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River Corridor
Closure Contract

Inter-Areas Component of the River Corridor Baseline Risk Assessment Sampling Summary

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Washington Closure Hanford

Prepared for the U.S. Department of Energy, Richland Operations Office
Office of Assistant Manager for River Corridor

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Author:

J. M. Queen

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ACRONYMS AND ABBREVIATIONS

AMVA	American Veterinary Medical Association
APEL	Applied Process Engineering Laboratory
ASL	Analytical Services Laboratory
ASTM	*American Society for Testing and Materials*
CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
cfs	cubic feet per second
DOH	Washington State Department of Health
DQO	data quality objective
EAS	Environmental Assessment Services, LLC
Ecology	Washington State Department of Ecology
ENRE	Environmental Restoration (Database)
EPA	U.S. Environmental Protection Agency
FETAX	Frog Embryo Teratogenesis Assay-Xenopus
GiSdT	Guided Interactive Statistical Decision Tools
GPS	global positioning system
HEPA	high-efficiency particulate air
MIS	multi-increment sampling
OSE	Orphan Site Evaluation
OU	operable unit
PCB	polychlorinated biphenyl
RCBRA	River Corridor Baseline Risk Assessment
SAF	Sample Authorization Form
SAI	sampling and analysis instructions
SAP	sampling and analysis plan
SDG	sample delivery group
STL	Severn-Trent Laboratories
SVOC	semi-volatile organic compounds
TLD	thermoluminescent dosimeter
T & E	threatened and endangered
WET	Whole Effluent Toxicity
WCH	Washington Closure Hanford, LLC

1.0 INTRODUCTION

1.1 PURPOSE

This report has been prepared in support of the Inter-Areas Component and describes the 2006/2007 supplemental data collection effort and noteworthy events. This report describes the sampling locations, identifies samples collected, and describes any modifications and additions made to the *Sampling and Analysis Plan for the 100 Area and 300 Area Component of the RCBRA* (DOE/RL-2005-42). Results from the sampling effort will be combined with previously collected risk assessment data and used to complete a baseline risk assessment on the environmental conditions remaining after completion of interim remedial actions on the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) waste sites in the 100 and 300 Areas of the Hanford Site. The risk assessment will help determine whether the interim remedial actions are protective of the ecological and human receptors found in these areas. The results of the assessment will be used to support risk management decision-making for final records of decision.

1.2 BACKGROUND AND SCOPE

During completion of Washington Closure Hanford's (WCH) 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment (RCBRA) sampling and analysis in late 2005, the need for additional data from riparian and near-shore aquatic zones of the nonoperational geographical areas of the River Corridor designated as the "Inter-Areas," as depicted in Figure 1-1 was identified. This additional study is referred to as the Inter-Areas Component of the RCBRA and will supplement data gaps of various locations, media types, and potential contaminants from the 100 Area and 300 Area Component of the RCBRA, herein referred to as the 100/300 Areas Component. The primary purpose of the Inter-Areas Component is to evaluate risks from current concentrations of chemicals and radionuclides between operational areas in the 100 and 300 Areas riparian and near-shore aquatic zones. This includes evaluating areas of emerging 200 Area groundwater plumes (under current conditions), slough and backwater areas, and habitats found predominantly in areas between reactor/operational areas.

Special attention was focused on the sediment depositional areas in sloughs along the Columbia River shoreline. Other investigation areas were selected based on presence of emergent groundwater contamination plumes from the 200 Area. In combination with the 100/300 Areas Component, the conclusion of sampling these inter-areas will result in a contiguous sampling campaign of the Hanford Site Columbia River shoreline from the Vernita Bridge downriver through the 300 Area (Figure 1-1). The Inter-Areas Component sampling also addresses data gaps by supplementing environmental data collection for the 100/300 Areas Component, namely additional data collection for the 100-B/C Pilot project (DOE-RL 2005b), the *Aquatic and Riparian Receptor Impact Information for the 100-NR-2 Groundwater Operable Unit* (DOE-RL 2006), and samples not collected in 2005 and 2006 during the 100/300 Areas Component of RCBRA (e.g., amphibian and kingbird tissue).

Upland investigation areas were not included as part of the Inter-Areas Component and not associated with reactor/operational areas, will be addressed through the Orphan Site Evaluation (OSE) process. These evaluations are a systematic approach to review land parcels outside of

known waste sites to identify potential waste sites within the river corridor designated under the CERCLA. The OSE process for the upland portion of the Inter-Areas is scheduled to begin in late 2008.

Because the Inter-Areas assessment is effectively an expansion of the shoreline evaluation performed for the 100/300 Areas Component, the data quality objectives (DQOs) and study design are similar between projects. The Inter-Areas DQOs and study design are documented in Appendix E of the *Sampling and Analysis Plan for the 100 Area and 300 Area Component of the RCBRA* (DOE/RL-2005-42), herein referred to as the SAP. Summaries of the 100/300 Area Component sampling events can be found in the *100 Area and 300 Area Component of the RCBRA Fall 2005 Data Compilation* (WCH-085) and the *100 Area and 300 Area Component of the RCBRA Spring 2006 Data Compilation* (WCH-139).

Draft A of the *Risk Assessment Report for the 100 Area and 300 Areas Component of the RCBRA* (DOE/RL-2007-21) was issued in June 2007 and did not include data collected during the Inter-Areas Component sampling effort. A web-based user interface for data, the Guided Interactive Statistical Decision Tools (GiSdT), was also created at this time to store the data used in Draft A of the RCBRA. During the review of Draft A, it was decided that both the 100/300 Areas and Inter-Areas Components would be combined in Draft B of the RCBRA. Draft B will therefore fully integrate all analytical, biotoxicity, and survey data from both components and is scheduled to be issued for review fall 2008. GiSdT will also be updated to include data collected during the Inter-Areas sampling effort.

1.2.1 Investigation Area Name Standardization

Due to the recent integration of the Inter-Areas data with the 100/300 Areas data, five of the Inter-Areas investigation area names have been standardized to reflect the original 100/300 Areas investigation area names. This change reflecting the original investigation area names has been documented in this summary, the Environmental Restoration (ENRE) Database, and with archived sample delivery groups (SDGs).

The original Inter-Areas investigation area names can be found in logbooks, chain of custodies, and SDGs and will not be updated. The original 100/300 Areas Component names will be used in this summary, Draft B of the Risk Assessment Report, the ENRE Database, and the GiSdT. Table 1-1 provides a crosswalk of the Inter-Areas names and the original 100/300 names.

In addition, investigation area RCBRA 100B/C was created as a fish sampling transect. By coincidence, fish were collected within the RCBRA 2b Aq investigation area, rather than the newly generated RCBRA B/C area. Therefore, the final and accepted name of RCBRA 2b Aq is documented in this summary, ENRE, and with the archived SDGs.

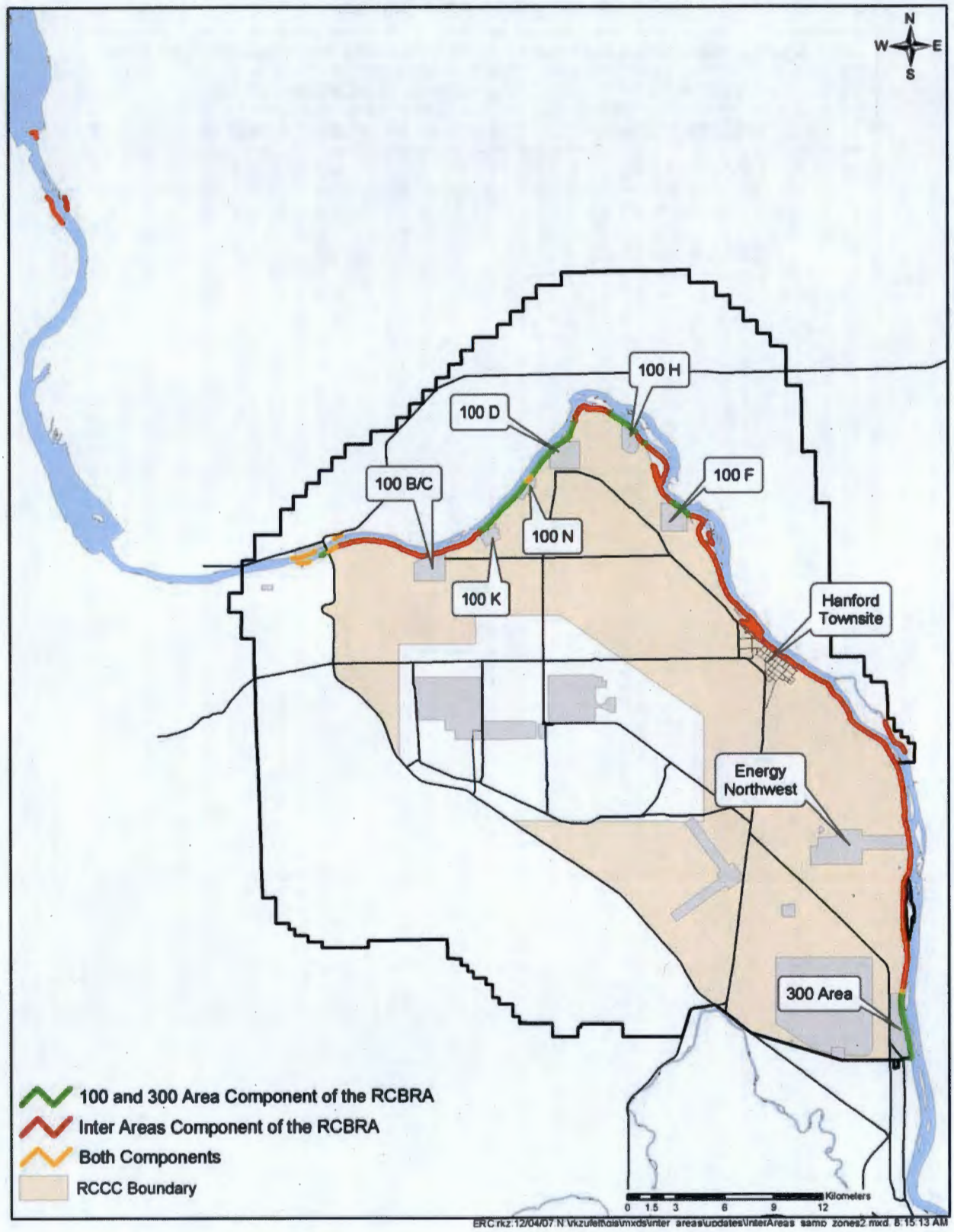
Table 1-1. Crosswalk of the Inter-Areas and 100/300 Areas Components Investigation Area Names.

Inter-Areas Investigation Area Name	100/300 Areas Investigation Area Name
RCBRA 1a Aq	RCBRA A[1] Ref 16
RCBRA 1b Rip	RCBRA R[2] Ref 14
RCBRA 2e Aq	RCBRA Sr5
RCBRA Ver Ref 1 Aq	RCBRA A[1] Ref 12
RCBRA A Ref 11 Aq	RCBRA A[1] Ref 11

[1] Aquatic.

[2] Riparian.

Figure 1-1. Inter-Areas Component and 100/300 Areas Component Study Regions.



2.0 SAMPLING OVERVIEW

Between October 2006 and December 2007, field sampling and surveys of soil, sediment, surface water, pore water, and biota were conducted. Since the Inter-Areas Component is an extension of the 100 Area and 300 Area (100/300 Areas) Component, the DQOs remained the same and resulted in sampling of similar media and analytical suites. Table 2-1 outlines the differences and similarities between the 100/300 Areas and Inter-Areas Components sample media.

Table 2-1. RCBRA Effort Type and Media in the Upland, Riparian, and Near-Shore Aquatic Investigation Areas. (2 Pages)

Effort Type	100/300 Areas Component Media	Inter-Areas Component Media
Upland Investigation areas		
Sampling	External radiation exposure (TLD)	---
	Groundwater	---
	MIS of Soil	---
	Discrete Soil	---
	Dominant Vegetation	---
	Terrestrial Invertebrates	---
	Small Mammals	---
Survey	T & E Plants & Habitat	---
	Plant Cover	---
	Small Mammal Population Attributes	---
	Soil Texture	---
Riparian Investigation areas		
Sampling	External radiation exposure (TLD)	External radiation exposure (TLD)
	MIS of Soil	MIS of Soil
	Discrete Soil	Discrete Soil
	Dominant Vegetation	Dominant Vegetation
	Terrestrial Invertebrates	Terrestrial Invertebrates
	Small Mammals	Small Mammals
	Kingbirds	Kingbirds
	---	Swallows

Table 2-1. RCBRA Effort Type and Media in the Upland, Riparian, and Near-Shore Aquatic Investigation Areas. (2 Pages)

Effort Type	100/300 Areas Component Media	Inter-Areas Component Media
Survey	Soil Texture	Soil Texture
	T & E Plants & Habitat	T & E Plants & Habitat
	Plant Cover	Plant Cover
	Small Mammal Population Attributes	Small Mammal Population Attributes
	Kingbird Nesting Performance	Kingbird Nesting Performance
	---	Swallow Nesting Performance
Near-Shore Aquatic Investigation areas		
Sampling	Sediment	Sediment
	Pore Water	Pore Water
	Surface Water	Surface Water
	Discrete Sediment	Discrete Sediment
	Aquatic Invertebrates	Aquatic Invertebrates
	Asiatic Clams	Asiatic Clams
	Asiatic Clam Histopathology	Asiatic Clam Histopathology
	Sculpin	Sculpin
	Sculpin Histopathology	Sculpin Histopathology
	---	Sucker
	---	Sucker Histopathology
	---	Amphibians
	---	Mussels
	---	Mussel Histopathology
Survey	Aquatic Invertebrate Community Structure	Aquatic Invertebrate Community Structure
	Asiatic Clam Survival	Asiatic Clam Survival
	T & E Fish Survey[1]	T & E Fish Survey
	T & E Gastropod Survey[1]	T & E Gastropod Survey

[1] Surveys for the 100/300 Areas Component occurred during Inter-Areas Effort in 2007.

Soils were characterized using physical parameters such as texture, moisture, angularity, and color. Rock cover estimates were recorded during the vegetation cover surveys. Soils were sampled using multi-increment and discrete methods. Biological surveys and sampling consisted of plants, small mammals, avian species, terrestrial invertebrates, fish, clams, mussels, aquatic invertebrates (macro invertebrates), and amphibians. Threatened and endangered (T & E) species' habitat surveys for plants, salmonids, and special status aquatic mollusks were also performed. Bioassays were performed on pore water, sediment, and soil samples. As with the 100/300 Areas component, each riparian investigation area was staked with metal T-posts at each end and center point and thermoluminescent dosimeters (TLDs)

were placed at each stake and remained in place for at least 6 months. TLDs were collected and analyzed for investigation area-specific levels of total background radiation.

Sampling was conducted in accordance with the *Sampling and Analysis Instructions for the 100 Area and 300 Area Component of the RCBRA Project* (WCH 2006) (herein referred to as the "SAI"). The SAI describes the detailed sampling and analysis activities that were performed. Sample collection, sample processing, and field surveys were completed by WCH subcontractor Environmental Assessment Services, LLC (EAS). Once the samples were collected, they were transported to locked storage at 4°C at the EAS facility, the Applied Process Engineering Laboratory (APEL). Samples requiring laboratory processing such as homogenization, dissection, or compositing were prepared at the EAS laboratory and secured there until batch shipment of the complete media group. Following sample processing, the samples were transferred to WCH custody where they were either stored in a secured refrigerator at 4°C or freezer at the sample receiving facility (the 3728 Building) until they were packaged and shipped to the analytical laboratories.

Samples were sent to the Lionville Laboratory, Inc. (Lionville) in Exton, Pennsylvania, for chemical constituents or Eberline Services (Eberline) in Richmond, California, for radiological constituents. Samples for toxicity bioassays were sent to CH2M HILL Analytical Services Laboratory (ASL) in Corvallis, Oregon. At ASL, multi-incremental samples of soil were tested using Sandberg bluegrass (*Poa secunda*) and nematode (*Caenorhabditis elegans*); discrete soil samples were tested using Sandberg bluegrass; sediment samples were tested using amphipod (*Hyalella azteca*) and pak choi (*Brassica chinensis*); and pore water samples were tested using water flea (*Ceriodaphnia dubia*). Additional pore water toxicity bioassays were sent to Fort Environmental in Stillwater, Oklahoma for Frog Embryo Teratogenesis Assay – Xenopus (FETAX) testing.

2.1 INVESTIGATION AREA SELECTION

The study area includes the riparian and near-shore aquatic zones of the Columbia River from the Wanapum Dam (River Mile; RM 416) and the south end of the 300 Area (RM 343) (Figure 1-1). Project initiation lead to the selection of 15 near-shore aquatic, 8 riparian, and 5 sediment sampling investigation areas; in addition, 3 reference areas in the riparian zone and 4 reference areas in the near-shore aquatic zone were selected. These investigation areas were chosen based on several factors including existing data, previously installed sampling tubes, areas of rare plant and animal habitat, proximity of near-shore aquatic to riparian investigation areas, river topography and areas of known deposition, and geographic distribution throughout the study area. By project completion, 21 near-shore aquatic investigation areas were added for collection of sediment (12 areas), fish (8 areas), and tadpoles (1 area).

2.2 RIPARIAN ZONE ACTIVITIES

Each of the 11 riparian zone investigation areas were 200 meters (m) in length of varying width, based on topography and river level (Figure 2-1). The sites were walked down and scanned for unexpected potential hazards (i.e., exposed cables, large holes). T-posts were placed at the middle and at each of the ends of the investigation area, and the coordinates of each T-post recorded (Table 2-2). The riparian sites were pin flagged at the upper and lower boundaries of the riparian zone to help delineate the borders within which to sample. Signs were constructed

and placed at the access point of each investigation area identifying the contact information, and a "do not disturb" notice for Hanford Site workers and/or members of the public.

Each of the riparian investigation areas were sampled and/or surveyed for TLDs, soil, vegetation, terrestrial invertebrates, small mammals, and birds. Three TLDs were hung on the T-posts and remained until collection after 9 months. Soil was collected using either the multi-increment sample (MIS) or discrete technique. Small mammal and invertebrate sampling was conducted by use of live traps distributed near the center of the sites. Avian sample locations were based on nest locations and therefore have unique investigation area names; they also have distinct sample numbers based on the species and in which sequence the nest was discovered. There were a total of eight juvenile bird samples collected along the Hanford Reach and eight juvenile bird samples collected in upstream reference areas; for further detail see Section 2.2.3. Surveys performed at each investigation area include soil texture evaluations, rare vegetation surveys, vegetation cover plot surveys, small mammal community surveys and sampling, and avian nesting performance evaluations.

Table 2-3 provides the effort type (sample collection or information gathering) and associated start and completion dates for both riparian and near shore zone. Completion dates are those dates for which data have been received, reviewed for quality assurance and/or validated. The sampling effort and any modifications to the SAP (DOE-RL 2006a) or SAI (WCH 2006) are described further in the following sections.

Figure 2-1. Riparian Sampling Locations.

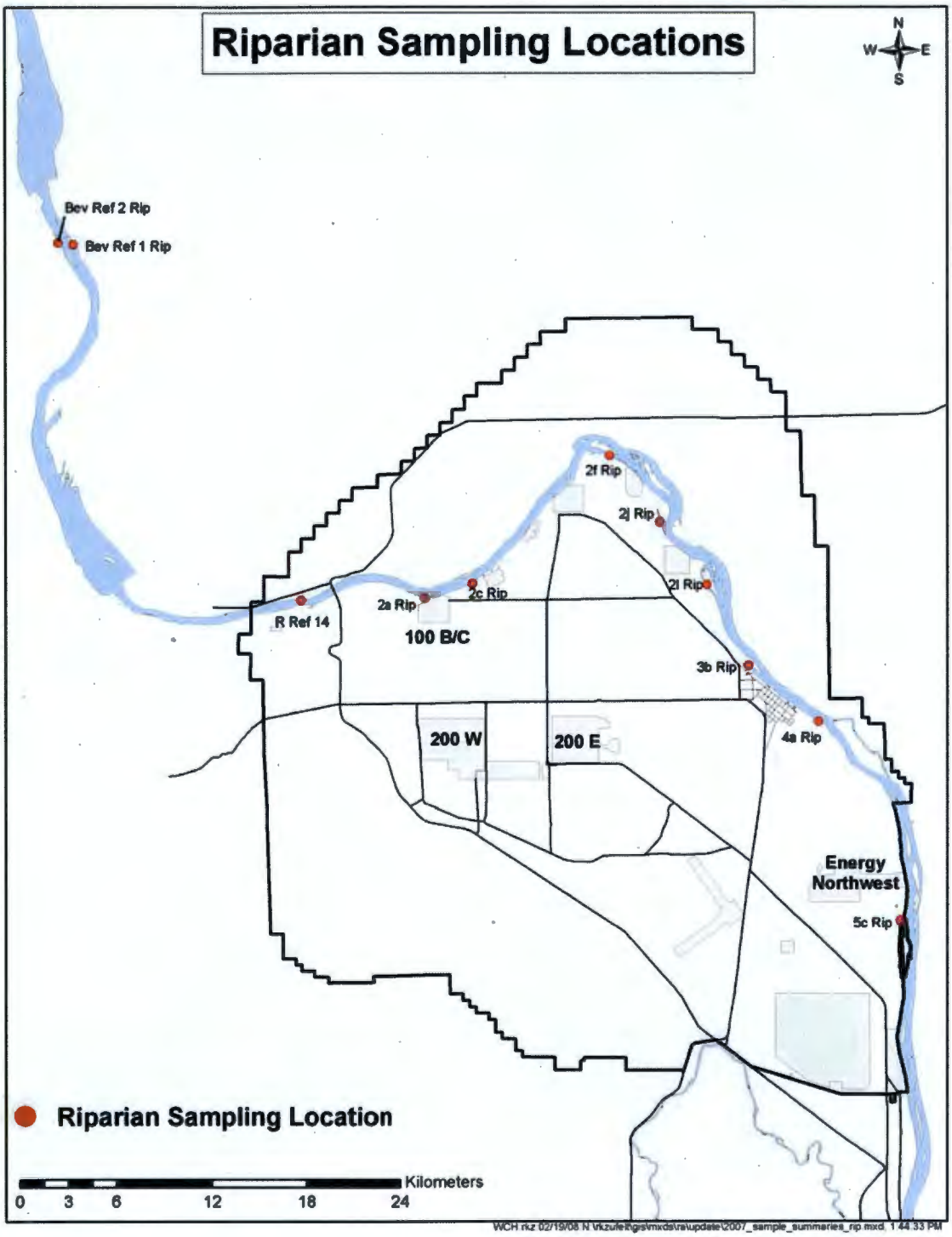


Table 2-2. Plot Coordinates for Riparian Surveys and Sampling Efforts[1]. (2 Pages)

Investigation Area[2]	Location Description	Northing	Easting
RCBRA Bev Ref 1 Rip	Beverly Reference 1 Riparian, below Wanapum Dam	167631.981 167701.261 167767.224	542500.317 542428.846 542353.637
RCBRA Bev Ref 2 Rip	Beverly Reference 2 Riparian, below Wanapum Dam	167718.853 167808.357 167904.745	541538.496 541493.988 541470.422
RCBRA R Ref 14	Upriver of Vernita; initially used during the 100/300 Area	145149.710 145144.848 145149.384	556815.254 556717.180 556618.094
RCBRA 2a Rip	100-B/C Area Shoreline	145285.501 145284.526 145298.317	564718.404 564618.501 564520.228
RCBRA 2c Rip	Coyote Rapids	146257.272 146210.159 146162.071	567687.283 567598.200 567509.998
RCBRA 2f Rip	North of 100-H Area	154253.789 154297.511 154332.741	576308.661 576222.844 576123.998
RCBRA 2j Rip	White Bluffs Slough	149998.089 150092.048 150185.284	579393.931 579360.971 579324.273
RCBRA 2l Rip	100-F Upper Slough	146079.924 146120.069 146148.348	582433.442 582341.212 582244.115
RCBRA 3b Rip	Hanford Townsite Slough	141010.203 141035.835 141065.166	585057.580 584961.205 584865.283

Table 2-2. Plot Coordinates for Riparian Surveys and Sampling Efforts[1]. (2 Pages)

Investigation Area[2]	Location Description	Northing	Easting
RCBRA 4a Rip	South of Hanford Townsite	137420.701 137480.985 137527.899	589429.126 589347.500 589258.819
RCBRA 5c Rip	Upper Wooded Island Slough, south of Energy Northwest power lines	124770.514 124869.182 124964.165	594491.688 594509.985 594544.057

[1] The three coordinates represent each T-post for the upstream, center, and downstream location of the investigation area within the riparian zone.

[2] Figure 2-1.

Table 2-3. Inter-Areas Component Effort Type, Start, and Completion Dates in the Riparian Zones.

Effort	Start Date	Completion Date
MIS Soil Sampling	11/6/06	1/9/07
Soil Texture Evaluations	11/6/06	11/16/06
Discrete Soil Sampling	7/16/07	7/26/07
Vegetation Sampling	4/16/07	5/16/07
Threatened and Endangered Vegetation Surveys	11/6/06	12/14/06
Vegetation Cover Surveys	8/6/07	8/30/07
Thermoluminescent Dosimeter Placement and Collection	7/16/07	8/16/07
Juvenile Bird Sampling	6/19/07	8/20/07
Avian Nest Location Surveys	5/29/07	8/13/07
Avian Nesting Success Evaluations	6/5/07	8/13/07
Terrestrial Invertebrate Trap Sampling	4/2/07	5/24/07
Small Mammal Sampling	4/2/07	5/24/07

2.2.1 Riparian Soil

Soil samples were collected at riparian sites using either a multi increment or discrete method. The procedures and utility of each method of collection have been discussed in previous data compilation reports for the 100/300 Areas Component of the RCBRA (*100 Area and 300 Area Component of the RCBRA Fall 2005 Data Compilation* [WCH-085] and the *100 Area and*

300 Area Component of the RCBRA Spring 2006 Data Compilation [WCH-139]). However, a brief overview of the sampling methodology and collection activities are described below.

2.2.1.1 Multi-Increment Sampling. Multi-increment sampling (MIS) is a methodology used to estimate the average concentrations of constituents in an investigation area and increase precision through the collection of a number of sub-samples (increments). Both the 100/300 Areas and Inter-Areas Components used MIS to evaluate residual contaminant concentrations in the soil fraction less than or equal to 2 mm (0.08 in.) in size, consistent with the "Model Toxics Control Act – Cleanup" regulation (*Washington Administrative Code* 173-340). Samples were collected in accordance with the *Instruction for Multi-Incremental Soil Sampling and Laboratory Subsampling for 100 Area and 300 Area Component of the River Corridor Baseline Risk Assessment* (IOM 124510).

Soil samples were collected using the MIS method at each of the riparian investigation areas (Figure 2-1). Five MIS samples were collected from each riparian investigation area (200 m [656 ft] long). The width of each area was determined using characteristics of the landscape; the upper boundary was defined by vegetation and topography, whereas lack of riparian vegetation and river level defined the lower boundary. For each sample, 50 increments were collected within the identified riparian zone investigation areas. The coordinates of each investigation area are presented in Table 2-2. Measures were taken at the time of sampling to remove any organic matter (e.g., vegetation and scat) to prevent skewed analytical results.

The samples were sent to the ASL in Corvallis, Oregon, for drying and subsampling prior to being sent for chemical and radiological analyses. ASL also performed analyzed for initial parameters (e.g., pH, percent moisture, particle size) and biotoxicity tests (Table 2-4 and Section 2.2.1.3, respectively). Samples analyzed for chemical constituents were sent to Lionville; samples analyzed for radiological constituents were sent to Eberline (Table 2-4). For each of the methods listed, the associated parameter(s) or constituent(s) analyzed for can be found in Appendices A and B.

Table 2-4. Initial Parameter, Chemical, and Radiological Analytical Methods for Multi-Increment Soil and Discrete Soil Samples.

Initial Parameter	Chemical Analytical Methods	Radiological Analytical Methods
300.0_ANIONS_IC	200.8_METALS_ICPMS[1]	C14_COX_LSC[1]
350.3_AMMONIA	7471_HG_CVAA[2]	GAMMA_GS
351.4_N_TKN	6010_METALS_ICP	SRTOT_SEP_PRECIP_GPC
9045_PH	8081_PEST_GC	TC99_TR_SEP_GPC[1]
D2216_%MOIS	8082_PCB_GC	THISO_IE_PLATE_AEA
D422_PARTCLSIZE	8270_SVOA_GCMS	UISO_PLATE_AEA
E777_TOC		

[1] Method performed on MIS soil samples only.

[2] Method performed on discrete soil samples only.

2.2.1.1.1 Modifications. Due to the existence of plumes, soil at RCBRA 2c Rip was analyzed for carbon-14 and RCBRA 2c, 2j, 2l, and 4a Rip were analyzed for technetium-99. Soil at RCBRA 2c and 4a Rip had detections of technetium-99 (between 0.035 and 1.43 pCi/L); therefore, all biota located in the riparian investigation areas at RCBRA 2c and 4a Rip were analyzed for technetium-99 where there was sufficient tissue mass.

2.2.1.1.2 Soil Bioassays. Bioassays of MIS of soil were conducted using Sandberg bluegrass and nematodes. Samples for toxicity bioassays remained at ASL for subsequent Sandberg bluegrass (*Poa secunda*) and nematode (*Caenorhabditis elegans*) testing. The test methods for Sandberg bluegrass were performed based on the "Standard Guide for Conducting Terrestrial Plant Toxicity Tests", *American Society for Testing and Materials* (ASTM) E1963-02. Bluegrass seeds were obtained from Native Grass Seeds, Cornville, Arizona, and all test conditions were maintained during planting, germination, and growth phases of the test as prescribed by the ASTM protocol. Hydration was accomplished via subirrigation. For the bluegrass tests, 50 seeds per concentration were used with five replicate test chambers per concentration and 10 seeds planted per chamber. Based on lessons learned during the 100/300 Areas Component, double planting of seeds was eliminated and therefore subsequent thinning was not required. Also new was the increase in air flow over the seedlings. Tests were terminated 14 days post-germination. The following data were recorded:

- Number of seedlings
- Shoot appearance
- Shoot height
- Root appearance
- Root length
- Percent survival
- Shoot weight (wet)
- Shoot weight (dry)
- Root weight (wet)
- Root weight (dry)
- Total mass (wet)
- Total mass (dry)
- Shoot height
- Root length.

Statistical analyses for each measurement were calculated from each replicate; each replicate was also compared to the laboratory control.

The test methods for nematodes were performed based on the "Standard Guide for Conducting Laboratory Soil Toxicity Tests with the Nematode Caenorhabditis elegans," ASTM E2172-01. The nematodes used were obtained from the laboratory's in-house cultures and were age-synchronized as 4-day-old organisms at test initiation. All organisms tested were fed and maintained during culturing, acclimation, and testing as prescribed by the ASTM protocol. For the nematode test, 30 organisms per concentration were used with 3 test chambers per concentration and 10 organisms per chamber. Tests were terminated after 24 hours. The endpoint measured was percent survival over the 24-hour exposure period. Statistical analyses for each result were performed to compare the survival data between the control and each test soil.

Table 2-5 presents the investigation area, habitat type, parent sample identification number used to generate the bioassay sample, the bioassay sample identification number and date the parent mass was collected.

Table 2-5. Summary of Multi-Increment Soil Samples.

Investigation Area	Parent Sample ID Numbers	Bioassay Sample ID Numbers	Collection Date
RCBRA Bev Ref 1 Rip	J13P26 – J13P30	J13NY9	20-Nov-06
RCBRA Bev Ref 2 Rip	J13P31 – J13P35	J13P00	16-Nov-06
RCBRA R Ref 14	J13P11 – J13P15	J13NY5	5, 7, 11-Dec-06
RCBRA 2a Rip	J13P06 – J13P10	J13NY4	21, 30-Nov-06
RCBRA 2c Rip	J13LR1 – J13LR5	J13LP6	30-Nov, 1-Dec-06
RCBRA 2c Rip (Equipment Blank of J13LR5)	J13NY3	---	30-Nov-06
RCBRA 2f Rip	J13LR6 – J13LR9, J13LT0	J13LP7	9, 14-Nov-06
RCBRA 2j Rip	J13LT1 – J13LT5	J13LP8	7, 8-Nov-06
RCBRA 2l Rip	J13LT6 – J13LT9, J13LV0	J13LP9	12-Dec-06
RCBRA 3b Rip	J13P16 – J13P20	J13NY6	4, 11-Dec-06
RCBRA 4a Rip	J13P01 – J13P05	J13NY7	14-Dec-06
RCBRA 5c Rip	J13P21 – J13P25	J13NY8	8, 9-Jan-06

2.2.1.2 Discrete Soil Sampling. Surveys for rare plant species were conducted at each of the riparian study sites to address the potential impact of past operation on Federal or State listed flora on the site (RCBRA 2a, 2c, 2f, 2j, 2l, 3b, 4a and 5c Rip). Based on the confirmation of rare plant species, discrete soil samples were collected at each confirmed location. Lowland toothcup (*Rotala ramosior),* Awned Halfchaff Sedge *(Lipocarpha aristulata),* and Chaffweed (*Centunculus minimus)* were found at RCBRA sites 2a, 2f, 2l, 3b, and 5c (Table 2-6).

Table 2-6. Summary of Threatened and Endangered Plant Species found Within Inter-Areas Investigation Areas. (2 Pages)

Investigation Area	T & E Species
RCBRA 2a Rip	*Rotala ramosior, Lipocarpha aristulata, Centunculus minimus*
RCBRA 2f Rip	*Rotala ramosior, Lipocarpha aristulata*
RCBRA 2j Rip	*Rotala ramosior*

Table 2-6. Summary of Threatened and Endangered Plant Species found Within Inter-Areas Investigation Areas. (2 Pages)

Investigation Area	T & E Species
RCBRA 2l Rip	*Rotala ramosior, Lipocarpha aristulata*
RCBRA 3b Rip	*Rotala ramosior, Lipocarpha aristulata, Centunculus minimus*
RCBRA 5c Rip	*Rotala ramosior*

The sampling team used a stainless steel trowel to obtain discrete soil samples from 0 cm to a maximum depth of 10 cm (~4 in.). After removing rocks, non-listed vegetation, and large debris from the ground surface, the team used a 2 mm (0.08 in.) stainless steel soil sieve to remove all particles greater than this dimension. The parent soil sample was placed in a pre-cleaned 1-L (0.3-gal) amber glass wide-mouth bottle. The soil depths at which samples were obtained were recorded in the field logbook. Instruments were washed with Liqui-Nox® solution and deionized water before they were used to collect samples at a new location.

Discrete soil samples analyzed for chemical constituents were sent to Lionville (Table 2-4); samples analyzed for radiological constituents were sent to Eberline (Table 2-4); and, samples for Sandberg bluegrass (*P. secunda*) toxicity bioassay were sent to ASL.

2.2.1.2.1 Modifications. Discrete soil sampling results indicated that Aroclor-1260 was detected in 6 samples collected in a single day. The six samples included an equipment blank and five subsequent soil samples. Three samples collected from RCBRA 3b Rip and two samples collected at RCBRA 2l Rip (including a duplicate) were suspected of being affected by cross-contamination. The appropriate procedure, ENV-1-2.15, "Field Decontamination of Sampling Equipment," was followed. However, due to the interwoven structure of the sieves, the decontamination process performed in between each sample collection event did not yield a fully cleaned instrument before collecting subsequent samples. In addition, due to their size, the sieves were not fully immersed in decontamination rinsate, contributing to the error.

Therefore, sites that were potentially suspect of cross-contamination were resampled with an equipment blank and a duplicate. New sampling equipment was purchased and one sieve was used per soil sample. The original analyses, including bioassays, were performed on the new samples (Table 2-4). Other equipment blank results associated with the RCBRA sampling do not indicated that a systematic or widespread problem had occurred with other sampling events.

All results associated with the original suspect samples will not be used in the Draft B of the Risk Assessment Report (DOE/RL-2007-21), will not be included in the Guided Interactive Statistical Decision Tools (GiSdT) data management interface, and will be flagged in the Environmental Restoration (ENRE) database as not usable.

2.2.1.2.2 Discrete Soil Bioassays. In order to assess potential toxicity to plants, discrete soil samples were tested for biotoxicity using bluegrass. The test methods for bluegrass were performed according to ASTM E1963-02 as described in as described in Section 2.2.1.1.1. Because the objective of these samples was to evaluate the potential toxicity to rare plants, the nematode bioassay was not run. The investigation area, parent sample identification number,

bioassay sample identification number and parent sample collection date for each discrete soil sample are listed in Table 2-7.

Table 2-7. Summary of Discrete Soil Samples.

Investigation Area	Chem/Rad Sample ID Numbers	Bioassay Sample ID Numbers	Collection Date
RCBRA 2a Rip	J156K5	J156L5	18-Jul-07
RCBRA 2f Rip	J156K6	J156L6	18-Jul-07
RCBRA 2j Rip	J156K7	J156L7	18-Jul-07
RCBRA 2l Rip	J156K8	J156L8	19-Jul-07
RCBRA 2l Rip (Duplicate)	J156K9	---	19-Jul-07
RCBRA 3b Rip	J156L2	J156M1	19-Jul-07
RCBRA 3b Rip	J156L3	J156M2	19-Jul-07
RCBRA 3b Rip	J156L0	J156L9	19-Jul-07
RCBRA 3b Rip (Equipment Blank)	J156L4	---	23-Jul-07
RCBRA 5c Rip	J156L1	J156M0	19-Jul-07
Resample event			
RCBRA 2l Rip	J15W03	J15VY9	22-Oct-07
RCBRA 2l Rip (Equipment Blank)	J15W08	---	22-Oct-07
RCBRA 2l Rip (Duplicate)	J15W04	---	22-Oct-07
RCBRA 3b Rip	J15W05	J15W00	22-Oct-07
RCBRA 3b Rip	J15W06	J15W01	22-Oct-07
RCBRA 3b Rip	J15W07	J15W02	22-Oct-07

2.2.1.3 Soil Classification. Soils were classified at each riparian investigation area using the "Standard Practice for Description and Identification of Soils (Visual – Manual Procedure)" (ASTM D2488–00). Physical parameters such as soil color, moisture condition, consistency, percent cover by rock fragments (e.g., gravel, cobble, boulder), gradation, angularity, shape, and cementation were recorded. Soil type was determined using a textural triangle and the texture-by-feel procedure (Thein 1979). Soil color was determined using Munsell Soil Color Charts. Moisture condition descriptions included dry (absence of moisture), moist (damp with no visible water), and wet (visible free water) conditions.

Consistency varied from very soft, soft, firm, hard, and very hard. Percent cover by rock fragments was estimated as percent gravel, cobbles, and boulders. Gradation of coarse-grained particles ranged from well-graded to poorly graded. Angularity descriptions of coarse-grained particles included angular (sharp edges with relatively plane sides with unpolished

surfaces, subangular (particles are similar to angular description, but have rounded edges), subrounded (particles have nearly plane sides, but have well-rounded corners and edges), and rounded (particles have smoothly curved sides and no edges). Shape of coarse-grained particles were flat (width:thickness >3), elongated (length:width >3), or both. Cementation was based on finger pressure amount: weak (crumbles or breaks with handling), moderate (crumbles or breaks with considerable finger pressure), and strong (will not crumble or break with finger pressure). Appendix C provides a summary of information collected during the soil texture surveys.

2.2.2 Riparian Vegetation

Vegetation was evaluated at each riparian investigation area for multiple parameters: estimation of herbaceous and shrub cover, identification of rare species and their habitat, and analyses of tissue for uptake of constituents (Figure 2-1). Samples of two dominant plant species were collected in each investigation area for uptake of Hanford Site legacy materials. The two species selected for sampling were generally common at all investigation areas, and at least one of the two dominant species collected was representative of deep-rooted plants (i.e., white mulberry [*Morus alba*]). Given the relative homogeneity in many of the vegetation communities, tissue concentrations of these two dominant plants represented the majority of vegetation at a given investigation area.

2.2.2.1 Dominant Vegetation Sampling. Dominant vegetation was collected for contaminant analyses to assess both risks to the plants as well to the consumers of plants. The dominant herbaceous species collected was reed canarygrass (*Phalaris arundinaceae*) and the dominant shrub species collected was white mulberry (*M. alba*) (Table 2-8). Each species was collected using pre-cleaned stainless steel snipping shears to cut samples of the current year's growth. After removing excess dirt and debris, the vegetation was rinsed thoroughly with deionized water, and placed directly into plastic bags. Samples were combined into separate bags for each sampled species, resulting in two composite samples for each investigation area. Vegetation samples were then taken to the processing facility and chopped into smaller (~1 in. long) pieces and sent to Lionville (chemical constituents) and Eberline (radiological constituents) laboratories for analyses (Table 2-9).

2.2.2.1.1 Modifications. In addition to the constituents listed in Tables 2-5 and 2-6, additional constituents were analyzed at specific locations due to existing nitrate, technetium-99, and tritium plumes. RCBRA 2c, 2j, 2l, 4a, and 5c Rip were analyzed for nitrogen as nitrate and nitrite. RCBRA 2c and 4a Rip were analyzed for technetium-99. RCBRA 2a, 2c, 2l, 3b, 4a, 5c Rip were analyzed for tritium. Table 2-8 presents a summary of the dominant plant samples collected including investigation area, sample identification number, and collection date.

Table 2-8. Summary of Dominant Vegetation Samples.

Investigation Area	Species Collected	Sample ID Number	Collection Date
RCBRA Bev Ref 1	Reed canarygrass	J15289	3-May-07
	Mulberry	J15288	3-May-07
RCBRA Bev Ref 2	Reed canarygrass	J15291	3-May-07
	Mulberry	J15290	3-May-07
RCBRA R Ref 14	Reed canarygrass	J15293	1-May-07
	Mulberry	J15292	1-May-07
RCBRA 2a Rip	Reed canarygrass	J15298	3-May-07
	Mulberry	J15299	3-May-07
RCBRA 2c Rip	Reed canarygrass	J152B8	9-May-07
	Mulberry	J152B9	9-May-07
RCBRA 2c Rip (DOH split)	Reed canarygrass	J152H1	9-May-07
	Mulberry	J152H2	9-May-07
RCBRA 2f Rip	Reed canarygrass	J15295	30-Apr-07
	Mulberry	J15294	1-May-07
RCBRA 2j Rip	Reed canarygrass	J15296	1-May-07
	Mulberry	J15297	1-May-07
RCBRA 2l Rip	Reed canarygrass	J152B0	2-May-07
	Mulberry	J152B1	2-May-07
RCBRA 3b Rip	Reed canarygrass	J152B2	2-May-07
	Mulberry	J152B3	2-May-07
RCBRA 3b Rip (Duplicate)	Reed canarygrass	J152C0	2-May-07
	Mulberry	J152C1	2-May-07
RCBRA 4a Rip	Reed canarygrass	J152B6	9-May-07
	Mulberry	J152B7	9-May-07
RCBRA 4a Rip (DOH split)	Reed canarygrass	J152C2	9-May-07
	Mulberry	J152C3	9-May-07
RCBRA 5c Rip	Reed canarygrass	J152B4	2-May-07
	Mulberry	J152B5	2-May-07

Table 2-9. Summary of Chemical and Radiological Analytical Methods and Constituents for Vegetation Samples.

Chemical Analytical Method	Radiological Analytical Method
7471_HG_CVAA	C14_COX_LSC1
353.2_NO3/NO2[1]	GAMMA_GS
6010_METALS_ICP	SRTOT_SEP_PRECIP_GPC
8081_PEST_GC	TC99_TR_SEP_GPC[1]
8082_PCB_GC	THISO_IE_PLATE_AEA
8270_SVOA_GCMS	TRITIUM_COX_LSC[1]
	UISO_PLATE_AEA

[1] Method performed on select vegetation samples only.

2.2.2.2 Vegetation Cover Survey. Vegetation cover in the riparian zone study grids consisted of grasses, forbs, shrubs, and trees. For grasses and forbs, vegetative cover found in each investigation area was estimated using a modified Daubenmire plot frame (Daubenmire 1959) to determine the percent coverage by species found within 20-cm [8-in.] by 50-cm [20-in.] plots that were divided into ten 10-cm (4-in.) squares. A full species inventory list was prepared for each study grid. Canopy cover was estimated using finite values for all plant species with at least 2% aerial coverage. Plant species encountered in each plot with ≥2% aerial cover were listed. The aerial extent of cryptogamic crust, bare ground, litter and rocks was visually estimated after spraying the ground surface with a mist of water to ensure accurate estimations were made. Plot points were systematically located throughout each investigation area for a total of approximately 24 samples per grid. The systematic sampling strategy varied between sites, depending on the site configuration and size.

The line intercept method was used to estimate the canopy cover of the shrubs and trees found in each sample grid. Total canopy was measured using line intercept techniques systematically along approximately 200 m [656 ft] of transect length (e.g., 4 lines each 50 m [164 ft] long for a total of 200 m [656 ft]) within each investigation area. The length of each transect varied depending on the shape and size of each investigation area. The maximum height (± 0.1 m [0.33 ft]) of each shrub and tree intercepted along each transect was measured. In addition, a 3-dimensional intercept (± 0.05 m [0.16 ft]) of live and dead shrubs and trees was measured and recorded separately to help assess the overall health of the shrubs (determine the percent dead). Shrub and tree species were determined and canopy cover estimates were separately identified for each species encountered.

2.2.2.3 Threatened and Endangered Plant Species and Habitat Surveys. As mentioned previously in Section 2.2.1.2, Discrete Soil Sampling, surveys for rare plant species were conducted at each riparian investigation area to address the potential for the species to occur. A rare plant species is one that is listed either by the Washington State Department of Natural Resources (as endangered, threatened, sensitive, possibly extinct, or of potential concern) or by the US Fish and Wildlife Service (as endangered, threatened, proposed endangered or threatened, candidate or species of concern). Based on the confirmation of the rare species or

habitat that appeared to be suitable for the plants, discrete soil samples were collected at each confirmed location. The following rare species were confirmed: Lowland toothcup (*Rotala ramosior;* state threatened), Awned Halfchaff Sedge (*Lipocarpha aristulata;* state threatened), and Chaffweed (*Centunculus minimus;* state potential concern) at RCBRA 2a, 2f, 2l, 3b, and 5c Rip (Table 2-6). A complete technical report associated with this effort is provided in Appendix D.

2.2.3 Avian

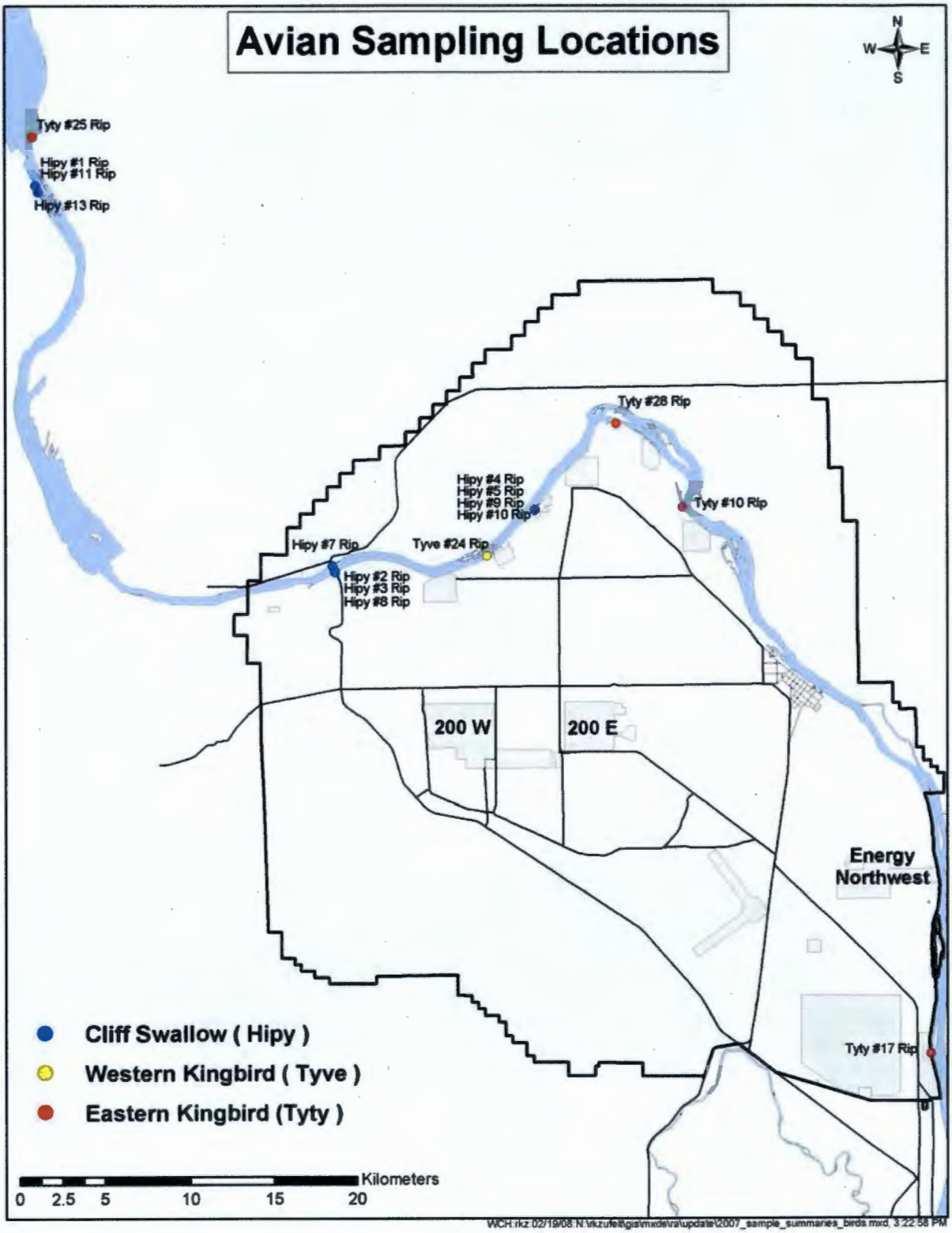
Surveys were performed to identify nesting activity of eastern kingbirds, western kingbirds, and cliff swallows (*Tyrannus tyrannus*, *T. verticalis,* and *Hirundo pyrrhonota,* respectively) along riparian areas of the Columbia River. Nest performance was measured by monitoring egg fate; the number of eggs laid and the number of eggs hatched in an effort to assess contaminant exposure on selected avian invertivores. Hatching success (number of young hatched per nest) was observed for an estimate of reproductive success. Downstream nest success was also compared to upstream success. A summary of the bird samples including the investigation area, whole body, and crop sample identification numbers, and collection date are provided in Table 2-14.

A map depicting kingbird survey and sampling locations is presented in Figure 2-2. Sample locations may or may not have been within the 200 m (656 ft) of a pre-designated investigation area; therefore, the site name was not used in Figure 2-1; rather, the scientific acronym representing the bird's genera and specific epithet and chronological number when located was used to identify the sites: eastern kingbirds, western kingbirds, and cliff swallows (*Tyrannus tyrannus* [Tyty], *T. verticalis* [Tyve], and *Hirundo pyrrhonota* [Hipy], respectively).

Nest disturbance caused by the observers was graduated to minimize observer effects on nest performance. The least intensive surveying occurred during mating and egg-laying and more intensive monitoring occurred when nestlings were almost ready to leave the nest.

Once hatching success was determined, one or two specimens were collected (depending on the size of nestlings at time of sample collection) for radionuclide and chemical analyses. Juvenile kingbird and cliff swallow tissues and diets (crop content) were sampled for contaminants to help assess risk to avian predators as well as avian risk from dietary uptake of Hanford Site legacy materials. Avian samples were placed into a 1-L (0.3-gal) amber glass bottle and stored frozen in locked storage until samples could be prepared for submission to the analytical laboratories.

Figure 2-2. Avian Sampling Locations.



At the laboratory facility, avian samples were removed from locked storage; surgical gloves were donned, washed with Liqui-Nox® solution, and rinsed with deionized water. Specimens were removed from the field bottle and weighed. Prior to dissection, the specimen was rinsed with deionized water, placed on an absorbent towel and the external condition of the specimen was inspected and recorded. Crop contents were removed, weighed, identified (if possible), and placed in an amber glass container. The crop is a muscular pouch used to temporarily store food. Depending on the mass of the crop, only certain analytes were tested for. The whole organism (minus the food contents removed from the crop) was again rinsed with deionized water and placed in a pre-cleaned 250 mL (8 oz) stainless steel blender with approximately equal fractions of dry ice and blended. The blended contents were emptied onto a pre-cleaned aluminum tray to allow dry ice to evaporate. The desired number and mass of subsamples were placed in containers consistent with individual Sample Authorization Forms (SAFs). Samples were sent to Lionville (chemical constituents) and Eberline (radiological constituents) for the methods listed in Table 2-10.

Table 2-10. Summary of Chemical Analytical Methods and Constituents Analyzed for Avian Crop Content and Offal Samples.

Chemical Analytical Method	Radiological Analytical Method
7471_HG_CVAA1	GAMMA_GS
6010_METALS_ICP1	SRTOT_SEP_PRECIP_GPC[3]
8081_PEST_GC[2]	TC99_TR_SEP_GPC[3]
8082_PCB_GC[2]	THISO_IE_PLATE_AEA
8270_SVOA_GCMS[2]	UISO_PLATE_AEA

[1] Crop content and offals were analyzed by these methods

[2] Combined samples were the only samples with enough mass to analyze for the associated constituents.

[3] Method performed on select crop content and offal samples only.

Juvenile kingbird and cliff swallow tissues and diets (crop content) were sampled for contaminants based on the expectation that the diet of these birds will be at least partially reflective of insects emerging from the Columbia River. Observations included the total number of eggs per clutch and the number of young successfully hatched per nest. In addition, breeding success of the birds was surveyed to obtain a sufficient sample population size. Measures such as nesting success will provide a qualitative evaluation of contaminant effects on aerial insectivores. Hatching success (number of young hatched per nest) was observed for an estimate of reproductive success. Downstream nest success was compared to upstream success as well as to measures of exposure. A summary of the bird samples including the investigation area, whole body, and crop sample identification numbers, and collection date are provided in Table 2-11.

Table 2-11. Summary of Avian Samples.

Investigation Area	Species	Offal Sample ID Number	Crop Content ID Sample Number	Collection Date
RCBRA Tyty #25 Rip	Eastern Kingbird	J15HC8	J15HC3	25-Jul-07
RCBRA Hipy #1 Rip	Cliff Swallow	J15HD2	J15HC7	6-Aug-07
RCBRA Hipy #11 Rip	Cliff Swallow	J15HC9	J15HC4	6-Aug-07
RCBRA Hipy #13	Cliff Swallow	J15HD0	J15HC5	8-Aug-07
RCBRA Hipy #7	Cliff Swallow	J15HP5	J15HR6	6-Aug-07
RCBRA Hipy #2	Cliff Swallow	J15HP3	J15HR4	25-Jul-07
RCBRA Hipy #3	Cliff Swallow	J15HP4	J15HR5	25-Jul-07
RCBRA Hipy #8	Cliff Swallow	J15HD1	J15HC6	6-Aug-07
RCBRA Tyve #24 Rip	Western Kingbird	J15HP6	J15HR7	10-Jul-07
RCBRA Hipy #4 Rip	Cliff Swallow	J15HR2	J15HT3	25-Jul-07
RCBRA Hipy #5 Rip	Cliff Swallow	J15HR3	J15HT4	25-Jul-07
RCBRA Hipy #5 Rip (Equipment Blank)	DI water	---	J15HV2	30-Aug-07 (Processed in Laboratory)
RCBRA Hipy #9 Rip	Cliff Swallow	J15HR0	J15HT1	6-Aug-07
RCBRA Hipy #10 Rip	Cliff Swallow	J15HR1	J15HT2	6-Aug-07
RCBRA Tyty #28 Rip	Eastern Kingbird	J15HR8	J15HP7	18-Jul-07
RCBRA Tyty #10 Rip	Eastern Kingbird	J15HP8	J15HR9	18-Jul-07
RCBRA Tyty #17 Rip	Eastern Kingbird	J15HP9	J15HT0	3-Jul-07
RCBRA Avian Samp Rip	All 3 species	J15JC1	---	---
RCBRA Avian Ref Rip	Cliff Swallow/ Eastern Kingbird	J15JC0	---	---

2.2.3.1 Modifications. Due to insufficient available sample mass for organic chemical analyses prescribed in the RCBRA Sampling and Analyses Plan, a portion of all avian samples collected from the reference site locations (upriver of Vernita Bridge) remaining after other analyses were combined to provide a single composite sample identified as "Avian Ref Rip." In addition, the remaining portion of all samples located between the Vernita Bridge and the 300 Area (investigation areas) were combined to provide a single composite sample identified as "Avian Samp Rip." Both of these combination samples allowed for the analysis of SVOAs, PCBs and pesticides.

Due to the presence of technetium-99 plumes emerging at the shoreline in some locations, samples from the following sites were analyzed for technetium-99: Hipy #4, #5, #9, and #10.

If carbon-14 was detected in soil samples at an investigation area, it was also to be analyzed for in biota samples collected at that location. Carbon-14 was not detected in soil results at RCBRA 2c Rip therefore, it was not analyzed in the nearest avian investigation area (Tyve #24 Rip).

2.2.3.2 Nesting Surveys. A total of 42 avian invertivore nests including 16 eastern kingbird nests (*T. verticalis)*, 12 western kingbird nests (*T. tyrannus)*, and 14 cliff swallow nests (*H. pyrrhonota*) were located and monitored during 2007. Table 2-12 summarizes the nest monitoring activities performed during 2007.

Table 2-12. Summary of Nesting Survey Data.

Species	Total Number of Nests	Number of Nests Monitored with Incubating Eggs	Number of Nests with 100% Survival Until Hatched
Eastern Kingbirds (Tyty)	16	8	4
Western Kingbirds (Tyve)	12	4	1
Cliff Swallows (Hipy)	14	10	8

2.2.4 Terrestrial Invertebrates.

A summary of terrestrial invertebrates including sample identification number, collection date and sample location is provided in Table 2-13.

Terrestrial invertebrates such as darkling beetles, harvester ants, and spiders represent the soil biota guild specified in *Washington Administrative Code* 173-340-7493, "Investigation area-Specific Terrestrial Ecological Evaluation Procedures." These invertebrates were collected in each of the riparian study sites to measure selected constituent levels found in their tissues (Figure 2-1).

Pitfall traps and hand-collection techniques were used to collect samples. Pitfall traps were placed near the center of each investigation area to reduce the possibility of sampling organisms from outside of the investigation area. All invertebrates caught during trapping were collected, weighed by major taxonomic group, and then combined for each sampling area for contaminant analyses.

Pitfall traps were buried level to the ground surface, ensuring the edge of each trap did not extend above ground level. A wooden lid was then placed over the top of the pitfall trap; during collection, the lid was raised to allow invertebrates to crawl into the trap, but remained to provide shade. Invertebrates were handpicked out of the pitfall traps using stainless steel tweezers and sample containers prescribed in the SAF. Sample mass was weighed to determine whether sufficient sample mass was collected. Pitfall traps were left open until sufficient sample mass was obtained, or until the pitfall traps no longer collected invertebrates. The number of trap-days and mass collected were recorded for a relative measure of invertebrate abundance. If a sufficient sample mass was not obtained from the pitfall traps, ground-dwelling invertebrates

were opportunistically collected by hand within each investigation area. In the event that alternate methods were used for invertebrate collection, the catch per unit effort was recorded as person-hours/mass of invertebrates collected. Invertebrate samples were placed in refrigerated locked storage at the subcontractor's laboratory facility between sample collection events.

Invertebrate samples collected from the field were reviewed for general taxa identification and prepared for laboratory analysis. Samples were segregated into major groups (e.g., beetles, spiders, crickets, etc.) enumerated and weighed. Invertebrate samples were rinsed with deionized water to remove exterior contamination in order to minimize any bias introduced from soil on the organisms. Large water droplets were shaken off of invertebrates and invertebrates were placed into pre-cleaned and tared sample bottles. Invertebrate samples were blended in precleaned micro-blender and the homogenized material was added into each sample bottle until desired sample masses required for each analysis were attained. Samples were sent to Lionville (chemical constituents) and Eberline (radiological constituents) laboratories for the methods listed in Table 2-14.

Table 2-13. Summary of Terrestrial Invertebrate Samples.

Investigation Area	Sample ID Numbers	Collection Date
RCBRA Bev Ref 1	J14Y53	15, 22-May; 7, 12-Jun-07
RCBRA Bev Ref 2	J14Y54	15, 22-May; 7, 12-Jun-07
RCBRA R Ref 14	J14Y55	15-May; 7-Jun-07
RCBRA R Ref 14 (Equipment Blank)	J14Y55-A	13-Jun-07
RCBRA 2a Rip	J14Y56	15, 22-May; 7-Jun -07
RCBRA 2c Rip	J14Y63	9, 22-May; 7-Jun -07
RCBRA 2f Rip	J14Y57	16, 22-May; 7-Jun -07
RCBRA 2j Rip	J14Y58	16, 22-May; 7-Jun -07
RCBRA 2l Rip	J14Y59	16, 22-May; 7-Jun -07
RCBRA 3b Rip	J14Y60	16, 22-May; 7-Jun -07
RCBRA 4a Rip	J14Y62	16, 22-May; 7-Jun -07
RCBRA 5c Rip	J14Y61	16, 22-May; 7-Jun -07

Table 2-14. Summary of Chemical and Radiological Analytical Methods and Constituents Analyzed for Terrestrial Invertebrate Samples.

Chemical Analytical Method	Radiological Analytical Method
7471_HG_CVAA	SRTOT_SEP_PRECIP_GPC
6010_METALS_ICP	TC99_TR_SEP_GPC[1]
	THISO_IE_PLATE_AEA
	UISO_PLATE_AEA

[1] Method performed on RCBRA 2c and 4a Rip only.

2.2.4.1 Modifications. Crickets were obtained from a commercial supplier and used as an equipment blank instead of silica sand. Limited sample invertebrate tissue mass collected from the investigation areas only allowed for analysis of metals and isotopic strontium, thorium and uranium. Due to existing technetium-99 plumes, RCBRA 2c and 4a Rip were also analyzed for technetium-99. PCBs, pesticides, and SVOAs (methods 8081, 8082, and 8270, respectively) were not analyzed for due to limited sample mass. Carbon-14 was not analyzed for because it was not detected in riparian soil to which invertebrates would be exposed.

2.2.5 Small Mammals

Small mammal sampling of Great Basin pocket mice and deer mice (*Perognathus parvus* and *Peromyscus maniculatus*, respectively) were accomplished using Sherman live-traps placed throughout the center of riparian investigation areas (Figure 2-1). Table 2-15 presents a summary of small mammal samples collected including the investigation area, offal and kidney/liver sample identification numbers, and date of collection.

Typically, one or two trap lines consisting of 7 to 10 Sherman live traps (8 cm [3 in.] wide by 9 cm [3.5 in.] high by 23 cm [9 in.] long) were placed near the center of each investigation area running parallel to the river's edge to accommodate the shape of the investigation area. Trap and trap lines were spaced systematically 10 m (33 ft) apart. Traps were placed nearby or underneath vegetation/rocks to reduce likelihood of heat/cold stress to the mice; if natural cover was insufficient then a trap shade was placed over the top of the trap. Traps were baited with an oatmeal-peanut butter mixture and were checked daily.

At least six small mammals were collected from each investigation area for analysis. Trapped specimens were placed into plastic bags and the species, age, sex, reproductive status, and weight were recorded in logbooks. If the specimen was selected for collection, the mouse was euthanized via the American Veterinary Medical Association (AVMA 1986) approved cervical dislocation technique. If the mouse was not euthanized, the ventral portion of its tail was marked with a nontoxic permanent marker to ensure all marked animals could be identified if recaptured. To the extent possible, the same species were collected at all investigation areas.

At the sample processing facility, the mammals were rinsed with deionized water to remove most exterior soil. All specimens were examined for external abnormalities. Sample preparation included removing liver and kidneys from the whole organism and placing these organs into a single sample for each site using pre-cleaned stainless steel scissors and forceps.

The offal (all other portions of the six specimens from each site) and target organs (liver and kidney) were weighed and homogenized separately. Whole organism subsamples were prepared by blending whole organisms in a laboratory-grade blender with dry ice for 30 seconds to 1 minute to allow homogenization of the entire organism. Samples were sent to Lionville (chemical constituents) and Eberline (radiological constituents) laboratories for the methods listed in Table 2-16. The combination of livers and kidneys were only analyzed for metals and mercury (methods 6010 and 7471, respectively) due to limited available sample mass.

Table 2-15. Summary of Small Mammal Samples.

Investigation Area	Offal Sample ID Number	Kidney/Liver Sample ID Number	Collection Date
RCBRA Bev Ref 1	J14XN9	J14XY0	10, 11-Apr-07
RCBRA Bev Ref 2	J14XP0	J14XY1	10, 11-Apr-07
RCBRA R Ref 14	J14XP1	J14XY2	10, 11, 12-Apr-07
RCBRA 2a Rip	J14XP2	J14XY3	10, 12-Apr-07
RCBRA 2c Rip	J14XP9	J14XY4	10, 12, 17-Apr-07
RCBRA 2f Rip	J14XP3	J14XY5	18, 19, 24-Apr; 1-May-07
RCBRA 2f Rip (Equipment Blank)	J15505	---	6-Jun-07
RCBRA 2j Rip	J14XP4	J14XY6	17, 18, 19, 24-Apr-07
RCBRA 2l Rip	J14XP5	J14XY7	17, 18, 24-Apr-07
RCBRA 3b Rip	J14XP6	J14XY8	17, 18, 24-Apr; 1-May-07
RCBRA 4a Rip	J14XP8	J14XY9	17, 18, 19-Apr-07
RCBRA 5c Rip	J14XP7	J14Y00	17, 18, 19-Apr-07

Table 2-16. Summary of Chemical Analytical Methods and Constituents Analyzed for Mammal Liver/Kidney and Offal Samples.

Method Name	Constituent
6010_METALS_ICP	GAMMA_GS[1]
7471_HG_CVAA	SRTOT_SEP_PRECIP_GPC[1]
8081_PEST_GC[1]	TC99_TR_SEP_GPC[1, 2]
8082_PCB_GC[1]	THISO_IE_PLATE_AEA[1]
8270_SVOA_GCMS[1]	UISO_PLATE_AEA[1]

[1] Method not performed on small mammal liver/kidney combinations.

[2] Method performed on small mammal offals at RCBRA 2c and 4a Rip.

2.2.5.1 Modifications. Small mammal offals were not analyzed for carbon-14, as it was not detected in riparian soils.

2.2.6 Thermoluminescent Dosimeters

External radiation was measured at each of the 11 riparian investigation areas using TLD-700 (Lithium Fluorine) chips to determine the average environmental dose rates measured at each station (Figure 2-1). Three TLDs were placed within each riparian investigation area at each of the three metal posts; one at each end and one in the center. The TLDs were placed in plastic jars and taped in an upright position at the top of the T-Post. During collection it was discovered that some TLDs had been disturbed by wildlife (e.g., chewed on, rubbed and torn from poles by browsing animals) or had leaks in the plastic envelopes. These were noted in the logbooks and in the dosimeter analysis performed by Pacific Northwest National Laboratory. The average daily exposure was determined by dividing the average total exposure for each set of five chips, divided by the number of days the TLDs were exposed at the study investigation area. A summary of TLDs placed at each investigation area can be found in Table 2-17.

Table 2-17. Summary of Thermoluminescent Dosimeters Collected.

Investigation Area	Dosimeter ID Number	Date Placed	Collection Date
RCBRA Bev Ref 1	WH226 – WH228	15-Nov-06	10-Jul-07
RCBRA Bev Ref 2	WH229 – WH231	15-Nov-06	10-Jul-07
RCBRA R Ref 14	WH232 –WH234	15-Nov-06	10-Jul-07
RCBRA 2a Rip	WH235 – WH237	14-Nov-06	10-Jul-07
RCBRA 2c Rip	WH238 – WH240	14-Nov-06	10-Jul-07
RCBRA 2f Rip	WH241 – WH243	14-Nov-06	10-Jul-07
RCBRA 2j Rip	WH244 – WH246	31-Jan-07[1]	10-Jul-07
RCBRA 2l Rip	WH247 – WH249	14-Nov-06	10-Jul-07
RCBRA 3b Rip	WH250 – WH252	14-Nov-06	10-Jul-07
RCBRA 4a Rip	WH253 – WH255	14-Nov-06	10-Jul-07
RCBRA 5c Rip	WH256 – WH258	14-Nov-06	10-Jul-07

[1] TLDs at RCBRA 2j Rip were not collected until January due to bald eagle restrictions.

2.3 NEAR-SHORE AQUATIC ZONE ACTIVITIES

The near-shore aquatic zone contained 20 primary investigation areas (Table 2-18). Zone activities include the following: sampling of pore water, surface water, sediment, aquatic invertebrates, clams, mussels, juvenile toads, and fish. In addition, surveys of T & E snails, T & E salmonids, clam histopathology and survival, fish histopathology, and invertebrate community structure were performed (Table 2-19). Additional investigation areas were added

throughout the sampling effort to accommodate specific situations discussed further in the Modification sections (e.g., 2.3.2.3, 2.3.3.1, 2.3.4.1, 2.3.5.1, 2.3.6.1, 2.3.9.3, and 2.3.10.1).

Pore water data collection locations were identified and staked prior to aquifer tube installation. Pore water was collected out of horizontal and vertical aquifer tubes. Sixteen horizontal pore water sampling devices were co-located with the aquatic biota investigation areas and coincide with, or just below, the estimated low-water mark. Three vertical pore water tubes were installed at RCBRA 2e, 2j, and 2l Aq and RCBRA Cr6 and Cr10. Sediment and surface water sample locations were co-located with pore water sample locations. Five sediment locations were identified during the DQO process in addition to those initially recommended locations. Figure 2-3 is a map illustrating the locations of pore water, surface water, and sediment investigation areas.

Six replicate clam tubes (each containing 25 mid-sized clams) and six replicate artificial substrate baskets were co-located with the aquifer tubes at each investigation area (Table 2-19). Clam tubes were placed in the riverbed and slightly buried with surrounding substrate and then staked at the ends to secure the tube. Unlike the 100/300 Areas Component, samples of native freshwater mussels, juvenile toads (tadpoles), and juvenile suckers were collected during the Inter-Areas Component. Rock baskets were placed halfway into the unconsolidated substrate by hand-digging a hole and backfilling against them. Figure 2-5 illustrates the locations of aquatic invertebrate, clam, mussel, and juvenile toad investigation areas. Figure 2-6 illustrates fish sampling regions.

During the 100/300 Areas Component, a number of activities were not performed; these activities were completed during the Inter-Areas Component and include T & E Gastropod, T & E fish surveys, and amphibian sample collection (Table 2-20).

Table 2-18. Plot Coordinates for Near-Shore Aquatic Sampling Efforts. (2 Pages)

Near-Shore Investigation Area	Location Description	Northing	Easting
RCBRA Bev Ref 1 Aq	Beverly Reference 1 Aquatic, Below Wanapum Dam	167694.683	542419.182
RCBRA Bev Ref 2 Aq	Beverly Reference 2 Aquatic, Below Wanapum Dam	167810.610	541514.145
RCBRA A Ref 11	Northeast of Vernita Bridge	146416.126	559465.271
RCBRA R Ref 12	Southeast of Vernita Bridge	145842	559265
RCBRA A Ref 16	Yaeger Slough	144935.982	557625.024
RCBRA 2a Aq	100-B/C Area Shoreline West of Intake	145298.628	564668.761
RCBRA 2b Aq	100-B/C Area Shoreline East of Intake	145428.225	565259.715
RCBRA 2c Aq	Coyote Rapids	146236.993	567584.938
RCBRA Sr5	100-N Area Shoreline	149954.369	571317.673
RCBRA 2f Aq	North of 100-H Area	154311.345	576228.331

Table 2-18. Plot Coordinates for Near-Shore Aquatic Sampling Efforts. (2 Pages)

Near-Shore Investigation Area	Location Description	Northing	Easting
RCBRA 2i Aq	100-F Upper Slough	152685.815	578265.323
RCBRA 2j Aq	White Bluffs Slough	150101.59	579388.301
RCBRA 2l Aq (Aq Invert Baskets)	100-F Upper Slough	146102.139	582232.116
RCBRA 2l Aq (Pore water tube)	100-F Upper Slough	146109.485	582188.210
RCBRA 2m Aq	100-F Lower Slough	145109.266	582905.762
RCBRA 3b Aq (Aq Invert Baskets)	Hanford Townsite Slough	140959.167	584923.258
RCBRA 3b Aq (Pore water tube)	Hanford Townsite Slough	140899.602	584928.693
RCBRA 4a Aq	South of Hanford Townsite	137467.506	589436.260
RCBRA 4b Aq	Savage Island Slough, Franklin County Outfall	134406.978	593531.366
RCBRA 4c Aq	Across River from Franklin County Outfall	133809.744	592845.504
RCBRA 5c Aq	Upper Wooded Island Slough, South of Energy Northwest Power lines	124864.886	594534.610
RCBRA 5d Aq	Lower Wooded Island Slough	121845.720	594529.356

Table 2-19. Inter-Areas Component Effort Type, Start, and Completion Dates in the Near-Shore Aquatic Zone. (2 Pages)

Effort	Sample/Survey Start Date	Completion Date
Pore Water Tube Sampling	11/25/06	3/25/07
Surface Water Sampling	11/10/06	2/6/07
Sediment Sampling	11/28/06	3/14/07
Fish Sampling	2/11/07	12/2/07
Threatened and Endangered Salmonid Habitat Surveys	2/24/07	2/25/07
Fish Histopathology	2/11/07	1/17/2008
Clam Sampling	1/24/07	4/2/07
Clam Histopathology	1/24/07	9/22/07

Table 2-19. Inter-Areas Component Effort Type, Start, and Completion Dates in the Near-Shore Aquatic Zone. (2 Pages)

Effort	Sample/Survey Start Date	Completion Date
Mussel Sampling	1/24/07	4/3/07
Mussel Histopathology	1/24/07	9/22/07
Aquatic Invertebrate Sampling	3/8/07	8/13/07
Aquatic Invertebrate Community Conditions	8/6/07	9/30/07
Rare Freshwater Snail Habitat Surveys	3/10/07	3/14/07
Amphibian Sampling	5/14/07	7/31/07
Amphibian Surveys	5/7/07	7/31/07

Table 2-20. Additional Sampling and Survey Efforts Within 100/300 Investigation Areas in the Near-Shore Aquatic Zone.

Effort	Sample/Survey Start Date	Completion Date
Threatened and Endangered Salmonid Habitat Surveys	2/19/07	2/24/07
Rare Freshwater Snail Habitat Surveys	12/4/06	1/28/07
Fish Sampling	9/10/07	9/26/07
Pore water Sampling (vertical and horizontal pore water comparisons and chromium site sampling during low flow with reduced sample volumes)	11/06	12/06
Sediment Sampling	9/24/207	9/26/07
Amphibian Sampling	5/14/07	7/31/07

Figure 2-3. Aquatic Abiotic Sampling Locations.

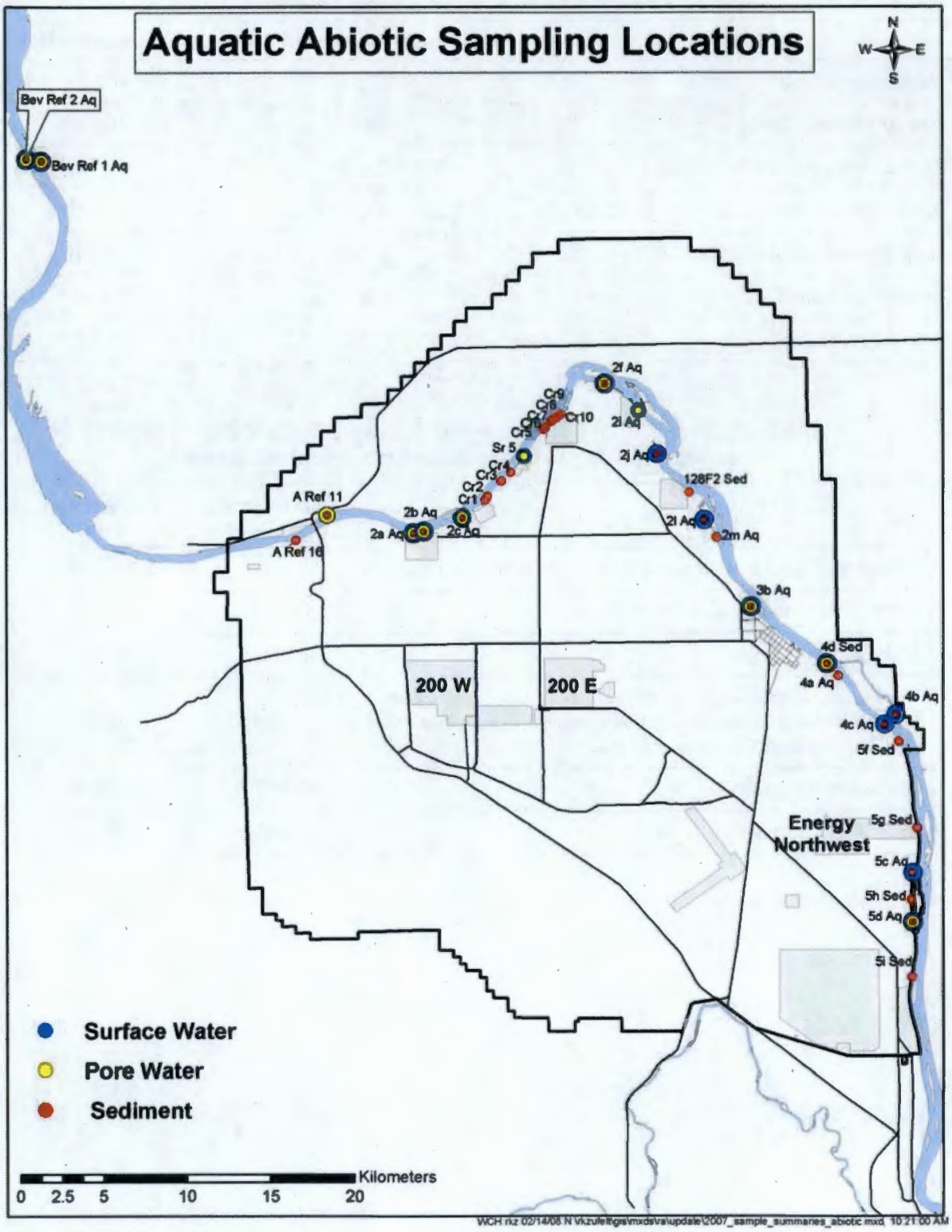


Figure 2-4. Aquatic Biotic Sampling Locations.

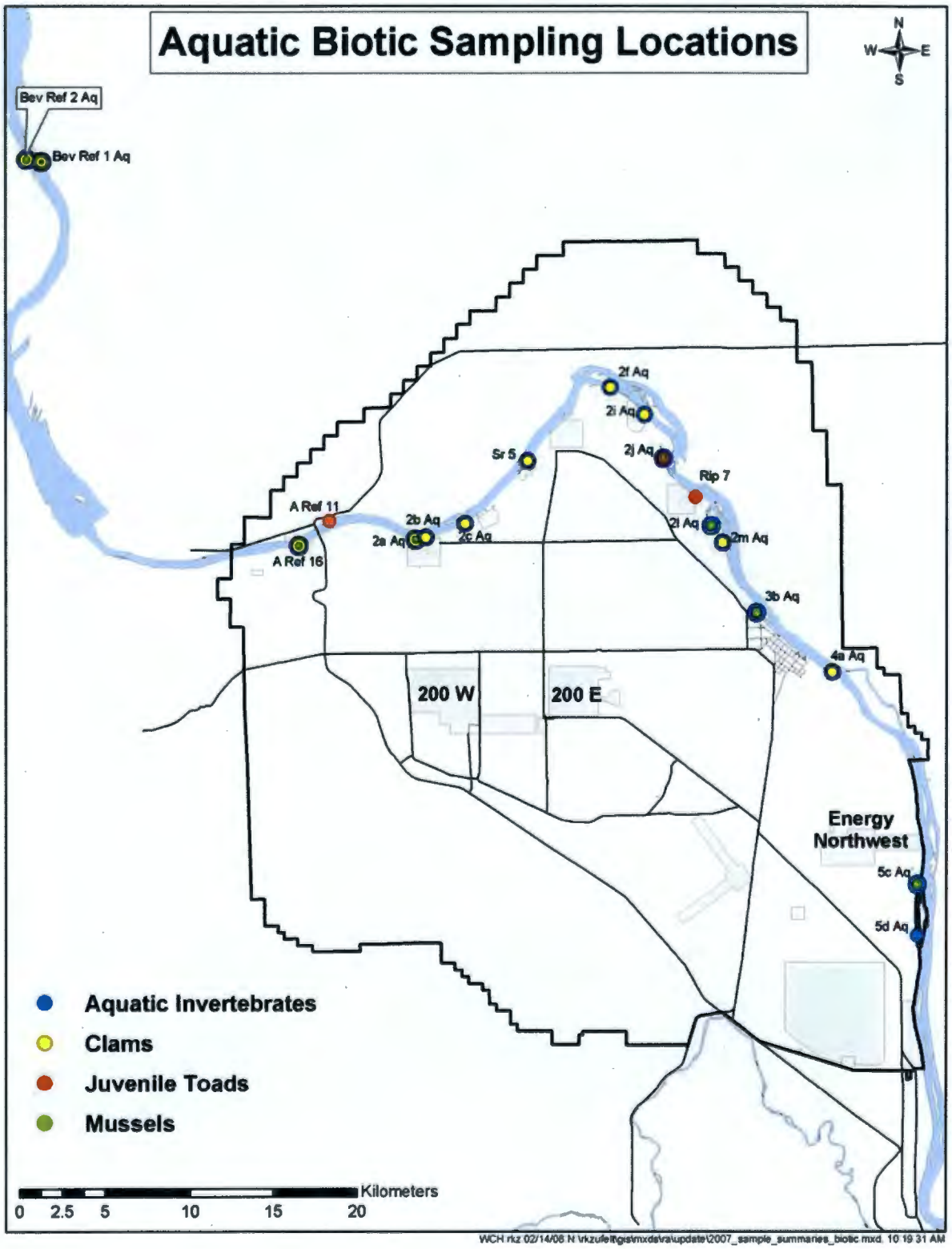
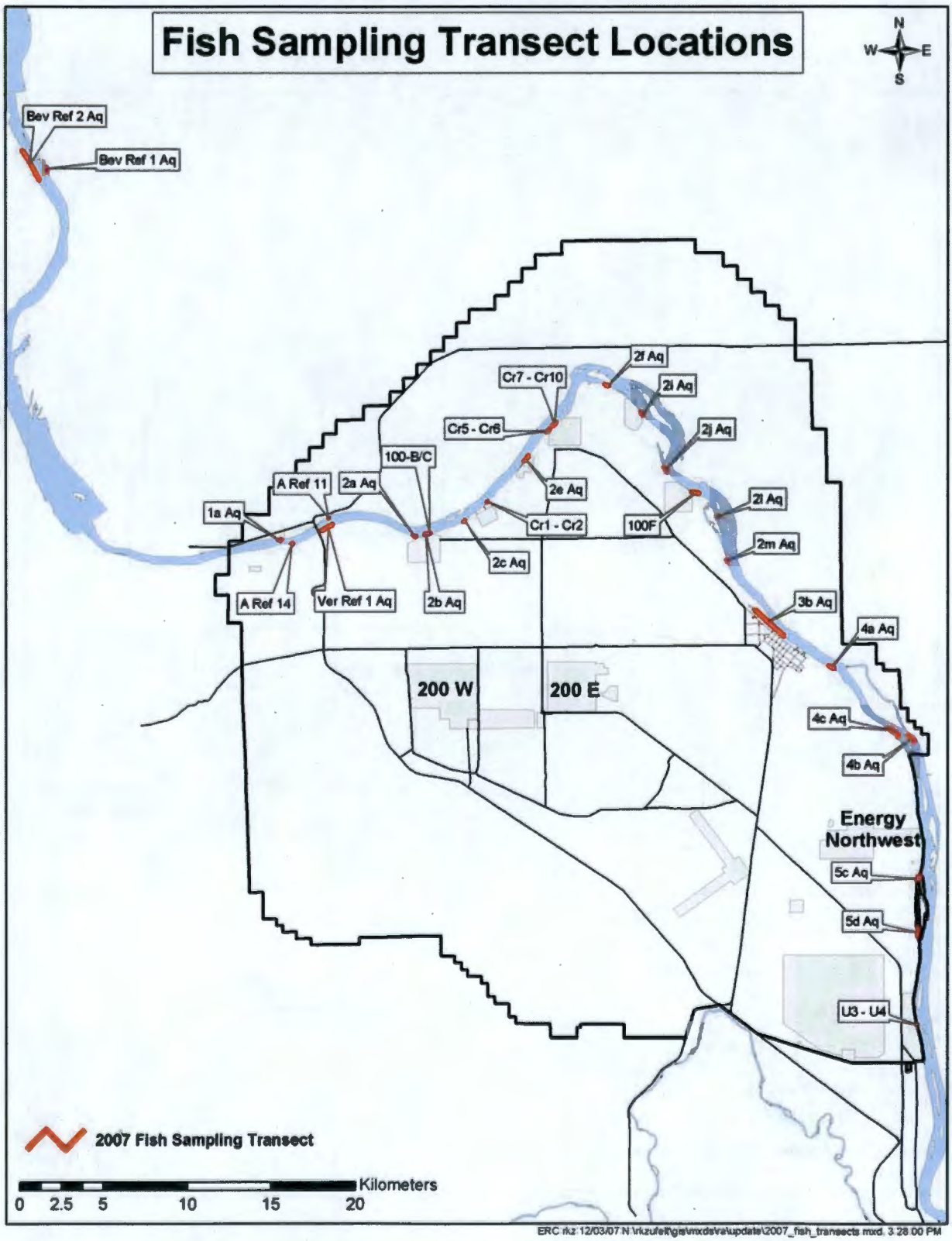


Figure 2-5. Sculpin Sampling Locations.



2.3.1 Water

Both surface and pore water were sampled as part of the Inter-Areas Component. Additional pore water samples were collected at select 100/300 Areas Component investigation areas (RCBRA Cr1, Cr2, Cr4, Cr6, Sr4, and Sr5) and are discussed further in Section 2.3.2.2.

2.3.1.1 Pore Water Sampling. Horizontal pore water sampling tubes were placed at 13 aquatic sites, 10 to 15 cm (4 to 6 in.) below the riverbed and allowed to settle for at least 15 days before sampling began (Table 2-21). Unfiltered surface water samples were collected 6 cm (2.5 in.) above the riverbed to evaluate the wildlife drinking water pathway and to evaluate the human health casual recreational user scenario. Most pore water samples were collected during Priest Rapids Dam flows ranging from approximately 70,000 cubic feet per second (cfs) to 120,000 cfs. The yearly average flow of the river is 120,000 cfs. Additionally, five vertical pore water tubes were installed 50 cm below the riverbed at selected sites for a comparison of the specific conductance measured in co-located horizontal pore water sample devices.

Samples were sent to the ASL for initial parameters and biotoxicity tests (Table 2-22). Samples analyzed for chemical constituents were sent to Lionville laboratory (Table 2-22). Initially, water samples were analyzed for hexavalent chromium by Severn Trent Laboratories (STL); however, to accommodate the sampling schedule and holding times, water samples were analyzed for hexavalent chromium by Energy Northwest (EN) using field screening Hach kit techniques (Table 2-22). Approval of this deviation from the SAP (DOE/RL-2005-42) was received by the regulators during the 100/300 Component of the RCBRA. Samples analyzed for radiological constituents were sent to Eberline laboratory (Table 2-22).

Table 2-21. Summary of Pore Water Samples. (2 Pages)

Investigation Area[1]	Chem/Rad Sample ID Numbers	Bioassay Sample ID Numbers	Hexavalent Chromium Sample ID Numbers	Collection Date
RCBRA Bev Ref 1 Aq	J13VB1	J13V89	J13V95	4-Dec-06
RCBRA Bev Ref 2 Aq	J13VB2	J13V90	J13V96	4-Dec-06
RCBRA A Ref 11	J13VB3	J13V91	J13V97	16-Dec-06
RCBRA 2a Aq	J13VB4	J13V92	J13V98	16-Dec-06
RCBRA 2b Aq	J13VB5	J13V93	J13V99	16-Dec-06
RCBRA 2c Aq	J13VC7	J13V94	J13VC9	16-Dec-06
RCBRA Sr5	J13VD9	---	J13VF2	9-Jan-07
RCBRA 2f Aq	J13VF0	---	J13VF3	9-Jan-07
RCBRA 2i Aq	J13VH5	J13VH2	J13VH3	4-Feb-07
RCBRA 2i Aq (Duplicate)	J13VH6	---	J13VH4	4-Feb-07
RCBRA 3b Aq	J13VR2	---	J13VP6	23-Dec-06

Table 2-21. Summary of Pore Water Samples. (2 Pages)

Investigation Area[1]	Chem/Rad Sample ID Numbers	Bioassay Sample ID Numbers	Hexavalent Chromium Sample ID Numbers	Collection Date
RCBRA 4a Aq	J13VR3	J13VP2	J13VP7	8-Jan-07
RCBRA 4a Aq (Duplicate)	J13VR4	---	J13VP8	8-Jan-07
RCBRA 5c Aq	J13VR5	J13VP3	J13VP9	3-Jan-07
RCBRA 5d Aq	J13VR6	J13VP4	J13VR0	3-Jan-07

[1] See Figure 2-3

Table 2-22. Initial Parameter, Chemical, and Radiological Analytical Methods for Pore Water and Surface Water Samples.

Initial Parameter	Chemical Analytical Methods	Radiological Analytical Methods
130.2_HARDNESS	300.0_ANIONS_IC[3]	903.1_RA226_LUC[5]
160.1_TDS[1, 3]	353.2_NO3/NO2[3]	906.0_H3_LSC[5]
160.2_TSS[1, 3]	415.1_TOC[1, 3]	C14_CHEM_LSC[4]
310.1_ALKALINITY	418.1_TPH_IR[3]	GAMMA_GS[5]
330.5_CHLORINE	6010_METALS_ICP	RAISO_SEP_GPC[5]
350.2_AMMONIA_N	7470_HG_CVAA	SRTOT_SEP_PRECIP_GPC[5]
350.3_AMMONIA[1, 3]	8015M_TPH_GC[3]	TC99_TR_SEP_GPC[6]
351.2_N_TKN[1, 3]	8081_PEST_GC[3]	THISO_IE_PLATE_AEA[5]
351.3_N_TKN_E[2]	8082_PCB_GC[3]	UISO_PLATE_AEA[5]
360.1_OXYGEN_FLD	8270_SVOA_GCMS[3]	
CONDUCT_FLD	9060_TOC[2]	
PH_ELECT_FLD	CR6_SM_3500	
TEMP_FLD	WTPH_DIESEL[3]	
	WTPH_GASOLINE[4]	

[1] Analysis performed on pore water only
[2] Analysis performed on Inter-Areas Component pore water samples only
[3] Analysis not performed on RCBRA Cr1 or Sr5
[4] Only at RCBRA Cr2, Cr4 and RCBRA 2c Aq
[5] Not at RCBRA Cr1
[6] Only at RCBRA 2c, 2i Aq for pore water; RCBRA 2c, 2i, 2j and 2l Aq for surface water

2.3.1.2 100/300 Areas Component Supplemental Sampling. The conductivity of pore water is a strong indicator of groundwater presence; the greater the conductivity, the higher the likelihood of sampling groundwater seeps. River level greatly affects the bank storage of surface water; as the river level decreases, it allows for the bank storage of surface water to drain into the river and, eventually, seeps begin to reflect conductivity indicative of groundwater influence. In November 2006, a second pore water sampling campaign was carried out during a period when river water levels were lower than what they had been during the spring 2006 pore water sampling efforts (WCH 2006). Seven sites were selected for re-sampling; RCBRA Cr2, Cr4, Cr6, Sr4, U1, and U4. Pore water collected at sites RCBRA Cr2, Cr4, Cr6, and Sr4 were sampled for the analyte suites summarized in Table 2-22. During the resampling, river water levels were lower than during the initial event. The initial specific conductance levels measured by the field sampling teams indicated a higher proportion of groundwater in the second round samples. However, at some of the sites, the field team noted that specific conductance of the pore water consistently dropped while they were collecting the 15 to 22 L sample volumes required for. The team proposed a modified sampling design to reduce the amount of water needed for a single sample and provide a more accurate representation of current ambient pore water conditions.

In December 2006, pore water re-sampling was conducted at RCBRA Cr1, Cr6, and Sr5 during low and steady flow conditions. These sites were chosen because they were known to contain elevated levels of chromium or strontium-90 or had consistently produced the highest specific conductance readings during previous RCBRA sampling events. The December 2006 pore water resampling approach included taking several approximately 1 L increments of water from the horizontal pore water device far enough apart in time (approximately 1 hour) so that the water within the device could regain an equilibrium state with the surrounding pore water conditions. The specific conductance levels measured in the field were used to determine which one of the two chromium plume sites (RCBRA Cr1 or Cr6) the final pore water sample would be collected for a trace metal analyses and toxicity testing. Hexavalent chromium analyses was also performed on all three 1 L increments and the final composite volume of pore water obtained from both sites (RCBRA Cr1 and Cr6) (Table 2-23). Specific conductance measured at RCBRA Cr1 was the highest during all three sample increments as well as the final composite sample and was therefore selected as the pore water sample that was submitted for trace metal and toxicity testing (Table 2-23).

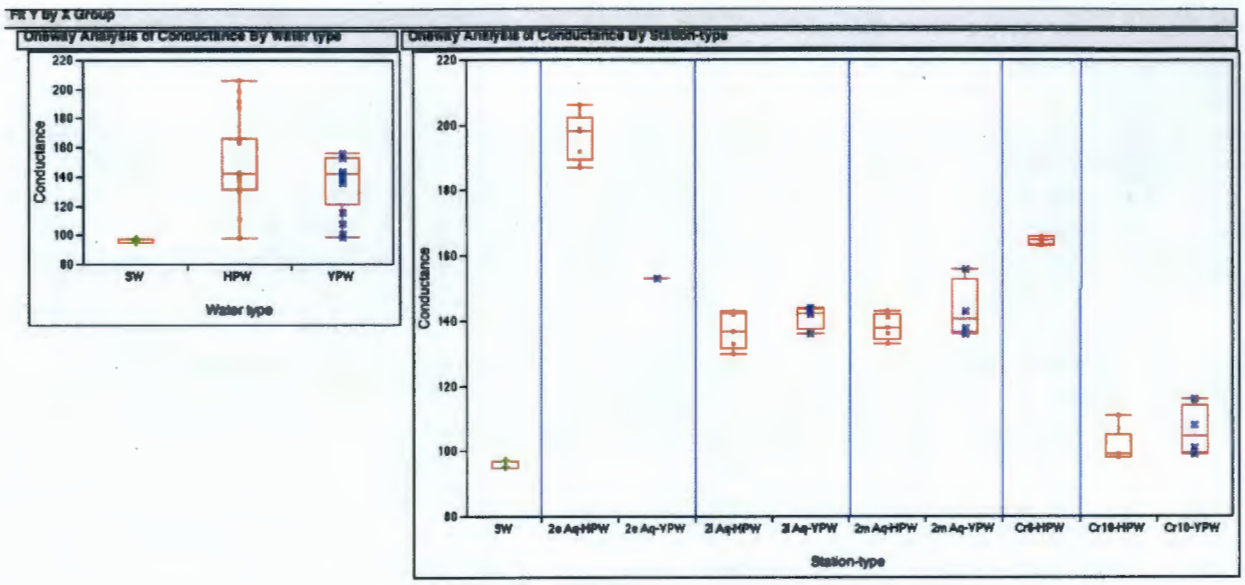
At the request of the regulatory agencies (US Environmental Protection Agency and Washington State Department of Ecology), a comparison between horizontal pore water devices and vertical pore water devices at five RCBRA investigation areas was performed. Specific conductance was measured and compared in horizontal aquifer tubes and vertical tubes co-located at sites RCBRA Sr4 and Sr5 and RCBRA 2j, 2l, and 2m Aq. Pore water from site RCBRA Cr6 was not remeasured in the vertical tube due to plugging of the screens with sediment and the question arose as to the value that vertical tubes have over horizontal tubes. A simple statistical analysis was performed by subcontractor Neptune & Company Inc. to compare the effectiveness of horizontal versus vertical pore water aquifer tubes in collecting pore water samples that are most indicative of groundwater. Figure 2-6 illustrates the results of the analysis; 4 out of 5 horizontal tubes had a statistically greater conductivity than that of the co-located vertical tubes indicating a greater presence of groundwater.

Table 2-23. Summary of 100/300 Supplemental Pore Water Samples.

Investigation Area	Chem/Rad Sample ID Numbers	Bioassay Sample ID Numbers	Hexavalent Chromium Sample ID Numbers	Collection Date
RCBRA Cr1	---	---	J13W66	16-Dec-07
	---	---	J13W67	16-Dec-07
	---	---	J13W68	16-Dec-07
	J13N75	J13W64	J13W69	16-Dec-07
RCBRA Cr2	J13HF8	J13HH2	J13HH6	25-Nov-07
RCBRA Cr4	J13HF9	J13HH3	J13HH7	25-Nov-07
RCBRA Cr6	J13HH0	J13HH8	J13HH4	25-Nov-07
	---	---	J13W71	16-Dec-07
	---	---	J13W72	16-Dec-07
	---	---	J13W73	16-Dec-07
	---	---	J13W74	16-Dec-07
RCBRA Sr4	J13LN3	J13LM9	J13LN1	25-Nov-07
RCBRA Sr5	J13W76	J13W65	J13W70	16-Dec-07

[1] See Figure 2-3.

Figure 2-6. Statistical Analysis of Horizontal versus Vertical Pore Water Conductivity.



2.3.1.3 Modifications. Conductivity from the vertical pore water tube at RCBRA Cr6 could not be measured due to plugging of the peristaltic pump tubing.

Pore water sampling design was modified at RCBRA Cr2, Cr4, Cr6, Sr5, U1, and U4 to sample during extremely low water level periods. Design was further modified at Cr1 and Sr4 to reduce total sample volume requirement and better represent current ambient conditions in the shallow riverbed. At RCBRA 2i Aq, a horizontal pore water tube was installed, but water sampled from the tube was not indicative of groundwater. Therefore, an additional tube was installed downriver and sampled.

Hexavalent chromium was analyzed using field screening Hach kit techniques to accommodate low-flow conditions on the weekend and short holding times.

Technetium-99 was detected at RCBRA 2c Aq (45.9 pCi/L) and was therefore analyzed for in subsequent aquatic tissue samples if sufficient mass existed.

2.3.1.4 Pore Water Bioassays. Bioassays of pore water were conducted with the water flea (*Ceriodaphnia dubia*) and FETAX tests. The water flea three brood toxicity test method used was adapted from the "Standard Guide for Conducting Three-Brood, Renewal Toxicity Tests with *C. dubia*" (ASTM E1295-01) and *Short-Term Methods for Estimating the Chronic Toxicity of Effluent and Receiving Waters to Freshwater Organisms*, US Environmental Protection Agency (EPA) Method 1002.0 "*Ceriodaphnia* Survival and Reproduction Test," (EPA 821/R-02/013). Additional guidance for the test interpretation was provided by: *Understanding and Accounting for Method Variability in Whole Effluent Toxicity Applications Under the National Pollutant Discharge Elimination System Program* (EPA 833/R-00/003) and *Method Guidance and Recommendations for Whole Effluent Toxicity (WET) Testing* (EPA 821/B-00/004) (40 CFR 136).

The water fleas were obtained from ASL in-house cultures. All organisms were fed and maintained during culturing, acclimation, and testing as prescribed by the EPA. For the water flea test, 1 organism per chamber with 10 chambers per sample for a total of 10 organisms per sample was used.

For the tests, pre- and post-renewal solutions were monitored for dissolved oxygen and pH daily in the control and all concentrations tested. Conductivity was measured at test initiation. Temperature was monitored continuously throughout the testing period. Water flea survival and neonate production were measured daily in the tests. The effects measured during the tests included survival and reproduction over the exposure period. Statistical analyses were used to compare the survival data between the control and each sample treatment.

The 96-hour whole frog embryo assay was performed in accordance with *Standard Guide for Conducting the Frog Embryo Teratogenesis Assay-Xenopus (FETAX)* (ASTM E1493-98). The *Xenopus laevis* (South African clawed frog) larvae used for the FETAX screens were obtained from in-house cultures originally purchased from *Xenopus I*, Dexter, Michigan. FETAX screens were conducted using 100% sample volumes without dilution. General water chemistry (e.g., pH, dissolved oxygen, hardness, conductivity, alkalinity, ammonia-nitrogen, and residual oxidants) was initially performed while temperature, pH and dissolved oxygen were measured daily. Mortality and malformation frequencies were determined for each sample tested; length was measured as an index of growth. A total of five FETAX tests performed over a 21-day period were required to screen the 39 pore water samples. Statistical analyses were used to compare the survival and malformation data between the control and each sample treatment.

2.3.2 Surface Water

Unfiltered surface water samples were collected 6 cm (approximately 2.5 in.) above the riverbed to evaluate the drinking water exposure pathway for wildlife and for the recreational exposure scenarios for human health. Surface water samples were co-located with pore water tubes and sediment samples. A map depicting surface water (pore water and sediment) sample locations is in Figure 2-3. Sample volume, sample containers, and sample preservation for each constituent group are described in the 100 Area and 300 Area SAP (DOE-RL 2006a) and SAF. The investigation area, sample identification numbers for chemical and radiological constituents, numbers for hexavalent chromium, and the collection date for each surface water sample collected are listed in Table 2-24.

As with the pore water, surface water samples were analyzed for hexavalent chromium by EN using field screening Hach kit techniques. Samples analyzed for chemical constituents were sent to Lionville laboratory (Table 2-22). Samples analyzed for radiological constituents were sent to Eberline laboratory (Table 2-22).

2.3.2.1 Modifications. A surface water sample was collected at RCBRA 5c Aq on January 10, 2007, and arrived at the laboratory with two of the sample bottles broken (two-1000 mL amber glass bottles for SVOAs and PCBs analyses). An agreement was reached by the Tri-Parties to recollect those two 1000 mL samples.

Table 2-24. Summary of Surface Water Samples.

Investigation Area	Chem/Rad Sample ID Numbers	Hexavalent Chromium Sample ID Numbers	Collection Date
RCBRA Bev Ref 1 Aq	J13VC2	J13VB7	4-Jan-07
RCBRA Bev Ref 2 Aq	J13VC3	J13VB8	4-Jan-07
RCBRA 2a Aq	J13VC4	J13VB9	27-Dec-06
RCBRA 2b Aq	J13VC5	J13VC0	11-Jan-07
RCBRA 2b Aq (Duplicate)	J13VC6	J13VC1	11-Jan-07
RCBRA 2c Aq	J13VD1	J13VD3	27-Dec-06
RCBRA 2c Aq (Equipment Blank)	J13PC8	J13PC9	27-Dec-06
RCBRA 2c Aq (Duplicate)	J13VD2	J13VD4	27-Dec-06
RCBRA Sr5	J13VD5	J13VD7	9-Jan-07
RCBRA 2f Aq	J13VD6	J13VD8	9-Jan-07
RCBRA 2i Aq	J13VJ7	J13VH7	6-Feb-07
RCBRA 2j Aq	J13VJ9	J13VK1	5-Feb-07
RCBRA 2l Aq	J13VK0	J13VK2	15-Jan-07
RCBRA 3b Aq	J13VT4	J13VR7	11-Jan-07
RCBRA 4a Aq	J13VT5	J13VR8	8-Jan-07
RCBRA 4c Aq (TOX-J13W35)	J13VT8	J13W35	15-Jan-07
RCBRA 5c Aq	J13VT9	J13VT2	10-Jan-07
RCBRA 5c Aq (Chemical analyses only)	J14CP8	---	6-Feb-07
RCBRA 5d Aq	J13VV0	J13VT3	10-Jan-07

[1] See Figure 2-3

2.3.3 Sediment

Sample collection of fine-grained near-shore Columbia River sediment locations were co-located with the aquatic biota and pore water sample locations (Table 2-25). A map showing sediment (pore water and surface water) sample locations is in Figure 2-3. Discrete sediment (grab) samples were collected along the water's edge of the shoreline. The upper boundary of the shoreline for sediment sampling corresponded with the lower boundary of MIS riparian soil

sampling. Persistent vascular vegetation, particularly the reed canarygrass (*Phalaris arundinaceae*) was typically used to define this boundary. This boundary corresponded to water levels when Priest Rapids discharge rates are approximately 80,000 cfs. The sediments were collected from between the rocks using pre-cleaned stainless steel scoops and transferred into a plastic-lined Rubbermaid® tub. Thirty multi-increments of sediment were obtained for each sample bottle by spreading out sediment from the tub onto a large stainless steel tray. The tray was then divided (6 rows of 5 squares each) and 30 multi-increment scoops of sediment were systematically collected and transferred to appropriate containers. All containers were labeled with collection location, date, and time and then immediately placed into a chilled cooler. In some cases, gravels and pebbles were screened with a 2 mm (0.08 in.) stainless steel sieve that was decontaminated between each sample.

Sediment samples were used for analysis of the following groups: organic chemicals, inorganic chemicals (metals), radionuclides, quality indicators (e.g., pH and total organic carbon), and physical characteristics (e.g., particle size analysis). Samples were sent to ASL for preparation to be sent to Lionville (chemical constituents) or Eberline laboratories (radiological constituents) (Table 2-25). Samples for toxicity bioassays remained at ASL for the amphipod and Pak Choi tests (Section 2.3.3.2).

Table 2-25. Summary of Sediment Samples. (2 Pages)

Investigation Area[1]	Chem/Rad Sample ID Numbers	Bioassay Sample ID Numbers	Hexavalent Chromium ID Numbers	Collection Date
RCBRA Bev Ref 1 Aq	J13TD4	J13TD0	J13TD2	28-Nov-06
RCBRA Bev Ref 2 Aq	J13TX0	J13TW6	J13TX4	20-Dec-06
RCBRA 1a Aq	J13TD3	J13TC9	J13TD1	28-Nov-06
RCBRA 2a Aq	J13TF3	J13TF1	J13TF2	28-Nov-06
RCBRA 2b Aq	J13TY8	J13V44	J13TX6	20-Dec-06
RCBRA 2c Aq	J13TW1	J13TV9	J13TW0	29-Nov-06
RCBRA 2c Aq (Equipment Blank)	J13TV5	---	J13TV4	29-Nov-06
RCBRA 2f Aq	J13TX1	J13TW7	J13TX5	27-Dec-06
RCBRA 2j Aq	J13TY9	J13V45	J13TX7	14-Mar-07
RCBRA 128F2 Sed	J15PB8	J15PC0	J15PB9	1-Oct-07
RCBRA 2l Aq	J13TD5	J13TD6	J13TD7	12-Dec-06
RCBRA 2l Aq (Duplicate)	J13TV7	J13TV8	J13TV6	12-Dec-06
RCBRA 2m Aq	J13V00	J13V46	J13TX8	17-Dec-06
RCBRA 3b Aq	J13V01	J13V47	J13TX9	12-Dec-06

Table 2-25. Summary of Sediment Samples. (2 Pages)

Investigation Area[1]	Chem/Rad Sample ID Numbers	Bioassay Sample ID Numbers	Hexavalent Chromium ID Numbers	Collection Date
RCBRA 4a Aq	J13V02	J13V48	J13TY0	
RCBRA 4b Aq	J13TY1	J13V49	J13V03	19-Dec-6
RCBRA 4c Aq	J13V04	J13V50	J13TY2	19-Dec-06
RCBRA 4d Sed	J13VD5	---	J13TY3	17-Dec-06
RCBRA 5c Aq	J13TW8	J13TW4	J13TX2	14-Dec-06
RCBRA 5d Aq	J13TW9	J13TW5	J13TX3	4-Dec-06
RCBRA 5f Sed	J13V06	---	J13TY4	14-Dec-06
RCBRA 5g Sed	J13V07	---	J13TY5	14-Dec-06
RCBRA 5h Sed	J13V08	---	J13TY6	4-Dec-06
RCBRA 5i Sed	J13V09	---	J13TY7	21-Dec-06

[1] See Figure 2-3.

Table 2-26. Initial Parameter, Chemical, and Radiological Analytical Methods for Sediment Samples. (2 Pages)

Initial Parameter	Chemical Analytical Methods	Radiological Analytical Methods
350.3_AMMONIA	300.0_ANIONS_IC	C14_COX_LSC[3]
351.4_N_TKN	418.1_TPH_IR	GAMMA_GS
9045_PH	6010_METALS_ICP	PUISO_PLATE_AEA
D2216_%MOIS	7196_CR6[1]	SRTOT_SEP_PRECIP_GPC
D422_PARTCLSIZE	7471_HG_CVAA	TC99_TR_SEP_GPC[4]
	8015M_TPH_GC	THISO_IE_PLATE_AEA
	8081_PEST_GC	UISO_PLATE_AEA
	8082_PCB_GC	
	8270_SVOA_GCMS	
	CR6_SM_3500[2]	
	E777_TOC	
	WTPH_DIESEL	

Table 2-26. Initial Parameter, Chemical, and Radiological Analytical Methods for Sediment Samples. (2 Pages)

Initial Parameter	Chemical Analytical Methods	Radiological Analytical Methods
	WTPH_GASOLINE	

[1] RCBRA 128F2 Aq.

[2] All except RCBRA 128F2 Aq .

[3] RCBRA 2c Aq.

[4] RCBRA 2c, 2j and 2l Aq.

2.3.3.1 Modifications. Due to an oversight during shipping of the sediment sample collected on December 13, 2006 at RCBRA 2m Aq, it was necessary recollect additional material to fill one 1 L poly bottle container. The material was collected at approximately the same location as the previously sampled spot, and analyzed according to SAP requirements

Once collected, sediment samples were bagged and placed in a 5 gal. bucket instead of a Rubbermaid® tub if mass requirements permitted. Due to extreme field conditions, sediment samples were typically taken back to the processing facility and final sub-sampling efforts were performed there.

During the initial sampling event for the 100/300 Areas RCBRA, sediment was collected from 35 of the 37 targeted locations; two locations had insufficient mass for sampling. Sediment analytical results for one of the analytes, hexavalent chromium were called into question because of data recording and holding time interpretation issues. All hexavalent chromium results for sediment from the initial sampling have been marked has not usable and were not evaluated in the risk assessment. However, with the completion of Draft A of the Risk Assessment Report (DOE/RL-2007-21), a data gap was identified: Amphipod growth and survival was significantly reduced in sediment samples associated with the chromium plume locations. Therefore, during September 2007, the 10 chromium plume locations were resampled for hexavalent chromium testing. Due to inherent variability associated with discrete sediment samples, metals, particle size, hexavalent chromium, nutrients (TKN, NH3, anions), and the Amphipod bioassay were also reanalyzed. The resampling effort took place during low-river conditions. Analysis of hexavalent chromium was performed by American Testing Lab using method 7196A rather than the field screening Hach kit method previously used.

2.3.3.2 Sediment Bioassays. Bioassays of sediment were conducted using Amphipod and Pak Choi. The amphipod test methods were performed according to the "Standard Test Method for Measuring the Toxicity of Sediment-Associated Contaminants with Freshwater Invertebrates" (ASTM E1706-05) and "Methods for Measuring the Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates – Second Edition (2000)" (EPA 600/R-99/064). The amphipods used in the sediment tests were obtained from Chesapeake Cultures, Nayes, Virginia, and were 7 to 8 days old at test initiation. All organisms tested were fed and maintained during culturing, acclimation, and testing as prescribed by ASTM and the EPA. The concentration in the amphipod tests was 100% sample sediment, with Beaver Creek sediment as laboratory control.

The effects measured during the amphipod test included survival and growth over a 28-day exposure period. The amphipod tests were monitored at initiation and termination for dissolved oxygen, pH, conductivity, total hardness, alkalinity, ammonia, and temperature. During the tests, dissolved oxygen and pH were monitored every 3 days, conductivity measured every 7 days, and temperature was monitored every 24 hours. Statistical analyses for each result were obtained comparing the survival data between the control and each test sediment.

The Pak Choi test method was adapted from the *Phytotoxicity of Dredged Sediment from Urban Canal as Land Application,* Environmental Pollution 117 (2002) 233-241 (Chen et al.). Additional guidance was provided by *The Water-Culture Method for Growing Plants without Soil*, California Agricultural Experiment Station Circular No. 347 (Hoagland and Amon 1950). The Pak Choi seeds were obtained from Snow Seed Organic, Salinas, California. The control sediment was artificial sediment comprised of 70 grade silica sand, kaolin clay, and peat moss. Calcium carbonate was added to adjust soil pH to 7.0 $\pm$ 0.5. Hydration was accomplished with deionized water and supplemental nutrients were supplied in accordance with test methods. The concentrations tested were 100% sample with artificial control sediment as the laboratory control.

Following sample preparation, four Pak Choi seeds were planted into each test chamber. Seeds were planted and water was sprayed onto the sediment surface to ensure seeds received moisture. Sediment pH was taken at test initiation and termination and temperature was monitored continuously throughout the 22-day testing period. On day 18, seedlings were transplanted in those test concentrations that had one or more test replicates with no germinated seeds and at least one replicate with more than one germinated seed. On day 22, test chambers that had more than one seedling growing were thinned to reduce the number of seedlings to one. For each test chamber, shoots were measured at wet and dry weights. Statistical analysis for each endpoint comprised of entering the data obtained from each replicate chamber of test sediment and comparing the result to the data from the replicate chambers of the laboratory control.

2.3.4 Fish

Sculpin (*Cottus bairdi*) and juvenile sucker (*Catostomus macrocheilus)* were evaluated for contaminant concentrations as well as measured for biological condition and histopathology. A summary of samples including whole body, liver, and kidney identification numbers, collection date and investigation area is provided below in Table 2-27. Electrofishing involves targeting a vicinity, not necessarily a specific sampling investigation area. As such, fish collection occurred along transects to characterize exposure to the groundwater contaminant plumes. A map depicting sculpin and juvenile sucker sampling transects is provided in Figure 2-8.

Fish were collected between 0.0 and 2.0 m (0.0 and 6.6 ft) in depth from approximately the low water mark using electro-fishing techniques consistent with state and federal scientific collection permit conditions and the *Threatened and Endangered Species Management Plan, Salmon and Steelhead* (DOE-RL 2000). The start and stop points of the waters electro-fished, the number of seconds shocked, and all specimens observed/stunned during the collection events were recorded. General habitat characteristics such as primary and secondary substrate sizes, amount of macrophytes, and substrate embeddedness were recorded at each site. Target fishes were netted, euthanized, and immediately placed into sample bottles and placed on ice. Fish collected for histological analyses were euthanized; their abdomens were opened with a

scalpel and immediately placed in 10% phosphate-buffered formalin. The first 5 fish stunned and captured at any given investigation area were selected for histopathology interpretation.

Using pre-cleaned stainless steel forceps, fish samples were placed on pre-cleaned tared Teflon® weighing tray. Whole-body length and weight were measured and recorded. A gross external body condition inspection was conducted and results recorded on the laboratory processing form. After donning surgical gloves and washing the gloves with Liqui-Nox® solution and deionized water, the whole liver was removed and weighed. After noting if the gall bladder was full or empty, the kidney was removed and placed in a separate weighing tray. Subsamples were prepared by blending whole organisms in laboratory-grade blender with dry ice for approximately 30 seconds to 1 minute to allow homogenization of the tissues.

Collected fish species were analyzed for aquatic contaminants at Lionville (chemical constituents) and Eberline (radiological constituents) (Table 2-28). Histopathological analyses of target tissues (kidney, liver, gills, bone, and muscle) were performed by Dr. Ralph Elston of AquaTechnics, Washington.

Table 2-27. Summary of Fish Samples Collected. (2 Pages)

Investigation Area	Fish Species	Whole body Sample ID Number	Liver Sample ID Number	Kidney Sample ID Number	PCB Congeners or Arsenic	Collection Date
RCBRA Bev Ref 1 Aq	Sculpin	J14BB1	J14BF7	J14BC9	---	13, 14, 15, 27-Feb-07
RCBRA Bev Ref 2 Aq	Juvenile Sucker	J14BB2	---	---	---	13, 14, 15, 26-Feb-07
RCBRA A Ref 11	Juvenile Sucker	---	J14BF8	J14BD0	---	27-Feb-07
RCBRA Ver Ref 1 Aq	Juvenile Sucker	J14JT8	J14JV0	J14JT9	---	23-Feb-07
RCBRA 1a Aq	Sculpin	J14B89	J14BD5	J14BB7	---	10, 11, 17-Feb-07
RCBRA 2a Aq	Juvenile Sucker	J14B90	J14BD6	J14BB8	---	10, 11, 12, 14, 19-Feb-07
RCBRA 2b Aq	Sculpin	J14B91	J14BD7	J14BB9	---	17-Feb-07
RCBRA 2c Aq	Sculpin	J14KD1	J14K86	J14K85	---	17-Feb-07
RCBRA 2c Aq	Juvenile Sucker	J14BB6	J14BH2	J14BD4	---	17-Feb-07
RCBRA Sr5	Sculpin	J14B92	J14BD8	J14BC0	---	21-Feb-07
RCBRA 2f Aq	Sculpin	J14B93	J14BD9	J14BC1	---	21-Feb-07
RCBRA 2i Aq	Sculpin	J14BB3	J14BF9	J14BD1	---	21-Feb-07

Table 2-27. Summary of Fish Samples Collected. (2 Pages)

Investigation Area	Fish Species	Whole body Sample ID Number	Liver Sample ID Number	Kidney Sample ID Number	PCB Congeners or Arsenic	Collection Date
RCBRA 2j Aq	Juvenile Sucker	J14BB4	J14BH0	J14BD2	--	20, 25-Feb-07
RCBRA 2j Aq (Additional)	Sculpin	J15J18	---	---	J15J20 (PCB) J15J20-A (As)	20-Sep-07
RCBRA 2l Aq	Sculpin	J15J22	J15J25	J15J28	J15J31 (PCB) J15J31-A(As)	19-Nov-07
RCBRA 2m Aq	Sculpin	J15J23	J15J26	J15J29	J15J32 (PCB) J15J32-A	11, 20-Sep; -19-Nov-07
RCBRA 3b Aq	Juvenile Sucker	J14B95	J14BF1	J14BC3	---	22-Feb-07
RCBRA 3b Aq (Additional)	Sculpin	J15J19	---	---	J15J21 (PCB) J15J21-A (As)	18-Sep-07
RCBRA 4a Aq	Sculpin	J14B96	J14BF2	J14BC4	---	22-Feb-07
RCBRA 4b Aq	Juvenile Sucker	J15J24	J15J27	J15J30	J15J33 (PCB) J15J33-A (As)	19-Nov-07
RCBRA 4c Aq	Sculpin	J14B98	J14BF4	J14BC6	---	17, 22-Feb-07
RCBRA 5c Aq	Juvenile Sucker	J14B99	J14BF5	J14BC7	---	12, 17-Feb-07
RCBRA 5d Aq	Sculpin	J14BB0	J14BF6	J14BC8	---	12, 17-Feb-07

[1] See Figure 2-4

Table 2-28. Summary of Initial Parameter Analytical Methods and Chemical Constituents Analyzed for Fish Samples. (2 Pages)

Method Name	Constituent or Parameter
1668A_PCB CONGENER[1]	C14_COX_LSC[2]
6010_METALS_ICP	GAMMA_GS
7471_HG_CVAA	SRTOT_SEP_PRECIP_GPC
8081_PEST_GC	TC99_TR_SEP_GPC[3]
8082_PCB_GC	THISO_IE_PLATE_AEA

Table 2-28. Summary of Initial Parameter Analytical Methods and Chemical Constituents Analyzed for Fish Samples. (2 Pages)

Method Name	Constituent or Parameter
8270_SVOA_GCMS	TRITIUM_DIST_LSC[4]
TIAS_HGCTGCAAS[1]	UISO_PLATE_AEA

[1] RCBRA 2b, 100F, 2j Aq, 2l Aq, 2m Aq, 3b Aq, 4b Aq, A Ref 14, Cr1-Cr2, Cr5 – Cr6, Cr7-Cr10, and U3-U4 only.

[2] RCBRA 2c and 4b Aq only.

[3] RCBRA 2c, 2i, and 2j Aq only.

[4] RCBRA 2b Aq only.

2.3.4.1 Modifications. During review of Draft A of the Risk Assessment Report (DOE/RL-2007-21), the need arose for analysis of PCB Congeners, PCB Aroclors, and Arsenic speciation. Select locations, including both 100/300 Areas and Inter-Areas investigation areas were therefore sampled and analyzed for the aforementioned constituents (RCBRA 2b Aq, 2j Aq, 3b Aq, 100F, A Ref 14, Cr1-Cr2, Cr5 – Cr6, Cr7-Cr10, and U3-U4) (Table 2-29). During this review, investigation areas RCBRA 2l, 2m and 4b had yet to be sampled for fish; therefore enough mass was collected at these locations to analyze for PCB congeners and Aroclors and Arsenic speciation as well.

Investigation area RCBRA 100F was added to fish investigation areas to aid in determining remediation options for an adjacent waste site (128-F-2). Fish collected at RCBRA 100F were sent to AquaTechnics for histopathological examinations. An attempt to analyze for hexavalent chromium on fish tissue from 100F was made, but the laboratory could not get the tissue sample to transition from a gel to liquid state.

Electrofishing at RCBRA Bev Ref 2 was conducted four days (February 13 – 15 and 28), with only 2 fish collected. In order to collect additional fish at reference locations, RCBRA Ver Ref 1 is a known location of juvenile sucker habitat and replaced RCBRA Bev Ref 2.

RCBRA 2j Aq is located within the 800 m buffer zone of a bald eagle nesting investigation area. Therefore, fish collection was relocated downriver of the original location, just outside of the buffer zone.

RCBRA 2l Aq is located on the west side of Island 9 (100F slough) and access to this area was not possible during permitted fish collection periods due to low water conditions. Therefore, fish collection was relocated to the east side of Island 9 upon Tri-Party approval.

RCBRA 2c Aq was the only location that contained both sculpin and juvenile suckers. Agreement was reached to collect both species allowing for later comparison of constituent concentrations in the tissue.

A juvenile sucker sample was collected from near Site RCBRA Ref 12 Aq to facilitate reference sample comparisons of this species.

The Washington State Department of Health (DOH) will analyze split samples to ensure consistency between laboratory methods. Three of the additional 100/300 Areas investigation areas were split with DOH: RCBRA A Ref 14, RCBRA Cr5 – Cr6, and RCBRA U3 – U4 (Table 2-29).

Results from carbon-14 testing had not arrived from the lab for water samples prior to the shipment of some fish samples; to be cautious, RCBRA 2c and 4b Aq were analyzed for the constituent.

Table 2-29. Summary of Additional 100/300 Areas Component Fish Samples Collected.

Investigation Area	Fish Species	Whole body Sample ID Number Chem/Rad	Whole body Sample ID Number (PCB Congeners or Arsenic)	Liver Sample ID Number	Kidney Sample ID Number	Collection Date
RCBRA 100F	Sculpin	J15J77	J15J75 (PCB) J15J92-A (As)	J15J85	J15J84	18-Sep-07
RCBRA 2b Aq	Sculpin	J15J97	J15J92 (PCB) J15J92-A (As)	---	---	17, 20, 21-Sep-07
RCBRA A Ref 14[1]	Sculpin	J15J96	J15J91 (PCB) J15J91-A (As)	---	---	17-Sep-07
RCBRA Cr1 – Cr2	Sculpin	J15J93	J15J88 (PCB) J15J88-A (As)	---	---	21-Sep-07
RCBRA Cr5 – Cr6[2]	Sculpin	J15J94	J15J89 (PCB) J15J89-A (As)	---	---	20, 21-Sep-07
RCBRA Cr7 – Cr10	Sculpin	J25J95	J15J90 (PCB) J15J90-A (As)	---	---	20, 21-Sep-07
RCBRA U3 – U4[3]	Sculpin	J15J73	J15J87 (PCB) J15J86 (As)	---	---	10-Sep-07

[1] J15J98 is a DOH Split of J15J96.
[2] J15J99 is a DOH Split of J15J97.
[3] J15J74 is a DOH Split of J15J73.

2.3.4.2 Threatened and Endangered Fish Surveys. The surveys helped to determine if suitable steelhead spawning habitat exists at RCBRA investigation areas and documented any steelhead spawning activity at those areas. The results were summarized in the *Suitability of Aquatic Habitat for Steelhead Spawning at Selected Sites in the Hanford Reach of the Columbia River* (Stables and Tiller, 2007 Report) (Appendix E). The 100/300 Areas Component investigation areas were located adjacent to plumes between RCBRA Cr1 – Cr10, Sr3 – 5, and U1 – U10. Inter-Areas Component investigation areas were located in selected regions where contamination was known or suspected to have been deposited; they include RCBRA 2a, 2b, 2c, 2f, 2i, 2j, 2m, 3b, 4a, and 5d Aq.

Conditions suitable for steelhead spawning were found at 30% of the 100/300 Areas Component investigation areas and 10% of the Inter-Areas Component areas. Except for two areas, all were at least partially suitable for steelhead spawning. Investigation area RCBRA U3 in the 300 area is located where a steelhead redd was observed and confirmed by DNA identification in 2005 (B. Tiller, unpublished data).

2.3.5 Asiatic Clams

Six replicate mesh tubes containing Asiatic clams of a standard size class were placed at locations selected for pore water sampling in the aquatic zone. Clam tubes were left in aquatic locations for a minimum of 97 days. These devices provide a standardized way to measure bioaccumulation in these organisms while controlling for potentially confounding age-variation. Clam tubes provided relative measures of contaminant uptake and survival rates. A map depicting clam tube placement (in addition to rock baskets for aquatic invertebrates, juvenile toads, and mussel sampling) locations is provided in Figure 2-4.

Asiatic clams (*Corbicula fluminea*) were collected from within the left-bank fish ladder at Priest Rapids Dam and represent the same life stage (15 mm [0.6 in.] to 22 mm [0.8 in.]). The clams were stored at RCBRA A Ref 14 for 15 days until insertion into mesh tubes and deployment to investigation areas. Tubes approximately 2 m long were prepared using six replicates of each clam tube (with 25 clams each (15 mm [0.6 in.] to 22 mm [0.8 in.]) and were co-located with horizontal porewater devices. Clam tubes were then placed at each of 11 aquatic sites for a total of 1,650 clams in 66 tubes. A summary of Asiatic clam samples, including tissue and shell sample identification number, collection date and investigation area is provided in Table 2-30.

Sample investigation area conditions, predominant and subdominant substrates, substrate embeddedness, and relative abundance of macrophyte populations were recorded. Clam tubes were nestled down into the matrix substrate and positioned perpendicular to the river current. Unconsolidated rocks were placed near the clam tubes, but not directly onto the clams. Three clam tubes were placed upstream and three placed downstream of the horizontal pore water sampling device. Unlike the 6-month minimum requirement during the 100/300 Areas Component, clam tubes were recovered at the end of the 3-month exposure period and survival measures were evaluated for each replicate. Each tube was then placed in an iced cooler in open plastic bags covered with a wetted absorbent towel.

Clam preparation in the laboratory began with removal from field coolers or refrigerators. Clam tubes were opened from the end and clams removed consecutively. Survival and observations such as appearance of parasites or whether the clam had recently died were noted. Up to 10 individual clams were systematically removed from the clam tubes (those nearest the artificial substrate baskets) and shipped to a certified histopathologist for interpretation of their conditions. The surface of each clam shell retained for COPEC analyses were cleaned in deionized water and placed into a single container. Soft tissue was separated from the shell tissue using a flash-steam (5 to 30 seconds) of deionized water in pre-cleaned stainless steel colander and pot.

Soft and hard tissues were submitted separately for contaminant analyses. Shell samples were sent to Eberline laboratory (Strontium-90) and soft tissue samples were sent to both Lionville and Eberline laboratories (Table 2-31). A portion of the clams were sent to AquaTechnics for histopathology.

Table 2-30. Summary of Asiatic Clam Samples Collected.

Investigation Area	Shell Sample ID Numbers	Tissue Sample ID Numbers	Collection Date
RCBRA Bev Ref 1 Aq	J14LH8	J14LF8	13-Mar-07
RCBRA 1a Aq	J14LH9	J14LF9	10-Mar-07
RCBRA 2a Aq	J14LJ0	J14LH0	8-Mar-07
RCBRA 2b Aq	J14LJ1	J14LH1	10-Mar-07
RCBRA 2c Aq	J14LJ2	J14LH2	11-Mar-07
RCBRA Sr5	J14LJ3	J14LH3	11-Mar-07
RCBRA 2f Aq	J14LH4	J14LH4	7-Mar-07
RCBRA 2i Aq	J14LJ5	J14LH5	7-Mar-07
RCBRA 2m Aq	J14LB6	J14LB7	7-Mar-07
RCBRA 4a Aq	J14LJ7	J14LH7	12-Mar-07

[1] See Figure 2-4.

Table 2-31. Summary of Chemical and Radiological Methods for Asiatic Clam and Mussel Soft Tissue Samples.

Chemical Analytical Method	Radiological Analytical Method
6010_METALS_ICP	C14_COX_LSC[4]
7471_HG_CVAA	GAMMA_GS[5]
8081_PEST_GC[1]	SRTOT_SEP_PRECIP_GPC[5]
8082_PCB_GC[2]	TC99_TR_SEP_GPC[6]
8270_SVOA_GCMS[3]	THISO_IE_PLATE_AEA[5]
	UISO_PLATE_AEA[5]

[1] Analysis performed on mussels only.

[2] Analysis performed on mussels and only clams from RCBRA 2b Aq.

[3] Analysis performed only on mussels from RCBRA 2j Aq.

[4] Analysis performed only on clams from RCBRA 2c Aq.

[5] Analysis not performed on clams from RCBRA 2m Aq due to limited mass.

[6] Analysis performed only on mussels from RCBRA 2l Aq and clams from RCBRA 2c Aq.

2.3.5.1 Modifications. Nitrate analysis for clam tissue was accidentally added to Table E-2 of the SAP (DOE/RL-2005-42) during preparation of the table. Discussion with the Tri-Parties confirmed that nitrate results from animal tissues would not be valuable and was therefore removed from the constituent list.

Limited mass was not a concern for clam tissue and all planned methods (and associated constituents) were performed. Due to extra tissue, additional methods (and associated constituents) that were performed include the following: 8082 (PCBs), gamma energy analysis, isotopic thorium and isotopic uranium.

At RCBRA 2m Aq only 12 clams were recovered alive. Ten of those clams were sent to AquaTechnics for histopathology; there, only the minimum amount of mass was taken to prepare the slides. The remaining tissues were sent back to APEL, where they were processed with the other 2 clams and shipped for limited analysis (Tables 2-31).

2.3.5.2 Clam Histopathology. Basic parameters reviewed for histopathology include shell length and overall clinical condition. More specific parameters reviewed include the following systems and organs: the digestive system (epithelial cell height, absorb cell vacuole, epithelial cell shedding, hemocytosis), reproductive system (sex, follicle and spermatic tubule stages, ova condition, number of follicle cysts, number of ducts with necrotic cells, number of hyaline degenerative follicles, connective tissue hemocytosis), gills (hemocytosis, epithelial cell shedding, larvae brooding in the gill), kidneys, nerves/ganglia, foot, adductor muscles, mantle, and heart.

In addition, special stains of specific tissue samples were completed in order to confirm the presence/absence of particular observations. Of the three slides that had special stains, the stains did not confirm the presence of microorganisms, ciliated protozoa, or bacteria/ protozoa.

2.3.6 Mussels

Native mussels found in the Hanford Reach today (*Anodonta* spp.) are thought to live up to 20 to 30 years and may integrate exposure across a larger area than other aquatic invertebrates because they are more mobile. Little to no data on adult mussel movement patterns have been published; however, their home ranges likely are limited to contiguous areas dominated by fine grain sediments.

Snorkel and scuba diving techniques were used to locate, identify, collect, and measure live native floater mussels (*Anodonta oregonensis*). Observers surveyed the riverbeds for mussels approximately 1 m from the river bottom along transects approximately 2 m wide. Specimens were placed in an iced cooler in open plastic bags with a wetted absorbent towel. Mussels were collected using dip-nets from a boat floating over the investigation area during low-flow conditions. As with clam collection, the extent of the substrate and macrophytic characteristics will be classified consistent with methods described for previously (e.g., substrate types, embeddedness, macrophyte abundances). A map depicting mussel collection locations (in addition to clam tube placement, rock basket placement for aquatic invertebrates, and juvenile toad sampling locations) is provided in Figure 2-4.

Mussels were identified based upon morphological characteristics of the shell and the taxa recognized by Nedeau, Smith and Stone (2005) and Turgeon et al. (1998). For age class characterizations, shell height, and width measurements were taken on all specimens collected.

Specimens were placed in an iced cooler in open plastic bags with a wetted absorbent towel. A summary of mussel samples, including tissue and shell sample identification number, collection date and investigation area is provided in Table 2-32.

Mussels were systematically selected (every other specimen collected) for histopathology analysis, opened, and placed in formalin prior to shipment. Remaining mussels were observed for visible abnormalities and then the tissue was separated from the shell for contaminant analysis. A total of 73 Oregon floater mussels were collected from nine of the RCBRA Inter-Areas locations.

Soft tissue was separated from the shell and then blended with equal fractions dry ice to homogenize multiple specimens. Soft and hard tissues were submitted separately for contaminant analyses. Shell samples were sent to Eberline (Strontium-90) and soft tissue samples were sent to both Lionville and Eberline (Tables 2-31). A portion of the mussels were sent to AquaTechnics for histopathology.

Table 2-32. Summary of Mussel Samples Collected.

Investigation Area	Shell Sample ID Numbers	Tissue Sample ID Numbers	Collection Date
RCBRA Bev Ref 1 Aq	J14CL6	J14HD8	12-Feb-07
RCBRA Bev Ref 2 Aq	J14CL7	J14HD9	24-Jan-07
RCBRA 1a Aq	J14CL8	J14HF0	24-Jan; 12-Feb-07
RCBRA 2a Aq	J14CL9	J14HF1	1, 12-Feb-07
RCBRA 2j Aq	J14CM6	J14HF6	20-Jan-07
RCBRA 2l Aq	J14CM7	J14HF7	14-Mar-07
RCBRA 3b Aq	J14CM1	J14HF3	14-Mar-07
RCBRA 5c Aq	J14CM2	J14HF4	15-Mar-07
RCBRA 5d Aq	J14CM3	J14HF5	15-Mar-07

[1] See Figure 2-4.

2.3.6.1 Modifications. There were no modifications made for mussel samples.

2.3.6.2 Mussel Histopathology. Basic parameters reviewed for histopathology include shell length and overall clinical condition. More specific parameters reviewed include the following systems and organs: the digestive system (epithelial cell height, absorb cell vacuole, epithelial cell shedding, hemocytosis), reproductive system (sex, follicle and spermatic tubule stages, ova condition, basophilic particles and materials, connective tissue hemocytosis), gills (hemocytosis, epithelial cell shedding, larvae brooding in the gill), kidneys, nerves/ganglia, foot, adductor muscles or other muscle bands, mantle, and heart.

In addition, special stains of specific tissue samples were completed in order to confirm the presence/absence of particular observations. Of the 18 slides that had special stains, all had a positive stain showing extracellular granules, intracellular (primarily hemocytes) granules, or amorphous extracellular material.

2.3.7 Mollusk Survey

Surveys of mollusk habitats were completed by Deixis Consultants and EAS in January and March 2007 for the 100/300 Areas and Inter-Areas components, respectively. Artificial substrate baskets containing colonized mollusk species were examined for the 100/300 Areas Component prior to conducting field-based surveys of each of the site's habitat characteristics. This information was used to help define whether the RCBRA aquatic study areas have habitat characteristics favorable for coldwater taxa such as the pebblesnail (*Fluminicola sp*). The habitat characteristics of the Inter-Areas investigation areas were reviewed prior to examining mollusk community recovered on artificial substrate baskets. A listing of mollusk taxa expected at these sites (including rare taxa) was then prepared.

For the 100/300 Areas Component, 27 aquatic investigation areas were selected to assess the presence/absence of mollusk species known to be present on the Columbia River. The results were summarized in the *Mollusk Observations along the Hanford Reach of the Columbia River: 100 and 300 Areas RCBRA* (Frest, Johannes and Tiller, unpublished data) (Appendix F). Rare species such as the pebblesnail (*Fluminicola* sp.) and spring snail (*Pyrgulopsis* sp.) were observed. The pebblesnail was confirmed at Ref 11, 12, 13, 16, U1- U3, U6, U7, U9, U10, Cr3, Cr7, Cr9, and Cr10. The spring snail was confirmed at 300 Ref 1 & 2, U2, U3, U5, U6, U8-U10, Cr5, and Cr9.

For the Inter-Areas Component, 14 aquatic investigation areas were selected to assess the habitat characteristics for mollusk species known to be present on the Columbia River. The results were summarized in the *Mollusk Observations along the Hanford Reach of the Columbia River: Inter-Areas RCBRA Habitat Assessment and Likelihood of Species Presence* (Frest, Johannes and Tiller, unpublished data) (Appendix G). Factors that may limit the presence of sensitive taxa such as pebblesnail, short-face lanx, and spring snail, were also noted. These factors include the dominant substrate size, sub-dominant substrate size, relative abundance of macrophytes (aquatic plants) and substrate embeddedness. Based on these factors and 100/ 300 Areas Component rock basket data, rare taxa were expected to occur at RCBRA 2a, 2b, 2l, and 4a Aq, and RCBRA Sr5.

2.3.8 Aquatic Invertebrates

Rock baskets were colonized by aquatic invertebrates and provided measures of contaminant uptake and of invertebrate diversity, abundance, and biomass. Six artificial substrate baskets containing standard size gravel-pebble were placed in the continuously submerged, unconsolidated substrate, allowing for the colonization of hyporheic organisms. Unlike the 100/300 Areas Component, the 3 rock baskets placed in the substrate for laboratory analysis were collected after 3 months instead of 6 months. (Rock baskets placed in the substrate for community structure remained there for approximately 6 months.) It was agreed by the Tri-Parties that 3 months was an adequate amount of time to allow for contaminant uptake, but 6 months was required for community structure evaluation and comparison to the 100/300 Areas Component dataset.

Rock baskets were installed together at the location of the aquifer tubes and placed parallel to the river flow. Three baskets were placed upstream of the horizontal pore water sampling device and three baskets downstream of the horizontal pore water sampling device. Baskets were deployed during low-flow periods (January) at ~0.5 m (1.6 ft) below the low water mark (a.k.a. green line) at each investigation area. Baskets at one site (RCBRA 2j Aq) were deployed on Jan 30, 2007 due to the potential disturbance of a pair of nesting bald eagles. Baskets were surrounded with unconsolidated substrate to help simulate natural conditions observed at each investigation area.

For retrieval, rock baskets were covered with mosquito netting and carefully removed from the riverbed to minimize disturbance to the baskets while retrieving. Three baskets were hand-picked with pre-cleaned stainless steel tweezers and the invertebrates were placed into a single pre-cleaned container for analysis. Samples were then placed in an iced cooler and transferred to a refrigerator at the laboratory. Organisms collected from the other three baskets were preserved and evaluated for diversity and abundance measures by Aquatic Biology Associates, Corvallis, Oregon.

2.3.8.1 Aquatic Invertebrate Sampling. For baskets picked for constituent analyses, the total mass of each general taxa and number of individuals per taxa were recorded. Organisms were rinsed with deionized water and placed into sample containers. If multiple laboratories or analyses methods were used for constituent analyses, then the specimens were homogenized in a pre-cleaned 250 mL (8 oz) stainless steel blender with approximately equal fractions of dry ice. The blended contents were emptied onto a pre-cleaned aluminum tray to allow the dry ice to evaporate. The desired number and mass of subsamples were placed in containers. A summary of aquatic invertebrates including sample identification number, collection date and investigation area is provided in Table 2-33. Samples were sent to Lionville (chemical constituents) or Eberline (radiological constituents) (Table 2-34).

Table 2-33. Summary of Aquatic Invertebrate Samples. (2 Pages)

Investigation Area[1]	Species Type Collected	Additional Opportunistic Collection	Sample ID Numbers	Collection Date
RCBRA Bev Ref 1 Aq	Crayfish Snails	Yes – 1 crayfish	J14LH6	13-Mar-07
RCBRA Bev Ref 2 Aq	Crayfish Caddisfly larvae Mayfly larvae Snails	Yes – 1 crayfish	J14IY8	13-Mar-07
RCBRA 1a Aq	Crayfish Snails	Yes – 1 crayfish	J14KD1-A	10-Mar-07
RCBRA 2a Aq	Crayfish Shrimp Snails	No	J14XF2	8-Mar-07
RCBRA 2b Aq	Crayfish Snails	Yes – 1 crayfish	J14XF3	11-Mar-07
RCBRA 2c Aq	Crayfish Shrimp Snails	Yes – 1 crayfish	J14M03	11-Mar-07

Table 2-33. Summary of Aquatic Invertebrate Samples. (2 Pages)

Investigation Area[1]	Species Type Collected	Additional Opportunistic Collection	Sample ID Numbers	Collection Date
RCBRA Sr5	Crayfish Worms	Yes – 1 crayfish	J14LY9	11-Mar-07
RCBRA 2f Aq	Crayfish Snails	Yes – 1 crayfish	J14M00	7-Mar-07
RCBRA 2i Aq	Leeches Worms	No	J14M01	7-Mar-07
RCBRA 2j Aq	Crayfish	Yes – 1 crayfish	J14YJ6	15-Mar-07
RCBRA 2j Aq (Additional)	Caddisfly larvae Chironomids Damselflies Mayfly larvae Snails Worms	No	J15747	25-Jun-07
RCBRA 2l Aq	Crayfish	Yes – 1 crayfish	J14YJ4	14-Mar-07
RCBRA 2m Aq	Caddisfly larvae Mayfly larvae Snails	No	J14M02	7-Mar-07
RCBRA 3b Aq	Crayfish Snails	Yes – 1 crayfish	J14LY4	7, 12-Mar-07
RCBRA 4a Aq	Crayfish Snails	Yes – 1 crayfish	J14LJ6	12-Mar-07
RCBRA 5c Aq	Crayfish Snails	Yes – 1 crayfish	J14LY5	12-Mar-07
RCBRA 5d Aq	Caddisfly larvae Damselflies Mayfly larvae Snails Worms	No	J14LY6	12-Mar-07

[1] See Figure 2-4.

Table 2-34. Summary of Chemical and Radiological Analytical Methods for Aquatic Invertebrate Samples.

Chemcial Analytical Method	Radiological Analytical Method
7471_HG_CVAA	C14_COX_LSC[1]
6010_METALS_ICP	SRTOT_SEP_PRECIP_GPC
	TC99_TR_SEP_GPC[1]
	THISO_IE_PLATE_AEA
	UISO_PLATE_AEA

[1] Method performed on RCBRA 2c Aq samples only.

2.3.8.2 Aquatic Invertebrate Community Sampling. Benthic community composition and abundance analyses were performed on all organisms greater than 500 microns that were obtained from three of the six baskets deployed at each site. Invertebrates were identified using a dissecting microscope and reference manuals with keys to family and genera (except for midges). The number of individuals in each family (or genera or species if possible) was recorded.

Seventy-six species of aquatic invertebrates were confirmed at the 16 investigation areas where rock baskets were placed. Table 2-35 provides a summary of the community analysis. The Hilsenhoff Biotic Index is an indicator of water quality; 5.51 -6.50 is fair with fairly significant organic pollution, 6.51 - 7.50 is fairly poor and significant organic pollution, and 7.51-8.50 represent poor conditions and severe organic pollution.

Shannon's diversity index is a method that accounts for both abundance and evenness of the species present. The percent of the three most dominant taxa provides a general idea in regards to how even the diversity is. For example, RCBRA Bev Ref 1 Aq had an average of 279 individuals; of those 61.39%, or 171 individuals were the same 3 taxa. Thus, the remaining 22 taxa (out of 25 taxa at the investigation area) comprise 279 – 171, or 108 individuals. In contrast, at RCBRA Bev Ref 2, although it has a close percentage of 60.01%, the remaining18 taxa are comprised of 67 individuals.

Table 2-35. Summary of Aquatic Invertebrate Community Analysis Results. (2 Pages)

Investigation Area	Total Invertebrate Abundance per Basket (mean)	Total Number Of Taxa Per Investigation Area	Hilsenhoff Biotic Index (modified)	Shannon Diversity (log2)	Percent Three Most Dominant Taxa
RCBRA Bev Ref 1 Aq	279	25	7.26	3.13	61.39
RCBRA Bev Ref 2 Aq	168	21	7.15	3.18	60.01
RCBRA 1a Aq	82	21	7.62	3.14	63.73
RCBRA 2a Aq	20	10	7.21	2.84	66.67
RCBRA 2b Aq	179	13	7.02	2.09	88.85
RCBRA 2c Aq	134	23	7.2	2.33	84.66
RCBRA Sr5	558	22	6.26	2	80.71
RCBRA 2f Aq	391	24	6.85	2.45	84.22
RCBRA 2i Aq	1122	28	6.97	2.59	77.07
RCBRA 2j Aq	181	23	7	2.83	70.35
RCBRA 2l Aq	425	18	6.74	2.66	71.76
RCBRA 2m Aq	411	28	7.35	3.33	62.51

Table 2-35. Summary of Aquatic Invertebrate Community Analysis Results. (2 Pages)

Investigation Area	Total Invertebrate Abundance per Basket (mean)	Total Number Of Taxa Per Investigation Area	Hilsenhoff Biotic Index (modified)	Shannon Diversity (log2)	Percent Three Most Dominant Taxa
RCBRA 3b Aq	218	26	6.61	3.36	56.82
RCBRA 4a Aq	247	23	6.71	2.4	80.84
RCBRA 5c Aq	79	24	7.12	2.89	70.17
RCBRA 5d Aq	263	22	7.79	2.83	68.4

2.3.8.3 Modifications. Because the aquifer tubes at RCBRA 2i Aq were not sampled due to misplacement and a new tube was installed down river, the rock baskets were also relocated on December 10, 2006. On that same day, the rock baskets located at RCBRA 4a Aq were also moved to better represent groundwater movement into that site.

Although the SAI directed the removal of every other basket for constituent analysis, the different collection periods (90 days for constituents and 180 days for community analysis) posed a unique situation. The probability of disturbing remaining community baskets while collecting the constituent baskets was high. Therefore, in order to reduce disturbance and potential decolonization of invertebrates, 3 consecutive baskets were collected for constituent analysis after 90 days and the remaining 3 baskets were collected for community analysis after 180 days.

The aquatic invertebrates that colonized each of the three baskets for community analysis were inadvertently combined into a single sample at RCBRA 1a and 2b Aq. Therefore, average abundances for these sites were calculated by dividing the total sample by 3 to compare to the other sites.

The bald eagle nest located near RCBRA 2j Aq presented a unique situation with access to the investigation area. Restrictions based on the Bald Eagle Management Plan reduced access times and methods. Thus, the baskets were not installed until January 30 and could not be removed prior to April 30. Rock baskets located at other investigation areas were deployed in November and ready for collection for constituent analysis in March. For consistency in collection time, Ecology requested that aquatic invertebrates be hand collected around the baskets located at RCBRA 2j Aq (Sample number J14YJ6). The rock baskets left for constituent analysis were collected in June (Sample number J15747). A comparison of values between the two samples is presented in Table 2 -36. Results for mercury, molybdenum, silver, thallium, uranium, and bismuth were reported as not detected above the limiting criteria for both samples and are therefore not listed in the table below. Results for lithium, silicon, tin, chromium, zinc, and calcium were detected in both samples and the associated QC blanks and are therefore also not listed in the table below.

Aquatic invertebrates were limited in sample mass and some hand collection was required to supplement the rock basket collections.

Table 2-36. Comparison of Aquatic Invertebrate Samples at RCBRA 2j Aq.

Constituent	J15YJ6 Value (ug/kg)	J15747 Value (ug/kg)
Aluminum	88000	38000
Iron	162000	120000[2]
Lead	270[1]	1100
Magnesium	916000	194000[2]
Manganese	89100[2]	6400
Nickel	630	270[1]
Potassium	2120000	1040000
Strontium	152000	4000[2]
Antimony	310[1]	400
Arsenic	1200	460
Barium	73300	2100[2]
Beryllium	20[1]	20[2]
Boron	410	360[1]
Cadmium	370	470
Cobalt	140	120
Copper	26600	4700[2]
Vanadium	250	160
Phosphorus	3530000	1260000[2]
Selenium	930	2300

[1] Analyzed for but not detected above limiting criteria.
[2] The constituent was detected in both the sample and the associated QC blank, and the sample concentration was less than or equal to 5 times the blank concentration.

2.3.9 Amphibians

During the 100/300 Areas Component, juvenile Woodhouse's toads (tadpoles) were not collected due to high-river flows scouring their habitat or dropping the rearing pool water temperatures too low. Samples were collected at only four of the eight potential sample locations during the Inter-Areas Component.

The following locations were surveyed and found to contain juvenile toads: RCBRA Bev Ref 1, A Ref 11, 1a, 2c, 2j, 3b, and 5d Aq (Table 2-37). Due to river fluctuations, samples were only collected at RCBRA Bev Ref 1 Aq, A Ref 11 Aq, 2j Aq, and Rip 7. The remaining locations did

not provide sufficient habitat to support juvenile toads. Table 2-37 presents a summary of where amphibians were collected.

Table 2-37. Summary of Amphibian Samples Collected.

Investigation Area	Collected	Reason for absence	Sample ID Numbers	Collection Date
RCBRA Bev Ref 1 Aq	Yes	---	J15698	2-Jul-07
RCBRA A Ref 11	Yes	---	J156B0	2-Jul-07
RCBRA 1a Aq	No	Water fluctuation	---	---
RCBRA 2c Aq	No	Water fluctuation	---	---
RCBRA 2j Aq	Yes	---	J156B2	2-Jul-07
RCBRA Rip 7	Yes	---	J156B3	2-Jul-07
RCBRA 3b Aq	No	Water fluctuation	---	---
RCBRA 5d Aq	No	Flushed out	---	---

[1] See Figure 2-4

2.3.9.1 Modifications. Juvenile toads were not found at RCBRA 2l Aq; however, they are known to be present at RCBRA Rip 7, less than 2 km upriver of RCBRA 2l Aq. A sample was collected at RCBRA Rip 7.

The balance between waiting for tadpoles to grow to adequate sample mass and maintaining a low-average velocity river flow is difficult. On average, 6 tadpoles weigh 1 gram and while waiting for them to grow, river flows can fluctuate unpredictably and wash them out into the river and downstream. Because the opportunity to sample tadpoles during the 100/300 Areas Component was lost due to river fluctuations, the decision was made to collect tadpoles early. Four small samples were collected, with the anticipation that as they grew, more may be collected. After the first 4 samples were collected, the river flows rose and washed out the remaining tadpoles.

3.0 DATA VALIDATION

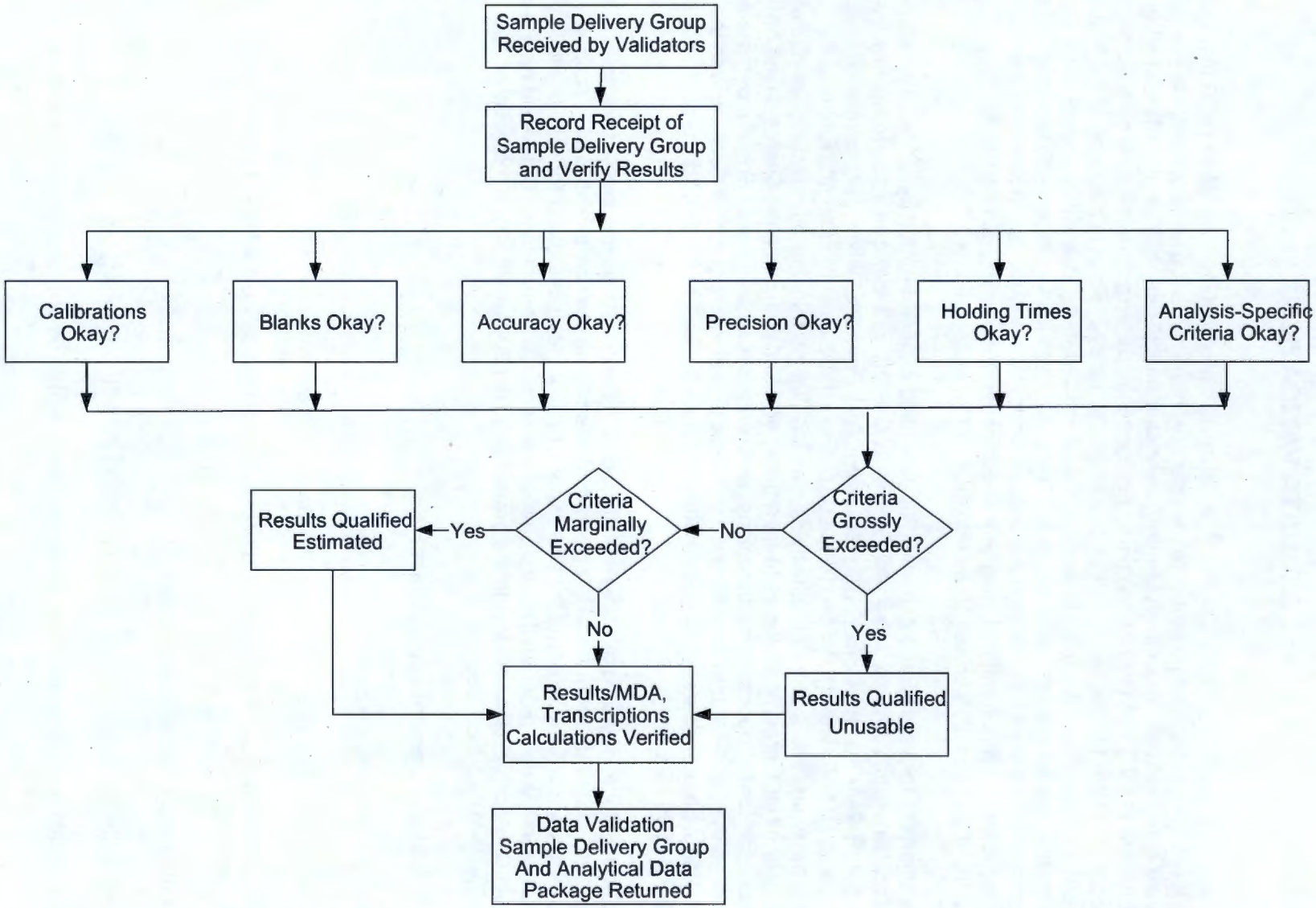
As stated in the SAP (DOE/RL-2005-42), validation by a contractor outside of WCH is required for at least 5% of risk assessment data. In practice, however, a larger percentage is validated because complete sample delivery groups, with often multiple sample identification numbers, are submitted to the validator at one time. For example, all terrestrial invertebrates were processed and sent to the laboratory in one shipment as a single data package. As a result, 100% of the terrestrial invertebrate sample data was validated. In addition, a data package from each media type will be sent for validation. The result of these logistical factors is that some percentage larger than 5% has been validated. Of the 618 samples collected over the course of the Inter-Areas Component, including any additional or re-sampling of 100/300 Areas Component investigation areas, 169 samples, or 27%, were validated.

The framework for validation procedures for data used in decision making is based on *USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review* (EPA 540/R-04/004) and *USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review* (EPA 540/R-99/008). The principles in the national functional guidelines, which are written for inductively coupled plasma metals and mercury, are expanded to apply to other inorganic analyses (e.g., anions) and radiological contaminants based on industry standards, laboratory methodology, and professional judgment. Specific parameters relevant to the RCBRA data are identified in Tables E-1 and E-2 of the SAP, along with the WCH validation procedure where parameters are not specified in the SAP document (DOE/RL-2005-42).

The decision logic and criteria for validating and assessing data quality are summarized in a Figure 3-1. Data that are not validated are evaluated using the same criteria. Persons performing data validation or quality assessment review the data looking for results within the categories in the flow diagram that are outside the required parameters. Data validation is done at Level C in accordance with validation procedures (FH 2004a, 2004b). This level of data validation includes the following:

- Verification of required deliverables
- Requested versus reported analyses
- Evaluation of requested versus achieved constituent detection limits
- Evaluation and qualification of results based on analytical holding times and sample preservation
- Verification of transcription errors
- Evaluation and qualification of results based on method blank result criteria
- Qualification of sample results based on matrix spike (as appropriate to the method)
-

Figure 3-1. Data Sample Delivery Group Validation Procedure.



Modified from the *Data Validation Procedure for Chemical Analysis* (BHI 2000)

- Laboratory control sample and laboratory duplicate or matrix spike/matrix spike duplicate (as appropriate to the method)
- Evaluation and qualification of sample results based chemical or tracer recovery criteria (as appropriate to the method).

When a potential data issue is recognized, the data reviewer determines if the issue indicates a systematic problem, or if the issue is characteristic of a random error. Multiple low surrogate or matrix spike recoveries are examples of a systematic error that would indicate a problem needing more extensive evaluation of how a given laboratory is performing. The response is to begin looking at larger bodies of data to help identify the potential for a widespread impact. Heterogeneity in the sample matrix can be a cause of random errors in analytical results.

Field blanks, field duplicates, and field splits (if information is provided) will be examined. Twelve equipment blanks were made: 2 MIS of soil, 2 discrete soil, 3 sediment, 1 pore water, 1 surface water, 1 small mammal, 1 avian, and 1 terrestrial invertebrate sample. Eighteen replicates were made: 2 discrete soils, 3 sediment, 3 vegetation, 4 surface water, 4 pore water, and 2 sediment from the additional 100/300 Areas Component samples.

Table 3-1. Sampling Effort Type, Start, Completion Dates, Validation/ Verification SDG(s) and Validation/Verification Completion Date. (2 Pages)

Effort	Data Validation/ Verification SDG(s)	Data Validation/ Verification Completion Date
MIS of Soil	K0660	4/23/2007
Discrete Soil	K0883	9/10/2007
Sediment (Inter-Areas)	K0631	4/23/2007
Pore Water (Inter-Areas)	K0652	7/24/2007
Surface Water	K0663	4/23/2007
Dominant Plant Species	K0792 K0802	7/24/2007 8/29/2007
Small Mammals	K0820	8/27/2007
Avian	K0932 K0938	10/1/2007 9/25/2007
Aquatic Invertebrates	K0753	7/3/2007
Terrestrial Invertebrates	K0831	8/27/2007
Amphibians	K0903	9/10/2007
Clams	K0750	7/16/2007
Mussel	K0756	7/3/2007

Table 3-1. Sampling Effort Type, Start, Completion Dates, Validation/ Verification SDG(s) and Validation/Verification Completion Date. (2 Pages)

Effort	Data Validation/ Verification SDG(s)	Data Validation/ Verification Completion Date
Fish	K0735 K0744	7/25/2007 7/16/2007

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APPENDIX A

METHODS AND CONSTITUENTS

APPENDIX A

METHODS AND CONSTITUENTS

Table A-1. Summary of Biotoxicity Initial Parameter Analytical Methods.

Method Name	Parameter or Constituent
130.2_HARDNESS	Hardness
160.1_TDS	Total dissolved solids
160.2_TSS	Total suspended solids
310.1_ALKALINITY	Alkalinity
330.5_CHLORINE	Chlorine
350.2_AMMONIA_N	Ammonia, distillation/nesslerization
350.3_AMMONIA	Ammonia, ion selective electrode
351.2_N_TKN	Total Kjeldahl nitrogen, technicon auto analyzer
351.3_N_TKN_E	Total Kjeldahl nitrogen, ion specific electrode
351.4_N_TKN	Nitrogen, Kjeldahl total
353.2_NO3/NO2	Nitrogen in nitrite and nitrate
360.1_OXYGEN_FLD	Dissolved oxygen measured in the field
415.1_TOC	Total organic carbon
418.1_TPH_IR	Total petroleum hydrocarbon
9045_PH	pH measurement
CONDUCT_FLD	Conductivity measured in the field
D2216_%MOIS	Percent moisture (wet sample)
D422_PARTCLSIZE	Cumulative % Retained on #8, #16, #30, #50, #100, #200, and Screens
E777_TOC	Total organic carbon
PH_ELECT_FLD	pH measured in the field
TEMP_FLD	Temperature measured in the field

Table A-2. Summary of Chemical Analytical Methods and Constituents.

Method Name	Constituent
1668A_PCB CONGENER	
200.8_METALS_ ICPMS	Mercury
300.0_ANIONS_IC	Chloride, Fluoride, Nitrate, Nitrogen in Nitrate, Nitrogen in Nitrite, Sulfate
353.2_NO3/NO2	Nitrogen in Nitrate and Nitrite
6010_METALS_IC P	Aluminum, Antimony, Arsenic, Barium, Beryllium, Bismuth, Boron, Cadmium, Calcium, Chromium, Cobalt, Copper, Iron, Lead, Lithium, Magnesium, Manganese, Molybdenum, Nickel, Phosphorus, Potassium, Selenium, Silicon, Silver, Sodium, Strontium, Thallium, Tin, Uranium, Vanadium, Zinc
7196_CR6	Hexavalent Chromium
7470_HG_CVAA	Mercury
7471_HG_CVAA	Mercury
8015M_TPH_GC	Total Petroleum Hydrocarbon – Gasoline
8081_PEST_GC	Aldrin, Alpha-BHC, alpha-Chlordane, beta-1,2,3,4,5,6-Hexachlorocyclohexane, Delta-BHC, Dichlorodiphenyldichloroethane, Dichlorodiphenyldichloroethylene, Dichlorodiphenyltrichloroethane, Dieldrin, Endosulfan I, Endosulfan II, Endosulfan sulfate, Endrin, Endrin aldehyde, Endrin ketone, Gamma-BHC (Lindane), gamma-Chlordane, Heptachlor, Heptachlor epoxide, Methoxychlor, Toxaphene
8082_PCB_GC	Aroclor-1016, Aroclor-1221, Aroclor-1232, Aroclor-1242, Aroclor-1248, Aroclor-1254, Aroclor-1260
8270_SVOA_GCM S	1,2,4-Trichlorobenzene, 1,2-Dichlorobenzene, 1,3-Dichlorobenzene, 1,4-Dichlorobenzene, 2,4,5-Trichlorophenol, 2,4,6-Trichlorophenol, 2,4-Dichlorophenol, 2,4-Dimethylphenol, 2,4-Dinitrophenol, 2,4-Dinitrotoluene, 2,6-Dinitrotoluene, 2-Chloronaphthalene, 2-Chlorophenol, 2-Methylnaphthalene, 2-Methylphenol (cresol, o-), 2-Nitroaniline, 2-Nitrophenol, 3,3'-Dichlorobenzidine, 3+4 Methylphenol (cresol, m+p), 3-Nitroaniline, 4,6-Dinitro-2-methylphenol, 4-Bromophenylphenyl ether, 4-Chloro-3-methylphenol, 4-Chloroaniline, 4-Chlorophenylphenyl ether, 4-Nitroaniline, 4-Nitrophenol, Acenaphthene, Acenaphthylene, Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(ghi)perylene, Benzo(k)fluoranthene, Bis(2-chloro-1-methylethyl)ether, Bis(2-Chloroethoxy)methane, Bis(2-chloroethyl) ether, Bis(2-ethylhexyl) phthalate, Butylbenzylphthalate, Carbazole, Chrysene, Dibenz[a,h]anthracene, Dibenzofuran, Diethylphthalate, Dimethyl phthalate, Di-n-butylphthalate, Di-n-octylphthalate, Fluoranthene, Fluorene, Hexachlorobenzene, Hexachlorobutadiene, Hexachlorocyclopentadiene, Hexachloroethane, Indeno(1,2,3-cd)pyrene, Isophorone, Naphthalene, Nitrobenzene, N-Nitroso-di-n-dipropylamine, N-Nitrosodiphenylamine, Pentachlorophenol, Phenanthrene, Phenol, Pyrene
9060_TOC[2]	Total Organic Carbon
CR6_SM_3500	Hexavalent Chromium
TIAS_HGCTGCAA	Total inorganic arsenic

Table A-2. Summary of Chemical Analytical Methods and Constituents.

Method Name	Constituent
S	
WTPH_DIESEL	Total Petroleum Hydrocarbon - Diesel
WTPH_GASOLINE	Total Petroleum Hydrocarbon - Gasoline

Table A-3. Summary of Radiological Analytical Methods and Constituents.

Method Name	Constituent
903.1_RA226_LUC	Radium-226
906.0_H3_LSC	Tritium
C14_CHEM_LSC	Carbon-14
C14_COX_LSC	Carbon-14
GAMMA_GS	Americium-241, Cesium-134, Cesium-137, Cobalt-60, Europium-152, Europium-154, Europium-155, Potassium-40, Radium-226, Radium-228, Thorium-228, Thorium-232, Uranium-235, Uranium-238
PUISO_PLATE_AEA	Plutonium-238, Plutonium-239/240
RAISO_SEP_GPC	Radium-228
SRTOT_SEP_PRECIP_GPC	Total beta radiostrontium
TC99_TR_SEP_GPC	Technetium-99
THISO_IE_PLATE_AEA	Thorium-228, Thorium-230, Thorium-232
TRITIUM_COX_LSC	Tritium
UISO_PLATE_AEA	Uranium-233/234, Uranium-235, Uranium-238

APPENDIX B

PCB CONGENERS

APPENDIX B

PCB CONGENERS

Polychlorinated Biphenyl Congeners

Short Name	CAS[1] No.	Name
PCB 1 (BZ)	2051-60-7	2-Monochlorobiphenyl
PCB 2 (BZ)	2051-61-8	3-Monochlorobiphenyl
PCB 3 (BZ)	2051-62-9	4-Monochlorobiphenyl
PCB 4 (BZ)	13029-08-8	2,2'-Dichlorobiphenyl
PCB 5 (BZ)	16605-91-7	2,3-Dichlorobiphenyl
PCB 6 (BZ)	25569-80-6	2,3'-Dichlorobiphenyl
PCB 7 (BZ)	33284-50-3	2,4-Dichlorobiphenyl
PCB 8 (BZ)	34883-43-7	2,4'-Dichlorobiphenyl
PCB 9 (BZ)	34883-39-1	2,5-Dichlorobiphenyl
PCB 10 (BZ)	33146-45-1	2,6-Dichlorobiphenyl
PCB 11 (BZ)	2050-67-1	3,3'-Dichlorobiphenyl
PCB 12 (BZ)	2974-92-7	3,4-Dichlorobiphenyl
PCB 13 (BZ)	2974-90-5	3,4'-Dichlorobiphenyl
PCB 14 (BZ)	34883-41-5	3,5-Dichlorobiphenyl
PCB 15 (BZ)	2050-68-2	4,4'-Dichlorobiphenyl
PCB 16 (BZ)	38444-78-9	2,2',3-Trichlorobiphenyl
PCB 17 (BZ)	37680-66-3	2,2',4-Trichlorobiphenyl
PCB 18 (BZ)	37680-65-2	2,2',5-Trichlorobiphenyl
PCB 19 (BZ)	38444-73-4	2,2',6-Trichlorobiphenyl
PCB 20 (BZ)	38444-84-7	2,3,3'-Trichlorobiphenyl
PCB 21 (BZ)	55702-46-0	2,3,4-Trichlorobiphenyl
PCB 22 (BZ)	38444-85-8	2,3,4'-Trichlorobiphenyl
PCB 23 (BZ)	55720-44-0	2,3,5-Trichlorobiphenyl
PCB 24 (BZ)	55702-45-9	2,3,6-Trichlorobiphenyl
PCB 25 (BZ)	55712-37-3	2,3',4-Trichlorobiphenyl
PCB 26 (BZ)	38444-81-4	2,3',5-Trichlorobiphenyl
PCB 27 (BZ)	38444-76-7	2,3',6-Trichlorobiphenyl
PCB 28 (BZ)	7012-37-5	2,4,4'-Trichlorobiphenyl
PCB 29 (BZ)	15862-07-4	2,4,5-Trichlorobiphenyl
PCB 30 (BZ)	35693-92-6	2,4,6-Trichlorobiphenyl
PCB 31 (BZ)	16606-02-3	2,4'5-Trichlorobiphenyl-1',1
PCB 32 (BZ)	38444-77-8	2,4',6-Trichlorobiphenyl
PCB 33 (BZ)	38444-86-9	2',3,4-Trichlorobiphenyl
PCB 34 (BZ)	37680-68-5	2',3,5-Trichlorobiphenyl
PCB 35 (BZ)	37680-69-6	3,3',4-Trichlorobiphenyl
PCB 36 (BZ)	38444-87-0	3,3',5-Trichlorobiphenyl
PCB 37 (BZ)	38444-90-5	3,4,4'-Trichlorobiphenyl
PCB 38 (BZ)	53555-66-1	3,4,5-Trichlorobiphenyl
PCB 39 (BZ)	38444-88-1	3,4',5-Trichlorobiphenyl
PCB 40 (BZ)	38444-93-8	2,2',3,3'-Tetrachlorobiphenyl

Polychlorinated Biphenyl Congeners

Short Name	CAS[1] No.	Name
PCB 41 (BZ)	52663-59-9	1,1'-Biphenyl,2,2',3,4-tetrachloro-
PCB 42 (BZ)	36559-22-5	1,1'-Biphenyl, 2,2',3,4'-tetrachloro-
PCB 43 (BZ)	70362-46-8	2,2',3,5-Tetrachlorobiphenyl
PCB 44 (BZ)	41464-39-5	2,2',3,5'-Tetrachloro-1-1'-biphenyl
PCB 45 (BZ)	70362-45-7	2,2',3,6-Tetrachlorobiphenyl
PCB 46 (BZ)	41464-47-5	2,2',3,6'-Tetrachlorobiphenyl
PCB 47 (BZ)	2437-79-8	2,2',4,4'-Tetrachlorobiphenyl
PCB 48 (BZ)	70362-47-9	2,2',4,5-Tetrachlorobiphenyl
PCB 49 (BZ)	41464-40-8	2,2',4,5'-Tetrachlorobiphenyl
PCB 50 (BZ)	62796-65-0	2,2',4,6-Tetrachlorobiphenyl
PCB 51 (BZ)	68194-04-7	2,2',4,6'-Tetrachlorobiphenyl
PCB 52 (BZ)	35693-99-3	2,2',5,5'-Tetrachlorobiphenyl
PCB 53 (BZ)	41464-41-9	2,2',5,6'-Tetrachlorobiphenyl
PCB 54 (BZ)	15968-05-5	1,1'-Biphenyl,2,2',6,6'-tetrachloro-
PCB 55 (BZ)	74338-24-2	2,3,3',4-Tetrachlorobiphenyl
PCB 56 (BZ)	41464-43-1	2,3,3',4'-Tetrachlorobiphenyl
PCB 57 (BZ)	70424-67-8	2,3,3',5-Tetrachlorobiphenyl
PCB 58 (BZ)	41464-49-7	2,3,3',5'-Tetrachloro-1-1'-biphenyl
PCB 59 (BZ)	74472-33-6	2,3,3',6-Tetrachlorobiphenyl
PCB 60 (BZ)	33025-41-1	2,3,4,4'-Tetrachlorobiphenyl
PCB 61 (BZ)	33284-53-6	2,3,4,5-Tetrachlorobiphenyl
PCB 62 (BZ)	54230-22-7	2,3,4,6-Tetrachlorobiphenyl
PCB 63 (BZ)	74472-34-7	2,3,4',5-Tetrachlorobiphenyl
PCB 64 (BZ)	52663-58-8	2,3,4',6-Tetrachlorobiphenyl
PCB 65 (BZ)	33284-54-7	2,3,5,6-Tetrachlorobiphenyl
PCB 66 (BZ)	32598-10-0	2,3',4,4'-Tetrachlorobiphenyl
PCB 67 (BZ)	73575-53-8	2,3',4,5-Tetrachlorobiphenyl
PCB 68 (BZ)	73575-52-7	2,3',4,5'-Tetrachlorobiphenyl
PCB 69 (BZ)	60233-24-1	2,3',4,6-Tetrachlorobiphenyl
PCB 70 (BZ)	32598-11-1	1,1'-Biphenyl,2,3',4',5-tetrachloro-
PCB 71 (BZ)	41464-46-4	2,3',4',6-Tetrachlorobiphenyl
PCB 72 (BZ)	41464-42-0	2,3',5,5'-Tetrachlorobiphenyl
PCB 73 (BZ)	74338-23-1	2,3',5',6-Tetrachlorobiphenyl
PCB 74 (BZ)	32690-93-0	2,4,4',5-Tetrachlorobiphenyl
PCB 75 (BZ)	32598-12-2	2,4,4',6-Tetrachlorobiphenyl
PCB 76 (BZ)	70362-48-0	2',3,4,5-Tetrachlorobiphenyl
PCB 77 (BZ)	32598-13-3	3,3',4,4'-Tetrachlorobiphenyl
PCB 78 (BZ)	70362-49-1	3,3',4,5-Tetrachlorobiphenyl
PCB 79 (BZ)	41464-48-6	3,3',4,5'-Tetrachlorobiphenyl
PCB 80 (BZ)	33284-52-5	3,3',5,5'-Tetrachlorobiphenyl
PCB 81 (BZ)	70362-50-4	3,4,4',5-Tetrachlorobiphenyl
PCB 82 (BZ)	52663-62-4	2,2',3,3',4-Pentachlorobiphenyl
PCB 83 (BZ)	60145-20-2	2,2',3,3',5-Pentachlorobiphenyl
PCB 84 (BZ)	52663-60-2	1,1'-Biphenyl,2,2',3,3',6-pentachloro-
PCB 85 (BZ)	65510-45-4	2,2',3,4,4'-Pentachlorobiphenyl
PCB 86 (BZ)	55312-69-1	2,2',3,4,5-Pentachlorobiphenyl

Polychlorinated Biphenyl Congeners

Short Name	CAS[1] No.	Name
PCB 87 (BZ)	38380-02-8	2,2',3,4,5'-Pentachlorobiphenyl
PCB 88 (BZ)	55215-17-3	2,2',3,4,6-Pentachlorobiphenyl
PCB 89 (BZ)	73575-57-2	2,2',3,4,6'-Pentachlorobiphenyl
PCB 90 (BZ)	68194-07-0	2,2',3,4',5-Pentachlorobiphenyl
PCB 91 (BZ)	68194-05-8	2,2',3,4',6-Pentachlorobiphenyl
PCB 92 (BZ)	52663-61-3	1,1'-Biphenyl,2,2',3,5,5'-pentachloro-
PCB 93 (BZ)	73575-56-1	2,2',3,5,6-Pentachlorobiphenyl
PCB 94 (BZ)	73575-55-0	2,2',3,5,6'-Pentachlorobiphenyl
PCB 95 (BZ)	38379-99-6	2,2',3,5',6-Pentachlorobiphenyl
PCB 96 (BZ)	73575-54-9	2,2',3,6,6'-Pentachlorobiphenyl
PCB 97 (BZ)	41464-51-1	1,1'-Biphenyl,2,2',3',4,5-pentachloro-
PCB 98 (BZ)	60233-25-2	2,2',3',4,6-Pentachlorobiphenyl
PCB 99 (BZ)	38380-01-7	2,2',4,4',5-Pentachloro-1,1'-Biphenyl
PCB 100 (BZ)	39485-83-1	2,2',4,4',6-Pentachlorobiphenyl
PCB 101 (BZ)	37680-73-2	2,2',4,5,5'-Pentachlorobiphenyl
PCB 102 (BZ)	68194-06-9	2,2',4,5,6-Pentachlorobiphenyl
PCB 103 (BZ)	60145-21-3	2,2',4,5',6-Pentachlorobiphenyl
PCB 104 (BZ)	56558-16-8	2,2',4,6,6'-Pentachlorobiphenyl
PCB 105 (BZ)	32598-14-4	2,3,3',4,4'-Pentachlorobiphenyl
PCB 106 (BZ)	70424-69-0	2,3,3',4,5-Pentachlorobiphenyl
PCB 108 (BZ)/107 (IUPAC)	70362-41-3	2,3,3',4,5'-Pentachlorobiphenyl
PCB 109 (BZ)/108 (IUPAC)	74472-35-8	2,3,3',4,6-Pentachlorobiphenyl
PCB 107 (BZ)/109 (IUPAC)	70424-68-9	2,3,3',4',5-Pentachlorobiphenyl
PCB 110 (BZ)	38380-03-9	1,1'-Biphenyl,2,3,3',4',6-pentachloro-
PCB 111 (BZ)	39635-32-0	2,3,3',5,5'-Pentachlorobiphenyl
PCB 112 (BZ)	74472-36-9	2,3,3',5,6-Pentachlorobiphenyl
PCB 113 (BZ)	68194-10-5	2,3,3',5',6-Pentachlorobiphenyl
PCB 114 (BZ)	74472-37-0	2,3,4,4',5-Pentachlorobiphenyl
PCB 115 (BZ)	74472-38-1	2,3,4,4',6-Pentachlorobiphenyl
PCB 116 (BZ)	18259-05-7	2,3,4,5,6-Pentachlorobiphenyl
PCB 117 (BZ)	68194-11-6	2,3,4',5,6-Pentachlorobiphenyl
PCB 118 (BZ)	31508-00-6	1,1'-Biphenyl,2,3',4,4',5-pentachloro-
PCB 119 (BZ)	56558-17-9	2,3',4,4',6-Pentachlorobiphenyl
PCB 120 (BZ)	68194-12-7	1,1'-Biphenyl,2,3',4,5,5'-pentachloro-
PCB 121 (BZ)	56558-18-0	2,3',4,5',6-Pentachlorobiphenyl
PCB 122 (BZ)	76842-07-4	2',3,3',4,5-Pentachlorobiphenyl
PCB 123 (BZ)	65510-44-3	2',3,4,4',5-Pentachlorobiphenyl
PCB 124 (BZ)	70424-70-3	2',3,4,5,5'-Pentachlorobiphenyl
PCB 125 (BZ)	74472-39-2	2',3,4,5,6'-Pentachlorobiphenyl
PCB 126 (BZ)	57465-28-8	3,3',4,4',5-Pentachlorobiphenyl
PCB 127 (BZ)	39635-33-1	3,3',4,5,5'-Pentachlorobiphenyl
PCB 128 (BZ)	38380-07-3	2,2',3,3',4,4'-Hexachlorobiphenyl
PCB 129 (BZ)	55215-18-4	2,2',3,3',4,5-Hexachlorobiphenyl
PCB 130 (BZ)	52663-66-8	2,2',3,3',4,5'-Hexachlorobiphenyl
PCB 131 (BZ)	61798-70-7	2,2',3,3',4,6-Hexachlorobiphenyl
PCB 132 (BZ)	38380-05-1	2,2',3,3',4,6'-Hexachlorobiphenyl

Polychlorinated Biphenyl Congeners

Short Name	CAS[1] No.	Name
PCB 133 (BZ)	35694-04-3	2,2',3,3',5,5'-Hexachlorobiphenyl
PCB 134 (BZ)	52704-70-8	2,2',3,3',5,6-Hexachlorobiphenyl
PCB 135 (BZ)	52744-13-5	2,2',3,3',5,6'-Hexachlorobiphenyl
PCB 136 (BZ)	38411-22-2	2,2',3,3',6,6'-Hexachlorobiphenyl
PCB 137 (BZ)	35694-06-5	2,2',3,4,4',5-Hexachlorobiphenyl
PCB 138 (BZ)	35065-28-2	2,2',3,4,4',5'-Hexachlorobiphenyl
PCB 139 (BZ)	56030-56-9	2,2',3,4,4',6-Hexachlorobiphenyl
PCB 140 (BZ)	59291-64-4	2,2',3,4,4',6'-Hexachlorobiphenyl
PCB 141 (BZ)	52712-04-6	2,2',3,4,5,5'-Hexachlorobiphenyl
PCB 142 (BZ)	41411-61-4	2,2',3,4,5,6-Hexachlorobiphenyl
PCB 143 (BZ)	68194-15-0	2,2',3,4,5,6'-Hexachlorobiphenyl
PCB 144 (BZ)	68194-14-9	2,2',3,4,5',6-Hexachlorobiphenyl
PCB 145 (BZ)	74472-40-5	2,2',3,4,6,6'-Hexachlorobiphenyl
PCB 146 (BZ)	51908-16-8	2,2',3,4',5,5'-Hexachlorobiphenyl
PCB 147 (BZ)	68194-13-8	2,2',3,4',5,6-Hexachlorobiphenyl
PCB 148 (BZ)	74472-41-6	2,2',3,4',5,6'-Hexachlorobiphenyl
PCB 149 (BZ)	38380-04-0	2,2',3,4',5',6-Hexachlorobiphenyl
PCB 150 (BZ)	68194-08-1	2,2',3,4',6,6'-Hexachlorobiphenyl
PCB 151 (BZ)	52663-63-5	2,2',3,5,5',6-Hexachlorobiphenyl
PCB 152 (BZ)	68194-09-2	2,2',3,5,6,6'-Hexachlorobiphenyl
PCB 153 (BZ)	35065-27-1	2,2', 4,4', 5,5',-Hexachloro-Biphenyl
PCB 154 (BZ)	60145-22-4	2,2',4,4',5,6'-Hexachlorobiphenyl
PCB 155 (BZ)	33979-03-2	2,2',4,4',6,6'-Hexachlorobiphenyl
PCB 156 (BZ)	38380-08-4	2,3,3',4,4',5-Hexachlorobiphenyl
PCB 157 (BZ)	69782-90-7	2,3,3',4,4',5'-Hexachlorobiphenyl
PCB 158 (BZ)	74472-42-7	2,3,3',4,4',6-Hexachlorobiphenyl
PCB 159 (BZ)	39635-35-3	2,3,3',4,5,5'-Hexachlorobiphenyl
PCB 160 (BZ)	41411-62-5	2,3,3',4,5,6-Hexachlorobiphenyl
PCB 161 (BZ)	74472-43-8	2,3,3',4,5',6-Hexachlorobiphenyl
PCB 162 (BZ)	39635-34-2	2,3,3',4',5,5'-Hexachlorobiphenyl
PCB 163 (BZ)	74472-44-9	2,3,3',4',5,6-Hexachlorobiphenyl
PCB 164 (BZ)	74472-45-0	2,3,3',4',5',6-Hexachlorobiphenyl
PCB 165 (BZ)	74472-46-1	2,3,3',5,5',6-Hexachlorobiphenyl
PCB 166 (BZ)	41411-63-6	2,3,4,4',5,6-Hexachlorobiphenyl
PCB 167 (BZ)	52663-72-6	2,3',4,4',5,5'-Hexachlorobiphenyl
PCB 168 (BZ)	59291-65-5	2,3',4,4',5',6-Hexachlorobiphenyl
PCB 169 (BZ)	32774-16-6	3,3',4,4',5,5'-Hexachlorobiphenyl
PCB 170 (BZ)	35065-30-6	2,2',3,3',4,4',5-Heptachlorobiphenyl
PCB 171 (BZ)	52663-71-5	2,2',3,3',4,4',6-Heptachlorobiphenyl
PCB 172 (BZ)	52663-74-8	2,2',3,3',4,5,5'-Heptachlorobiphenyl
PCB 173 (BZ)	68194-16-1	2,2',3,3',4,5,6-Heptachlorobiphenyl
PCB 174 (BZ)	38411-25-5	2,2',3,3',4,5,6'-Heptachlorobiphenyl
PCB 175 (BZ)	40186-70-7	2,2',3,3',4,5',6-Heptachlorobiphenyl
PCB 176 (BZ)	52663-65-7	2,2',3,3',4,6,6'-Heptachlorobiphenyl
PCB 177 (BZ)	52663-70-4	2,2',3,3',4',5,6-Heptachlorobiphenyl
PCB 178 (BZ)	52663-67-9	2,2', 3,3', 5,5', 6-Heptachloro-1,1'-Biphenyl

Polychlorinated Biphenyl Congeners

Short Name	CAS[1] No.	Name
PCB 179 (BZ)	52663-64-6	2,2',3,3',5,6,6'-Heptachlorobiphenyl
PCB 180 (BZ)	35065-29-3	2,2',3,4,4',5,5'-Heptachlorobiphenyl
PCB 181 (BZ)	74472-47-2	2,2',3,4,4',5,6-Heptachlorobiphenyl
PCB 182 (BZ)	60145-23-5	2,2',3,4,4',5,6'-Heptachlorobiphenyl
PCB 183 (BZ)	52663-69-1	2,2',3,4,4',5',6-Heptachlorobiphenyl
PCB 184 (BZ)	74472-48-3	2,2',3,4,4',6,6'-Heptachlorobiphenyl
PCB 185 (BZ)	52712-05-7	2,2',3,4,5,5',6-Heptachlorobiphenyl
PCB 186 (BZ)	74472-49-4	2,2',3,4,5,6,6'-Heptachlorobiphenyl
PCB 187 (BZ)	52663-68-0	2,2',3,4',5,5',6-Heptachlorobiphenyl
PCB 188 (BZ)	74487-85-7	2,2',3,4',5,6,6'-Heptachlorobiphenyl
PCB 189 (BZ)	39635-31-9	2,3,3',4,4',5,5'-Heptachlorobiphenyl
PCB 190 (BZ)	41411-64-7	2,3,3',4,4',5,6-Heptachlorobiphenyl
PCB 191 (BZ)	74472-50-7	2,3,3',4,4',5',6-Heptachlorobiphenyl
PCB 192 (BZ)	74472-51-8	2,3,3',4,5,5',6-Heptachlorobiphenyl
PCB 193 (BZ)	69782-91-8	2,3,3',4',5,5',6-Heptachlorobiphenyl
PCB 194 (BZ)	35694-08-7	2,2',3,3',4,4',5,5'-Octachlorobiphenyl
PCB 195 (BZ)	52663-78-2	2,2',3,3',4,4',5,6-Octachlorobiphenyl
PCB 196 (BZ)	42740-50-1	2,2',3,3',4,4',5,6'-Octachlorobiphenyl
PCB 197 (BZ)	33091-17-7	2,2',3,3',4,4',6,6'-Octachlorobiphenyl
PCB 198 (BZ)	68194-17-2	2,2',3,3',4,5,5',6-Octachlorobiphenyl
PCB 201 (BZ)/199 (IUPAC)	52663-75-9	2,2',3,3',4,5,5',6'-Octachlorobiphenyl
PCB 199 (BZ)/200 (IUPAC)	52663-73-7	2,2',3,3',4,5,6,6'-Octachlorobiphenyl
PCB 200 (BZ)/201 (IUPAC)	40186-71-8	2,2',3,3',4,5',6,6'-Octachlorobiphenyl
PCB 202 (BZ)	2136-99-4	2,2',3,3',5,5',6,6'-Octachlorobiphenyl
PCB 203 (BZ)	52663-76-0	2,2',3,4,4',5,5',6-Octachlorobiphenyl
PCB 204 (BZ)	74472-52-9	2,2',3,4,4',5,6,6'-Octachlorobiphenyl
PCB 205 (BZ)	74472-53-0	2,3,3',4,4',5,5',6-Octachlorobiphenyl
PCB 206 (BZ)	40186-72-9	2,2',3,3',4,4',5,5',6-Nonachlorobiphenyl
PCB 207 (BZ)	52663-79-3	2,2',3,3',4,4',5,6,6'-Nonachlorobiphenyl
PCB 208 (BZ)	52663-77-1	2,2',3,3',4,5,5',6,6'-Nonachlorobiphenyl
PCB 209 (BZ)	2051-24-3	2,2',3,3',4,4',5,5',6,6'-Decachlorobiphenyl

[1] Chemical Abstracts Service

APPENDIX C

SOIL TEXTURE REPORT

RCC INTER-AREAS SHOREL ISK ASSESSMENT SAMPLING

Survey Date	Site	Soil Type	Color	Moisture Cond.	Consistency	% Cover Rock Fragments (> 2mm			Gradation	Angularity	Shape	Cementation	Maximum Particle Size
						Gravel	Cobble	Boulder					
11/15/2006	RCBRA REF1 Rip	Sandy Clay Loam	2.5YR 3/2	Moist	Soft	10	5	<1	Poorly Graded	Rounded	N/A	Weak	Cobble 30cm
11/15/2006	RCBRA REF2 Rip	Clay Loam	5YR 4/1	Moist	Soft	10	15	5	Poorly Graded	Angular	N/A	Weak	Boulder 100cm
11/7/2006	RCBRA 2A Rip	Sandy Clay	2.5YR 3/2	Moist	Soft	7	3	1	Poorly Graded	Rounded	N/A	Weak	Boulder 70cm
11/8/2006	RCBRA 2C Rip	Clay	2.5YR 3/2	Moist	Soft	1	5	5	Poorly Graded	Rounded	N/A	Weak	Boulder 80cm
11/7/2006	RCBRA 2F Rip	Sandy Loam	2.5YR 4/2	Moist	Soft	10	10	0	Poorly Graded	Rounded	N/A	Weak	Cobble 20cm
11/6/2006	RCBRA 2J Rip	Silty Clay Loam	2.5YR 4/2	Moist	Soft	0	0	0	N/A	N/A	N/A	N/A	Fine Sand
11/7/2006	RCBRA 2L Rip	Sandy Clay Loam	10YR 4/2	Moist	Soft	1	0	0	Poorly Graded	Rounded	N/A	Weak	Cobble 15cm
11/7/2006	RCBRA 2M Rip	Sandy Clay Loam	2.5YR 4/2	Moist	Soft	0	0	0	N/A	N/A	N/A	N/A	Fine Sand
11/16/2006	RCBRA 3B Rip	Sandy Clay Loam	2.5YR 3/2	Moist	Soft	<1	<1	0	Poorly Graded	Rounded	N/A	Weak	Fine Sand, Cobble 15cm
11/16/2006	RCBRA 4A Rip	Clay Loam	2.5YR 4/2	Moist	Soft	<1	<1	7	Poorly Graded	Rounded	N/A	Weak	Boulder 60cm
11/9/2006	RCBRA 5C Rip	Sandy Clay Loam	2.5YR 4/2	Moist	Soft	35	5	1	Poorly Graded	Rounded	N/A	Weak	Boulder 90cm

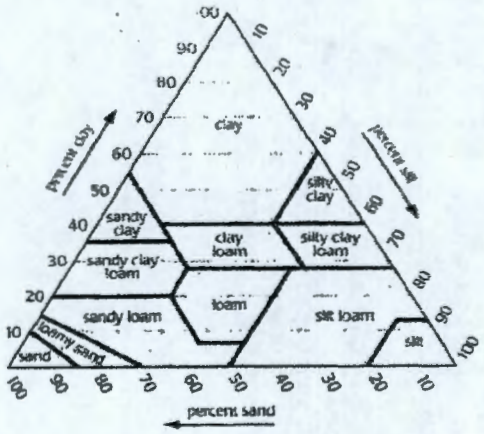
100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/7/06
Time: 12:43
Site: 2F
Weather Conditions: OVERCAST, WINDY

Soil

Muck (Organic)	Peat (Organic)	
Sand	Loamy Sand	(Sandy Loam)
Silty Loam	Loam	Sandy Clay Loam
Silty Clay Loam	Clay Loam	Sandy Clay
Silty Clay	Clay	N/A

Textural Triangle



Color (Moist):
2.5Y 4/2

Moisture Condition
Dry (Moist) Wet

Consistency
Very Soft (Soft) Firm Hard Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 10
Cobbles (%) 10
Boulders (%) 0

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded (Poorly Graded) N/A

Angularity of Coarse-Grained Particles
Angular Subangular Subrounded (Rounded) N/A

Shape of Coarse-Grained Particles
Flat Elongated Flat and Elongated (N/A)

Cementation of Coarse-Grained Particles
(Weak) Moderate Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)
10% FINE TO COARSE GRAVEL

Maximum Particle Size
Fine Sand Medium Sand Coarse Sand Gravel (Size)____ (Cobble) or Boulder (Size) 20cm

100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/6/06
Time: 13:32
Site: 2J
Weather Conditions: OVERCAST, WINDY

Soil

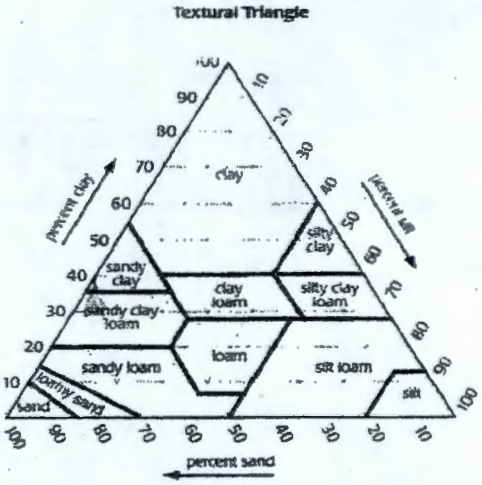
Muck (Organic) Peat (Organic)

Sand Loamy Sand Sandy Loam

Silty Loam Loam Sandy Clay Loam

Silty Clay Loam Clay Loam Sandy Clay

Silty Clay Clay N/A



Color (Moist): 2.5Y 4/2

Moisture Condition
Dry Moist Wet

Consistency
Very Soft Soft Firm Hard Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 0
Cobbles (%) 0
Boulders (%) 0

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded Poorly Graded N/A

Angularity of Coarse-Grained Particles
Angular Subangular Subrounded Rounded N/A

Shape of Coarse-Grained Particles
Flat Elongated Flat and Elongated N/A

Cementation of Coarse-Grained Particles
Weak Moderate Strong N/A

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)
N/A

Maximum Particle Size
Fine Sand Medium Sand Coarse Sand Gravel (Size)____ Cobble or Boulder (Size)____

GA 11-28-06 SMW

100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/7/06
Time: 10:54
Site: 2L
Weather Conditions: OVERCAST, LIGHT WIND

Soil

Muck (Organic) Peat (Organic)

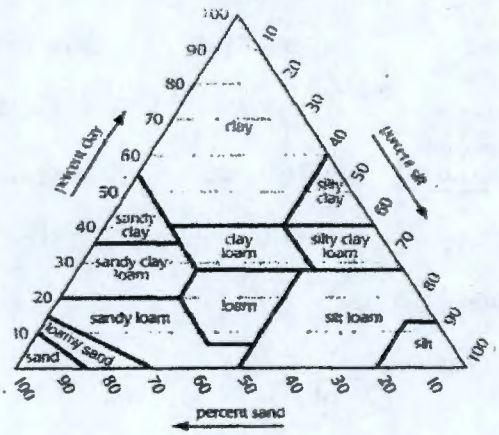
Sand Loamy Sand Sandy Loam

Silty Loam Loam (Sandy Clay Loam)

Silty Clay Loam Clay Loam Sandy Clay

Silty Clay Clay N/A

Textural Triangle



Color (Moist): 10YR 4/2

Moisture Condition
Dry (Moist) Wet

Consistency
Very Soft (Soft) Firm Hard Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 1
Cobbles (%) 0
Boulders (%) 0

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded (Poorly Graded) N/A

Angularity of Coarse-Grained Particles
Angular Subangular Subrounded (Rounded) N/A

Shape of Coarse-Grained Particles
Flat Elongated Flat and Elongated (N/A)

Cementation of Coarse-Grained Particles
(Weak) Moderate Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)
1% FINE TO COARSE GRAVEL

Maximum Particle Size
Fine Sand Medium Sand Coarse Sand Gravel (Size)____ (Cobble) or Boulder (Size) 15 CM

QA 11-28-06

100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/7/06
Time: 9:10
Site: ZM
Weather Conditions: OVERCAST, LIGHT BREEZE

Soil

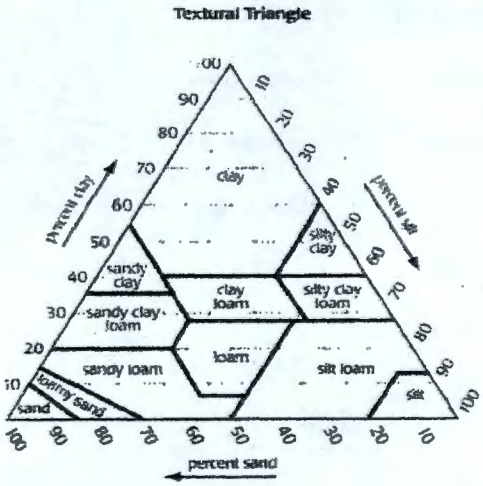
Muck (Organic) Peat (Organic)

Sand Loamy Sand Sandy Loam

Silty Loam Loam Sandy Clay Loam

Silty Clay Loam Clay Loam Sandy Clay

Silty Clay Clay N/A



Color (Moist): 2.5Y 4/2

Moisture Condition
Dry Moist Wet

Consistency
Very Soft Soft Firm Hard Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 0
Cobbles (%) 0
Boulders (%) 0

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded Poorly Graded N/A

Angularity of Coarse-Grained Particles
Angular Subangular Subrounded Rounded N/A

Shape of Coarse-Grained Particles
Flat Elongated Flat and Elongated N/A

Cementation of Coarse-Grained Particles
Weak Moderate Strong N/A

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)

Maximum Particle Size
Fine Sand Medium Sand Coarse Sand Gravel (Size)____ Cobble or Boulder (Size)____

C-5

100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/16/06
Time: 12:55
Site: 3B
Weather Conditions: SUNNY, CLEAR, LIGHT WIND

Soil

Muck (Organic) Peat (Organic)

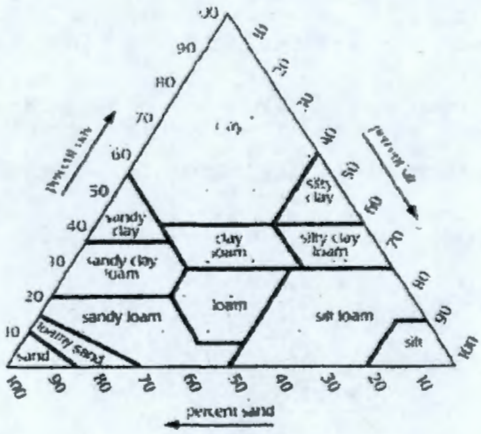
Sand Loamy Sand Sandy Loam

Silty Loam Loam (Sandy Clay Loam)

Silty Clay Loam Clay Loam Sandy Clay

Silty Clay Clay N/A

Textural Triangle



Color (Moist): 2.5Y 3/2

Moisture Condition

Dry (Moist) Wet

Consistency

Very Soft (Soft) Firm Hard Very Hard

Comments (Odors, etc.):

Rock Fragments

Gravel (%) <1
Cobbles (%) <1
Boulders (%) 0

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)

Well-Graded (Poorly Graded) N/A

Angularity of Coarse-Grained Particles

Angular Subangular Subrounded (Rounded) N/A

Shape of Coarse-Grained Particles

Flat Elongated Flat and Elongated (N/A)

Cementation of Coarse-Grained Particles

(Weak) Moderate Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)

<1 FINE TO COARSE GRAVEL

Maximum Particle Size

(Fine Sand) Medium Sand Coarse Sand Gravel (Size)____ (Cobble) or Boulder (Size) 15CM

11-28-06 DMC

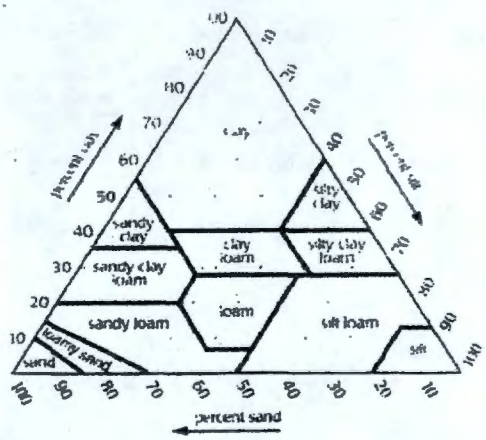
100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/16/06
Time: 13:53
Site: 4A
Weather Conditions: SUNNY, CLEAR, LIGHT WIND

Soil

Muck (Organic)	Peat (Organic)	
Sand	Loamy Sand	Sandy Loam
Silty Loam	Loam	Sandy Clay Loam
Silty Clay Loam	Clay Loam	Sandy Clay
Silty Clay	Clay	N/A

Textural Triangle



Color (Moist): 2.5Y 4/2

Moisture Condition
Dry | Moist | Wet

Consistency
Very Soft | Soft | Firm | Hard | Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) <1
Cobbles (%) <1
Boulders (%) 7

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded | Poorly Graded | N/A

Angularity of Coarse-Grained Particles
Angular | Subangular | Subrounded | Rounded | N/A

Shape of Coarse-Grained Particles
Flat | Elongated | Flat and Elongated | N/A

Cementation of Coarse-Grained Particles
Weak | Moderate | Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)
<1 COARSE GRAVEL

Maximum Particle Size
Fine Sand | Medium Sand | Coarse Sand | Gravel (Size)____ | Cobble or Boulder (Size) 60CM

4A 12/8/06 DMW

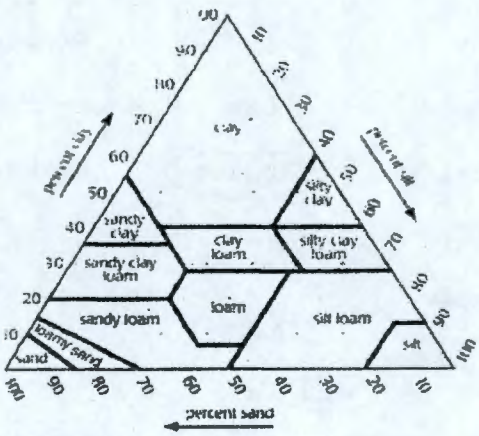
100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/9/06
Time: 15:25
Site: SC
Weather Conditions: PARTLY CLOUDY

Soil

Muck (Organic)	Peat (Organic)	
Sand	Loamy Sand	Sandy Loam
Silty Loam	Loam	Sandy Clay Loam
Silty Clay Loam	Clay Loam	Sandy Clay
Silty Clay	Clay	N/A

Textural Triangle



Color (Moist): 2.5Y 4/2

Moisture Condition
Dry | Moist | Wet

Consistency
Very Soft | Soft | Firm | Hard | Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 35
Cobbles (%) 5
Boulders (%) 1

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded | Poorly Graded | N/A

Angularity of Coarse-Grained Particles
Angular | Subangular | Subrounded | Rounded | N/A

Shape of Coarse-Grained Particles
Flat | Elongated | Flat and Elongated | N/A

Cementation of Coarse-Grained Particles
Weak | Moderate | Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)
35% FINE TO COARSE GRAVEL

Maximum Particle Size
Fine Sand | Medium Sand | Coarse Sand | Gravel (Size)____ | Cobble or Boulder (Size) 90 CM

100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/15/06
Time: 10:49
Site: REF 1
Weather Conditions: CLOUDY & WINDY

Soil

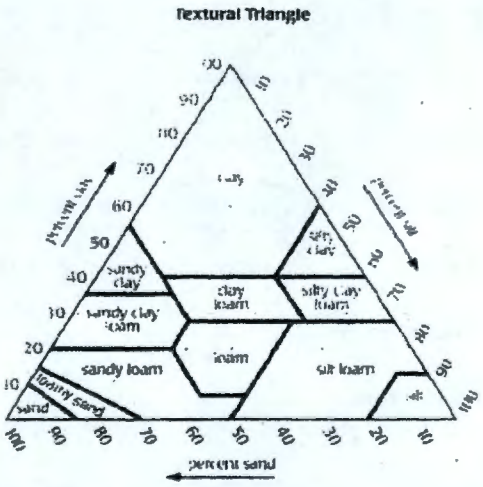
Muck (Organic) Peat (Organic)

Sand Loamy Sand Sandy Loam

Silty Loam Loam Sandy Clay Loam

Silty Clay Loam Clay Loam Sandy Clay

Silty Clay Clay N/A



Color (Moist): 2.5Y 3/2

Moisture Condition
Dry Moist Wet

Consistency
Very Soft Soft Firm Hard Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 10
Cobbles (%) 5
Boulders (%) <1

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded Poorly Graded N/A

Angularity of Coarse-Grained Particles
Angular Subangular Subrounded Rounded N/A

Shape of Coarse-Grained Particles
Flat Elongated Flat and Elongated N/A

Cementation of Coarse-Grained Particles
Weak Moderate Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)

Maximum Particle Size
Fine Sand Medium Sand Coarse Sand Gravel (Size)____ Cobble or Boulder (Size) 30cm

QA 11-28-06

100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/15/06
Time: 11:41
Site: REF 2
Weather Conditions: CLOUDY & WINDY

Soil

Muck (Organic) Peat (Organic)

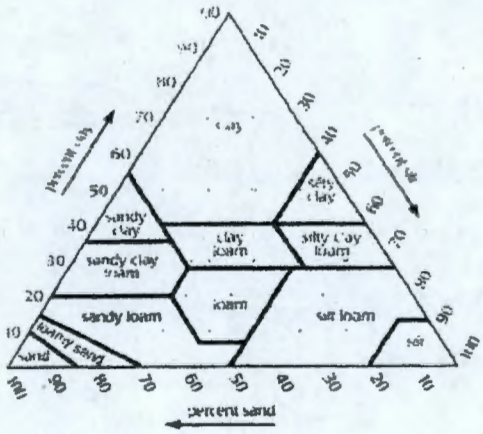
Sand Loamy Sand Sandy Loam

Silty Loam Loam Sandy Clay Loam

Silty Clay Loam (Clay Loam) Sandy Clay

Silty Clay Clay N/A

Textural Triangle



Color (Moist): 5Y 4/1

Moisture Condition
Dry (Moist) Wet

Consistency
Very Soft (Soft) Firm Hard Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 10
Cobbles (%) 15
Boulders (%) 5

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded (Poorly Graded) N/A

Angularity of Coarse-Grained Particles
(Angular) Subangular Subrounded Rounded N/A

Shape of Coarse-Grained Particles
Flat Elongated Flat and Elongated (N/A)

Cementation of Coarse-Grained Particles
(Weak) Moderate Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)
10% COARSE GRAVEL

Maximum Particle Size
Fine Sand Medium Sand Coarse Sand Gravel (Size)____ Cobble or (Boulder) (Size) 100 CM

QA 11/28/06 SMD

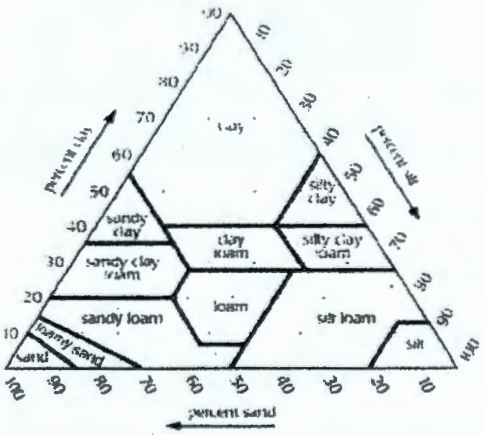
100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/9/06
Time: 11:18
Site: 2A
Weather Conditions: OVERCAST

Soil

Muck (Organic)	Peat (Organic)	
Sand	Loamy Sand	Sandy Loam
Silty Loam	Loam	Sandy Clay Loam
Silty Clay Loam	Clay Loam	Sandy Clay
Silty Clay	Clay	N/A

Textural Triangle



Color (Moist): 2.5Y 3/2

Moisture Condition
Dry | Moist | Wet

Consistency
Very Soft | Soft | Firm | Hard | Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 7
Cobbles (%) 3
Boulders (%) 1

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded | Poorly Graded | N/A

Angularity of Coarse-Grained Particles
Angular | Subangular | Subrounded | Rounded | N/A

Shape of Coarse-Grained Particles
Flat | Elongated | Flat and Elongated | N/A

Cementation of Coarse-Grained Particles
Weak | Moderate | Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)
7% FINE TO COARSE GRAVEL

Maximum Particle Size
Fine Sand | Medium Sand | Coarse Sand | Gravel (Size)____ | Cobble or Boulder (Size) 70 CM

100/300 Risk Assessment Soil Description (Visual Estimate)

Date: 11/8/06
Time: 9:46
Site: 2C
Weather Conditions: SUNNY & CLEAR

Soil

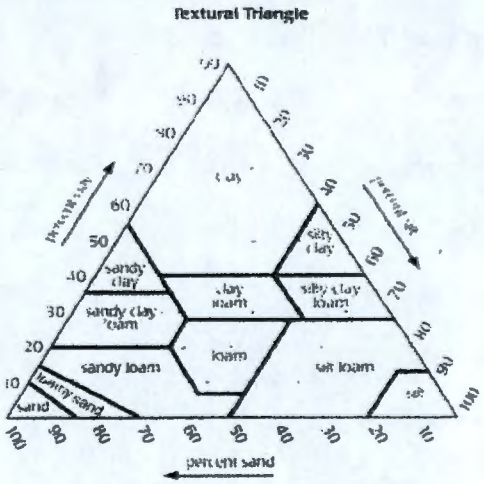
Muck (Organic) Peat (Organic)

Sand Loamy Sand Sandy Loam

Silty Loam Loam Sandy Clay Loam

Silty Clay Loam Clay Loam Sandy Clay

Silty Clay (Clay) N/A



Color (Moist): 2.5Y 3/2

Moisture Condition
Dry (Moist) Wet

Consistency
Very Soft (Soft) Firm Hard Very Hard

Comments (Odors, etc.):

Rock Fragments
Gravel (%) 1
Cobbles (%) 5
Boulders (%) 5

Gradation of Coarse-Grained Particles (Coarse Sand, Gravel, Cobbles, and Boulders)
Well-Graded (Poorly Graded) N/A

Angularity of Coarse-Grained Particles
Angular Subangular Subrounded (Rounded) N/A

Shape of Coarse-Grained Particles
Flat Elongated Flat and Elongated (N/A)

Cementation of Coarse-Grained Particles
(Weak) Moderate Strong

Range of Particle Sizes for Gravel and Sand Components (For example; about 20% fine to coarse gravel)
1% FINE TO COARSE GRAVEL

Maximum Particle Size
Fine Sand Medium Sand Coarse Sand Gravel (Size)____ Cobble or (Boulder) (Size) 80 cm

QA 11-28-06 SMD

APPENDIX D

THREATENED AND ENDANGERED SPECIES VEGETATION REPORT

RARE PLANT INVENTORY
RCBRA RIPARIAN SITES
2006

SUBMITTED BY
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DECEMBER 14, 2006

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INTRODUCTION

This rare plant inventory is part of a multi-disciplinary study to address the potential impact of past management of the Hanford Nuclear Reservation on the flora and fauna of the site, and to assess whether the remediation activities have achieved the objective of restoring the landscape to pre-Hanford Reservation conditions. Representative plots were established within the remediated area and sampled intensively; this rare plant survey was part of that sampling under contract with Environmental Assessment Services. Eight riparian plots (RCBRA 2a, 2c, 2f, 2j, 2l, 3b, 4a and 5c) were surveyed for this study; reference plots were not included in this inventory.

Landscape description

Vegetation along the Hanford Reach riparian zone was described by Salstrom and Easterly (1995)[1]. The most important potential rare plant habitats in the riparian sites include cobble with gradual slopes and backwater areas with mud, in addition to more general riparian habitat.

On gravel and cobble along the riparian area, the vegetation occurs as semi-recognizable zones of associated species. Widths of the vegetation zones are directly related to the slope of the riparian zone, which compresses or expands each particular zone. In turn, the profile of the riparian zone can relate to the position of the shoreline relative to the trajectory of the river flow, where steep-sided riparian areas with compressed vegetation zones are located along channelized lateral flow. Broad riparian areas and corresponding broad vegetation zones are located in association with point bars and the multiple bank-attached island bar complexes found within the Hanford reach.

Backwater areas and sloughs often form in the lee of features such as point bars, cobble bars, or bank-attached island-bar complexes. The emergent wetlands that occur in these areas are scattered throughout the length of the reach, occurring anywhere silt has been deposited and range in size from less than a meter square to over 20 acres (Salstrom and Easterly 1995). These systems are rich in species diversity, both within and between sites (Salstrom and Easterly 1995, Caplow and Beck 1995, Wilderman 1994). The emergent wetlands are primarily in sites in which silt is being periodically deposited, which may occur as a mud on cobble or other substrate. The sites are transitory in some areas, appearing in somewhat different settings from year to year depending on the flow volumes of the river, which is manipulated by upriver dam management.

METHODS

Rare plant species with the potential to occur in the study areas were identified by reviewing known rare species, assessing potential habitat of the landscape and culling through rare species known in the Columbia Basin for those with similar habitat requirements. The highest potential habitats for rare plants along the Hanford Reach are gravel-cobble with gradual slopes and backwater areas with mud. Species likely to occur in the study area are listed in Table 1. Field surveys were done November 6-14, 2006.

[1] The initial study, vegetation characterization and map of the "south" shore and islands, was done during 1995 for The Nature Conservancy's Biodiversity Inventory project. We revisited the project during 1996 and 1997 and mapped the north shore and more finely remapped some of the large point bar and slough complexes on the south shore. Battelle PNNL purchased the results of that revised mapping effort in 2001.

Table 1. Species with potential to occur in remediation site study plots.

Scientific Name	Common Name	State/ Federal Status[2]	Known From Hanford Reach?	Annual/ Perennial	Potential habitat within study area
Ammania robusta	Grand Redstem	T	Y	A	Riparian emergent wetland.
Artemisia campestris ssp. borealis var. *wormskioldii*	Northern Wormwood	E/C	N	P	Riparian gravel and cobble.
Centunculus minimus	Chaffweed	R1	Y	A	Emergent wetlands.
Hierochloe odorata	Common Northern Sweet Grass	R1	N	P	Streambanks
Hypericum majus	Canadian St. John's-wort	S	Y	P	Seasonally submerged riparian sites.
Juncus uncialis	Inch-high Rush	S	N	A	Moist areas, vernal pools.
Lipocarpha aristulata	Awned Halfchaff Sedge	T	Y	A	Riparian emergent wetland
Monolepis pusilla	Red Poverty-weed	T	N	A	Primarily alkaline or saline soil.
Polyctenium fremontii var. fremontii	Fremont's Combleaf	T	N		Gravelly clay, damp or wet sites, sagebrush desert
Polygonum austiniae	Austin's Knotweed T	T	N	A	Dry to moist flats or banks.
Rorippa columbiae	Persistentsepal Yellowcress	E/SC	Y	P	Wet sites; along the Columbia River in gravel and cobble.
Rotala ramosior	Lowland Toothcup	T	Y	A	Riparian emergent wetland.
Spartina pectinata	Prairie Cordgrass	S	N	P	Riparian

[2] SC: Federal Species of Concern, unofficial status, species appears in jeopardy, but insufficient information to support listing.
E=Endangered in Washington; in danger of becoming extinct in Washington.
T= Threatened in Washington; likely to become endangered in state.
S=Sensitive in Washington, vulnerable or declining, could become threatened or endangered in state.
R=Species status in review.

RESULTS

Rare plant findings are presented in Table 2.

Table 2. Rare plant findings at RCBRA riparian sites, November 2006.

Species	2A	2C	2F	2J	2L	3B	4A	5C
Ammania robusta						Y		
Centunculus minimus	Y					Y		
Lipocarpha aristulata	Y		Y		Y	Y		
Rotala ramosior	Y		Y	Y	Y	Y		Y

Occurrence information forms (Washington Natural Heritage Program) for rare species found within the study sites are attached as Appendix A[3]. An assessment of habitat suitability of each site for the rare species considered as potentially occurring in the riparian study area is presented in Appendix B. A list of all species found in the riparian sites is presented in Appendix C.

The occurrences of *Rotala ramosior* at sites 2l and 3b are large and extensive within the abundant emergent wetland habitat present within the study plots, as is the occurrence of *Lipocarpha aristulata* at Site 3b. Those same species at sites 2f, and *R. ramosior* 5c, were found relatively high in the riparian profile, an atypical habitat setting for those species, which are more usually known from emergent wetlands lower in the riparian profile (see "Site Descriptions" below, and "Rare Plant Occurrence Records", Appendix A).

Ammania robusta and *Centunculus minimus* were represented at Site 3b by only one plant each. *Centunculus minimus* at Site 2A was abundant (hundreds of plants).

Although the rare taxa already known from the Hanford Reach were mostly identifiable during the fieldwork, the timing of the field visits was later in the year than optimal, especially after heavy frosts during early November. In particular, an important potential taxon, *Artemisia campestris* ssp. *borealis* var. *wormskioldii,* was likely indistinguishable from the more common variety *scouleriana.* In addition, although degraded individuals of *Ammania robusta* and *Centunculus minimus* were found during the inventory, it is likely that the individuals/sites with earlier phenology were missed. *A. robusta* was not seen at one site from which it was previously known (2j; WNHP 2006), and was found in one previously unknown site (3b). *C. minimus* was found at one known site (2a) and one new site (3b; WNHP 2006).

In addition, flooding patterns during 2006 may have caused mud to be repositioned and bury existing vegetation in some areas (particularly at portions of sites 2j and 3b), creating an early seral stage at those sites. However, periodic flooding may be important to maintaining the diversity of vegetation at these sites by precluding or derailing invasion by other species, particularly *Phalaris arundinacea* (reed canarygrass; personal observation 1997).

Several occurrences were found of a species of *Hypericum* that did not appear to fit descriptions of known species, although it did share some features with *Hypericum majus*, a WNHP sensitive

[3] For record-keeping purposes, occurrences of most rare plant species along the Hanford Reach riparian are considered subpopulations of single occurrences in the WNHP Information System. Thus, occurrences reported here are treated as subpopulations.

species. However, some of the key characters needed to identify the taxon were not present due to the late survey date. Specimens will be compared to herbarium collections of the genus; results will be submitted when they become available.

Some of the sites were near known occurrences of *Rorippa columbiae;* that taxon was not found within the study sites, probably due to lack of appropriate habitat. The species was identifiable elsewhere during the inventory.

SITE DESCRIPTIONS

Descriptions of habitats present in each study site are presented below; slope is referred to in three general classes: low (<5 degrees), medium (between 3-8 degrees) and steep (>8 degrees).

Riparian 2a: The shore and upland transition zone has a low slope, creating a relatively broad riparian zone. The site is located above Coyote Rapids, and the substrate consists of gravel and cobble lag, which sometimes is overlain by mud in backwater depositional settings. Coyote willow is located along the upslope margin of this riparian site. Along much of the site is a longitudinal gravel bar, a small point-bar and associated fine soil deposited in a downstream backwater zone, which created abundant habitat for the suite of rare plants that occurs in emergent wetlands.

Riparian 2c: The shore and upland transition zone has a low slope, which creates a relatively broad riparian zone. The site is located just upstream from Coyote Rapids, and the substrate consists of a gravel-cobble lag. Near Stake A is a secondary channel/bar complex consisting of large cobble boulders. A large zone of pooled water is contained between this point bar and Stake A along the shore, downstream from which it appears to provide a secondary river channel during periods of flooding. *Morus alba* dominates a band of woody vegetation along a portion of the upslope margin of this riparian site, especially between Stakes A and B.

The area below these shrubs and above the zone of daily inundation is dominated by *Phalaris arundinacea*, below which is unconsolidated gravel and cobble with low cover of vegetation.

Riparian 2f: The middle and lower riparian zone at this site is medium to steep. There is little sedimentation in the active riparian zone due to exposure to water flow, and the substrate is mostly gravel to large cobble. However, in the upper riparian zone is a series of bench terraces comprised of cobble overlain by a bench of fine soil, the latter of which was probably deposited during historic flood events. The margin of the fine sediments on the cobble terrace is relatively abrupt in most places, with an eroded riser 1-3 feet in some areas. *Lipocarpha aristulata* plants occur along the length of the study site along this sediment margin, and occasionally in patches of sediment on the cobble below, in a band approximately 0.5-3 meters wide. In addition, one patch of *Rotala ramosior* plants was located in this zone near the downstream stake (A).

This is an atypical habitat setting for either of those species, which are more usually known from emergent wetlands lower in the current riparian profile. Before upriver dams were constructed, the transition of the riparian margins may have been more gradual, and the fines-textured deposits may have occupied a larger footprint, tapering more gradually into the lower riparian zone.

The moderately to steep sloped series of terrace benches described above culminates in a relatively flat terrace (Fecht et. al.'s 2004 fifth terrace) located above the current riparian zone. On this upper terrace are signs of historic disturbance (farming, Hanford activities, etc.). The

lower margin of these remaining, uneroded terrace fine soils corresponds to the top margin of the riparian zone.

Riparian 2j: This site is located at the White Bluffs Slough within the channel portion of this large bank-attached island-bar complex (Fecht et al. 2004). The site has a low sloped, broad riparian zone, above which a relatively steep bank leads to a flat upland terrace. The substrate in the lower portion of the riparian zone is gravel and cobble overlain by a patina of freshly deposited mud, with low cover of vegetation. Higher in the profile, especially between Stakes B and C, the mud becomes deeper, although it is still apparently being redeposited after being stripped during recent flood events. In the riparian zone between the shrubs on the terrace bank and the zone that is inundated daily is a thick sward of the rhizomatous *Phalaris arundinacea*, whose thick root mat has apparently retained much of the accumulating fine soils present within the slough system. The bank slope is dominated by *Morus alba* (white mulberry), along with other woody vegetation[4].

Heavy spring runoff in 2006 activated this backwater setting into a secondary flow channel (chute), and most of the soils that typify the emergent wetland habitat expected at this setting (below the *Phalaris arundinacea* root mat) are still open mud, as described above. This early seral state appears to be perpetuated by the daily inundation due to flow management by upstream dams. As a result, this know site for *Ammania robusta* and *Rotala ramosior* had limited emergent wetland habitat during the fall of 2006, with only widely scattered *R. ramosior* observed along the narrow margin at the low edge of the *P. arundinacea* zone where it met the open mud deposition zone. Even this zone was flooded daily, and between our two visits to the site (November 6 and 8) changes in mud depth and movement was very apparent.

This sample site is located near a Bald Eagle night roost and attempted nest site; it was closed to further visits after November 8 after eagles were observed using the roosting trees.

Riparian 2l: This site is located within a "secondary channelway that separates the right riverbank from the F-Slough island-bar complex [near river mile 366.5]" (Fecht et al. 2004). The site has a low-sloped, broad riparian zone, above which a relatively steep bank that leads to a flat upland terrace.

The riparian zone at this point expands in width due to the historic meandering of this secondary channelway, creating a broad lower terrace above the current water channel located on the east side of the study site. This lower terrace appears to be regularly inundated by sediment rich floodwaters, apparently at least once during the floods of 2006. The lower portion of the flood zone is the portion of the study area where *Rotala ramosior* was seen in high concentrations. Additional widespread *Rotala ramosior* was also observed on much of the western and northern portions of the study site, as well as on a point of sediments associated with the current water channel along the east side of the study site. A small population of *Lipocarpha aristulata* was observed where the lower terrace begins its rise up the bank of the upland terrace.

Riparian 3b: This site is located on the island portion of the Hanford Slough, a large bank-attached island-bar complex (Fecht et al. 2004). The site has a low sloped, broad riparian zone that occupies a backwater setting during all but the largest current flood events. The substrate in the lower portion of the riparian zone has gravel and cobble overlain by a patina of mud, with low

[4] A porcupine was observed in one of the larger trees near Stake C on both November 6 and 8.

Washington Natural Heritage Program
Rare Plant Sighting Form

Taxon Name: ***Lipocarpha aristulata***

Are you confident of the identification? **Yes**

Survey Site Name: **Hanford Reach (Sites 2a, 2f, 2l, 3b)**

Surveyor's Name/Phone/Email: **Debra Salstrom and Richard Easterly/360-481-1786 /SEEbotanical@comcast.net**

Survey Dates: **2006-11-6 through 14** (yr-mo-day) County: **Benton**

Quad Name:

Township: Range: Section(s):1/4 of 1/4:

2a: T13N R25E S02 SE1/4 of SE1/4
2f: T14N R26E S12 NW1/4 of SW1/4
2l: T13N R27E S03 NE1/4 of SW1/4 and SE1/4 of NW1/4
3b: T13N R27E S23 NE1/2 of SE1/4

Directions to site:

Site 2a: From Route 11A, drive toward the Yakima Barricade. At about 3 miles east of the Yakima Barricade, 5 miles west of the intersection of Route 11A and Route 6, take a right (north) toward the 100-B/C Area on Route 6. Continue for about 3.8 miles to a right turn onto the last paved road. Continue on this road about ¼ until you go through the fence. Just past the fence, take a left (toward the river) and continue for another ¼ mile, until you hit the improved gravel haul road. Cross the road, to the outside of the fence and park; the 2a sampling area is below this point.

Site 2f: Go through 100-H area to road paralleling river. Drive upriver (north) past Bald Eagle Roosting Area closure signs (***only during emergencies! Will need to get pre-approval to enter closed area from November 15 through March 15 for other reasons***) until paved road veers to the left, just before trees. Continue straight on dirt road for ¾ mile to second large grove of trees. The sampling area is below these trees.

Site 2l: From Route 2 North, take the first entrance (F Avenue) to the 100-F Area. Drive north for about 1 mile until the intersection with the 100-F Area perimeter road. Take a right on the perimeter road, toward the river (*the road is partly blocked with an orange "road closed" fence—for emergencies, drive around it on the right side, and notify F-Area field remediation office: Stacey Callison at 778-1821, or Shane Bigham at 528-4503.*) Drive for ¼ mile, until the point where the perimeter road takes a sharp left (90 degree) turn. Turn right instead at this point (downriver), onto the dirt road. Continue down this road for approximately ¾ mile; the riparian plot will be on the left. (***Enter Bald Eagle Roosting Closure Area only during emergencies! Will need to get pre-approval to enter closed area from November 15 through March 15 for other reasons***)

Site 2m: From the intersection of Routes 11A and 2 North (Intersection is at Hanford Townsite), go north on Route 2 North for about 2.9 miles; take the dirt road on your right (through the cut bank). The turn is just before the mile post marker 3. Continue on this dirt road for about 1 1/3 miles. Take a right-hand turn onto another dirt road leading to the river for about 100 meters; the

sampling area is the riparian area below the road. (***Enter Bald Eagle Roosting Closure Area only during emergencies! Will need to get pre-approval to enter closed area from November 15 through March 15 for other reasons***)

Site 3b: From the intersection of Routes 11A and 2 North (Intersection is at Hanford Townsite), go north on Route 2 North for about 1 ¼ miles until road bends slightly to the left. At this turn, make a very sharp right hand turn onto the old paved road leading back into the Hanford Townsite. Continue south for ½ mile; take a sharp left turn on a dirt/gravel road toward the south and drive to the slough. The sampling area is in the slough at this point.

Mapping:
1. I used GPS to map the population: **Yes**
Description of what coordinates represent: **Extent of occurrence within 200 meter plots in November, 2006.**
GPS accuracy: **Corrected to <10m**
GPS datum: **NAD 1983, Zone 11 (WAAS enabled)**
GPS coordinates:

2a: (Polygon Centroid) 296767.4; 5168285
2f: (Polygon Centroid) 308649.6; 5176797
(Polygon Centroid) 308758.1; 5176750
2l: Point: 314461.7; 5168177
3b:(Polygon Centroid) 316893; 5163188

To the best of my knowledge, I mapped the entire extent of this population **No. Survey was done within plot boundaries (200m). Although surveyed thoroughly during inventory, because survey was done late in the year the taxon may be even more extensive within the plots earlier in the year or different years (due to differing weather and hydrologic regimes).**
Is a revisit needed?
Ownership (if known): **USDOE (in transition to management by USFWS—Hanford Reach National Monument).**

Population Size (# of individuals or ramets) or estimate:

2a: 50-100 plants.
2f: More than a thousand plants.
2l: Patch of 20 plants.
3b: Thousands of plants.

Population (EO) Data (include population vigor, microhabitat, phenology, etc):

2a: In fruit. In small, intermittent backwater areas.
2f: In fruit. In strip 1 (2) meters wide in upper profile of riparian zone. Above vegetated zone with Poa compressa, and below cut slope erosion of Sporobolus.
2l: In fruit. One patch.
3b: In fruit. Very vigorous, codominant with *Rotala ramosior* in portions of the occurrence.

Plant Association (include author, citation, or classification, e.g. Daubenmire): **Nonpersisent riverine emergent wetland (Salstrom and Easterly 1995)**

Associated Species

2a

Lichen/moss layer:
Herb layer: ***Rotala ramosior, Plantago lanceolata, Cyperus bipartitus, Coreopsis atkinsoniana, Apocynum cannabium, Poa compressa, Hypericum* sp., *Centunculus minimus, Eleocharis* sp.**
Shrub layer(s):
Tree layer:

2f
Lichen/moss layer:
Herb layer: ***Cyperus aristatus* 10%, *Plantago lanceolata* 3%, *Sporobolus cryptandrus* 3%, *Bromus tectorum, Centaurea diffusa,***
Shrub layer(s):
Tree layer:

2l:
Lichen/moss layer: **0-10%**
Herb layer: ***Agrostis* sp., *Coreopsis tinctoria* var. *atkinsoniana* 0-30%, *Rumex crispus* 3%, *Juncus* spp. 20%; *Cyperus strigosus* 3%, *Panicum* sp. 10-30, Graminoid 10, Unknown forb (veg) 10, *Eleocharis englemanii* 3-10%, *Phalaris arundinacea, Aster spp. 0-10%, Poa compressa 20-40, Equisetum sp., Ludwegia palustris, Pascopyrum smithii, Marsillea vestita, Distichlis spicata***
Shrub layer(s): ***Euthamia* spp. 0-20%.**
Tree layer:

3b:
Lichen/moss layer: **0-20%**
Herb layer: ***Eleocharis englemanii, Juncus* sp, *Aster* sp., *Coreopsis tinctoria* var. *atkinsoniana, Hypericum* sp., *Centunculus minimus, Cyperus bipartitus, Rotala ramosior, Plantago lanceolata, Phalaris arundinacea, Asparagus, Eleocharis palustris, Schoenoplectus* sp., *Helenium autumnale, Eragrostis* sp., *Marsillea vestita, Polygonum* sp., *Poa compressa, Agrostis* sp.**
Shrub layer(s): ***Artemisia ludoviciana***
Tree layer:

General Description (include description of landscape, surrounding plant communities, land forms, land use, etc.):

2a: Along much of the site is a longitudinal gravel bar, a small point-bar and associated fine soil deposited in a downstream backwater zone, which created abundant habitat for the suite of rare plants that occurs in emergent wetlands.

2f: The middle and lower riparian zone at this site is medium to steep. There is little sedimentation in the active riparian zone due to exposure to water flow, and the substrate is mostly gravel to large cobble. However, in the upper riparian zone is a series of bench terraces comprised of cobble overlain by a bench of fine soil, the latter of which was probably deposited during historic flood events. The margin of the fine sediments on the cobble terrace is relatively abrupt in most places, with an eroded riser 1-3 feet in some areas. *Lipocarpha aristulata* plants occur along the length of the study site along this sediment margin, and occasionally in patches of sediment on the cobble below, in a band approximately 0.5-3 meters wide. In

addition, one patch of *Rotala ramosior* plants was located in this zone near the downstream stake (A).

This is an atypical habitat setting for either of those species, which are more usually known from emergent wetlands lower in the current riparian profile.

The moderately to steep sloped series of terrace benches described above culminates in a relatively flat terrace (Fecht et. al.'s 2004 fifth terrace) located above the current riparian zone. On this upper terrace are signs of historic disturbance (farming, Hanford activities, etc.). The lower margin of these remaining, uneroded terrace fine soils corresponds to the top margin of the riparian zone.

2l: This site is located within a secondary channelway that separates the right riverbank from the F-Slough island-bar complex. The occurrence is located along the current riparian edge and on low microsites on the flood terrace.

3b: This site is in a low upland to the riverside of Hanford Slough. Substrate is mud over cobble on undulating topography.

Minimum elevation (ft.): Maximum elevation (ft.):
Size (acres): _____ Aspect: Slope: **0-7 degrees**
Photo taken? **Yes; see Appendix D.**

Management Comments (exotics, roads, shape/size, position in landscape, hydrology, adjacent land use, cumulative effects, etc.): **The species appears in two settings within the riparian profile. The typical site is in emergent wetland communities located low in the river profile, which under current river management are inundated frequently (daily) during the growing season. The second is much higher in the profile, above the zone of daily inundation, usually in zone with little vegetative cover due to either erosion or sediment deposition.**

Protection Comments (legal actions/steps/strategies needed to secure protection for the site): **None at this time.**

Additional Comments (discrepancies, general observations, etc.): **The primary threat to species at the site is wide fluctuation in daily water flow of the river during the growing season. The site is within a plot being intensively studied (multi-discipline) as part of an assessment of remediation of Hanford Site environment.**

Washington Natural Heritage Program
Rare Plant Sighting Form

Taxon Name: ***Rotala ramosior***

Are you confident of the identification? **Yes**

Survey Site Name: **Hanford Reach (2a, 2f, 2j, 2l, 3b, 5c)**

Surveyor's Name/Phone/Email: **Debra Salstrom and Richard Easterly/360-481-1786 /SEEbotanical@comcast.net**

Survey Date: **2006-11-06 through 14** (yr-mo-day) County: **Benton**

Quad Name:

Township: Range:Section(s):1/4 of 1/4:

2a: T13N R25E S02 SE1/4 of SE1/4
2f: T14N R26E S12 NW1/4 of SW1/4
2j: T14N R27E S20 SE1/4 of SW1/4 and SW1/4 of SE1/4
2l: T13N R27E S03 NE1/4 of SW1/4 and SE1/4 of NW1/4
3b: T13N R27E S23 NE1/2 of SE1/4
5c: T11N R28E S11 SE1/4 of SW1/4

Directions to site:

Site 2a: From Route 11A, drive toward the Yakima Barricade. At about 3 miles east of the Yakima Barricade, 5 miles west of the intersection of Route 11A and Route 6, take a right (north) toward the 100-B/C Area on Route 6. Continue for about 3.8 miles to a right turn onto the last paved road. Continue on this road about ¼ until you go through the fence. Just past the fence, take a left (toward the river) and continue for another ¼ mile, until you hit the improved gravel haul road. Cross the road, to the outside of the fence and park; the 2a sampling area is below this point.

Site 2f: Go through 100-H area to road paralleling river. Drive upriver (north) past Bald Eagle Roosting Area closure signs (***only during emergencies! Will need to get pre-approval to enter closed area from November 15 through March 15 for other reasons***) until paved road veers to the left, just before trees. Continue straight on dirt road for ¾ mile to second large grove of trees. The sampling area is below these trees.

Site 2j: From Route 2, Turn east at the old White Bluffs bank building (the building with the side spalling off), toward the river. Drive past the Bald Eagle Nesting Site closure sign (***go past closure sign only during emergencies—do not violate closure just to observe work or site***!), 1¼ miles to the boat launch, at the top of the launch take the dirt road to the left. Drive up this road about ¼ mile; the sampling area is on the right.

Site 2l: From Route 2 North, take the first entrance (F Avenue) to the 100-F Area. Drive north for about 1 mile until the intersection with the 100-F Area perimeter road. Take a right on the perimeter road, toward the river (*the road is partly blocked with an orange 'road closed" fence—for emergencies, drive around it on the right side, and notify F-Area field remediation office: Stacey Callison at 778-1821, or Shane Bigham at 528-4503.*) Drive for ¼ mile, until the point where the perimeter road takes a sharp left (90 degree) turn. Turn right instead at this point (downriver), onto the dirt road. Continue down this road for approximately ¾ mile; the riparian

plot will be on the left. (***Enter Bald Eagle Roosting Closure Area only during emergencies! Will need to get pre-approval to enter closed area from November 15 through March 15 for other reasons***)

Site 3b: From the intersection of Routes 11A and 2 North (Intersection is at Hanford Townsite), go north on Route 2 North for about 1 ¼ miles until road bends slightly to the left. At this turn, make a very sharp right hand turn onto the old paved road leading back into the Hanford Townsite. Continue south for ½ mile; take a sharp left turn on a dirt/gravel road toward the south and drive to the slough. The sampling area is in the slough at this point.

Site 5c: From Route 4 South, take the southern entrance to the Energy Northwest Reactor at mile post #16. Continue up this road for ¾ miles until it reaches the first powerlines. Take a right onto the improved gravel powerline maintenance road and stay on the gravel and next to the powerlines for 2 ½ miles until it T's at the Benton Substation (there is a small concrete building and enclosed electrical equipment.) Take a right and follow the curving gravel road around the substation until it heads back toward the river- it becomes dirt just past the substation. Follow this for about ½ mile—it ends under the powerlines next to the river. The sampling area is to the right about ½ mile—no dirt roads lead to the sampling area.

Mapping:
1. I used GPS to map the population: **Yes**
Description of what coordinates represent: **Extent of occurrence within 200 meter plots in November, 2006.**
GPS accuracy: **Corrected to <10m**
GPS datum: **NAD 1983, Zone 11 (WAAS enabled)**
GPS coordinates:
2a: (Polygon Centroid) 296767.4; 5168285
2f: (Point) 308788.5; 5176732
2j: (Polygon Centroid) 311668.3; 5172449
2l: (Polygon Centroid) 314425.3; 5168285
3b: (Polygon Centroid) 316893; 5163188
316816.2; 5163116
316889.15163127
5c: (Point) 325699. 6; 5146622
(Point) 325680.9; 5146591
(Polygon Centroid) 325674.8; 5146572
(Polygon Centroid) 325672.9; 5146558

To the best of my knowledge, I mapped the entire extent of this population **No. Survey was done within plot boundaries (200m). Although surveyed thoroughly during inventory, because survey was done late in the year the taxon may be even more extensive within the plots earlier in the year or different years (due to differing weather and hydrologic regimes).**

Is a revisit needed? **No**

Ownership (if known): **USDOE (in transition to management by USFWS—Hanford Reach National Monument).**

Population Size (# of individuals or ramets) or estimate:
2a: A couple hundred plants
2f: Small patch of 5 plants

2l: Thousands
3b: Thousands
5c: Patches of 3-60 plants; 200-300 total.

Population (EO) Data (include population vigor, microhabitat, phenology, etc):

2a: Along much of the site is a longitudinal gravel bar, a small point-bar and associated fine soil deposited in a downstream backwater zone, which created abundant habitat for the suite of rare plants that occurs in emergent wetlands.

2f: The middle and lower riparian zone at this site is medium to steep. There is little sedimentation in the active riparian zone due to exposure to water flow, and the substrate is mostly gravel to large cobble. However, in the upper riparian zone is a series of bench terraces comprised of cobble overlain by a bench of fine soil, the latter of which was probably deposited during historic flood events. The margin of the fine sediments on the cobble terrace is relatively abrupt in most places, with an eroded riser 1-3 feet in some areas.

This is an atypical habitat setting for either of those species, which are more usually known from emergent wetlands lower in the current riparian profile. Before upriver dams were constructed, the transition of the riparian margins may have been more gradual, and the fines-textured deposits may have occupied a larger footprint, tapering more gradually into the lower riparian zone.

2l: Vigorous population; most all plants with several sets of fruits. Mud patina on sand (overbank deposition).

This site is located within a "secondary channelway that separates the right riverbank from the F-Slough island-bar complex [near river mile 366.5]" (Fecht et al. 2004). The site has a low-sloped, broad riparian zone, above which a relatively steep bank that leads to a flat upland terrace.

The riparian zone at this point expands in width due to the historic meandering of this secondary channelway, creating a broad lower terrace above the current water channel located on the east side of the study site. This lower terrace appears to be regularly inundated by sediment rich floodwaters, apparently at least once during the floods of 2006. The lower portion of the flood zone is the portion of the study area where *Rotala ramosior* was seen in high concentrations. Additional widespread *Rotala ramosior* was also observed on much of the eastern and northern portions of the study site, as well as on a point of sediments associated with the current water channel along the east side of the study site.

3b: Extremely vigorous occurrence; in fruit (not dehisced). RORA plants up to 50% cover in local areas. Habitat relatively open.

This site is located on the island portion of the Hanford Slough, a large bank-attached island-bar complex (Fecht et al. 2004). The site has a low sloped, broad riparian zone that occupies a backwater setting during all but the largest current flood events. The substrate in the lower portion of the riparian zone has gravel and cobble overlain by a patina of mud, with low cover of vegetation. Higher in the

profile, the mud and fine soils become deeper and vegetation cover increases with abundant emergent wetland habitat.

5C: Intermittent patches, relatively isolated by inappropriate habitat (too little silt) between. Only a few plants below undercut *Phalaris* zone; several more sizeable in unusual habitat above the *Phalaris* zone in relatively open sites.

The riparian zone at this site is medium to steep. The active riparian zone has a gravel to cobble substrate with little fine sediment. This zone quickly transitions upward into a cobble zone dominated by *Phalaris arundinacea*. The cobble in the upper riparian zone, however, is more open and is overlain by fine soil that was probably deposited during flood events. Patches of *Rotala ramosior* occur in a zone with a medium slope on the fine soil over cobble near the site's center stake (Stake B). Elsewhere in that zone, the *R. ramosior* disappears where the slope becomes steeper and there is higher cover of *P. arundinacea* and *Morus alba*.

Plant Association (include author, citation, or classification, e.g. Daubenmire): **Nonpersisent riverine emergent wetland (Salstrom and Easterly 1995)**

Associated Species

2a
Lichen/moss layer:
Herb layer: ***Plantago lanceolata, Lipocarpha aristulata, Cyperus bipartitus, Coreopsis tinctoria* var. *atkinsoniana, Apocynum cannabium, Poa compressa, Hypericum* sp.**
Shrub layer(s):
Tree layer:

2f
Lichen/moss layer:
Herb layer: ***Phalaris arundinacea, Lipocarpha aristulata,***
Shrub layer(s):
Tree layer:

2l
Lichen/moss layer: **0-10%**
Herb layer: ***Agrostis* sp., *Coreopsis tinctoria* var. *atkinsoniana* 0-30%, *Rumex crispus* 3%, *Juncus* spp. 20%; *Cyperus strigosus* 3%, *Panicum* sp. 10-30, Graminoid 10, Unknown forb (veg) 10, *Eleocharis englemanii* 3-10%, *Phalaris arundinacea, Eleocharis palustris, Cyperus bipartitus. Aster spp. 0-10%, Poa compressa 20-40, Equisetum sp., Ludwegia palustris, Pascopyrum smithii, Marsillea vestita, Distichlis spicata***
Shrub layer(s): ***Euthamia* spp. 0-20%.**
Tree layer:

3b
Lichen/moss layer: **0-20%**

Herb layer: ***Lipocarpha aristulata, Eleocharis englemanii, Juncus* spp, *Carex* spp., *Ludwegia palustre, Hypericum* sp., *Eragrostis* sp., *Polygonum* sp., *Cyperus bipartitus, Marsillea vestita, Poa compressa, Agrostis* sp.,**
Shrub layer(s): ***Artemisia ludoviciana***
Tree layer:

5c
Lichen/moss layer:
Herb layer: **[Lower patches] *Phalaris arundinacea* 30%, *Equisetum variagatum* 10%, *Aster* sp. 3%, *Ludwegia palustre* 3%, *Plantago lanceolata* 3%.[Upper patches] *Sporobolus cryptandrus, Gnaphalium* sp., *Aster* sp., *Cyperus* sp., *Marsillea* sp. *Distichlis spicata***
Shrub layer(s): **[Upper patches] *Artemisia campestris scouleriana,***
Tree layer:

General Description (include description of landscape, surrounding plant communities, land forms, land use, etc.):

2a: Along much of the site is a longitudinal gravel bar, a small point-bar and associated fine soil deposited in a downstream backwater zone, which created abundant habitat for the suite of rare plants that occurs in emergent wetlands. Site is near known occurrence.

2f: The margin of the fine sediments on the cobble terrace is relatively abrupt in most places, with an eroded riser 1-3 feet in some areas. One patch of RORA plants located in this zone near the downstream stake (A).

2l: This site is located within a secondary channelway that separates the right riverbank from the F-Slough island-bar complex. The occurrence is located along the current riparian edge and on low microsites on the adjacent flood terrace.

3b: This site is in a low upland to the riverside of Hanford Slough. Substrate is mud over cobble on undulating topography.

5c: Above the immediate riparian zone on cobble bench associated with fine sediments from an upper terrace.

Minimum elevation (ft.): Maximum elevation (ft.):
Size (acres): Aspect: Slope:
Photo taken? **Yes; see Appendix D.**

Management Comments (exotics, roads, shape/size, position in landscape, hydrology, adjacent land use, cumulative effects, etc.): **The species appears in two settings within the riparian profile. The typical site is in emergent wetland communities located low in the river profile, which under current river management are inundated frequently (daily) during the growing season. The second is much higher in the profile, above the zone of daily inundation, usually in zone with little vegetative cover due to either erosion or historic (fine) sediments or current sediment deposition.**

Protection Comments (legal actions/steps/strategies needed to secure protection for the site):
None at present.

Additional Comments (discrepancies, general observations, etc.): **The primary threat to species at the site is wide fluctuation in daily water flow of the river during the growing season. The site is within a plot (200m) being intensively studied (multi-discipline) as part of an assessment of remediation of Hanford Site environment.**

APPENDIX B. Assessment of habitat suitability of each site for potential species within the riparian sites. H – Apparently suitable habitat present; species not found. N- No apparently suitable habitat present. P – Species present. U—Possible but unlikely.

	RCBRA Sites							
Scientific Name	**2a**	**2c**	**2f**	**2j**	**2l**	**3b**	**4a**	**5c**
Ammania robusta	H	H	U	H	H	P	U	H
Artemisia campestris ssp. *borealis* var. *wormskioldii*	H/U	N	N	N	N	H?	N	N
Centunculus minimus	P	U	U	H	H	P	U	H?
Hierochloe odorata	U	U	U	U	U	H	U	U
Hypericum majus	H	H	U	U	H	H	U	U
Juncus uncialis	U	U	U	U	U	U	U	U
Lipocarpha aristulata	P	H	P	H	P	P	U	H
Polygonum austiniae	U	U	U	U	U	U	U	U
Polyctenium fremontii var. *fremontii*	U	U	U	U	U	U	U	U
Rorippa columbiae	H	H	H	N	N	U	U	H
Rotala ramosior	P	H	P	P	P	P	U	P
Spartina pectinata	U	U	U	U	U	U	U	U

APPENDIX C. Species observed in RCBRA study sites, November 2006.

ITIS (2006)	2a 11/13/06	2c 11/9/06	2j 11/6,8/06	2f 11/8,14/2006	2l 11/9,13/2006	2m 11/7/2006	3b 11/11/06	4a 11/11/06	5c 11/13/06
Achillea millefolium		1		1	1				1
Agrostis spp.		1		1	1		1	1	1
Allium schoenoprasm		1						1	1
Amaranthus blitoides		1		1					1
Ammania robusta						1	1		
Amsinckia spp.				1	1				
Apocynum cannabium	1	1		1		1		1	1
Aristida purpurea var. *longiseta*				1	1	1			
Artemisia campestris ssp. *borealis* var. *scouleriana*	1	1		1	1				1
Artemisia dracunculus	1	1							1
Artemisia ludoviciana var. *ludoviciana*	1	1		1	1	1	1	1	1
Artemisia tridentata					1				
Asclepias speciosa	1	1		1	1			1	
Asparagus officianalis				1	1		1		1
Aster hesperius		1	1		1			1	
Aster spp.	1	1	1	1	1	1	1	1	1
Bidens cernua					1				
Bidens sp.	1					1		1	
Bromus hordeaceus var. *hordeaceus*		1							
Bromus tectorum	1	1		1					1
Cardimine sp.								1	
Carex arthrostachya			1	1		1			
Carex douglasii					1				1
Carex lenticularis								1	
Carex microptera							1		
Carex spp.		1		1		1	1	1	

Carex vulpinoidea					1				
Centauria diffusa	1			1					1
Centunculus minimus	1						1		
cf. *Iris pseudacorus*	1	1		1					1
Chaesysce glyptosperma					1	1			
Cichorium intybus		1		1				1	1
Cirsium sp.				1	1				1
Convolvulus arvensis				1				1	1
Coreopsis tinctoria var. atkinsoniana	1	1		1	1	1	1	1	1
Crypsis alopecuroides									1
Cuscuta pentagona var. *pentagona*									1
Cyperus bipartitus	1		1		1	1	1		1
Cyperus esculentus					1	1			1
Cyperus spp.					1	1			
Cyperus squarrosus				1	1	1	1	1	
Cyperus strigosus	1			1	1	1	1	1	1
Dianthus armeria				1	1				
Dichanthelium acuminatum var. fasciculatum		1					1		
Distichlis spicata				1	1				1
Echinocloa crus-gali		1							
Eleocharis acicularis							1		
Eleocharis englemanii	1		1				1		
Eleocharis palustris		1	1	1	1	1	1	1	1
Eleocharis spp.			1		1				1
Elymus canadensis					1				
Elymus lanceolatus					1				1
Elymus lanceolatus									
Elymus sp.		1		1					
*Epilobium pygmaeum**							1		
Epilobium sp.	1								
Equisetum hyemale ssp. *affine*					1		1		

Equisetum laevigatum		1			1	1	1	1	
Equisetum spp.	1	1		1					
Equisetum variegatum var. *variagatum*		1	1	1	1			1	1
Eragrostis pectinacea							1		
Eragrostis spp.	1					1			
Ericameria nauseosa	1			1					
Eriogonum sp.				1					
Erodium cicutarium					1				
Euthamia occidentalis				1			1		
Euthamia spp.	1	1	1	1	1	1	1	1	1
Galium sp.	1	1		1					
Gnaphalium palustre	1	1	1	1	1	1	1		
Gnaphallium spp.				1		1			1
Gratiola neglecta	1	1			1				
Grindelia columbiana		1		1	1				1
Helenium autumnale	1	1	1	1	1	1	1	1	1
Holosteum umbellatum					1				
Hypericum perfoliatum		1		1	1		1	1	1
Hypericum spp.	1	1	1	1	1	1	1	1	
Juncus balticus					1				1
Juncus bufonius	1				1	1			
Juncus cf. *saximontanus*					1				
Juncus spp.	1	1	1	1	1	1	1	1	1
Lactuca serrioa								1	
Lepidium sp.									1
Leymus/Elymus spp.	1								
Liliopsis occidentalis	1	1		1			1	1	1
Limosella spp.	1					1			1
Lindernia anagalloides	1								
Lindernia dubia					1				
Lindernia sp.						1			1

Lindernia spp.				1					
Lipocarpha aristulata	1			1	1	1	1		
Lomatium sp.				1					
Ludwegia palustris	1		1		1	1	1		1
Lupinus sp.				1	1				1
Lycopus asper				1		1		1	1
Lycopus sp.		1	1		1	1	1		
Marsillea vestita				1	1		1		1
Medicago/Melica		1		1					
Melica sp.	1								
Mentha arvense				1		1	1	1	
Mentha sp.					1	1			1
Mollugo verticellata	1	1	1	1	1	1			1
Morus alba	1	1						1	1
Orobanche ludoviciana				1					
Panicum capillare						1			1
Panicum spp.		1		1	1				
Pascopyrum smithii		1			1			1	1
Pennisteum glaucum		1		1					
Phalaris arundinacea	1	1	1	1	1	1	1	1	1
Plantago lanceolata	1	1	1	1				1	1
Plantago major	1	1	1	1	1	1	1	1	1
Plantago patigonica				1					
Poa bulbosa	1			1					
Poa compressa	1	1	1	1	1	1	1	1	1
Poa compressa					1				
Poa juncifolia				1					
Poa spp.					1				
Polygonum spp.	1	1		1		1	1	1	1
Polypogon monospielensis							1		
Potentilla sp.				1	1	1			
Prunella vulgaris					1				

Rorippa sp.		1	1			1		1	1
Rosa sp.					1				1
Rosaceae				1					
Rotala ramosior	1			1	1	1	1		1
Rumex crispus		1			1			1	
Rumex salicifolia									1
Rumex sp.		1		1	1				
Salix exigua	1	1	1			1	1	1	1
Salsola kali		1		1					
Schoenoplectus acutus					1		1	1	
Schoenoplectus spp.					1				
Schoenoplectus tabernaemontani			1						
Sisymbrium altissimum		1		1					1
Sporobolus asper		1			1				
Sporobolus cryptandrus	1	1		1	1				1
Stellaria sp.				1				1	1
Tragopogon dubius					1				
Trifolium sp.		1		1					1
Verbascum thapsis	1	1	1	1					1
Verbena hastata		1						1	
Veronica sp.		1			1				
Vicia sp.								1	
Vulpia sp.				1					
Xanthium strumarium	1	1		1	1	1		1	1
Unidentifiable Plants									
Leguminoseae (perennial; vegetative)				1					
Graminoid; vegetative.				1					1
Graminoid (Appressed spikelets; one glume much reduced; lemma awned.)				1					
Forb (Opposite leaves; slightly								1	

toothed; branched hairs. Mimulus ringens?)				
Herb(s); vegetative.	1	1	1	1

*The specimen was degraded; it fit the description of *Epilobium pygmaea* except for apparently canescent hairs in the inflorescence (unlike for that species). The plant should be recollected earlier in the year to reassess identity.

APPENDIX D. PHOTOS OF RCBRA RIPARIAN SITES (RARE PLANTS)

Figure D-1. Site RCBRA 2a Rip. Surveyor in habitat for *Centunculus minimus Lipocarpha aristulata* and *Rotala ramosior*. At Stake A, looking upstream.

Figure D-2. Site RCBRA 2a Rip. Surveyor in habitat for *Centunculus minimus Lipocarpha arisulata* and *Rotala ramosior*. Looking downstream.

Figure D-3. Site RCBRA 2a Rip. Habitat for *Centunculus minimus* and *Rotala ramosior*. Looking downstream from near Stake C

Figure D-4. Site RCBRA 2f Rip. Habitat for *Lipocarpha arisulata.* Looking upstream from near Stake B.

Figure D-5. Site RCBRA 2f Rip. Habitat for *Lipocarpha arisulata* and *Rotala ramosior.* Looking downstream to Stake A

Figure D-6. Site RCBRA 2f Rip. Closeup of *Lipocarpha aristulata*

Figure D-7. Site RCBRA 2f Rip. Habitat for *Lipocarpha aristulata.* Looking downstream from near Stake C.

Figure D-8. Site RCBRA 2j Rip. Habitat for *Rotala ramosior*. Looking upstream past Stake A

Figure D-9. Site RCBRA 2j Rip. Habitat for *Rotala ramosior*. Looking downstream past Stake A.

Figure D-10. Site RCBRA 2j Rip. Habitat for *Rotala ramosior*. Looking upstream

Figure 11. Site RCBRA 2l Rip. *Rotala ramosior* habitat. Near Stake B looking towards Stake C.

Figure D-12. Site RCBRA 21 Rip. Habitat for *Rotala ramosior*. Stake B on left in mid distance, very distant surveyor still in habitat at *Lipocarpha aristulata* site.

Figure D-13. Site RCBRA 21 Rip. Habitat for *Rotala ramosior*. Stake B in mid distance, Stake A very distant on right center.

Figure D-14. Site RCBRA 21 Rip. Habitat for *Rotala ramosior*. Along secondary channelway.

Figure 15. Site RCBRA 3b Rip. *Rotala ramosior* habitat. Surveyor at point location with *R. ramosior, Centunculus minimus* and *Ammania robusta.*

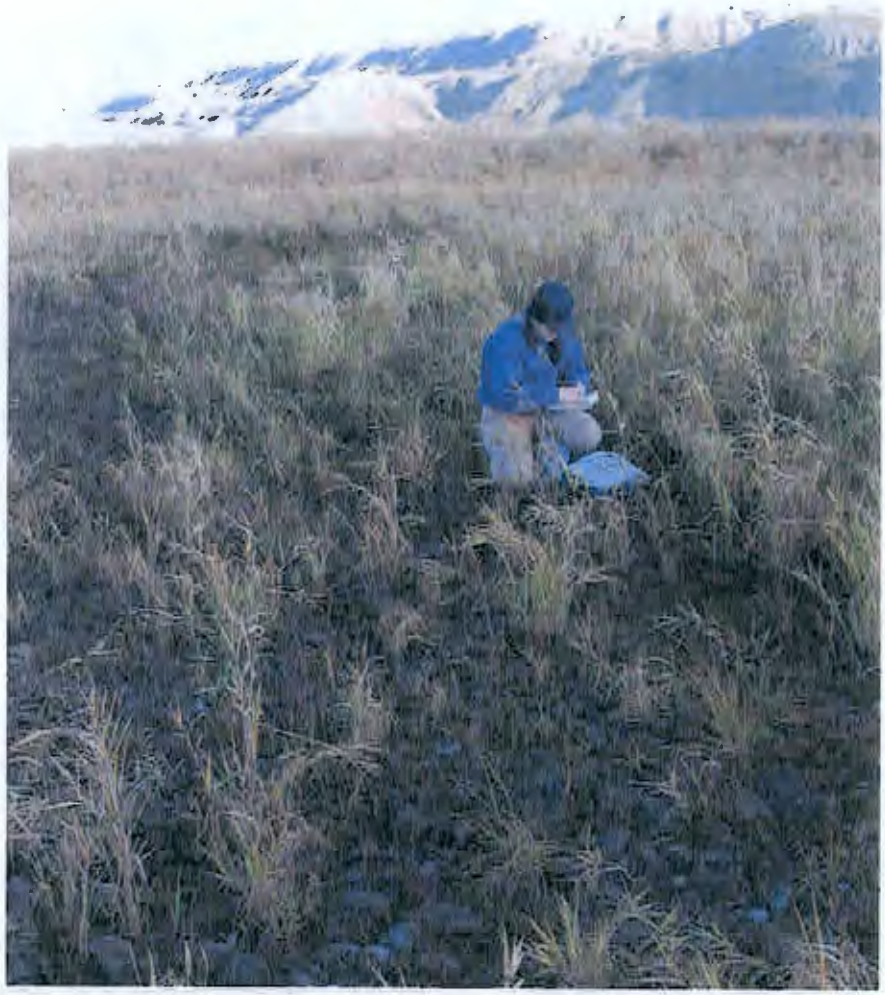


Figure 16. Site RCBRA 3b Rip. Surveyor at point location with *R. ramosior, Centunculus minimus* and *Ammania robusta.*

Figure 17. Site RCBRA 3b Rip. *Rotala ramosior* habitat. Surveyor at point location with *R. ramosior, Centunculus minimus* and *Ammania robusta.*

Figure 18. Site RCBRA 3b Rip. *Rotala ramosior* and *Lipocarpha aristulata* habitat.

Figure 19. Site RCBRA 3b Rip. *Rotala ramosior* and *Lipocarpha aristulata* habitat.

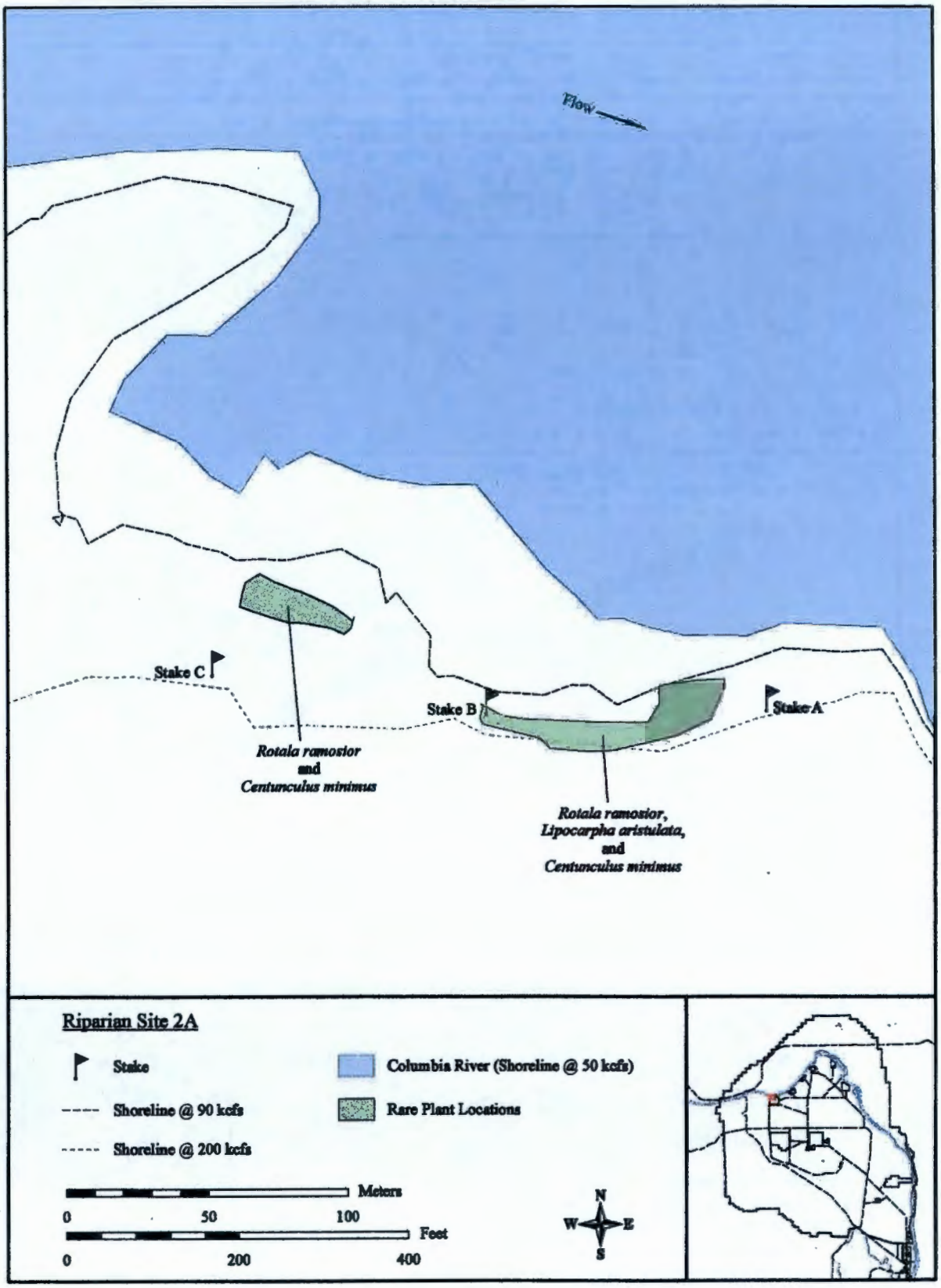
Figure 20. Site RCBRA 3b Rip. *Rotala ramosior* and *Lipocarpha aristulata* habitat.

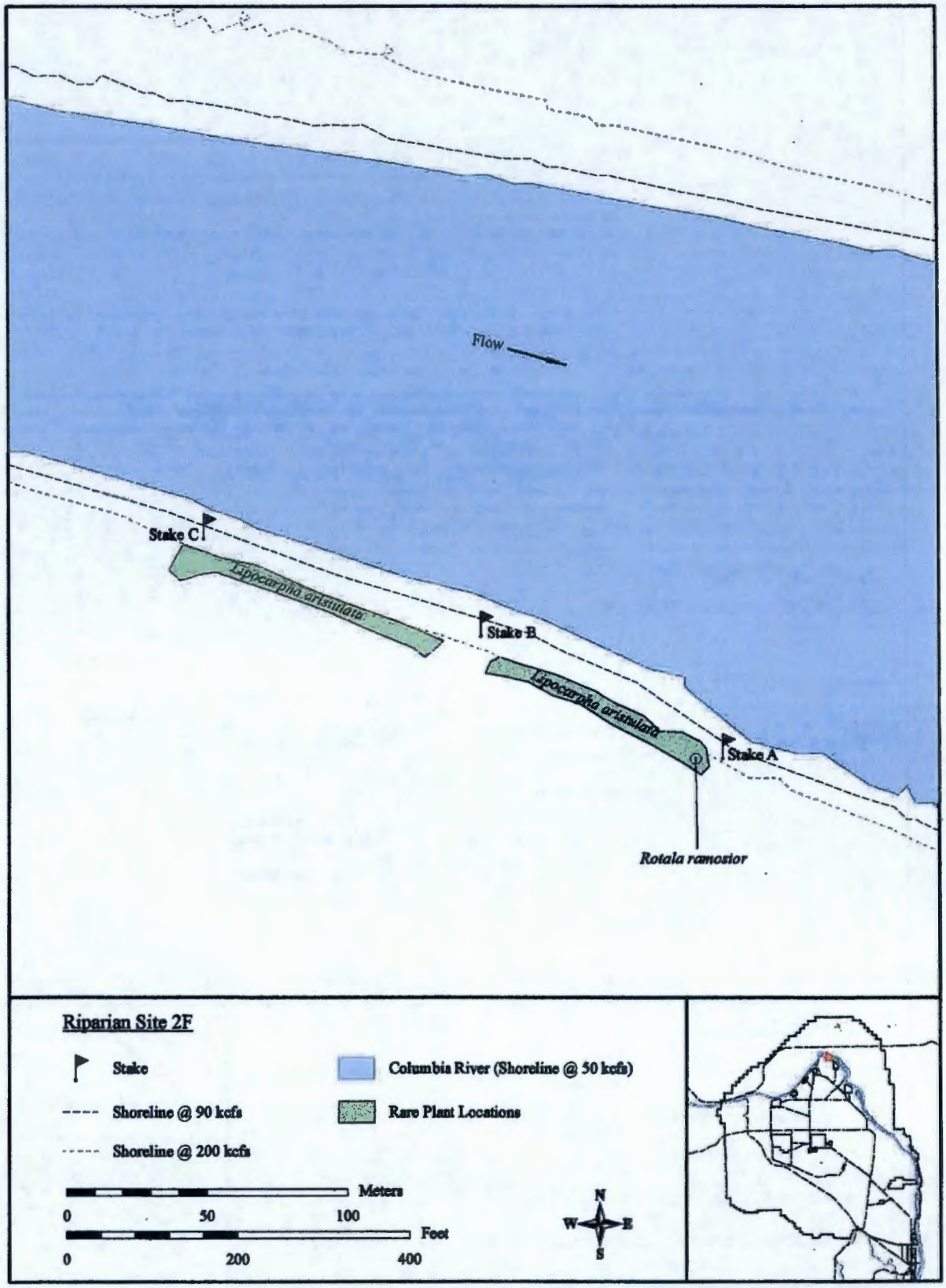
Figure 21. Site RCBRA 5c Rip. *Rotala ramosior* habitat intermittent along margin of cobble and *Phalaris arundinacea*. Looking downriver.

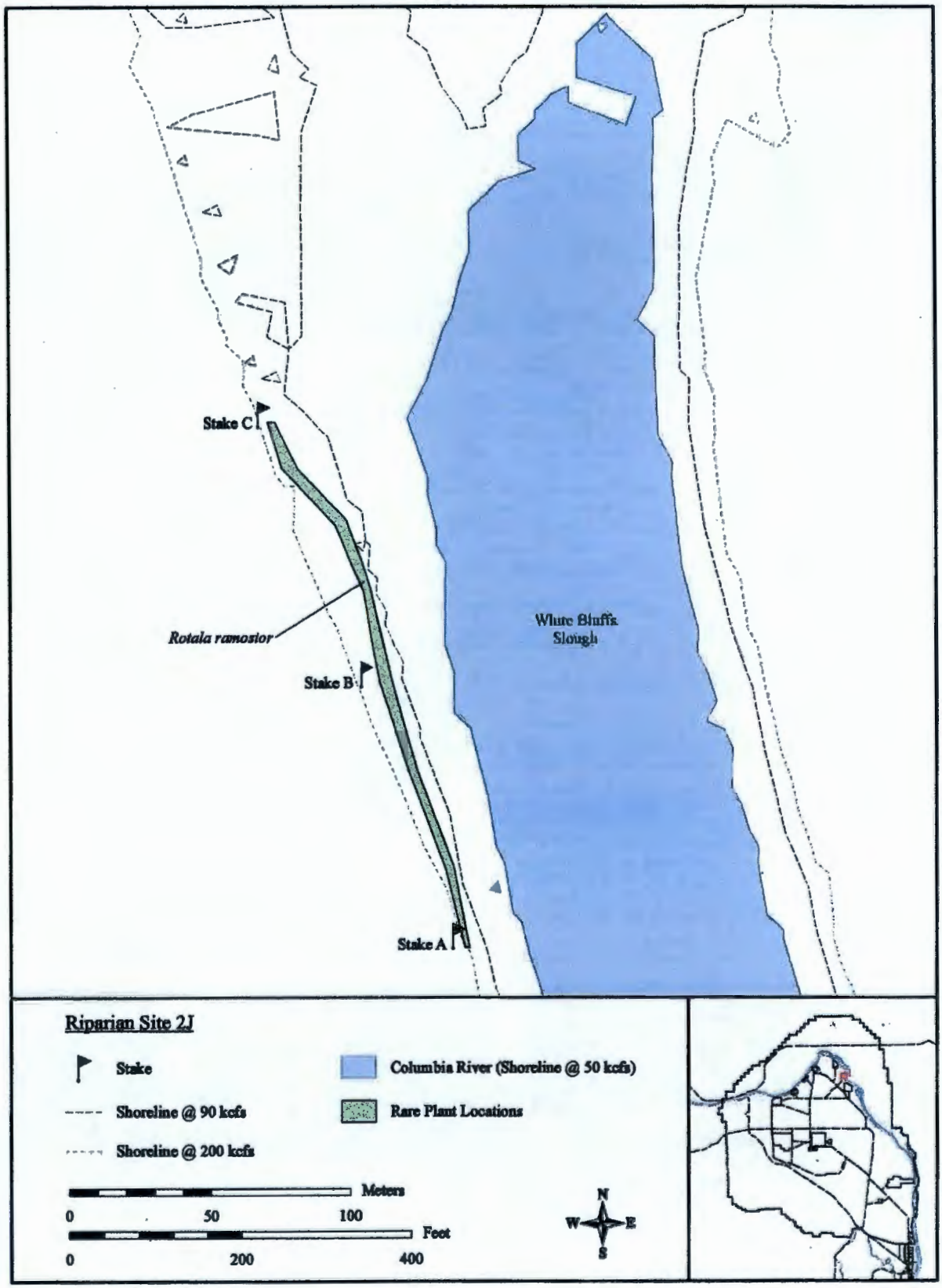
Figure 22. Site RCBRA 5c Rip. *Rotala ramosior* habitat. Looking downstream.

Figure 23. Site RCBRA 5c Rip. *Rotala ramosior* habitat. Looking upstream.

Figure 24. Site RCBRA 5c Rip. *Rotala ramosior* habitat. Looking upstream past Stake B.


Flow
Stake C
Stake B
Stake A
Rotala ramosior
and
Centunculus minimus
Rotala ramosior,
Lipocarpha aristulata,
and
Centunculus minimus
Riparian Site 2A
Stake
Shoreline @ 90 kcfs
Shoreline @ 200 kcfs
Columbia River (Shoreline @ 50 kcfs)
Rare Plant Locations
Meters
0
50
100
Feet
0
200
400
N
W
E
S


Flow
Stake C
Lipocarpha aristulata
Stake B
Lipocarpha aristulata
Stake A
Rotala ramosior
Riparian Site 2F
Stake
Shoreline @ 90 kcfs
Shoreline @ 200 kcfs
Columbia River (Shoreline @ 50 kcfs)
Rare Plant Locations
Meters
0
50
100
Feet
0
200
400
N
W
E
S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Stake B
Stake A
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Riparian Site 2J
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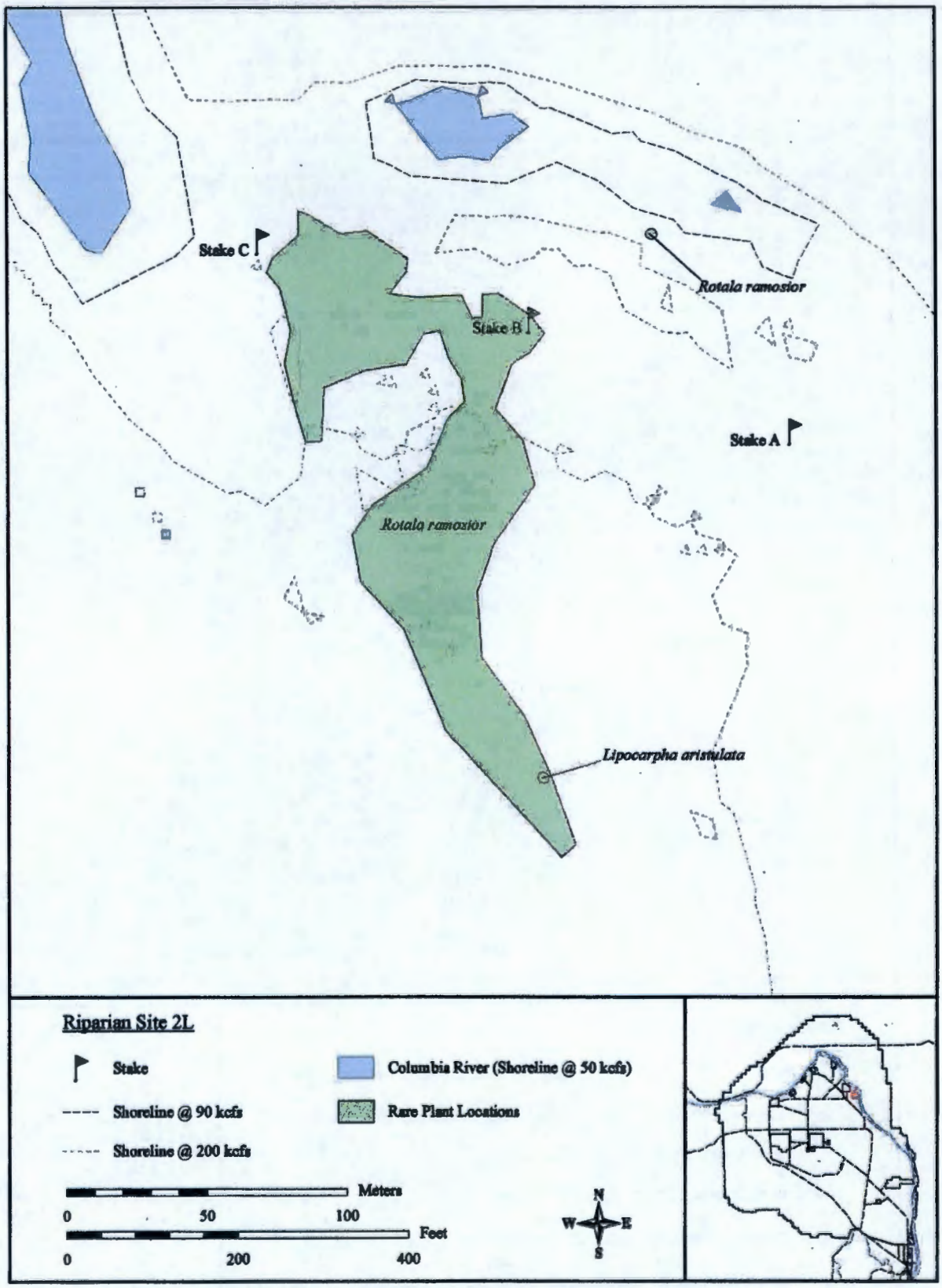
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Stake B
Stake A
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Rotala ramosior
Lipocarpha aristulata
Riparian Site 2L
Stake
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Shoreline @ 200 kcfs
Columbia River (Shoreline @ 50 kcfs)
Rare Plant Locations
Meters
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50
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200
400
N
W
E
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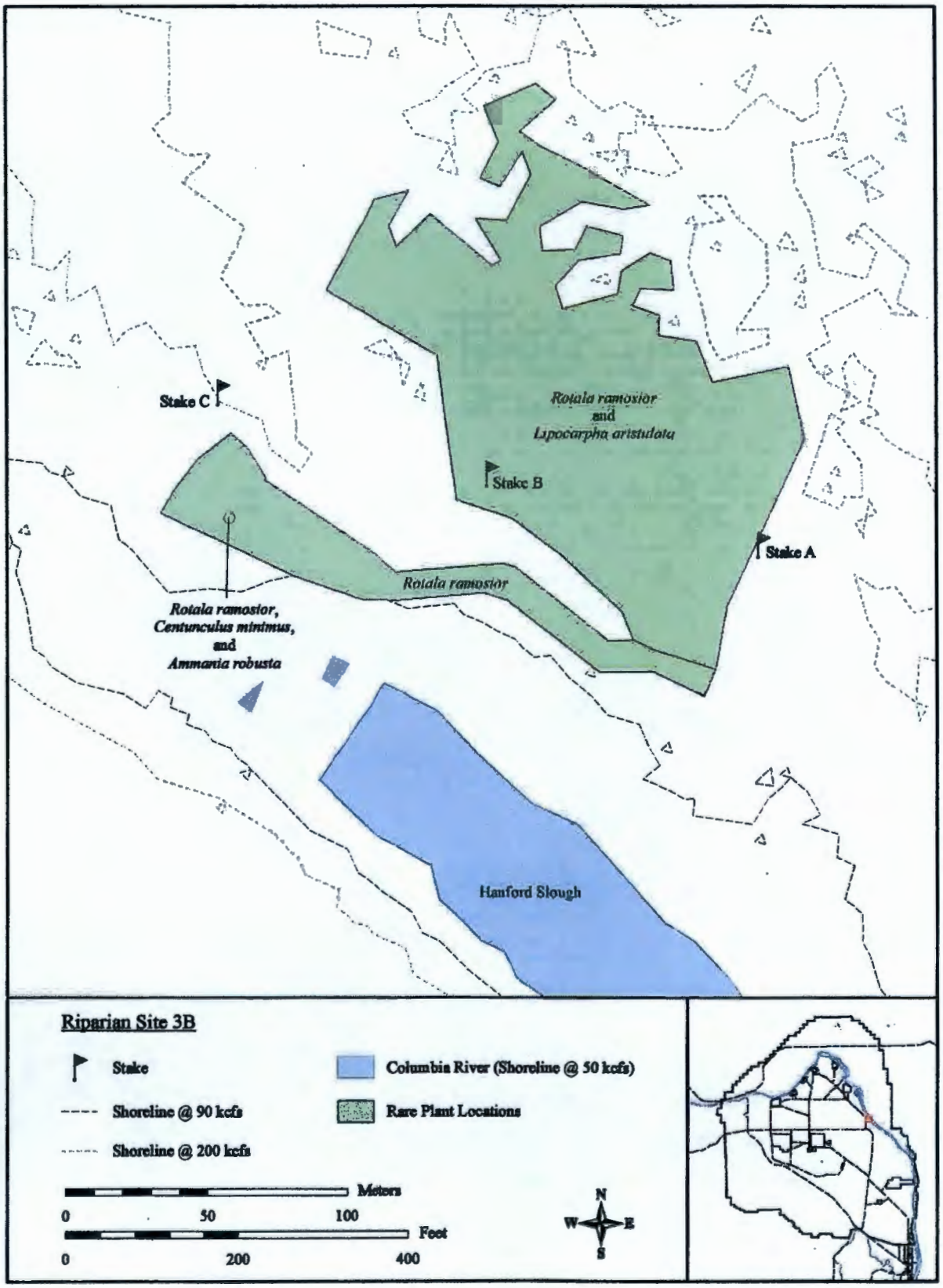
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and
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Stake B
Stake A
Rotala ramosior
Rotala ramosior,
Centunculus minimus,
and
Ammania robusta
Hanford Slough
Riparian Site 3B
Stake
Shoreline @ 90 kcfs
Shoreline @ 200 kcfs
Columbia River (Shoreline @ 50 kcfs)
Rare Plant Locations
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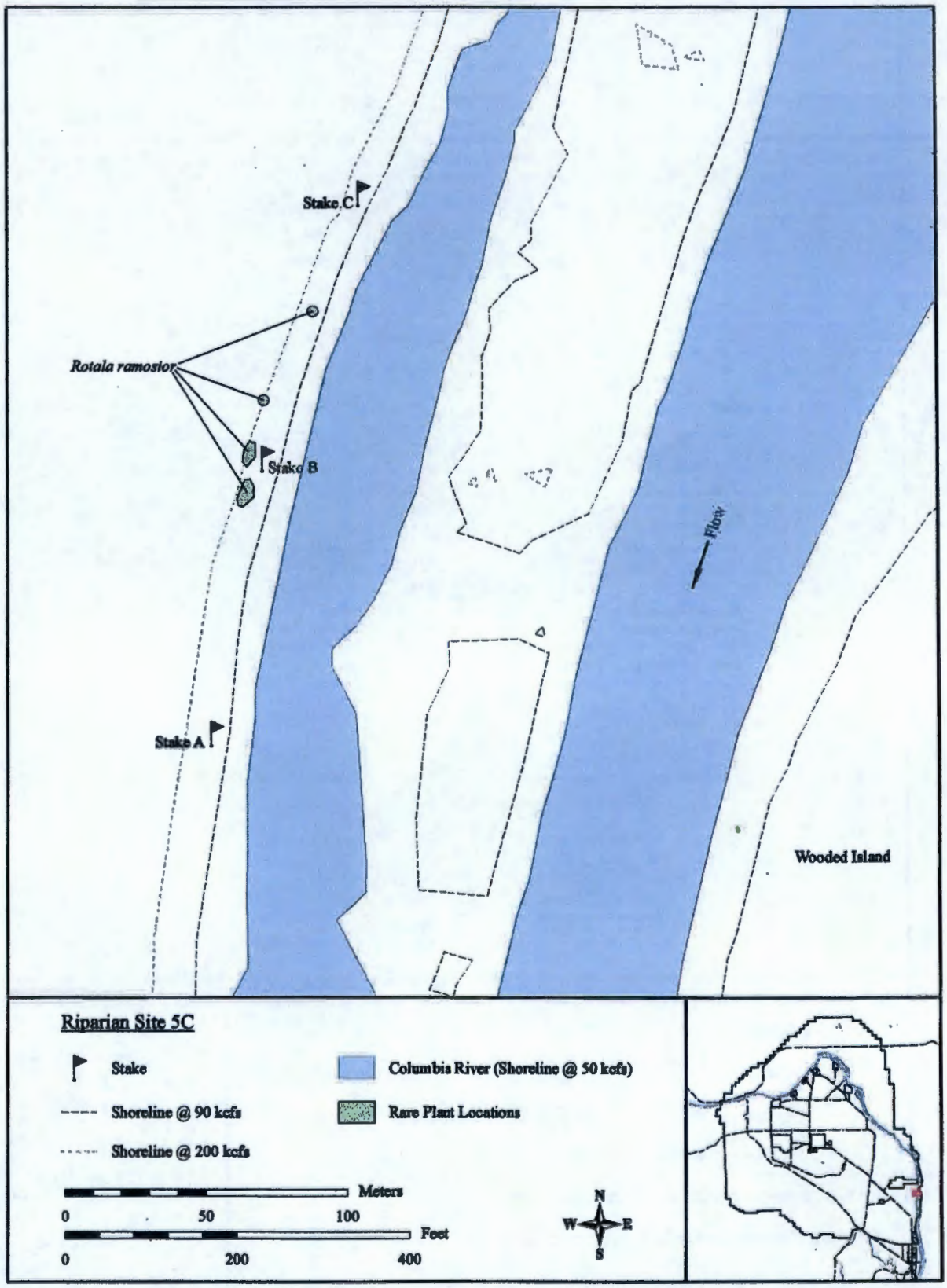
200
400
N
W
E
S


Stake C
Rotala ramosior
Stake B
Stake A
Flow
Wooded Island
Riparian Site 5C
Stake
Shoreline @ 90 kcfs
Shoreline @ 200 kcfs
Columbia River (Shoreline @ 50 kcfs)
Rare Plant Locations
Meters
0
50
100
Feet
0
200
400
N
W
E
S

APPENDIX E

THREATENED AND ENDANGERED FISH HABITAT SURVEYS

SUITABILITY OF AQUATIC HABITAT FOR STEELHEAD SPAWNING AT SELECTED SITES IN THE HANFORD REACH OF THE COLUMBIA RIVER, MEASURED FEBRUARY 21-25, 2007

SUMMARY REPORT

JUNE 2007

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SUITABILITY OF AQUATIC HABITAT FOR STEELHEAD SPAWNING AT SELECTED SITES IN THE HANFORD REACH OF THE COLUMBIA RIVER, MEASURED FEBRUARY 21-25, 2007

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Introduction

Steelhead in the Columbia River within the boundaries of the Hanford Site are part of the Upper Columbia River Evolutionarily Significant Unit (ESU), which includes all naturally spawned steelhead in Columbia Basin streams from the Yakima River to the United States-Canada border, as well as the Wells Hatchery stock (NMFS 61 FR 56138). Steelhead of this ESU were listed as federally-endangered under the Endangered Species Act (ESA) by NMFS on August 11, 1997.

Estimates of the number of steelhead that spawn in the Hanford Reach are sketchy and the amount of suitable spawning habitat in the area is poorly understood (DOE 2000). Watson (1973, cited in DOE 2000) estimated that 10,000 steelhead may have spawned in the Hanford Reach each year from 1962 to 1971. Between 1977 and 1996, approximately 9,000 steelhead may have spawned there per year (DOE 2000). Accurate information about location and amount of steelhead spawning in the Hanford Reach has been difficult to obtain because their spawning period (February through early June) usually coincides with high, turbid spring runoff, which render aerial and underwater video survey methods ineffective (Mueller and Geist 1999, DOE 2000). The only direct counts of steelhead redds in the river came from the late 1960s and early 1970s when unusually low flows allowed effective aerial surveys (DOE 2000). More recently spawning population estimates were based on counts of steelhead passing dams upstream and downstream of the Reach. More recent attempts to locate steelhead redds using underwater video have been unsuccessful so far (Mueller and Geist 1999). However, other indirect evidence such as the presence gravid and ripe steelhead in the Hanford Reach during April and May supports the idea that spawning may occur there (DOE 2000), and at least one verified steelhead redd was found within the Reach in spring 2005 (B. Tiller, unpublished data). Perhaps due to the inconsistency of evidence, DOE (2000) describes steelhead spawning activity within the Hanford Reach as "limited", and the Washington State Salmonid Stock Inventory indicates no steelhead spawning there (WDFW 2002, WDOE 2002).

Despite the lack of identified redds in recent years, the potential for steelhead spawning in the Hanford Reach may be considerable. Mueller and Geist (1999) reported 163,680 m^2 of potentially suitable habitat (based on substrate size alone) in a single 2 km long stream segment near Locke Island where steelhead redds were reported in the 1960s and 1970s. Based on an average size of 2.5 m^2 per steelhead redd (Wydoski and Whitney 2003), this is enough area for over 64,000 redds. If even a small fraction of this area is truly suitable, it could support a sizable number of spawners. Estimates of suitable habitat at other historically important spawning sites (Vernita Bar, Coyote Rapids, 100-F Islands, and Ringold) and in smaller pockets of habitat scattered about the Reach are not available.

Steelhead that spawn within the Hanford Reach, their eggs and alevins while in the gravel, and the resulting fry that rear in the river are subject to many man induced risks. These risks include impingement and entrainment from water withdrawals, toxicity of wastewater discharges, shoreline and riverbed modifications that cause siltation or affect habitat, siltation from surface runoff, toxic modifications of groundwater plumes, harassment from boat traffic, incidental capture during biological monitoring activities, disturbance by groundwater monitoring activities near the shoreline, groundwater treatment activities conducted near the shoreline, ecological and cultural research and monitoring programs conducted on the river or shoreline, and alterations of the shoreline for public access purposes (DOE 2000).

Our study focused on sites where steelhead may be affected by chemical and/or radiological releases as prescribed in the River Corridor Baseline Risk Assessment (RCBRA). The overall scope of the ecological risk assessment project has been described in the *Risk Assessment Work Plan for the 100 Area and 300 Area Component of the RCBRA* (DOE-RL 2004b) and further refined in the *100 Area and 300 Area Component of the RCBRA Sampling and Analysis Plan* (DOE-RL-2005-42 Rev 1). The process for evaluating risks to threatened and endangered (T&E) species for the ecological risk assessment project was developed as part of the 100-NR-2 groundwater operable unit ecological risk assessment (FH-WMP-23141 Rev. 0). We conducted steelhead spawning habitat surveys in February 2007 for 1 part of this 4-step process for assessing potential risk to ESU-listed steelhead from chemical and/or radiological releases attributable to Hanford Site operations.

Our specific survey objectives were to:

1) determine if suitable steelhead spawning habitat exists at several RCBRA investigation areas according to accepted habitat suitability criteria; and

2) document any steelhead spawning activity (fish or redds) at these sites.

Methods

Figure 1 provides an overall depiction of where steelhead spawning habitat surveys were conducted as part of the RCBRA ecological risk assessments currently underway. The 100 Area & 300 Area RCBRA sites were located within three key contaminant plumes originating from Hanford Site operations (hexavalent chromium at the 100-K and 100-D Areas, strontium-90 at the 100-N Area, and uranium at the 300 Area, DOE RL 2005-42 Rev. 1). Ten additional investigation areas (Inter-Areas Sites) were located in selected regions where Hanford's legacy materials were known or suspected to have been deposited. We measured spawning habitat characteristics (depth, velocity, substrate size, and substrate embeddedness) on several short transects perpendicular to shore in each survey area; 3 transects in the strontium area, 10 transects in the chromium area, 10 in the uranium area, and at 10 additional inter-area sites (see Fig. 1).

On each transect, spawning steelhead habitat characteristics were systematically measured at three stations that encompassed the range of depths where steelhead typically spawn (0.5-4.5 ft or 0.15-1.38 m). The resulting transect lengths ranged from 16 ft (~5 m) to 262 ft (~80 m) in length from shore to the deepest sampling station. Fewer than three stations were sampled on transects that were clearly unsuitable for spawning (e.g., the substrate was too fine all along the transect or water velocities were too low). Although in most rivers steelhead spawn in water less than 3.5 feet deep, we chose a deeper maximum measurement limit (4.5 ft) because the depth limit for steelhead spawning is uncertain in large rivers (H. Beecher, WDFW, personal communication), and experience has shown that salmonids may spawn in deeper water than expected when other habitat characteristics are suitable (Groves and Chandler 1999, Quinn 2005).

Sampling was conducted by wading at the shallowest stations or from an anchored boat at deeper, faster locations. Station positions were measured and recorded with a Trimble XP GPS (nominal accuracy better than 1 m) using U.S. State Plane 1983 Washington South 4602 Meters. Habitat measurements made at each station were dominant and subdominant particle size and percent cover, substrate embeddedness, water depth, and water velocity. Dominant and subdominant particle size and their percentage contribution to the substrate were visually

estimated within a square gravel gauge (512 mm x 512 mm) that was placed on the river bottom (Bovee and Cochnauer 1977, Bovee 1986, Table 1, Figure 2).

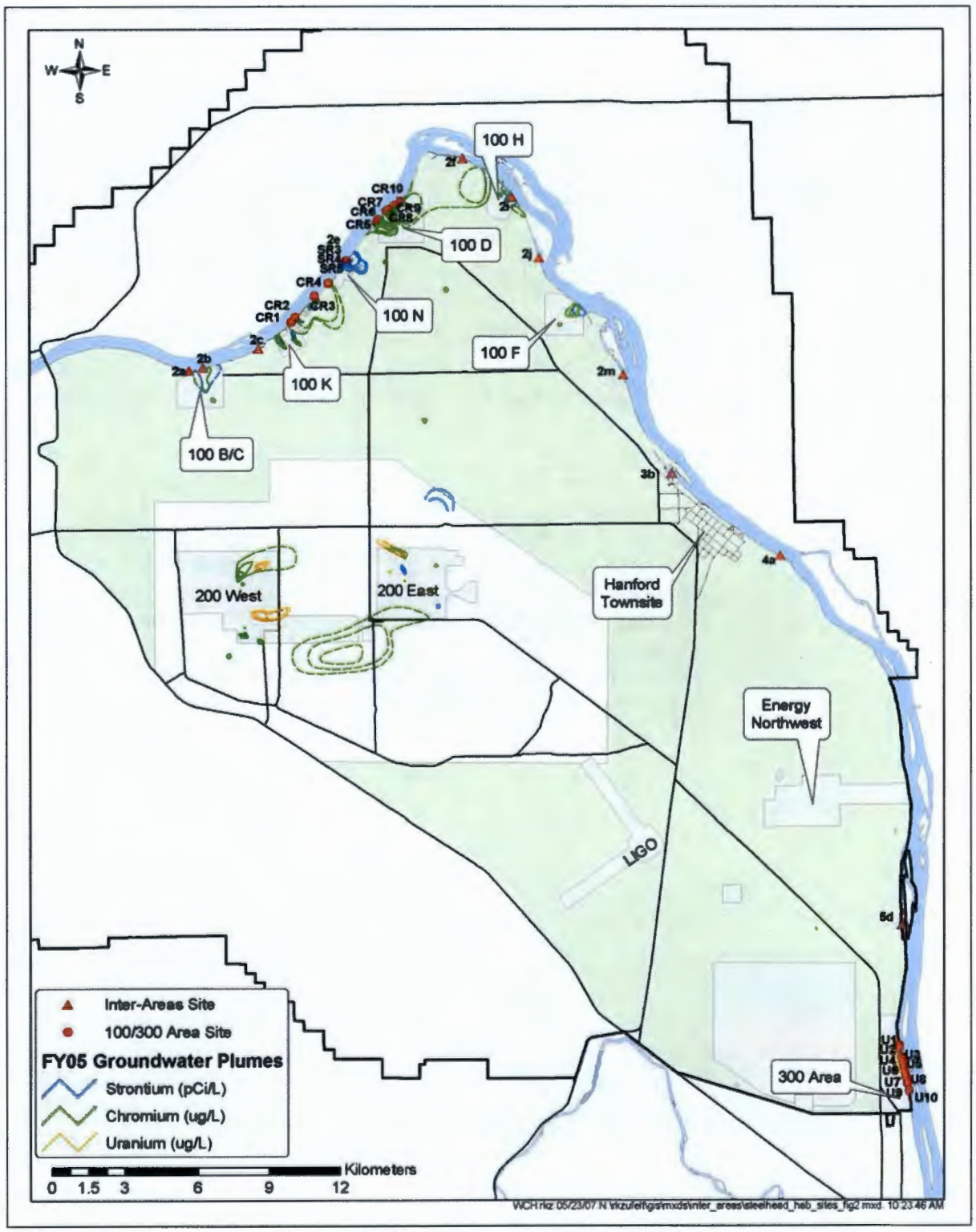

Figure 1. Ecological risk assessment sites within the Hanford Reach of the Columbia River where steelhead spawning habitat surveys were conducted in February 2007.

Embeddedness was also estimated visually within the square according to Bovee's (1986) criteria (Table 2). Underwater photos were taken at each station to further document substrate conditions. Visual observations were made with the aid of a viewing bucket to reduce the obscuring effect of surface turbulence and suspended bubbles.

Table 1. Substrate particle size categories from Bovee and Cochnauer (1977).

		Diameter (inches)		Diameter (mm)*	
Category	Code	min	max	min	max
sand	4	0.00	0.08	0.062	2
gravel	5	0.08	2.52	2	64
cobble	6	2.52	10.09	64	256
boulder	7	10.09		256	

* Medial axis diameter.

Table 2. Substrate embeddedness categories and approximate % fines from Bovee (1986).

Category	% Fines	Description
1	0 - 25	Openings between dominant-sized particles are one-third to one-half the size of particles. Few fines in between. Edges are clearly discernable.
2	26 - 50	Openings are apparent but less than one-fourth the size of particles. Edges are discernable but up to half obscured.
3	51 - 75	Openings are completely filled but half of the edges are still discernable.
4	76 - 100	All openings are obscured. Only one or two edges discernable and size cannot be determined without removal.

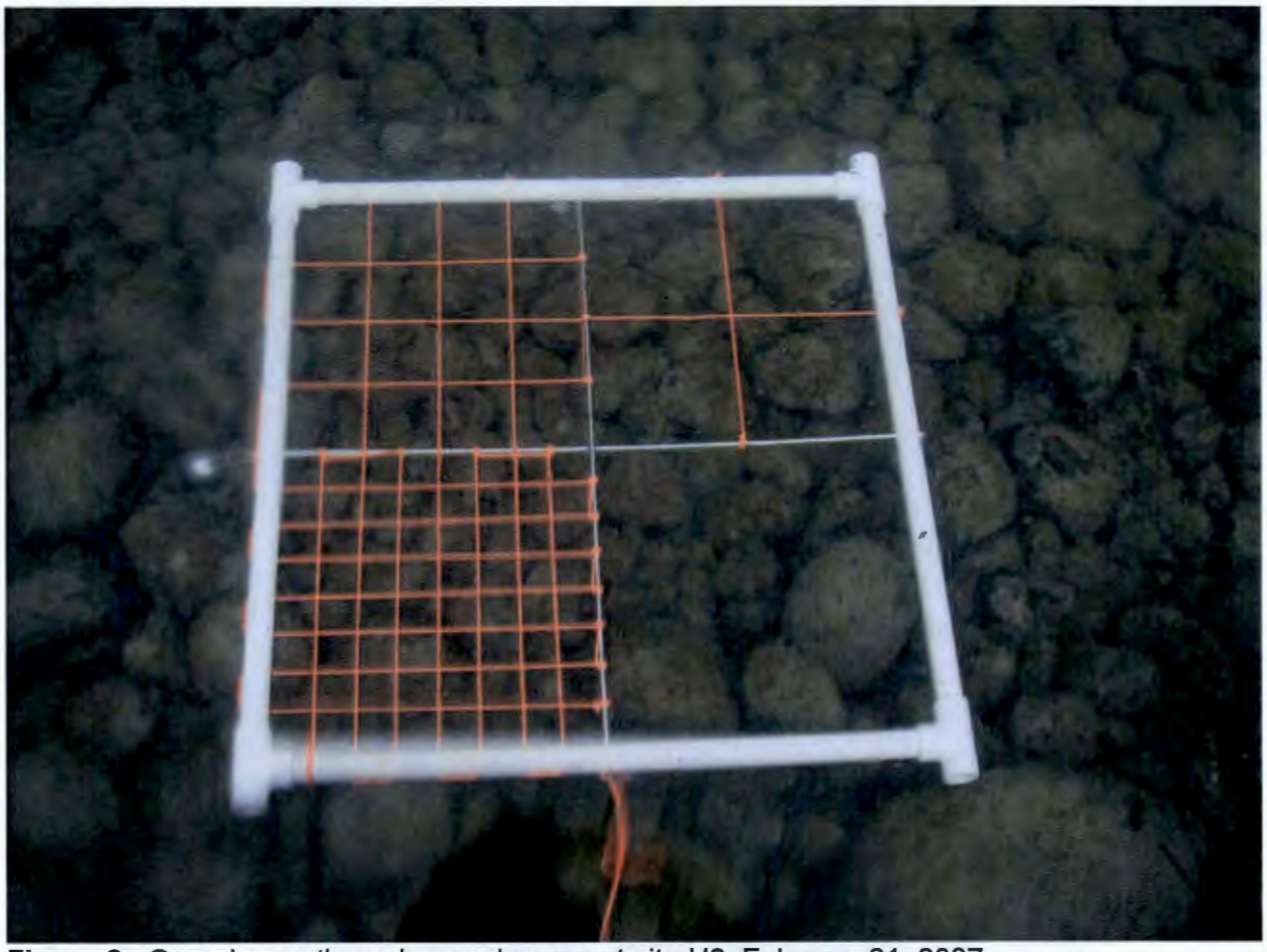

Figure 2. Gravel seen through gravel gauge at site U2, February 21, 2007.

Total water column depth was measured at each station with a 6 foot wading rod (Figure 3). Velocity was measured for calculation of mean water column velocity as described in Platts et al. (1983). In water 0.3-2.5 ft deep (0.1-0.75 m), one measurement at 60% of the distance from surface to bottom represented mean velocity. In deeper water, measurements taken at 20% and 80% of water column depth were averaged. In addition, "nose velocity" was measured at each station 4.8 inches (0.12 m) above the river bottom (Bovee 1997). All velocity measurements were made with a calibrated Marsh-McBirney Flo-mate model 2000 electromagnetic velocity meter, and all reported velocities were 40 second averages automatically computed by the meter.

Figure 3. Measuring velocity and depth from the anchored boat with a Marsh-McBirney velocity meter on a 6 foot wading rod.

The suitability of depth, velocity, and substrate characteristics for steelhead spawning were judged by comparison to Bovee's (1978) probability-of-use (POU) curves as our primary standard, with similar curves from WDFW (2004) also presented for comparison (Figures 4-6). Measurements of these variables were categorized as unsuitable (POU = 0), marginal (POU >0 and ≤ 50%), and good (POU > 50%). Because the maximum depth for steelhead spawning is uncertain (WDFW 2004; H. Beecher, WDFW, personal communication), we classified depths >3.4ft (~1m, Bovee's suitability cutoff) as marginal rather than unsuitable. This is similar to the method that WDFW (2004) employs (Figure 4). Curves for POU related to embeddedness have not been developed, so we considered 0-25% embeddedness suitable and >25% embeddedness unsuitable (Figure 6). This classification was easily applied to data collected using Bovee's (1986) embeddedness categories and is similar to WDFW's (2004) dichotomous scheme which cuts off suitability at >20% embeddedness (Figure 6).

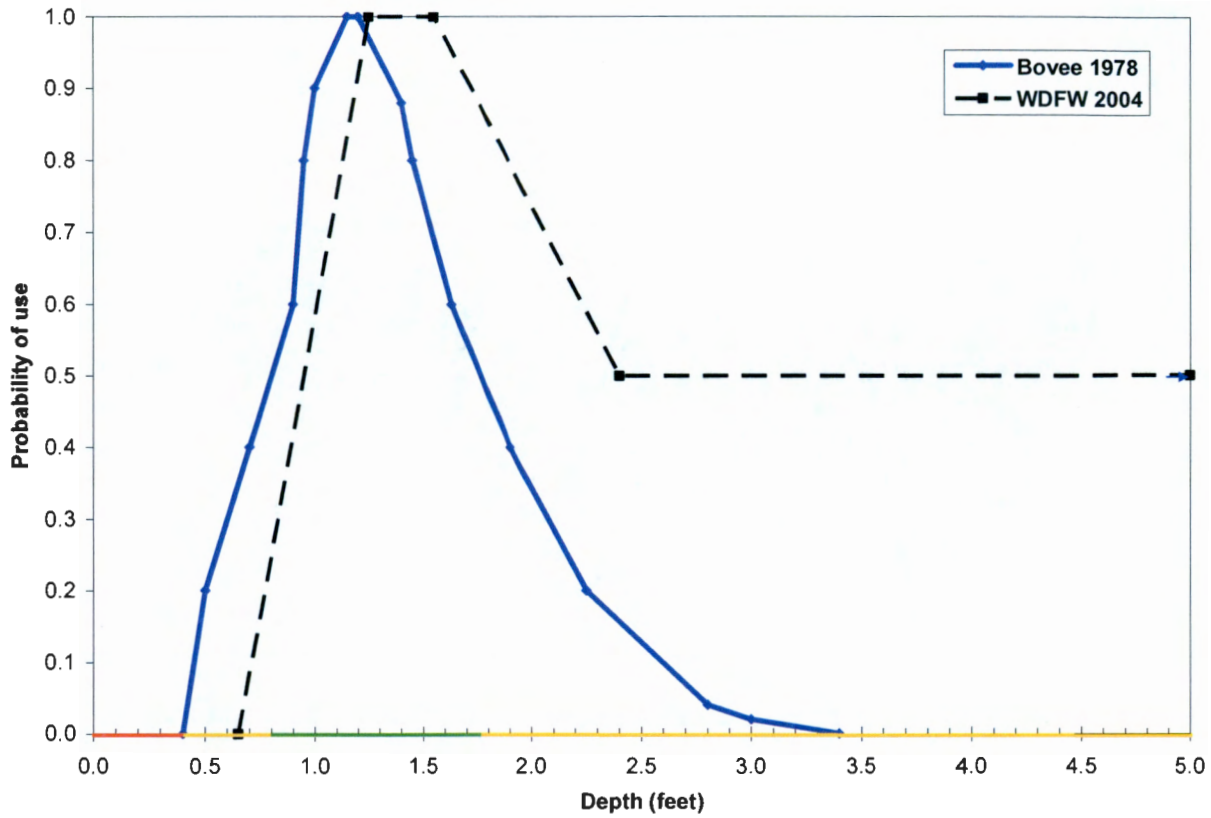

Figure 4. Probability of use for steelhead spawning versus water depth. Colored segments on the X-axis show our classification categories: red indicates unsuitable conditions (probability of use = 0), yellow shows marginal conditions (probability of use > 0 and ≤ 50%), and green indicates good conditions (probability of use > 50%).

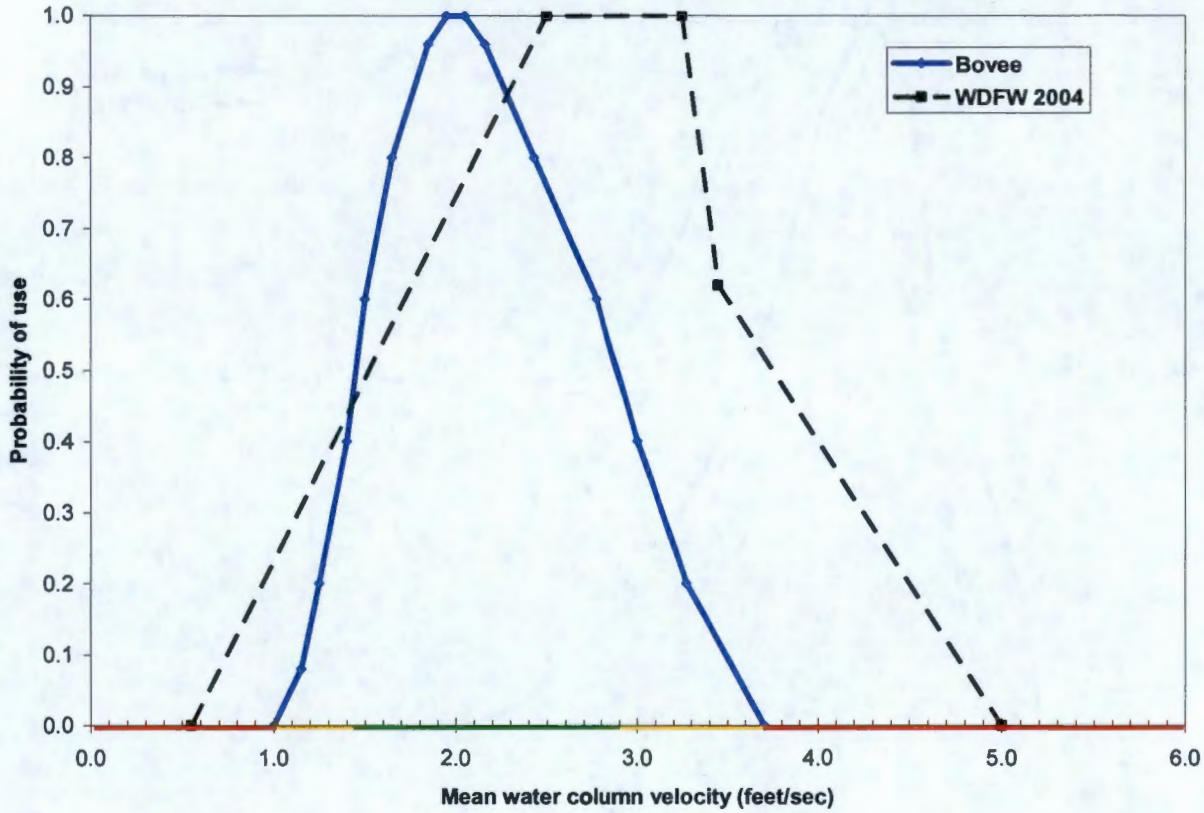

Figure 5. Probability of use for steelhead spawning versus velocity (mean water column velocity). Colored segments on the X-axis show our classification categories: red indicates unsuitable conditions (probability of use = 0), yellow shows marginal conditions (probability of use > 0 and ≤ 50%), and green indicates good conditions (probability of use > 50%).

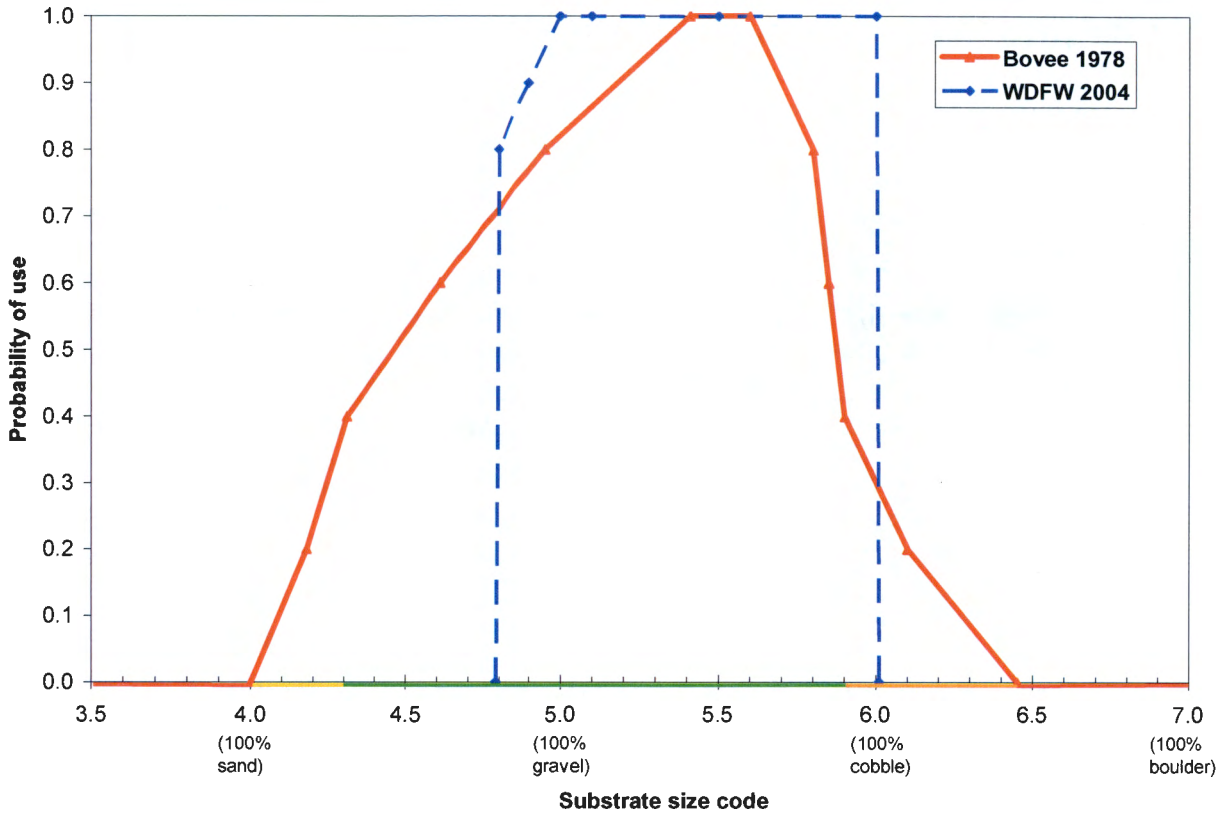

Figure 6. Probability of use for steelhead spawning versus substrate size. Colored segments on the X-axis show our classification categories: red indicates unsuitable conditions (probability of use = 0), yellow shows marginal conditions (probability of use > 0 and ≤ 50%), and green indicates good conditions (probability of use > 50%). The curve for WDFW (2004) was approximated by adapting their data to Bovee's sediment classification scheme.

Results and Discussion

Sampling conditions were good throughout the survey period (February 21-25, 2007). Flows were low and unusually stable for the Columbia River, ranging from 68.5 to 79.4 cfs (Table 3). All sites were measured under similar, comparable flow conditions. Water clarity was high during the study, and the river bed was clearly visible for substrate and embeddedness observations at all sampling locations.

Table 3. Discharge from Priest Rapids Dam, upstream from the study site, during the 2007 steelhead spawning habitat surveys.

	Discharge (kcfs)			
Date	Mean	Min.	Max.	SE
2/21/2007	75.2	72.4	79.4	0.4
2/22/2007	73.2	68.5	78.1	0.5
2/23/2007	73.1	69.9	76.4	0.3
2/24/2007	73.8	71.8	75.1	0.2
2/25/2007	73.4	71.8	74.4	0.1

Conditions entirely suitable for steelhead spawning (i.e., for all variables) were found at 7 of 23 (30%) of the 100 and 300 Area sites: Cr7, Cr8, Cr9, Cr10, U3, U4, Sr3 (Figure 7, Table 4). Entirely suitable conditions occurred at only 1 of 10 (10%) of the Inter-area sites (2i). At three of the 100 and 300 Area sites (Cr9, Cr10, and U3), two of three stations (points along transect) were entirely suitable (Table 4). Site U3 in the 300 area is located where a steelhead redd was observed and confirmed by DNA identification in 2005 (B. Tiller, unpublished data). At stations that were not entirely suitable, a number were suitable for two or three of the four variables (Appendix 1). Spawning habitat measurements were not made at Inter-area sites 2m and 3b because these sites were located in backwater sloughs with little or no water flow and it was assumed that they lacked suitable water velocity conditions and/or substrates (Table 4).

We observed no adult steelhead or steelhead redds during February 2007, however, these dates are relatively early in the spawning period for steelhead in the Hanford Reach (February through early June, with peak spawning in mid-May).

Our findings are specific to the flows present when we sampled, and the conditions precisely where we made measurements may not be suitable for spawning at higher or lower river discharges (Figure 8). River water surface elevations shown in Figure 8 were calculated using MASS1 flow model (Richmond and Perkins 1998) with hourly discharge data from Priest Rapids hydro-electric facility. Qualitative observations made during our study suggest that many of the stations where suitable conditions existed were adjacent to habitat that would have also been suitable at other flows. However, a more comprehensive study at a variety of river flows would be necessary to say whether suitable habitat persists over the wide range of flows typical of the steelhead spawning season (February through June). A more complete analysis should address how daily and weekly flow fluctuations (Figure 8) potentially affect steelhead spawning and incubation.

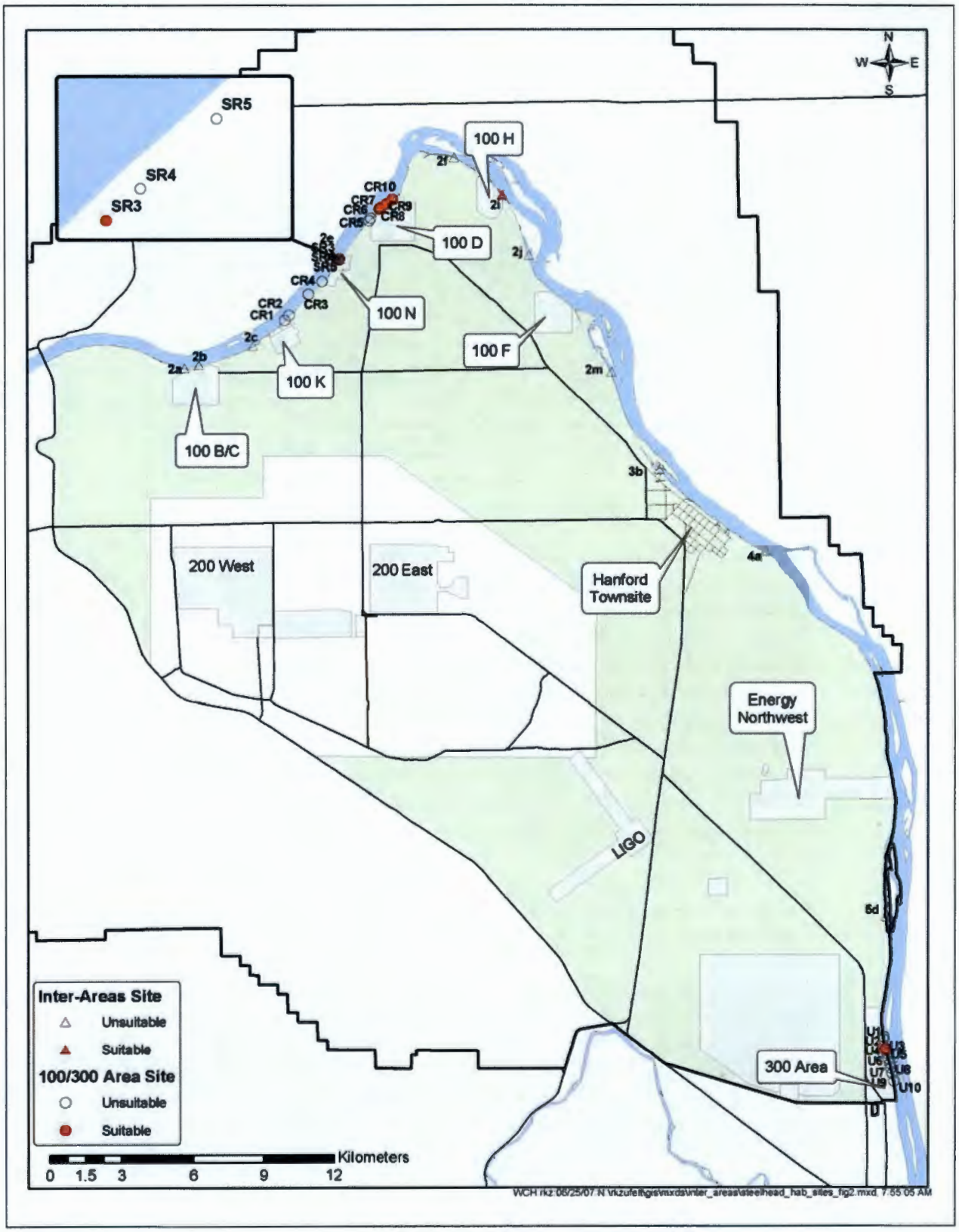

Figure 7. Ecological risk assessment sites within the Hanford Reach of the Columbia River where suitable steelhead spawning habitat surveys were recorded in February 2007.

Table 4. Number of stations (sampling points) at each site (transect) that were classified as suitable or unsuitable for steelhead spawning. Classification as "suitable" required that all measured variables (depth, velocity, substrate size, and substrate embeddedness) were within the acceptable range.

		Number of stations per site		
Area	RCBRA Site	Unsuitable	Suitable	Total
100	CR1	2	0	2
"	CR2	2	0	2
"	CR3	2	0	2
"	CR4	3	0	3
"	CR5	2	0	2
"	CR6	2	0	2
"	CR7	2	1	3
"	CR8	2	1	3
"	CR9	1	2	3
"	CR10	1	2	3
"	SR3	1	1	2
"	SR4	2	0	2
"	SR5 (2E)	2	0	2
300	U1	1	0	1
"	U2	3	0	3
"	U3	1	2	3
"	U4	2	1	3
"	U5	2	0	2
"	U6	2	0	2
"	U7	2	0	2
"	U8	2	0	2
"	U9	2	0	2
"	U10	2	0	2
Inter-Area	2A	2	0	2
"	2B	2	0	2
"	2C	2	0	2
"	2E (SR5)	2	0	2
"	2F	2	0	2
"	2I	2	1	3
"	2J	1	0	1
"	4A	2	0	2
"	5D	3	0	3
"	2M*	-	0	-
"	3B*	-	0	-

* No measurements were made at these stations, but they were in backwater sloughs with little or no water flow, so habitat conditions were assumed to be unsuitable for spawning.

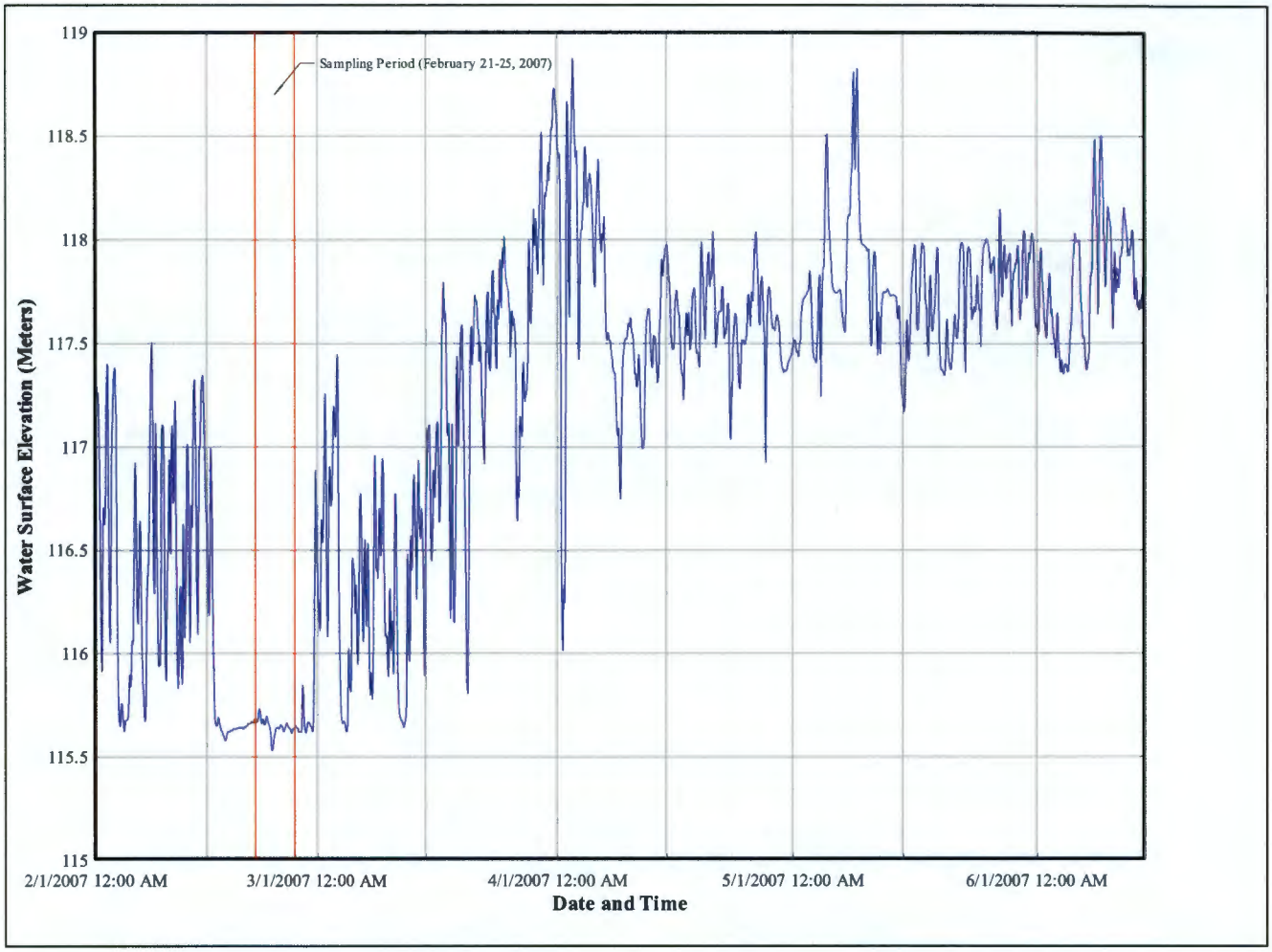

Figure 8. River level fluctuation patterns near 100-D Area during the steelhead spawning period (February – June, 2007).

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Appendix 1. Measurements of habitat characteristics and their suitability for steelhead spawning at all sites (transects) and stations (points) sampled in the Hanford Reach, February 21-25, 2007. Suitability classifications are defined by Probability Of Use (POU): unsuitable (POU = 0), marginal (POU >0 and ≤ 50%), and good (POU > 50%).

								Suitability classification				
Easting	Northing	Transect (SiteID)	Station (Point)	Depth (feet)	Embed. code	Velocity (ft/sec)	Substrate size code	Depth	Embed.	Velocity	Substrate size	Overall
568965	147343	CR1	2	3.0	2	0.0	5.2	marginal	unsuitable	unsuitable	good	unsuitable
568962	147348	CR1	3	4.5	2	0.0	5.0	marginal	unsuitable	unsuitable	good	unsuitable
569134	147551	CR2	2	2.5	2	0.0	5.5	marginal	unsuitable	unsuitable	good	unsuitable
569130	147554	CR2	3	4.5	3	0.0	5.5	marginal	unsuitable	unsuitable	good	unsuitable
569963	148462	CR3	2	0.0	1	-0.2	6.0	unsuitable	good	unsuitable	marginal	unsuitable
569960	148466	CR3	3	4.5	4	-0.2	5.3	marginal	unsuitable	unsuitable	good	unsuitable
570539	148999	CR4	2	1.0	2	0.3	6.5	good	unsuitable	unsuitable	unsuitable	unsuitable
570537	149005	CR4	3	2.9	1	0.4	6.6	marginal	good	unsuitable	unsuitable	unsuitable
570534	149009	CR4	4	4.5	1	0.9	5.2	marginal	good	unsuitable	good	unsuitable
572568	151584	CR5	2	2.3	3	0.5	5.3	marginal	unsuitable	unsuitable	good	unsuitable
572568	151584	CR5	3	4.5	1	0.5	5.1	marginal	good	unsuitable	good	unsuitable
572639	151684	CR6	3	4.5	3	0.0	3.4	marginal	unsuitable	unsuitable	unsuitable	unsuitable
572639	151688	CR6	2	0.0	4	0.0	3.5	unsuitable	unsuitable	unsuitable	unsuitable	unsuitable
573003	152065	CR7	2	1.0	1	0.4	6.0	good	good	unsuitable	marginal	unsuitable
573001	152068	CR7	3	2.4	2	0.6	5.7	marginal	unsuitable	unsuitable	good	unsuitable
572998	152070	CR7	4	4.5	1	1.6	6.0	marginal	good	good	marginal	**suitable**
573100	152137	CR8	2	1.0	2	0.8	5.5	good	unsuitable	unsuitable	good	unsuitable
573097	152138	CR8	3	2.8	2	1.2	5.6	marginal	unsuitable	marginal	good	unsuitable
573096	152140	CR8	4	4.5	1	1.9	5.0	marginal	good	good	good	**suitable**
573331	152291	CR9	2	1.0	1	1.0	5.9	good	good	unsuitable	marginal	unsuitable
573331	152293	CR9	3	2.5	1	1.4	5.4	marginal	good	marginal	good	**suitable**
573329	152295	CR9	4	4.5	1	2.2	5.1	marginal	good	good	good	**suitable**
573594	152487	CR10	2	1.0	1	1.0	5.6	good	good	unsuitable	good	unsuitable
573594	152490	CR10	3	2.8	1	1.2	5.5	marginal	good	marginal	good	**suitable**
573590	152491	CR10	4	4.5	1	1.7	5.3	marginal	good	good	good	**suitable**
594403	116702	U1	2	4.3	4	0.2	3.0	marginal	unsuitable	unsuitable	unsuitable	unsuitable
594404	116597	U2	1	0.5	1		5.3	marginal	good	unsuitable	good	unsuitable
594410	116598	U2	2	3.4	4	0.0	3.0	marginal	unsuitable	unsuitable	unsuitable	unsuitable
594413	116599	U2	3	4.6	4	0.1	3.0	marginal	unsuitable	unsuitable	unsuitable	unsuitable
594492	116213	U3	2	1.0	2	0.4	5.3	good	unsuitable	unsuitable	good	unsuitable
594498	116216	U3	3	4.2	1	1.3	5.1	marginal	good	marginal	good	**suitable**
594505	116214	U3	4	4.5	1	2.6	5.5	marginal	good	good	good	**suitable**
594507	116159	U4	2	1.0	3	0.1	5.6	good	unsuitable	unsuitable	good	unsuitable
594513	116160	U4	3	3.2	2	0.8	5.2	marginal	unsuitable	unsuitable	good	unsuitable
594520	116161	U4	4	4.5	1	2.2	5.4	marginal	good	good	good	**suitable**
594548	115980	U5	2	2.5	1	-0.3	5.5	marginal	good	unsuitable	good	unsuitable
594549	115980	U5	3	4.5	1	-0.4	5.1	marginal	good	unsuitable	good	unsuitable
594606	115750	U6	2	2.0	2	-0.1	5.2	marginal	unsuitable	unsuitable	good	unsuitable
594610	115750	U6	3	4.5	2	0.4	5.0	marginal	unsuitable	unsuitable	good	unsuitable
594670	115551	U7	2	2.0	2	0.4	5.8	marginal	unsuitable	unsuitable	good	unsuitable
594676	115552	U7	3	4.5	2	1.1	5.5	marginal	unsuitable	marginal	good	unsuitable
594708	115354	U8	2	2.6	2	-0.1	5.1	marginal	unsuitable	unsuitable	good	unsuitable
594711	115355	U8	3	4.5	4	-0.1	3.3	marginal	unsuitable	unsuitable	unsuitable	unsuitable
594765	115130	U9	2	2.4	4	-0.1	3.1	marginal	unsuitable	unsuitable	unsuitable	unsuitable
594767	115131	U9	3	4.5	4	-0.1	3.0	marginal	unsuitable	unsuitable	unsuitable	unsuitable

Suitability of aquatic habitat for steelhead spawning at selected sites in the Hanford Reach

								Suitability classification				
Easting	Northing	Transect (SiteID)	Station (Point)	Depth (feet)	Embed. code	Velocity (ft/sec)	Substrate size code	Depth	Embed.	Velocity	Substrate size	Overall
594825	114798	U10	2	3.1	4	-0.7	3.1	marginal	unsuitable	unsuitable	unsuitable	unsuitable
594827	114799	U10	3	4.5	4	-0.7	3.0	marginal	unsuitable	unsuitable	unsuitable	unsuitable
571274	149916	SR3	2	2.6	1	0.6	5.3	marginal	good	unsuitable	good	unsuitable
571273	149919	SR3	3	4.4	1	1.3	5.4	marginal	good	marginal	good	**suitable**
571286	149928	SR4	3	4.5	1	0.2	5.3	marginal	good	unsuitable	good	unsuitable
571288	149925	SR4	2		1	0.0	7.0	unsuitable	good	unsuitable	unsuitable	unsuitable
571319	149951	2e(SR5)	1	0.0	1	0.4	5.5	unsuitable	good	unsuitable	good	unsuitable
571318	149954	2e(SR5)	2	2.1	1	0.0	7.0	marginal	good	unsuitable	unsuitable	unsuitable
564669	145315	2A	2	3.8	4	0.0	3.0	marginal	unsuitable	unsuitable	unsuitable	unsuitable
564666	145324	2A	3	4.5	2	0.0	5.1	marginal	unsuitable	unsuitable	good	unsuitable
565262	145427	2B	2	3.2	3	0.1	5.6	marginal	unsuitable	unsuitable	good	unsuitable
565261	145431	2B	3	4.5	2	0.1	5.0	marginal	unsuitable	unsuitable	good	unsuitable
567580	146240	2C	2	3.4	4	-0.2	5.3	marginal	unsuitable	unsuitable	good	unsuitable
567575	146244	2C	3	4.5	4	-0.2	5.0	marginal	unsuitable	unsuitable	good	unsuitable
576228	154310	2F	2	2.2	2	-0.1	5.4	marginal	unsuitable	unsuitable	good	unsuitable
576229	154313	2F	3	4.5	1	-0.1	5.5	marginal	good	unsuitable	good	unsuitable
578226	152740	2I	2	1.0	2	1.3	5.3	good	unsuitable	marginal	good	unsuitable
578259	152757	2I	3	2.6	1	3.2	5.0	marginal	good	marginal	good	**suitable**
578296	152728	2I	4	4.5	1	4.8	5.0	marginal	good	unsuitable	good	unsuitable
579563	149606	2J	3	4.5	2	0.1	5.2	marginal	unsuitable	unsuitable	good	unsuitable
589452	137504	4A	2	1.8	1	0.4	6.5	marginal	good	unsuitable	unsuitable	unsuitable
589455	137509	4A	3	4.5	1	0.7	5.5	marginal	good	unsuitable	good	unsuitable
594552	121828	5D	2	1.0		0.5	4.0	good	unsuitable	unsuitable	marginal	unsuitable
594574	121822	5D	4	4.0	2	2.6	5.1	marginal	unsuitable	good	good	unsuitable
594565	121826	5D	3	4.3	3	1.7	5.6	marginal	unsuitable	good	good	unsuitable

APPENDIX F

MOLLUSK OBSERVATIONS FOR THE 100/300 AREA

Mollusk Observations Along the Hanford Reach of the Columbia River: 100 and 300 Areas River Corridor Baseline Risk Assessment

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1.0 INTRODUCTION

Benthic community samples from a number of Washington Columbia River sites within the Hanford Reach were collected for analysis of their freshwater mollusk and invertebrate fauna during 2006 as part of the U.S. Department of Energy's River Corridor Ecological Risk Assessment efforts. The samples were retrieved from 27 sites, each containing 3 replicate plastic laminated wire baskets (16.5 cm x 28 cm) containing cobbles (45 mm to 64 mm medial axis diameter) and were left in place for at least 6 months (December 2005 through July 2006). The artificial substrate baskets were partially buried by divers in the riverbed immediately below the low-water level and were spaced 1 m (3 ft) apart and parallel to the river's shoreline.

The samples were processed identically. The substrate baskets were carefully retrieved by divers from the river by covering the basket with mosquito netting while in place and then each basket rolled into separate sheets of the netting and carried to the shoreline then placed into individual tubs of pre-screened water for processing. Each basket was opened and all rock and basket surfaces were brushed clean. The water and basket contents were then poured through a 0.5 mm sieve and the remaining material was placed into bottles containing >95% ethanol. All samples were processed separately and lists prepared for each replicate. Upon final inspection, each sample was run through a series of Taylor standard brass sieves to 40 mesh (<0.5mm).

For this report, mollusk fauna summaries were combined to represent each site; but the original table has been retained as a separate document if needed. Mollusks were removed under a Leica MZ 7.5 binocular dissecting scope and retained in 95% ethanol. Picking was done at low power and the residues, insects, etc., were retained under alcohol. Mollusks were later segregated by species, identified, enumerated, and stored in labeled, smaller bottles. After identification and counting, all material, including substrate, insects, etc., were returned to the original sample bottles and stored in the original preserving fluid. Representative samples were retained for some taxa for possible later DNA analysis.

The most comprehensive and accurate literature sources, rather than necessarily the most recent, were used to identify mollusks, with extensive western U.S. collections and recent specialist periodical contributions supplemented by Deixis Consultants and Environmental Assessment Services. Early collections in this region are thoroughly covered by Henderson (1929, 1932). Unfortunately, changes in taxonomy have rendered most older identifications incorrect or obsolete. The recent summary of Idaho's freshwater malacofauna by Frest and Johannes (2001) was very useful here also, as was a summary prepared for the State of Washington but unpublished (Frest 1990, unpub.; last revised 2004). Many recent and historic publications on Washington freshwater mollusks are referenced in Frest and Johannes (2002a).

Particular emphasis was placed upon several historic summaries for information on the past and present freshwater mollusk fauna of the Hanford Reach specifically and of the Columbia system generally. Results of many past surveys are reviewed and discussed in Newell (1998) and TNC (2003). The oldest and perhaps most comprehensive survey was the dredging operation conducted by Davis and Cooper (1951). These authors reported a variety of species, including some not subsequently noted. As they were not professional malacologists, some identifications may be doubtful. Subsequent studies by Washington Public Power Supply System (WPPSS)

aquatic biologists include (WPPSS 1977, 1984, 1986). Wolf (1976) also contains valuable information on mollusk aquatic benthos. Neitzel and Frest (1989, 1992, 1993a, 1993b) also has Hanford Sites as well as some 200 sites scattered through the Columbia system. Recently Newell (1998) and TNC (2003) added more recent results for sites in the Hanford Reach. Frest (2005) records results from some Methow, Okanogan, and mainstem Columbia sites. Most of the WPPSS sites, as well as those of Neitzel and Frest were done by placement of rock baskets, much as in the present study. A history and discussion of this method is given in Jacobi (1971) and Mason et al. (1967). Neitzel and Frest discuss methodology of their studies in Neitzel and Frest (1993a, b). The Newell (TNC) studies were done by walking the shoreline (Newell 1998). None of these references is completely comprehensive. For example Neitzel and Frest (1993b) is not referenced by Newell, and additional benthic mollusk references are given therein (e.g., Page et al., 1979; Page et al., 1982) and WPPSS (1985, 1987). Only a few of these provide synoptic lists of collected taxa. This can be extracted from Davis and Cooper (1951). Faunal lists for each site are provided in several references, notably Neitzel and Frest (1993b), Newell (1998, 2003 Table 8.1), TNC (2003, Table 1) and the present study. A critical review of older data is necessary to serve as a background for these results. Newell was also not a malacologist and did not claim comprehensive knowledge of the subject. Consequently his appraisal is valuable but contains various taxonomic inconsistencies and omissions. These are reviewed here. Taxonomic procedure is discussed below. Each taxon is summarily discussed followed by a historic and current overview of the Columbia mainstem and Hanford Reach malacofaunas, as well as recent results. The primary focus is on Table 8.1 of Newell (2003).

Fluminicola nuttalliana is presumably *F. nuttallianus* (Lea, 1838) of Hershler and Frest (1996). This species was retained as valid by Hershler and Frest (*op. cit.*) and recognized as genotype of *Fluminicola* (Carpenter, 1854). As revised by Hershler and Frest, this species is recorded from only two sites in the lower Willamette River, Oregon both in the vicinity of Willamette Falls and Oregon City. These areas are much modified from historic conditions and Hershler and Frest were unable to locate living or preserved material. They regard the species as likely extinct and other records as erroneous. Commonly recorded from the Hanford Reach and other sites is *Fluminicola columbiana* (Pilsbry, 1899). This taxon was the subject of particular study by Neitzel and Frest, and also noted from either the Reach or other areas in several WPPSS studies, among others. Under the name *columbiana*, Neitzel and Frest (1993b) provide tables of pre-1988 and 1988-1993 sites for this taxon, as well as a review of museum records, many from the Hanford Reach (Neitzel and Frest 1993b, Tables 1-4). They also provide collection information and faunal lists for sites for this taxon collected from 1988 to 1991 (Neitzel and Frest 1993a, Appendices A.1 and B.1). The taxon receives special attention as it was a candidate for Federal listing. They noted only two large populations remaining, in the lower Methow and Okanogan Rivers in Washington State. Smaller populations were noted from the lower and middle Snake Rivers; lower Salmon River, Hells Canyon, a few scattered sites in the lower Columbia and a population in the Hanford Reach and Grand Ronde River. At least six Hanford Reach sites were noted (see Table 1, Appendices A.1 and B.1 in Neitzel and Frest 1993b). Hershler and Frest (1996) in their revision of the genus noted perhaps 18 extant sites of which 6 were in the Hanford Reach. Their Figure 11 and text provide a useful summary of historic sites, unfortunately not always distinguishing between historic and extant locations. These authors synonymize *columbiana with F. fuscus* (Haldeman, 1841) and some sites for *F. hindsi* (Baird, 1863), indicating that many historic sites were now extirpated. This is a cold-water stenothermic taxon,

most often found in large rivers and lower reaches of larger tributaries, but not in springs. Sites have large liths, stable substrates, few or no macrophytes, and strong flow. When present, this species is often abundant at a site dominant in terms of numbers.

Fluminicola virens (Lea, 1838) is cited in some WPPSS reports and reported widely in the literature. As revised by Hershler and Frest (1996), a taxon of the lower Willamette River, Oregon and the lower Columbia from The Dalles to the estuary only (Figure 14 of Hershler and Frest 1996; hence not likely to have occurred in the Hanford Reach, even historically.

Flumincola sp. likely refers to various undescribed species in the Columbia system and elsewhere. Undescribed taxa are known to be found in the mainstem lower Columbia (likely two taxa), the Willamette, lower Salmon Okanogan, middle Snake, and other ricer systems. For references to some of these see Hershler and Frest (1996) and Frest and Johannes (1995b), as well as Frest and Johannes (2003). The most recent anatomical treatment of *Fluminicola* is that of Hershler and Frest (1996) referenced in Newell (1998, 2003) but not used by him either for current or historical records. Prior to this Taylor (1966) had reviewed the genus and treated it as a synonym of the European *Lithoglyphus*. A position he continued to espouse in Taylor (1985). This evaluation was reviewed and rejected by Hershler and Frest's more comprehensive review (*op. cit.,* 1996) on cladistic and anatomical grounds. Taylor (1982) argued that the type species was best regarded as *F. columbiana* since *F. fuscus* (Haldeman, 1843) was a homonym of *Lithoglyphus fuscus* in Europe and hence that *F. columbiana* (Pilsbry, 1899) was the next available name. This analysis was repeated in Taylor (1981, 1982) and Taylor and Smith (1971) and also accepted by Clarke (1976, 1981) and Beetle (1989). This argument was also decisively refuted by Hershler and Frest (1996), who regarded several older Lea names as valid. *Fluminicola* and *nuttaliana* as valid genotype by original designation of Carpenter (1864). This treatment has been reiterated recently by Hershler (1998) and accepted also by Turgeon et al. (1998). The first DNA-based phylogeny (Hershler and Frest in press) also uses similar reasoning and reached the same conclusions. Reference in Newell (1998) and TNC (2003) to *Lithoglyphus* sp. are hence taken to refer to *Fluminicola* sp.

According to Newell (1998, Table 8.1) pleurocerids belonging to th genus *Goniobasis* have been ascribed to the Reach, notably *G. plicifera* by Davis and Cooper (1951). Validly documented records are not known. More properly, western pleurocerids would be placed in the genus *Juga*, a well-accepted western endemic genus (e.g., Taylor 1966; Burch 1989; Turgeon et al., 1988, 1998). This genus has been reported from the Columbia system (e.g., Taylor 1975, 1981, 1985: Burch 1989; Turgeon et al., 1998) but has limited distribution in it. Historic records document it in the mainstem lower Columbia only as far as The Dalles and in tributaries possibly to Union Gap, Washington and to one spring in the Grand Coulee area (Taylor 1975). Thus reports from southern Canada (e.g., Clarke, 1981) and from the Hanford Reach (Davis and Cooper 1951; Newell 1998; TNC, 2003) are very doubtful and unsubstantiated by archived specimens. T. Frest's collections have also not turned up any members of the family Pleuroceridae in the Hanford Reach or further north in the system than the Yakima area, even though the family is prominent in the Lower Columbia and its major tributaries.

Two species of the pulmonate genus *Gyraulus* have been ascribed to the Hanford Reach, *parvus* and *vermicularis* (Newell 1998). The latter is not currently accepted as a valid taxon in Turgeon

et al. (1998) but treated as a synonym of *parvus*. Newell (1998) also lists a *Limnaea sp.*, evidently an invalid misspelling for *Lymnaea*. The same reference also lists *Lymnaea stagnalis*, cited from WPPSS sources. As far as the lead authors of this report are aware, the ascription to the Hanford Reach, of this shallow water warm habitat taxon is in error. Like much of the recent malacological literature Newell (1998) uses both *Parapholyx* and *Vorticifex* as valid names for this distinctive western endemic pulmonate genus. Burch (1989) and Turgoen et al. (1998) are followed in using Vorticifex for extant taxa, but regard the matter as unsettled. In any case, the taxon if the mainstem Columbia River in the Hanford Reach has been termed either *V. effusus effusus* or *V. effusus costata* (Hemphill, 1891). Revision of this genus is needed: the belief is that Columbia specimens of this coldwater form are better ascribed to *effusus costata* than to the Sacramento River form. Populations in the middle Snake River are also problematic. In the lower Columbia and lowermost Willamette River another taxon, *V. neritoides* (Baker, 1945) was present historically (Taylor 1985); but that taxon, also a cold water form, is likely extinct. The primary authors of this report agree with Taylor (1985 and unpub.) that this species is valid and likely occurred historically from The Dalles to the Columbia River mouth as well as in the Willamette River below Oregon City but it has likely been extirpated. Ascription to the Reach as in Davis and Cooper (1951) are not likely valid and the name *V. effusus neritoides* is a *nomen nudum*. References in Newell (1998) and TNC (2003) to *Parapholyx* sp. and *Vorticifex (Parapholyx)* sp. are likely *V. effusus costata*. References in WPPSS reports (1977, 1984-86) to *Planorbis* sp. could refer either to *Gyraulus parvus* or to *Menetus callioglyyptus:* the genus *Planorbis* itself is very unlikely to occur in the Reach. *Physa* sp. as listed in Newell (1998) and elsewhere most likely refers to *Physella gyrina* as interpreted by Taylor (2003). *Physa nuttalla* of Newell (1998) is likely a misspelling. Newell (1998) suggests that what is referred to in Davis and Cooper (1951) and PNL (1979) is *nuttalli* (Lea, 1864) but this taxon is regarded by Taylor (2003) as a synonym of *Physella gyrina*. It is uncertain about the occurrence of this taxon in the Reach and prefer to interpret most physids found there as *Physella propinqua*, a taxon accepted as valid by Taylor (2003) as well as by Burch (1989) and Taylor (1993).

Two forms of the probable non-native genus *Radix* have been reported from the Reach by Newell (1998) Neitzel and Frest (1993) and others (e.g., Davis and Cooper 1951). References to the European ear snail *R. auricularia* are believed valid, but references to *R. japonica* as in Davis and Cooper (1951) are believed mistaken. This species has not been reliably reported, even as an introduction, anywhere in the U. S. (Turgeon et al., 1998). *Stagnicola apicina* has been reported from the Reach by Davis and Cooper (1951) and by WPPSS (1977, 1984 to 1986) as well as by Neitzel and Frest (1993a, b) and herein. Also reported previously is *Stagnicola nuttalliana* (Newell 1998; Davis and Cooper 1951; WPPSS 1977, 1984-86). This taxon, though having a long history of usage (Taylor 1975) is currently unrecognized (Burch 1989, Tugron et al., 1998). It is not clear from Taylor's bibliography which taxon was intended in the various historic usages, so old records were not evaluated.

Among the freshwater limpet or limpet-like tax ascribed to the Reach the only one to merit Newell's(1998) scrutiny is the lancid *Fisherola nuttalli*, like *Fluminicola columbianus* a one-time nominee for possible Federal listing studied in detail in the Reach, notably by Coutant and Becker (1970) and surveyed for comprehensively more recently by Neitzel and Frest (1992 1993a, b). This cold-water form lacks both lungs or gills (ctenidia) and respires directly through a highly vascularized mantle (Baker, 1925); it has long been thought to be a sensitive species and

useful habitat indicator (Baker, 1925). Available phylogenetic data is sparse, although genetic studies in progress indicate that most historic lancid taxa are valid but that Fisherola may be the only Columbia Basin taxon aside from the rare spring form, the undescribed Banbury limpet, a Federally Endangered middle Snake species (D. Campbell, pers. comm., 2006). This taxon may represent a third lancid genus (S. Clark, pers. comm., 2006). *Fisherola nuttalli* has been divided into at least three subspecies, but these may not be valid DNA entities (D. Campbell. pers. comm., 2006). This taxon has been regarded historically as common in the Hanford Reach, one of about six areas thought to harbor large populations and historically a major source of museum material (Neitzel and Frest 1993b) provide a useful table of historic (pre-1988) sites for the shortface lanx (Table 2, *op.cit.* review historic museum collections (*op. cit.*, Table 3) and provides data on 1888-1993 collections (Table 4, op. cit. also Appendix B.2). Hanford Reach material is among the most historically prominent (Neitzel and Frest 1993b). Despite common historical records, this species did not turn up in the Reach recently (discussed below). Warm water limpet species such as *Ferrissia sp.*, were found fairly prominent members of the Reach malacofauna despite a dearth of historic records (see below).

Results of past Hanford Reach bivalve studies are also tabulated and compared in Newell (1998) and TNC (2003). As above, these require careful review and are only accepted for species with validated records, preferably in museum collections or samples examined by professional specialists. Thus the apparent *nomen nudum (fide* Taylor 1975*) Anodonta compressum*, ascribed by Newell (1998) and TNC (2003) to WPPSS collections is ignored here. *Cyclas fluminea* is an obsolete synonym of *Corbicula fluminea*, as implied by Newell (1998) and TNC (2003) and similarly discounted. The authors of this report accept long-time literature consensus and accept *M. falcata* as valid and replace references to *M. margaritifera.* Like Smith (2001) f*alcata* was accepted as the major U. S. species of *Margaritinopsis*. Taylor (1981) is followed regarding *Anodonta nuttalliana* as a synonym of *A. californiensis*, *contra* (Nideau et al., 2005). *Pisidium* sp. is unfortunately not further identified. *Pisidium columbiana* (Sterki, 1917) is one of a number of late Sterki species not generally accepted in the literature (e.g., Taylor 1975). Barring documented material, this is a doubtful species, although it is most likely a synonym of *Musculium raymondi* or *lacustre.* As such this warm-water generally lacustrine taxon has recently been reported from Columbia sites by Frest (2005) and could now occur in the Reach. The bivalve site listings and ascriptions are discussed below.

Generally, Burch (1989) was used as a standard for identification of the snails and limpets (gastropods); but this was sometimes modified due to later periodical literature changes or by reference to Taylor (1981), a better standard in some instances for western freshwater mollusks. A combination of Burch (1975a) and Clarke (1981) was used for sphaeriid (fingernail clam) identifications. For unionids, Taylor (1981) and Burch (1975b) were primarily used; the terminology for *falcata* follows Smith (2001). Note that it is not recommended to use the derivative Nideau et al. (2005) for northwestern freshwater mussels. Endings and common names were those of Turgeon et al. (1998). A few modifications of both were needed to accommodate very recent changes. References for these are in Frest and Johannes (1995a,b, 2001) or are referred to individually below.

This report is arranged as follows. The fauna as a whole and by sample, where needed, is discussed in a short summary section. This is succeeded by discussion of individual taxa. A

penultimate summary table covers each sample's specific contents, counts, and comments. The references constitute the final section.

2.0 MOLLUSK FAUNA BACKGROUND

2.1 WESTERN U. S. MOLLUSK DIVERSITY

Western U. S. freshwater mollusk faunas have in the past generally been considered to conform to general ecologic models as regards diversity and distribution in streams. Thus, in particular, two models of overall diversity and distribution have been widely employed. Particular emphasis has been placed upon the Intermediate Disturbance Hypothesis (IDH) (for summary and discussion see Connell 1975, Petraitis et al., 1989) and the more commonly seen River Continuum Hypothesis (RCH) (for discussion, see Vannote et al., 1980; Minshall et al., 1985; Cushing et al., 1996). For recent attempts to redefine the latter and apply it world wide, see Cushing, Cummings, and Minshall, in Cummings et al. 2006; see also Fisher in Cummings et al., 2006, for western U. S. applications. See also (Stanford, Hauer, Gregory and Snyder, in Behnke and Cushing 2005) for the Columbia Basin and (Shozawa and Rader, in Behnke and Cushing 2005) for Great Basin streams for comprehensive overview. Basically, as pointed out by Frest and Johannes (2002a) both hypotheses lead to similar conclusions as regards overall benthic biodiversity. This would imply relatively low diversity for headwater (lower order), increasing downstream to a maximum in higher order stream sites, but declining as the stream mouth is approached. By this criterion, the Hanford Reach should show a maximum of benthic freshwater mollusk and other invertebrate taxa for the system, with a downstream decline as regions with more uniform conditions are encountered. Areas with large or frequent disturbance should be low in diversity as should areas with relatively low habitat heterogeneity (for more detailed discussion, see references previously cited). However, data system-wide for freshwater mollusks is limited. In the most thorough such study, that of the Upper Sacramento system (Frest and Johannes 1995b, 1997, and references therein) different conclusions were reached (Frest and Johannes (2002a). These authors concluded that aggregate diversity for western stream mollusks was reached in crenon (lower order), especially spring sites. They generalized from this and other system–wide surveys that this pattern was typical of western U. S. freshwater mollusks generally. For example, there are relatively few amniphile mollusk endemics (there are some) and the great majority of endemics or precinctives, especially in hydrobiids, were crenophile specialists, often confined wholly to headwater cold springs. Among the best documented are the numerous *Pyrgulopsis* species, now known to be over 100, in the largely crenon springs of the U. S. Great Basin (see Hershler 1998). Only a few of the 53 species described in that monograph are amniphiles and stream habitats are not typical for the genus. This is also true for *Tryonia* and related taxa (Hershler 1999) and is proving true also for the Great Basin peripheral genus *Fluminicola* (Hershler et al., 2007). For detailed discussion, see Frest and Johannes (2002b).

Frest and Johannes (2002b) offer several hypotheses to explain the pattern found in western U.S. stream mollusks. Western streams are relatively young geologically and drainage patterns have been subject to drastic change due to major geomorphic and geologic disruptions. Western

rivers have been disrupted by vulcanism, including effects of massive lava flows, ash falls, and mountain range origin and growth. Unlike the eastern situation, in which rivers such as the Mississippi may have flowed in much the same area since the Cretaceous, many western drainage systems are thought to be composites and to have had major relatively recent origin and rearrangements. As well as vulcanism and mountain building, major changes due to changes in sea level and glaciation have been widely noted. Particularly significant timings would be the Late Tertiary (Pliocene) and Pleistocene, and would include extensive flooding modifications such as those bought about by the Bonneville and Lake Missoula floods. In the eastern U. S. only a relatively small area was affected by continental glaciation, but such changes did produce profound effects. In this region, both vulcanism and other tectonic changes, as well as Pleistocene glacial effects would have been profound. Some authors, such as Taylor (1966, 1985; Taylor and Bright 1987) prefer to emphasize Pliocene drainage changes, while others (e.g., Hershler and Liu 2004a,b) emphasize Pleistocene events.

2.2 COLUMBIA SYSTEM HISTORY

Both glaciation and tectonic considerations are specifically important in the Columbia drainage system history. According to Taylor (1985; see also Taylor and Bright 1987; Taylor 1988b) the mainstem Columbia is a composite system. The lower Columbia has been affected by flood basalts of several ages from the Miocene to the Holocene, mostly originating in southeastern Washington and Northeastern Oregon. Tectonic accretion was extensive along the Washington-Idaho border in particular and in the current Blue Mountains of Oregon and Washington. The extensive Snake River system of Washington and Oregon may be a relatively recent addition to the Columbia system, having formerly into the Late Pliocene flowed into the Klamath or Sacramento systems perhaps as far down as the current Feather River (Taylor 1985). The Hells Canyon connection of the Snake drainage to the Columbia according to Taylor may date from the Pleistocene. The Snake drainage assumed its present configuration only after the extensive Bonneville Floods of the Late Pleistocene.

There is extensive molluscan evidence for many of these drainage changes. During the Late Pliocene much of the middle Snake was occupied by the extensive Lake Idaho, which had a massive endemic fauna of perhaps 75 out of 90 freshwater mollusks derived from several quite disparate habitats. Most of the Lake Idaho endemics became extinct during the Pleistocene, but a few taxa persist to the present. Among these are the five listed middle Snake River taxa, *Taylorconcha serpenticola*, *Pyrgulopsis idahoensis*, *Physa natricina*, *Valvata utahensis*, and *Lanx* n.sp. (Banbury lanx). Thus, there is a high diversity area in the Snake system far above the lower river course. Frest and Johannes (2001) list numerous taxa for the Snake system and other areas in Idaho. According to these authors there are numerous undescribed taxa in the upper Snake system, particularly in southeastern Idaho. Hershler (1998, 1999) has described many new freshwater molluscan taxa from the Great Basin portions of the drainage, especially in Nevada, Idaho, and Utah. Over 50 of these are springsnails in the genus *Pyrgulopsis*. However, a scattering of other forms have been described from the Snake and Great Basin drainages, together with a few other taxa scattered over the system, including most recently an additional species of the hydrobiid genus Taylorconcha from the Owyhee River in Oregon (Hershler et al., 2006). Many others remain to be described (see e.g., Hershler et al., 2007 and Frest and

Johannes 2002b). Despite the current incomplete status of present knowledge of Columbia system mollusks, enough published information is available to allow review of the system fauna historically (prior to human disturbance) and currently and of the two best known regions, the Hanford Reach and middle Snake River, to outline distant past, recent past, and current faunas.

The work of Taylor (1985, 1988a) and Taylor and Bright (1987), is particularly emphasized here as to provide especially useful regional reviews. According to Taylor the Columbia is a composite system, which has had major modifications during the Pliocene and Pleistocene. Perhaps most significant of these were the addition of the middle and upper Snake system, first in the late Tertiary, probably in the late Pliocene, and likely again in the late Pleistocene. Both of these events probably occurred in conjunction with the creation, development, and eventual dissolution of late Pliocene-Pleistocene Lake Idaho. This area currently lies entirely in the Washigntonian freshwater molluscan Province as the term is used by Frest and Johannes (2001). Early on, it is possible that such more typically Klamath Province taxa as *Lanx* were added to the middle Snake system. According to Taylor (1985) certain other taxa such as *Vorticifex*, are relatively recent additions to the Snake and Columbia system. This may explain why *Vorticifex* at present occurs in the lower Columbia and a few major tributaries only as far up stream as the Grand Coulee and is then disjunct to the middle Snake. It is possible that such forms were introduced to the Columbia *via* diverse tributaries such as the Oregon Deschutes River, leaving forms such as *Vorticifex* and *Anodonta wahlametensis* disjunct from Klamath (California) sites. In a similar fashion such forms as the *pleurocerid Juga* may have reached the lower Columbia, where it remains isolated to this day. *Juga* are widespread in much of the Klamath Province but scattered in the Columbia system, reliably reported from the Columbia Gorge and Deschutes but not found in the mainstem Columbia as far as the Hanford Reach (except the undocumented report by Davis and Cooper 1951). In general, the Columbia mainstem has a diverse Washingtonian Province malacofauna. Most diverse is the lowermost Columbia, which had such relatively widespread genera as *Vorticifex* and *Fluminicola* as typical forms, but also had a suite of half a dozen or more taxa restricted to that reach, as well as the more common forms. Examples cited by Taylor include *Physella columbiana*, in his usage restricted to the Columbia below Wallula Gap. Burch (1989) uses a less restrictive definition to extend this taxon to Idaho and Wyoming: Taylor (1985) states that the upper system taxon is another species. *Vorticifex neritoides* (probably found originally from The Dalles to the mouth of the Columbia R.), as well as *Vorticifex effusus*. *Fluminicola nuttalliana* and *virens* as well as *F. columbiana* and *F.* n. sp. and *Anodonta wahlametensis* as well as *A. californiensis* would provide other examples. Thus the basal Columbia from roughly The Dalles to the estuary likely were most diverse. *Juga plicifera* and possibly *silicula* or other forms may fall into the same group, which would have totaled about 25 taxa. The Hanford Reach would have had a fairly diverse malacofauna of about 20 taxa; excluding the basal Columbia endemics. Common to both would be a group of species including *V. effusus costata, Fluminicola columbiana*, and *Fisherola nuttalli* notably. All of these taxa share some common features of habitat or ecology. Basically, the unmodified Columbia was regionally an area of solid substrate (rock as bedrock and extensive riffles, bars, and other exposures), free and fast flow, relatively strong currents, little mud or soft substrate, few macrophytes, high dissolved oxygent, low temperature. Taxa favoring such sites are particularly characteristic of undisturbed, oligotrophic habitats throughout the region, and have been termed cold water taxa (cold water stenotherms) in Idaho (Frest and Johannes 2001, 2002a, b). Most high diversity western freshwater mollusk genera, such as *Pyrgulopsis, Fluminicola*,

and *Juga* deploy their species mostly in specific lineages specialized for such habitats, either in cold springs or near amniphile equivalents, such as areas with groundwater influence. Proceeding up the system, the mainstem fauna becomes generally less diverse, until such biogeographically unique areas as the Middle Snake system, or the Great Basin or otherwise spring-rich regions are encountered. In these areas diversity may be fairly low but regional diversity is much higher than in sites lower in the system (Frest and Johannes 2002b). As emphasized by Frest and Johannes (2002b), this is contrary to ecological theory predictions but appears typical for western stream mollusks. Examination of regional compilations such as Newell (1998) and TNC (2003) make it evident that there has been very major change in malcofaunas in the mainstem Columbia and specifically in the Hanford Reach historically. In earlier results eg., WPPSS collections and those of Neitzel and his associates (e.g., Page et al., 1979; Neitzel and Frest 1992, 1993a,b), the most frequently encountered forms were nearly all cold-water forms such as *Fluminicola* spp., *Vorticifex effusus*, and *Fisherola nuttalli*. Specifically, such taxa were community dominants and many historical records for these tax were from Hanford sites (see Neitzel and Frest 1993a, b; Hershler and Frest 1996). Such sites often had a diversity of less than 10 taxa, nearly all of which were cold-water stenotherms. In old collections, as noted by Newell (1998, 2003), the dominant native bivalve was *Margaritinopsis falcata*. The more recent collections are very different (see Newell 1998, 2003).

These sites collectively have a freshwater mollusk richness of roughly 19 species, 16 gastropods and 3 bivalves (2 sphaeriids or fingernail clams, both native; and 1 non-native corbiculid) (by long convention, e.g., as in Counts [1985, 1986] and Turgeon et al. [1998], this is identified as *Corbicula fluminea*). There is some possibility of a second corbiculid in the Columbia (see discussion in Hillis and Patton 1988 and Frest and Johannes 1995a, for two examples); but pending definitive work only *fluminea* is recognized here. The presence of *Fluminicola* n. sp. in this set of samples can not be confirmed because of limited material: but this taxon has been reported from the Okanogan River in Washington before (Neitzel and Frest 1993b; see also discussion in Frest and Johannes 1995a, 2003).

This compares very favorably with historically reported malacofaunas of the Hanford Reach, which were generally low in diversity (see Table 8.1 in Newell [1998], but compare also Appendix B.2 in Neitzel and Frest [1993b]). However, the additional taxa reported both by Newell (1998, 2003) and by Neitzel and Frest (1993b) are largely warm-water taxa more typically reported from reservoir or back-water sites. Thus while diversity at the sites and other recently collected sites is historically high, the newly or recently reported taxa are warm-water, impoundment, or reservoir forms historically rare regionally, particularly from historically dominant habitats. No live *Fisherola nuttalli* or *Fluminicola Columbiana* were found. Also no live *Margaritinopsis falcate* were found. Current results thus parallel those of Newell (1998, 2003) and contrast considerably with those of Neitzel and Frest (1993a, b) for the Hanford Reach, even though they are some of the same sites. There thus appears to be a major molluscan faunal turnover in the Reach in recent years, with cold-water stenotherms particularly affected, specifically the former candidate taxa *F. columbiana* and *F. nuttalli*. Some cold-water taxa persist in the Reach, particularly *Vorticifex effusus*, and some *Fluminicola*, such as *F.* n. sp. Newly reported is *Pyrgulopsis* n. sp. 6, a cold water form likely closely related to the listed *P. idahoensis* (Hershler and Liu 2004a,b). Judging from Newell (1998, 2003, Table 8.1) the changeover may have occurred relatively recently, perhaps since 1993. Neitzell and Frest

(1993b) noted the increasing rarity of *F. columbiana*, but still found *F. nuttalli* common at several Reach sites.

There are some parallels with changing conditions in the middle Snake, which has recently been declared water quality limited by the United States Environmental Protection Agency. In that stream also, cold water stenotherms, including listed taxa, seem to have been disproportionately affected by damming and impoundment, nutrient enhancement, agricultural and piscicultural pollution, water warming and other factors (Frest and Johannes 2001). In that stream also species formerly present, such as *F. columbiana* and *Fisherola nuttalli,* are now of rare occurrence, though still likely persisting (Frest 2006 *pers. comm.*). *Fluminicola spp.* and *Vorticifex effusus* are the most persistent of the cold-water forms (Frest pers. obs., 2005-2006). Exact importance of the many individual factors is hard to evaluate . Exact tolerances for most of the cold-water forms have not been established. One possible exception is the freshwater limpet *Fisherola nuttalli.* This taxon was extensively studied, both in natural and laboratory settings, by Coutant and Becker (1970) (see also Coutant 1991). In their studies, the maximum temperature tolerated for successful reproduction by lab populations was 17.3°C and no natural populations were noted in areas that warmed over 17.0°C. It is quite possible that similar tolerances affect populations of *Fluminicola columbiana* and similar native taxa in the Columbia system. In any case, essential extinction of three of the most commonly encountered (historically) freshwater mollusk taxa of the Hanford Reach is notable and worrisome. Reduction in *Margaritinosis falcata* is region wide and probably also correlates with changes in the region's ichthyofauna: the host fish for glochidial attachment in this unionid are mostly salmonids (Nideau et al., 2005). Changes for *F. columbiana* and *F. nuttalli* must be due to other factors.

The level of mollusk richness compares favorably with freshwater mollusk faunas previously reported from the Methow, Okanogan and Columbia by Taylor (1993), Neitzel and Frest (1993a,b) and from the Columbia system generally by Neitzel and Frest (1993a,b), and Frest and Johannes (1995, 2003, 2005). Note, however, that most previously reported faunal lists for Methow and Okanogan sites are for more typical mainstem habitats (i.e., with more flow, colder water, coarse substrate, etc.). Collection methods between this suite of samples and those in earlier works may differ also, as discussed below. This level of alpha (site) diversity may be low compared to the lower portions of the Columbia River itself and some lower tributaries, such as the Willamette and Chehalis rivers. Frest and Johannes (2003) noted at least 14 taxa from a small number of Lower Columbia River sites, with some river sites having 8 or more and perhaps over 2 dozen likely overall. The Columbia River in the relatively swift Hanford Reach commonly has a site diversity of about six taxa; but the overall diversity is similar (Frest and Johannes 2005). More common in the Reach are such taxa as *Vorticifex effusus* (absent locally), *Fluminicola* spp., and *Fisherola nuttalli* (Neitzel and Frest 1993a, b; Frest and Johannes 2005). The Lower Columbia frequently has a still more diverse mollusk fauna, sometimes including the genera *Pyrgulopsis* (native), *Potamopyrgus* (non-native), and others such as *Juga* (native) and *Vorticifex* (native). Other springsnail genera are present in springs (e.g., *Amnicola*, *Colligyrus*, *Pristinicola*) or spring-fed tributaries even this high in the system. Lower major tributaries also may be more diverse as regards gastropods, due to the presence of such genera as *Vorticifex* and *Juga*. Occasionally, lower parts of the system will have additional taxa in some of these genera;

or taxa present in the upper system in Washington, such as *Physella* (*P.*) *propinqua propinqua*, will be replaced by congeners, e.g., *Physella* (*P.*) *columbiana*.

Note that the lower mainstem Columbia river may have up to six native taxa that are now extinct or nearly so, such as *Fluminicola nuttalliana*, *Vorticifex neritoides*, *Physella columbiana*, etc. Similarly, lower mainstem river sites often have a larger sphaeriid fauna. On the other hand, smaller headwater streams high in the system collectively have higher diversity, due to the presence of numerous local endemics. This diversity pattern differs from that of eastern and midwestern streams, as noted by Frest and Johannes (2002a), and is particularly true of freshwater rissooids and pleurocerids. Locally, examples are known from *Colligyrus* and *Fluminicola*. Finally, diversity patterns of a complex system, such as the Columbia, are defined as much by drainage history as by current conditions. Hence, such upstream tributaries as the Idaho Snake River or its tributaries, such as the Owyhee River, Oregon, may have very substantial endemic swarms, locally very high headwater diversity, and overall much higher freshwater mollusk diversity (Frest and Johannes 1995b). But some genera, such as *Juga*, may never or only very long ago ranged as high in the system as the sample streams. There is little evidence, for example, of *Juga* occurring either recently or historically north of the Hanford Reach, despite statements by Clarke (1981).

These sites share habitats with low flow velocity much of the year; comparatively fine substrate; and seasonally warm water as compared to unimpounded habitats or unobstructed mainstem river sites. Interestingly, site diversity is essentially identical for all three streams (about nine taxa each) despite differences in stream order or flow volume. This is rather low for the mainstem Columbia. It is likely ascribable to the predominant reservoir or backwater habitats and such factors as rather soft, muddy substrate; presence of macrophytes; and slow flow. Most noticeably absent or rare are taxa which prefer oligotrophic, cold, high velocity, hard substrate habitats, such as the limpet (*Fisherola nuttalli*) and the hydrobiid pebblesnail (*Fluminicola fuscus*). These two were once under consideration as federal listing candidates (the latter under the name *Fluminicola columbianus*). Sites were reported for both from the mainstem Okanogan and Methow, but not from the adjoining Columbia, where the two are largely absent from the impoundment habitats above the Hanford Reach. *Fuscus* is common in some parts of the Methow, while *nuttalli* is more sporadic. *Fluminicola*, including one undescribed taxon and *fuscus*, is more common in typical rocky habitats in the Okanogan, where *nuttalli* may also be locally common (Frest and Johannes unpub. obs, 1988).

In such muddy habitats as these, the introduced corbiculid *C. fluminea* is very abundant; this taxon is very spotty in mainstem Methow and Okanogan habitats. Sphaeriid bivalves are much less often encountered in rocky river habitats; but sphaeriids like *Pisidium dubium* and *Pisidium variabile* more common. Backwater and reservoir habitats are more likely to have *Sphaerium striatinum* and *Pisidium compressum*. The now widely introduced *Radix auricularia* (Taylor 1981) was quite common in these sites and in lakes and impounded areas elsewhere in the system; the big-ear radix is seldom seen in more free-flowing rivers, especially smaller rivers such as the Okanogan and Methow. The western U. S. endemic planorbid *Vorticifex* was not seen at these sites. Lower in the system, this genus may be a site dominant (Frest and Johannes 2005); but it may not occur much to the north of the Hanford Reach except in a relict

site in the Grand Coulee. This is more for historical biogeographic reasons than for lack of suitable habitat.

The presence of large unionid mussels in some abundance is notable, especially as most sample sites have rather full ontogenies and very young specimens. Many Washington populations of all species show few signs of recent reproduction, making these sites somewhat exceptional. This is especially true of *Margaritinopsis falcata*, which uses salmonids as larval (glochidial) hosts. Distribution of this taxon is now very sporadic in eastern Washington. Note that this mussel was found only at Methow sites. The most commonly encountered mussel was *Gonidea angulata*, particularly in the Okanogan. This taxon is fairly widespread in eastern Washington. Also noted were common *Anodonta kennerlyi*. Floaters (*Anodonta*) generally prefer lake, backwater, or reservoir habitats and are quite uncommon in the mainstem Methow or Okanogan. As well, there are rare in unimpounded stretches of the Columbia but more widespread in impoundments. The Lower Columbia has three *Anodonta*: *oregonensis*, *californica*, and *wahlametensis* (*sensu* Taylor 1981; *nuttalliana* as used by Burch 1975b). Along the Cascades axis, especially on the east side, *A. kennerlyi* may be locally common in lakes and impoundments. Scattered throughout interior Washington are occasional finds of *Anodonta californiensis*, sometimes considered a sensitive species, this taxon has been noted from the Okanogan previously (e.g., Neitzel and Frest 1993b; see also Frest 1992 and Frest and Johannes 1992).

A striking feature of the samples from many of these sites is the lack of a complete ontogeny for about half the taxa. This is not likely to be a result of the collection method, except for less common and very fragile taxa, such as the freshwater limpets. Most likely, most taxa are basically opportunistic colonizers in backwater, slack water, or impounded habitats. Colonies may thus be relatively impersistent for many. Among gastropods, examples would include *Physella propinqua* (many physids thrive in the habitats sampled; but this taxon is a river form), *Fluminicola*, and *Fisherola*. On the contrary, certain sphaeriids, such as *Sphaerium striatinum* and *Pisidium compressum*, plus gastropods such as *Fossaria* (*Bakerilymnaea*) *bulimoides* and *Radix auricularia*, may thrive in such habitats. Many unionid juveniles are found as young examples in such habitats also, even though adults may prefer more flow and harder substrates. Note that both gastropod and bivalve taxa do not have full ontogenies at some or all sites (see Tables below), in similar proportions. Note also that the full possible range from live to long-dead is seldom noted for any taxon, even those having either a very short life span or a rather long life. Unionid life spans range from roughly 20 years (*Anodonta*) to 60 years (*Gonidea*) to perhaps 120 years (*Margaritinopsis*). Gastropods (most NW forms) and sphaeriids seldom live for more than a single year. The non-native *Corbicula* is mostly present as young specimens (only a few sites have very young or large specimens). In contrast, Hanford Reach populations often have most over 1.5 cm in maximum dimension. Species abundance curves are mostly strongly left-skewed for all sites, with one taxon or another overwhelmingly abundant and several rather rare. This also suggests short-lived opportunistic colonization for most taxa. However, similarity of species composition in most sites suggests that chances for colonization must be frequent for most taxa.

Note that this material apparently was collected by dredging. This method is particularly appropriate for softer substrates, especially for larger and more robust forms, such as unionids.

It can be overly rough for small and delicate forms, such as *Ferrissia*. It is also not terribly effective on coarser substrate. Efficacy can also vary according to exact method of dredging used. Suction dredging in particular can be hard on smallest and most fragile forms, tending to cause them to be underrepresented in the resultant collection. The method of sieving may also cause differences in results. In general suction and other dredging can give a good representation of the recent and near to present time fauna. Live collection by hand may be most effective in determining the present fauna, especially on coarser substrates. Of primary importance is to compare results done by the same methods. Most historic collecting in this area was conducted either by drag, rather then suction, dredging, by hand (several methods); or by a combination of both methods. Some old collections done by Neitzel or Neitzel and Frest (1993 a,b) were done by placement of rock baskets which begin with quantities of sterile river gravel or cobbles anchored to the substrate and left for colonization for various periods then recovered and counted. This has proved a very effective collection method provided rock baskets can be left long enough (generally 6 months or more) both for freshwater mollusks and for other invertebrates). It is possible that such taxa as *Ferrissia californica* were better represented in previous collections. The small total number of specimens noted and at only a couple of sites was slightly surprising and might be an artifact of collection method. This reservation might not apply to more robust taxa, which make up most of the malacofauna. Note that *F. californica* was among the most common taxa in this study. Discussions of the advantages and drawbacks of the rock basket collecting method are found in Neitzel and Frest (1993 a,b).

In summary the study sites have a moderately diverse freshwater mollusk fauna, perhaps of up to 20 species (18 native). It is one characteristic of slack water, reservoir, backwater, or impoundment habitats of Washington and of limited parts of the Columbia system in other states, (e.g., Idaho). There are relatively few endemic or sensitive taxa, perhaps because most of these are characteristic in Washington of more oligotrophic, cold, hard-substrate, swift flowing streams or springs. *Fluminicola fuscus* and *Fisherola nuttalli*, sometime candidates for listing status, are rarely present and live in very few instances, despite occurrence in the more typical stream habitats of the Methow and Okanogan rivers. Freshwater mussels of three taxa in currently reproducing populations are present in one or all of the study streams (Methow; Okanogan; adjacent Columbia River). The possibly Sensitive *Anodonta californiensis* was not encountered at the study sites. This portion of Washington sometimes has species suggestive of eastern and central U.S. drainages, presumably relicts of glacial drainage patterns. These do not appear present at the study sites. See Frest and Johannes (1995 a,b) for discussion. Population sizes and abundance patterns suggest mostly short-lived, opportunistic colonizations of possibly frequently shifting and somewhat unstable habitats. Unionid populations may be more persistent, though, than those of smaller bivalves and gastropods under such conditions.

3.0 COMMENTS ON TAXA FOUND AT 100 AREAS AND 300 AREA SITES

The current set of Hanford Reach sites are compared and contrasted with those of Frest (2005). The current set consists of 27 sites located as indicated in Figure 1. This includes 10 sites

located in the 300 Area with a prominent uranium plume, 10 sites located in the 100 Areas with a prominent chromium plume, 2 sites placed in the 300 reference area for comparison to the uranium sites, and finally 5 additional reference sites placed upstream of the Hanford Reach proper (i.e., near the Vernita Bridge on Highway 240). Species richness and the number of Special Status species are presented in tabular form in Table 1. Special Status species are *Fluminicola* n. sp., *Pyrgulopsis* n. sp. 6 of (Frest and Johannes 1995b) and *Vorticifex effusus costata*. *Fluminicola fuscus* and *Fisherola nuttalli* was originally intended to be included with the gastropods and *Margaritinopsis falcata* among the unionid bivalves based upon past occurrence in the Hanford Reach, but no live sites for these species were found in this study. This contrasts with past studies through 1994 which found live examples of these taxa (see Newell 1998 and TNC, 2003, Table 8.1 for examples). Note that these taxa were formerly dominants at many Hanford sites, including some that overlap with the current set, see Neitzel and Frest (1993b, Tables 1 and 2 and Appendices A.1 and B.1) for examples. In the current set, species richness ranged from a low of 1 to a high of 12. Average diversity was approximately 7 taxa (Table 1). Species richness of special status taxa ranged from 0 to 2 sites, averaging 1 taxon. A complete faunal list and numbers and distribution in basket samples are specified in Table 2. A minimum of 12 definite species of gastropods were noted, with 3 not always identifiable to the species level, all but 1 native species. Two bivalves were noted, the nonnative *Corbicula fluminea* and native sphareiids, which were too small to identify to species but could represent both *Sphaerium* and *Pisidium*.

Abundances varied drastically from sites to site but were often quite low (Table 2 and Figure 2. Abundance of special status species was similarly variable and often low (Table 2 and Figure 2). Abundances in Methow and Okanogan River sites were higher on average, as was average species richness (Frest 2005). Note also that live or recently dead specimens of *Fluminicola fuscus*, *Fisherola nuttalli*, and *Margaritinopsis falcata* though not typical or dominant were found at a few Methow and Okanogan or nearby mainstem Columbia sites in the 2005 set (Frest 2005). Note that all of the special status species are coldwater stenotopes, with one exception (*Pyrgulopsis* n. sp. 6, a near relative of *P. idahoensis*), occur also in the middle Snake River in Idaho. These taxa have also seen similar reductions in abundance and distribution in Idaho (Frest and Johannes 2001) in recent years. Many of the same taxa as noted in Table 2 as more common forms also occur in the Snake. Some taxa, like *Pyrgulopsis* n. sp. 6 are newly recorded herein or first recorded in recent years (e.g., in Frest 2002, 2005), so that overall Hanford Reach mollusk diversity here is often higher than recorded by previous authors (e.g., Newell 1998, Table 8.1.; Neitzel and Frest 1993b, Table B.2; Davis and Cooper 1951). However, as noted above there is no reason to accept many taxa in Davis and Cooper, and good reason to doubt identity or occurrence or both for many. What can be stated with certainty is that in recent collections some former dominants are no longer found, even at the same sites. Moreover, most of the species loss (perhaps all) takes place among coldwater stenotopes. Near or possibly complete loss of sensitive forms, such as *Fluminicola fuscus*, *Fisherola nuttalli*, and *Margaritinopis falcata* are particularly notable as is the fact that loss occurs among both gastropods and bivalves. In effect major faunal turnover has occurred, dating from perhaps 1994. Added species are notably almost all warm water widely distributed forms, with the exception of *Pyrgulopsis* n. sp. 6 not reported from the system until 1988 (Frest and Johannes 1995a). As can be seen from Table 2 and Figure 2 most of these warm water forms are

present in low numbers. Dominance is most frequent in *Fossaria bulimoides*, *Ferrissia californica*, or *Vorticifex effusus*.

To explain differences in richness, abundance and distribution, it was found helpful to provide further site information. Site diversity and abundance for special status taxa is provided in Table 3. This table also records porewater specific conductivity (in uS/cm) as a measure of groundwater or spring influence at some sites. Similarly, measures of riverbed conditions provided used three common measures (Table 3). Substrate lith size is given as two measures, dominant substrate particle size 1-4, with 4 being largest and average in mm and the subdominant particle size, also ranked into 4 classes, with size in mm. Substrate embeddedness also ranked 1-4, with 4 being most embedded, to give a better feel for fine sediment presence. Finally, macrophyte abundance is also estimated on a 1-4 scale, again with 1 indicating the low end of the scale. In a rough sense, large liths, low mud or silt, low macrophyte abundance and low conductivity might be expected to correlate with original Hanford Reach conditions, and hence with abundance and diversity of coldwater forms, though not necessarily with overall species richness of the current fauna. Habitat and substrate preferences of the current and past malacofauna species are given in Table 4. These are specified in terms of soft vs. hard substrate (mud vs. cobble or boulder) association with macrophytes, cold vs. warm water preferences and general characterization as either stenotopes (for any reason) vs. more eurytopic forms. This same sort of breakdown was specified recently for Idaho freshwater forms (Frest and Johannes 2001, 2002a) and has been used by Idaho and the Federal Environmental Protection Agency to characterize Idaho freshwater mollusk species.

Generally speaking there are correlations of certain taxa groups with these criteria. High species richness sites, particularly for coldwater stenotopes, tend to correlate with sites with low embeddedness, large lith size, and low macrophyte abundance (Tables 2 to 4). Also there do appear to be correlations with swift water flow and with groundwater influence. In general, sites with the highest species richness, even of warm water taxa, tend to have most of these conditions prevalent. A few sites, however, appear to deviate from this pattern. Specifically sites U4 and Cr4 through Cr9, are unexpectedly low in diversity. Reference sites are usually moderate to high in diversity with the exception of Ref14. These sites were revisited in late January 2007 to try to account for diversity differences. The original characterizations appear correct; and it appears that local differences in habitat characterization or groundwater differences are not responsible.

Overall, these sites are comparatively low in species richness, particularly in coldwater or sensitive forms. In Figure 2 it is notable that abundance at most sites was quite low, even if the taxon was present. High densities for each were noted only at a few sites. For example, high numbers of *Vorticifex effusus* were seen at U3 and C9, high numbers of *Pyrgulopsis* n. sp. 6 were noted at U2 and U8. *Fluminicola* n. sp. was unusually common at U3 and C9. Notably high peaks for two or more were noted at U3 and C9. These densities give some idea of maximum achievable density, even if seldom reached at the sites. The most ubiquitous cold water form by number of sites with the taxon was clearly *Vorticifex effusus* (Figure 2). Rather similar results have been seen at middle Snake River sites, in which only this taxon appeared to remain either abundant or broadly distributed at many sites currently. *Pyrgulopsis* n. sp. 6 is particularly erratically distributed and is only abundant at one site (Figure 2). This species is mostly noted from uranium sites low down in the Reach and often absent from Reference sites and those with

chromium. Since many of the sites in these areas seem suitable there is no ready explanation for current absence from them. It is speculated that this species not formerly noted from the Lower Columbia and first reported in 1988 (Frest and Johannes 1995a) may be a recent migrant to the Columbia. It is possible that this species is currently expanding its range in the Hanford Reach and may simply not yet have migrated to the more northern sites. Based upon the habitat assessments and substrate features, it is also estimated the expected species richness at the Hanford sites (Table 5). Expected species richness in gastropods was nearly double what was actually noted, and bivalve richness would also have been expected to be higher.

Reasons for the generally low species richness and abundance are probably multiple and vary between taxa. Current rarity of *Margaritinopsis falcata* could be related to reduced salmonid diversity and abundance in the Hanford Reach, as this taxon is known to utilize specific salmonids as hosts for the larval form, the glochidial stage see references in Nideau et al. (2005). This sort of change appears to be widespread in the Columbia system. Several of the gastropod taxa share similar life styles (they are cold water stenotopes preferring strong water velocities, cold water temperatures, high dissolved oxygen, low macrophyte abundance, and large substrate particles. All of these features were once typical of the Hanford Reach but are now much less widespread. Detailed tolerances for these taxa, in particular *Fluminicola fuscus*, *Fisherola nuttalli,* and similar forms (see Table 4) have not been investigated in detail except for *Fisherola nuttalli*. Lab raising and detailed collection at sites with measured parameters by Coutant and Becker (1970) indicate that this species may not reproduce successfully in water warmer than 17.3°C. These same authors noted live *Fisherola* populations only at sites with water temperatures never exceeding 17.0°C. Many of the cold water forms may be similarly affected or have similar habitat tolerances. In any case, turnover in the Reach has been dramatic and may be relatively recent or have reached a crisis point only since the work of Neitzel and Frest (1993a, b). These authors reached the conclusion that *nuttalli* and *fuscus* did not justify Federal listing throughout their range at the time of their 1988-1993 studies. Minimally, loss of Hanford Reach populations suggest that these taxa and others need resurvey. At present, the Hanford Reach fauna is relatively nondiverse even as compared to some lower Columbia River sites (e.g., Frest 2003, 2005). The current Hanford Reach mollusk fauna may be a relatively unstable mix of old natives, some newer native and nonnative forms, and several recent warm water migrants. It is unlikely that the faun is at equilibrium, and further changes, including expansion of such pest introduced taxa as *Potamopyrgus antipodarum*, introduced into the Columbia system in recent years, is to be expected.

These collection sites in the Methow and Okanogan and adjoining middle Columbia sites (Frest 2005) have an overall diversity of roughly 20 species, 10 gastropods (9 native) and 10 bivalves (5 sphaeriids or fingernail clams, all native; 3 native unionids; and 1 non-native corbiculid. This compares favorably with freshwater mollusk faunas previously reported from the Methow, Okanogan and Columbia by Neitzel and Frest (1993a,b) and from the Columbia system generally by Neitzel and Frest (1993a,b) and Frest and Johannes (1995b, 2003, 2005). Species summaries here are derived principally from Frest and Johannes (1995a,b, 2001-2003), and have been updated here. For species not mentioned below and for background, see these works and others listed in Section 5.0. Frest and Johannes (2001) is a good starting place.

4.0 SPECIES DESCRIPTIONS AND LIFE HISTORY CHARACTERISTICS

4.1 GASTROPODS

Potamopyrgus antipodarum (Gray, 1834) New Zealand mudsnail

The most difficult Columbia freshwater forms are the small Rissooidean groups, as used here including as separate families the Hydrobiidae (including the genera *Potamopyrus* [nonnative here]-and the native *Pyrgulopsis*), Lithoglyphidae (*Flumninicola)*, and Amnicolidae (native *Colligyrus*) as their distribution is currently changing rapidly. In particular, the New Zealand mudsnail (*Potamopyrgus antipodarum*), is invading the mainstem Columbia River from coastal settings possibly founded around 1996 and from the better established Snake River (Middle Snake River sites, established *circa* 1984. This taxon may have been found in Hells Canyon and Asotin County, Washington by 2006. It has been present in Crooked Creek in the Owyhee River drainage for some time. Finds must be preserved properly to establish identity and to avoid confusion with native hydrobiids, such as *Pyrgulopsis* n. sp. 6 of Frest and Johannes (1995a). As far as the authors of this report are aware currently *P. antipodarum* has penetrated about 120 miles upstream from the Coast. Hence material from the Hanford Reach would represent a considerable, though possible range extension.

Pyrgulopsis sp. (*Pyrgulopsis* n. sp. 6 of Frest and Johannes 1995a,b) Springsnail

This taxon has a short but complex history in the Columbia system. It was not noted by classic collectors such as Henderson or Hemphill, nor found in historic museum collections. However, it was noted by U. S. Fish and Wildlife Service personnel near Bonneville in deep pools in 1988. Since then it has been found at 6 to 12 lower Columbia sites, roughly from the mouth to Rufus, Oregon. Very recently it has been noted from the Hanford Reach by Tiller et al. (2004) and now has been shown to be moderately widespread there (see Table 3). It was not noted there by previously studies such as those of Neitzel or Neitzel and Frest (1993a,b). The shell morphology and some anatomical features are similar of those of the listed species (Endangered) *Pyrgulopsis idahoensis,* which has caused some confusion. In an attempt to clarify the status of *Pyrgulopsis* n. sp. 6 and some similar species such as *P. idahoensis*, *P. robusta* and others sometimes placed in the subgenus *Natricola* (Gregg and Taylor 1965). The U. S. Fish and Wildlife Service has recently sponsored genetic work on these taxa.

Relevant papers are Hershler and Liu (2004 a,b), Liu and Hershler (2005). The general result is that *robusta, idahoensis*, and n. sp. 6 should be regarded as a single clade (*Natricola*) and possibly a single species, while forms such as *intermedia* and the Teton River taxon are independent taxa.

Fluminicola fuscus (Haldeman, 1847) ashy pebblesnail

This is a former federal listing candidate under the name *columbiana*. It is currently rare in several streams in the eastern part of the state and in the lower-upper Columbia River; see Neitzel and Frest (1993a,b) and Hershler and Frest (1996) for distribution summary. See also Newell (1998, 2003) for past records Not found in western Washington except in the Lower Columbia. Recorded previously from both the Methow and the Okanogan Rivers. Name as revised by Hershler and Frest (1996). This taxon is mostly found live in oligotrophic, hard-substrate, swift-flow habitats, mostly in larger streams.

Fluminicola undescribed species unnamed pebblesnails

About seven undescribed taxa known over the state; range from common to highly restricted; see Frest and Johannes (1995a,b, 2003, 2005) for details. One taxon in this group was reported from Okanogan R. by Frest and Johannes (1995a,b); see also Neitzel and Frest (1993a,b). *Fluminicola* is likely to be a large and complex genus when revision is completed (Hershler and Frest 1996). See forthcoming paper by Hershler et al. (in press) for details. The genus as now defined is likely not monophyletic. Many taxa are spring snails; but Washington undescribed taxa are mostly amniphiles. Ecology is much like that for *fuscus* but some taxa may occur in smaller streams than is typical for *fuscus*. Material found in this study is mostly juveniles belonging to a single undescribed taxon. *F. fuscus* has been reported previously from the mainstem river, including the Hanford Reach, mostly under the synonym *F. columbiana*. For cladistic anatomic treatment see Hershler and Frest (1996). For DNA phylogeny see Hershler et al. (in press).

Fisherola nuttalli (Haldeman, 1841) shortface lanx

Former federal listing candidate; rare in the Lower Columbia and several eastern Washington streams; see Neitzel and Frest (1993a, b) for state and regional distribution. This large limpet is found mostly on boulders and cobbles in clear, cold, swift and large streams. Reported historically from the Methow and Okanogan, Columbia, and a few other Washington streams (Neitzel and Frest 1993b). Note that other freshwater limpets, e.g., *Ferrissia*, are characteristic of backwater or lake habitats. Reported from the Hanford Reach previously but not common there currently.

Physella (P.) propinqua propinqua (Tryon, 1865) Rocky Mountain physa

Found over the state but mostly found on the east side and perhaps most characteristic of streams. Reported previously from the streams. Note that an endemic physid, *Archiphysa lordi* in current taxonomy, has been reported from the Okanogan previously (Taylor 2003). This taxon has not been found to live in Washington. It is likely a big-stream form; and its type locality and occurrence in the Okanogan may be doubtful. The table below sometimes does not list *Physella* to species. The authors believe only one taxon is present in these recent collections; but most specimens were too immature to conclusively identify multiple taxa from this group.

*Menetus (M.) callioglyptus (*Vanatta, 1894) button sprite

Note that most sources regard this taxon as *Menetus opercularis* (Gould, 1847); but Taylor (1981) argues that that name applies mostly to snails from Mountain Lake, California and now extinct. This is a widespread taxon in western Washington, northern Oregon, and northwestern California in a variety of habitats. It is usually uncommon in larger streams. Abundant in western and northern Washington and sporadic in the southeast; usually termed *opercularis* but true *opercularis* rare in Washington. This taxon is found in a variety of habitats, mostly in shallow water, and including springs and lakes a well as streams. Substrate preference is similarly broad. Uncommon in the samples.

Ferrissia californica (Rowell, 1863) fragile ancylid

Taylor (1981) believes that this name precedes *Ferrissia fragilis* for the common North American river limpet. This taxon is uncommon in the West and seems to prefer low-elevation, rather warm and eutrophic habitats, often with low flow (especially in lotic settings) or is found in similar lentic habitats, such as ponds and lakes. Note that another form often confused with this, *Ferrissia rivularis* (Say, 1817) (creeping ancylid), is more often found in flowing habitats. For mainstream Columbia habitats the species term *fragilis* or *californica* are preferable of *rivularis*. This form may be present also in the Okanogan and Methow in rocky, swift-flow areas in some abundance. Sporadic over the state but common taxon in these rock basket Hanford Reach Columbia River sites.

Fossaria (Bakerilymnaea) bulimoides (Lea, 1841) prairie fossaria

In Washington, in and west of Cascades and throughout the Columbia system. This taxon is found in a variety of forms, often correlated with habitat and possibly ecophenotypic. The stout and blunt form, often thin-shelled, seems more typical of lacustrine habitats. Often found in relatively shallow water and in muddy substrates: other forms may prefer rocky substrate and deeper water or shorelines. A single form is common in the large-river samples.

Fossaria (F.) obrussa (Say, 1825) golden fossaria

Found rather generally in Washington. This group of *Fossaria* species (as used by Burch 1989) ranges in habitat from springs to rivers but is often found in rather shallow water and along shorelines (including both streams and lakes), generally with soft substrate. Not common but occasionally present in the big river samples.

Stagnicola elodes (Say, 1821)

This relatively large freshwater form occurs in one form or another over most of the country. The taxonomy is as yet poorly understood, and many local forms have been named (Burch 1989). It is very sporadic in Washington, Oregon, and California. It usually occurs in strongly eutrophic settings but is quite generalized in habitat. Not previously reported from the Columbia and seemingly quite rare there. Often confused with other widespread *Stgnicola*, such as *catascopium*, or local endemics like *apicina*.

Stagnicola apicina (Lea, 1838)

Mostly found in the western United States, especially in the lower Columbia River, but also reported from part of the Upper Snake River in Wyoming and in the lower peninsula of Michigan according to Burch (1989). Common as an endemic form in the lower Columbia mainstem. Rare this far up the Columbia.

**Radix auricularia* (Linnaeus, 1758) big-ear radix

Introduced; sporadic over the state; abundant in impounded areas of the Columbia but also in ponds and quiet areas ranging up from horse troughs. Note that it is common in this set of sites but seldom reaches full size. Not a significant pest species.

Gyraulus (Torquis) parvus (Say, 1817) ash gyro

Over the state; but perhaps found more commonly on the east side. West of the Cascades, may be replaced often by the form termed *G. vermicularis*. Occurs in a variety of habitats, ranging from spring runs to large rivers and including lentic sites just as well. Most frequent in quieter areas with muddy substrate and along shorelines. Fairly widespread in third set of samples.

4.2 BIVALVES

While bivalves were not likely to be found often using this study method, those known from the mainstem Columbia and nearby tributaries are included here for completeness. A few Corbicula were found in the basket samples as noted as were a few mostly unidentifiable sphaeriids (generally shell-less juveniles).

Margaritinopsis falcata (Gould, 1850) western pearlshell

Now sporadic over state; formerly ubiquitous on west side and common on east side. Many populations show little evidence of reproduction. This mussel generally uses salmon and trout as glochidial host species. As a result, now somewhat restricted, especially in interior Washington. Reported formerly from the Methow and Okanogan; but not recently found live in typical

Okanogan habitats. Seldom seen in the mainstem Columbia currently. This taxon prefers fast water, cold and clean, and gravel, cobble, or boulder habitat and is seldom seen in lakes. May occur in streams of almost all sizes except the smallest. This taxon is usually seen as *falcata*; but Smith (2001) cites cogent reasons for separating *falcata* from other U.S. margaritiferids.

Gonidea angulata (Lea, 1839) western ridgemussel

The western ridgemussel is an isolated taxon not closely related to other U.S. unionids but rather with Asian affines. It occurs in eastern Washington sporadically, in the Columbia and major tributaries (streams only); in western Washington in the Chehalis drainage and Lower Columbia. Found mostly in creeks and rivers of all sizes; rarely in lakes or reservoirs unless with substantial flow. This amniphile, filter-feeding taxon can live on firm mud substrate as well as on more coarse materials (which are more typical). More pollution-tolerant than some unionids; but still absent from highly polluted areas and places with unstable or very soft substrate. The host fishes for the glochidia of this species are unknown.

Anodonta californiensis (Lea, 1852) California floater

This mussel is widely but sporadically distributed in eastern Washington but is much less common west of the Cascades in Washington. The species may well be composite (Taylor 1981; Frest pers. obs.). It is currently rare in the southwestern states and southern California, which includes the type locality, and is under study for possible listing in Arizona and California. The species appears to be declining seriously in Washington, including in the Columbia proper. It has been found previously in the Okanogan and in this stretch of the Columbia (Tiller et al., 2004): but kennerlyi and oregonensis are more frequently noted, especially in impounded and muddy area.

Anodonta oregonensis (Lea, 1838) Oregon floater

The mussel termed the Oregon floater was first described from the lower Columbia River but appears currently uncommon to rare in it. It is found over much of Washington and Oregon, although seldom in large numbers. Along the Cascade axis, it seems to be replaced by *Anodonta kennerlyi*, and is more often found in streams than that largely lentic taxon.

Corbicula fluminea (Müller, 1774) Asiatic clam

Bivalves of the widespread Order Corbiculida were native to North America for a considerable time, becoming extinct on the continent relatively recently (Taylor 1988a,b). The recent introductions seem to have begun in the Columbia in the last 75 years; and this corbiculid is now widely distributed across the continent. Taxonomic status of *Corbicula* in North America is still somewhat cloudy, with claims for at least two taxa. Most recently, morphological differences within the introduced populations have been suggested to result from origin as separate clones,

currently of uncertain number, distribution, and status. If more than one taxon is present, the morphological range seen in the Columbia is great enough to suggest that two taxa may be present. Personal observations suggest that most populations may be mixes of two clones belonging to one species. But specimens from this area differ from typical Lower Columbia material. Despite the early introduction (early 1900's), *Corbicula* is only moderately successful as an invader in Washington and Oregon, especially as compared with, say, the Tennessee Valley. It is a pest species with considerable economic impact in the central and eastern states. Lower Columbia populations are more dense than those here; and local specimens are consistently smaller than those of the Hanford Reach or lower Columbia River Corbicula is not very successful in smaller streams except in exceptional circumstances, and in the warm, nutrient-rich Yakima River.

McMahon (1999, fig. 22.2; 2001, fig. 11) seems to restrict *Corbicula* to the Lower Columbia in Washington. However, the species also occurs commonly in the state to the Idaho border and in the Snake River in Idaho, as well as in Utah (Counts, 1985, 1986). The Idaho records date to at least 1966 (Hanna, 1966; Frest and Bowler 1993; Frest and Johannes 2001). McMahon (1999, p. 317) has it that *Corbicula* in North America likely derives from a single introduction in northeastern Washington. Presumably, he means southwestern Washington, i.e., the lower Columbia River, as Counts (1986) says. This now seems unlikely, given the widespread occurrences, sometimes in isolated drainages.

Musculium raymondi (Cooper, 1890) western lake fingernailclam

Most often seen in the literature as *Musculium lacustre* (Müller, 1774) (lake fingernailclam); Taylor (1981) argues that the western form is distinct. As this common name would suggest, this taxon is most often found in lentic habitats, or at least in low flow situations. It has been found elsewhere in the lower Columbia proper; but not yet here. *Lacustre* is a frequently seen taxon in eastern and central North America in warm-water, soft-sediment situations but *raymondi* is rather uncommon in the West (Frest and Johannes 2001). Here, it id often a lake form and occasionally an impoundment or reservoir (or similar habitat) form.

Sphaerium striatinum (Lamarck, 1818) striate fingernailclam

Scattered over the state; most common north and to the east of the Cascades. This large sphaeriid is often found in disturbed, somewhat muddy and eutrophic habitats.

Pisidium (Cyclocalyx) casertanum (Poli, 1791) ubiquitous peaclam

As the common name implies, this is a very frequently encountered sphaeriid species, perhaps the most widespread native mollusk in the northern hemisphere. It is rapidly spreading currently south of the Equator a well. Very frequent in a wide variety of habitats in the West. For examples, see Frest and Johannes (2001). Note, however, that the species is quite rare in the sites analyzed here.

Pisidium (Cyclocalyx) compressum (Prime, 1852) ridgebeak peaclam

This small taxon is found widely in both the western and eastern portions of the U. S. It is perhaps less common in the West, particularly in the formerly ubiquitous cold oligotrophic habitats once prevalent but now much reduced in areal extent. It appears here to be much more common in slow or slack water habitats.

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Table 1. Species Richness Reported at 100 and 300 Areas Study Sites

SITE ID	Site Species Richness	
	Special Status Species	All Species
U1	2	10
U2	2	12
U3	2	8
U4	0	1
U5	1	6
U6	2	8
U7	2	4
U8	1	7
U9	2	9
U10	2	8
Cr1	0	7
Cr2	0	7
Cr3	1	6
Cr4	0	2
Cr5	1	8
Cr6	0	3
Cr7	2	6
Cr8[a]	ns	ns
Cr9	1	3
Cr10	1	5
300 Ref1	1	8
300 Ref2	1	8
Ref11	1	7
Ref12	1	6
Ref13	1	4
Ref14	0	2
Ref16	1	8

[a] basket not found

Table 2. Relative Abundance of Mollusk Taxa at 100 and 300 Areas Reference Stations

Species	Common name	Average #/basket						
		Ref 11	Ref 12	Ref 13	Ref 14	Ref 16	300-Ref1	300-Ref2
Corbicula fluminea[a]	Asiatic clam	0.0	0.7	0.0	0.0	0.0	0.3	0.0
sphaeriids	fingernail clams	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ferrissia californica	fragile ancylid	1.0	0.0	0.7	0.0	0.0	1.0	1.7
Hydrobiidae undet. juv.		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fluminicola n. sp.	unnamed pebblesnail	1.3	0.3	0.7	0.0	0.3	0.0	0.0
Potamopyrgus antipodarum? [a]	New Zealand mudsnail	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrgulopsis n. sp.	spring snail	0.0	0.0	0.0	0.0	0.0	1.0	1.0
Lymnaea sp.	pond snail	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Radix auricularia[a]	big-ear snail	0.0	0.0	0.0	0.0	0.3	0.7	0.0
Fossaria (B.) bulimoides	prairie fossaria	1.0	0.0	0.0	0.0	0.7	0.0	1.3
Stagnicola apicina	abbreviate pondsnail	0.0	0.0	0.3	0.0	0.0	0.0	0.0
Fossaria (F.) obrussa	golden fossaria	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Stagnicola elodes	marsh pondsnail	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Physella (P.) propinqua propinqua	Rocky Mountain physa	1.0	1.0	0.0	0.0	0.0	0.3	0.3
Planorbidae		0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyraulus (T.) parvus	ash gyro	3.0	0.7	0.0	0.0	0.0	1.0	0.0
Menetus (M.) callioglyptus	button sprite	1.7	0.0	0.0	0.0	0.0	0.0	0.0
Vorticifex effusus effusus	artemesian rams-horn	3.0	0.3	2.7	0.0	0.0	0.0	4.7
undet. gast.		0.3	0.0	0.0	0.0	7.0	0.0	0.0

[a] introduced species

Table 3. Relative Abundance of Mollusk Taxa at 100 and 300 Areas Uranium Plume Stations

Species	Common name	Average #/basket									
		U1	U2	U3	U4	U5	U6	U7	U8	U9	U10
Corbicula fluminea[a]	Asiatic clam	2.7	1.3	0.0	0.0	0.0	0.0	0.0	0.3	0.3	0.3
sphaeriids	fingernail clams	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Ferrissia californica	fragile ancylid	14.0	0.7	2.7	0.0	0.3	0.3	0.3	0.0	0.0	0.3
Hydrobiidae undet. juv.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fluminicola n. sp.	unnamed pebblesnail	0.7	1.0	27.7	0.0	0.0	0.3	0.3	0.0	0.3	0.3
Potamopyrgus antipodarum?[a]	New Zealand mudsnail	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Pyrgulopsis n. sp.	spring snail	0.0	5.0	3.3	0.0	1.3	0.7	0.0	30.3	3.0	2.0
Lymnaea sp.	pond snail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Radix auricularia[a]	big-ear snail	0.3	2.7	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.7
Fossaria (B.) bulimoides	prairie fossaria	19.3	5.7	0.3	0.0	1.0	2.3	0.0	0.7	0.0	0.0
Stagnicola apicina	abbreviate pondsnail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fossaria (F.) obrussa	golden fossaria	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0
Stagnicola elodes	marsh pondsnail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Physella (P.) propinqua propinqua	Rocky Mountain physa	1.0	0.3	0.0	0.0	0.0	0.3	0.0	1.3	0.3	0.7
Planorbidae		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gyraulus (T.) parvus	ash gyro	1.7	1.0	0.7	0.0	1.0	1.7	0.0	1.3	0.7	2.7
Menetus (M.) callioglyptus	button sprite	0.0	0.3	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0
Vorticifex effusus effusus	artemesian rams-horn	9.3	12.7	32.0	0.0	6.7	0.7	0.7	0.0	0.0	2.7
undet. gast.		0.3	0.7	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0

[a] introduced species

Table 4. Relative Abundance of Mollusk Taxa at 100 and 300 Areas Chromium Plume Stations

Species	Common name	Average #/basket									
		Cr1	Cr2	Cr3	Cr4	Cr5	Cr6	Cr7	Cr8[b]	Cr9	Cr10
Corbicula fluminea[a]	Asiatic clam	0.3	0.3	0.0	0.0	0.0	0.0	0.0	ns	1.0	0.3
sphaeriids	fingernail clams	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ns	0.0	0.0
Ferrissia californica	fragile ancylid	0.0	0.3	1.3	0.0	0.3	0.3	0.7	ns	0.0	0.7
Hydrobiidae undet. juv.		0.0	0.0	0.0	0.0	0.0	0.0	0.0	ns	0.0	0.0
Fluminicola n. sp.	unnamed pebblesnail	0.0	0.0	1.0	0.0	0.0	0.0	1.0	ns	7.0	2.7
Potamopyrgus antipodarum?[a]	New Zealand mudsnail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ns	0.3	0.0
Pyrgulopsis n. sp.	spring snail	0.0	0.0	0.0	0.0	0.3	0.0	0.0	ns	1.0	0.0
Lymnaea sp.	pond snail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ns	0.0	0.0
Radix auricularia[a]	big-ear snail	0.0	0.3	0.0	0.0	0.0	0.0	0.0	ns	0.0	0.0
Fossaria (B.) bulimoides	prairie fossaria	2.7	1.0	1.0	0.0	0.0	0.0	0.3	ns	0.3	1.0
Stagnicola apicina	abbreviate pondsnail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	ns	0.0	0.0
Fossaria (F.) obrussa	golden fossaria	0.0	0.0	0.3	0.0	0.0	0.0	0.0	ns	0.0	0.0
Stagnicola elodes	marsh pondsnail	0.3	0.0	0.0	0.0	0.0	0.0	0.0	ns	0.0	0.0
Physella (P.) propinqua propinqua	Rocky Mountain physa	0.0	0.0	0.3	0.0	1.0	0.0	0.0	ns	0.0	0.0
Planorbidae		0.0	0.0	0.0	0.0	0.0	0.0	0.0	ns	0.0	0.0
Gyraulus (T.) parvus	ash gyro	0.7	1.7	0.0	0.0	0.7	1.0	0.0	ns	0.7	0.0
Menetus (M.) callioglyptus	button sprite	0.3	1.0	0.0	0.0	0.7	0.0	0.0	ns	0.3	0.0
Vorticifex effusus effusus	artemesian rams-horn	1.3	0.7	1.7	0.0	3.7	0.0	1.0	ns	10.7	8.7
undet. gast.		0.0	0.3	0.3	0.0	0.0	0.0	0.0	ns	1.7	0.0

[a] introduced species
[b] basket not found

Table 5. Density (#/600cm^3) of Special Status Mollusk Taxa at Selected 100 and 300 Areas Study Sites (2 sheets)

SITE ID	Average Density (#/600cm^3) of Special Status Spp.				Porewater Specific Cond. (µS/cm)	Riverbed Conditions			
	Fluminicola n. sp.	*Fluminicola fuscus*	*Pyrgulopsis sp.*	*Fisherola nuttalli*		Dominant Substrate Class (1-4) and Size (mm)	Sub-Dominant Substrate Class (1-4) and Size (mm)	Substrate Embeddedness Class (1-4)	Macrophyte Abundance Class (1-4)
U1	0.7	0	3.7	0	273	1 (<6 mm)	2 (86 mm)	4	3
U2	1.0	0	30.7	0	341	2 (53 mm)	2 (92 mm)	2	3
U3	35.0	0	6.5	0	309	2 (30 mm)	2 (83 mm)	1	1
U4	0	0	0	0	347	2 (33 mm)	2 (73 mm)	1	1
U5	0	0	1.7	0	383	2 (49 mm)	2 (72 mm)	2	1
U6	0.3	0	0.7	0	333	2 (31 mm)	2 (86 mm)	1	1
U7	0.7	0	1.8	0	411	2 (79 mm)	3 (288 mm)	1	1
U8	0	0	80.0	0	428	2 (95 mm)	2 (58 mm)	3	2
U9	0.3	0	4.0	0	504	2 (32 mm)	2 (45 mm)	3	2
U10	1.7	0	2.7	0	497	2 (40 mm)	2 (18 mm)	3	2
Cr1	0	0	0	0	395	2 (37 mm)	2 (78 mm)	3	1
Cr2	0	0	0	0	236	2 (25 mm)	2 (115 mm)	3	2
Cr3	2.0	0	0	0	186	2 (50 mm)	2 (95 mm)	3	2
Cr4	0	0	0	0	298	2 (65 mm)	3 (260 mm)	2	1
Cr5	0	0	0.3	0	181	2 (35 mm)	2 (135 mm)	1	1
Cr6	0	0	0	0	390	1 (<6 mm)	2 (209 mm)	2	1
Cr7	5.3	0	4.0	0	162	2 (132 mm)	2 (40 mm)	1	1
Cr8[a]	ns	ns	ns	ns	149	2 (28 mm)	2 (73 mm)	1	1
Cr9	100.0	0	0	0	201	2 (65 mm)	2 (33 mm)	1	1
Cr10	44.3	0	0	0	178	2 (86 mm)	2 (45 mm)	1	1
300 Ref1	0	0	1.0	0	147	2 (36 mm)	2 (55 mm)	1	1
300	0	0	1.0	0	192	2 (95 mm)	2 (117 mm)	3	2

Table 5. Density (#/600cm^3) of Special Status Mollusk Taxa at Selected 100 and 300 Areas Study Sites (2 sheets)

SITE ID	Average Density (#/600cm^3) of Special Status Spp.				Porewater Specific Cond. (µS/cm)	Riverbed Conditions			
	Fluminicola n. sp.	*Fluminicola fuscus*	*Pyrgulopsis sp.*	*Fisherola nuttalli*		Dominant Substrate Class (1-4) and Size (mm)	Sub-Dominant Substrate Class (1-4) and Size (mm)	Substrate Embeddedness Class (1-4)	Macrophyte Abundance Class (1-4)
Ref2									
Ref11	1.3	0	0	0	236	2 (180 mm)	1 (<6 mm)	3	2
Ref12	0.7	0	0	0	164	1 (<6mm)	1 (<6 mm)	4	2
Ref13	1.0	0	0	0	137	2 (35 mm)	2 (150 mm)	2	1
Ref14	0	0	0	0	180	2 (130 mm)	2 (45 mm)	2	1
Ref16	0.3	0	0	0	153	1 (<6 mm)	2 (65 mm)	4	2

[a] basket not found

Table 6. Habitat Characteristics of Mollusk Observed on the Hanford Reach

Species	Common name	Substrate/Habitat Preferences						
		Soft	Hard	Macros	Cold	Warm	Stenotopes	Eurytopes
Corbicula fluminea[a]	Asiatic clam	x				x		x
sphaeriids	fingernail clams	x						
Ferrissia californica	fragile ancylid		x	x		x		x
Hydrobiidae undet. juv.								
Fluminicola n. sp.	unnamed pebblesnail		x		x		x	
Potamopyrgus antipodarum?[a]	New Zealand mudsnail	x				x		x
Pyrgulopsis n. sp.	spring snail	x	x		x		x	
Lymnaea sp.	pond snail							
Radix auricularia[a]	big-ear snail	x				x		x
Fossaria (B.) bulimoides	prairie fossaria	x				x		x
Stagnicola apicina	abbreviate pondsnail		x		x		x	
Fossaria (F.) obrussa	golden fossaria	x				x		x
Stagnicola elodes	marsh pondsnail	x				x		x
Physella (P.) propinqua propinqua	Rocky Mountain physa	x		x	x	x		x
Planorbidae	ramshorn snails							
Gyraulus (T.) parvus	ash gyro	x		x		x		x
Menetus (M.) callioglyptus	button sprite	x		x		x		x
Vorticifex effusus	artemesian rams-horn		x		x		x	
Fluminicola fuscus	ashy pebblesnail		x		x		x	
Fisherola nuttalli	shortface lanx		x		x		x	
Totals:		12	7	4	7	10	6	10

bold=species not found during this survey

[a] introduced species

Figure 1. Average Density (#/600cm^3) of Special Status Mollusk Taxa Observed at 100 and 300 Areas Study Sites

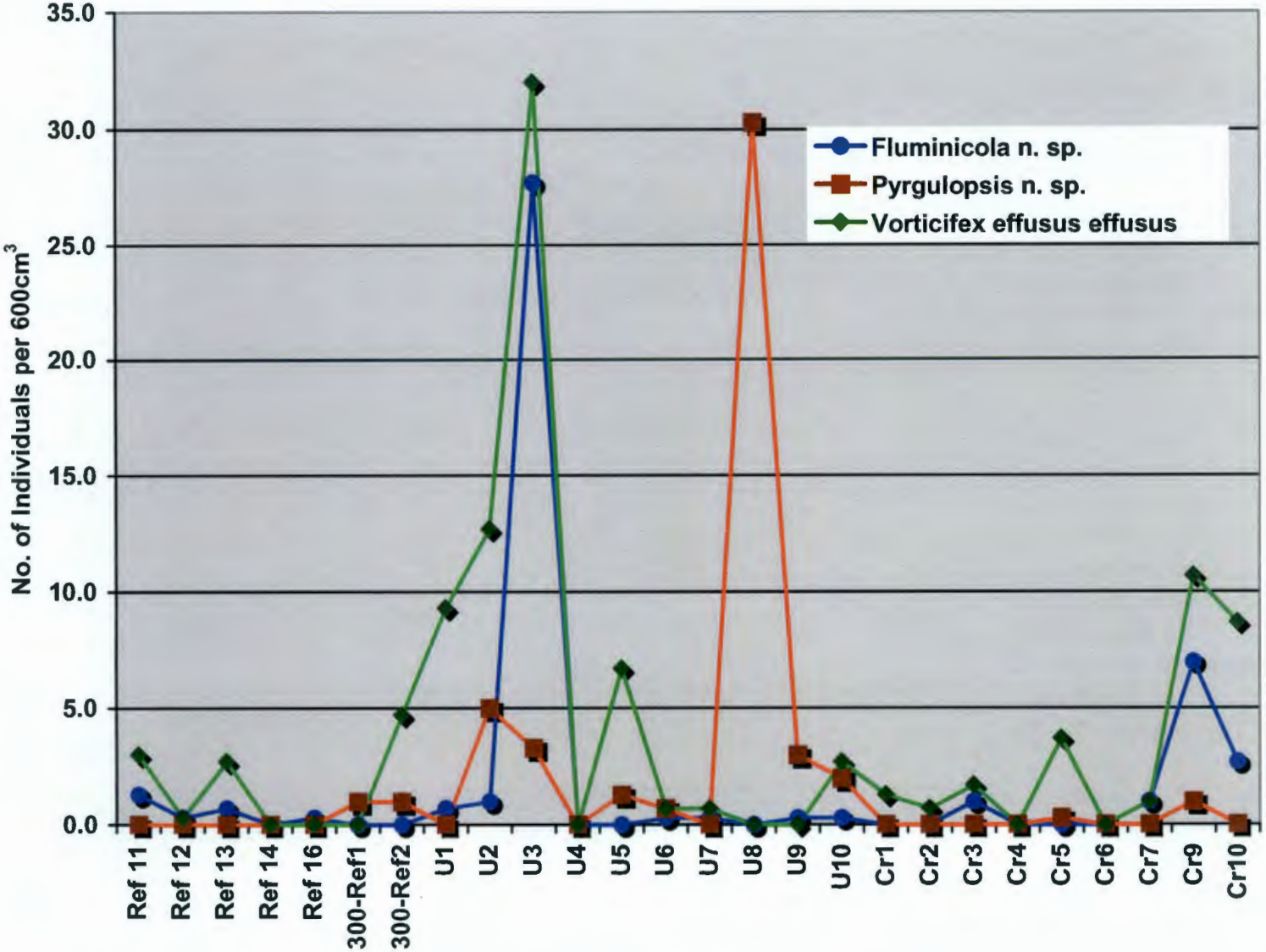
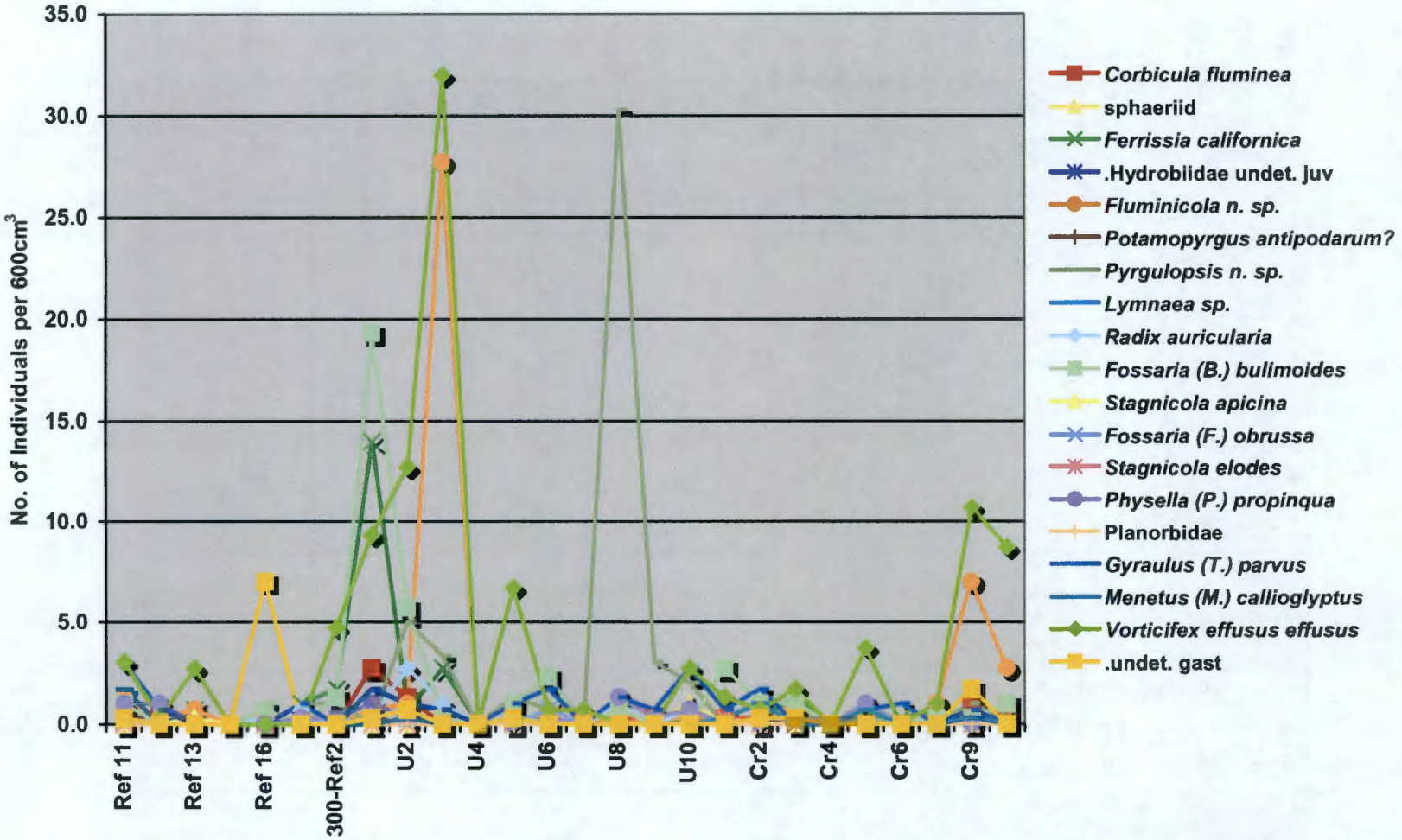


Figure 2. Average Density (#/600cm^3) of Mollusk Taxa Observed at 100 and 300 Areas Study Sites



APPENDIX G

MOLLUSK OBSERVATIONS FOR THE INTER-AREAS

Mollusk Observations Along the Hanford Reach of the Columbia River:

Inter-Areas River Corridor Baseline Risk Assessment

Habitat Assessment and Likelihood of Species Presence

Submitted by:

Terrence J. Frest and Edward J. Johannes - Deixis Consultants

&

Brett L. Tiller - Environmental Assessment Services, LLC

May, 2007

A letter report titled "Mollusk Observations Along the Hanford Reach of the Columbia River: River Corridor 100 & 300 Areas Risk Assessment Sampling" was prepared in February 2007 by Deixis Consultants. This report contained discussions of the mollusk fauna that had colonized artificial substrate baskets (3 replicates per site) placed at each of the twenty-seven 100 & 300 Areas Risk Assessment sampling locations during 2006. Onsite assessments were subsequently conducted during January 2007 to further evaluate the mollusk habitat conditions that yielded the mollusk communities observed on the rock baskets, paying particular attention to habitat conditions that may explain the absence of special status species at these sites. A discussion of these observations was provided in the letter report.

In addition, twelve aquatic study sites selected for the River Corridor Baseline Risk Assessment (RCBRA) Inter-Areas Ecological Risk Assessment Project were visited during this same time (late January, 2007) to assess the habitat characteristics for mollusk species known to be present on the Columbia River, paying particular attention to factors that may limit the presence or numbers of rare taxa such as the pebblesnail (*Fluminicola sp.*), short-face lanx (*Fisherola nuttalli*), and spring snail (*Pyrgulopsis sp.*). The RCBRA Inter-Areas study sites are shown in Figure 1.

The field surveys were conducted prior to having artificial substrate colonization basket data from these sites. As such, the Inter-Areas study site assessment of mollusk communities provided herein is limited to the author's knowledge of datasets collected as part of the RCBRA 100 & 300 Areas, other previously published records of mollusk observations along the Hanford Reach of the Columbia River, and their best judgment of the likelihood that a given species would be found at each of the sites based on the habitat characteristics observed there during January, 2007.

Table 1 provides a summary of key aquatic habitat characteristics measured at each of the RCBRA Inter-Areas investigation areas. Table 2 summarizes the likelihood of use by selected mollusk taxa for each of the 12 RCBRA Inter-Areas investigation areas. Appendix A contains the field record of observations associated with the site assessments.

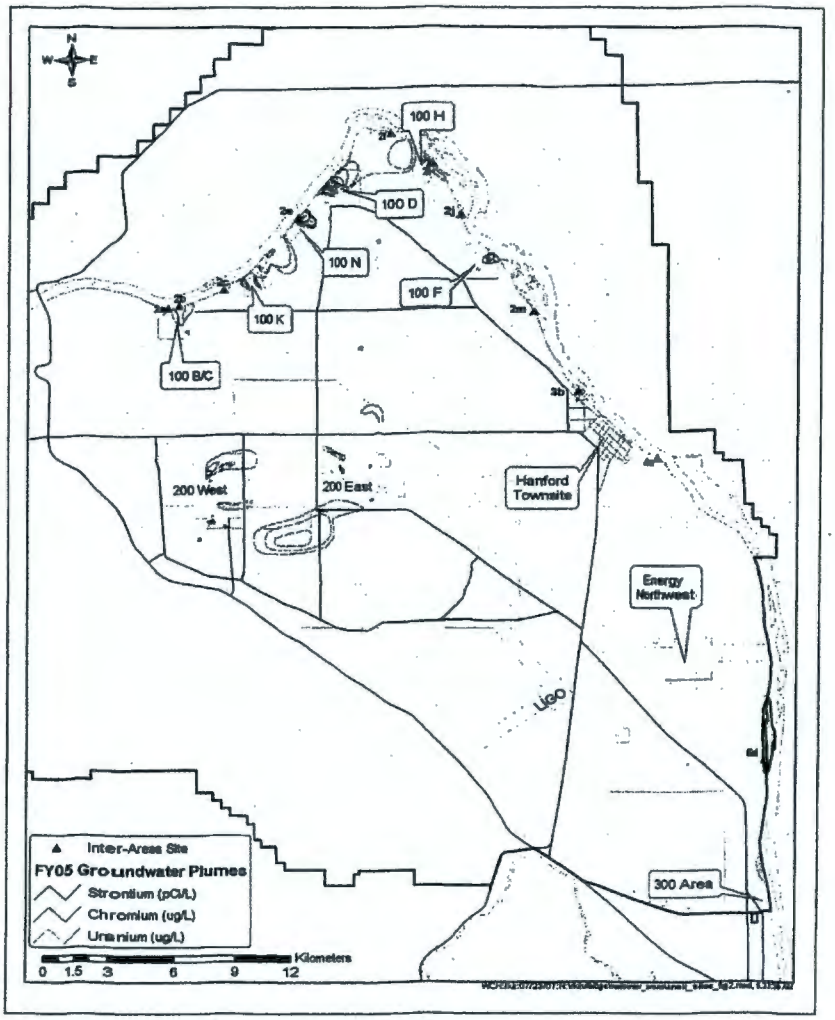


Figure 1. RCBRA Inter-Areas Investigation Areas Surveyed for Mollusk Habitats

Table 1. Selected Aquatic Habitat Characteristics Measured at each RCBRA Inter-Areas Investigation Areas.

Site ID	Riverbed Conditions					
	Dominant Substrate		*Sub-Dominant Substrate*		*Relative Abundance of Macrophyte*	*Substrate Embeddedness*
	Class	Medial Axis (mm)	Class	Medial Axis (mm)		
RCBRA 2A Aq	1		2		0	4
RCBRA 2B Aq	2	43	2	85	0	2
RCBRA 2C Aq	3	164	2	72	1	3
RCBRA 2E Aq	4	>305	2	121	0	2
RCBRA 2F Aq	2	67	2	124	0	3
RCBRA 2J Aq	2	145	2	42	1	1
RCBRA 2L Aq	2	125	1	<6	2	4
RCBRA 2M Aq	2	186	1	<6	1	4
RCBRA 3B Aq	2	128	1	<6	0	3
RCBRA 4A Aq	2	145	3	285	0	3
RCBRA 5C Aq	2	95	2	67	0	3
RCBRA 5D Aq	1	<6	1	<6	2	4
RCBRA BEV REF 1 Aq	2	93	2	126	1	3
RCBRA BEV REF 2 Aq	1	<6	1	<6	3	4

Table 2. Likelihood of use of RCBRA Inter-Areas Investigation Areas by Selected Mollusks

Species	Common name	RCBRA 2A aq	RCBRA 2B aq	RCBRA 2C aq	RCBRA 2E aq	RCBRA 2F aq	RCBRA 2I Aq	RCBRA 2M aq	RCBRA 2J aq	RCBRA 3B aq	RCBRA 4A aq	RCBRA 5C aq	RCBRA 5D aq
*Corbicula fluminea**	Asiatic clam	1	1	1	1	1	1	1	1	1	1	1	1
sphaeriids	fingernail clams	1	2	3	3	3	2	2	2	2	2	3	1
Ferrissia californica	fragile ancylid	3	3	2	3	3	3	3	3	3	3	3	3
Fluminicola n. sp.[a]	unnamed pebblesnail	3	2	3	2	3	2	3	3	4	2	4	3
Fluminicola lewisi	lewis pebblesnail	3	2	4	2	4	2	3	3	4	2	4	3
Pyrgulopsis n. sp. 6[a]	springsnail	2	2	3	2	4	2	3	3	4	2	3	3
*Radix auricularia**	big-ear snail	3	3	3	3	3	3	3	3	3	3	3	3
Fossaria (B.) bulimoides	prairie fossaria	1	2	3	2	3	2	2	2	4	2	3	3
Fossaria (F.) obrussa	golden fossaria	3	3	3	3	3	3	3	3	4	3	3	3
Stagnicola apicina	abbreviate pondsnail	3	2	3	3	3	3	2	3	4	2	2	3
Stagnicola elodes	marsh pondsnail	3	3	3	3	3	3	3	3	4	3	3	3
Physella (P.) propinqua propinqua	Rocky Mountain physa	2	3	2	3	3	3	2	2	2	3	3	3
Gyraulus (T.) parvus	pish gyro	3	2	3	3	3	3	3	2	3	3	3	3
Menetus (M.) calloglyptus	button sprite	2	2	2	2	3	2	3	2	3	2	3	3
*Fisherola nuttalli**	shod face lymn	2	2	4	2	4	4	4	4	4	4	4	4
Vorticifex effusus effusus	artemesian rams-horn	2	2	2	2	2	2	2	2	3	2	2	3
Total # of Species Likely to Occur		11	12	5	11	4	9	8	9	4	11	5	3
Total # of Rare Taxa[a] Likely to Occur		2	4	0	4	0	3	0	0	0	3	0	0

1=known or very likely occurrence
2=likely occurrence
3=unlikely occurrence
4=very unlikely occurrence
*=introduced species
a=rare taxon as described in Debis Letter Report for 100 & 300 Areas RCBRA

Appendix A

Field Notes Recorded for each RCBRA Inter-Areas Investigation Areas

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Project: Inter-Areas Shoreline Assessment Logbook No: EL 1614

Continued from page: NA

03-12-07 BL Tiller (EAS) B Tiller, TJ Frest (EAS), and E. Johannsen Conduct Surveys of SNAIL Habitat at all Sites selected for Potential Contamination of Hanford's Legacy Materials. WP# 070102-005 Partly cloudy, water levels ~ 75KCFS

We recorded details on Mollusca survey Forms and need to Summarize electronically. Lacking Macro invert community data from Substrate Baskets, we simply examined the hydro-geomorphic conditions, looked at the substrate baskets, and listed the species we may expect exist there.

Below is a List of Sites examined and general habitat Features.

SITE	Habitat	
RCBRA 2a	backwater / sediment	
RCBRA 2b	slow riffle / gravel	
RCBRA 2c	backwater / sediment-gravel.	
RCBRA 2e	slow moving water / boulder-gravel	
RCBRA 2f	slow moving water / gravel	2 eagles Flushed from coast
RCBRA 2i	Fast water / small gravel	
RCBRA 2j	Slough / sediment	- geese sitting on eagle nest
RCBRA 2l	slough / sediment	
RCBRA 2m	Slow moving / gravel-sediment	
RCBRA 3b	Slough / sediment	
RCBRA 4a	mix riffle/pools / cobble-boulder	
RCBRA 5c	backwater w/occasional Flushing / gravel sediment	
RCBRA 5d	Slough / sediment.	

For Rare Mollusk Taxa; Fluminicola, Fisherola, Pyrgulopsis, & Vertigifex any site with some Fast - slow moving water and cobble/gravel may be suitable. However, Fisherola seems to be extinct on the Reach now and they are not likely to be Found on small-sized gravels like RCBRA 2i. Also Pyrgulopsis is only prominent around the 300 Area so they are not likely to be Found in these sites.

BT 03-12-07

Continued on page: NA

Entered By: B. Tiller (Print) Reviewed By: Randy M. Hartmann (Print)

Signature: [signature] Date: 03-12-07 Signature: [signature] Date: 3-29-07

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