampling location and date of sample collection. The data processing steps are described in the following subsections.

L3.1.1 Laboratory and Data Validation Flags

Analytical data are received from the laboratory with data qualification flags. Validation qualifiers are assigned during the data validation process. The following rules determine how flagged and/or qualified sample results are used in identifying contaminants of interest (COIs).

- Sample results flagged with a “U” qualifier, or combinations of qualifiers that include a “U,” such as a “UJ,” are considered nondetected results.
- Sample results without a “U” qualifier are considered detected concentrations, including results with no qualifier or with a “J” qualifier.
- Sample results that are rejected and flagged with an “R” qualifier are not used in identifying COPECs.

L3.1.2 Analytes Reported by Numerous Analytical Methods

Often analytes are reported by more than one analytical method, resulting in multiple results for the same analyte from the same location and sample date. When analytes are reported by more than one analytical method for a sample, the set of data that best represents the actual concentrations is retained. For example, the gamma spectroscopy method provides concentration results for the uranium isotopes; however, uranium concentrations reported by a uranium-isotope-specific method are preferred.

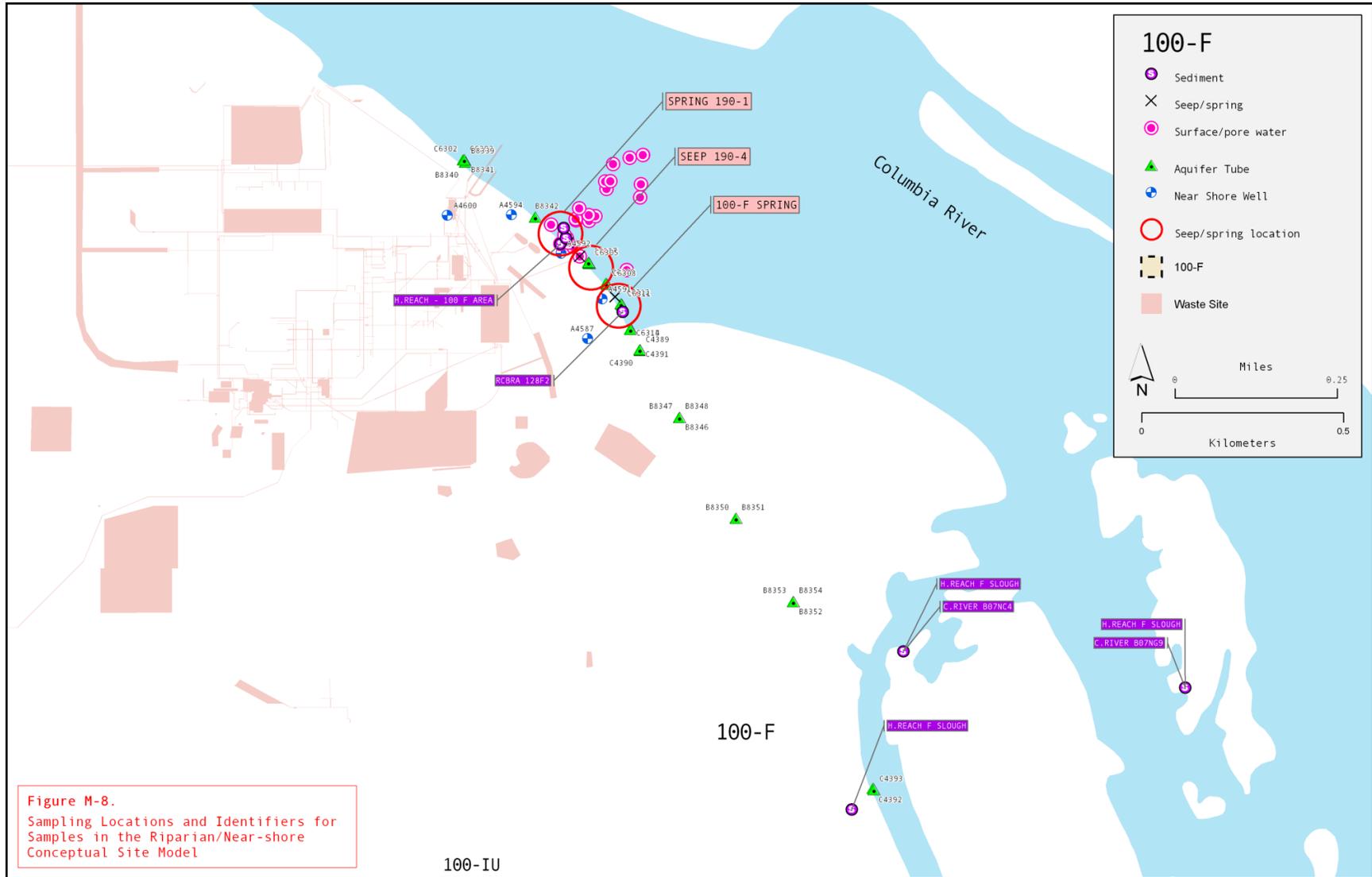


Figure L-8. Sampling Locations in 100-F and Identifiers for Samples in the Riparian/Nearshore Area Conceptual Model

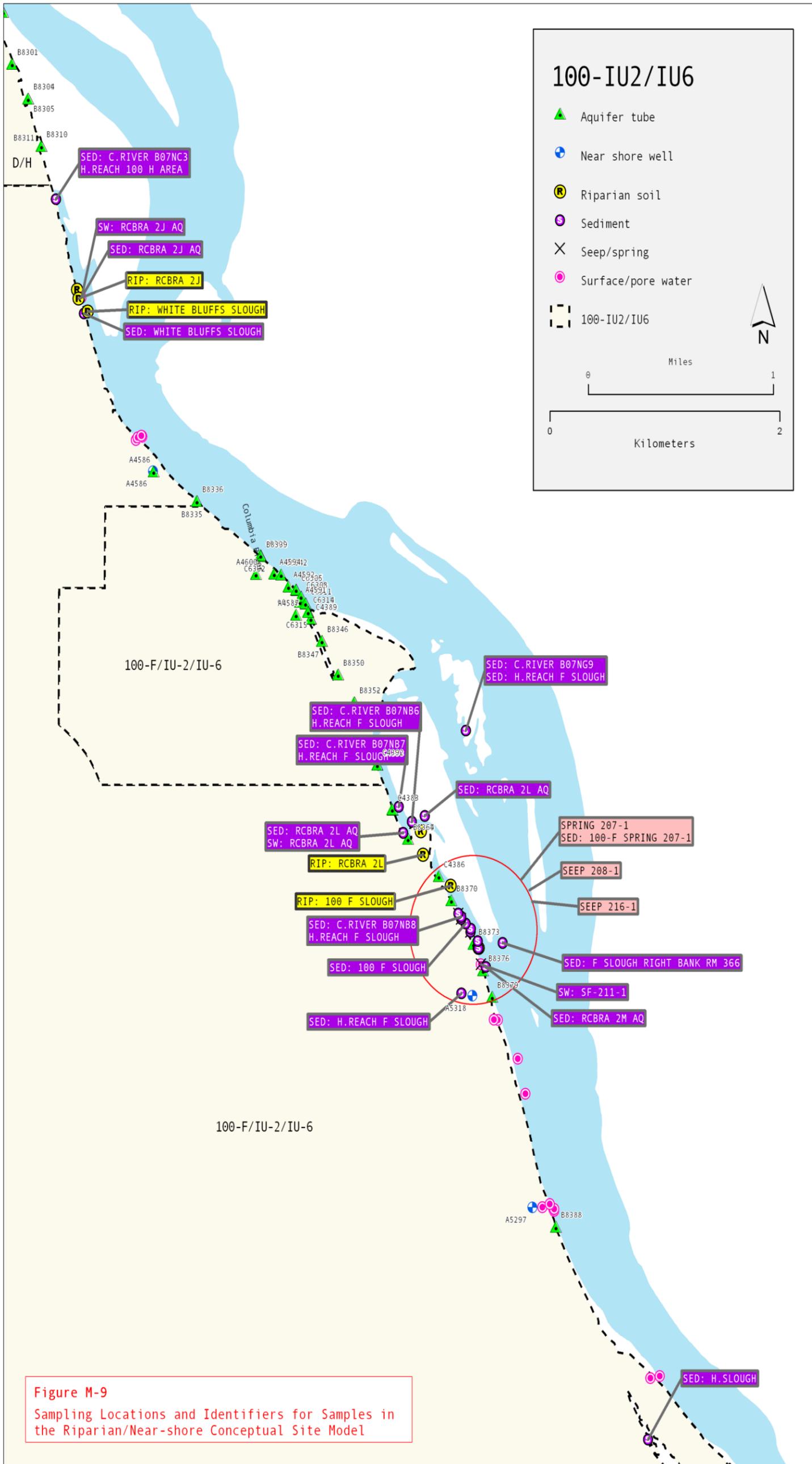


Figure L-9. Sampling Locations in 100-IU-2/IU-6 and Identifiers for Samples in the Riparian/Nearshore Area Conceptual Model

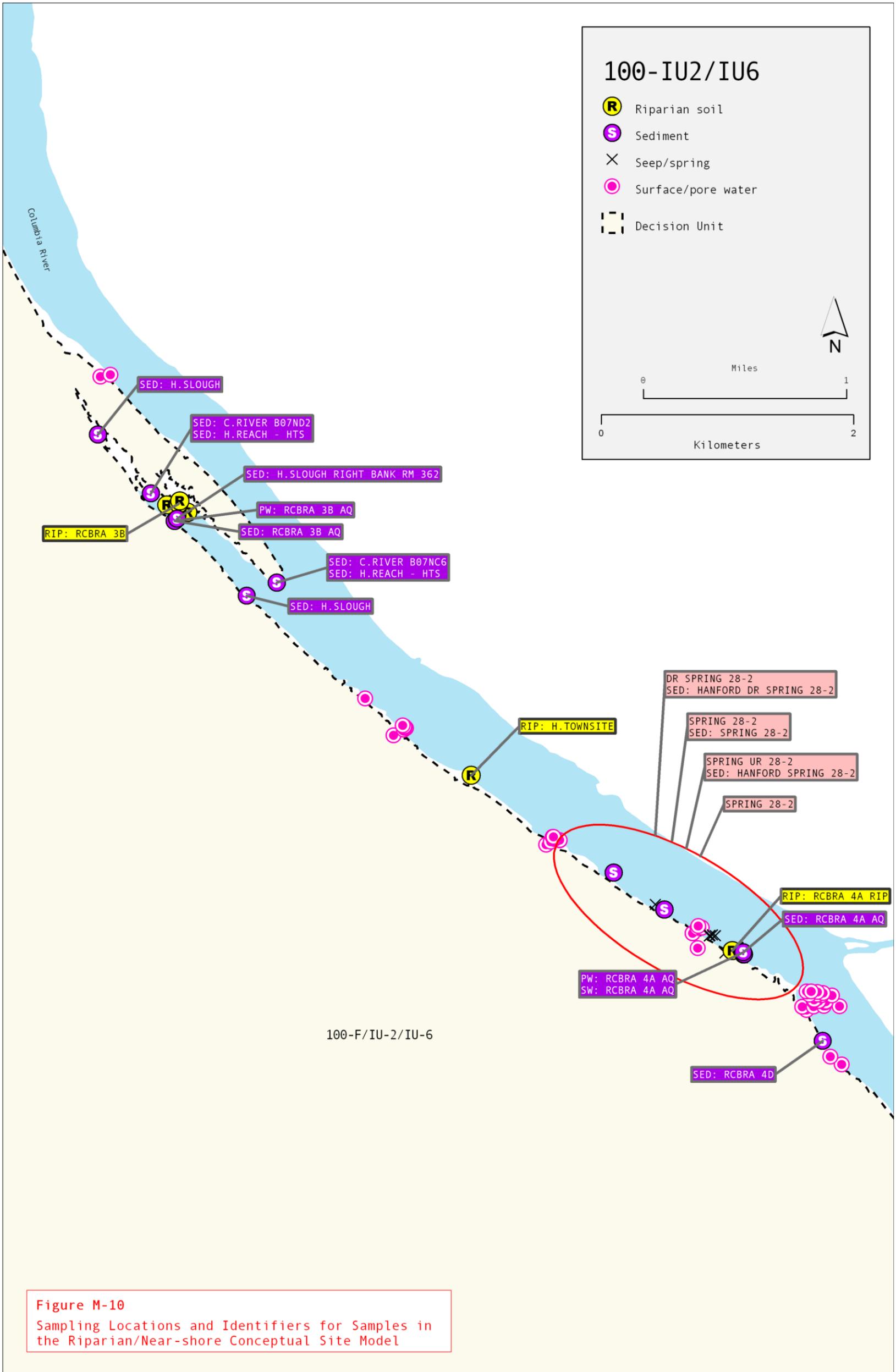


Figure L-10. Sampling Locations in 100-IU-2/IU-6 and Identifiers for Samples in the Riparian/Nearshore Area Conceptual Model

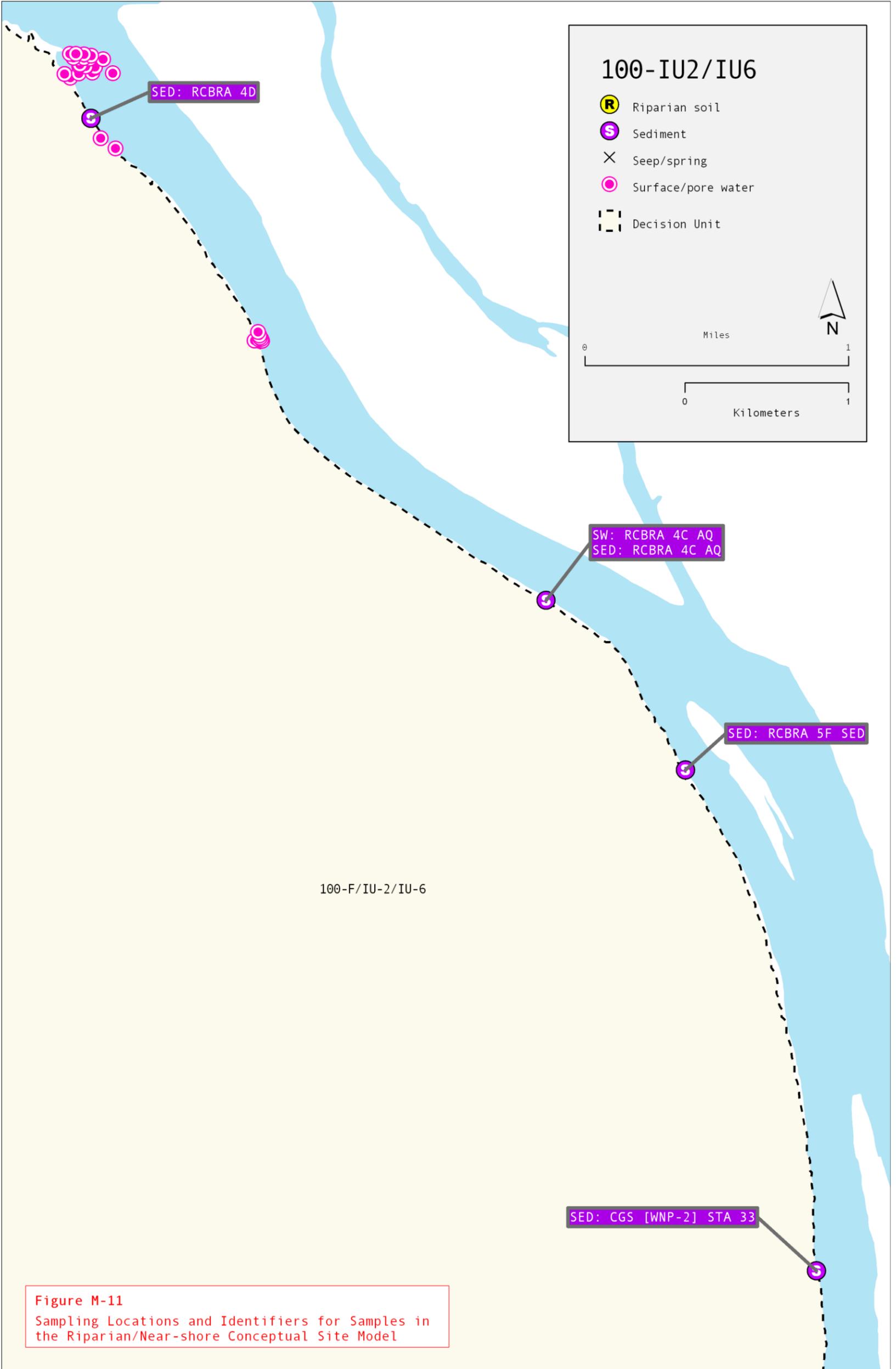


Figure L-11. Sampling Locations in 100-IU-2/IU-6 and Identifiers for Samples in the Riparian/Nearshore Area Conceptual Model

This page intentionally left blank.

L3.1.3 Field Duplicate and Field Split Results

Field quality control (QC) samples (field duplicates and field splits) are collected in the field and analyzed by the laboratory as unique samples. The parent sample and QC samples are collected from the same location (i.e., monitoring well) on the same date, resulting in more than one sample per location/date. The following criteria are used to reduce multiple sample results for an individual location/date to a single result:

- If two or more detections exist, the maximum concentration is used.
- If at least one detection and one or more nondetected results exist, the detected concentration is used.
- If only (two or more) nondetected results exist, the lowest detection limit is used.

L3.2 Identification of Ecological Screening Levels

Ecological screening levels (ESLs) were used for comparison with analytical results in water, soil, and sediment to identify COPECs, and were derived from available sources of chemical-specific applicable or relevant and appropriate requirements, readily available soil screening levels (SSLs), or site-specific preliminary remediation goals (PRGs) for plants and invertebrates or wildlife. A summary of ESLs for water are listed in Table L-3. A summary of the plant/invertebrate and wildlife ESLs are listed in Table L-4. A summary of the lower and upper threshold sediment ESLs is provided in Table L-5.

L3.2.1 Ecological Screening Levels for Water

The following are sources of surface water ESLs:

- “Phosphorous Toxicity in Chara” (Blindow, 1988)
- *Ambient Water Quality Criteria for Fluoride* (BCMOE, 1995)
- *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater* (CRWQCB, 2007)
- *RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User’s Guide, Version 1* (DOE/EH-0676)
- *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE-STD-1153-2002)
- *Ambient Aquatic Life Water Quality Criteria for Antimony (III)* (EPA 440-5-88-093)
- *National Recommended Water Quality Criteria* (EPA, 2009)
- *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision* (ES/ER/TM-96/R2)
- “Acute and Chronic Toxicity of Nitrate to Early Life Stages of Lake Trout (*Salvelinus Namaycush*) and Lake Whitefish (*Coregonus Clupeaformis*)” (McGurk et al., 2006)
- “Water Quality Values,” Rule 57 (MDEQ, 2011)
- “Detrimental Effects of Nitrite on the Development of Benthic Chironomus Larvae, in Relation to Their Settlement in Muddy Sediments” (Neumann et al., 2001)
- “Derivation of Ecotoxicity Thresholds for Uranium” (Sheppard et al., 2005)

- “Water Quality Standards for Surface Waters of the State of Washington” (WAC 173-201A)
- *Vanadium Pentoxide and Other Inorganic Vanadium Compounds* (WHO, 2001)

The ESL was selected from lowest of the available values for protection of aquatic receptors.

L3.2.2 Ecological Screening Levels for Soil

The sources of the plant/invert ESLs and wildlife ESLs are described below. In general, values for metals are PRGs, while those for organics are SSLs. The specific values and the sources and basis for each value are provided in Table L-3.

Plant/invert ESLs. PRGs for plant and invertebrates are documented in *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* (ECF-HANFORD-11-0158). When appropriate, these represent thresholds of toxicity to plants and invertebrates at Hanford and are reflective of site-specific conditions. SSLs were employed when a PRG was not available as documented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784). The most appropriate value for each COPEC was selected from the following:

- Site-specific no observed effect concentrations (NOEC) from samples collected in 2011 as documented in (*Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* [ECF-HANFORD-11-0158]).
- Site-specific NOECs from samples collected in 2006 and 2007 as documented in the RCBRA (DOE/RL-2007-21).
- Site-specific PRGs for lead and arsenic presented in *Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Ecology* (Ecology Publication 11-03-006).
- Hanford background:
 - *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* (DOE/RL-92-24)
 - *Hanford Site Background: Part 2, Soil Background for Radionuclides* (DOE/RL-96-12)
 - *Hanford Site Background: Evaluation of Existing Soil Radionuclide Data* (DOE/RL-95-55)
 - *A Review of Metal Concentrations Measured in Surface Soil Samples Collected on and Around the Hanford Site* (PNNL-18577)
 - *Soil Background Data for Interim Use at the Hanford Site* (ECF-HANFORD-11-0038)
- *Guidance for Developing Ecological Soil Screening Levels* (OSWER Directive 9285.7-55)
- *Washington State Department of Ecology (Ecology) Ecological Indicator Soil Concentrations for Protection of Terrestrial Plants and Animals* (MTCA (WAC 173-340), Table 749-3).
- Oak Ridge National Laboratory (ORNL) screening benchmarks:
 - *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision* (ES/ER/TM-85/R3)

- *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Processes: 1997 Revision (ES/ER/TM-126/R2)*

Wildlife PRGs. PRGs for wildlife represent sets of site-specific values derived to be protective of wildlife that are found or that represent feeding guilds at the Hanford Site. PRGs rely on desktop food chain models that are effectively equivalent to those published by U.S. Environmental Protection Agency (EPA) (*Guidance for Developing Ecological Soil Screening Levels [OSWER Directive 9285.7-55]*) and Ecology (MTCA [WAC 173-340], Table 749-3). PRGs use a combination of literature-based information for the species specifically found at the Hanford Site, while incorporating site-specific tissue data into the food chain models. Wildlife PRGs are documented in *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311), and SSLs are documented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784).

L3.2.3 Ecological Screening Levels for Sediment

ESLs for sediment are the same as those used in the RCBRA (DOE/RL-2007-21) and in *Columbia River Component Risk Assessment Volume 1: Screening Level Ecological Risk Assessment* (DOE/RL-2010-117, Volume 1), hereinafter called the Columbia River Component (CRC), and come from a variety of published sources. When available, preference was given to values published in *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho* (Ecology Publication 11-09-054). Other sources were used when a value was not available in this report with preference toward specificity toward datasets from the Pacific Northwest.

L3.3 Identification of Contaminants of Interest - Water

After extracting and processing the 100-FR-3 OU groundwater analytical data set from HEIS, a multi-step screening process was used to identify initial. The steps:

- Apply exclusion criteria.
- Identify nondetected analytes.
- Identify analytes with maximum detected concentrations less than their respective ESLs.
- Identify analytes with maximum detected concentrations greater than their respective ESLs.

L3.3.1 Apply Exclusion Criteria

The first step in the COI identification process is to apply certain exclusion criteria. Analytes that meet the exclusion criteria were eliminated as COI. The only exclusion criterion used was the absence of toxicity information for an analyte – if there were no ESLs available as described in Section L3.2.1, that analyte was not carried into the next step of the data evaluation process. Analytes that did not meet any of the exclusion criteria were carried forward into the next step.

The analytes in nearshore groundwater wells, aquifer tubes, pore water samples, seep/spring, and surface water samples that do not have ESLs are summarized in Table L-6 through L-14 for the 100-FR-3 Groundwater OU and the 100-IU-2/IU-6 Groundwater Area. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum method detection limits (MDLs), are also provided in Table L-6 through L-14.

L3.3.2 Identify Nondetected Analytes

The next step in the groundwater COI identification process was to identify nondetected analytes. Chemicals and radionuclides that have been analyzed for, but not detected in any sample (collected from appropriate locations, with adequate detection limits), are eliminated as COIs. All analytes detected at least once were carried forward to the next step.

Analytes that were not detected in near-river groundwater wells, aquifer tubes, pore water samples, seep/spring or surface water samples are summarized in Table L-15 through L-23 for the 100-FR-3 Groundwater OU and the 100-IU-2/IU-6 Groundwater Area.

L3.3.3 Identify Analytes with Maximum Detected Concentrations Less Than ESLs

This step identifies analytes with maximum concentrations less than ESLs. In this screening step, the maximum concentration of each analyte detected in groundwater was compared to its ESL to identify analytes not likely to contribute significantly to overall risk. If the maximum detected concentration of an analyte was less than its ESL, the analyte was eliminated as a COI.

A list of analytes with maximum concentrations less than their ESL is presented in Table L-24 through M-32 for the 100-FR-3 Groundwater OU and the 100-IU-2/IU-6 Groundwater Area. With regard to groundwater, the focus of this analysis has been on analytes that are not identified as the contaminants that have already been identified for remedial alternatives evaluation in the FS, including Cr(VI), nitrate, strontium-90, and trichloroethene. Further discussion of these contaminants is provided in Section 4.3.2 of the RI/FS Report.

L3.3.4 Identify Analytes with Maximum Detected Concentrations Greater Than ESLs

This step identifies analytes with maximum concentrations greater than their respective ESLs. Such analytes are likely to contribute to overall risk. If the maximum detected concentration of an analyte is greater than its ESL, the analyte is identified as a COI.

L3.3.5 100-FR-3 Groundwater OU

Analytes with maximum detected concentrations greater than their respective ESLs are described below. Table L-33 through L-36 provides a summary of the analytes with maximum detected concentrations greater than their respective ESL for each water media. Table L-37 summarizes the results for all water media and all COIs described in the following subsections.

L3.3.5.1 Aluminum

Groundwater. Aluminum was detected in six of 19 unfiltered groundwater samples (32 percent frequency) with concentrations ranging from 6.1 µg/L to 49 µg/L. Aluminum was detected in one of 17 filtered groundwater samples (5.9 percent frequency) at a concentration 10 µg/L. All aluminum concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 87 µg/L.

Aquifer Tubes. Aluminum was not detected in filtered aquifer tube samples (3 samples). All MDLs are greater than the ESL of 87 µg/L.

Seep/Spring. Aluminum was detected in all three unfiltered seep/spring samples (100 percent frequency). Aluminum concentrations in unfiltered samples range from 41 to 20,000 µg/L. Of the three detected results, two samples were reported with concentrations greater than the ESL of 87 µg/L. Aluminum was detected at location 100-F Spring (1,700 and 20,000 µg/L) with concentrations greater than the action level.

Aluminum was not detected in filtered seep/spring samples (2 samples). One MDL is greater than the action level of 87 µg/L.

Surface Water. Aluminum was detected in all four unfiltered surface water samples (100 percent frequency). Aluminum concentrations in filtered samples range from 60 to 94 µg/L. Of the four detected results, one sample was reported with a concentration greater than the ESL of 87 µg/L. The single detection greater than the ESL was reported at location 100 F-8 HRM 19.0.

L3.3.5.2 Antimony

Groundwater. Antimony was not detected in unfiltered (31 samples) and filtered (33 samples) groundwater samples. Samples analyzed by Method 6010 had MDLs that range from 4.4 to 60 µg/L. Samples analyzed by Method 200.8 had MDLs that range from 0.3 to 0.6 µg/L. MDLs reported by Method 200.8 are less than the ESL of 30 µg/L.

Aquifer Tubes. Antimony was detected in two of 47 unfiltered aquifer tube samples (4.3 percent frequency). Antimony concentrations in unfiltered samples are 34 and 42 µg/L. Of the two detected results, two samples were reported with concentrations greater than the ESL of 30 µg/L. Although the maximum detected concentrations is greater than the ESL, antimony concentrations are less than the Hanford Site background level of 55 µg/L.

Antimony was not detected in filtered aquifer tube samples (51 samples). Samples analyzed by Method 6010 had MDLs that range from 23 to 47 µg/L. Samples analyzed by Method 200.8 have MDLs of 0.3 µg/L. MDLs reported by Method 200.8 are less than the ESL of 30 µg/L.

Seep/Spring. Antimony was not detected in unfiltered (1 sample) and filtered (2 samples) seep/spring samples. Samples analyzed by Method 6010 had MDLs that range from 2.8 to 39 µg/L. Most MDLs are less than the ESL of 30 µg/L.

Surface Water. Antimony was detected in 10 of 11 unfiltered surface water samples (91 percent frequency). Of the 10 detected results, one sample was reported with a concentration greater than the ESL of 30 µg/L. Antimony was detected at location 100 F-4 HRM 19.0 (77 µg/L) with a concentration greater than the ESL. All MDLs are less than the ESL.

Antimony was detected in all five filtered surface water samples (100 percent frequency), with concentrations ranging 0.20 to 0.32 µg/L. All antimony concentrations are less than the ESL of 30 µg/L.

L3.3.5.3 Cadmium

Groundwater. Cadmium was not detected in unfiltered (31 samples) and filtered (33 samples) groundwater samples. MDLs for filtered and unfiltered samples range from 0.10 to 4.0 µg/L. Samples analyzed by Method 6010 had MDLs that ranged 0.7 to 4.0 µg/L. Samples analyzed by Method 200.8 have MDLs that range from 0.1 to 0.2 µg/L. MDLs reported by Method 200.8 are less than the ESL of 0.22 µg/L.

Aquifer Tubes. Cadmium was detected in one of 51 filtered aquifer tube samples (2 percent frequency) at a concentration of 4.1 µg/L. Cadmium was detected at location C6309 (4.1 µg/L) with a concentration greater than the ESL of 0.22 µg/L. Cadmium was not detected in unfiltered aquifer tube samples (47 samples). Samples analyzed by Method 6010 had MDLs that ranged 0.86 to 4.0 µg/L. Samples analyzed by Method 200.8 have MDLs of 0.1 µg/L.

Seep/Spring. Cadmium was detected in all two unfiltered seep/spring samples (100 percent frequency). Cadmium concentrations in unfiltered samples are 1.1 and 4.8 µg/L. Of the two detected results, one sample was reported with a concentration greater than the ESL of 0.22 µg/L. Cadmium was reported at location 100-F Spring (4.8 µg/L). Cadmium was not detected in filtered seep/spring samples (2 samples). All MDLs for filtered samples are greater than the ESL.

Surface Water. Cadmium was detected in nine of 11 unfiltered surface water samples (82 percent frequency) with concentrations ranging from 0.015 to 0.057 µg/L. Cadmium was detected in four of five filtered surface water samples (80 percent frequency) with concentrations ranging from 0.0099 µg/L to 0.015 µg/L. All cadmium concentrations in filtered and unfiltered samples are less than the ESL 0.22 µg/L. Most MDLs in filtered and unfiltered samples are greater than the ESL.

L3.3.5.4 Calculated Total Uranium

Seep/Spring. Calculated total uranium was detected in all five seep/spring samples (100 percent frequency). Calculated total uranium concentrations range from 4.1 to 13 µg/L. Of the five detected results, three samples were reported with concentrations greater than the ESL of 5.0 µg/L. One calculated total uranium concentration was reported at greater than the Hanford Site background level of 9.9 µg/L. Calculated total uranium was reported at location 100-F Spring at a concentration greater than the Hanford Site background level.

Surface Water. Calculated total uranium was detected in all 30 surface water samples (100 percent frequency), with concentrations ranging from 0.20 to 1.2 µg/L. All calculated total uranium concentrations are less than the ESL of 5.0 µg/L.

L3.3.5.5 Chromium

Groundwater. Chromium was detected in 24 of 31 unfiltered groundwater samples (77 percent frequency) with concentrations ranging from 1.4 to 56 µg/L. Chromium was detected in 25 of 33 filtered groundwater samples (76 percent frequency) with concentrations ranging from 1.8 to 60 µg/L. All chromium concentration and MDLs in filtered and unfiltered samples are less than the ESL of 64 µg/L.

Aquifer Tubes. Chromium was detected in 19 of 47 unfiltered aquifer tube samples (40 percent frequency) with concentrations ranging from 2.0 to 17 µg/L. Chromium was detected in 21 of 51 filtered aquifer tube samples (41 percent frequency) with concentrations ranging from 0.75 to 18 µg/L. All chromium concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 64 µg/L.

Seep/Spring. Chromium was detected in all three unfiltered seep/spring samples (100 percent frequency). Chromium concentrations in unfiltered samples range from 6.0 to 99 µg/L. Of the three detected results, one sample was reported with a concentration greater than the ESL of 64 µg/L. Chromium was detected at location 100-F Spring (99 µg/L) at a concentration greater than the ESL. Chromium was detected in one of two filtered seep/spring samples (50 percent frequency) at a concentration of 0.70 µg/L. Chromium concentrations in filtered samples are less than the ESL of 64 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Surface Water. Chromium was detected in 10 of 12 unfiltered surface water samples (83 percent frequency) with concentrations ranging from 0.061 to 58 µg/L. Chromium was detected in three of five filtered surface water samples (60 percent frequency) with concentrations ranging from 0.026 to 0.074 µg/L. Chromium concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 64 µg/L.

L3.3.5.6 Copper

Groundwater. Copper was detected in nine of 31 unfiltered groundwater samples (29 percent frequency) with concentrations ranging from 0.23 to 6.4 µg/L. Copper was detected in seven of 33 filtered groundwater samples (21 percent frequency) with concentrations ranging from 0.22 to 6.7 µg/L. All copper concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 10 µg/L.

Aquifer Tube. Copper was detected in five of 32 unfiltered aquifer tube samples (16 percent frequency) with concentrations ranging from 4.0 to 6.2 µg/L. Copper was detected in three of 38 filtered aquifer tube samples (7.9 percent frequency) with concentrations ranging from 5.1 to 7.7 µg/L. All copper concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 10 µg/L.

Seep/Spring. Copper was detected in all two unfiltered seep/spring samples (100 percent frequency) and was not detected in filtered samples (2 samples). Copper concentrations in unfiltered samples are 3.9 and

85 µg/L. The single copper concentration was reported at location 100-F Spring (85 µg/L) and was greater than the ESL of 10 µg/L

All MDLs for filtered samples are less than the ESL.

Surface Water. Copper was detected in 10 of 12 unfiltered surface water samples (83 percent frequency) with concentrations ranging from 0.55 to 5.2 µg/L. Copper was detected in five of five filtered surface water samples (100 percent frequency) with concentrations ranging from 0.47 to 0.68 µg/L. Copper concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 10 µg/L.

L3.3.5.7 Cr(VI)

Groundwater. Cr(VI) was detected in 7 of 19 unfiltered groundwater samples (37 percent frequency). Cr(VI) concentrations range from 2.5 to 61 µg/L. Of the seven detected results, four detections reported concentrations greater than the ESL of 10 µg/L. Cr(VI) was detected at monitoring wells 199-F5-6 and 199-F5-44 with concentrations greater than the ESL.

Cr(VI) was detected in 8 of 18 filtered groundwater samples (44 percent frequency). Cr(VI) concentrations range from 2.7 to 60 µg/L. Of the eight detected results, five detections reported concentrations greater than the ESL of 10 µg/L. Cr(VI) was reported at monitoring wells 199-F5-6 and 199-F5-44 with concentrations greater than the ESL.

All MDLs for filtered and unfiltered samples are less than the ESL.

Aquifer Tubes. Cr(VI) was detected in 49 of 83 unfiltered aquifer tube samples (59 percent frequency). Cr(VI) concentrations in unfiltered samples range from 2.0 to 42 µg/L. Of the 49 detected results, four samples were reported with concentrations greater than the ESL of 10 µg/L. Cr(VI) was detected at locations C6303 (13 and 15 µg/L), C6309 (17 µg/L), and C6316 (42 µg/L) with concentrations greater than the ESL.

Cr(VI) was detected in 31 of 50 filtered aquifer tube samples (62 percent frequency). Cr(VI) concentrations in filtered samples range from 2.0 to 15 µg/L. Of the 31 detected results, one sample was reported with a concentration greater than the ESL of 10 µg/L. Cr(VI) was reported at location C6303 (15 µg/L) with a concentration greater than the ESL.

All MDLs for filtered and unfiltered samples are less than the ESL.

Seep/Spring. Cr(VI) was detected in one unfiltered seep/spring sample (100 percent frequency) with a concentration greater than the ESL of 10 µg/L. Cr(VI) was detected at location 100-F Spring (34 µg/L) with a concentration greater than the ESL.

Surface Water. Cr(VI) was not detected in unfiltered surface water samples (1 sample). All MDLs were less than the ESL.

L3.3.5.8 Fluoride

Groundwater. Fluoride was detected in 12 of 35 unfiltered groundwater samples (34 percent frequency). Fluoride concentrations in unfiltered samples range from 49 to 540 µg/L. Of the 12 detected results, four samples reported concentrations greater than the ESL of 300 µg/L. Although the maximum detected concentration is greater than the ESL, fluoride concentrations are less than the Hanford Site background level of 1,047 µg/L.

Aquifer Tube. Fluoride was detected in 41 of 60 unfiltered aquifer tube samples (68 percent frequency). Fluoride concentrations in unfiltered samples range from 22 to 1,100 µg/L. Of the 41 detected results, one

sample reported a concentration greater than the ESL of 300 µg/L. Fluoride was detected at location AT-F-2-M (1,100 µg/L) at a concentration greater than the ESL and the Hanford Site background level of 1,047 µg/L.

Seep/Spring. Fluoride was detected in all seven unfiltered seep/spring samples (100 percent frequency). Fluoride concentrations in unfiltered samples range from 120 to 600 µg/L. Of the seven detected results, two samples reported concentrations greater than the ESL of 300 µg/L. Although the maximum detected concentration is greater than the ESL, fluoride concentrations are less than the Hanford Site background level of 1,047 µg/L.

Surface Water. Fluoride was detected in 10 of 12 unfiltered surface water samples (83 percent frequency). Fluoride concentrations in unfiltered samples range from 40 to 1,300 µg/L. Of the 10 detected results, two samples reported concentrations greater than the ESL of 300 µg/L. Fluoride was detected at location 100 F-2 HRM 19.0 (1,300 µg/L) at a concentration greater than the ESL and the Hanford Site background level of 1,047 µg/L.

L3.3.5.9 Iron

Groundwater. Iron was detected in 23 of 31 unfiltered groundwater samples (74 percent frequency) with concentrations ranging from 14 to 528 µg/L. Iron was detected in 13 of 33 filtered groundwater samples (39 percent frequency) with concentrations ranging from 20 to 146 µg/L. Iron concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 1,000 µg/L.

Aquifer Tubes. Iron was detected in 32 of 47 unfiltered aquifer tube samples (68 percent frequency). Iron concentrations in unfiltered samples range from 31 to 5,270 µg/L. Of the 32 detected results, six samples were reported with concentrations greater than the ESL of 1,000 µg/L. Iron was detected at six aquifer tube locations with concentrations greater than the ESL.

Iron was detected in 15 of 51 filtered groundwater samples (29 percent frequency) with concentrations ranging from 11 to 970 µg/L. All iron concentrations and MDLs in filtered samples are less than the ESL of 1,000 µg/L.

Seep/Spring. Iron was detected in all three unfiltered seep/spring samples (100 percent frequency). Iron concentrations in unfiltered samples range from 18 to 21,000 µg/L. Of the three detected results, two detections reported concentrations greater than the ESL of 1,000 µg/L. Iron was reported at location 100-F Spring with concentrations greater than the ESL. Iron was detected in all two filtered seep/spring samples (100 percent frequency) at concentrations 61 and 98 µg/L. Iron concentrations in filtered samples are less than the ESL of 1,000 µg/L.

Surface Water. Iron was detected in all four unfiltered surface water samples (100 percent frequency) with concentrations ranging from 36 to 490 µg/L. Iron concentrations in unfiltered samples are less than the ESL of 1,000 µg/L.

L3.3.5.10 Lead

Groundwater. Lead was detected in one of 19 unfiltered groundwater samples (5.3 percent frequency) at a concentration of 0.21 µg/L. The single unfiltered lead concentration was less than the ESL of 2.1 µg/L. Lead was not detected in filtered groundwater samples (17 samples). Most MDLs are less than the ESL.

Seep/Spring. Lead was detected in one unfiltered seep/spring sample (100 percent frequency) at a concentration of 110 µg/L. The single lead concentration in unfiltered samples was reported at location 100-F Spring at a concentration greater than the ESL of 2.1 µg/L.

Surface Water. Lead was detected in 10 of 12 unfiltered surface water samples (83 percent frequency) with concentrations ranging from 0.029 to 1.8 µg/L. Lead was detected in four of five filtered surface water samples (80 percent frequency) with concentrations ranging from 0.010 to 0.014 µg/L. Lead concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 2.1 µg/L.

L3.3.5.11 Manganese

Groundwater. Manganese was detected in eight of 31 unfiltered groundwater samples (26 percent frequency), with concentrations ranging from 4.2 to 31 µg/L. Manganese was detected in four of 33 unfiltered groundwater samples (12 percent frequency), with concentrations ranging from 3.4 to 6.1 µg/L. All manganese concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 120 µg/L.

Aquifer Tubes. Manganese was detected in 27 of 47 unfiltered aquifer tube samples (57 percent frequency), with concentrations ranging from 2.0 to 101 µg/L. Manganese was detected in 14 of 51 filtered aquifer tube samples (27 percent frequency), with concentrations ranging from 0.12 to 60 µg/L. All manganese concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 120 µg/L.

Seep/Spring. Manganese was detected in all three unfiltered seep/spring samples (100 percent frequency). Manganese concentrations in unfiltered samples range from 3.1 to 470 µg/L. Of the three detected results, one sample was reported with a concentration greater than the ESL of 120 µg/L. Manganese was detected at location 100-F Spring (470 µg/L) with a concentration greater than the ESL.

Manganese was detected in one of two filtered seep/spring samples (50 percent frequency), at a concentration of 24 µg/L. Manganese concentrations in filtered samples are less than the ESL of 120 µg/L.

Surface Water. Manganese was detected in all four unfiltered surface water samples (100 percent frequency), with concentrations ranging from 2.1 to 8.7 µg/L. Manganese concentrations in unfiltered samples are less than the ESL of 120 µg/L.

L3.3.5.12 Nitrate

Groundwater. Nitrate was detected in 34 of 35 unfiltered groundwater samples (97 percent frequency). Nitrate concentrations in unfiltered samples range from 912 to 30,700 µg/L. Of the 34 detected results, 22 samples were reported with concentrations greater than the ESL of 7,100 µg/L. All MDLs are less than the ESL. All results were below the lowest observed effect concentration (LOEC) ESL of 37,640 µg/L presented in the CRC ERA (DOE/RL-2010-117).

Aquifer Tubes. Nitrate was detected in all 60 unfiltered aquifer tube samples (100 percent frequency). Nitrate concentrations in unfiltered samples range from 367 to 1.2×10^6 µg/L. Of the 60 detected results, 17 samples were reported with concentrations greater than the NOEC ESL of 7,100 µg/L, but less than the LOEC ESL of 37,640 µg/L, in all but 4 samples.

L3.3.5.13 Nitrogen in Nitrate

Seep/Spring. Nitrogen in nitrate was detected in all seven unfiltered seep/spring samples (100 percent frequency). Nitrogen in nitrate concentrations in unfiltered samples range from 580 to 9,010 µg/L. Of the seven detected results, six samples were reported with concentrations greater than the NOEC ESL of 1,600 µg/L (NO₃-N) and one sample was reported with a concentration greater than the LOEC ESL (DOE/RL-2010-117) of 8,498 µg/L (NO₃-N).

Surface Water. Nitrogen in nitrate was detected in all 12 unfiltered surface water samples (100 percent frequency) with concentrations ranging from 23 to 587 µg/L. Nitrogen in nitrate concentrations in unfiltered samples are less than the NOEC ESL of 1,600 µg/L.

L3.3.5.14 Potassium-40

Groundwater. Potassium-40 was detected in one of 19 unfiltered groundwater samples (5.3 percent frequency). The single potassium-40 concentration in unfiltered samples was reported at location 199-F5-42 (388 pCi/L) at a concentration greater than the ESL of 250 pCi/L.

Seep/Spring. Potassium-40 was detected in two of five unfiltered seep/spring samples (40 percent frequency) at concentrations 70 to 143 pCi/L. Potassium-40 concentrations in unfiltered samples are less than the ESL of 250 pCi/L.

Surface Water. Potassium-40 was not detected in surface water samples (1 sample). All MDLs are less than the ESL of 250 pCi/L.

L3.3.5.15 Selenium

Groundwater. Selenium was detected in eight of 19 unfiltered groundwater samples (42 percent frequency) with concentrations ranging from 0.64 to 3.7 µg/L. Selenium was detected in seven of 17 filtered groundwater samples (41 percent frequency) with concentrations ranging from 0.88 to 3.7 µg/L. All selenium concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 5.0 µg/L.

Seep/Spring. Selenium was detected in one unfiltered sample (100 percent frequency) at a concentration of 6.4 µg/L. Although the maximum detected concentration is greater than the ESL of 5.0 µg/L, the single selenium concentration is less than the Hanford Site background level of 11 µg/L.

Surface Water. Selenium was detected in five of 11 unfiltered surface water samples (45 percent frequency) with concentrations ranging from 0.13 to 0.27 µg/L. Selenium was detected in four of five filtered surface water samples (80 percent frequency) with concentrations ranging from 0.10 to 0.18 µg/L. All selenium concentrations in filtered and unfiltered samples are less than the ESL of 5.0 µg/L.

L3.3.5.16 Silver

Groundwater. Silver was detected in one of 33 filtered groundwater samples (3 percent frequency). The single filtered silver concentration was reported at monitoring Well 199-F5-1 (5.3 µg/L) with a concentration greater than the ESL of 2.6 µg/L. Silver was not detected in unfiltered groundwater samples (31 samples). Most MDLs are less than the ESL.

Aquifer Tubes. Silver was detected in three of 51 filtered aquifer tube samples (5.9 percent frequency). Silver concentrations in filtered samples range from 5.3 to 7.2 µg/L. Of the three detected results, three samples were reported with concentrations greater than the ESL of 2.6 µg/L. Silver was detected at three aquifer tube locations with concentrations greater than the ESL. Silver was not detected in unfiltered aquifer tube samples (47 samples). Most MDLs are greater than the ESL.

Seep/Spring. Silver was not detected in unfiltered (1 sample) and filtered (2 samples) seep/spring samples. All MDLs are greater than the ESL of 2.6 µg/L.

Surface Water. Silver was detected in five of 11 unfiltered surface water samples (45 percent frequency). Silver concentrations in unfiltered samples range from 0.0020 to 7.4 µg/L. Of the five detected results, one sample was reported with a concentration greater than the ESL of 2.6 µg/L. Silver was detected at

locations 100 F-8 HRM 19.0 (7.4 µg/L) with a concentration greater than the ESL. Silver was not detected in filtered surface water samples (5 samples).

All MDLs for filtered and unfiltered samples are less than the ESL.

L3.3.5.17 Uranium

Groundwater. Uranium was detected in one unfiltered groundwater sample (100 percent frequency) at a concentration of 22 µg/L. The single lead concentration in unfiltered samples was reported at location 199-F5-42 (22 µg/L) at a concentration greater than the ESL of 5.0 µg/L.

Surface Water. Silver was not detected in unfiltered surface water samples (1 sample). All MDLs are greater than the ESL of 5.0 µg/L.

L3.3.5.18 Zinc

Groundwater. Zinc was detected in six of 31 unfiltered groundwater samples (19 percent frequency), with concentrations ranging from 4.5 to 21 µg/L. Zinc was detected in seven of 33 filtered groundwater samples (21 percent frequency), with concentrations ranging from 5.0 to 19 µg/L. Zinc concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 90 µg/L.

All MDLs for filtered and unfiltered samples are less than the ESL.

Aquifer Tubes. Zinc was detected in 13 of 47 unfiltered aquifer tube samples (28 percent frequency). Zinc concentrations in unfiltered samples range from 1.2 to 500 µg/L. Of the 13 detected results, two samples were reported with concentrations greater than the ESL of 90 µg/L. Zinc was detected at locations 68-D (500 µg/L) and 67-M (173 µg/L) with concentrations greater than the ESL.

Zinc was detected in 12 of 51 filtered aquifer tube samples (24 percent frequency). Zinc concentrations in filtered samples range from 0.89 to 253 µg/L. Of the 12 detected results, two samples were reported with concentrations greater than the ESL of 90 µg/L. Zinc was detected at locations 67-M (253 µg/L) and 68-D (250 µg/L) with concentrations greater than the ESL.

All MDLs for filtered and unfiltered samples are less than the ESL.

Seep/Spring. Zinc was detected in all three unfiltered seep/spring samples (100 percent frequency). Zinc concentrations in unfiltered samples range from 7.3 to 910 µg/L. Of the three detected results, one sample was reported with a concentration greater than the ESL of 90 µg/L. Zinc was detected at location 100-F Spring (910 µg/L) with a concentration greater than the ESL.

Zinc was detected in one of two filtered seep/spring samples (50 percent frequency) at a concentration of 12 µg/L. Zinc concentrations in filtered samples are less than the ESL. All MDLs are less than the ESL.

Surface Water. Zinc was detected in 12 of 13 unfiltered surface water samples (92 percent frequency) with concentrations ranging from 1.3 to 33 µg/L. Zinc was detected in all five filtered surface water samples (100 percent frequency), with concentrations ranging from 0.87 to 1.2 µg/L. Zinc concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 90 µg/L.

L3.3.6 100-IU-2/IU-6 Groundwater OU

Analytes with maximum detected concentrations greater than their respective ESLs are described below. Table L-38 through L-42 provides a summary of the analytes with maximum detected concentrations greater than their respective ESL for each water media. Table L-43 summarizes the results for all water media and all COIs described in the following subsections.

L3.3.6.1 Aluminum

Groundwater. Aluminum was detected in two of three unfiltered groundwater samples (67 percent frequency) with concentrations ranging from 14 to 67 µg/L. Aluminum was detected in one of three filtered groundwater samples (33 percent frequency) at a concentration 23 µg/L. Aluminum concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 87 µg/L.

Pore Water. Aluminum was detected in all three unfiltered pore water samples (100 percent frequency). Aluminum concentration in unfiltered samples range from 35 to 108 µg/L. Of the three detected results, one sample was reported with a concentration greater than the ESL of 87 µg/L. Aluminum was detected at location RCBRA 4A AQ (108 µg/L) with a concentration greater than the ESL.

Seep/Spring. Aluminum was detected in all four unfiltered seep/spring samples (100 percent frequency), and was not detected in filtered seep/spring samples (3 samples). Aluminum concentrations in unfiltered samples range from 67 to 940 µg/L. Of the four detected results, three samples were reported with concentrations greater than the ESL of 87 µg/L. Aluminum was detected at location Spring 28-2 with concentrations greater than the ESL.

Surface Water. Aluminum was detected in eight of nine unfiltered surface water samples (89 percent frequency). Aluminum concentration in unfiltered samples range from 45 to 390 µg/L. Of the eight detected results, four samples were reported with concentrations greater than the ESL of 87 µg/L. Aluminum was detected at four surface water locations at concentrations greater than the ESL.

L3.3.6.2 Antimony

Groundwater. Antimony was not detected in unfiltered (4 samples) and filtered (5 samples) groundwater samples. Most MDLs for filtered and unfiltered samples are less than the ESL of 30 µg/L.

Aquifer Tubes. Antimony was detected in one of 20 filtered aquifer tube samples (5 percent frequency), and was not detected in unfiltered aquifer tube samples (16 samples). The single antimony concentration in filtered samples was reported at a concentration of 0.35 µg/L. Antimony concentrations in filtered samples are less than the ESL of 30 µg/L. Most MDLs for filtered and unfiltered samples are greater than the ESL.

Pore Water. Antimony was not detected in unfiltered pore water samples (3 samples). All MDLs are less than the ESL of 30 µg/L.

Seep/Spring. Antimony was detected in 13 of 14 unfiltered seep/spring samples (93 percent frequency), with concentrations ranging from 0.11 to 0.39 µg/L. Antimony was detected in eight of 10 filtered seep/spring samples (80 percent frequency), with concentrations ranging from 0.15 to 4.3 µg/L. All antimony concentrations are less than the ESL of 30 µg/L. Most filtered and unfiltered MDLs are less than the ESL.

Surface Water. Antimony was detected in 42 of 47 unfiltered surface water samples (89 percent frequency). Antimony concentrations in unfiltered samples range from 0.15 to 60 µg/L. Of the 42 detected results, one sample was reported with a concentration greater than the ESL of 30 µg/L. Antimony was reported at location TS-9 HRM 28.7 (60 µg/L) at a concentration greater than the ESL. All MDLs are less than the ESL.

Antimony was detected in all 16 filtered surface water samples (100 percent frequency), with concentrations ranging from 0.16 to 0.38 µg/L. All antimony concentrations in filtered samples are less than the ESL of 30 µg/L.

L3.3.6.3 Cadmium

Groundwater. Cadmium was not detected in unfiltered (4 samples) and filtered (5 samples) groundwater samples. Most MDLs for filtered and unfiltered samples are less than the ESL of 0.22 µg/L.

Aquifer Tubes. Cadmium was not detected in unfiltered (16 samples) and filtered (20 samples) aquifer tubes samples. Most MDLs for filtered and unfiltered samples are less than the ESL of 0.22 µg/L.

Pore Water. Cadmium was not detected in unfiltered pore water samples (3 samples). All MDLs are less than the ESL of 0.22 µg/L.

Seep/Spring. Cadmium was detected in 12 of 13 unfiltered seep/spring samples (92 percent frequency). Cadmium concentrations in unfiltered samples range from 0.020 to 0.63 µg/L. Of the 12 detected results, three samples were reported with concentrations greater than the ESL of 0.22 µg/L. Although the maximum detected concentrations is greater than the ESL, cadmium concentrations are less than the Hanford Site background level of 0.92 µg/L.

Cadmium was detected in seven of 10 filtered seep/spring samples (70 percent frequency), with concentrations ranging 0.016 to 0.045 µg/L. Cadmium concentrations in filtered samples are less than the ESL of 0.22. All MDLs for filtered samples are greater than the ESL.

Surface Water. Cadmium was detected in 33 of 47 unfiltered surface water samples (70 percent frequency). Cadmium concentrations in unfiltered samples range from 0.011 to 0.38 µg/L. Of the 33 detected results, one sample was reported with a concentration greater than the ESL of 0.22 µg/L. Although the maximum detected concentration is greater than the ESL, cadmium concentrations are less than the Hanford Site background level of 0.92 µg/L.

Cadmium was detected in 10 of 16 filtered seep/spring samples (63 percent frequency), with concentrations ranging 0.0091 to 0.026 µg/L. Cadmium concentrations in filtered samples are less than the ESL of 0.22 µg/L. All MDLs for filtered samples are less than the ESL.

L3.3.6.4 Calculated Total Uranium

Pore Water. Calculated total uranium was detected in all three unfiltered pore water samples (100 percent frequency), with concentrations ranging from 0.43 to 1.1 µg/L. All calculated total uranium concentrations are less than the ESL of 5.0 µg/L.

Seep/Spring. Calculated total uranium was detected in all 35 unfiltered seep/spring samples (100 percent frequency). Calculated total uranium concentrations in unfiltered samples range from 0.89 to 10 µg/L. Of the 35 detected results, six samples were reported with concentrations greater than the ESL of 5.0 µg/L. Calculated total uranium was reported at one seep/spring location, Spring 28-2, (10 µg/L) with concentrations greater than the Hanford Site background level of 9.9 µg/L.

Surface Water. Calculated total uranium was detected in all 84 unfiltered surface water samples (100 percent frequency), with concentrations ranging from 0.12 to 3.3 µg/L. All calculated total uranium concentrations are less than the ESL of 5.0 µg/L.

L3.3.6.5 Copper

Groundwater. Copper was detected in two of four unfiltered groundwater samples (50 percent frequency) with concentrations ranging from 0.25 to 0.26 µg/L. Copper was detected in one of five filtered groundwater samples (20 percent frequency) at a concentration of 0.22 µg/L. All copper concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 10 µg/L.

Aquifer Tubes. Copper was detected in two of eight unfiltered aquifer tube samples (25 percent frequency) with concentrations ranging from 4.2 to 6.1 µg/L. Copper was not detected in filtered aquifer tube samples (12 samples). All copper concentrations and MDLs are less than the ESL of 10 µg/L.

Pore Water. Copper was detected in one of three unfiltered pore water samples (33 percent frequency) at a concentration of 0.81 µg/L. Copper concentrations and MDLs in unfiltered samples are less than the ESL of 10 µg/L.

Seep/Spring. Copper was detected in 14 of 15 unfiltered seep/spring samples (93 percent frequency). Copper concentrations in unfiltered samples range from 0.73 to 15 µg/L. Of the 14 detected results, one sample was reported with a concentration greater than the ESL of 10 µg/L. Copper was detected at location 100-F Spring 207-1 (15 µg/L) with a concentration greater than the ESL.

Copper was detected in seven of 10 filtered seep/spring samples (70 percent frequency) with concentrations ranging from 0.38 to 1.1 µg/L. Copper concentrations in filtered samples are less than the ESL of 15 µg/L.

Surface Water. Copper was detected in 43 of 48 unfiltered surface water samples (90 percent frequency) with concentrations ranging from 0.45 to 3.5 µg/L. Copper was detected in all 16 filtered surface water samples (100 percent frequency) with concentrations ranging 0.45 to 0.63 µg/L. All copper concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 10 µg/L.

L3.3.6.6 Fluoride

Groundwater. Fluoride was detected in five of nine unfiltered groundwater samples (56 percent frequency). Fluoride concentrations in unfiltered samples range from 85 to 370 µg/L. Of the five detected results, two samples were reported with concentrations greater than the ESL of 300 µg/L. Although the maximum detected concentration is greater than the ESL, fluoride concentrations are less than the Hanford Site background level of 1,047 µg/L.

Aquifer Tubes. Fluoride was detected in 33 of 40 unfiltered aquifer tube samples (83 percent frequency) with concentrations ranging from 26 to 210 µg/L. All fluoride concentrations and MDLs are less than the ESL of 300 µg/L.

Pore Water. Fluoride was not detected in unfiltered pore water samples (3 samples). All MDLs are less than the ESL of 250 µg/L.

Seep/Spring. Fluoride was detected in all 25 unfiltered seep/spring samples (100 percent frequency). Fluoride concentrations in unfiltered samples range from 77 to 700 µg/L. Of the 25 detected results, four samples were reported with concentrations greater than the ESL of 300 µg/L. Although the maximum detected concentration is greater than the ESL, fluoride concentrations are less than the Hanford Site background level of 1,047 µg/L.

Surface Water. Fluoride was detected in 45 of 51 unfiltered seep/spring samples (88 percent frequency). Fluoride concentrations in unfiltered samples range from 30 to 600 µg/L. Of the 45 detected results, three samples were reported with concentrations greater than the ESL of 300 µg/L. Although the maximum detected concentration is greater than the ESL, fluoride concentrations are less than the Hanford Site background level of 1,047 µg/L.

L3.3.6.7 Heptachlor

Aquifer Tubes. Heptachlor was detected in one of three aquifer tube samples (33 percent frequency). The single heptachlor concentration was reported at location C6356 (0.011 µg/L) and was greater than the ESL of 0.0038 µg/L. All MDLs are greater than the ESL.

Pore Water. Heptachlor was not detected in unfiltered pore water samples (3 samples). All MDLs are greater than the ESL of 0.0038 µg/L.

Surface Water. Heptachlor was not detected in unfiltered surface water samples (5 samples). All MDLs are greater than the ESL of 0.0038 µg/L.

L3.3.6.8 Cr (VI)

Groundwater. Cr(VI) was detected in one of three unfiltered groundwater samples (33 percent frequency) at a concentration of 2.6 µg/L. Cr(VI) was detected in one of three filtered groundwater samples (33 percent frequency) at a concentration of 2.4 µg/L. All Cr(VI) concentrations and MDLs are less than the ESL of 10 µg/L.

Aquifer Tubes. Cr(VI) was detected in 16 of 25 unfiltered aquifer tube samples (64 percent frequency). Cr(VI) concentrations in unfiltered samples range from 2.3 to 12 µg/L. Of the 16 detected results, two samples were reported with concentrations greater than the ESL of 10 µg/L. Cr(VI) was detected at location B8373 (11 and 12 µg/L) with concentrations greater than the ESL.

Cr(VI) was detected in 7 of 12 filtered aquifer tube samples (58 percent frequency). Cr(VI) concentrations in filtered samples range from 2.2 to 11 µg/L. Of the 7 detected results, one sample was reported with a concentration greater than the ESL of 10 µg/L. Cr(VI) was reported at location B8373 (11 µg/L) with a concentration greater than the ESL.

All MDLs for filtered and unfiltered samples are less than the ESL.

Pore Water. Cr(VI) was detected in two of three unfiltered pore water samples (67 percent frequency) at concentrations 3.3 and 4.7 µg/L. All Cr(VI) concentrations and MDLs in unfiltered samples are less than the ESL of 10 µg/L.

Seep/Spring. Cr(VI) was detected in one unfiltered seep/spring sample (100 percent frequency) at a concentration of 1.4 µg/L. The single Cr(VI) concentration is less than the ESL of 10 µg/L.

Surface Water. Cr(VI) was detected in one of five unfiltered pore water samples (20 percent frequency) at a concentration of 3.2 µg/L. All Cr(VI) concentrations and MDLs in unfiltered samples are less than the ESL of 10 µg/L.

L3.3.6.9 Iron

Groundwater. Iron was detected in three of four unfiltered groundwater samples (75 percent frequency), with concentrations ranging from 23 to 38 µg/L. Iron was detected in one of five filtered groundwater samples (20 percent frequency) at a concentration of 24 µg/L. The single iron concentration and MDLs in filtered and unfiltered samples are less than the ESL of 1,000 µg/L.

Aquifer Tubes. Iron was detected in 12 of 13 unfiltered aquifer tube samples (92 percent frequency). Iron concentrations in unfiltered samples range from 16 to 1,590 µg/L. Of the 12 detected results, two samples were reported with concentrations greater than the ESL of 1,000 µg/L. Iron was detected at locations 77-D (1,040 µg/L) and 74-D (1,590 µg/L), with concentrations greater than the ESL.

Iron was detected in six of 17 filtered aquifer tube samples (35 percent frequency) with concentrations ranging from 10 to 28 µg/L. Iron concentrations and MDLs in filtered samples are less than the ESL of 1,000 µg/L.

Pore Water. Iron was detected in two of three unfiltered pore water samples (67 percent frequency), with concentrations ranging from 40 to 127 µg/L. Iron concentrations and MDLs in filtered samples are less than the ESL of 1,000 µg/L.

Seep/Spring. Iron was detected all four unfiltered seep/spring samples (100 percent frequency). Iron concentrations in unfiltered samples range from 100 to 1,600 µg/L. Of the four detected results, two samples were reported with concentrations greater than the ESL of 1,000 µg/L. Iron was detected at location Spring 28-2 (1,200 and 1,600 µg/L) with concentrations greater than the ESL.

Iron was detected in two of three filtered seep/spring samples (67 percent frequency) at concentrations of 61 and 68 µg/L. Iron concentrations and MDLs in filtered samples are less than the ESL of 1,000 µg/L.

Surface water. Iron was detected in all nine unfiltered surface water samples (100 percent frequency) with concentrations ranging from 35 to 420 µg/L. Iron concentrations in unfiltered samples are less than the ESL of 1,000 µg/L.

L3.3.6.10 Lead

Groundwater. Lead was not detected in filtered (3 samples) and unfiltered (3 samples) groundwater samples. All MDLs are less than the ESL of 2.1 µg/L.

Aquifer Tubes. Lead was not detected in filtered (3 samples) and unfiltered (3 samples) aquifer tube samples. Most MDLs are greater than the ESL of 2.1 µg/L.

Pore Water. Lead was not detected in unfiltered pore water samples (3 samples). Most MDLs are less than the ESL of 2.1 µg/L.

Seep/Spring. Lead was detected in all 14 unfiltered seep/spring samples (100 percent frequency). Lead concentrations in unfiltered samples range from 0.19 to 19 µg/L. Of the 14 detected results, six samples were reported with concentrations greater than the ESL of 2.1 µg/L. Lead was detected at four seep/spring locations with concentrations greater than the ESL.

Lead was detected in six of seven filtered seep/spring samples (86 percent frequency) with concentrations ranging from 0.0082 to 0.16 µg/L. All lead concentrations and MDLs in filtered samples are less than the ESL of 2.1 µg/L.

Surface Water. Lead was detected in 42 of 48 unfiltered surface water samples (88 percent frequency) with concentrations ranging from 0.0099 to 1.7 µg/L. Lead was detected in 10 of 16 filtered surface water samples (63 percent frequency), with concentrations ranging from 0.013 to 0.031 µg/L. All lead concentrations for filtered and unfiltered samples are less than the ESL. Most MDLs are less than the ESL of 2.1 µg/L.

L3.3.6.11 Manganese

Groundwater. Manganese was not detected in filtered (5 samples) and unfiltered (4 samples) groundwater samples. All MDLs are less than the ESL of 120 µg/L.

Aquifer Tubes. Manganese was detected in 13 of 16 unfiltered aquifer tube samples (81 percent frequency). Manganese concentrations in unfiltered samples range from 0.18 to 189 µg/L. Of the 13 detected results, one sample was reported with a concentration greater than the ESL of 120 µg/L. Manganese was detected at C6359 (189 µg/L) with concentrations greater than the ESL.

Manganese was detected in 9 of 20 filtered aquifer tube samples (45 percent frequency). Manganese concentrations in filtered samples range from 0.10 to 189 µg/L. Of the 9 detected results, one sample was

reported with a concentration greater than the ESL of 120 µg/L. Lead was detected at C6359 (189 µg/L) with concentrations greater than the ESL.

Pore Water. Manganese was detected in all three unfiltered pore water samples (100 percent frequency) with concentrations ranging from 1.2 to 6.3 µg/L. All manganese concentrations in unfiltered samples are less than the ESL of 120 µg/L.

Seep/Spring. Manganese was detected in all four unfiltered seep/spring samples (100 percent frequency) with concentrations ranging from 7.1 to 82 µg/L. Manganese was detected in two of three filtered seep/spring samples (67 percent frequency) with concentrations ranging from 1.4 to 7.9 µg/L. All manganese concentrations and MDLs in filtered and unfiltered samples are less than the ESL of 120 µg/L.

Surface Water. Manganese was detected in all nine unfiltered surface water samples (100 percent frequency) with concentrations ranging from 2.1 to 18 µg/L. All manganese concentrations unfiltered samples are less than the ESL of 120 µg/L.

L3.3.6.12 Nitrate

Groundwater. Nitrate was detected in all nine unfiltered groundwater samples (100 percent frequency). Nitrate concentrations in unfiltered samples range from 1,670 to 36,100 µg/L. Of the nine detected results, four samples were reported with concentrations greater than the NOEC ESL of 7,100 µg/L. Two samples were reported with concentration greater than the Hanford Site background level of 26,871 µg/L. Nitrate was reported at location 699-37-E4 (35,900 and 36,100 µg/L) with concentrations greater than the Hanford Site background level, but less than the LOEC ESL (37,640 µg/L).

Aquifer Tubes. Nitrate was detected in all 40 unfiltered aquifer tube samples (100 percent frequency). Nitrate concentrations in unfiltered samples range from 177 to 43,100 µg/L. Of the 40 detected results, 23 samples were reported with concentrations greater than the ESL of 7,100 µg/L. Six samples were reported with concentrations greater than the Hanford Site background level of 26,871 µg/L. Two samples (well location B8373) were greater than the LOEC ESL (37,640 µg/L).

L3.3.6.13 Nitrogen in Nitrate

Pore Water. Nitrogen in nitrate was detected in all three unfiltered pore water samples (100 percent frequency) with concentrations ranging from 169 to 476 µg/L. All nitrogen in nitrate concentrations in unfiltered samples are less than the ESL of 1,600 µg/L.

Seep/Spring. Nitrogen in nitrate was detected in all 29 unfiltered seep/spring samples (100 percent frequency). Nitrogen in nitrate concentrations in unfiltered samples range from 470 to 32,600 µg/L. Of the 29 detected results, 25 samples were reported with concentrations greater than the NOEC ESL of 1,600 µg/L. Seven of these samples were also greater than the LOEC ESL (8,498 µg/L).

Surface Water. Nitrogen in nitrate was detected in 51 of 52 unfiltered surface water samples (98 percent frequency). Nitrogen in nitrate concentrations in unfiltered samples range from 32 to 6,323 µg/L. Of the 51 detected results, one sample was reported with a concentration greater than the NOEC ESL of 1,600 µg/L (location HTS at 6,323 µg/L). No samples exceeded the LOEC ESL of 8,498 µg/L.

L3.3.6.14 Potassium-40

Groundwater. Potassium-40 was not detected in unfiltered groundwater samples (3 samples). All MDLs are less than the ESL of 250 pCi/L.

Pore Water. Potassium-40 was not detected in unfiltered pore water samples (3 samples). All MDLs are less than the ESL of 250 pCi/L.

Seep/Spring. Potassium-40 was detected in 12 of 37 unfiltered seep/spring samples (32 percent frequency). Potassium-40 concentrations in unfiltered samples range from 18 to 542 pCi/L. Of the 12 detected results, one sample was reported with a concentration greater than the ESL of 250 pCi/L. Potassium-40 was reported at location Spring 28-2 (542 pCi/L) with a concentration greater than the ESL.

Surface Water. Potassium-40 was detected in three of eight unfiltered surface water samples (38 percent frequency) with concentrations ranging from 29 to 70 pCi/L. All potassium-40 concentrations and MDLs are less than the ESL of 250 pCi/L.

L3.3.6.15 Silver

Groundwater. Silver was not detected in filtered (5 samples) and unfiltered (4 samples) groundwater samples. Most MDLs are less than the ESL of 2.6 µg/L.

Aquifer Tubes. Silver was not detected in filtered (17 samples) and unfiltered (13 samples) aquifer tube samples. Most MDLs are greater than the ESL of 2.6 µg/L.

Pore Water. Silver was detected in one of three unfiltered pore water samples (33 percent frequency) at a concentration of 0.63 µg/L. The single silver concentration and all MDLs are less than the ESL of 2.6 µg/L.

Seep/Spring. Silver was detected in 11 of 14 unfiltered seep/spring samples (79 percent frequency) and was not detected in filtered seep/spring samples (10 samples). Silver concentrations in unfiltered samples range from 0.0058 to 0.074 µg/L. All silver concentrations and most MDLs are less than the ESL of 2.6 µg/L.

Surface Water. Silver was detected in 15 of 47 unfiltered surface water samples (32 percent frequency). Silver concentrations in unfiltered samples range from 0.0018 to 7.4 µg/L. Of the 15 detected results, one sample was reported with a concentration greater than the ESL of 2.6 µg/L and greater than the Hanford Site background level of 5.3 µg/L. Silver was reported at location TS-1 HRM 28.7 (7.4 µg/L) at a concentration greater than the ESL.

Silver was detected in one of 16 filtered surface water samples (6.3 percent frequency) at a concentration of 0.0037 µg/L. All silver concentration and MDLs in filtered samples are less than the ESL of 2.6 µg/L.

L3.3.6.16 Zinc

Groundwater. Zinc was detected in one of four unfiltered groundwater samples (25 percent frequency) at a concentration of 5.0 µg/L. Zinc was not detected in filtered groundwater samples (5 samples). The single zinc concentration and all MDLs in filtered and unfiltered samples are less than the ESL of 90 µg/L.

Aquifer Tubes. Zinc was detected in seven of 16 unfiltered aquifer tube samples (44 percent frequency) with concentrations ranging from 1.2 to 71 µg/L. Zinc was detected in 11 of 20 filtered aquifer tube samples (55 percent frequency) with concentrations ranging from 0.93 to 61 µg/L. All zinc concentrations in filtered and unfiltered samples are less than the ESL of 90 µg/L.

Pore Water. Zinc was detected in all three unfiltered pore water samples (100 percent frequency) with concentrations ranging 2.9 to 39 µg/L. All zinc concentration in unfiltered samples are less than the ESL of 90 µg/L.

Seep/Spring. Zinc was detected in all 17 unfiltered seep/spring samples (100 percent frequency). Zinc concentrations in unfiltered samples range from 1.3 to 113 µg/L. Of the 17 detected results, two samples were reported with concentrations greater than the ESL of 90 µg/L. Zinc was reported at location Hanford SPR UR 28-2 (113 µg/L) and 100-F Spring 207-1(106 µg/L) with concentrations greater than the ESL.

Zinc was detected in eight of 10 filtered seep/spring samples (80 percent frequency), with concentrations ranging from 0.54 to 3.1 µg/L. Zinc concentrations in filtered samples are less than the ESL of 90 µg/L.

Surface Water. Zinc was detected in all 50 unfiltered surface water samples (100 percent frequency) with concentrations ranging from 0.52 to 30 µg/L. Zinc was detected in all 16 filtered surface water samples (100 percent frequency) with concentrations ranging from 0.76 to 2.2 µg/L. All zinc concentrations in filtered and unfiltered samples are less than the ESL of 90 µg/L.

L3.4 Identification of Contaminants of Interest – Riparian Soil

COIs were identified using the same process that was used for water.

L3.4.1 Apply Exclusion Criteria

The analytes in riparian soil that do not have plant/invert ESLs are summarized in Table L-44 and Table L-45 for the 100-F Area and 100-IU Area, respectively. Analytes that do not have a wildlife screening level are summarized in Table L-46 and Table L-47 for the 100-F Area and 100-IU Area, respectively. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Table L-44 through L-47.

L3.4.2 Identify Nondetected Analytes

Analytes that were not detected in riparian soil samples and have a plant or invertebrate soil ESL are summarized in Table L-48 and Table L-49 for the 100-F Area and 100-IU Area, respectively. Analytes that were not detected in riparian soil samples but have a wildlife ESL are summarized in Table L-50 and Table L-51 for the 100-F Area and 100-IU Area, respectively. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Table L-48 and L-51.

L3.4.3 Identify Analytes with Maximum Detected Concentrations Less Than ESLs

A summary of the riparian soil analytes that do not exceed the lowest plant/invertebrate ESLs is provided in Table L-52 and Table L-53 for the 100-F Area and 100-IU Area, respectively. A summary of the riparian soil analytes that do not exceed the lowest wildlife ESLs is provided in Table L-54 and Table L-55 for the 100-F Area and 100-IU Area, respectively. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Table L-52 and L-55.

L3.4.4 Identify Analytes with Maximum Detected Concentrations Greater Than ESLs

This step identifies analytes with maximum concentrations greater than their plant/invert or wildlife ESLs.

L3.4.4.1 100-F Area

A summary of the riparian soil analytes that exceed the lowest plant/invertebrate ESLs is provided in Table L-56. As shown in Table L-56, chromium and copper are greater than the plant/invertebrate ESL.

- Chromium was detected in all 11 riparian soil samples (2 MIS locations), with concentrations ranging from 14.4 to 190 mg/kg. Chromium was detected above the invertebrate ESL of 149 mg/kg. Chromium was reported at location RCBRA Rip 7 with one sample greater than the ESL.

- Copper was detected in all 11 riparian soil samples (2 MIS locations), with concentrations ranging from 17 to 76 mg/kg. Copper was detected above the invertebrate ESL of 70 mg/kg. Copper was reported at location RCBRA Rip 7 with one sample greater than the ESL.

A summary of the riparian soil analytes that exceed the lowest wildlife PRGs is provided in Table L-57. As shown in Table L-57, aluminum, chromium, and vanadium are greater than the wildlife ESLs.

- Aluminum was detected in 11 riparian soil samples (2 MIS locations) with concentrations ranging from 5,390 to 7,830 mg/kg. Aluminum concentrations measured in riparian soil are less than the Hanford Site 90th percentile background value of 11,800 mg/kg.
- Chromium was detected in 11 RCBRA riparian soil samples (2 MIS locations), with concentrations ranging from 14.4 to 190 mg/kg. Chromium was reported at location RCBRA Rip 7, with five samples greater than the ESL of 109 mg/kg. An additional sample was also collected from near the 100-F-59 Area C that was reported at 286 mg/kg. This sample was initially reported as a sediment sample and is included as one of the six sediment samples for 100-F in section L3.5. However, the area is dry 7 months of the year and terrestrial pathways should also be evaluated. This detect at 286 mg/kg is above both the sediment and soil ESLs. Confirmation and verification sampling at the 100-F-59 site (128-F-2 Area C) is not included in the riparian soil summary tables which just included RCBRA samples. The verification sampling chromium results from the 100-F-59 waste site are displayed in Figure L-12 and L-13 and included detects as high as 671 mg/kg within what is referred to as Area C. The slough area south of the waste site also had concentrations up to 371 mg/kg. In total the 100-F-59 soil samples had 12 samples that exceeded terrestrial invertebrate ESLs and 19 that exceeded aquatic invertebrate ESLs. The 100-F-59 area also included samples above the wildlife ESL of 109 mg/kg that warranted further detailed discussion. Chromium in the 100-F-59 Area C, near waste site, and slough area are discussed in more detail in Section L4.7. A detailed discussion of the 100-F-59 area is presented in Section M.4.7.
- Vanadium was measured in 11 riparian soil samples (2 MIS locations), with concentrations ranging between 31 and 89 mg/kg. Vanadium concentrations measured in riparian soil are less than the Hanford Site 90th percentile background value of 85 mg/kg.

A discussion of the ecological risk considerations associated with this result is presented in Section L4.

L3.4.4.2 100-IU Area

A summary of the riparian soil analytes that exceed the lowest wildlife ESLs is provided in Table L-58. No analytes were reported with concentrations exceeding the lowest Plant/Invertebrate ESL. As shown in Table L-58, aluminum, bis(2-ethylhexyl) phthalate, and vanadium are greater than the wildlife ESL.

Aluminum was measured in 19 riparian soil samples (3 MIS samples) with concentrations ranging between 5,130 and 11,700 mg/kg. Aluminum concentrations measured in riparian soil are less than the Hanford Site 90th percentile background value of 11,800 mg/kg.

Bis(2-ethylhexyl) phthalate was detected in 19 riparian soil samples with concentrations ranging between 0.02 and 0.28 mg/kg. Although the maximum detected concentrations of bis(2-ethylhexyl) phthalate are greater than the ESL of 0.14 mg/kg, bis(2-ethylhexyl) phthalate is considered to be a common laboratory contaminant and is not related to the Hanford Site.

Vanadium was measured in 19 riparian soil samples (3 MIS samples) with concentrations ranging between 28 and 55 mg/kg. Vanadium concentrations measured in riparian soil are less than the Hanford Site 90th percentile background value of 85 mg/kg.

A discussion of the ecological risk considerations associated with this result is presented in Section L4.

L3.5 Identification of Contaminants of Interest – Nearshore Sediment

COIs were identified using the same process that was used for water.

L3.5.1 Apply Exclusion Criteria

The analytes in sediment that do not have an ESL are summarized in Table L-59 and Table L-60 for the 100-F Area and 100-IU Area, respectively. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Table L-59 and L-60.

L3.5.2 Identify Nondetected Analytes

Analytes that were not detected in sediment samples are summarized in Table L-61 and Table L-62 for the 100-F Area and 100-IU Area, respectively. Sampling dates and minimum and maximum MDLs are also provided in Table L-61 and Table L-62.

L3.5.3 Identify Analytes with Maximum Detected Concentrations Less Than ESLs

A summary of the sediment analytes that do not exceed the sediment screening levels is provided in Table L-63 and Table L-64 for the 100-F Area and 100-IU Area, respectively. Sampling dates, minimum and maximum detected concentrations, and minimum and maximum MDLs are also provided in Table L-63 and Table L-64.

L3.5.4 Identify Analytes with Maximum Detected Concentrations Greater Than ESLs

This step identifies analytes with maximum concentrations greater than sediment screening levels.

L3.5.4.1 100-F Area

A summary of the sediment analytes that exceed the lower threshold sediment screening levels is provided in Table L-65. Table L-65 shows that concentrations of four analytes (bis(2-ethylhexyl) phthalate, cadmium, chromium, and phosphorous) are greater than their sediment screening level.

In at least one sediment sample, there were metals (cadmium, chromium, and phosphorous) detected at concentrations higher than an ESL.

The analytes listed above that exceed the lower threshold sediment screening value are subsequently compared to the upper threshold sediment screening values; the results of this comparison are shown in Table L-66. Table L-66 shows that chromium exceeds the upper threshold sediment screening values.

Chromium was detected in six samples with concentrations ranging from 11 to 286 mg/kg. Of the six detections, one sample was reported with a concentration greater than the upper threshold sediment screening value of 88 mg/kg. Chromium was detected above the upper threshold sediment screening level at sampling location RCBRA 128F2 SED.

A discussion of the ecological risk considerations associated with this result is presented in Section L4.

L3.5.4.2 100-IU Area

A summary of the sediment analytes that exceed the lower threshold sediment screening levels is provided in Table L-67. Table L-67 shows that concentrations of one analyte (antimony) are greater than the sediment screening level.

In at least one sediment sample, there were metals (antimony) detected at concentrations higher than an ESL.

The analytes listed above that exceed the lower threshold sediment screening value are subsequently compared to the upper threshold sediment screening values; the results of this comparison are shown in Table L-68. Table L-68 shows that chromium exceeds the upper threshold sediment screening values.

Antimony was detected in two of four samples with at concentration of 2.3 and 5.9 mg/kg. Antimony was detected above the upper threshold sediment screening value of 0.6 mg/kg at sampling location 100 F Slough.

A discussion of the ecological risk considerations associated with this result is presented in Section L4.

L3.6 Data Evaluation Summary

A range of inorganic and radionuclide contaminants were detected in near-river groundwater samples collected from the 100-F/IU-2/IU6 OU. In many cases, these contaminants also could be detected in aquifer tube, pore water, spring/seep and surface water samples. In most cases, the analytical results that were most relevant to assessing aquatic water quality (i.e., from filtered analyses) were at concentrations below aquatic criteria. In other cases, where concentrations higher than aquatic criteria were observed, these results were associated with analytical data quality issues such as presence of contamination in blank samples, or elevated detection limits relative to the criteria.

The analytical results addressed in this evaluation did not provide evidence that contaminants from Hanford Site soils or groundwater or associated with Hanford Site operations evaluated in this appendix have potentially been discharged to riparian or nearshore media, or to the Columbia River. A more detailed discussion of potential ecological risks in the context of abiotic and biotic media evaluations and potential contributions to these risks from the Hanford Site is presented in Section L4.

L4 Summary of Ecological Risks

Ecological risks in riparian and nearshore areas were assessed as part of the RCBRA (DOE/RL-2007-21). The risk evaluation in this appendix incorporates the results from the assessment of ecological risks in the riparian and nearshore areas based on the data evaluation and calculations performed in the RCBRA (DOE/RL-2007-21).

The RCBRA (DOE/RL-2007-21) evaluated risks to an array of assessment endpoints using multiple measures of exposure, effect, and ecosystem/receptor characteristics at representative nearshore study sites. The study sites were selected to represent locations that may be adjacent to or directly affected by known contaminated media (groundwater seeps and springs, soil, sediment).

L4.1 Risks to Terrestrial Plants

As shown in Table 5-61 of the RCBRA (DOE/RL-2007-21), central tendency estimates (CTEs) of some COPECs in riparian soil collected across the Hanford Reach (i.e., estimate of central tendency across both the 100 and 300 Areas) exceeded literature-based plant SSL concentrations developed for the RCBRA (DOE/RL-2007-21), indicating that the potential for effects in plants warranted further evaluation. CTEs for arsenic, chromium, lead, vanadium, and zinc were greater than SSLs across the Hanford Site; in the 100-FR-1, 100-FR-2, 100-IU-2, and 100-IU-6 (100-F/IU) riparian soil study areas (2j, Riparian #7, 2l, 3b, and 4a), concentrations of arsenic, chromium, lead, vanadium, and zinc were higher than the benchmark values for protection of terrestrial plants (RCBRA [DOE/RL-2007-21], Table 5-61). SSLs are literature-based values compiled from state and federal criteria and were initially presented in both the RCBRA (DOE/RL-2008-21) and in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784). For risk driving inorganics, bioassays were collected using a representative native plant species (Sandberg's bluegrass [*Poa secunda*]) to develop site specific

toxicity thresholds. These refined values were presented in the RCBRA (DOE/RL-2007-21) and used to establish plant PRGs. Additional bioassays were conducted in 2011 on the same species with a broader concentration gradient of inorganic constituents to further refine toxicity thresholds and establish PRGs as described in *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site* [ECF-HANFORD-11-0158]. The organic SSLs and inorganic PRGs were identified as the ecological ESLs presented in this RI/FS as summarized in Table L-4.

Measurements of all chemicals within the riparian soils of the 100-F/IU OUs were below plant ESLs, except for one occurrence of copper within the 100-F OUs (Table L-56). Also, other lines of evidence obtained through seven different measures in bioassay testing indicate that COPECs may not adversely affect riparian plants, including those at the rare plant sites which performed better than bioassays from reference soils. Bioassays showed no differences in plant growth between study sites and reference sites. Some chemicals were detected in plant tissues, but the concentrations of the chemicals were statistically different between riparian study area site concentrations and reference site concentrations for only four chemicals: barium, copper, thallium, and zinc (Table 5-32, RCBRA [DOE/RL-2007-21]). Similar to the upland plant data, chemical concentrations found in riparian plant tissues did not correlate to those in riparian soil. Therefore, although soil concentrations are greater than plant SSLs for some chemicals, the weight attributed to this line of evidence is low, and SSL hazard quotient (HQ) results do not overwhelm the conclusions of the other lines of evidence. While several analytes were detected in RCBRA plant tissue, and statistical differences between riparian study area sites and reference site concentrations were noted, there were no statistically significant relationships of chemical concentrations in plant tissue and soil. Therefore, no chemicals are in 100-F/IU2/IU6 riparian soils that warrant further evaluation in the FS, based on risks to terrestrial plants.

L4.2 Risks to Aquatic Plants

Potential effects on aquatic plants were evaluated through comparison of sediment and pore water concentrations to screening levels developed for the RCBRA (DOE/RL-2007-21; Tables 6-88 through 6-91) and CRC ecological risk assessment (DOE/RL-2010-117) and results of a bioassay in sediment (DOE/RL-2007-21). The combined pore water and sediment concentrations RCBRA COECs were identified as cadmium, total chromium, Cr(VI), manganese, and uranium warranting further evaluation for potential effects on aquatic plants, as noted in Section 8.5.1.1 (DOE/RL-2007-21). The Executive Summary of the CRC (DOE/RL-2010-117) identified the final COECs for pore water and sediment within the 100-FR-3 OU as Cr(VI) and manganese.

Laboratory bioassays (i.e., toxicity tests) were conducted with field-collected sediments. Some significant relationships were determined with observed response within aquatic plant toxicity tests in association with confounding factors and some chemicals. Additionally, there were clear measures of exposure (i.e., accumulation into plants), primarily for inorganic COPECs that were detected in pore water and sediment. However, of the significant relationships determined, none was with COPECs for which pore water concentrations were greater than aquatic plant benchmarks. Further, no risks to aquatic plants were noted based on toxicity testing. Though the analysis represents only one season of sampling and analysis, the weight of the available data does not suggest risk to plants.

For the 100-F nearshore sampling sites, total chromium and, for the 100-IU-2/IU-6 sites, antimony were detected in sediment at concentrations greater than the upper threshold sediment biota ESL. However, the RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) did not identify these analytes as COECs for aquatic plants, so additional evaluation for risks to aquatic plants is not warranted for these COPECs. These sediment COPECs are discussed in more detail below with respect to risks to aquatic invertebrates.

Pore water data were not collected specifically within 100-F nearshore sampling sites. For 100-IU-2/IU-6 nearshore sampling sites, the pore water concentration for aluminum was greater than the water criteria (Table L-40). No other chemicals in pore water samples from the 100-F/IU Groundwater OUs exceeded water ESLs. The 100-F/IU nearshore water data are further discussed in Section 3.3.4 of this Appendix. The RCBRA (DOE/RL-2007-21) and CRC (DOE/RL-2010-117) pore water COECs, as well as the 100-F/IU nearshore pore water COPECs, are discussed below in more detail, with respect to potential contributions from the 100-F/IU2/IU6 riparian area to risks to aquatic plants in the Columbia River.

Aluminum – Within the 100-IU-2/IU-6 Areas, concentrations of aluminum were elevated in one of three unfiltered pore water samples (Table L-43). Three of four unfiltered seep samples exceeded the ESL; however, none of the filtered seep samples exceeded. No filtered or unfiltered nearshore groundwater wells exhibited concentrations in excess of the ESL. Within the 100-F Area, only two of three unfiltered seeps exceeded the ESLs, while all other aqueous media sampled were below the ESL (nearshore groundwater wells and aquifer tubes). Thus, aluminum within the 100-FR-3 Groundwater OU is not contributing to concentrations of aluminum within the reach of the Columbia River.

Cr(VI) – Concentrations of Cr(VI) were elevated in pore water samples presented in the CRC (DOE/RL-2010-117), for the 100-HR-3, 100-FR-3, 200-PO-1, 100-KR-3, 100-NR-2, and 100-BC-5 OUs and in the RCBRA (DOE/RL-2007-21). Within 100-IU-2/IU-6, aquifer tube samples (1 of 12 filtered and 2 of 25 unfiltered) exceeded the ESL (Table L-43). Samples collected within all other the 100-IU riparian and nearshore aqueous media (pore water, seep, and nearshore well samples) were below the ESL. Within the vicinity of 100-F, Cr(VI) samples were detected above the ESL in aquifer tubes (1 of 50 filtered samples and 4 of 50 unfiltered samples), seeps (1 of 1 sample), and groundwater wells (5 of 18 filtered samples and 4 of 19 unfiltered samples). While concentrations appear to be decreasing (Table L-37) as they approach the hyporheic zone (i.e., they are decreasing at the point of exposure where groundwater meets pore water). Cr(VI) within the 100-FR-3 Groundwater OU has some limited potential to discharge to surface water above ambient water quality standards. Therefore, it is recommended to be monitored at discharge points to surface water and be brought forward to the alternatives evaluation in the 100-F/IU FS.

Manganese – Manganese was elevated in pore water samples presented in the RCBRA (DOE/RL-2007-21) and for the 100-FR-3 and 100-KR-4 in the CRC (DOE/RL-2010-117). Within the vicinity of 100-IU, only aquifer tubes (1 of 20 filtered samples and 1 of 16 unfiltered samples) exceeded the ESL (Table L-43). Samples collected within all other 100-IU riparian and nearshore aqueous media (pore water, seeps, and nearshore well samples) were below the ESL. Further, within the 100-F Area, all aqueous media (groundwater, aquifer tubes, and filtered seeps) were detected below the ESL, except one of three unfiltered seeps samples (Table L-37). Therefore, manganese concentrations from 100-F/IU OUs are not contributing to concentrations of manganese within the reach of the Columbia River adjacent to or downstream from the 100-F/IU OUs nearshore area.

Nitrate – Concentrations of nitrate were elevated in pore water samples presented in the CRC ERA (DOE/RL-2010-117) for 100-NR-2, 100-HR-3, and 300-FF-5, but not for 100-FR-3. Although these concentrations were greater than the benchmark, concentrations were equal to or less than reference sites, presented in the CRC (DOE/RL-2010-117). Nitrate was not identified as a COEC for 100-FR-3 in the CRC ERA (DOE/RL-2010-117) or the RCBRA (DOE/RL-2007-21). The value identified in the RCBRA (DOE/RL-2007-21, Volume I) was considered uncertain; therefore, no value was recommended for toxicity to plants. Nitrate is not considered a COPEC for aquatic plants.

Uranium – Uranium was elevated in pore water samples presented in the RCBRA (DOE/RL-2007-21). While concentrations of uranium were elevated in one nearshore groundwater well unfiltered sample

(Table L-37) within 100-F, all other aqueous media samples collected within the vicinity of 100-F or 100-IU OUs were below the ESL. Thus, uranium within the 100-F/IU OUs is not contributing to concentrations of uranium observed in pore water.

L4.3 Risks to Terrestrial Invertebrates

Concentrations of chromium, mercury, copper, and zinc in riparian soil exceeded benchmarks developed for the RCBRA (DOE/RL-2007-21) that are protective of terrestrial invertebrates (RCBRA [DOE/RL-2007-21], Tables 5-69 and 5-70). However, only concentrations of chromium and copper were above Hanford Site-specific ESLs protective of terrestrial invertebrates (Table L-56 of this appendix). Total chromium and copper concentrations were detected, at one of eleven locations, in the 100-F riparian soil study sites in exceedance of Hanford Site-specific ESLs for soil². Measurements of all other chemicals within the riparian soils of the 100-F/IU Source OUs were below soil invertebrate ESLs. The maximum detects of chromium and copper exceed ESLs that represent NOECs; thus, there is no certainty that any adverse effects would occur at the concentrations observed. The magnitude of exceedances of these NOECs is low as less than two times the ESL. Also, there is ample unaffected habitat for terrestrial invertebrates available in the adjacent area and along the River Corridor. Hence, no further evaluation is warranted.

Terrestrial invertebrate tissue concentrations, which provide an indication of contaminant uptake and bioavailability, were measured at River Corridor study sites and reference locations, and some, but not all, COPECs were detected in terrestrial invertebrates. Statistical differences were found between RCBRA (DOE/RL-2007-21) terrestrial invertebrate tissue concentrations for some chemicals between study sites and reference sites. However, this line of evidence was ranked low in the RCBRA (DOE/RL-2007-21) because of the lack of detections in invertebrate tissue for riparian COPECs and the possibility of bias because of sample collection methods. Statistical differences in tissue concentrations of zinc and mercury in terrestrial organisms were noted between River Corridor and reference study sites; this relationship is based on data across the entire River Corridor and should not be inferred as a relationship that is specific for 100-F/IU. However, there is insufficient evidence for chemicals in general of a correlation between tissue concentrations in terrestrial invertebrates and concentrations in soil (DOE/RL-2007-21). Based on this analysis, no chemicals in riparian soil for terrestrial invertebrates warrant further evaluation in the FS because of risks to terrestrial invertebrates.

L4.4 Risks to Aquatic Invertebrates

The primary lines of evidence used to evaluate risks to aquatic invertebrates are field surveys, the results of bioassays, and comparison of sediment and water concentrations to benchmarks, such as ESLs.

L4.4.1 Abiotic Media Concentrations Compared to Literature Values

The final COECs for pore water in CRC within 100-FR-3 OU were identified as Cr(VI) and manganese, as noted in the executive summary of the CRC (DOE/RL-2010-117). Pore water concentrations at study sites were greater than chronic ambient water quality criteria or benchmarks for three COECs (Cr(VI), manganese, and uranium) (RCBRA [DOE/RL-2007-21], Sections 8.5.1.1 and 8.5.1.2). A more detailed discussion of each of the three COECs from the RCBRA (DOE/RL-2007-21, Volume I) and CRC ERA (DOE/RL-2010-117) is presented in the following paragraphs.

² As described briefly in Section L3.4 and in more detail in Section L4.7, twelve of 60 samples collected for verification samples in and around the 100-F-59 waste site exceed the chromium terrestrial invertebrate ESL but are not expected to result in a community level impact.

Cr(VI) - Detected in two of three RCBRA (DOE/RL-2007-21) pore water samples in 100-IU-2/IU-6 near-shore area. Within 100-IU-2/IU-6, aquifer tube samples (1 of 12 filtered, and 2 of 25 unfiltered) exceeded the ESL (Appendix L, Table L-43). Samples collected within all of the other the 100-IU-2/IU-6 riparian and near-shore aqueous media (pore water, seep, and near-shore well samples) were below the ESL. Within the vicinity of 100-F, Cr(VI) samples were detected above the ESL in aquifer tubes (1 of 50 filtered samples, and 4 of 50 unfiltered samples), seeps (1 of 1 sample), and near-shore groundwater wells (5 of 18 filtered samples, and 4 of 19 unfiltered samples). Concentrations appeared to be decreasing (Appendix L, Table L-37) as they approach the hyporheic zone (i.e., decreasing at the point of exposure where groundwater meets pore water). Cr(VI) within the 100-FR-3 Groundwater OU was not contributing to concentrations in the Hanford Reach of the Columbia River adjacent to or downstream from the 100-FR-3 Groundwater OU near-shore area. However, while Cr(VI) has not been determined to be an ongoing risk for aquatic invertebrates within the area of discharge of the 100-F/IU OUs, there is some potential for groundwater discharge above state surface water quality standard at discharge points to surface water. Therefore, monitoring is recommended to ensure that ARARs are met.

Manganese - was identified as COEC in the CRC (DOE/RL-2010-117) based on 1 of 3 detections exceeding the LOEC ESL of 1.31 mg/L. Within the vicinity of 100-IU-2/IU-6, only aquifer tubes (1 of 20 filtered samples, and 1 of 16 unfiltered samples) exceeded the ESL (Appendix L, Table L-43). Samples collected within all other 100-IU-2/IU-6 riparian and near-shore aqueous media (pore water, seeps, and near-shore well samples) were below the ESL. Further, within the reach of the Columbia River to which the 100-FR-3 discharges, all aqueous media (groundwater, aquifer tubes, and filtered seeps) were detected below the ESL, except one of three unfiltered seep samples. Therefore, it was concluded that there was no elevated risk to aquatic invertebrates from concentrations of manganese from the 100-FR-3 Groundwater OU.

Uranium - Uranium was not sampled from the 100-F near-shore area pore water and was not detected in the pore water from the 100-IU-2/IU-6 near-shore area. While concentrations of uranium were elevated in one near-shore groundwater well unfiltered sample (Appendix L, Table L-37) within 100-F, all other aqueous media samples collected within the vicinity of the 100-F or 100-IU-2/IU-6 OUs were below the ESL. Therefore, it was concluded that there was no elevated risk to aquatic invertebrates from concentrations of uranium from the 100-FR-3 Groundwater OU.

Nitrate - Nitrate was given additional consideration for aquatic invertebrates because of the uncertainty associated with the plant ESL and because the concentrations identified at other OUs may be in plumes going to the river. Nitrate was not identified as a COEC for 100-F/IU OUs in the CRC (DOE/RL-2010-117) or RCBRA (DOE/RL-2007-21). Nitrate exceeded the LOEC screening benchmark (37.64 mg/L) in aquifer tubes (6 of 100 samples in 100-F/IU OUs combined), but was below the LOEC benchmark for all other media (nearshore groundwater wells) (Tables L-37 and L-43) except seeps. Nitrate was not sampled in seeps, pore water, or surface water samples for this evaluation. Nitrogen in nitrate concentrations are likely predominantly based on nitrate and were greater the NOEC ESL (7.1 mg/L) at only one surface water location and seeps (31 of 36 samples). Nitrogen in nitrate concentrations were detected below the nitrate LOEC ESL in 27 of 36 seep samples and in all but 1 of 64 total surface water samples. Further, within other OUs, such as 100-N, key community metrics did not suggest that contaminant-related impacts to benthic macroinvertebrates were evident in aquatic study sites as a group. As noted in Section 7.2.2 of the CRC (DOE/RL-2010-117), analytical results for nitrate in the Columbia River mid channel surface water indicated that the downstream study area concentrations were statistically lower than or not significantly different than concentrations found in reference locations. While aquifer tubes may suggest there is an ongoing source of nitrate to the Columbia River, there is no direct evidence of ecological risk. Future risks are not expected either because the maximum plume concentration of 100 mg/L nitrate representing the future groundwater source to the Columbia River is equal to the nearshore plume concentration of 100 mg/L

within the 100-NR-2 Groundwater OU for which no evidence of ecological risk was found (*Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units* [DOE/RL-2012-15]).

No further consideration is warranted for nitrate with the 100-F/IU OUs for aquatic invertebrates.

The RCBRA identified three COECs (cadmium, chromium, and manganese) in sediment for the River Corridor as a whole (RCBRA [DOE/RL-2007-21], Sections 8.5.1.1 and 8.5.1.2). Total chromium and Cr(VI) in sediment were also identified as COECs for the 100-Area OUs in the CRC (DOE/RL-2010-117). For sediment samples collected within the 100-F/IU2/IU6, nearshore, concentrations were greater than ESLs for two chemicals (total chromium and antimony) (Tables L-66 and L-68). Given the uncertainty with representativeness mentioned above, a more detailed discussion of each of the five COECs/COPECs from the RCBRA (DOE/RL-2007-21), CRC (DOE/RL-2010-117), and 100-F/IU nearshore sediment is presented below.

Antimony – Antimony was detected in two (2.3 mg/kg and 5.9 mg/kg) of four samples within the 100-IU nearshore sediments. Both detected concentrations (samples B0G184 and B0CWF0) from the slough exceeded the ESL. The groundwater/seep/pore water analysis showed no substantial concentrations of antimony, as concentrations were below the ESL and background. Thus, concentrations were not likely from suspended solids in groundwater. Table 5-29 of the RCBRA (DOE/RL-2007-21) indicates that antimony concentrations across the Hanford Site riparian soils were not statistically different from riparian reference soil concentrations (maximum = 0.83 mg/kg). Riparian soil concentrations (900 µg/kg) are significantly lower than sediment concentrations (5,900 µg/L); indicating overland flow is not likely. With no groundwater or soil contributions identified, there is no complete pathway for observed antimony concentrations in sediment from the 100-F/IU2/IU6 Source OUs.

Cadmium – Cadmium was identified as a COEC for sediment along the River Corridor (RCBRA [DOE/RL-2007-21]). The maximum study site sediment concentration was 2.4 mg/kg at sample U10 (300 Area), which was not within the 100-F/IU2/IU6 Area. Cadmium was detected in three of six sediment samples in the 100-F nearshore environment and in all five samples in the 100-IU nearshore environment, with all concentrations below the upper threshold ESL of 5.4 mg/kg. The groundwater/seep/pore water analysis showed no substantial concentrations of cadmium related to the 100-F/IU2/IU6 Area, as concentrations were below the ESL and/or background. Thus, concentrations were not likely from suspended solids in groundwater. There is no complete or significant pathway for observed cadmium concentrations in sediment from the 100-F/IU2/IU6 riparian area.

Total Chromium³ – Total chromium was identified as a sediment COEC for the 100 Area in the CRC (DOE/RL-2010-117) because of concentrations above a LOEC in three of the 123 samples collected. It was also identified as a COPEC in the RCBRA (DOE/RL-2007-21). One CRC (DOE/RL-2010-117) sample that exceeded the ESL was located upstream of 100-F across from the 100-N reactor at 122 mg/kg, a second was identified across from the White Bluffs town site (IU2) at 275 mg/kg, and one was identified across from the 100-F reactor at 151 mg/kg. The other CRC (DOE/RL-2010-117) sediment samples adjacent to 100-F and downstream in the slough area were all below the ESL. The CRC (DOE/RL-2010-117) samples were collected in the midchannel area and are not marked on Figures L-8 through L-11. Chromium was detected in all six sediment samples collected for the RCBRA (DOE/RL-2007-21) from the 100-F nearshore environment, with one detection reported above the upper threshold ESL of 88 mg/kg. Verification sampling at the 100-F-59 waste site, conducted after completion of the RCBRA sampling, also included close to 60 samples, 19 of which exceeded the sediment ESL;

³ This discussion does not include the slackwater slough, downstream of the former 100-F-2 waste site. The slackwater slough and the 100-F-59 site are discussed separately in Section L4.7. The location of the slackwater slough can be identified by the designation of the samples from this slough presented in Figure L-13.

however, as noted briefly in Section L3.4 and in greater detail in L4.7, these samples are reflective of a terrestrial environment more than half the year and are not expected to result in community level impacts to benthic or terrestrial organisms. The RCBRA (DOE/RL-2007-21) samples for 100-F are described in Section L2 and are identified in Figures L-8 through L-11. As shown more clearly in Figure L-12⁴, one of the RCBRA samples (the maximum soil/sediment sample of 286 mg/kg) was collected at the southwest corner of the 100-F-59 waste site. This area is only inundated above 210 kcfs (April to August) and, while identified as sediment, actually represents a soil sample from a riparian area. Chromium concentrations in all five sediment samples from the 100-IU Area, again identified in Figures L-8 through L-11, were below the lower threshold ESL. Table 5-29 of the RCBRA (DOE/RL-2007-21) indicates that chromium concentrations across the Hanford Site riparian soils were statistically different from riparian reference and background soil concentrations. Chromium was detected in all 30 riparian soil samples in the 100F/IU2/IU6 Areas with a maximum detect of 190 mg/kg in the RCBRA MIS sample (Table L-57, Figure L-13)⁵. As presented above, the detailed analysis, the groundwater/seep/pore water analysis, showed no substantial concentrations of chromium related to the 100-F/IU2/IU6 Area.

The sample measured at 286 mg/kg and the riparian soil MIS sample were collected in an area near the former 100-F-2 burn pit. The 100-F-2 burn pit source area has been removed. The area that remains today is only seasonally inundated when river flow is at 210 kcfs or greater. Thus, exposure of benthic organisms where the chromium was measured above the ESL is not reflective of a high quality habitat. From September to the end of March, this area is not inundated and represents a terrestrial environment, not an aquatic habitat. While some smaller and free floating benthic species may wash into the area when river flow exceeds 210 kcfs, these aquatic species are only temporary residents and will not survive once the area dries out. A resident benthic community is not present.

With respect to the remaining nearshore sediment area samples, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there was no correlation between chromium concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*)⁶. Figures L-12 and L-13⁷ demonstrate that concentrations closest to the river are all below the ESL (88 mg/kg) suggesting that source material is not reaching the river. With source material not reaching the river, no correlation between chromium and bioassay results on sensitive species in nearshore sediment samples, no resident community present in the only area exceeding the ESL (which is in a riparian soil environment) coupled with a unique environment that does not support establishment of a resident community, the conclusion was that no further evaluation was warranted for effects to benthic organisms.

⁴ Figures L-12 and L-13 present chromium verification sample results collected between January 2007 and 2008 in the vicinity of 100-F-59 (formerly 128-F-2 Area C) after the closure of 128-F-2. RCBRA nearshore and riparian MIS samples collected in the same vicinity are also depicted for a complete understating of the distribution.

⁵ This maximum of 190 mg/kg was from the Riparian 7 MIS sample, also in the vicinity of 100-F-59, that is evaluated in detail in Section L4.7.

⁶ No sediment bioassay was conducted on the sample measured at 286 mg/kg. However, as described previously, exposure of benthic organisms in this area is not realistic as the habitat is ephemeral, and no resident community is present.

⁷ Within Figures L-12 and L-13, lines are drawn to depict where soil becomes temporarily inundated when river stage exceeds 210 and 300 kcfs. For 7 months of the year (September through March), these areas are dry. Beginning in April, the areas become inundated when river stage exceeds 210 kcfs and remain such until they gradually dry out once river stage decreases. Inundation can last through the end of August, though decreasingly less area is uninundated once not recharged by the river. These maps also show that samples are located below the OHWM.

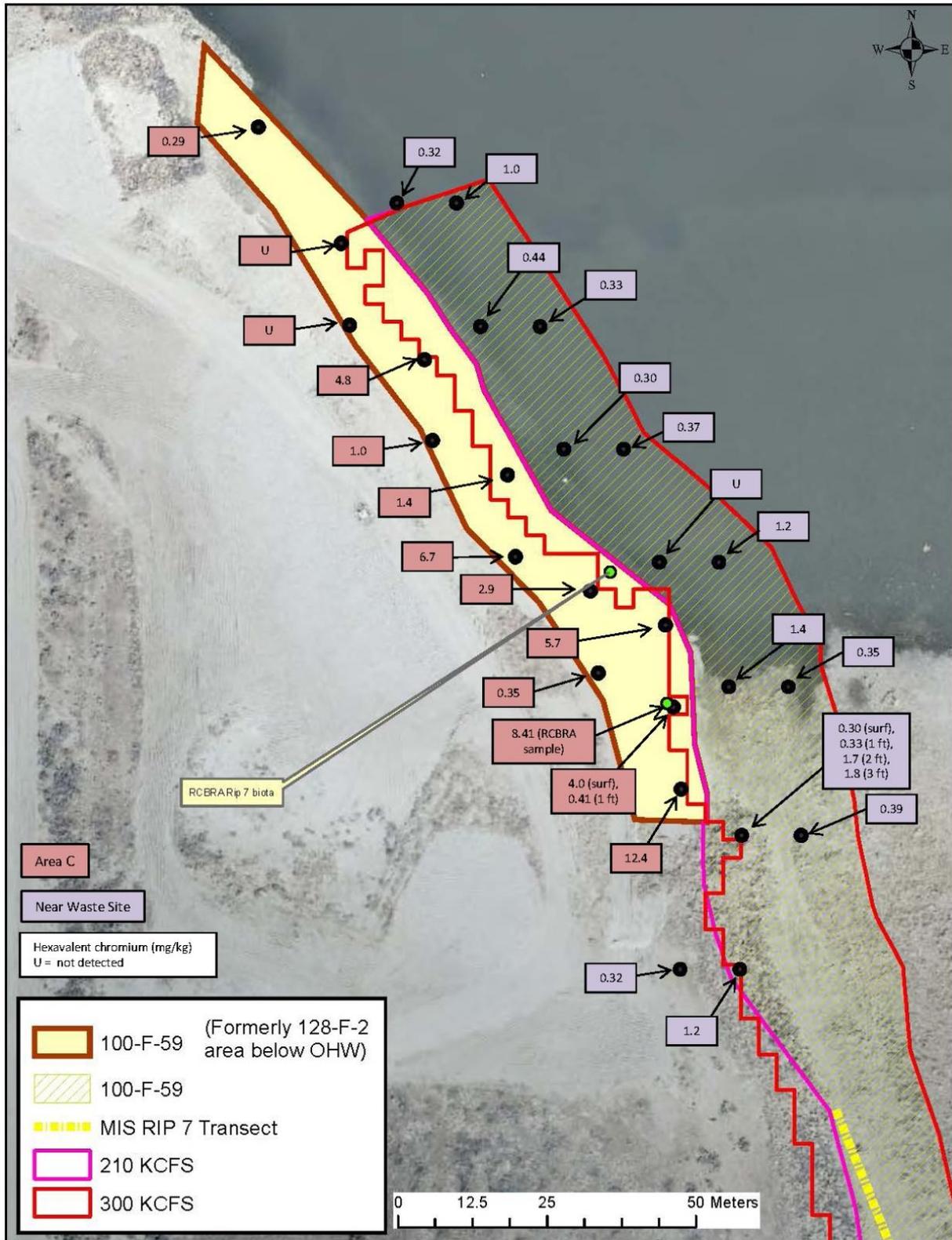


Figure L-12. Chromium Samples Collected at the 100-F-59 Waste Site

Cr(VI) – Cr(VI) is a known site contaminant of concern and was detected in 31 of 117 sediment samples in the 100-Areas reach of the Columbia River as part of the CRC ecological risk assessment (DOE/RL-2010-117) with a maximum of 7.38 mg/kg. It was also detected in nearshore sediment samples collected for the RCBRA (DOE/RL-2007-21) at 8.41 mg/kg at 100-IU-2/IU-6 (sample 128-F2). With no substantial toxicological data available with which to evaluate the bulk sediment measurements, this contaminant was identified as a COPEC in both reports.

Although there are acknowledged groundwater plumes of Cr(VI) that could serve as a potential source to sediments, Cr(VI) does not persist in natural aquatic environments such as those present in the Columbia River. Oxidation of Cr⁺³ to Cr⁺⁶ has been observed in soil and sediment under oxidizing conditions (*Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 2, Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium* [EPA/600/R-07/140]). *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc)* [EPA-600-R-02-011], Appendix D: Chromium) states that geochemical processes govern the reduction of Cr(VI) to Cr(III) in aquatic environments, and geochemical processes are critical to the attenuation of chromium in sediments. The presence of Chromium(III) is strongly favored in natural waters and sediments because the concentrations of sediment constituents known to reduce Cr(VI) to Chromium(III) generally far outweigh the concentrations of the few constituents known to oxidize Chromium(III) to Cr(VI). Furthermore, once reduced, Chromium(III) is very stable in aquatic environments and highly unlikely to oxidize to Cr(VI). Thus, chromium in sediments is more likely to be in its Chromium(III) form than its Cr(VI) form (“Behavior of Chromium in Soils: V. Fate of Organically Complexed Cr(III) Added to Soil” [James and Bartlett, 1983]; “Chromium(III) Oxidation by Delta-MnO₂. 1. Characterization” [Fendorf and Zasoski, 1992]; “Fractionation and Oxidation of Chromium in Tannery Waste- and Sewage-Sludge-Amended Soils” [Milacic and Stupar, 1995]; “The Reactivity of Seven Mn-oxides with Cr³⁺aq: A Comparative Analysis of a Complex, Environmentally Important Redox Reaction” [Weaver and Hochella, 2003]).

More detail regarding the Cr(VI) in sediment and the environment within the Columbia River and particularly at groundwater upwelling locations is found in *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington* (WCH-398) and *Field Summary Report for the 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). Because pore water is the major indicator for risk for Cr(VI), and Cr(VI) has some limited potential to discharge to surface water above ambient water quality standards, it is recommended to be monitored at discharge points to surface water.

Manganese – Manganese was identified as a COEC for sediment along the River Corridor (RCBRA [DOE/RL-2007-21]). The maximum study site sediment concentration was 920 mg/kg at Sr6 (in 100-N OUs), which was not within the 100-F/IU Area. Further, all manganese study site concentrations are rarely greater than the maximum reference site concentration (RCBRA [DOE/RL-2007-21], Figure 8-34). Manganese was detected in all 11 sediment samples in the 100-F/IU nearshore environment, with all concentrations below the screening level of 460 mg/kg published in Buchman, 2008 (Tables L-63 and L-64). The groundwater/seep/pore water analysis showed no substantial concentrations of manganese related to the 100-F/IU Area. Thus, concentrations were not likely from suspended solids in groundwater. Manganese was detected in all 30 soil samples collected below the ESL (Tables L-53 and L-54). Although, maximum soil concentrations were greater than the maximum sediment concentrations, Table 5-29 of the RCBRA (DOE/RL-2007-21) indicates that manganese concentrations across the Hanford Site riparian soils were not statistically different from riparian reference soil concentrations or background. There is no complete or significant pathway for observed manganese concentrations in sediment from the 100-F/IU riparian areas.

L4.4.2 Direct Toxicity Measures

Risks to aquatic macroinvertebrates based on toxicity testing showed some relationships with confounding factors and some chemicals. Histopathology measures differed in study sites compared to reference sites; these measures also showed some negative relationships with chemicals. Sediment bioassays representing 100-F/IU showed statistical difference in amphipod (*Hyalella azteca*) survival relative to reference sites at 2j and 2l, and 4c (low survival and growth) (DOE/RL-2007-21; Section 6.3.5.2 and Table 6-105). However, there was no overall correlation between amphipods and chemistry data, with the exception of mercury. Correlation between abiotic media chemistry and any observed differences in measured effects from bioassays was conducted across the whole Hanford Reach, instead of at individual OU areas. Across the Hanford Reach, mercury was the only chemical with a significant correlation that showed a potential negative effect with a significant regression for amphipods in sediment; however, mercury was below sediment ESLs at the 100-F/IU study sites. Clams were also monitored for survival. There was a statistical decrease in survival at study sites compared to reference sites, but there was no correlation of clam survival with COPECs. Together these measures do not indicate substrate concentrations were toxic. However, they do represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations.

L4.4.3 Community Structure Measures

Key community metrics do not suggest that contaminant-related impacts to benthic macroinvertebrates are evident in aquatic study sites as a group, as evident by the comparison of Ephemeroptera, Plecoptera, Trichoptera data from study sites relative to reference sites. Most of the aquatic community measures did not differ between the study sites and reference sites. There were exceptions among the large number of aquatic community measures evaluated, but the agreement among measures was weak and the biological significance to populations is not evident.

L4.4.4 Measures of Exposure

Within the RCBRA (DOE/RL-2007-21), clear measures of exposure (accumulation), primarily for inorganic COPECs, were detected in water, sediment, and tissues. There were no statistically significant correlations between COPEC concentrations in pore water or sediment with tissues of aquatic organisms, indicating a lack of significant COPEC bioaccumulation. Further, no tissue effect levels for COPECs in invertebrate tissue were exceeded.

Most histopathology measures of clams and mussels showed no significant differences between study sites and reference. While there were some exceptions, COPEC concentrations generally did not correlate with differences in histopathology measures.

L4.4.5 Weight of Evidence

As stated previously, both the abiotic and biotic measures collected for the RCBRA (DOE/RL-2007-21) represent only a snapshot in time and do not represent all seasonal conditions and river stage fluctuations. Abiotic measurements do exceed literature based screening values for some COPECs, and this line of evidence is generally given the lowest weight given the lack of site-specificity in the literature-based values. Although biological measures give a different perspective than the chemistry, given the limited data set and the uncertainty with full representation of seasonal measurements, the results of the chemistry cannot be ignored.

Of the key groundwater plume contaminants investigated, none have been detected at concentrations of ecological relevance in the nearshore environment for 100-F/IU OU's decision area. For the 100-F/IU area, no COPECs in groundwater in the 100-FR-3 Groundwater OU represent a potential ongoing source

for pore water concentrations that exceed water quality criteria; therefore, no further evaluation is warranted in the FS. This conclusion is applicable to both aquatic invertebrates and amphibians.

L4.5 Risk to Riparian Wildlife

For riparian soils, field ecological measures of the small mammal community were developed as qualitative information on the status of these populations. Estimated dietary contaminant exposures and biological concentrations in bird or small mammal tissues are compared to ecological effects levels established for dietary ingestion or related to tissue residues. For selected COPECs (cadmium, chromium, lead, selenium, and PCBs), measured tissue concentrations in small mammals trapped in River Corridor study sites were not greater than reference areas (RCBRA [DOE/RL-2007-21], Table 5-48), and were less than available tissue effect levels (RCBRA [DOE/RL-2007-21], Volume 1, page 5-91). Dietary exposure to terrestrial birds and mammals estimated using wildlife exposure models, estimated for riparian concentrations across the River Corridor indicated potential exposure higher than lowest observed adverse effect level (LOAEL)-based SSL values for copper, selenium, vanadium, and zinc. Only zinc was identified as a final COEC for risk to birds and mammals from riparian soils (RCBRA [DOE/RL-2007-21], Section 8.4.1.3). PRGs for wildlife exposure to zinc (856 mg/kg and 1,037 mg/kg) were compared with the highest zinc concentration in 100-F/IU riparian soil (621 mg/kg). The results from this comparison show that all zinc concentrations fall below the PRG (Tables L-54 and L-55). Therefore, zinc concentrations in riparian soil do not warrant further evaluation in the FS based on risks to wildlife.

Most concentrations detected in riparian soils within the 100-F/IU fell below ESLs (in this case, specifically SSLs and PRGs described earlier) and do not warrant further evaluation in the FS with the exception of aluminum (Tables L-57 and L-58). While all samples were above the ESLs for mammals, the EPA ecological soil screening level (EcoSSL) for aluminum (*Ecological Soil Screening Level for Aluminum: Interim Final* [OSWER Directive 9285.7-60]) presents a clear discussion that toxicity is only identified in soils when the pH is 5.5 or less. Measures of pH in soils in the 100-F/IU Area are above 5.5; thus, aluminum toxicity to wildlife is not a concern (RCBRA [DOE/RL-2007-21], Table 5-65).

Within the RCBRA (DOE/RL-2007-21, Section 8.5.1.5), information on dietary contaminant exposures were also compared to ecological dietary effects levels to assess risks to birds and mammals potentially exposed to contaminants in nearshore sediments, biota, and water. Only chromium was considered a final COEC based on a LOEC HQ of 1.2 for the bufflehead at a single study site. The single study site (2m) for which this risk was associated is within the 100-F/IU nearshore environment (RCBRA [DOE/RL-2007-21]). Although chromium exposures are greater than the LOAEL and sediment and pore water concentrations are statistically greater than reference, it does not necessarily indicate risk to populations of the bufflehead or other waterfowl found in the vicinity of the site.

Scatterplots (Figures L-14 and L-15) of paired sediment and benthic invertebrate chromium data (Table L-69) from the RCBRA (DOE/RL-2007-21) showed a single observation falling outside the distribution of the other observations. An outlier test was, therefore, performed to determine whether this sample was a statistical outlier. Grubb's test was performed on the tissue and sediment chromium data and on the station-specific bioaccumulation factor (BAF) (Table L-70). Chromium in tissue and the associated BAF for the samples from the 2m location were statistically identified as outliers; chromium in sediment from this location was not. This indicates that chromium concentrations in tissue but not sediment from 2m are anomalous and unrepresentative of tissue concentrations of chromium observed at the other 34 sample locations for which co-located tissue and sediment data are available. Exclusion of sample 2m from the wildlife exposure calculations results in no point estimates for the bufflehead above the LOAEL (RCBRA [DOE/RL-2007-21], Table 6-124).

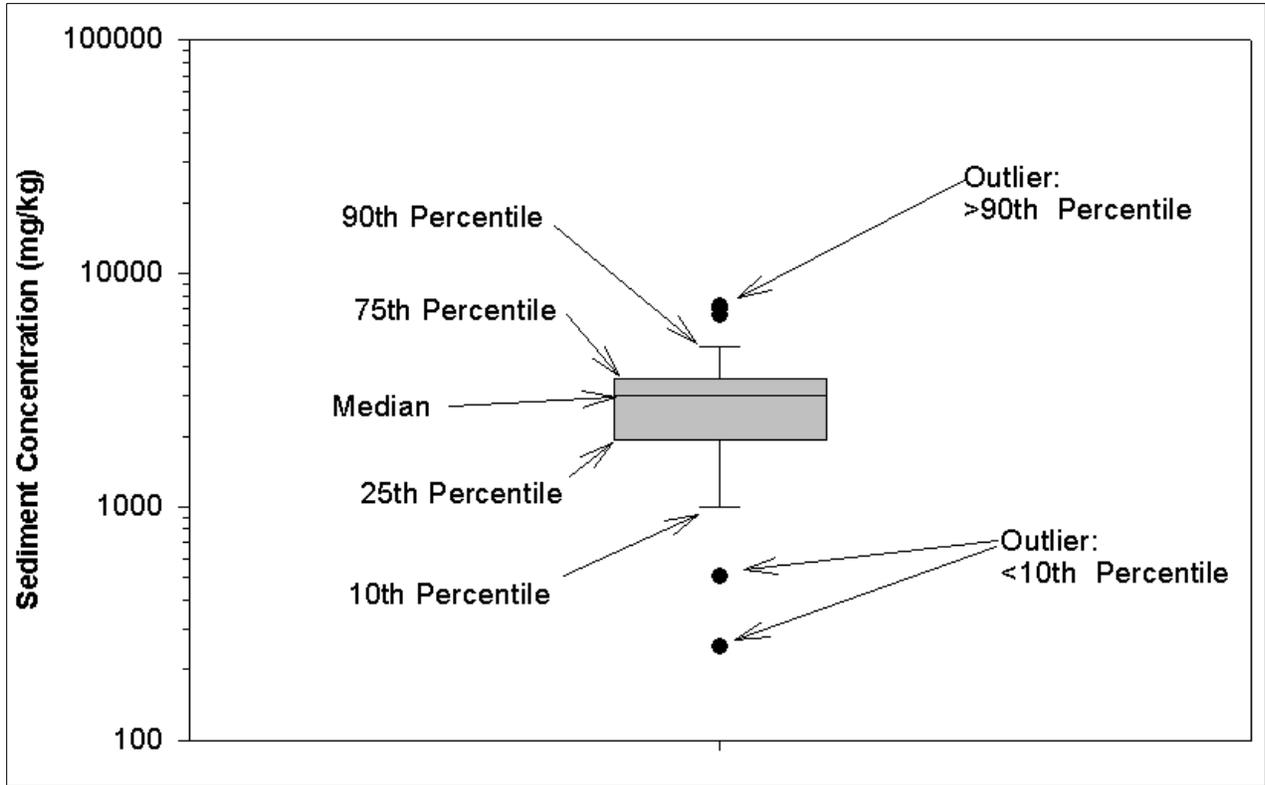


Figure L-14. Example Boxplot Diagram Displaying a Graphical Representation of Underlying Data Distribution

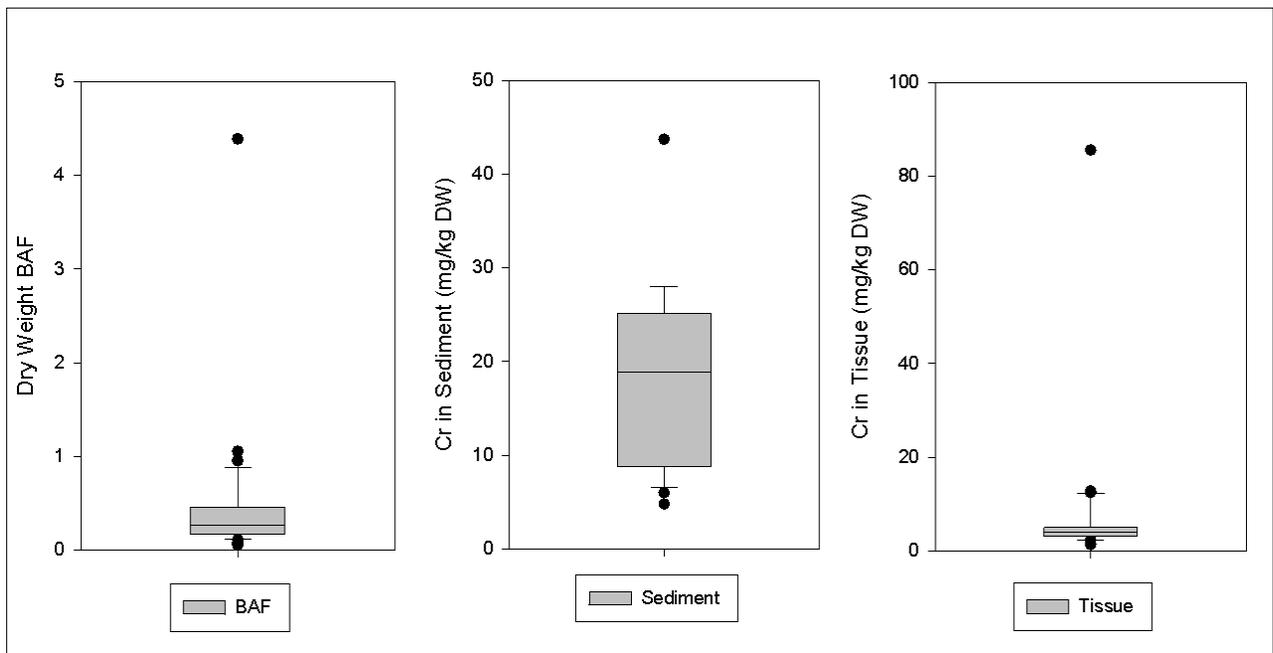


Figure L-15. Distribution of Bioaccumulation Factor and Total Chromium in Sediment and Tissue

In addition to the chromium in the clam tissue sample from 2m being an outlier, the risk estimate for the bufflehead was calculated with several conservative assumptions which may not be realistic. First, the LOAEL HQ of 1.2 represented a point estimate for sample 2m collected in the backwater slough downstream of the 100-F/IU OUs and assumes that all foraging would occur in this area or at least in areas with a similar concentration. However, it is very unlikely that ducks will foraging exclusively in this one backwater slough. Further, detected concentrations of chromium in benthic invertebrate tissue samples from many other areas up and downstream on the Columbia River were much lower (Table L-69). In addition, several studies have shown that chromium ingested by wildlife is not readily assimilated (absorbed), and thus most is excreted. As summarized in “Bioaccumulation and Toxicology of Chromium: Implications for Wildlife” (Outridge and Scheuhammer, 1993), gastrointestinal uptake of Cr(VI) is 2-10 percent of the presented dose, compared with 0.5 to 3 percent for Cr(III) (“Chromium” *Handbook on the Toxicology of Metals* [Langard and Norseth, 1979]; “Chromium Intake, Absorption and Excretion of Subjects Consuming Self-Selected Diets” [Anderson and Kozlovsky 1985]; “Effects of Chromium Supplementation on Urinary Cr Excretion of Human Subjects and Correlation of Cr Excretion with Selected Clinical Parameters” [Anderson et al., 1983]; “Experimental Study of Adsorption, Distribution and Excretion of Trivalent and Hexavalent Chromium” [Ogawa, 1976]; and “Chromium” [EPA, 1988]). The HQ of 1.2 represents the ratio of ingested dose to the toxicity reference value (TRV) without accounting for differences in assimilation from the laboratory study used to establish the TRV versus the modeled diet of the bufflehead, which included a clam tube sample measured at 15.4 mg/kg fresh weight. Assimilation of chromium in a spiked laboratory food may be more readily absorbed than chromium bound within the tissue of ingested clam. While not applied to the entire ingestion dose, the EPA has previously used absorption factors within a risk assessment to account for the assimilation of chromium from incidentally ingested soil. The risk assessment for the Tex Tin site assumed only 6 percent of incidentally ingested soil and sediment was absorbed and thus reduced the incidental ingestion dose by multiplying by a gut absorption factor (GAF) of 0.06 (*Final Report Tex Tin Site Texas City, Texas* [EPA, 1997]).

Given the low level of risk identified and the uncertainty with risk estimate for the bufflehead (only exceedance was an outlier, assumed preferential feeding from one area, and assimilation efficiency), risk to omnivorous waterfowl from chromium concentrations in sediment and aquatic prey from the Hanford Reach is considered unlikely. A separate discussion of potential risks to wildlife feeding in the area of the 100-F-59 waste site is provided in Section L4.7.

L4.6 Risk to Fish

No COECs in the RCBRA (DOE/RL-2007-21) or CRC (DOE/RL-2010-117) were identified for surface water exposures to fish.

The RCBRA (DOE/RL-2007-21) identified Cr(VI) pore water concentrations indicative of risk to fish and warranting additional consideration. The CRC (DOE/RL-2010-117) also indicated exceedances of water quality criteria or benchmark (Cr(VI) and manganese) in pore water. In addition, nitrate exceeded a literature-based nitrate fish NOEC screening benchmark in aquifer tubes and nearshore groundwater, but was detected at concentrations less than the NOEC benchmark in pore water and surface water (except in one sample) (Tables L-37 and L-43). However, most other lines of evidence suggest that there is no unacceptable risk to fish in the Columbia River.

In general, across the River Corridor, fish were smaller (in length and mass) at study sites relative to reference sites. However, many factors either confound or contribute to the size of fish captured, such as fishing pressure or ease of capture of the target size range. Correlation with capture size and chemical concentration or any other factor (e.g., habitat, nutrient availability) was not possible since it was not

considered as part of the original study design. No strong trends in fish histopathology were observed between those collected at study sites and those from reference site locations. No tissue COPECs were correlated with histopathological endpoints associated with adverse effects at study sites. No exceedances of tissue effects levels for nearshore aquatic COPECs were measured in fish tissue. In addition, evidence of greater contaminant uptake in fish from study sites was not apparent for most COPECs and tissues.

There are significant uncertainties relative to any of the conclusions based on pore water sampling. Further, all of these abiotic measurements represent a single point measurement within a dynamic river system with daily and seasonal fluctuations and flow volumes that can shift the composition of the substrates that were sampled. Thus, exceedances should not be ignored as they can be indicative of exposure and levels presenting a risk. But because of the uncertainty in the representativeness of the measurements because of the dynamic environment, the exceedances should be considered along with other data that identify whether there is, in fact, an ongoing source of the measurements. The interpretation of pore water results as an indication of potential adverse effects to fish is the same as that for aquatic plants, ESLs selected are intended to be protective of all aquatic organisms (e.g., they represent a conservative screening value); no COPECs in the 100-FR-3 Groundwater OU in the 100-F/IU2/IU6 Area represent a potential source for pore water concentrations, so no further evaluation in the FS is warranted. COPECs detected in pore water above ESLs do not appear to be issues in groundwater, seeps or aquifer tubes suggesting that the 100-F/IU Groundwater OUs are not the source of observed elevated concentrations.

Nitrate concentrations in a limited number of nearshore wells and aquifer tubes within the 100-F/IU OUs exceed a fish NOEC benchmark from published peer review literature. Surface water concentrations, the direct exposure medium for fish, were below the identified fish benchmark (Table L-37, Table L-43, and CRC [DOE/RL-2010-117], Table 7-1), except at one sample, represented by nitrogen in nitrate. Nitrate was not identified as a COPEC for the 100-FR-3 OU within the CRC (DOE/RL-2010-117) or RCBRA (DOE/RL-2007-21). The CRC (DOE/RL-2010-117) did not identify nitrate as a COPEC in any other abiotic media (surface water, mid channel sediment, shoreline sediment, island soils, and riparian soils) either. Likewise, the CRC (DOE/RL-2010-117) did not identify nitrate as a COPEC for any receptor group evaluated (soil invertebrate, sediment biota, terrestrial plants, terrestrial mammals, terrestrial birds, and aquatic biota). Nitrate benchmarks, readily available in literature, focus on effects to water column organisms (free-floating invertebrates and fish), not those communities in the sediment biologically active zone. Therefore, surface water concentrations most accurately depict concentrations at which these organisms may show effects. Typically, nitrogen in nitrate ($\text{NO}_3\text{-N}$) concentrations are predominantly based on nitrate. These measurements were detected below the nitrate ($\text{NO}_3\text{-N}$) NOEC in all surface water samples (Tables L-37 and L-43). As noted in Section 7.2.2 of the CRC (DOE/RL-2010-117), analytical results for nitrate in the Columbia River mid channel surface water indicated that the downstream study area concentrations were statistically lower than or not significantly different than concentrations found in reference locations. While aquifer tubes may suggest there is an ongoing source of nitrate to the Columbia River, there is no direct evidence of ecological risk. Future risks are not expected either because the maximum plume concentration of 100 mg/L nitrate representing the future groundwater source to the Columbia River is equal to the nearshore plume concentration of 100 mg/L within the 100-NR-2 Groundwater OU for which no evidence of ecological risk was found (*Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units* [DOE/RL-2012-15]). No additional consideration for nitrate (or nitrogen in nitrate) is warranted.

L4.7 Evaluation of Risks in the Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C

The area in and around the former 128-F-2 burn pit and the 100-F-59 Area C represent unique conditions warranting special consideration and evaluation. The 128-F-2 burn pit site was excavated and backfilled with 36 cm (12 in.) of gravel. Verification samples indicated that the inland-most portion of the burn pit site that abuts a steep cliff were sufficiently low to meet remediation goals, but the samples in the proportion closer to the Columbia River were not (“Remaining Sites Verification Package for the 128-F-2, 100-F Burning Pit Waste Site” [WSRF 2008-031]). Hence, the riparian portion abutting the Columbia River was assigned a new waste site status as 100-F-59. Additional verification samples were collected downstream of the 100-F-59 site boundary in a slough area and an area known as the northern shore. These areas are all identified in Figures L-12 and L-13.

The 100-F-59 Area C is inundated when river stage exceeds 210 kcfs or greater. However, this is not an area attractive to aquatic or terrestrial wildlife. As shown in Figure L-13, the site is unvegetated and covered with gravel and rocks. Terrestrial and riparian wildlife inhabiting or visiting this area would be far more likely to forage in the slough just south of 100-F-59 Area C (Figure L-16) or the plateau heading east to the river (“the northern shore”). Dietary exposure in 100-F-59 Area C is expected to be minimal and if present would consist of consuming mostly emergent insects.



Figure L-16. View of 100-F-59 Area C

The slough area just south of the former burn pit becomes inundated when river stage exceeds 210 kcfs. Once filled, water remains for 3 to 5 months, from April until June to late August. Once filled, benthic invertebrates may wash in from upstream and may remain long enough to reproduce. Emergent insects will hatch and represent a source of food to wildlife such as bats and swallows. In theory, larger benthic organisms such as mussels could also wash in, serving as a food source for waterfowl such as bufflehead. However, this scenario is unlikely because it would require flows much stronger than the slackwater flows typically observed in this slough area. Regardless of what organisms wash in, the site is dry for 7 to 9 months per year, thus preventing a resident benthic community from establishing. For the RCBRA (DOE/RL-2007-21), a transect was established in this slough as a riparian soil transect from which an MIS soil sample (Riparian 7) was collected along with terrestrial grass and invertebrate samples. The presence of any benthic invertebrate community was not noted.

Once dry (7 to 9 months a year), the slough provides habitat for terrestrial wildlife such as killdeer, quail, elk, and deer. Thus, the site represents a unique combination of wet and dry exposure scenarios that must be evaluated independently. It is important to recognize that this slough is NOT what is commonly referred to as the 100-F slough. Samples from this slackwater slough were collected north/upstream of, within, and just south of RCBRA (DOE/RL-2007-21) station Riparian 7 (Figure L-13) but well upstream of the 21 station (Figure L-10) that was collected from what is known as “The 100-F Slough” and has been identified as the third largest slough in the Hanford Reach⁸.

A fourth area called the Northern Shore is located due east of the slough (Figure L-13). The full extent of the shore is dry an even greater portion of the year than the slough, requiring greater flows for it to become inundated. Two transects of samples were collected as indicated in Figure L-13. While it represents a highly attractive area, contamination in this area is minimal and does not pose an ecological risk (evaluation is supported by no PRG exceedances). It appears that concentrations from the former burn pit have not migrated to this area.

Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C are located within the 100-F/IU2/IU6 Source OU area below the OHWM during flows of 210 kcfs or greater. The 100-F-59 waste site boundary includes 1) the portion of 128-F-2 that is below the OHWM and could not be interim closed due to elevated metals, 2) an additional area to the east of the 100-F-59 Area C, and 3) a portion of the northern slough area where contaminant concentrations were relatively high⁹. The 100-F-59 site boundaries were loosely defined given the area is below the OHWM. Therefore, most of the slough, north shore, and some of the near waste site samples are not within the 100-F-59 boundary, but were gathered to support reclassification of 128-F-2 waste site. The samples from the north shore are not all below the OHWM (Samples NS-6, 7, 8, 14, 15, and 16). While these areas were initially classified as soil, the areas are inundated from tidal fluctuations. To address the potential for adverse effects to aquatic life during periods of inundation, when aquatic life could be exposed to constituents in this riparian sediment, the following assessment was completed. These data were evaluated separately from the riparian sediment evaluated in previous sections of this Appendix because these data are within a waste site being addressed as part of this RI/FS document and may contain source material, while the other sediment data are not from waste sites but rather are collected in the river in the nearshore area.

The following sections consider multiple lines of evidence to evaluate the potential for adverse effects to aquatic life from constituents in riparian sediment within the four areas identified as Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C. The analysis focuses on the evaluation of risk to

⁸ Concentrations of total chromium in sediment at the “100-F Slough” were all below the chromium ESL of 88 mg/kg.

⁹ This third area does not represent a unique area. The distinction of this area is visible from reviewing Figure L-13 and was only made as the concentration of 371 mg/kg indicated transport from the former burn pit.

aquatic invertebrates (primarily benthic invertebrates) because these organisms are opportunistic and the most likely to use the riparian habitats during the periods of surface water inundation. Furthermore, aquatic invertebrates generally have limited mobility and, therefore, provide a conservative indication of the potential for adverse effects to aquatic life. However, as is described above in Section L4.4, this scenario is unrealistic as no community is present and the unique environmental conditions do not support survival of a benthic community.

L4.7.1 Benthic Invertebrates

L4.7.1.1 Abiotic Media Concentrations Compared to Literature Values

The first line of evidence used to evaluate risks to aquatic invertebrates involved the comparison of riparian sediment concentrations to lower threshold and upper threshold ESL sediment benchmarks. Contaminants in riparian sediment were identified as a potential risk to aquatic invertebrates if the maximum detected concentration in sediment exceeded its upper threshold sediment ESL.

This comparison is analogous to the process that was used in previous sections to identify COIs.

However, in this assessment, the medium is being evaluated as sediment, to determine the potential for adverse effects to aquatic invertebrates during the periods when it is inundated with water, and has the potential to support aquatic life.

The results of this comparison for benthic invertebrates are summarized in Table L-71 for each of the four riparian sediment areas. Contaminants with maximum detected concentrations that do not exceed the upper threshold sediment ESLs within an area were concluded not to represent a potential risk to aquatic invertebrates and were not further evaluated as a potential risk to aquatic invertebrates in this assessment. All other contaminants, including those which did not have sediment ESLs, were further evaluated using methods described in Section L4.7.2.

L4.7.1.2 Comparison to Reference Concentrations

Contaminants in riparian sediment with maximum detected concentrations exceeding the upper threshold ESLs for an area (or which did not have an ESL) were further evaluated for their potential to have adverse effects on aquatic invertebrates by comparing their detected concentrations to the range of concentrations detected in reference soils and reference sediments that have been established for the Hanford facility.

This includes comparison to the range of RCBRA riparian reference soil and sediment concentrations (comparison to range of reference concentrations), Columbia River background sediment concentrations (comparison to 95 percent upper confidence limit [UCL] concentration), and background soil concentrations (comparison to maximum reference concentration) (RCBRA [DOE/RL-2007-21]). Site concentrations were compared to both reference soils and sediments because the riparian habitat represents a transitional zone between terrestrial and aquatic habitats and comparison to both media types is, therefore, applicable.

The results of this comparison are summarized in Table L-72 for each of the four riparian sediment areas. Contaminants with maximum detected concentrations that do not exceed one or more of the reference concentration ranges within an area were not identified as a potential site-related risk and were not selected for further evaluation. All other contaminants, including those which did not have reported reference concentrations, were further evaluated using methods described in Section L4.7.3.

L4.7.1.3 Comparison to Estimated Pore water Concentrations

COIs in riparian sediment that exceeded reference concentrations for an area (or which did not have reference concentrations) were further evaluated for their potential to have adverse effects on ecological receptors by estimating and evaluating chemical concentrations in pore water and comparing those estimated concentrations to surface water ESLs established for the protection of aquatic life.

Pore water measurements were not collected at these locations largely because the data that were collected were verification samples during the remediation of the site. Additional sampling during the River Corridor RI did not include pore water in this area because the area is not inundated for 7 to 9 months of the year; further, the area is not fully inundated for the remaining 3 to 5 months when ponding does occur. Estimated chemical concentrations in pore water were evaluated because pore water concentrations predict the bioavailable fraction of the total chemical concentration in sediment, and provide a more accurate indication of the potential for adverse effects to ecological receptors than do bulk sediment chemical concentrations. Without available pore water data, concentrations in pore water were calculated by applying a soil-water partitioning coefficient (K_d). For this evaluation at 100-F-59, the scenario to be modeled would be metals in the cobbled soil/sediment desorbing to pore water during periods of inundation. This calculation should be considered highly conservative because it does not include any dilution from mixing of groundwater with surface water within the hyporheic zone. The following equation was used to estimate the pore water concentration of each evaluated contaminant:

$$\text{Estimated pore water concentration (mg/L)} = \text{Sed}_{\text{BC}}/K_d$$

where:

Sed_{BC} = bulk sediment concentration (mg/kg)

K_d = chemical-specific partition coefficient between sediment and pore water

Estimated pore water concentrations were then compared to ESLs for surface water to evaluate the potential for adverse effects to aquatic life. The K_d values used to estimate the pore water concentration and the surface water ESLs are presented in Table L-73.

The results of the comparison of the estimated pore water concentrations to the surface water ESLs are summarized in Table L-73 for each of the four riparian sediment areas. Contaminants were identified as a potential risk to aquatic life if the maximum estimated pore water concentration exceeds the surface water ESL. Contaminants with maximum detected concentrations that do not exceed the surface water ESL were not identified as a potential site-related risk and were not selected for further consideration. All other contaminants, including those which did not have reported surface water ESLs, were considered a potential risk to aquatic life.

L4.7.1.4 Additional Considerations

Following the evaluation described in Sections L4.7.1 through L4.7.3, additional lines of evidence were considered, as appropriate, to evaluate the overall potential for adverse effects to aquatic invertebrates for any contaminants indicating a potential for adverse effect to aquatic life at the conclusion of the evaluation described in Section L4.7.3. These considerations varied with the specific contaminant and the nature of the risk indicated, but included consideration of the magnitude ESL and/or reference concentration exceedance and the area of potential impact.

L4.7.1.5 Results for Aquatic Invertebrates in Riparian Sediment

The following subsections present the risk results in riparian sediment for the Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C.

Slough Area

Antimony – The maximum detected antimony concentration in the Slough Area exceeded the upper threshold ESL (Table L-71). The maximum detected antimony concentration also exceeds those detected in reference/background sediment and soil (Table L-72). Antimony is also estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73). However, antimony was detected in only two of 10 riparian sediment/soil samples, and the detected

concentrations only marginally exceed the RCBRA (DOE/RL-2007-21) riparian reference sediment concentrations (Table L-72). The reporting limits at the other sample locations marginally exceed the upper threshold ESL (Table L-68), and it is possible that antimony is present at concentrations exceeding the upper sediment threshold ESL at these nondetect locations. However, the low frequency of antimony detection, coupled with the marginal exceedance of the upper sediment threshold ESL by the reporting limit, suggests the likelihood that antimony is actually present at concentrations exceeding the upper sediment threshold ESL is low. Therefore, antimony will, at most, have an extremely localized affect, will not adversely affect aquatic invertebrate populations, and does not warrant further evaluation in this area. Also, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there was no correlation between antimony concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*).

Beryllium – A sediment threshold ESL was not available for beryllium (Table L-71). However, the maximum detected beryllium concentration falls within the range of concentrations detected in RCBRA (DOE/RL-2007-21) riparian reference sediment and soil (Table L-72). Therefore, beryllium does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Boron – A sediment threshold ESL was not available for boron (Table L-71). However, the maximum detected boron concentration falls within the range of concentrations detected in the RCBRA riparian reference soil and background soil (Table L-72). Therefore, boron does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Chromium – The maximum detected chromium concentration in the Slough Area and 5 of 10 total samples exceeded the upper threshold ESL (Table L-71), and the maximum detected chromium concentration also exceeds chromium concentrations detected in reference/background sediment and soil (Table L-72). Chromium is also estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73). Chromium exceeded the upper threshold ESL in 5 of the 10 riparian sediment/soil samples. However, the riparian areas represent ephemeral habitat that are only periodically inundated with surface water when river flow is at 210 kcfs. Thus, exposure to benthic organisms where the chromium was measured above the ESL is not reflective of a high quality habitat. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. From September to the end of March, this area represents a terrestrial environment, not an aquatic habitat. While some smaller and free floating benthic species may wash into the area when river flow exceeds 210 kcfs, these aquatic species are not expected to survive once the area dries out. A resident benthic community is not present and a community can't be supported under the current conditions. Figures L-11 and L-12 demonstrate that concentrations closest to the Columbia River in the 100-F-59 area were all below the ESL (88 mg/kg) suggesting that source material is not reaching the river. Thus, although 6 of 10 samples plus sample Rip7 exceeded the ESL of 88 mg/kg, it is not recommended that remedial alternatives be developed to address these risks as the prevailing environmental conditions suggest the risk is acceptable.

Hexavalent Chromium – A sediment threshold ESL was not available for Cr(VI) (Table L-71), and the maximum detected Cr(VI) concentration consistently exceeds those detected in reference soil and sediment samples (Table L-72). The concentration of Cr(VI) estimated to occur in pore water also exceeds its water quality screening value (Table L-73). This calculation should be considered highly conservative because (1) it does not include any dilution from mixing of groundwater with surface water within the hyporheic zone and (2) uses a small K_d value even though the soil leachability test at the 100-F-19 reactor cooling water effluent pipelines showed that residual Cr(VI) remaining in the soil

column is not readily mobilized. The K_d value of 0.8 L/kg represents the lower 10th percentile of K_d values based on residual soil concentration leaching data throughout the Hanford Site indicating the degree of conservatism. As can be seen in Table L-73, when the K_d value of 0.8 L/kg is used with the maximum observed soil/sediment concentration, the resulting pore water concentration for Cr(VI) is calculated to be about 5,380 µg/L, which would indicate significantly higher Cr(VI) measurements at all nearby aquifer tubes; however, high Cr(VI) concentrations have not been measured in nearby aquifer tube samples (Figure L-17). Table L-73 identifies the maximum soil concentrations and corresponding calculated pore water concentrations with no dilution factor for groundwater or surface water flow, resulting in the overly conservative modeled pore water measurements, represented by the fact that these maximum values are surrounded by much lower concentrations (Figure L-17).

While characterization of potential pore water exposure to benthic organisms in this area is presented, it should be recognized that estimates are conservative and representative of a worst case scenario. The 100-F-59 Area was downstream of the former 100-F-2 burn pit for a number of years. Residuals from the burn pit washed into the sub areas decades ago. While having received some runoff from the old burn pit, the area has been subject to a highly dynamic and forceful river system for over 40 years. Due to highly mobile nature of Cr(VI), a large fraction is likely to have been leached out from the soil/sediments of the 100-F-59 sub areas quickly upon contact with water, with only a small residual fraction remaining at low detectable levels as shown in Figures L-12 and L-13. These residual concentrations represent the relatively immobile fraction that is not easily leachable because it is more tightly bound to the soil/sediment. Several studies demonstrate that a small fraction of Cr(VI) remains bound to the soil matrix after many pore-flow (drainage) cycles and this fraction is not easily leached into the aqueous phase (*Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* [PNNL-17674], Figure 3.2). In addition, hundreds of batch leach tests across the River Corridor area (including dozens of batch leach tests for aged soils within waste sites in the 100-F area) clearly demonstrate the same phenomenon and persistence of difficult-to-leach fraction of Cr(VI) (*Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area* [ECF-HANFORD-11-0165]). It should be noted that the K_d value of 0.8 L/kg is meant to be used for upland area waste sites to provide a conservative estimate (one that maximizes potential leaching from sediments) and is not meant to be representative, especially for situations where historical leaching is greatest, such as the 100-F-59 site. While measurements of the subterranean aqueous environment at this area are not from within the hyporheic zone, groundwater contour mapping has shown the subterranean environment to be less dominated by groundwater recharge and more reflective of the Columbia River. Given this understanding, aquifer tube measurements from the 100-F-59 area collected at 3 to 6 m (10 to 20 ft) below ground surface (bgs) serve as a representation of leaching from the soil/sediment during periods of high river stage. The aquifer tubes are typically sampled when river stage is low (November) to moderate (March) and they cannot be sampled when river stage is high. The maximum aquifer tube measurements (Area C and the Slough Area) are all at or below the 10 µg/L state surface water quality standard supporting the fact that leaching from soil/sediment is minimal, if it exists at all, from this waste site. Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time periods in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. Also, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there was no correlation between Cr(VI) concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*). Therefore, the bioavailable fraction of chromium in sediment pore water is not high enough to have adverse effects on aquatic invertebrates and does not warrant further evaluation in this area.

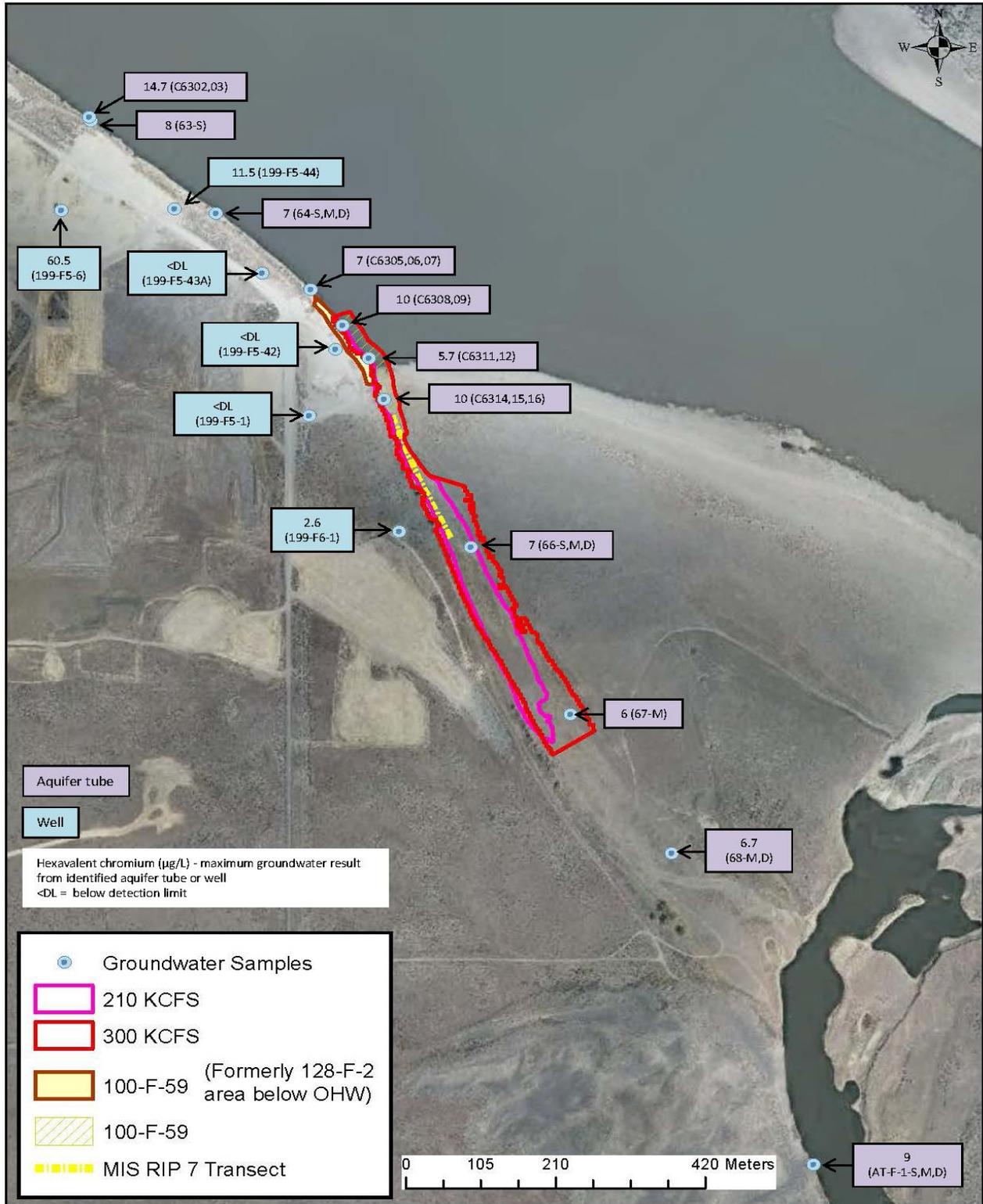


Figure L-17. Maximum Aquifer Tube and Nearshore Groundwater Well Measurements of Cr(VI) in the Vicinity of 100-F-59 (2007 to 2011)

Iron – The maximum detected iron concentration in the Slough Area exceeded the upper threshold ESL (Table L-71). However, the maximum detected iron concentration falls within the range of concentrations detected in RCBRA (DOE/RL-2007-21) riparian reference soil and sediment (Table L-72). Therefore, beryllium does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Silicon – A sediment threshold ESL was not available for silicon (Table L-71). Silicon oxides, the form of silica that would be present in the environment, comprise the most abundant constituent of the earth's crust mass. Synthetic amorphous silica and silicates are similar to natural forms of silica and are expected to mix with and be subjected to the same natural processes as silicon dioxides already present in the environment (*Synthetic Amorphous Silica and Silicates* [UNEP, 2004]). Although very limited toxicological investigations have been conducted, and most of the investigations that have been conducted are based on acute bioassays, the available toxicological information strongly suggest that silicon has very low toxicity. Acute bioassays conducted with the fish *Brachydanio rerio* indicated no effects when loading rates of up to 10,000 mg/L were tested for a period of 96 hours (*The Acute Toxicity of AEROSIL 2000 to Brachydanio rerio* [Degussa AG, 1992a], *The Acute Toxicity of ULTRASIL VN 3 to Brachydanio rerio* [Degussa AG, 1992b]). The aquatic invertebrate *Daphnia magna* indicated immobilization when exposed to loading rates of 1,000 and 10,000 mg/L for a period of 24 hours (*The Acute Toxicity of AEROSIL 2000 to Daphnia magna* [Degussa AG, 1992c], *The Acute Toxicity of ULTRASIL VN 3 to Daphnia magna* [Degussa AG, 1992d]). However, this response was attributed to the physical immobilization caused by the silicon dioxide particles adhering to the *D. magna* appendages, and was not the result of a toxic response. Finally, growth inhibition bioassays conducted with the algae *Scenedesmus subspicatus* indicated no effects when loading rates of up to 10,000 mg/L were tested for a period of 72 hours (*Study on the toxicity towards algae of "SIPERNAT 820 A (sodium aluminum silicate)"* [Degussa AG, 1998]). Therefore, silicon has very low toxicity to aquatic life and does not warrant further evaluation in the FS.

Vanadium – The maximum detected vanadium concentration in the Slough Area exceeded the upper threshold ESL (Table L-71). However, the maximum sediment concentration falls within the range of concentrations detected in RCBRA (DOE/RL-2007-21) riparian reference soil and background soil (Table L-72). Therefore, vanadium does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

128-F-2 Area C

Antimony – The maximum detected antimony concentration in the 128-F-2 Area C exceeded the upper sediment threshold ESL (Table L-71), and the maximum detected antimony concentration exceeds those detected in reference/background sediment and background soil (Table L-72). Antimony is also estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73). However, antimony was detected in only three of 13 riparian sediment/soil samples. Although the reporting limits at the other sample locations marginally exceed the upper sediment threshold ESL (Table L-68) and the concentrations of antimony at these locations cannot be definitively determined, it is likely that antimony does not exceed the upper sediment threshold ESL at many of these nondetect locations. Therefore, antimony will, at most, have an extremely localized affect and is unlikely to have adverse effects on aquatic invertebrate populations. Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. Also, as shown in the RCBRA (DOE/RL-2007-21,

Table 104), there was no correlation between antimony concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*).

Barium – The maximum detected barium concentration in the 128-F-2 Area C exceeded the upper threshold ESL (Table L-71), and the maximum detected barium concentration exceeds those detected in reference/background sediment and background soil (Table L-72). Barium is also estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73). However, barium exceeded the sediment threshold ESL in only two of the 13 riparian sediment/soil samples. Therefore, barium will, at most, have an extremely localized affect and is unlikely to have adverse effects on aquatic invertebrate populations. Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. Also, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there were significant regression with barium concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*), but the R^2 values were only 0.1, suggesting a weak goodness of fit.

Beryllium – A sediment threshold ESL was not available for beryllium (Table L-71). However, the maximum detected beryllium concentration falls within the range of concentrations detected in the RCBRA riparian reference sediment and background soil (Table L-72). Therefore, beryllium does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Boron – A sediment threshold ESL was not available for boron (Table L-71). However, the maximum detected boron concentration falls within the range of concentrations detected in the RCBRA riparian reference soil and sediment, Columbia River background sediment, and background soil (Table L-72). Therefore, boron does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Chromium – The maximum detected chromium concentration and 6 of 13 total samples exceeded the upper threshold ESL (Table L-71), and the maximum detected chromium concentration exceeds those detected in reference/background sediment and background soil (Table L-72). Chromium is also estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73). Chromium exceeded the sediment threshold ESL in 7 of the 14 riparian sediment/soil samples, and there is potential for chromium to have adverse effects on aquatic invertebrates at these locations. However, the riparian areas represent ephemeral habitat that are only periodically inundated with surface water when river flow is at 210 kcfs. Thus, exposure to benthic organisms where the chromium was measured above the ESL is not reflective of a high quality habitat. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. From September to the end of March, this area represents a terrestrial environment, not an aquatic habitat. While some smaller and free-floating benthic species may wash into the area when river flow exceeds 210 kcfs, these aquatic species are not expected to survive once the area dries out. A resident benthic community is not present and a community can't be supported under the current conditions. Figures L-11 and L-12 demonstrate that concentrations closest to the Columbia River in the 100-F-59 area were all below the ESL (88 mg/kg) suggesting that

source material is not reaching the river. Thus, although 6 of 13 samples plus the RCBRA sample exceeded the ESL of 88 mg/kg, it is not recommended that remedial alternatives be developed to address these risks as the prevailing environmental conditions suggest the risk is acceptable.

Hexavalent Chromium – A sediment threshold ESL was not available for Cr(VI) (Table L-71). The maximum detected Cr(VI) sediment concentration exceeds those detected in reference soil and sediment (Table L-72). The concentration of Cr(VI) estimated to occur in pore water also exceeded its water quality screening value (Table L-73). This calculation should be considered highly conservative because (a) it does not include any dilution from mixing of groundwater with surface water within the hyporheic zone and (b) uses a small K_d value even though the soil leachability test at the 100-F-19 reactor cooling water effluent pipelines showed that residual Cr(VI) remaining in the soil column is not readily mobilized. The K_d value of 0.8 L/kg represents the lower 10th percentile of K_d values based on residual soil concentration leaching data throughout the Hanford Site indicating the degree of conservatism. As can be seen in Table L-73, when the K_d value of 0.8 L/kg is used with the maximum observed soil/sediment concentration, the resulting pore water concentration for Cr(VI) is calculated to be about 15,000 µg/L, which would indicate significantly higher Cr(VI) measurements at all nearby aquifer tubes; however, high Cr(VI) concentrations have not been measured in nearby aquifer tubes locations (Figure L-17). Table L-73 identifies the maximum soil concentrations and corresponding calculated pore water concentrations with no dilution factor for groundwater or surface water flow, resulting in the overly conservative modeled pore water measurements, represented by the fact that these maximum values are surrounded by much lower concentrations (Figure L-17).

While characterization of potential pore water exposure to benthic organisms in this area is presented, it should be recognized that estimates are conservative and representative of a worst case scenario. The 100-F-59 Area was downstream of the former 100-F-2 burn pit for a number of years. Residuals from the burn pit washed into the sub areas decades ago. While having received some runoff from the old burn pit, the area has been subject to a highly dynamic and forceful river system for over 40 years. Due to highly mobile nature of Cr(VI), a large fraction is likely to have been leached out from the soil/sediments of the 100-F-59 sub areas quickly upon contact with water, with only a small residual fraction remaining at low detectable levels as shown in Figures L-12 and L-13. These residual concentrations represent the relatively immobile fraction that is not easily leachable because it is more tightly bound to the soil/sediment. Several studies demonstrate that a small fraction of Cr(VI) remains bound to the soil matrix after many pore-flow (drainage) cycles and this fraction is not easily leached into the aqueous phase (*Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* [PNNL-17674], Figure 3.2). In addition, hundreds of batch leach tests across the River Corridor area (including dozens of batch leach tests for aged soils within waste sites in the 100-F area) clearly demonstrate the same phenomenon and persistence of difficult-to-leach fraction of Cr(VI) (*Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area* [ECF-HANFORD-11-0165]). It should be noted that the K_d value of 0.8 L/kg is meant to be used for upland area waste sites to provide a conservative estimate (one that maximizes potential leaching from sediments) and is not meant to be representative, especially for situations where historical leaching is greatest, such as the 100-F-59 site. While measurements of the subterranean aqueous environment at this area are not from within the hyporheic zone, groundwater contour mapping has shown the subterranean environment to be less dominated by groundwater recharge and more reflective of the Columbia River. Given this understanding, aquifer tube measurements from the 100-F-59 area collected at 3 to 6 m (10 to 20 ft) bgs serve as a representation of leaching from the soil/sediment during periods of high river stage. The aquifer tubes are typically sampled when river stage is low (November) to moderate (March) and they cannot be sampled when river stage is high. The maximum aquifer tube measurements (Area C and

the Slough Area) are all at or below the 10 µg/L state surface water quality standard supporting the fact that leaching from soil/sediment is minimal, if it exists at all, from this waste site.

Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time periods in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. Also, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there was no correlation between Cr(VI) concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*). Therefore, the bioavailable fraction of chromium in sediment pore water is not high enough to have adverse effects on aquatic invertebrates and does not warrant further evaluation in this area.

Iron – The maximum detected iron concentration exceeded the upper threshold ESL (Table L-71). The maximum detected iron concentrations also exceed those detected in the reference/background sediment and soil (Table L-72). Estimated risk associated with the bioavailable fraction of iron in pore water was not determined based on the absence of a partition coefficient for this constituent (Table L-73). However, iron exceeded the upper threshold ESL in only three of the 13 riparian sediment/soil samples. Therefore, iron will at most have an extremely localized affect and is unlikely to have adverse effects on aquatic invertebrate populations. Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system.

Manganese – The maximum detected manganese concentration exceeded the upper sediment threshold ESL (Table L-71). However, the maximum detected sediment concentration falls within the range of concentrations detected in the Columbia River background sediment (Table L-72). Therefore, manganese does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Silicon – A sediment threshold ESL was not available for silicon (Table L-71). However, the maximum detected silicon concentration falls within the range of concentrations detected in RCBRA riparian reference sediment and Columbia River background sediment (Table L-72). Therefore, silicon does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Vanadium – The maximum detected vanadium concentration exceeded the upper threshold ESL (Table L-71). However, the maximum detected vanadium concentration falls within the range of concentrations detected in background soil (Table L-72). Therefore, vanadium does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Near Waste Site

Antimony – The maximum detected antimony concentration in the Near Waste Site exceeded the upper threshold ESL (Table L-71). The maximum detected antimony concentration also exceeds reference/background sediment and soil concentrations (Table L-72). Antimony is estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73) in this area. However, antimony was detected in only three of 13 riparian sediment/soil samples. Although the reporting limits at sample locations marginally exceed the upper sediment threshold ESL

(Table L-68), the overall low frequency of detection in the dataset suggests that antimony is unlikely to occur at concentrations at the undetected locations exceeding the upper sediment threshold ESL. Therefore, antimony will at most have an extremely localized effect and will be unlikely to have adverse effects on aquatic invertebrate populations. Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. Also, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there was no correlation between antimony concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*).

Beryllium – A sediment threshold ESL was not available for beryllium (Table L-71). However, the maximum detected beryllium concentration falls within the range of concentrations detected in the RCBRA riparian reference soil and sediment, Columbia River background sediment, and background soil (Table L-72). Therefore, beryllium does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Boron – A sediment threshold ESL was not available for boron (Table L-71). However, the maximum detected boron concentration falls within the range of concentrations detected in RCBRA riparian reference soil and background soil (Table L-72). Therefore, boron does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Chromium – The maximum detected chromium concentration and 8 of 17 total samples exceeded the upper threshold ESL (Table L-71) in the Near Waste Site. The detected chromium concentrations also exceed reference/background sediment and background soil (Table L-72). Chromium is also estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73). Chromium exceeded the sediment threshold ESL in eight of the 21 riparian sediment/soil samples, and there is the potential for chromium to have adverse effects on aquatic invertebrates at these locations. However, the riparian areas are only periodically inundated with surface water when river flow is at 210 kcfs. Thus, exposure of benthic organisms to chromium in excess of the ESL is not reflective of a high quality habitat. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these ephemeral aquatic habitats, and they would only be able to make use of these habitats during the time periods in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. From September to the end of March, this area represents a terrestrial environment, not an aquatic habitat. While some smaller and free floating benthic species may wash into the area when river flow exceeds 210 kcfs, these aquatic species are not expected to survive once the area dries out. A resident benthic community is not present and a community can't be supported under the current conditions. Figure L-11 demonstrates that concentrations closest to the Columbia River in the 100-F-59 area were all below the ESL (88 mg/kg) suggesting that source material is not reaching the river. Thus, while 8 of 17 samples exceeded the ESL of 88 mg/kg, it is not recommended that remedial alternatives be developed to address these risks as the environmental conditions suggest the risk is acceptable.

Hexavalent Chromium – A sediment threshold ESL was not available for Cr(VI) (Table L-71), and the maximum detected Cr(VI) concentration exceeds those detected in reference soil and sediment (Table L-72). As can be seen in Table L-73, when the K_d value of 0.8 L/kg is used with the maximum observed soil/sediment concentration, the resulting pore water concentration for Cr(VI) is calculated to be about 2,250 µg/L, which would indicate significantly higher Cr(VI) measurements at all nearby aquifer

tubes. This calculation should be considered highly conservative because (a) it does not include any dilution from mixing of groundwater with surface water within the hyporheic zone and (b) uses a small K_d value even though the soil leachability test at the 100-F-19 reactor cooling water effluent pipelines showed that residual Cr(VI) remaining in the soil column is not readily mobilized. The K_d value of 0.8 L/kg represents the lower 10th percentile of K_d values based on residual soil concentration leaching data throughout the Hanford Site indicating the degree of conservatism. High Cr(VI) concentrations have not been measured in nearby aquifer tubes locations (Figure L-17). Table L-73 identifies the maximum soil concentrations and corresponding calculated pore water concentrations with no dilution factor for groundwater or surface water flow, resulting in the overly conservative modeled pore water measurements, represented by the fact that these maximum values are surrounded by much lower concentrations (Figure L-17).

While characterization of potential pore water exposure to benthic organisms in this area is presented, it should be recognized that estimates are conservative and representative of a worst case scenario. The 100-F-59 Area was downstream of the former 100-F-2 burn pit for a number of years. Residuals from the burn pit washed into the sub areas decades ago. While having received some runoff from the old burn pit, the area has been subject to a highly dynamic and forceful river system for over 40 years. Due to highly mobile nature of Cr(VI), a large fraction is likely to have been leached out from the soil/sediments of the 100-F-59 sub areas quickly upon contact with water, with only a small residual fraction remaining at low detectable levels as shown in Figures L-12 and L-13. These residual concentrations represent the relatively immobile fraction that is not easily leachable because it is more tightly bound to the soil/sediment. Several studies demonstrate that a small fraction of Cr(VI) remains bound to the soil matrix after many pore-flow (drainage) cycles and this fraction is not easily leached into the aqueous phase (*Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* [PNNL-17674], Figure 3.2). In addition, hundreds of batch leach tests across the River Corridor area (including dozens of batch leach tests for aged soils within waste sites in the 100-F area) clearly demonstrate the same phenomenon and persistence of difficult-to-leach fraction of Cr(VI) (*Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area* [ECF-HANFORD-11-0165]). It should be noted that the K_d value of 0.8 L/kg is meant to be used for upland area waste sites to provide a conservative estimate (one that maximizes potential leaching from sediments) and is not meant to be representative, especially for situations where historical leaching is greatest, such as the 100-F-59 site.

While measurements of the subterranean aqueous environment at this area are not from within the hyporheic zone, groundwater contour mapping has shown the subterranean environment to be less dominated by groundwater recharge and more reflective of the Columbia River. Given this understanding, aquifer tube measurements from the 100-F-59 area collected at 3 to 6 m (10 to 20 ft) bgs serve as a representation of leaching from the soil/sediment during periods of high river stage. The aquifer tubes are typically sampled when river stage is low (November) to moderate (March) and they cannot be sampled when river stage is high. Since the aquifer tube measurements from the areas of highest concentrations (Area C and the Slough Area) are all at or below the 10 µg/L state surface water quality standard supporting the fact that leaching is minimal in these areas, it can be deduced that leaching is minimal to non-existent in this area as well, where the measurements are much lower than those areas.

Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. Also, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there was no correlation between Cr(VI) concentrations in bulk

sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*). Therefore, the bioavailable fraction of chromium in sediment pore water is not high enough to have adverse effects on aquatic invertebrates and does not warrant further evaluation in this area.

Iron – The maximum detected iron concentration in the Near Waste Site exceeded the upper threshold ESL (Table L-71). However, the maximum detected iron concentration falls within the range of concentrations detected in RCBRA (DOE/RL-2007-21) riparian reference soil and sediment (Table L-72). Therefore, iron does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Silicon – A sediment threshold ESL was not available for silicon (Table L-71). Silicon oxides, the form of silica that would be present in the environment, comprise the most abundant constituent of the earth's crust mass. Synthetic amorphous silica and silicates are similar to natural forms of silica and are expected to mix with and be subjected to the same natural processes as silicon dioxides already present in the environment (*Synthetic Amorphous Silica and Silicates* [UNEP, 2004]). Although very limited toxicological investigations have been conducted, and most of the investigations that have been conducted are based on acute bioassays, the available toxicological information strongly suggest that silicon has very low toxicity. Acute bioassays conducted with the fish *Brachydanio rerio* indicated no effects when loading rates of up to 10,000 mg/L were tested for a period of 96 hours (*The Acute Toxicity of AEROSIL 2000 to Brachydanio rerio* [Degussa AG, 1992a]; *The Acute Toxicity of ULTRASIL VN 3 to Brachydanio rerio* [Degussa AG, 1992b]). The aquatic invertebrate *Daphnia magna* indicated immobilization when exposed to loading rates of 1,000 and 10,000 mg/L for a period of 24 hours (*The Acute Toxicity of AEROSIL 2000 to Daphnia magna* [Degussa AG, 1992c], *The Acute Toxicity of ULTRASIL VN 3 to Daphnia magna* [Degussa AG, 1992d]). However, this response was attributed to the physical immobilization caused by the silicon dioxide particles adhering to the *D. magna* appendages and was not the result of a toxic response. Finally, growth inhibition bioassays conducted with the algae *Scenedesmus subspicatus* indicated no effects when loading rates of up to 10,000 mg/L were tested for a period of 72 hours (*Study on the toxicity towards algae of "SIPERNAT 820 A (sodium aluminum silicate)"* [Degussa AG, 1998]). Therefore, silicon has very low toxicity to aquatic life and does not warrant further evaluation in the FS.

Silver – The maximum detected silver concentration in the Near Waste Site exceeded the upper threshold ESL (Table L-71). The maximum detected silver concentration also exceeds those detected in the reference/background sediment and background soil (Table L-72). Silver is also estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73). However, silver was detected in only one of 21 riparian sediment/soil samples, and the detected concentration only marginally exceeds the upper threshold ESL (Table L-71). Therefore, silver will at most have an extremely localized affect, will not adversely affect aquatic invertebrate populations, and does not warrant further evaluation in this area.

Northern Shore

Antimony – The maximum detected antimony concentration in the Northern Shore was greater than the upper sediment threshold ESL (Table L-71). The maximum detected antimony concentration also exceeds those detected in reference/background sediment and background soil (Table L-72). Antimony is also estimated to occur at concentrations in pore water that could represent a potential risk to aquatic invertebrates (Table L-73). However, antimony was detected in only one of 19 riparian sediment/soil samples. Although the reporting limits at the other sample locations marginally exceed the upper sediment threshold ESL (Table L-68), and the concentrations of antimony at these locations cannot be definitively determined, it is likely that antimony does not exceed the upper sediment threshold ESL at

many of these nondetect locations. Therefore, antimony will at most have an extremely localized affect and is unlikely to have adverse effects on aquatic invertebrate populations. Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. Also, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there was no correlation between antimony concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyalella azteca*).

Beryllium – A sediment threshold ESL was not available for beryllium (Table L-71). However, the maximum detected beryllium concentration falls within the range of concentrations detected in RCBRA (DOE/RL-2007-21) riparian reference soil and sediment and background soil (Table L-72). Therefore, beryllium does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Boron – A sediment threshold ESL was not available for boron (Table L-71). However, the maximum detected boron concentration falls within the range of concentrations detected in background soil (Table L-72). Therefore, boron does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Hexavalent Chromium – A sediment threshold ESL was not available for Cr(VI) (Table L-71). The maximum detected Cr(VI) concentration also exceeds those detected in reference soil and sediment samples (Table L-72).

As can be seen in Table L-73, when the K_d value of 0.8 L/kg is used with the maximum observed soil/sediment concentration, the resulting pore water concentration for Cr(VI) is calculated to be about 1,630 $\mu\text{g/L}$, which would indicate significantly higher Cr(VI) measurements at all nearby aquifer tubes. This calculation should be considered highly conservative because (a) it does not include any dilution from mixing of groundwater with surface water within the hyporheic zone and (b) uses a small K_d value even though the soil leachability test at the 100-F-19 reactor cooling water effluent pipelines showed that residual Cr(VI) remaining in the soil column is not readily mobilized. The K_d value of 0.8 L/kg represents the lower 10th percentile of K_d values based on residual soil concentration leaching data throughout the Hanford Site indicating the degree of conservatism. High Cr(VI) concentrations have not been measured in nearby aquifer tubes locations (Figure L-17). Table L-73 identifies the maximum soil concentrations and corresponding calculated pore water concentrations with no dilution factor for groundwater or surface water flow, resulting in the overly conservative modeled pore water measurements, represented by the fact that these maximum values are surrounded by much lower concentrations (Figure L-17).

While characterization of potential pore water exposure to benthic organisms in this area is presented, it should be recognized that estimates are conservative and representative of a worst-case scenario. The 100-F-59 Area was downstream of the former 100-F-2 burn pit for a number of years. Residuals from the burn pit washed into the sub areas decades ago. While having received some runoff from the old burn pit, the area has been subject to a highly dynamic and forceful river system for over 40 years. Due to highly mobile nature of Cr(VI), a large fraction is likely to have been leached out from the soil/sediments of the 100-F-59 sub areas quickly upon contact with water, with only a small residual fraction remaining at low detectable levels as shown in Figures L-12 and L-13. These residual concentrations represent the relatively immobile fraction that is not easily leachable because it is more tightly bound to the soil/sediment. Several studies demonstrate that a small fraction of Cr(VI) remains bound to the soil matrix

after many pore-flow (drainage) cycles and this fraction is not easily leached into the aqueous phase (*Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site* [PNNL-17674], Figure 3.2). In addition, hundreds of batch leach tests across the River Corridor area (including dozens of batch leach tests for aged soils within waste sites in the 100-F area) clearly demonstrate the same phenomenon and persistence of difficult-to-leach fraction of Cr(VI) (*Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area* [ECF-HANFORD-11-0165]). It should be noted that the K_d value of 0.8 L/kg is meant to be used for upland area waste sites to provide a conservative estimate (one that maximizes potential leaching from sediments) and is not meant to be representative, especially for situations where historical leaching is greatest, such as the 100-F-59 site.

While measurements of the subterranean aqueous environment at this area are not from within the hyporheic zone, groundwater contour mapping has shown the subterranean environment to be less dominated by groundwater recharge and more reflective of the Columbia River. Given this understanding, aquifer tube measurements from the 100-F-59 area collected at 3 to 6 m (10 to 20 ft) bgs serve as a representation of leaching from the soil/sediment during periods of high river stage. The aquifer tubes are typically sampled when river stage is low (November) to moderate (March) and they cannot be sampled when river stage is high. Since the aquifer tube measurements from the areas of highest concentrations (Area C and the Slough Area) are all at or below the 10 $\mu\text{g/L}$ state surface water quality standard supporting the fact that leaching is minimal in these areas, it can be deduced that leaching is minimal to non-existent in this area as well, where the measurements are much lower than those areas.

Furthermore, the riparian areas are only periodically inundated with surface water. This would limit both the types of aquatic life that could occur in these habitats and the frequency of exposure. Only a limited diversity of highly opportunistic aquatic species would make use of these transient aquatic habitats, and they would only be able to make use of these habitats during the time in which they are inundated, further reducing the potential for adverse effects to aquatic life within the river system. Also, as shown in the RCBRA (DOE/RL-2007-21, Table 104), there was no correlation between Cr(VI) concentrations in bulk sediment samples and the results of survival and growth tests in bioassays conducted on sensitive benthic organisms (*Hyaella azteca*). Therefore, the bioavailable fraction of chromium in sediment pore water is not high enough to have adverse effects on aquatic invertebrates.

Iron – The maximum detected iron concentration exceeded the upper threshold ESL (Table L-71). However, the maximum sediment concentration falls within the range of concentrations detected in RCBRA riparian reference soil and sediment and Columbia River background sediment (95 percent UCL) (Table L-72). Therefore, iron does not represent a potential site-related risk to aquatic invertebrates and does not warrant further evaluation in this area.

Silicon – A sediment threshold ESL was not available for silicon (Table L-71). Silicon oxides, the form of silica that would be present in the environment, comprise the most abundant constituent of the earth's crust mass. Synthetic amorphous silica and silicates are similar to natural forms of silica and are expected to mix with and be subjected to the same natural processes as silicon dioxides already present in the environment (*Synthetic Amorphous Silica and Silicates* [UNEP, 2004]). Although very limited toxicological investigations have been conducted, and most of the investigations that have been conducted are based on acute bioassays, the available toxicological information strongly suggest that silicon has very low toxicity. Acute bioassays conducted with the fish *Brachydanio rerio* indicated no effects when loading rates of up to 10,000 mg/L were tested for a period of 96 hours (*The Acute Toxicity of AEROSIL 2000 to Brachydanio rerio* [Degussa AG, 1992a], *The Acute Toxicity of ULTRASIL VN 3 to Brachydanio rerio* [Degussa AG, 1992b]). The aquatic invertebrate *Daphnia magna* indicated immobilization when exposed to loading rates of 1,000 and 10,000 mg/L for a period of 24 hours (*The Acute Toxicity of*

AEROSIL 2000 to Daphnia magna [Degussa AG, 1992c], *The Acute Toxicity of ULTRASIL VN 3 to Daphnia magna* [Degussa AG, 1992d]). However, this response was attributed to the physical immobilization caused by the silicon dioxide particles adhering to the *D. magna* appendages and was not the result of a toxic response. Finally, growth inhibition bioassays conducted with the algae *Scenedesmus subspicatus* indicated no effects when loading rates of up to 10,000 mg/L were tested for a period of 72 hours (*Study on the toxicity towards algae of "SIPERNAT 820 A (sodium aluminum silicate)"* [Degussa AG, 1998]). Therefore, silicon has very low toxicity to aquatic life and does not warrant further evaluation in the FS.

L4.7.2 Terrestrial Plants and Invertebrates

The 100-F-59 area is dry between September and April. When flows increase above 210 kcfs and the area fills with water, then ponds form and remain while the flow decreases exposing some of the area (near waste site, Area C, and North Shore Area). Soils from the 100-F-59 area were evaluated in the same fashion as the upland waste sites described in Chapter 7 of this report. Exposure point concentrations (EPC)¹⁰ from the combined four sub areas (Area C, near waste site, slough, and North Shore Area) were compared to the plant and invertebrate ESLs (i.e., screening levels and PRGs) as shown in Table L-74. EPCs exceeded the lowest plant or invertebrate SSL for boron, chromium, lithium, manganese, vanadium, and zinc. However, only the chromium EPC exceeded a Hanford Site-specific PRG.

The chromium EPC of 156 mg/kg was above the invertebrate PRG of 149 mg/kg, with 12 of 60 samples exceeding (Table L-75). However, Area C and the near waste site, the areas with the most samples exceeding the PRG, are small (1,983 m² [20,860 ft²] and 4,265 m² [45,908 ft²] respectively) rocky areas. There is extensive unimpacted habitat available for terrestrial invertebrates in the adjacent area, such as the north shore area and along the rest of the River Corridor. The basis of the PRG value is the Hanford Site-specific NOEC for invertebrates published in the RCBRA (DOE/RL-2007-21). There is high confidence with respect to a lack of toxicity at this concentration because there was no correlation between chromium soil concentration up to this value and the measured response in the bioassays. The PRG is a NOEC set at the highest concentration tested in Hanford samples (no LOEC established), thus the concentration at which effects might be observed is unknown. Given the basis of the PRG, small area affected, poor habitat quality, and availability of large unimpacted areas nearby, risk to the terrestrial invertebrate community is not considered significant, and further evaluation is not warranted.

The chromium EPC of 156 mg/kg was below the plant PRG of 259 mg/kg. Like the PRG for invertebrates, this value represents a no effect concentration as there was no correlation with measured response in plant toxicity tests up to the highest concentration tested of 259 mg/kg. There are no significant risks to the plant community in the four 100-F-59 sub areas, and further evaluation is not warranted.

L4.7.3 Risk to Wildlife

A separate analysis of total chromium risks to wildlife was also conducted to evaluate dietary exposure to both terrestrial and aquatic wildlife potentially foraging in the 100-F-59 area. For the terrestrial evaluation, EPCs from the combined four sub areas (Area C, near waste site, slough, and North Shore Area) were compared to wildlife ESLs (i.e., screening levels and PRGs). ESLs were not previously derived for aquatic wildlife. Exposure models for the bufflehead and mallard were created using the same TRVs as presented in *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-00784) and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311), which are both presented in Appendix H of *Remedial*

¹⁰ EPCs were calculated using ProUCL software, Version 4 using the same methods and assumptions as were used for the risk assessment in Chapter 7.

Investigation/Feasibility Study for the 100-KR-1, 100-KR, and 100-KR-4 Operable Units (DOE/RL-2010-97), combined with exposure assumptions from the RCBRA (DOE/RL-2007-21) for the bufflehead and from *Wildlife Exposure Factors Handbook* (EPA/600/R-93/187) for the mallard. For aquatic wildlife, the EPC was generated using just the areas that become inundated for a substantial amount of time and would contain aquatic food items (Area C, near waste site, and slough). The distribution of chromium concentrations shown in Figures L-12 and L-13 suggest that potential residues from the former burn pit did not reach the north shore area supporting this assumption.

Results for terrestrial wildlife are in Table L-76. EPCs exceeded wildlife-screening levels for chromium, lead, vanadium, and zinc. EPCs exceeded the PRGs for bis(2-ethylhexyl) phthalate, chromium, and vanadium. For all three chemicals that exceeded the PRGs, the EPCs only exceeded the killdeer PRG. The PRG for bis(2ethylhexyl) phthalate is based upon a no effect level so there is no certainty that risk from this common lab contaminant is significant. The vanadium PRG for the killdeer is well below the site-specific background value, and only 3 samples actually exceed background (Table L-77).

Results for aquatic wildlife are in Tables L-78 and L-79. The HQ for chromium exceeded 1.0 for the bufflehead suggesting a potential risk. The HQs for chromium, vanadium, and bis(2-ethylhexyl) phthalate exceeded 1.0 for the mallard. Uncertainty in the bis(2ethylhexyl) phthalate HQ and the vanadium HQ is the same as that for the killdeer.

Refined risk estimates for the killdeer, bufflehead, and mallard are found Tables L-80 through L-82 for those chemicals with HQs greater than 1.0. The refined evaluations include a number of scenarios using site-specific tissue residue data when available and published models from ORNL as a comparison (*Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation* [BJC/OR-112]). Exposure parameters such as body weights, ingestion rates, and dietary composition were the same as those in the RCBRA and *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site* (CHPRC-01311) (Appendix H of DOE/RL-2010-97) for killdeer, Table L-78 for bufflehead, and Table L-79 for mallard. Several exposure-modifying factors were employed under various scenarios (using one or more or all of the factors) to generate a range of risks estimates:

- Area use factors (AUFs) were established using a ratio of the site boundary to home range of the receptor assuming the following sizes of the sub areas
 - 1,983 m² (20,860 ft²)
 - 4,265 m² (45,908 ft²)
 - 50 m (164 ft) wide bank to bank and 500 m (1,640 ft) long for the slough
 - 35,500 m² (382,119 ft²) for the North Shore Area
- A site use factor (SUF) for waterfowl was estimated as the proportion of the year that the slough is inundated (5 months) and for the killdeer as the portion of the year that the site was not inundated (7 months).
- GAFs for incidentally ingested soil/sediment were estimated at 0.06 (6 percent) as used by EPA for the Tex Tin Superfund Site (*Final Report Tex Tin Site Texas City, Texas* [EPA, 1997]).
- A second GAF for incidentally ingested soil/sediment was estimated at 0.003 (0.3 percent) using a more recent study conducted on swan (“Bioaccessibility of Trace Metals in Sediment, Microalga and Antifouling Paint to the Wild Mute Swan, *Cygnus olor*” [Turner and Hambling, 2012]).

Results in Tables L-80 through L-82 show that for waterfowl and killdeer, low-level risks exist without incorporation of any exposure-modifying factors (AUFs, SUFs, and GAFs). However, all of these exposure-modifying factors are common practice within ERAs and are described as part of *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final* (EPA 540-R-97-006). As such, the quantitative estimates of exposure with incorporation of exposure modifying factors result in HQs below 1, suggesting that risks are sufficiently low and remedial action is not warranted.

L4.7.4 Final Conclusion for 100-F-59

Of the key groundwater plume contaminants investigated, none were detected at concentrations of ecological relevance in the riparian environments for the Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C waste sites. Therefore, no further evaluation is warranted in the FS for these four waste sites.

L4.8 Conclusions for 100-F/IU2/IU6

The purpose for preparing this CSM was to address, on a reactor decision area basis, the potential for Hanford Site contaminants in soil or groundwater to migrate to riparian or nearshore areas at concentrations that could be of concern for ecological receptors. This CSM supplements the analysis of River Corridor-wide ecological risks presented in the ecological risk assessment of the RCBRA (DOE/RL-2007-21). The RCBRA (DOE/RL-2007-21) identified, on a site-wide basis, some COECs that warranted further evaluation. Consideration for this site-wide evaluation is inclusive of portions of waste sites within the riparian zone, such as 100-F-42, 100-F-43, and 116-F-16. Based on the results of the further evaluation contained in this CSM, only detected concentrations of Cr(VI) have some limited potential to discharge to surface water above ambient water quality standards. Other chemicals in riparian or nearshore groundwater, seeps/springs, aquifer tubes, and pore water are not reliably detectable at levels of ecological concern or are not associated with contaminated groundwater resulting from Hanford Site operations. It is recommended that Cr(VI) be monitored at discharge points to surface water and be brought forward to the alternatives evaluation in the 100-F/IU FS.

There are uncertainties in this evaluation related to analytical data quality. With the exception of most recently collected analytical data in groundwater, analytical methods had MDLs that approached or were higher than aquatic benchmark. When methods with adequate detection limits are used, the results show that contaminant concentrations are less than aquatic benchmark. In many cases, where analytical results were higher than aquatic benchmark, it was determined that the results were based on unfiltered samples. Unfiltered analytical results are inappropriate for comparison with aquatic benchmark; in general, filtered analytical results were less than aquatic benchmark. In some cases, where concentrations were reported higher than aquatic benchmark, further evaluation of the data revealed that it was qualified because of the presence of blank contamination. The analytical detection limit considerations and data quality issues further support the conclusion that contaminant concentrations in water were not reliably detected above levels of ecological significance.

In addition, riparian soil located within the Near Waste Site, Slough Area, Northern Shore, and 128-F-2 Area C waste sites was evaluated as sediment for those periods when the sites are inundated. The sediment concentrations themselves do not represent risks of significance, and no COPECs in the 100-FR-3 Groundwater OU represent a potential ongoing source for the inundated soil/sediment concentrations; therefore, no further evaluation is warranted in the FS.

L5 References

- Anderson, Richard A., Marilyn M. Polansky, Noella A. Bryden, Kristine Y. Patterson, Claude Veillon, and Walter H. Glinsmann, 1983, "Effects of Chromium Supplementation on Urinary Cr Excretion of Human Subjects and Correlation of Cr Excretion with Selected Clinical Parameters," *The Journal of Nutrition* 113(2):276-281. Available at: <http://jn.nutrition.org/content/113/2/276.full.pdf>.
- Anderson, Richard A. and Adriane S. Kozlovsky, 1985, "Chromium Intake, Absorption and Excretion of Subjects Consuming Self-Selected Diets," *Am. J. Clin. Nutr.* 41(6):1177-1183. Available at: <http://ajcn.nutrition.org/content/41/6/1177.full.pdf+html>.
- Atomic Energy Act of 1954*, as amended, 42 USC 2011, Pub. L. 83-703, 68 Stat. 919. Available at: <http://www.nrc.gov/reading-rm/doc-collections/nuregs/staff/sr0980/v1/sr0980v1.pdf#page=13>.
- BCMOE, 1995, *Ambient Water Quality Criteria for Fluoride*, British Columbia Ministry of the Environment, British Columbia, Canada. Available at: <http://www.env.gov.bc.ca/wat/wq/BCguidelines/fluoride/index.html>.
- Beyer, W. Nelson, Matthew C. Perry, and Peter C. Osenton, 2008, "Sediment Ingestion Rates in Waterfowl (Anatidae) and Their Use in Environmental Risk Assessment," *Integr. Environ. Assess. Manag.* 4(2):246-251.
- BHI-00538, 1996, *100 Area River Effluent Pipelines Characterization Report*, Rev. 00, Bechtel Hanford, Inc., Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=DA06639804>.
- BHI-01141, 1998, *100 Area River Effluent Pipelines Risk Assessment*, Rev. 0, Bechtel Hanford, Inc., Richland, Washington.
- BJC/OR-112, 1998, *Biota Sediment Accumulation Factors for Invertebrates: Review and Recommendations for the Oak Ridge Reservation*, Bechtel Jacobs Company LLC, Oak Ridge, Tennessee. Available at: <http://rais.ornl.gov/documents/bjcor-112a1.pdf>.
- Blindow, Irmgrad, 1988, "Phosphorous Toxicity in *Chara*," *Aquatic Botany* 32(4):393-395.
- CHPRC-00784, 2011, *Tier 1 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=0093652>.
- CHPRC-01311, 2011, *Tier 2 Risk-Based Soil Concentrations Protective of Ecological Receptors at the Hanford Site*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=0093653>.
- 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>.
- CRWQCB, 2007, *Screening for Environmental Concerns at Sites with Contaminated Soil and Groundwater*, Interim Final, California Regional Water Quality Control Board, San Francisco Bay Region, Oakland, California. Available at: http://www.swrcb.ca.gov/sanfranciscobay/water_issues/available_documents/ESL_May_2008.pdf.

- Degussa AG, 1992a, *The Acute Toxicity of AEROSIL 2000 to Brachydanio rerio*, (OECD Guideline 203, 96 hr), Unpublished Report: Degussa AG – US – IT – No.91-0132 – DGT, Dusseldorf, Germany.
- Degussa AG, 1992b, *The Acute Toxicity of ULTRASIL VN 3 to Brachydanio rerio*, (OECD Guideline 203, 96 hr), Unpublished Report: Degussa AG – US – IT – No.91-0140 – DGO, TNO, Dusseldorf, Germany.
- Degussa AG, 1992c, *The Acute Toxicity of AEROSIL 2000 to Daphnia magna*, (OECD Guideline 202, 24 hr), Unpublished Report: Degussa AG – US – IT – No.92-0139 – DGO, TNO, Dusseldorf, Germany.
- Degussa AG, 1992d, *The Acute Toxicity of ULTRASIL VN 3 to Daphnia magna*, (OECD Guideline 202, 24 hr), Unpublished Report: Degussa AG – US – IT – No.92-0162 – DGO, TNO, Dusseldorf, Germany.
- Degussa AG, 1998, *Study on the toxicity towards algae of “SIPERNAT 820 A (sodium aluminum silicate)”*, Institut Fresenius IF-98/30577-00, Unpublished Report: Degussa AG – US – IT – No.98-0072 – DGO, Dusseldorf, Germany.
- DOE/EH-0676, 2004, *RESRAD-BIOTA: A Tool for Implementing a Graded Approach to Biota Dose Evaluation, User’s Guide, Version 1*, ISCORS Technical Report 2004-02, U.S. Department of Energy, Washington, D.C. Available at: http://web.ead.anl.gov/resrad/documents/RESRAD-BIOTA_Manual_Version_1.pdf.
- DOE/RL-92-12, 1992, *Sampling and Analysis of 100 Area Springs*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=D196090827>.
- DOE/RL-92-24, 2001, *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*, Rev. 4, 2 vols., U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www2.hanford.gov/arpir/?content=findpage&AKey=0096062>.
<http://www2.hanford.gov/arpir/?content=findpage&AKey=0096061>.
- DOE/RL-95-55, 1995, *Hanford Site Background: Evaluation of Existing Soil Radionuclide Data*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www2.hanford.gov/arpir/?content=findpage&AKey=E0041830>.
- DOE/RL-96-12, 1996, *Hanford Site Background: Part 2, Soil Background for Radionuclides*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www2.hanford.gov/arpir/?content=findpage&AKey=D1808987>.
- DOE/RL-96-17, 2009, *Remedial Design Report/Remedial Action Work Plan for the 100 Area*, Rev. 6, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=0095436>.
- DOE/RL-2003-04, 2005, *Sampling and Analysis Plan for the 200-PO-1 Groundwater Operable Unit*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=DA01974685>.

- DOE/RL-2004-37, 2005, *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA*, Rev 2, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=DA01946743>.
- DOE/RL-2005-42, 2006, *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=DA04279469>.
<http://www5.hanford.gov/arpir/?content=findpage&AKey=DA04279655>.
- DOE/RL-2007-21, 2012, *River Corridor Baseline Risk Assessment, Volume I: Ecological Risk Assessment*, Volume 1, Parts 1 and 2, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=0093215>.
<http://www5.hanford.gov/arpir/?content=findpage&AKey=0093214>.
- DOE/RL-2008-46, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan*, Rev. 0, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=1002260412>.
- DOE/RL-2008-46-ADD4, 2010, *Integrated 100 Area Remedial Investigation/Feasibility Study Work Plan, Addendum 4: 100-FR-1, 100-FR-2, 100-FR-3, 100-IU-2, and 100-IU-6 Operable Units*, Rev. 0, Reissue, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www2.hanford.gov/arpir/?content=findpage&AKey=1006220804>.
- DOE/RL-2010-11, 2010, *Hanford Site Groundwater Monitoring and Performance Report for 2009: Volumes 1 & 2*, Rev. 1, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=0084237>.
- DOE/RL-2010-97, 2011, *Remedial Investigation/Feasibility Study for the 100-KR-1, 100-KR, and 100-KR-4 Operable Units*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/?content=findpage&AKey=0093615>.
- DOE/RL-2010-117, 2011, *Columbia River Component Risk Assessment, Volume I: Screening-Level Ecological Risk Assessment*, Volume I, Part 1, Draft A, Department of Energy, Richland Operations Office, Richland, Washington. Available at: <http://www5.hanford.gov/arpir/index.cfm?content=findpage&AKey=0093619>.
- DOE/RL-2012-15, 2013, *Remedial Investigation/Feasibility Study for the 100-NR-1 and 100-NR-2 Operable Units*, Draft A, U.S. Department of Energy, Richland Operations Office, Richland, Washington.
- DOE-STD-1153-2002, 2002, *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota*, DOE Technical Standard, U.S. Department of Energy, Washington, D.C. Available at: http://www.hss.doe.gov/nuclearsafety/techstds/docs/standard/1153_module2.pdf.
- ECF-HANFORD-11-0038, 2012, *Soil Background Data for Interim Use at the Hanford Site*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.

- ECF-HANFORD-11-0158, 2011, *Tier 2 Terrestrial Plant and Invertebrate Preliminary Remediation Goals (PRGs) for Nonradionuclides for Use at the Hanford Site*, Rev. 0, CH2M HILL Plateau Remediation Company, Richland, Washington.
- ECF-HANFORD-11-0165, 2012, *Evaluation of Hexavalent Chromium Leach Test Data Conducted on Vadose Zone Sediment Samples from the 100 Area*, Rev. 1, CH2M HILL Plateau Remediation Company, Richland, Washington.
- Ecology Publication 11-03-006, 2011, *Ecological Soil Screening Levels for Arsenic and Lead in the Tacoma Smelter Plume Footprint and Hanford Site Old Orchards Ecology*, Washington State Department of Ecology, Olympia, Washington. Available at: <http://www.ecy.wa.gov/pubs/1103006.pdf>.
- Ecology Publication 11-09-054, 2011, *Development of Benthic SQVs for Freshwater Sediments in Washington, Oregon, and Idaho*, Washington State Department of Ecology, Olympia, Washington. Available at: <http://www.ecy.wa.gov/pubs/1109054.pdf>.
- EPA, 1997, *Final Report Tex Tin Site Texas City, Texas*, Environmental Response Team, U.S. Environmental Protection Agency, Cincinnati, Ohio.
- EPA, 1988, "Chromium," *Rev. Environ. Contam. Toxicol.* 107:39-52.
- EPA, 2009, *National Recommended Water Quality Criteria*, U.S. Environmental Protection Agency, Office of Water, Office of Science and Technology, Washington, D.C. Available at: <http://www.epa.gov/waterscience/criteria/wqcriteria.html>.
- EPA 440-5-88-093, 1988, *Ambient Aquatic Life Water Quality Criteria for Antimony (III)*, Draft, Environmental Research Laboratories, Office of Research and Development, U.S. Environmental Protection Agency, Duluth, Minnesota. Available at: <http://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=00001OIA.txt>.
- EPA 540-R-97-006, 1997, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments: Interim Final*, OSWER 9285.7-25, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: <http://www.epa.gov/swerrims/riskassessment/ecorisk/ecorisk.htm>.
- EPA-600-R-02-011, 2005, *Procedures for the Derivation of Equilibrium Partitioning Sediment Benchmarks (ESBs) for the Protection of Benthic Organisms: Metal Mixtures (Cadmium, Copper, Lead, Nickel, Silver, and Zinc)*, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/nheerl/download_files/publications/metalsESB_022405.pdf.
- EPA/600/R-07/140, 2007, *Monitored Natural Attenuation of Inorganic Contaminants in Ground Water: Volume 2 – Assessment for Non-Radionuclides Including Arsenic, Cadmium, Chromium, Copper, Lead, Nickel, Nitrate, Perchlorate, and Selenium*, U.S. Environmental Protection Agency, Washington, D.C. Available at: <http://www.epa.gov/nrmrl/pubs/600R07140.html>.
- EPA/600/R-93/187, 1993, *Wildlife Exposure Factors Handbook*, Vol. I and II, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

- EPA/ROD/R10-99/039, 1999, *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-F/IUR-1, 100-F/IUR-2, 100-IU-2, 100-IU-6, and 200-CW-3 Operable Units, Hanford Site, Benton County, Washington (100 Area Remaining Sites)*, U.S. Department of Energy, U.S. Environmental Protection Agency, Region 10, Washington State Department of Ecology, Olympia, Washington. Available at: <http://www.epa.gov/superfund/sites/rods/fulltext/r1099039.pdf>.
- ES/ER/TM-85/R3, 1997, *Toxicological Benchmarks for Screening Contaminants of Potential Concern for Effects on Terrestrial Plants: 1997 Revision*, Lockheed Martin Energy Systems, Inc., Oak Ridge, Tennessee. Available at: <http://rais.ornl.gov/documents/tm85r3.pdf>.
- ES/ER/TM-96/R2, 1996, *Toxicological Benchmarks for Screening Potential Contaminants of Concern for Effects on Aquatic Biota: 1996 Revision*, Lockheed Martin Energy Systems, Inc., Oak Ridge, Tennessee. Available at: <http://rais.ornl.gov/documents/tm96r2.pdf>.
- ES/ER/TM-126/R2, 1997, *Toxicological Benchmarks for Contaminants of Potential Concern for Effects on Soil and Litter Invertebrates and Heterotrophic Process: 1997 Revision*, Lockheed Martin Energy Systems, Inc., Oak Ridge, Tennessee. Available at: <http://www.ornl.gov/~webworks/cpr/rpt/75155.pdf>.
- Fendorf, S.E. and R.J. Zasoski, 1992, "Chromium(iii) Oxidation by Delta-MnO₂ .1. Characterization," *Environmental Science & Technology* 26:79-85.
- Hirsch, Marianne P., 1998, Bioaccumulation of Silver from Laboratory-Spiked Sediments in the Oligochaete (*Lumbriculus Variegatus*), *Environ. Toxicol. Chem.* 17(4):605-609. Available at: <http://onlinelibrary.wiley.com/doi/10.1002/etc.5620170412/pdf>.
- Jackson, B.J.S. and J.A. Jackson, 2000, "Killdeer (*Charadrius vociferous*)," *The Birds of North America*, No. 517, A. Poole and F. Gill (eds.), The Birds of North America, Inc., Philadelphia, Pennsylvania.
- James, Bruce R. and Richmond J. Bartlett, 1983, "Behavior of Chromium in Soils: V. Fate of Organically Complexed Cr(III) Added to Soil," *J. Environ. Qual.* 12:169-172.
- Langard, S. and T. Norseth, 1979, "Chromium," *Handbook on the Toxicology of Metals*, L. Friberg, G.F. Nordberg, and V. Vouk (eds.), Elsevier/North Holland Biomedical Press, Amsterdam, The Netherlands, pp. 383-397.
- Mace, Terrence R., 1971, *Nest Dispersion and Productivity of Killdeers (Charadrium vociferous)*, M.S. Thesis, St. Paul University, St. Paul, Minnesota.
- McGurk, M.D., F. Landry, A. Tang, and C.C. Hanks, 2006, "Acute and Chronic Toxicity of Nitrate to Early Life Stages of Lake Trout (*Salvelinus Namaycush*) and Lake Whitefish (*Coregonus Clupeaformis*)," *Env. Sci. Tox.* 25(8):2187-2196. Available at: <http://onlinelibrary.wiley.com/doi/10.1897/05-270R.1/pdf>.
- MDEQ, 2011, "Water Quality Values," Rule 57, Michigan Department of Environmental Quality, Lansing, Michigan. Available at: http://www.michigan.gov/deq/0,1607,7-135-3313_3686_3728-11383--,00.html.
- Milacic R. and J. Stupar, 1995, "Fractionation and Oxidation of Chromium in Tannery Waste- and Sewage-Sludge-Amended Soils," *Environ. Sci. Technology* 29(2):506-514.

- Nagy, Kenneth A., 2001, "Food Requirements of Wild Animals: Predictive Equations for Free-living Mammals, Reptiles, and Birds," *Nutrition Abstracts and Reviews*, Series B, 71:21R-32R.
- Neumann, Dietrich, Meike Kramer, Ina Raschke, and Brigitte Gräfe, 2001, "Detrimental Effects of Nitrite on the Development of Benthic Chironomus Larvae, in Relation to Their Settlement in Muddy Sediments," *Archiv für Hydrobiologie* 153(1):103-128.
- ORNL-5786, 1984, *A Review and Analysis of Parameters for Assessing Transport of Environmentally Released Radionuclides through Agriculture*, Oak Ridge National Laboratory, Oak Ridge, Tennessee. Available at:
<http://www2.hanford.gov/arpir/?content=findpage&AKey=D196016829>.
- OSWER Directive 9285.7-55, 2005, *Guidance for Developing Ecological Soil Screening Levels*, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at:
http://www.epa.gov/ecotox/ecossl/pdf/ecossl_guidance_chapters.pdf.
- OSWER Directive 9285.7-57, 2007, *Ecological Soil Screening Levels for DDT and Metabolites: Interim Final*, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://rais.ornl.gov/documents/eco-ssl_ddt.pdf.
- OSWER Directive 9285.7-60, 2003, *Ecological Soil Screening Level for Aluminum: Interim Final*, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C. Available at: http://www.epa.gov/ecotox/ecossl/pdf/eco-ssl_aluminum.pdf.
- Ogawa, E., 1976, "Experimental Study of Adsorption, Distribution and Excretion of Trivalent and Hexavalent Chromium" *Japanese Journal of Pharmacology* 26:92.
- Outridge, P.M. and A.M. Scheuhammer, "Bioaccumulation and Toxicology of Chromium: Implications for Wildlife," *Environ. Contam. Toxicol.* 130:31-77.
- PNL-5289, 1984, *Investigation of Ground-Water Seepage from the Hanford Shoreline of the Columbia River*, Pacific Northwest Laboratory, Richland, Washington. Available at:
<http://www2.hanford.gov/arpir/?content=findpage&AKey=D196018566>.
- PNL-5685, 1986, *A Preliminary Survey of Polychlorinated Biphenyls (PCBs) in Aquatic Habitats and Great Blue Herons on the Hanford Site*, Pacific Northwest Laboratory, Richland, Washington. Available at: <http://www.osti.gov/bridge/servlets/purl/6391002/6391002.pdf>.
- PNL-7500, 1990, *1988 Hanford Riverbank Springs Characterization Report*, Pacific Northwest Laboratory, Richland, Washington. Available at:
<http://www2.hanford.gov/arpir/?content=findpage&AKey=D196110656>.
- PNL-8167, 1992, *Hydrogeologic Controls on Ground-Water and Contaminant Discharge to the Columbia River Near the Hanford Townsite*, Pacific Northwest Laboratory, Richland, Washington. Available at:
<http://www.osti.gov/energycitations/servlets/purl/10116996-346uaK/10116996.pdf>.
- PNL-10535, 1995, *Environmental Monitoring of Columbia River Sediments: Grain-Size Distribution and Contaminant Association*, Pacific Northwest Laboratory, Richland, Washington. Available at:
<http://www.osti.gov/bridge/servlets/purl/56591-HdoKf8/56591.pdf>.

- PNNL-13417, 2001, *Simultaneously Extracted Metals/Acid-Volatile Sulfide and Total Metals in Surface Sediment from the Hanford Reach of the Columbia River and the Lower Snake River*, Pacific Northwest National Laboratory, Richland, Washington. Available at:
http://www.pnl.gov/main/publications/external/technical_reports/PNNL-13417.PDF.
- PNNL-13674, 2001, *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*, Pacific Northwest National Laboratory, Richland, Washington. Available at:
http://www.pnl.gov/main/publications/external/technical_reports/pnnl-13674.pdf.
- PNNL-17674, 2008, *Geochemical Characterization of Chromate Contamination in the 100 Area Vadose Zone at the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at:
http://www.pnl.gov/main/publications/external/technical_reports/PNNL-17674.pdf.
- PNNL-18577, 2009, *A Review of Metal Concentrations Measured in Surface Soil Samples Collected on and Around the Hanford Site*, Pacific Northwest National Laboratory, Richland, Washington. Available at:
http://www.pnl.gov/main/publications/external/technical_reports/PNNL-18577.pdf.
- PNNL-19455, 2010, *Hanford Site Environmental Report for Calendar Year 2009*, Pacific Northwest National Laboratory, Richland, Washington. Available at:
http://www.pnl.gov/main/publications/external/technical_reports/PNNL-19455.pdf.
- PNNL-SA-41467, 2004, *Literature Review of Environmental Documents in Support of the 100 and 300 Area River Corridor Baseline Risk Assessment*, Pacific Northwest National Laboratory, Richland, Washington. Available at:
http://www.washingtonclosure.com/documents/mission_complete/PNNL-SA-41467.pdf.
- Resource Conservation and Recovery Act of 1976*, 42 USC 6901, et seq. Available at:
<http://www.epa.gov/lawsregs/laws/rcra.html>.
- SGW-39305, 2008, *Technical Evaluation of the Interaction of Groundwater with Columbia River at the Department of Energy Hanford Site, 100-D Area*, Rev. 0, Fluor Hanford, Inc., Richland, Washington. Available at:
<http://www5.hanford.gov/arpir/?content=findpage&AKey=0812290631>.
- Sheppard Steve C., Marsha I. Sheppard, Marie-Odile Gallerand, and Barb Sanipelli, 2005, "Derivation of Ecotoxicity Thresholds for Uranium," *J. Environ. Radioact.* 79(1):55-83.
- Standley, L.J., 1997, "Effect of Sedimentary Organic Matter Composition on the Partitioning and Bioavailability of Dieldrin to the Oligochaete *Lumbriculus variegatus*," *Environ. Sci. Technol.* 31(9):2577-2583.
- Turner, Andrew and Jessica Hambling, 2012, "Bioaccessibility of Trace Metals in Sediment, Microalga and Antifouling Paint to the Wild Mute Swan, *Cygnus olor*," *Water, Air, & Soil Pollution* 223(5):2503-2509. Available at:
<http://link.springer.com/article/10.1007%2Fs11270-011-1043-y#page-1>.
- UNEP, 2004, *Synthetic Amorphous Silica and Silicates*, SIDS Initial Assessment Report for SIAM 19, United Nations Environment Program, Berlin, Germany, October 19-22. Available at:
<http://www.chem.unep.ch/irptc/sids/oecd/sids/Silicates.pdf>.

- UNI-3262, 1986 (declassified 1990), *River Discharge Lines Characterization Report*, UNC Nuclear Industries, Inc., Richland, Washington. Available at:
<http://www5.hanford.gov/arpir/?content=findpage&AKey=E0009368>.
- WAC 173-201A, “Water Quality Standards for Surface Waters of the State of Washington,” *Washington Administrative Code*, Olympia, Washington. Available at:
<http://apps.leg.wa.gov/WAC/default.aspx?cite=173-201A>.
- WAC 173-340, “Model Toxics Control Act—Cleanup,” *Washington Administrative Code*, Olympia, Washington. Available at: <http://apps.leg.wa.gov/WAC/default.aspx?cite=173-340>.
- WCH-380, 2010, *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*, Rev. 1, Washington Closure Hanford, Richland, Washington. Available at:
http://www.osti.gov/bridge/product.biblio.jsp?osti_id=1017505.
- WCH-398, 2011, *Data Summary Report for the Remedial Investigation of Hanford Site Releases to the Columbia River, Hanford Site, Washington*, Rev. 0, Washington Closure Hanford, Richland, Washington. Available at:
http://www.washingtonclosure.com/documents/mission_complete/WCH-398_Rev.0/WCH-398%20Rev.%200%20Sections%201-8.pdf.
- Weaver, Robert M. and Michael F. Hochella, Jr., 2003, “The reactivity of seven Mn-oxides with Cr³⁺aq: A comparative analysis of a complex, environmentally important redox reaction,” *American Mineralogist* 88:2016-2027. Available at:
<http://ag.udel.edu/soilchem/Weaver03AmerMin.pdf>.
- WHC-SD-EN-TI-198, 1993, *100 Area Columbia River Sediment Sampling*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at:
<http://www5.hanford.gov/arpir/?content=findpage&AKey=D196111730>.
- WHC-SD-EN-TI-278, 1994, *Columbia River Effluent Pipeline Survey*, Rev. 0, Westinghouse Hanford Company, Richland, Washington. Available at:
<http://www5.hanford.gov/arpir/?content=findpage&AKey=D196074913>.
- WHO, 2001, *Vanadium Pentoxide and Other Inorganic Vanadium Compounds*, Concise International Chemical Assessment Document 29, World Health Organization, Geneva, Switzerland. Available at: <http://www.who.int/ipcs/publications/cicad/en/cicad29.pdf>.
- WSRF 2008-031, 2008, *Waste Site Reclassification Form*, Operable Unit 100-FR-1, Waste Site Code 128-F-2, with attachment “Remaining Sites Verification Package for the 128-F-2, 100-F Burning Pit Waste Site,” Rev. 0, U.S. Environmental Protection Agency and U.S. Department of Energy, Richland Operations Office, Richland, Washington. Available at:
<http://www5.hanford.gov/arpir/?content=findpage&AKey=0902180709>.

This page intentionally left blank.