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River Data Package for Hanford Assessments

C. L. Rakowski
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August 2006

Prepared for the U.S. Department of Energy
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Preface

This data package was originally prepared to support a 2004 composite analysis (CA) of low-level waste disposal at the Hanford Site. The *Technical Scope and Approach for the 2004 Composite Analysis of Low Level Waste Disposal at the Hanford Site* (Kincaid et. al. 2004) identified the requirements for that analysis and served as the basis for initial preparation of this data package. Completion of the 2004 CA was later deferred, with the *2004 Annual Status Report for the Composite Analysis of Low-Level Waste Disposal in the Central Plateau at the Hanford Site* (DOE 2005) indicating that a comprehensive update to the CA was in preparation and would be submitted in 2006.

However, the U.S. Department of Energy (DOE) has recently decided to further defer the CA update and will use the cumulative assessment currently under preparation for the environmental impact statement (EIS) being prepared for tank closure and other site decisions as the updated CA. Submittal of the draft EIS is currently planned for FY 2008.

Summary

This data package documents the technical basis for selecting physical and hydraulic parameters and input values that will be used in river modeling for Hanford assessments. This work was originally conducted as part of the Characterization of Systems Task of the Groundwater Remediation Project managed by Fluor Hanford, Inc., Richland, Washington, and revised as part of the Characterization of Systems Project managed by the Pacific Northwest National Laboratory for the U.S. Department of Energy, Richland Operations Office.

The river data package provides calculations of flow and transport in the Columbia River system. The module is based on the legacy code for the Modular Aquatic Simulation System II (MASS2), which is a two-dimensional, depth-averaged model that provides the capability to simulate the lateral (bank-to-bank) variation of flow and contaminants. It simulates river hydrodynamics (water velocities and surface elevations), sediment transport, contaminant transport, biotic transport, and sediment-contaminant interaction, including both suspended sediments and bed sediments. The theoretical basis and use of MASS2 are presented in Perkins and Richmond (2004a) and Perkins and Richmond (2004b), respectively.

This document presents the data assembled to run the river module components for the section of the Columbia River from Vernita Bridge to the confluence with the Yakima River. MASS2 requires data on the river flow rate, downstream water surface elevation, groundwater influx and contaminants flux, background concentrations of contaminants, channel bathymetry, and the bed and suspended sediment properties. Stochastic variability for some input parameters such as partition coefficient (K_d) values and background radionuclide concentrations is generated by the Environmental Stochastic Preprocessor (Eslinger et al. 2002). River flow is randomized on a yearly basis. At this time, the conceptual model does not incorporate extreme flooding (for example, 50 to 100 years) or dam removal scenarios.

Flow data are adequate to the current task of running at a monthly time step. Daily and hourly flow data are available if the time step is reduced in the future. A very good bathymetric grid has been developed that provides increased resolution where necessary. Sediment data are the least available, but there is little evidence demonstrating an immediate need for additional resolution on this model component. Partition coefficient values, as developed by Last et al. (2006) have been stochastically incorporated into the model. Groundwater inputs (flux and contaminants) are defined by the groundwater model results. The basis for background concentrations of radionuclides in the river is presented.

Acronyms

2D	two-dimensional
CD	compact disc
CRCIA	Columbia River Comprehensive Impact Assessment
CSTF	Containment Systems Test Facility
DOE	U.S. Department of Energy
DOE-RL	U.S. Department of Energy, Richland Operations Office
EIS	environmental impact statement
ESP	Environmental Stochastic Preprocessor
FY	fiscal year
GIS	geographic information system
GWDROP	groundwater data translator
HEIS	Hanford Environmental Information System
LiDAR	light detection and ranging
MASS2	Modular Aquatic Simulation System in Two Dimensions
NASQAN	National Stream Water Quality Network
RM	river mile
SAC	System Assessment Capability
SHOALS	scanning hydrographic operational LiDAR survey
USGS	U.S. Geological Survey
VZDROP	VADose zone Environmental Release

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1.0 Introduction

Beginning in fiscal year (FY) 2003, the U. S. Department of Energy, Richland Operations Office (DOE-RL) initiated activities, including the development of data packages, to support a Hanford assessment. This report describes the data compiled in FY 2003 and updated in FY 2005 to support Columbia River modeling for Hanford assessments. This work was originally conducted as part of the Characterization of Systems Task of the Groundwater Remediation Project (formerly the Groundwater Protection Project) managed by Fluor Hanford, Inc., Richland, Washington. It was revised in FY 2005 and FY 2006 as part of the Characterization of Systems Project managed by the Pacific Northwest National Laboratory (PNNL), for DOE-RL.

The purpose of this data package is to summarize the underlying data used as input for numerical simulation as part of a Hanford assessment and to provide the input parameters needed for the simulations. The general approach for this work was to extract data and interpreted information from existing documents and databases. Every attempt was made to provide traceability back to the original source of the data or interpretations. In addition to using river flows and river bathymetry, the river model also uses inputs from the groundwater model. The relationship and connections between the river module and other modules is described in Eslinger et al. (2002).

2.0 Background

The long-term impact of the Hanford Site on ecological and human health is of interest to environmental managers, engineers, and scientists responsible for the cleanup, as well as the public. The Systems Assessment Capability (SAC) is a system of linked modeling tools and data intended to provide a way to evaluate these impacts. Details of the Hanford assessment models and the initial assessments are presented in Kincaid et al. (2000) and background information on the development of SAC is presented in Bryce et al. (2002). SAC primarily consists of contaminant inventory estimates and models of contaminant release; vadose zone, groundwater, river, and shoreline models; and impact or risk assessment tools.

The River Flow and Transport Module provides the capability to calculate flow and transport in the Columbia River system. The module is based on the Modular Aquatic Simulation System in Two Dimensions (MASS2) is a two-dimensional (2D), depth-averaged hydrodynamics and transport model. The theoretical basis and use of MASS2 are presented in Perkins and Richmond (2004a) and Perkins and Richmond (2004b), respectively. The model simulates time varying distributions of depth-averaged velocities, water surface elevations, and water quality constituents. MASS2 uses a structured, multi-block, boundary-fitted, curvilinear computational mesh, which allows the simulation of very complex riverine or estuarine networks. The blocks may be of varying resolution, which allows high resolution to be used only where needed. MASS2 can simulate a wide variety of hydrodynamic conditions, including supercritical flow and hydraulic jumps. It can also simulate a wide variety of water quality conditions, including sediment, conservative or decaying contaminants, sediment-sorbed contaminants, water temperature, and total dissolved gas. Any number of these constituents may be simulated simultaneously. In addition, transport simulations may be performed using pre-calculated hydrodynamic conditions, allowing long-term transport simulations unencumbered by the more intensive hydrodynamic calculations, or repeated transport simulations without re-simulating hydrodynamics.

For the Hanford assessment, MASS2 is used to simulate river flows and contaminant transport through the Hanford Reach of the Columbia River. MASS2 uses groundwater inputs from another model in the Hanford assessment, and the MASS2 output is used by the modules for impact assessment. This document presents the data assembled to run the river module for the section of the Columbia River from Vernita Bridge to the confluence with the Yakima River. The Environmental Stochastic Preprocessor (ESP) generates stochastic variability for some input parameters for many of the SAC modules (Eslinger et al. 2002). For the River Flow and Transport Module, ESP provides inputs such as the partition coefficient (K_d) values and background radionuclide concentrations. Monthly river flow is randomized on a yearly basis. At this time, the conceptual model does not incorporate scenarios for extreme flooding (50 to 100 years) or dam removal.

3.0 Data Gathering Methods and Data Limitations

MASS2 requires data on the river flow rate, downstream water surface elevation, groundwater influx, channel bathymetry, and the bed and suspended sediment properties. In the subsections below, the data requirements, data sources, model inputs, and data limitations are discussed for each required component for the River Flow and Transport Module.

These data sets are managed under a data configuration and communication management plan.[a] A readiness review was conducted prior to placing each data set under configuration management. Any subsequent changes were managed and documented via a data change request (DCR). The flow rates and boundary conditions described in this report are consistent with the data describe in DCR-0007. The input parameters for the stochastic realizations are consistent with the data described in DCR-0007.

3.1 Bathymetry and the Computational Grid

River bathymetry describes the shape of the channel. Multiple data sources were integrated into a single bathymetric surface, and then the bathymetric surface was used in the creation of the computational grid. The computational grid is the representation of the channel shape that is input into MASS2. Two distinct types of data are required for the creation of the computational grid: shoreline data defining the lateral extent of the river and bathymetric data to represent the shape of the river bottom.

3.1.1 Requirements

Accurate representation of the channel bathymetry is vital to realistically simulate the river depth and velocity characteristics. However, a coarse computational grid is necessary to maximize processing speed and ensure that the long time periods required by the Hanford assessment can be simulated in reasonable amounts of time. Therefore, the river channel features must be represented using as coarse of a grid as

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[a] Nichols WE, PW Eslinger, and GV Last. February 3, 2006. *Hanford Remediation Assessment Project Data Configuration and Communication Management Plan, Rev. 1.1.* Pacific Northwest National Laboratory, Richland, Washington.

possible. To achieve this, a computational grid with variable grid cell densities was developed. The Hanford assessment computational grid has double the resolution in the cross-stream direction for complex regions of interest. These complex regions are represented by smaller grid cells while the less complex river segments are represented by larger, coarser grid cells (see Section 3.1.3).

3.1.2 Data Gathering

River bathymetry was based on data obtained in 1998 by the U.S. Geological Survey Biological Resource Division in Cook, Washington (Tiffan et al. 2002). A scanning hydrographic operational LiDAR survey (SHOALS) light detection and ranging (LIDAR) system (Irish et al. 2000) was used to measure bottom elevations in near shore and shallow areas. These point data and data from cross section surveys were used to create a continuous, three-dimensional bathymetric surface of the study area in ArcInfo (Figures 1 through 3).

The computational grid for the river simulations was based on this bathymetric surface and shorelines that included the large islands in the Hanford Reach. The shorelines were based on flows of 80 kcfs and digitized from aerial photos. The ArcInfo bathymetric surface was used to determine the bed elevation at each point in the computational grid. Recent MASS2 code enhancements allow grids with grid density changes at matched boundaries to be used. These enhancements allow the increased resolution around the islands, where it is needed, while reducing the computational time relative to having the higher resolution in all areas of the river. The new grid contains 58 blocks with a total of 2,708 cells.

3.1.3 Proposed Input Parameters

The computational grid, created in Gridgen, had 7 cells across in areas without islands, 14 cells across in areas with islands (Figure 4), and a total of 2,708 cells partitioned into 58 blocks. The grid extended from the Yakima River confluence (Columbia River mile [RM] 335) upstream to RM 389 near Vernita Bridge.

3.1.4 Data Issues, Uncertainties, and Recommendations

The most notable technical issue with the bathymetry is that the areal extent of the river is limited to that of the simulated lowest flow channel because the current implementation of the model does not allow any cells to go dry. As a result, the model will underestimate the channel width at higher or flood flows and, therefore, may overestimate the depth in extreme cases.

The other technical issues result from gaps in geographic coverage of the data and limitations to the data collection technique. The SHOALS LiDAR data were only collected for a portion of RM 355 to 377 and can only penetrate into 4.6 meters (15 feet) of water. Consequently, there were data gaps in: areas not covered by the SHOALS survey or in areas too deep for LiDAR, or areas not included in the Pacific Northwest National Laboratory (PNNL) hydrosurvey data.[a] In these areas, a bathymetric data set was derived from the U.S. Army Corps of Engineers cross-section data. The cross-section data were

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[a] Unpublished data from Tim Hanrahan, Pacific Northwest National Laboratory, Richland, Washington.

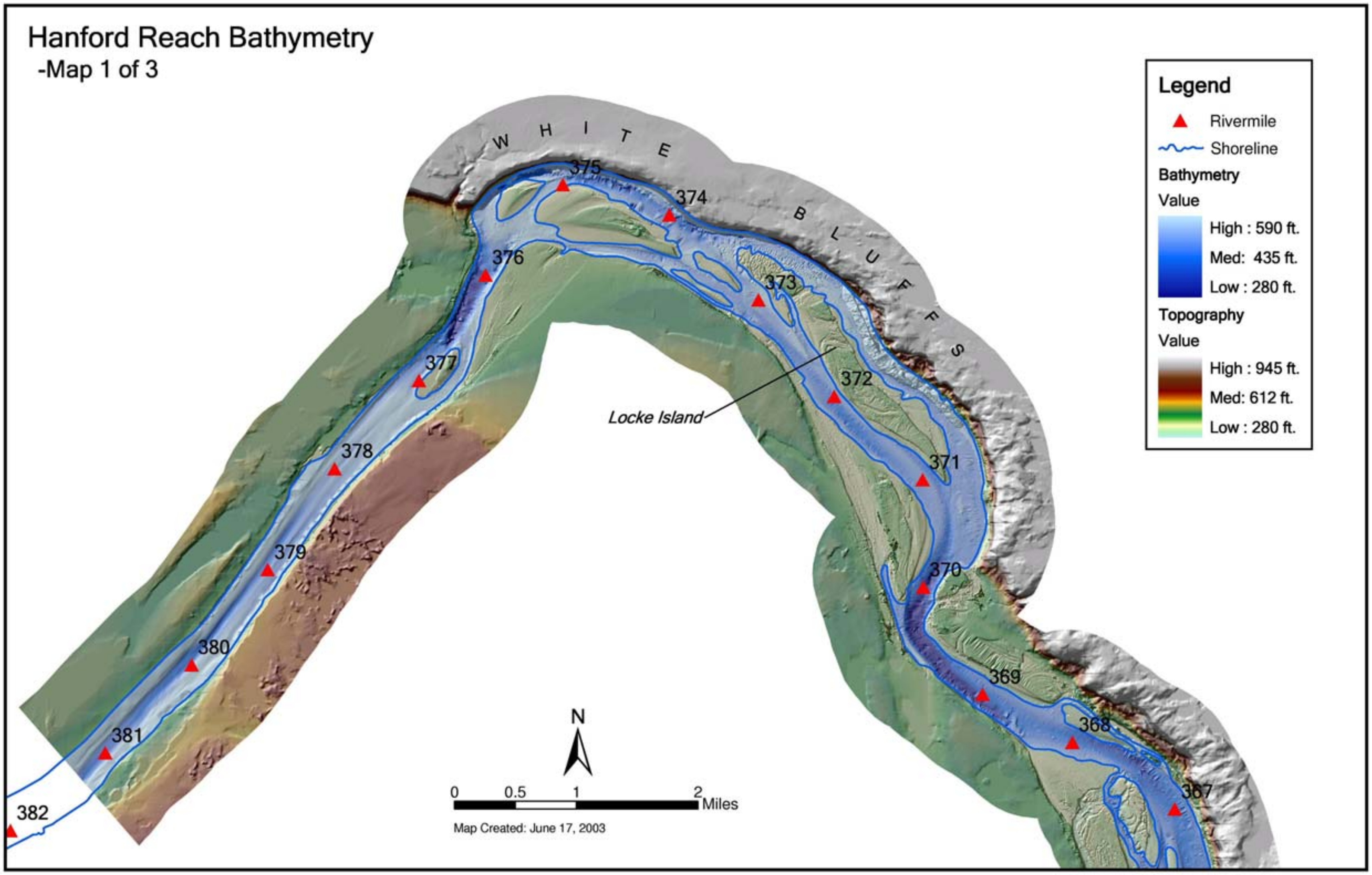
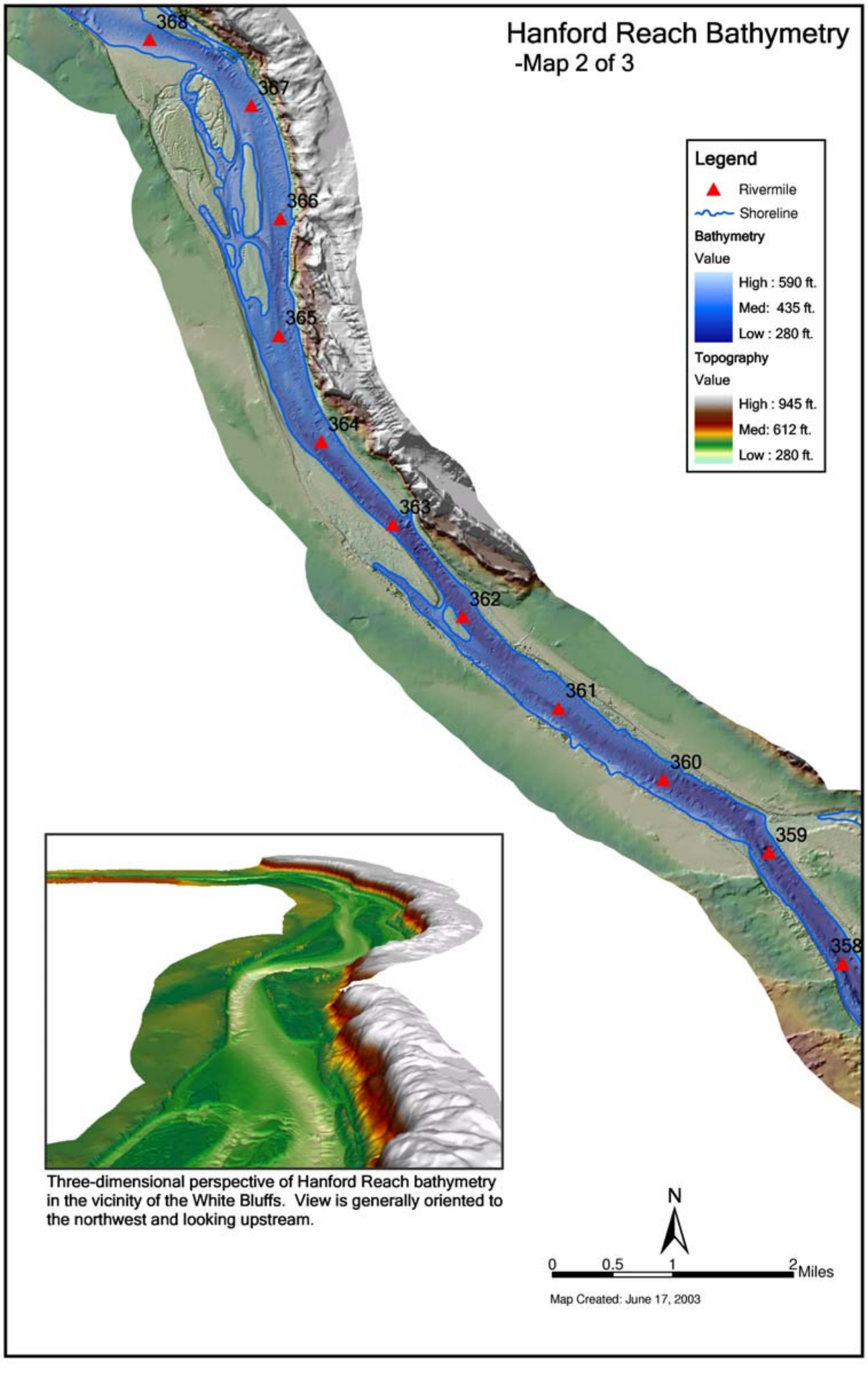


Figure 1. Updated Bathymetry, River Mile 368 to 381



Three-dimensional perspective of Hanford Reach bathymetry in the vicinity of the White Bluffs. View is generally oriented to the northwest and looking upstream.

Map Created: June 17, 2003

Figure 2. Updated Bathymetry, River Mile 359 to 367

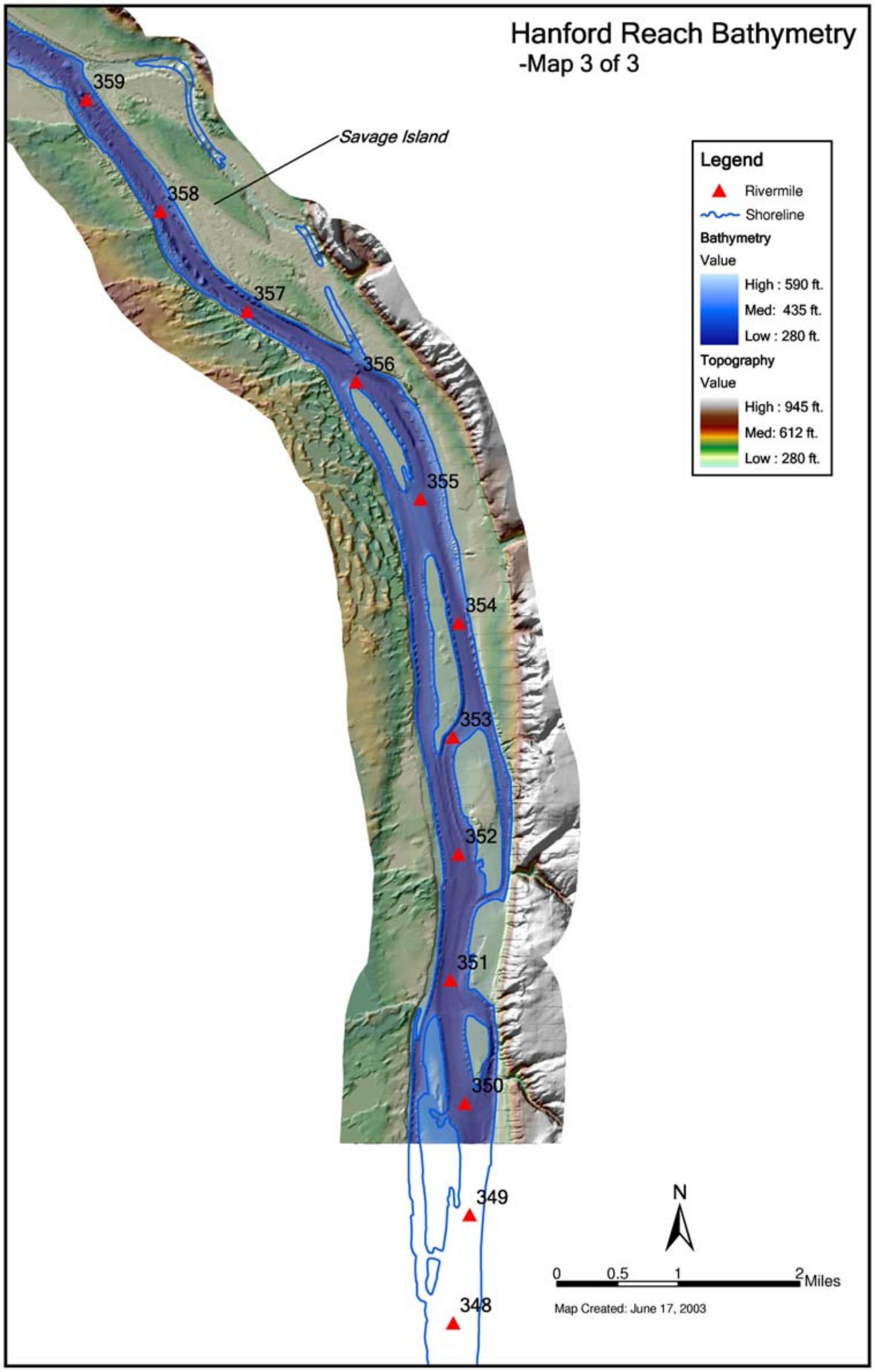


Figure 3. Updated Bathymetry, River Mile 350 to 358

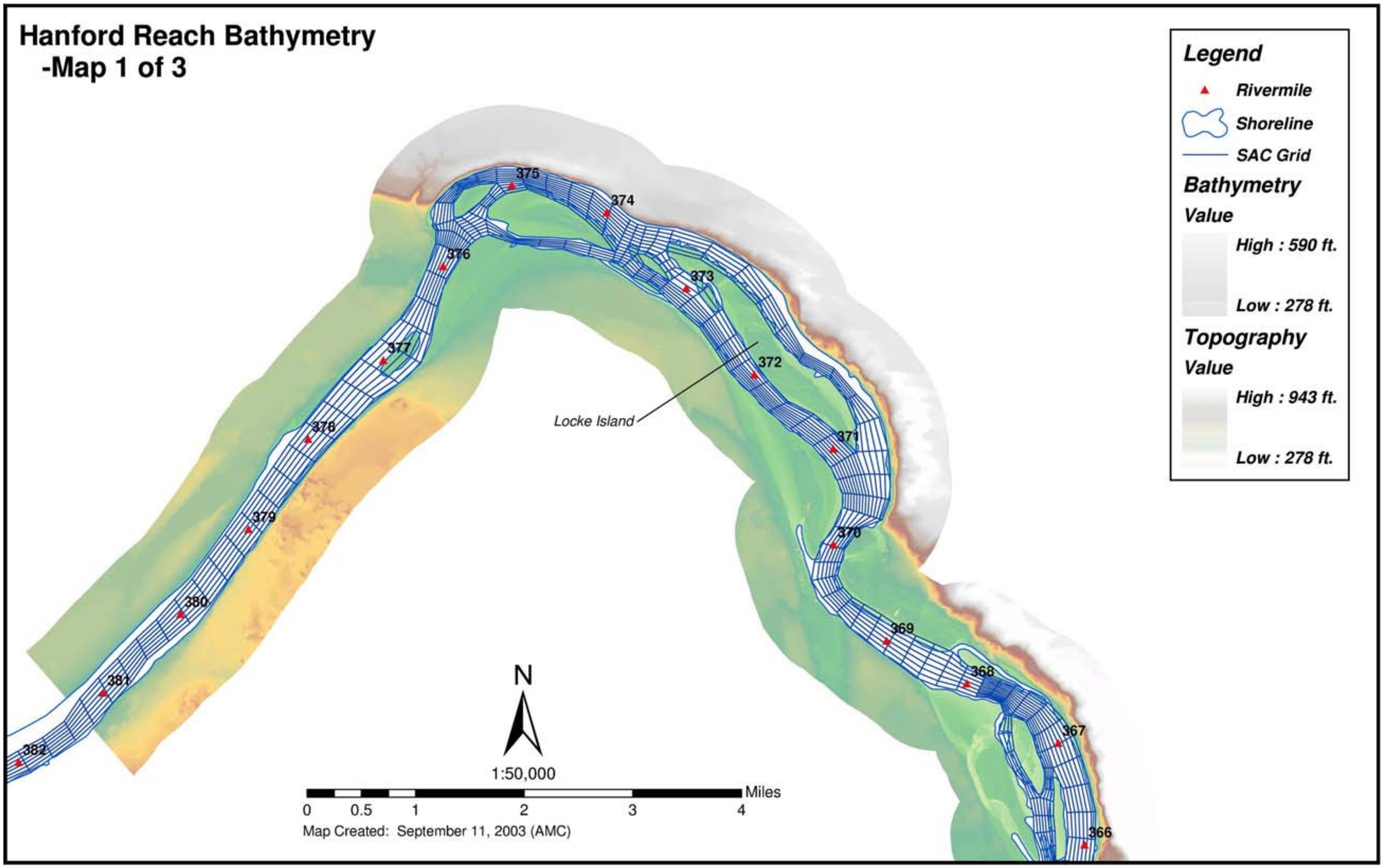


Figure 4. Computational Grid Example for the Upper Portion of the Study Area

interpolated in the stream-wise direction on an orthogonal grid system to fill the gaps between the cross sections. These interpolated data were only used for those areas not represented by any other source in the creation of a bathymetric surface.

3.2 River Discharge

A realistic representation of river discharge is important to simulate the hydrodynamic conditions within the river. Consequently, the choice of representative inflow conditions is crucial to obtaining the realistic transport of contaminants in the Columbia River.

3.2.1 Requirements

Two hydrodynamic inputs are required for MASS2: upstream discharge and the downstream water surface elevation. The downstream boundary of the model is the Columbia River near its confluence with the Yakima River. The water surface elevation is controlled by McNary Dam, so the only variable hydrologic data needed to run MASS2 are the flow of the Columbia River at the upstream end of the study area. This information is available through hydropower project operations records and U.S. Geological Survey (USGS) flow gaging data.

3.2.2 Data Gathering

Mean monthly flows were computed from the USGS Vernita Bridge gage data for use as model inflows. These monthly flows were not taken individually, but were grouped as flow years (i.e., January through December for each year), which preserved the character of the yearly hydrograph. The downstream stage was held at a constant 103.63 meters (340 feet) above sea level, the normal operating stage of McNary Dam.

3.2.3 Proposed Input Parameters

The historic Columbia River flow data at Priest Rapids Dam are shown in Figure 5. For the post-dam period (1975 to 2001), these data were grouped into a series of flow years from which the model selected at random. The probability density plot of the flow data is positively skewed (Figure 6).

3.2.4 Data Issues, Uncertainties, and Recommendations

The flow data are fairly straightforward and complete, although it does not reflect the daily flow fluctuations. The flow rate of the Columbia River in the Hanford Reach fluctuates significantly and is controlled primarily by releases from upstream dams. There are both seasonal and daily fluctuations in flow, which also cause fluctuations in river stage. Seasonal flows typically peak from April through June, during spring runoff from snowmelt, and are lowest from September through October. The seasonal change in average water level is up to about 2 meters (6.6 feet). Daily fluctuations in discharge are caused by releases from dams based on demand for power production. Because of these changes in flow, the river stage varies significantly over a short time period. Vertical fluctuations of more than 1.5 meters (4.9 feet) during a 24-hour period are common along the Hanford Reach (Poston et al. 2003). These fluctuations are not significant at the monthly output interval currently employed in the model, however.

The flow data also represent only current conditions and the current conceptual model does not include future climate or hydropower changes that may affect the hydrograph, nor does it include extreme flood events.

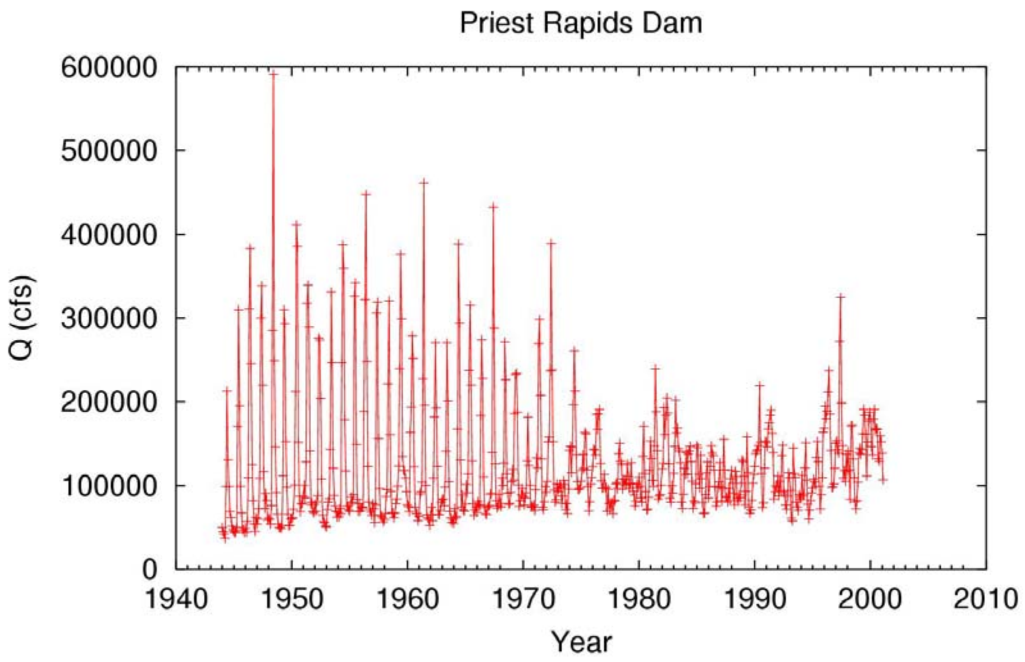


Figure 5. Columbia River Flow Data

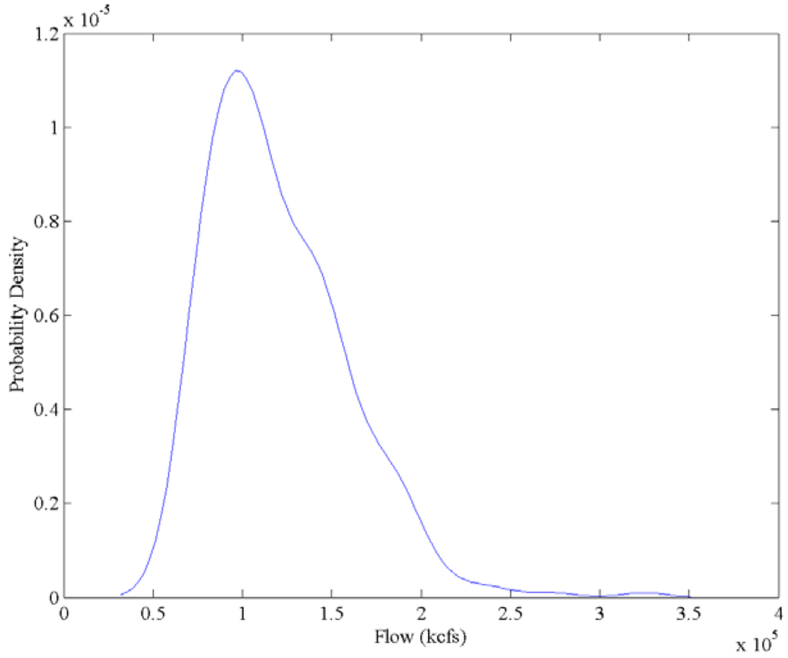


Figure 6. Probability Density Function of Priest Rapids Dam Flow Data for the Post-Dam Period (1975 to 2001)

3.3 Sediment

The characteristics of suspended and bed sediment are important for estimating the adsorption and subsequent fate and transport of contaminants in the study area. Many parameters are needed to accurately characterize the bed and suspended sediments.

3.3.1 Requirements

The bed sediment can be characterized for each river cell by material type, depth, median particle size, density, settling velocity, erodibility, and erosional and depositional critical shear values. The suspended sediment is characterized by these same properties, except that concentration (kg/m^3) is used to characterize the amount of suspended sediment, instead of the depth, as for bed sediment. These characteristics are estimated from available data or established relationships derived from empirical data.

3.3.2 Data Gathering

The background suspended sediment data were obtained from the USGS National Stream Water Quality Network (NASQAN) web site (http://water.usgs.gov/nasqan). Water quality parameters for the Columbia River water samples collected at Vernita Bridge were downloaded and used as model boundary conditions. Each dataset included additional information on numerous aspects of water quality including temperature, conductance, dissolved oxygen, pH, alkalinity, dissolved constituents, and suspended sediment concentrations. These data consisted of several measurements per year (typically quarterly) starting in 1996. All of the suspended sediment concentration data were averaged for each location to estimate the background suspended sediment concentration.

In past analyses, multiple bed depths had been assigned based on observed sediment size. The material types were derived from a geographic information system (GIS) coverage of the approximate spatial distribution of bottom material types, created by Tim Hanrahan from USGS data (Figure 7). When the sediment size was determined for the computational grid, it was observed that only 1% of the nodes had a depth, based on past criteria, which would be different than 0.3 meter (1 foot) depth. Previous work had varied bed depths, in meters (feet), based on material types:

• Organic	0.3 (1.00)
• Organic-sand	0.3 (1.00)
• Organic-cobble	0.3 (1.00)
• Clay (soft)	0.9 (3.00)
• Silt	0.9 (3.00)
• Silt-sand	0.6 (2.00)
• Silt-gravel	0.3 (1.00)
• Silt-cobble	0.3 (1.00)
• Clay (hard)	0.9 (3.00)

More resistant or organic types have 0.3 meter (1 foot) depths. Consequently, all initial bed depths were set to 0.3 meter (1 foot). The presence of coarse or resistant sediments at the grid locations is reasonable as the river grid was restricted to locations that are inundated at all flows.

3.3.3 Proposed Input Parameters

Suspended sediment concentration in the Columbia River was set to a constant 3.75 mg/L. One sediment class with the following properties was used:

- Median particle diameter (d50): 0.003 cm (0.0001 feet)
- Solids density: 2,650 kg/m^3 (75.04 kg/ft^3)
- Settling velocity: 0.000010 m/s (0.000033 ft/s)
- Erodibility: 0.0
- Critical shear for erosion: 0.0073 kgf/m^2 (0.0015 lbf/ft^2)
- Critical shear for deposition: 0.0073 kgf/m^2 (0.0015 lbf/ft^2)

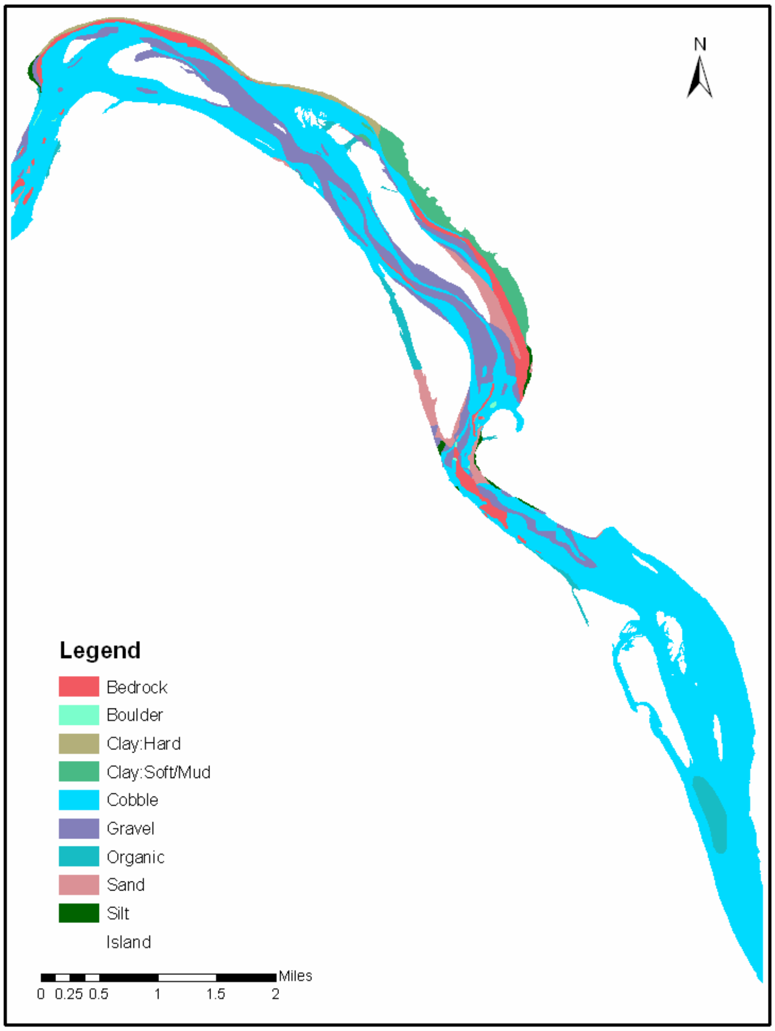


Figure 7. Sample of Color Coded Bed Material Coverage (Tim Hanrahan, Pacific Northwest National Laboratory, Richland, Washington)

The river bed was represented as one sediment class that was 0.3 meter (1 foot) deep. There are no initial contaminant concentrations in the bed, but rather all contaminant accumulation results from the adsorption of contaminants input from the background contaminants (see Section 3.6) and the groundwater module (Section 3.4).

3.3.4 Data Issues, Uncertainties, and Recommendations

Almost all data gathered since the closure of the Hanford Site single pass reactors (early 1970s) have been for upper sediment (river/sediment interface). Only limited information is available for sediment grain size, total organic content, and sequestration by sulfide (Blanton et al. 1995; Patton and Crecelius 2001). Total organic content plays a large role in the variability of k_d values, which is discussed in Last et al. (2006).

The relative importance of sediment transport in the fate of in-river contaminants in the Columbia River is uncertain. The low concentrations of suspended and bed sediment moving in the Columbia River suggests that sediment may not be a high priority factor at this time. Therefore, in effort to minimize processing time, continuing to use one sediment class is recommended until the need for additional refinement is demonstrated with reliable data and analysis.

3.4 Groundwater Flux and Contaminant Input (CFEST)

A series of scripts have been developed to allow the use of model outputs for groundwater and vadose zone flows and contaminants into the Hanford Reach of the Columbia River. The output locations for both models are mapped onto the MASS2 grid then time series of flows and transported variables (contaminants) used as inputs to MASS2.

3.4.1 Requirements

MASS2 receives input from the coupled fluid energy and solute transport (CFEST) groundwater module, and in the case of reactor discharges, directly from the release module (VADER, Eslinger et al. 2002). Contaminant and water influx from CFEST is input to the bed sediment layer in MASS2 using output from the groundwater data translator (GWDROP, Eslinger et al. 2002), which matched the cells from the CFEST model to the appropriate cells in the MASS2 computational grid. Vadose zone releases from STOMP are input into MASS2 with the VZDROP code. MASS2 then generates and outputs annual average concentrations of contaminants in the water column (dissolved and total sediment-sorbed) and in the bed sediment (pore water and total sediment-sorbed).

3.4.2 Data Issues, Uncertainties, and Recommendations

The data issues and uncertainties for the CFEST data are documented in Thorne (2006).

3.5 Distribution Coefficients (K_d Values)

Partition coefficient (K_d) values are used to describe the adsorption of dissolved contaminants to ground, bed, and suspended sediment particles. This process affects both the bio-availability, and the fate and transport of contaminants. The partition coefficients used for the river model are the same as those developed for the vadose zone (Last et al. 2006).

A stochastic approach was taken to capture the wide range of values of $K_{d,}$ reported in field and laboratory studies. This approach is documented in Eslinger et al. (2002).

3.6 Background Radionuclides

The background concentrations of radionuclides in Columbia River water are needed for an analysis. The requirements, data gathering methods, proposed model input parameters, and other data issues related to background concentration of radionuclides in river water are discussed this section. A longer discussion of the development of the input parameters is in the Appendix. These data are in electronic form and are consistent with those describe in DCR-0028.

3.6.1 Requirements

Background values of radionuclide concentrations for the river water are necessary for MASS2 to simulate contaminant fate and transport. Background concentrations of dissolved radionuclides in the Columbia River were estimated. The sediment concentrations were computed from the estimated dissolved concentrations assuming equilibrium partitioning discussed in Section 3.5 and in Last et al. (2006).

3.6.2 Data Gathering

Surface water background radionuclide estimates were developed based on measured data and assumptions about natural decay. The following governing equation for the background concentration in surface water is used for all years before 1990:

$$C_R = C_B$$

The following equation is used for 1990 or later years:

$$C_R = C_B + M_B e^{(-\lambda_b [\text{Year} - 1990])}$$

where C_R = Concentration of the analyte in surface water (Ci/m^3 or kg/m^3)
C_B = Nominal background concentration (Ci/m^3 or kg/m^3) from natural sources
M_B = Concentration (Ci/m^3 or kg/m^3) from manmade sources (weapons testing fallout)
λ_B = Decay term (1/yr) that includes the effect of radioactive decay and leaching from the land surface into surface waters for the manmade sources

The values for C_B, M_B, and λ_B have different values for every analyte. The variables C_B and M_B are defined as stochastic variables. The variable for λ_B is defined as a constant. The values for C_B and M_B can be set to a constant, including the constant zero. The value for λ_B can also be set to zero. Complete documentation for the individual contaminants is found in the Appendix.

3.6.3 Proposed Input Parameters

The nominal values in the governing concentration equation for the analytes used in the Composite Analysis are provided in Table 1. The values in Table 1 have been modified to have units of Ci/m^3. The modification is performed by multiplying the original data in pCi/L by 10^{-9}.

The stochastic distributions associated with the nonzero coefficients defined in Table 1 are defined using the following rules:

- **Variable C_B.** The triangular distribution will be used for all values of C_B. The distribution will be symmetric about the midpoint, and the half-range will be 50% of the mid-point. The variable tag will be CB.

Table 1. Nominal Coefficient Values for Background Concentrations in the Columbia River

Analyte ID	C_B	M_B	λ_B	Fallout?
^{14}C	5.3×10^{-11}	0	0	No
^{136}C	0	0	0	No
^{137}Cs	0	5.49×10^{-12}	0.223	Yes
^{152}Eu	0	0	0	Very small
^{3}H[(a)]	1.5×10^{-8}	3.04×10^{-8}	0.0562	Yes
^{129}I	0	1.1×10^{-14}	4.41×10^{-8}	Very small
^{237}Np	0	0	0	Very small
^{231}Pa	8.7×10^{-12}	0	0	No
^{226}Ra	Not modeled	Not modeled	Not modeled	No
^{79}Se	0	0	0	Very small
^{90}Sr	0	9.99×10^{-11}	0.0241	Yes
^{99}Tc	0	5.52×10^{-11}	3.28×10^{-6}	Yes
^{233}U	0	0	0	No
^{234}U	2.0×10^{-10}	0	0	No
^{235}U[(b)]	8.7×10^{-12}	0	0	No
^{238}U	1.9×10^{-10}	0	0	No
^{234}U+^{238}U	3.9E-10	0	0	0

(a) Recent ^{3}H samples in the Columbia River have been decreasing towards about 15 pCi/L.
(b) The ^{235}U value is based on the ^{238}U value and 0.71% relative weight natural abundance.

- **Variable M_B.** The triangular distribution will be used for all values of M_B. The distribution will be symmetric about the midpoint, and the half-range will be 50% of the mid-point. The variable tag will be MB.

- **Variable λ_B.** This variable is always defined as a constant (except for ^{137}Cs which will be assigned a triangular distribution). For ^{137}Cs, the variability is ±0.05. The variable tag will be LB.

3.6.4 Data Issues, Uncertainties, and Recommendations

Uncertainties in the background concentrations are addressed by using a stochastic approach. The stochastic distribution of concentrations should span the range of possible values.

4.0 Input Parameters

This section describes the input data sets assembled for use in river modeling for large-scale Hanford Assessments. These data sets are managed under a data configuration and communication management plan.[a] A readiness review was conducted prior to placing each data set under configuration management. Any subsequent changes were managed and documented via a data change request (DCR). Each revised data set is uniquely identified with a descriptive name, the date the data set was revised, and the corresponding DCR number. The river portion of the model is somewhat unique in that there are two distinct types of model runs: one to generate libraries of river hydraulics for the river for a given discharge from Priest Rapids Dam and the use of those libraries in transport only simulations as part of assessments (see Perkins and Richmond 2004b).

Table 2. Summary of River Input Parameter Data Sets used to Generate River Hydraulics

Description	File Name	File Type	Location
Configuration file. Specifies grid files and the parameters to be used in the simulation of the hydrodynamics	Mass2_v027.cfg	ASCII text file as described by DCR-0007.	Available from author
Restart file. General flow condition file to improve time for model convergence.	Hotstart.bin	Binary data file as described by DCR-0007.	Available from author
Boundary conditions file. Specifies inflow and outflow locations for the grids and file names of the boundary condition files. Connectivity between the grid blocks for the river is also specified.	Bcspecs.dat	ASCII text file as described by DCR-0007.	Available from author
Computational grid files. Each file contains a single block with the block size and node locations for that block of the computational grid.	Sac_n-pt.nnn where nnn is a number between 000 and 056, inclusive.	ASCII text files as described by DCR-0007.	Available from author
Flow and stage files	PRD-Flow.dat, Yakima-Flow.dat, IHR-Flow.dat, Steady_ZMCN.prn	ASCII text files as described by DCR-0007.	Available from author

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[a] Nichols, WE, PW Eslinger, and GV Last. February 3, 2006. *Hanford Remediation Assessment Project Data Configuration and Communication Management Plan, Rev. 1.1.* Pacific Northwest National Laboratory, Richland, Washington.

Table 3. Summary of Transport-only River Input Parameter Data Sets

Description	File Name	File Type	Location
Configuration file. Specifies grid files and the parameters to be used in the simulation of the hydrodynamics	Mass2_v027.cfg	ASCII text file as described by DCR-0007.	Available from author
Restart file. Hydrodynamics to be used for the transport realizations. These are managed as a library.	Hotstart_MM-DD-YYYY-00000.bin where MM-DD-YYYY indicates a date for the hotstart file.	Binary data file as described by DCR-0007.	Available from author
Boundary conditions file. Specifies inflow and outflow locations for the grids and file names of the boundary condition files. Connectivity between the grid blocks for the river is also specified.	Bcspecs.dat	ASCII text file as described by DCR-0007	Available from author
File names for river inflow concentration files for the realization analyte.	Scalar_bcspecs.dat	ASCII text file as described by DCR-0007.	Available from author
Input parameters and files for realization analyte. Documented in Eslinger et al. 2002.	Scalar_source.dat	ASCII text file as described by DCR-0007.	Available from author
Specification of files to be used for inflow concentration of suspended sediments	Sediment_scalar_bcspecs.dat	ASCII text files as described by DCR-0007.	Available from author
Computational grid files. Each file contains a single block with the block size and node locations for that block of the computational grid.	Sac_n-pt.nnn where nnn is a number between 000 and 057.	ASCII text files as described by DCR-0007.	Available from author
Bed depth files. Depth of the bed sediment at all nodes of the computational grid. Numbering corresponds to grid block file numbers.	Coarse-depth.nnn	ASCII text files as described by DCR-0007	Available from author
List of analyte input files to be used. Numbering corresponds to computational mesh block numbers.	Cfestmap.dat	ASCII text file as described by DCR-0007.	Available from author
Realization parameters	Realize.dat	ASCII text file as described by DCR-0007.	Generated for realizations as documented in Eslinger et al. 2002

Table 3. cont.

Description	File Name	File Type	Location
Background river concentrations of analytes used for stochastic realizations	Background_2005-11-23_DCR-0028.xls	Table, Excel files	Appendix A
Flow parameters. List of the restart files to be used as river inflows for the given realization.	Transport_only.dat	ASCII text file as described by DCR-0007	Generated as documented in Eslinger et al. 2002
Bed depth files – depth of the sediment at each computational node.	Initial_bed.dat points to coarse_depth.nnn where nnn is the number corresponding to the computational block.	ASCII text files as described by DCR-0007.	Available from author
List files for groundwater flow and analyte concentration. Gives the names of the input files for groundwater flow and concentration.	Bedflow-list.dat and [analyte]-list.dat	ASCII text files as described by DCR-0007.	Generated for specific realization as documented in Eslinger et al. 2002
Analyte input files. Input files with inflow volumes and concentrations as determined from the groundwater and vadose zone models.	Various. Supplied and documented by the SAC modeling team (Eslinger et al. 2002).	ASCII text files in cfest and ecem directories as described by DCR-0007	Generated for specific realization as documented in Eslinger et al. 2002.

5.0 Conclusions and Recommendations

River discharge estimates were adequate to the current task of running the simulation model at a monthly time interval. Daily and hourly flow data are available if the time is reduced in the future. A good bathymetric grid has been developed that provides increased resolution where necessary. Sediment data are the least available, but there is little evidence demonstrating an immediate need for additional resolution on this model component. Partition coefficient values have been broadly defined with carefully defined distributions based on the best available data, and stochastically incorporated into the model. Groundwater inputs are defined by the groundwater model results. Substantial data on radionuclide background levels and river inputs exist, and additional information is continually becoming available through programs such as the HEIS and Hanford Site Surface Environmental Surveillance Project.

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Appendix

Upstream Background Concentrations of Radionuclides in the Columbia River

Appendix

Upstream Background Concentrations of Radionuclides in the Columbia River

Applications of Hanford's System Assessment Capability (SAC) have been designed so that incremental increases of contaminants of Hanford origin in the Columbia River can be directly added to, or contrasted with, background concentrations coming with the river water from upstream. This design, naturally, requires estimates of background of all contaminants.

Radioactive background contaminants can originate in one or more of three sources. Primordial radionuclides are those that exist as a natural constituent of the earth's crust, and that are slowly and steadily released into the river via erosion. Examples of primordial radionuclides are members of the uranium and actinium decay series such as ^{234}U, ^{235}U, and ^{238}U and their immediate decay progeny ^{234}Th, ^{234m}Pa, or ^{231}Th, as well as members of these chains that are frequently not in equilibrium such as ^{226}Ra, ^{222}Rn, ^{210}Pb, ^{210}Po, and ^{210}Bi – some of which may have greater radiogenic hazard than their decay parents. Cosmogenic radionuclides are those created in the earth's atmosphere via interaction with cosmic rays. Examples of cosmogenic radionuclides include tritium (^{3}H) – about 4 million curies of which are produced annually due to cosmic ray interactions [NCRP Report No. 62, 1979], and ^{14}C – about 0.04 million curies per year are produced [UNSCEAR 1977]. Finally, anthropogenic radionuclides – those caused by human activities – are also present in the river water, primarily resulting from atmospheric fallout from past atmospheric testing of nuclear weapons. Examples of anthropogenic radionuclides include tritium, ^{137}Cs, ^{90}Sr, isotopes of plutonium, and other fission products in smaller amounts such as ^{99}Tc and ^{129}I. With the termination of atmospheric weapon testing in the 1960s, the amount of most anthropogenic radionuclides in the Columbia River has been falling with natural cleansing and radioactive decay.

Notice that some radionuclides, such as tritium, have substantial contributions from both natural and anthropogenic sources, and therefore do not have a constant background concentration.

For natural radionuclides that do not have a substantial anthropogenic source, the current and projected future background concentrations will remain essentially constant, within the range of current annual variations caused by minor differences in rainfall, turbidity, etc. For these radionuclides, recent measurements are summarized in Table A.1. The inter-annual variability is the measure of uncertainty. ^{234}U is slightly enhanced over its equilibrium value with ^{238}U, as is commonly measured.

A few radionuclides of interest in SAC calculations have not been measured in Columbia River water. These are anthropogenic radionuclides with small fission production rates, so concentrations, while possible in the river, are well below the levels of detection. These radionuclides are listed in Table A.2.

Table A.1. Natural Radionuclides with Little Anthropomorphic Influence

Radionuclide	Concentration	Variability	Basis
^{238}U	0.19 pCi/L	0.02	Measurements 1990 - 2004
^{235}U	0.0087 pCi/L	0.0002	Natural ratio with ^{238}U
^{231}Pa	0.0087 pCi/L	0.0002	Equilibrium with ^{235}U (EPA 1993)
^{234}U	0.20 pCi/L	0.03	Equilibrium with ^{238}U, enhanced release
^{14}C	0.054 pCi/L	0.004	Measurements 1990 - 1999

Table A.2. Radionuclides with Unmeasurable Background Concentrations

Radionuclide	Assigned Background
^{36}Cl	0 pCi/L
^{79}Se	0 pCi/L
^{152}Eu	0 pCi/L
^{237}Np	0 pCi/L

Most other radionuclides of interest in SAC calculations have been influenced to some extent by fallout. UNSCEAR (2000) Appendix C provides estimates of worldwide levels of fallout, with fraction by latitude band. Ratios are provided for numerous other radionuclides to ^{90}Sr. The yearly amount of fallout deposition for the Columbia Basin was estimated from the UNSCEAR (2000) values. Using simple radioactive accumulation and decay, the local fallout accumulation per unit area was estimated for every year from 1945 through the present. Using environmental monitoring data from Hanford, a relationship between fresh fallout, accumulated fallout, and concentrations of each radionuclide in Columbia River water was estimated. These radionuclide relationships are illustrated in Figure A.1, and compared with the annual monitoring data.

In the development of the relationships for projecting the radionuclide concentrations, for most radionuclides, the only diminution assumed after the end of the fallout period is due to radioactive decay. However, to best fit the data, two special considerations were added.

First, tritium is both a cosmogenic radionuclide as well as one derived from fallout. A constant cosmogenic background of 15 pCi/L has been assumed for tritium. (According to UNSCEAR (1982), background before nuclear weapons was 200-900 Bq/m^3 (5.4 - 24.3 pCi/L) for continental waters and 100 Bq/m^3 (2.7 pCi/L) for oceans, and they use 400 Bq/m^3 (10.8 pCi/L) for continental surface waters. UNSCEAR (1982) get this from Kaufman and Libby (1954). NCRP Report 62 (1979) reports that the natural equilibrium concentrations are 16.6 pCi/L in air, 10.4 pCi/L in streams, and 1.6 pCi/L in oceans, on the basis of cosmic ray production estimates and a dilution model. Eisenbud (1987) reports 5- 25 pCi/L in lakes, rivers, and potable water (but references UNSCEAR 1982). A reasonable uncertainty range on this value would be ±5 pCi/L.

Second, the data indicate that ^{137}Cs concentrations in Columbia River water are declining at a much faster rate than could be accounted for by radioactive decay alone. It is likely that fallout ^{137}Cs is both migrating deeper into subsurface soils and also sorbing to these soils, rather than washing into Columbia

Basin surface water with runoff and/or groundwater. The other radionuclides considered in this fallout analysis tend to be non-sorbing or less-sorbing than cesium. Therefore, a second reduction factor was added to the algorithm for ^{137}Cs; an 'enhanced immobilization' rate constant of 0.2 yr^{-1} has been added.

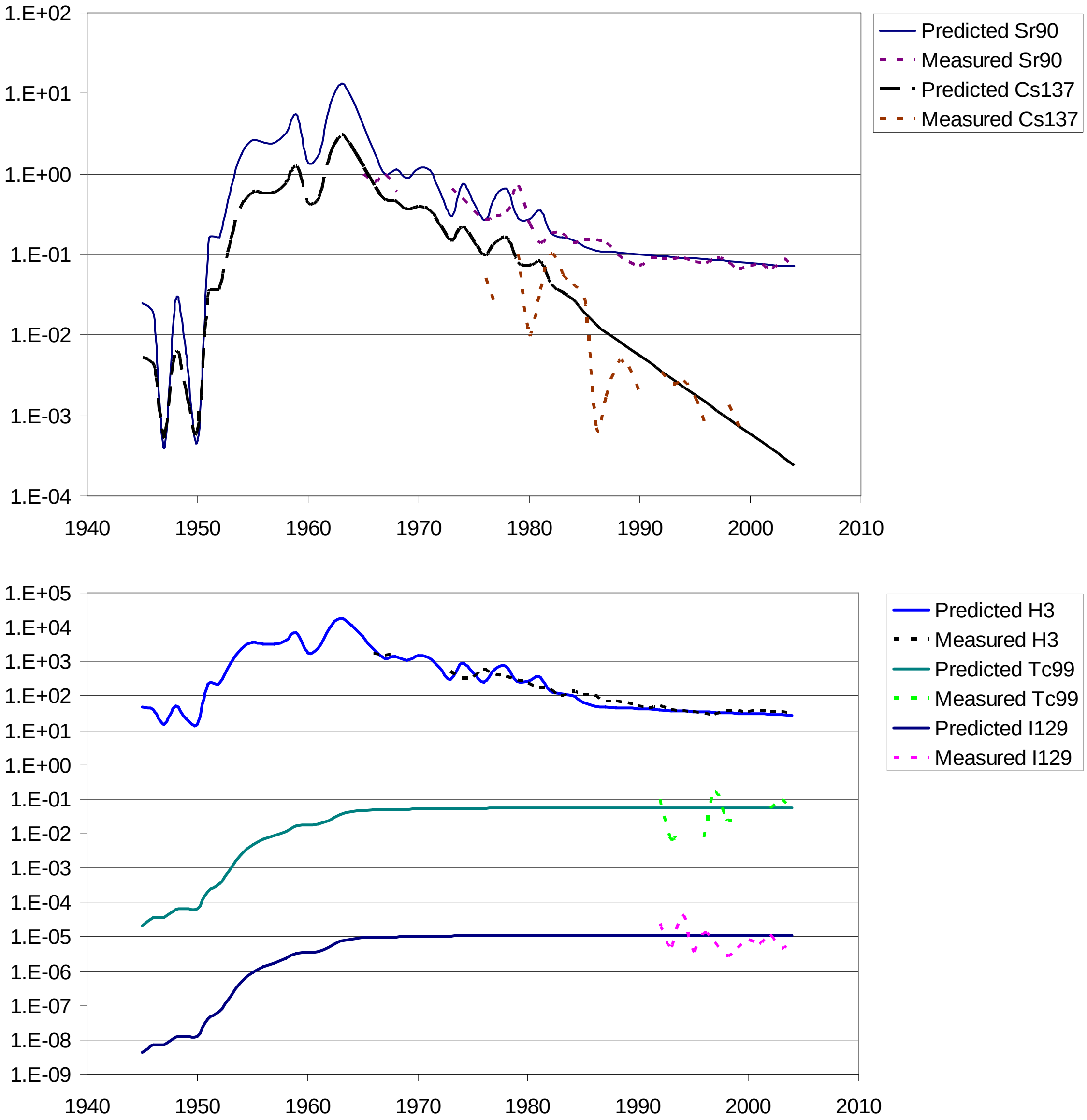

Figure A.1. Comparison of Estimated Fallout Radionuclide Concentrations in Columbia River Water with Measurements

As a result of these considerations, a general equation for calculating background concentrations in surface water will be applied to all analytes irrespective of whether they have any significant contribution from atmospheric fallout from nuclear weapons testing. For simplicity sake, contributions from fallout are considered only in 1990 or later years. The following governing equation for the background concentration in surface water is used for all years before 1990:

$$C_R = C_B$$

The following equation is used for 1990 or later years:

$$C_R = C_B + M_B e^{(-\lambda_b [\text{Year}-1990])}$$

where C_R = Concentration of the analyte in surface water (Ci/m^3 or kg/m^3)
C_B = Nominal background concentration (Ci/m^3 or kg/m^3) from natural sources
M_B = Concentration (Ci/m^3 or kg/m^3) from manmade sources (weapons testing fallout)
λ_B = Decay term (1/yr) that includes the effect of radioactive decay and leaching from the land surface into surface waters for the manmade sources

The values for C_B, M_B, and λ_B have different values for every analyte. The variables C_B and M_B are defined as stochastic variables. The variable for λ_B is defined as a constant. The values for C_B and M_B can be set to a constant, including the constant zero. The value for λ_B can also be set to zero.

The nominal values in the governing concentration equation for the analytes used in the Composite Analysis are provided in Table A.3. The values in Table A.3 have been modified to have units of Ci/m^3. The modification is performed by multiplying the original data in pCi/L by 10^{-9}.

Table A.3. Nominal Coefficient Values for Background Concentrations in the Columbia River

Analyte ID	C_B	M_B	λ_B	Fallout?
^{14}C	5.3×10^{-11}	0	0	No
^{136}C	0	0	0	No
^{137}Cs	0	5.49×10^{-12}	0.223	Yes
^{152}Eu	0	0	0	Very small
^{3}H(a)	1.5×10^{-8}	3.04×10^{-8}	0.0562	Yes
^{129}I	0	1.1×10^{-14}	4.41×10^{-8}	Very small
^{237}Np	0	0	0	Very small
^{231}Pa	8.7×10^{-12}	0	0	No
^{226}Ra	Not modeled	Not modeled	Not modeled	No
^{79}Se	0	0	0	Very small
^{90}Sr	0	9.99×10^{-11}	0.0241	Yes
^{99}Tc	0	5.52×10^{-11}	3.28×10^{-6}	Yes
^{233}U	0	0	0	No
^{234}U	2.0×10^{-10}	0	0	No
^{235}U(b)	8.7×10^{-12}	0	0	No
^{238}U	1.9×10^{-10}	0	0	No
^{234}U+^{238}U	3.9E-10	0	0	0

(a) Recent ^{3}H samples in the Columbia River have been decreasing towards about 15 pCi/L.
(b) The ^{235}U value is based on the ^{238}U value and 0.71% relative weight natural abundance.

The stochastic distributions associated with the nonzero coefficients defined in Table A.3 are defined using the following rules:

- **Variable C_B.** The triangular distribution will be used for all values of C_B. The distribution will be symmetric about the midpoint, and the half-range will be 50% of the mid-point. The variable tag will be CB.

- **Variable M_B.** The triangular distribution will be used for all values of C_B. The distribution will be symmetric about the midpoint, and the half-range will be 50% of the mid-point. The variable tag will be MB.

- **Variable λ_B.** This variable is always defined as a constant (except for ^{137}Cs which will be assigned a triangular distribution). For ^{137}Cs, the variability is ±0.05. The variable tag will be LB.

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