



## Appendix I-A

### Selection of Contaminants for the Screening Assessment

This appendix provides details of the process for selecting contaminants considered in the screening assessment. The references used as data sources are annotated in Appendix A.1. A composite list of radionuclides and chemicals identified as being present in environmental samples is presented in Appendix A.2. Appendix A.3 presents the numerical approach to screening the several hundred analytes to obtain those evaluated in the assessment. Appendix A.4 discusses the tables of supporting data used in the screening assessment but that are too large to display in the text.

The results of the screening process are listed in Section I-2.1. The discrete radioactive particles in the sediment of the Columbia River shoreline and islands are discussed in Section I-2.2. Section I-2.3 addresses special effects from Hanford facilities located adjacent to the river. Section I-2.4 addresses existing and potential future contaminants from groundwater sources distant from the river. The overall conclusions, listed as the contaminants to be evaluated in the screening assessment, are given in Section I-2.5. The references for this appendix are included under the Section 2 references provided in Section I-7.0.

#### A.1 Data Sources

This section provides an annotated bibliography of the sources used to identify the analytes sampled in environmental media. No single document or electronic database was available that covered the entire scope of contaminants for this research. Baseline efforts similar to the scope of our task were done in a project by Fowler et al. (1993). However, because that project covered all exposure pathways and numerous DOE sites, and identified only the presence of contaminants and not their concentrations, it is not directly applicable or as comprehensive as required for this task.

The CRCIA Project developed a compendium of existing data on Columbia River contamination (Eslinger et al. 1994). The compendium is a large bibliography of Hanford and non-Hanford sources that potentially contain relevant environmental monitoring information. This compendium was used as a starting point for data information.

**To find which materials might have harmful effects on humans or the environment, we looked at recent information gathered through monitoring of the Columbia River and groundwater, river sediment, and soil in the 100, 300, and 1100 Areas of the Hanford Site. Those are the areas next to the river most affected by hazardous materials. We only looked at groundwater information gathered from within 500 feet of the Columbia River because the screening assessment is primarily looking at current conditions. Any contaminants in the groundwater farther than 500 feet away from the river would not currently be reaching the river. In this section, we list all the documents we used to find information on what contaminants are in or near the river today. Knowing the documents we used helps other scientists to follow our footsteps and verify our results.**



The screening assessment is primarily concerned with the potential risk from current levels of contaminants of Hanford origin. Therefore, the most recent sampling data were used in selecting the contaminants. Because of the concern about potential future contamination of the river from Hanford facilities away from the river (although beyond the scope of the screening assessment), summary information was also reviewed relating to existing groundwater plumes outside the 100 Areas or farther than 150 meters (500 feet) from the Columbia River on the Hanford Site.

To understand some of the key terms in the bibliography, it is necessary to know that the radioactive, hazardous chemical, and mixed wastes are found in various individual waste sites, referred to as waste management units, located throughout the Hanford Site. These individual waste management units include past practice sites; surplus facilities; and treatment, storage, and disposal (TSD) facilities. Past practice sites and TSD facilities may take the form of spills, cribs, ditches, ponds, tanks, trenches, landfills, burial grounds, pits, French drains, and other means of intentional or unintentional disposal. Surplus facilities include contaminated buildings, exhaust stacks, and underground transfer lines. The individual waste management units are organized into “operable units” based on geographic proximity or similarity of waste disposal history. Operable unit is the term used to identify specific areas designated for cleanup. The number and first letter in the operable unit name indicate the location of the operable unit; for example, operable unit 100-HR-3 is in the 100-H Area.

The following annotated bibliography summarizes the sampling data sources and primary references used in selecting the contaminants. The annotated bibliography provides the complete reference, sampling purpose, sampling time frame, media sampled, as well as supplementary comments. Tables A.1 and A.2 (on diskette) present a complete list of radionuclides and chemicals evaluated at the Hanford Site. These data sources are not always the same as the ones ultimately used as the source term for the screening assessment of potential risk. The data sources used as the contaminant concentrations for the screening assessment of potential risk are described in Section I.-3.0.

### **A.1.1 General References**

Blanton, M. L., W. W. Gardiner, and R. L. Dirkes. 1995. *Environmental Monitoring of Columbia River Sediments: Grain-Size Distribution and Contaminant Association*, PNL-10535, Pacific Northwest Laboratory, Richland, Washington.

This document reports an evaluation of the characteristics associated with contaminant absorption that 1) documents the differences in sediment grain size and organic content, and 2) provides associations between grain size, organic matter, and contaminants in sediment occurring at six established monitoring sites. Sediment at the six sites (upstream of, within, and downstream of Hanford) was analyzed for grain size, organic carbon content, radionuclides, metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and pesticides.

Dirkes, R. L. 1993. *Columbia River Monitoring: Distribution of Tritium in Columbia River Water at the Richland Pumphouse*. PNL-8531, Pacific Northwest Laboratory, Richland, Washington.



This document reports the results of a special investigation conducted by the Surface Environmental Surveillance Project at the Pacific Northwest National Laboratory (PNNL). Supplemental monitoring of tritium (hydrogen-3) in the Columbia River was conducted in the summers of 1987 and 1988. The purpose of the monitoring was to provide information related to the dispersion and distribution of Hanford-originating contaminants entering the river through the seepage of groundwater along the Hanford Site.

Dirkes, R. L. 1994. *Summary of Radiological Monitoring of Columbia River Water along the Hanford Reach, 1980 through 1989*. PNL-9223, Pacific Northwest Laboratory, Richland, Washington.

A portion of PNNL's Surface Environmental Surveillance Project is involved with monitoring the Columbia River. This document summarizes the river water monitoring activities of the Columbia River monitoring program during the 1980s. Routine and special monitoring projects and radiological and chemical constituents are reviewed. This report summarizes the information presented in the annual environmental reports.

Dirkes, R. L., G. W. Patton, and B. L. Tiller. 1993. *Columbia River Monitoring: Summary of Chemical Monitoring Along Cross Sections at Vernita Bridge and Richland*. PNL-8654, Pacific Northwest Laboratory, Richland, Washington.

Chemical monitoring was performed by PNNL's Surface Environmental Surveillance Project at the Vernita Bridge and the Richland Pumphouse. Potential Hanford-originating chemicals of interest were selected for sampling, including volatile organic compounds (VOCs), metals, and anions. Sample frequency was monthly from August 1991 to December 1991, but was reduced to quarterly during calendar year 1992. The monitoring results were benchmarked with those of the United States Geological Survey monitoring program, and no variants were found.

DOE - U.S. Department of Energy. 1992a. *Sampling and Analysis of 100 Area Springs*. DOE/RL-92-12, Rev. 1, U.S. Department of Energy, Richland, Washington.

This document provides validated monitoring data from the sampling of the Columbia River, seeps, springs, and sediment adjacent to the Hanford 100 Areas National Priorities List Site. The data were published as part of a Tri-Party Agreement milestone to evaluate how the contaminated seeps and springs impact the Columbia River. An assessment of the data is included. Samples were collected in September and October 1991 during the normal low-flow period of the Columbia River. Twenty-six locations were sampled along a 37-kilometer (22-mile) stretch of the river, ranging from just upstream of the 100-B/C Area water intake to the old Hanford townsite.

DOE - U.S. Department of Energy. 1992b. *Hanford Site Groundwater Background*. DOE/RL-92-23, U.S. Department of Energy, Richland, Washington.

This report is a preliminary evaluation of data and information related to the natural composition of groundwater in the unconfined aquifer system beneath the Hanford Site. This information is to be used as a baseline for distinguishing the presence and significance of contamination in the groundwater. The relevant



part of the aquifer evaluated extended from the surface waters that potentially recharge the aquifer to the uppermost portion of the underlying confined aquifer. Surface waters were found, in general, to have lower concentrations of constituents than the springs, unconfined groundwater, and confined groundwater. The provisional background threshold levels of background constituent concentrations in groundwater presented in this report are described as “likely to be conservatively low” (p. iv).

DOE - U.S. Department of Energy. 1994a. *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes*. DOE/RL-92-24, Rev. 2, Vol. 1 of 2, U.S. Department of Energy, Richland, Washington.

This document was written to support environmental restoration, waste management, and facilities operations activities at Hanford. The background composition of Hanford Site soil is characterized to identify soil contamination and to provide a baseline in risk assessment processes used to determine soil cleanup and treatment levels. The compositions of naturally occurring soil in the zone above the groundwater level have been determined for non-radioactive inorganic and organic analytes and related physical properties. The range of inorganic and organic analytes that can be expected in Hanford Site background soil is evaluated. The highest measured background concentrations occur in three volumetrically minor soil types (the most important of which is topsoil adjacent to the Columbia River), which are rich in organic carbon. The chemical composition of more than 170 soil samples from 22 places on the Hanford Site and 3 places adjoining the Hanford Site was determined for inorganic analytes in accordance with U.S. Environmental Protection Agency (EPA) protocols. Twelve of the samples were analyzed for volatile and semivolatile organic chemicals, as well as for pesticides and polychlorinated biphenyls (PCBs). Samples were collected from September through November 1991.

DOE - U.S. Department of Energy. 1994b. *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities*. DOE/RL-93-88, Rev. 0, U.S. Department of Energy, Richland, Washington.

This report is an annual hydrologic evaluation of 20 groundwater monitoring projects for RCRA (Resource and Conservation Recovery Act) and one non-hazardous waste facility at the Hanford Site. The report includes an interpretation of groundwater data collected at 30 waste management units between October 1992 and September 1993. Also, recent groundwater quality evaluations for the 100 and 300 Areas and the entire Hanford Site are described. Widespread contaminants include nitrate, chromium, carbon tetrachloride, tritium (hydrogen-3), and other radionuclides.

DOE - U.S. Department of Energy. 1996a. *Hanford Site Background: Part 2, Soil Background for Radionuclides*. DOE/RL-96-12, U.S. Department of Energy, Richland, Washington.

This document was written to support environmental restoration, waste management, and facilities operations activities at Hanford. The background composition of Hanford Site soil is characterized to identify soil contamination and to provide a baseline in risk assessment processes used to determine soil cleanup and treatment levels. Radionuclides are differentiated as being either natural or anthropogenic, and a very limited suite is provided.



Dunks, K. L. 1996. *100 Area River Effluent Pipelines Characterization Report*. BHI-00538, Bechtel Hanford, Inc., Richland, Washington.

In the summer of 1995, the river effluent pipelines at the 100-B and 100-D Reactor sites were radiologically, chemically, and physically characterized using a robotic transporter for the sampling and characterization equipment. The inspections documented each pipeline's interior condition by video recording the interior, using radiation monitoring instruments, using ultrasonic testing to determine the pipe's thickness, and collecting interior scale and sediment samples. The samples were evaluated for 12 radionuclides and 19 metals.

Eslinger, P. W., L. R. Huesties, A. D. Maughan, T. B. Miley, and W. H. Walters. 1994. *Data Compendium for the Columbia River Impact Assessment*. PNL-9785, Pacific Northwest Laboratory, Richland, Washington.

This document provides a bibliography of sources of existing data on Columbia River contamination, listing about 4,500 documents and 13 major databases that potentially contain information about contaminants in the Columbia River from Hanford activities. The bibliography was further refined to highlight 60 key documents containing data or describe analyses important in evaluating the health of the Columbia River. The work was performed to meet the Tri-Party Agreement milestone number M-13-80.

Ford, B. H. 1993. *Groundwater Field Characterization Report for the 200 Aggregate Area Management Study*. WHC-SD-EN-TI-020, Westinghouse Hanford Company, Richland, Washington.

This report provides contaminant plume maps for the unconfined aquifer of the 200 East and 200 West groundwater aggregate areas. Data deficiencies are identified with recommendations for additional sampling and well drilling. Individual plumes are identified for arsenic, chromium, cyanide, fluoride, nitrate, carbon tetrachloride, chloroform, trichloroethylene, tritium (hydrogen-3), gross beta, cobalt-60, strontium-90, technetium-99, iodine-129, cesium-137, gross alpha, uranium, and plutonium.

Fowler, K. M., K. B. Miller, M. O. Hogan, and J. F. Donaghue. 1993. *Risk-Based Standards Chemicals of Interest Database Documentation*. U.S. Department of Energy, Richland, Washington.

A comprehensive set of risk-based standards is needed by the DOE to conduct its waste management, environmental restoration, and decontamination and decommissioning activities. The first step in developing the standards was to gather information on hazardous and radioactive substances that are found as contaminants or that are stored at DOE facilities. Twenty-six DOE sites were surveyed for substances that are generated, used, or present. Sources of information included Superfund Amendments and Reauthorization Act Title III reports (SARA 1986), remedial investigation/feasibility study reports, and other miscellaneous sources. The document indicates the radionuclide and chemical names and media type in which they were found (air, groundwater, sediment, soil, surface water, tank wastes, and not specified/available), but does not provide any quantitative sampling results. For the Hanford Site, 326 radionuclides and chemicals were identified.



Hartman, M. J., and K. A. Lindsey. 1993. *Hydrogeology of the 100-N Area, Hanford Site, Washington*. WHC-SD-EN-EV-027, Westinghouse Hanford Company, Richland, Washington.

The report primarily describes the hydrologic units beneath the 100-N Area. It describes primary contaminants of interest, including strontium-90 and tritium (hydrogen-3) associated with the liquid waste disposal sites, sulfate and sodium, and petroleum products associated with leaks and spills. Eight petroleum (diesel oil) spills are documented between 1966 and 1988. Following a 1966 leak, an interceptor trench was built to collect migrating diesel oil and was periodically burned. A significant amount of free petroleum apparently remains in the zone above groundwater level. As much as 45 centimeters (1.5 feet) of petroleum product has been observed floating on top of the water in some of the monitoring wells. The petroleum seems to appear on the water table following periods of recharge to the aquifer.

Hope, S. J., and R. E. Peterson. 1995. *Chromium Concentrations in 100-H Reactor Area Pore Water within Chinook Salmon Spawning Habitat of the Hanford Reach, Columbia River*. BHI-00345, Bechtel Hanford, Inc., Richland, Washington.

The report describes the results of a study using a unique method of obtaining pore water samples from salmon spawning habitat within river substrate in proximity to the 100-H Reactor area. Pore water was obtained by divers from a depth of 45 centimeters (1.5 feet) in the substrate. Pore water was collected from 31 sample points along 17 transects from a 1524-meter (5000-foot) reach of river adjacent to the 100-H area and along 3 transects containing 6 sample points at Vernita Bar. Of these samples, 3 at the 100-H area exceeded the Ambient Water Quality Criterion of 11 microgram/liter (EPA 1992).

Law, A. G. 1990. *Status of Groundwater in the 1100 Area*. Correspondence No. 8900604B R4, Westinghouse Hanford Company, Richland, Washington.

This document provides the quarterly results from the operational groundwater monitoring program at Westinghouse Hanford Company for five wells installed in the vicinity of the 1100 Area. Results for approximately 380 analytes are presented. All are essentially undetected or are at background levels.

Peterson, R. E., and V. G. Johnson. 1992. *Riverbank Seepage of Groundwater Along the 100 Areas Shoreline, Hanford Site*. WHC-EP-0609, Westinghouse Hanford Company, Richland, Washington.

Data were obtained during environmental surveillance activities and remedial investigations to characterize the influence of contaminated groundwater on the Columbia River. Radionuclides and metals in the seepage, sediment associated with the seepage, and near-shore Columbia River water were sampled. Samples collected in September and October of 1991 are compared with both data collected in 1984 and 1988 and nearby groundwater data.

Rowley, C. A. 1993. *100-N Area Underground Storage Tank Closures*. WHC-SD-EN-TI-136, Westinghouse Hanford Company, Richland, Washington.



This report describes removal/characterization actions undertaken from 1990-199 concerning underground petroleum storage tanks in the 100-N Area. Instances of leaks from underground connections are noted. No groundwater contamination resulting from these tanks was found.

Weiss, S. G. 1993. *100 Area Columbia River Sediment Sampling*. WHC-SD-EN-TI-198, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

To determine whether radiological and chemical contaminants are present in the Columbia River, 44 sediment samples were collected from 28 locations in the Hanford Reach in the fall of 1992. The sand-sized and smaller sediment samples collected from the near shore and shoreline were analyzed for metals and radionuclides. Three of the sample locations were upriver from Hanford. Sediment was collected at depths of 0-15 centimeters (0-6 inches) and 30-60 centimeters (12-24 inches) below the surface. Contamination from arsenic, chromium, copper, lead, and zinc was found. The arsenic, lead, and zinc contamination may not be of Hanford origin. Cesium-137 and europium-152 were the most frequently detected radionuclides.

Wells, D. 1994. *Radioactivity in Columbia River Sediments and Their Health Effects*. Special Report, Washington State Department of Health, Olympia, Washington.

This document addresses the current human health effects of artificial radioactivity in the Columbia River sediment. The Columbia River sediment data from the early 1960s to the present were provided by state agencies, federal agencies, and academic researchers. The sediment samples were collected from the Hanford area to the estuaries and coastlines of Oregon and Washington. Samples include surface sediment and deeper sediment behind the dams of the lower Columbia River. Ecological risk was not evaluated nor was the human health risk from sediment contaminated with radioactive materials entering the Columbia River at riverbank seeps and springs.

### **A.1.2 Hanford Environmental Information System**

DOE - U.S. Department of Energy. 1994c. *HEIS - Hanford Environmental Information System*. For documentation supporting the HEIS database, see DOE/RL-93-24, 9 volumes, U.S. Department of Energy, Richland, Washington. Queried: August 24, 1994.

The Hanford Environmental Information System (HEIS) is an electronic database that consolidates the data gathered during environmental monitoring and restoration of the Hanford Site. Data stored in HEIS are collected under several regulatory programs. The basis of HEIS is individual sample data for air, biota, groundwater, soil, sediment, surface water, and miscellaneous materials. HEIS was queried for information about maximum contaminant concentrations in groundwater within 150 meters (500 feet) of the Columbia River.



### **A.1.3 Remedial Investigation/Feasibility Studies**

EPA is the lead regulatory agency for the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). Under CERCLA, a specific process has been established to identify potentially hazardous sites, characterize site contamination, assess treatment technologies, and then design and construct the appropriate treatment facilities. The remedial investigation/feasibility study portion of the process defined in CERCLA requires determining the nature and extent of the threat posed by a release of hazardous substances to the environment and evaluating proposed remedies. The following remedial investigation/feasibility studies contributed information to the CRCIA Project.

DOE - U.S. Department of Energy. 1990a. *Remedial Investigation/Feasibility Study Work Plan for the 300-FF-5 Operable Unit, Hanford Site, Richland, Washington*. DOE/RL 89-14, U.S. Department of Energy, Richland, Washington.

The 300-FF-5 operable unit consists of the groundwater aquifer beneath the 300-FF-1, 300-FF-2, and 300-FF-3 source operable units and adjacent areas defined by the extent of the groundwater contamination. The scope of the remedial investigation/feasibility study of the 300-FF-5 operable unit focuses on groundwater, soil, surface water/sediment and aquatic biota and considers all contaminant sources in the 300 Area that contribute to the existing groundwater contamination beneath the 300 Area and the surrounding environment. The sample data upon which the remedial investigation/feasibility study is based appear to have been taken in the mid-1980s. Groundwater monitoring for metals began in 1985.

DOE - U.S. Department of Energy. 1990b. *Remedial Investigation/Feasibility Study Work Plan for the 300-FF-1 Operable Unit, Hanford Site, Richland, Washington*. DOE/RL 88-31, U.S. Department of Energy, Richland, Washington.

The purpose of the remedial investigation of the 300-FF-1 operable unit was to provide sufficient information to conduct the feasibility study by determining the nature and extent of the threat to public health and the environment posed by releases of hazardous substances from 300-FF-1, a process liquid operable unit that contains all the liquid waste disposal facilities within the 300 Area. Hazardous and radioactive materials from this operable unit contribute to groundwater contamination. Soil sampling data are provided for radionuclides, inorganics, and an extensive list of organics. Monitoring of groundwater analytes was more limited.

### **A.1.4 Hanford Site Environmental Reports**

Every year, beginning in 1957, a report is prepared summarizing environmental data that characterize the Hanford Site environmental management performance and demonstrate compliance status. These reports summarize the activities and results of monitoring by PNNL's Surface Environmental Surveillance Project. In recent years, data have been provided in separate volumes. The following annual reports were used in selecting contaminants for the screening assessment.



Bisping, L. E. 1992. *Hanford Site Environmental Data 1991 - Surface and Columbia River*. PNL-8149, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E. 1994. *Hanford Site Environmental Data for Calendar Year 1993 - Surface and Columbia River*. PNL-9824, Pacific Northwest Laboratory, Richland, Washington.

Bisping, L. E., and R. K. Woodruff. 1993. *Hanford Site Environmental Data for Calendar Year 1992 - Surface and Columbia River*. PNL-8683, Pacific Northwest Laboratory, Richland, Washington.

Dirkes, R. L., and R. W. Hanf. 1995. *Hanford Site Environmental Report for Calendar Year 1994*. PNL-10574, Pacific Northwest Laboratory, Richland, Washington.

Dirkes, R. L., R. W. Hanf, R. K. Woodruff, and R. E. Lundgren. 1994. *Hanford Site Environmental Report for Calendar Year 1993*. PNL-9823, Pacific Northwest Laboratory, Richland, Washington.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren. 1992. *Hanford Site Environmental Report for Calendar Year 1991*. PNL-8148, Pacific Northwest Laboratory, Richland, Washington.

Woodruff, R. K., R. W. Hanf, and R. E. Lundgren. 1993. *Hanford Site Environmental Report for Calendar Year 1992*. PNL-8682, Pacific Northwest Laboratory, Richland, Washington.

### **A.1.5 Limited Field Investigations**

Limited Field Investigations (LFIs) are abbreviated versions of remedial investigations conducted as part of Tri-Party Agreement activities to identify Hanford waste sites that are recommended to remain as candidates for interim remedial measures. The assessments consider whether contaminant concentrations pose an unacceptable risk that warrants action through interim remedial measures.

Each LFI is conducted on a single Hanford operable unit (for example, operable unit 100-HR-3). Many of the column headings in Tables A.1 and A.2 (on diskette) correspond to the operable unit name. The LFI reports annotated in this section are available to the public. Since the completion of this work, additional LFIs have become available. These newer LFIs are not listed here because they were not used in developing the list of contaminants.

DOE - U.S. Department of Energy. 1993a. *Limited Field Investigation Report for the 100-BC-5 Operable Unit*. DOE/RL-93-37, Draft A, U.S. Department of Energy, Richland, Washington.

This study was initiated to further characterize the groundwater contamination in the 100-BC Area. Groundwater, surface water, sediment, and soil sampling data are provided. Volatile constituent concentrations were of primary interest, but the media were also sampled for radionuclides, organics, inorganics, and physical properties. The LFI groundwater sampling data are reported for July 1992, October 1992, and January 1993.



DOE - U.S. Department of Energy. 1993b. *Limited Field Investigation Report for the 100-DR-1 Operable Unit*. DOE/RL-93-29, Draft A, U.S. Department of Energy, Richland, Washington.

The purpose of this study was to characterize the waste facility sites associated with the D Reactor and the water retention basin systems for both the D and DR Reactors and in the 100-DR Area. Soil sampling results are reported. Groundwater sampling data for this same region are contained in the LFI, 100-HR-3 (see DOE 1993d below). Media were sampled for VOCs, semivolatiles, inorganics, metals, PCBs, pesticides, radionuclides, specific anions, hexavalent chromium, and physical properties. Samples were collected in March 1993.

DOE - U.S. Department of Energy. 1993c. *Limited Field Investigation Report for the 100-HR-1 Operable Unit*. DOE/RL-93-51, Draft A, U.S. Department of Energy, Richland, Washington.

This study was initiated to characterize the waste units associated with facility sites supporting the H Reactor in the 100-H Area. This document provides sludge, sediment, and soil sampling data. Groundwater sampling data are contained in the LFI, 100-HR-3 (see below). Media were sampled for VOCs, semivolatiles, inorganics, metals, PCBs, pesticides, radionuclides, and physical properties. The media were sampled from December 1991 through August 1992.

DOE - U.S. Department of Energy. 1993d. *Limited Field Investigation Report for the 100-HR-3 Operable Unit*. DOE/RL-93-43, Draft A, U.S. Department of Energy, Richland, Washington.

This study was initiated to further characterize the groundwater contamination in the 100-HR-3 operable unit, which is inclusive of three sub-areas: 100-D, 100-H, and the 600 Area between the D and H Reactor areas. This document provides groundwater, sediment, and soil sampling data for radionuclides, volatile and semivolatile organic compounds, inorganics, and pesticides. Media were sampled from May 1992 through March 1993.

DOE - U.S. Department of Energy. 1994d. *Limited Field Investigation Report for the 100-BC-1 Operable Unit*. DOE/RL-93-06, U.S. Department of Energy, Richland, Washington.

This study was initiated to characterize the liquid and sludge at disposal sites associated with the B Reactor in the 100-BC Area. Groundwater sampling data are contained in the LFI, 100-BC-5 (see DOE 1993a above). Surface water and sediment sampling are not applicable to the 100-BC-1 area. Media were sampled for VOCs, semivolatiles, inorganics, metals, PCBs, pesticides, radionuclides, and physical properties. Sampling data were collected from April 1992 through July 1992.

DOE - U.S. Department of Energy. 1994e. *Limited Field Investigation Report for the 100-KR-1 Operable Unit*. DOE/RL-93-78, Draft A, U.S. Department of Energy, Richland, Washington.

This document provides soil sampling data. Groundwater sampling data are contained in the LFI, 100-KR-4 (see DOE 1994f below). Surface water and sediment sampling are not applicable to the



100-KR-1 operable unit. Media were sampled for VOCs, inorganics, metals, radionuclides, hexavalent chromium, and physical properties. Samples were taken from October 1992 through March 1993.

DOE - U.S. Department of Energy. 1994f. *Limited Field Investigation Report for the 100-KR-4 Operable Unit*. DOE/RL-93-79, U.S. Department of Energy, Richland, Washington.

This LFI was initiated to further characterize the groundwater contamination in the 100-KR area operable units: 100-KR-1, 100-KR-2, and 100-KR-3. In addition to the groundwater samples, other sampling data include surface water, sediment, soil, and aquatic biotic impacted by the KE and KW reactors. The media were sampled for VOCs, semivolatiles, inorganics, metals, pesticides, and radionuclides. Samples were collected in October 1991, September 1992, December 1992, March 1993, and June 1993.

### **A.1.6 Discrete Radioactive Particles and Other Direct Exposure Sources**

In addition to the routine environmental monitoring documented in the Hanford Site annual reports, occasional special studies are performed to evaluate particular conditions. Key studies are described here.

Cooper, A. T., and R. K. Woodruff. 1993. *Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River*. PNL-8789, Pacific Northwest Laboratory, Richland, Washington.

This report documents the first major field study to investigate exposure rates along the Columbia River shoreline since the Sula (1980) investigation of 1979. Radionuclides and trace metals were surveyed between Priest Rapids Dam and north Richland. A smaller number of discrete radioactive particles were also noted.

EG&G Energy Measurements. 1990. *An Aerial Radiological Survey of the Hanford Site and Surrounding Area, Richland, Washington*. EGG-10617-1062, EG&G Energy Measurements, The Remote Sensing Laboratory, Las Vegas, Nevada.

EG&G used a radiation detection system in a helicopter to conduct a radiological survey of the Hanford area. The detection system was calibrated to suppress natural background radiation and therefore only detected sources of anthropogenic gamma-emitting radioactivity. The aerial data are presented as isopleths overlaid onto maps of the Hanford Site. The aerial survey is an aid in locating areas with elevated exposure rates but does not stringently define contaminated areas.

Sula, M. J. 1980. *Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and the Snake River Confluence*. PNL-3127, Pacific Northwest Laboratory, Richland, Washington.

This report describes a radiological survey performed to evaluate the magnitude and distribution of radioactive contamination on the exposed shorelines of the Columbia River. External exposure rate



measurements were made at nearly 30,000 locations. In addition, discrete particles of radioactive material and discrete metallic flakes containing cobalt-60 were found. The highest areal density of particles was found on an island near D Reactor, although the presence of particles was indicated as far downriver as the survey extended.

Thatcher, A.H. 1995. *100N Area Shoreline Radiation Survey and Dose Evaluation*, Washington State Department of Health, Olympia, Washington.

Washington State Department of Health staff performed a radiation survey along the 100-N area shoreline in July of 1994 and one of the opposite shoreline in February of 1995. The surveys' goal was to measure "skyshine" (caused by Compton scattering of gamma rays) as a result of sources of cobalt-60 and cesium-137 in the 100-N Area. Results indicated two areas of elevated exposure near the Emergency Dump Tank and the Liquid Waste Disposal Facilities. In both areas, the net maximum exposure rate is 19 microrentgen/hour, occurring along approximately 244 meters (800 feet) of shoreline. Analysis of the results for the opposite shoreline identified no observable increases over background.

Wade, C. D., and M. A. Wendling. 1994. *100-D Island USRADS Radiological Surveys Preliminary Report Phase II*. BHI-00-134, Bechtel Hanford, Inc., Richland, Washington.

This report describes the results of radiological surveys made in April 1994 over the upstream third of the island adjacent to the 100-D Reactor Area. The survey used the Ultrasonic Ranging and Data System. A significant note is that "with a few exceptions, every area which was determined to be gamma elevated was sampled and the sampling removed the entire contamination present. In these locations, extremely small 'hot particles' were removed from the silt layer beneath the river rock." Analyses of these particles showed them to contain almost entirely cobalt-60 activity, between 0.4 and 22 microcuries each. From an area of about 5 hectares (12.5 acres), 103 particles were recovered.

### **A.1.7 National Environmental Policy Act (NEPA) Documents**

Quantifying the potential for future releases of contaminants to the Columbia River from surplus facilities or waste sites requires a significant investigation, one that is defined in Part II of this report, but is beyond the scope of the screening assessment. However, several major environmental impact statements (EISs) concerning Hanford facilities and waste management practices have been written. Each of these reports contains evaluations of potential future conditions based on current or projected Hanford Site status.

DOE - U.S. Department of Energy. 1987. *Final Environmental Impact Statement, Disposal of Hanford Defense High-Level, Transuranic, and Tank Wastes, Hanford Site, Richland, Washington*. DOE/EIS-0113, U.S. Department of Energy, Washington, D.C.

This EIS addressed the selection and implementation of final disposal actions for high-level, transuranic, and tank wastes at Hanford. Although a decision on the existing single-shell tanks was



ultimately deferred, this EIS describes the potential releases of radionuclides to the groundwater, and ultimately the Columbia River, for each of the major waste categories at Hanford.

DOE - U.S. Department of Energy. 1989. *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington, Draft Environmental Impact Statement*. DOE/EIS-0119D, U.S. Department of Energy, Washington, D.C.

and

DOE - U.S. Department of Energy. 1992c. *Decommissioning of Eight Surplus Production Reactors at the Hanford Site, Richland, Washington, (Final Environmental Impact Statement)*. DOE/EIS-0119F, U.S. Department of Energy, Washington, D.C.

This EIS, together with its addendum, which constitutes the final EIS, describes the potential future releases of radionuclides to groundwater, and ultimately the Columbia River, from decommissioning the eight original Hanford reactors (excluding N Reactor) and the associated fuel storage basins. The preferred alternative for disposal was selected to be one-piece removal of the reactors from the riverside and burial in the 200 Areas.

DOE - U.S. Department of Energy. 1990c. *Low-Level Burial Grounds Dangerous Waste Permit Application: Request for Exemption from Lined Trench Requirements for Submarine Reactor Compartments*. DOE/RL-88-20, Supplement 1, U.S. Department of Energy, Richland, Washington.

and

DOE - U.S. Department of Energy. 1992d. *Low-Level Burial Grounds Dangerous Waste Permit Application: Request for Exemption from Lined Trench Requirements and from Land Disposal Restrictions for Residual Liquid at 218-E-12B Burial Ground Trench 94*. DOE/RL-88-20, Supplement 1, Revision 1, U.S. Department of Energy, Richland, Washington.

These two reports discuss decommissioned, defueled naval submarine reactor compartments containing radioactivity caused by exposure of structural components to neutrons during normal operation of the submarines. After all the alternatives were evaluated in the 1984 EIS by the U.S. Department of the Navy, land burial of the submarine reactor compartments was selected as the preferred disposal option (Navy 1984). The reactor compartments currently are sent to Trench 94 of the Hanford 218-E-12B Burial Ground. In addition to radioactivity, the reactor compartments disposed of contain lead and PCBs as hazardous constituents. Modeling results indicate that release of contaminants to the groundwater or surface water will not occur until after long periods of time and that even after reaching the groundwater, contaminants will not be in excess of current regulatory limits, such as drinking water standards.

DOE - U.S. Department of Energy. 1996c. *Hanford Remedial Action Draft Environmental Impact Statement*. DOE/DEIS-0222, U.S. Department of Energy, Washington, D.C.



This EIS provides estimates of long-term risk resulting from the current groundwater plumes existing beneath the Site, as well as projections of future risk from non-tank, non-operating-facility waste management units.

Navy - U.S. Department of the Navy. 1984. *Final Environmental Impact Statement on the Disposal of Decommissioned, Defueled Naval Submarine Reactor Plants*. U.S. Department of the Navy, Washington, D.C.

This EIS discusses various alternatives for disposing of the radioactive portions of decommissioned nuclear submarines, leading to the selection of the Hanford Site as the location for permanent disposal. Estimates are presented for potential future radiation doses resulting from these activities.

Rhoads, K., B. N. Bjornstad, R. E. Lewis, S. S. Teel, K. J. Cantrell, R. J. Serne, L. H. Sawyer, J. L. Smoot, J. E. Szecsody, M. S. Wigmosta, and S. K. Wurstner. 1994. *Estimation of the Release and Migration of Nickel Through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground*. PNL-9791, Pacific Northwest Laboratory, Richland, Washington.

This report evaluates the potential for radioactive and non-radioactive nickel to migrate from buried submarine reactor compartments to the Columbia River. The estimated time of arrival of the contaminant plume ranges from 60,000 years to 4 million years.

Rhoads, K., B. N. Bjornstad, R. E. Lewis, S. S. Teel, K. J. Cantrell, R. J. Serne, J. L. Smoot, C. T. Kincaid, and S. K. Wurstner. 1992. *Estimation of the Release and Migration of Lead Through Soils and Groundwater at the Hanford Site 218-E-12B Burial Ground*. PNL-8356 Vol. 1, Pacific Northwest Laboratory, Richland, Washington.

This report evaluates the potential for radioactive and non-radioactive lead to migrate from buried submarine reactor compartments to the Columbia River. The estimated time of arrival of the contaminant plume ranges from 60,000 years to 4 million years.

## **A.2 Composite List of Identified Radionuclides and Chemicals**

A data matrix (Tables A.1 and A.2, on diskette) was developed using the information found in the documents listed in Section A.1. The matrix includes all radionuclides and chemicals analyzed in surface water (the Columbia River, springs, and seeps), sediment, groundwater, and soil samples in the 100, 300, 1100 Areas as well as other areas within 150 meters (500 feet) of the Columbia River. The data matrix is a composite list of all detected and not detected (in other words, analyzed for but not detected)



Using the documents listed in the previous section, we compiled a list of all contaminants that were tested for between 1980-1994 (current conditions). Tables A.1 and A.2 (on diskette) show the list, even the contaminants that were tested for but not found. The tables list 568 analytes as having been tested for in the Columbia River and groundwater, and 560 analytes as having been tested for in soil and sediment. An analyte is any substance that has been tested for. Of the analytes tested, 73 were detected in the Columbia River or groundwater, and 86 were detected in soil and sediment. These contaminants are listed in Table A.4 for Columbia River water and groundwater and Table A.5 for soil and sediment.

radionuclides and chemicals from the reviewed literature. Sampling data from 1980 through 1994 were considered.

### A.2.1 Risk-Based Standards Database

The development of the data matrix began with all chemicals identified in the Risk-Based Standards Database (Fowler et al. 1993), which is a list of hazardous and radioactive substances that are reportedly found as contaminants or that are stored at DOE facilities nationwide. The Risk-Based Standards Database contains 326 radionuclide and chemical entries for the Hanford Site. The radionuclides and

chemicals in the database are sorted by their presence in the following media: Columbia River water, groundwater, soil, air, tank waste, and sediment. A total of 120 organic compounds, 133 inorganics, and 73 radionuclides are identified. These data formed the early basis for the data matrix.

Duplicate entries were removed from the database. Three mixtures (diesel fuel, hydrocarbons, and kerosene) contained in the database were included in the data matrix. The primary database references were consulted for the concentration detected for each media. However, the presence of the organics could not be confirmed from the primary references cited in the database. Additional sources were reviewed to obtain information on the organic constituents.

### A.2.2 Environmental Sampling Data Reports

The chemical, analytical, and radioanalytical data collected and presented in published environmental sampling reports were compiled and are presented in the data matrix. These reports include LFI reports, qualitative risk assessments, reports from remedial investigation/feasibility studies, RCRA groundwater monitoring, and special studies reports (Section A.1). The scope was limited to the 100, 300, and 1100 Areas and monitoring of the Columbia River and its riparian zone because they are most likely to have current impact.

The names of all radionuclides and chemicals examined (including those reported as non-detected) were added to the data matrix. The reported maximum concentration or activity is noted by media along with the background value, its reference, and the operable unit or geographical area where the sampling occurred. In the reviewed literature, 568 and 560 analytes (Tables A.1 and A.2, on diskette) were reported to be tested for in groundwater/Columbia River and soil/sediment, respectively.

Of the analytes tested, 73 were detected in groundwater or Columbia River water, and 86 were detected in soil and sediment. The concentrations detected were compared, where possible, with the background



concentrations existing in other, uncontaminated locations. Impacts from contaminants present in concentrations near background (within a factor of two or less of reported background levels) were not calculated.

A separate data matrix incorporates data related to existing groundwater plumes in areas outside the area of primary interest (the 200 Areas and 600 Area groundwater plumes) as well as 100 Area plumes outside the boundaries of the operating areas. These data are designated as “contaminants away from the Columbia River” and are presented in Table A.3 (on diskette).<sup>(a)</sup> Table A.3 presents both the maximum concentrations and the parameters used to screen for contaminants.

### A.2.3 Detected Analytes

Table A.4 lists the 73 radionuclides and chemicals detected and their maximum concentration or activity in groundwater and Columbia River water. These maximum values were used in the screening process described in Section A.3. Table A.5 lists the 86 radionuclides and chemicals detected and their maximum concentration or activity in sediment and soil. Table A.6 lists the maximum concentration or activity reported in existing Hanford groundwater plumes away from the river. The data in Tables A.4-A.6 were used in the screening criteria described in Section A.3.

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(a) Because the data on the diskette for this appendix have not changed since the diskette was issued in the April 1997 draft report, the diskette is not being reissued to those who already have it from the April 1997 version. However, since April 1997, a large portion of the text and three tables in Section 2 were moved to Appendix I-A. Therefore, some of the table **callouts and numbers** for the diskette tables have changed in the text. Tables A.1 and A.2 (on diskette) remain the same in the text and on the diskette. However, Table A.3 (on diskette) is now called out as Table A.7 in the text; Table A.4 (on diskette) is now called out as Table A.8 in the text, and Table A.5 (on diskette) is now called out as Table A.3 in the text.



**Table A.4.** Maximum Detected Concentrations in the Columbia River and Groundwater in the Hanford Site 100, 300, and 1100 Areas Near the Columbia River, 1980-1994

Name of Analyte	Background <sup>(a)</sup>	Background Reference	Maximum Concentration in			
			Surface Water		Groundwater	
<b>Radionuclides</b>						
AMERICIUM 241					0.021	pCi/L
ANTIMONY 125					20	pCi/L
CARBON 14					23000	pCi/L
CESIUM 134	ND (SW)	Dirkes 1994	0.012	pCi/L		
CESIUM 137	ND (SW)	Dirkes et al. 1994	0.13	pCi/L	0.5	pCi/L
COBALT 60	ND (SW)	Dirkes et al. 1994	0.011	pCi/L	140	pCi/L
EUROPIUM 154					2	pCi/L
IODINE 129	5 Ci/L (SW)	Dirkes et al. 1994	0.16	pCi/L		
PLUTONIUM 238	ND (SW)	Dirkes et al. 1994			0.01	pCi/L
PLUTONIUM 239/240					0.03	pCi/L
RADIUM 226	0.23 pCi/L	DOE 1992b			0.3	pCi/L
RUTHENIUM 106+D	ND (SW)	Dirkes et al. 1994			34.4	pCi/L
STRONTIUM 90	0.09 pCi/L (SW)	Dirkes and Hanf 1995	0.16	pCi/L	80000	pCi/L
TECHNETIUM 99	0.02 pCi/L (SW)	Dirkes and Hanf 1995			2270	pCi/L
THORIUM 228					3	pCi/L
THORIUM 232					44.5	pCi/L
TRITIUM (HYDROGEN 3)	40 pCi/L (SW)	Dirkes et al. 1994	175	pCi/L	1900000	pCi/L
URANIUM 233					3.3	pCi/L
URANIUM 234	0.24 pCi/L (SW)	Dirkes 1994	18	pCi/L	120	pCi/L
URANIUM 235	0.009 pCi/L (SW)	Dirkes 1994	0.01	pCi/L	17	pCi/L
URANIUM 238	0.19 pCi/L (SW)	Dirkes 1994	19	pCi/L	93	pCi/L
<b>Chemicals</b>						
ACETONE	ND (SW)	Dirkes et al. 1993	11	µg/L	30	µg/L
ALUMINUM	< 200 ppb	DOE 1992b			7000	µg/L
AMMONIA	20 ppb	Dirkes and Hanf 1995			70	µg/L
AMMONIUM	120 PPB	DOE 1992b			1630	µg/L
ANTIMONY	ND (SW)	Dirkes et al. 1993			60	µg/L
ARSENIC	10 ppb	DOE 1992b	3.4	µg/L	37	µg/L
BARIUM	68.5 ppb 28 (SW)	DOE 1992b, Dirkes 1994	48.2	µg/L	719	µg/L
BERYLLIUM	< 5 ppb	DOE 1992b			6	µg/L
BIS(2-ETHYLHEXYL) PHTHALATE					50	µg/L
BORON	< 100 ppb	DOE 1992b			64	µg/L
CADMIUM	< 10 ppb	DOE 1992b			31	µg/L
CALCIUM	63600,18000 (SW) ppb	DOE 1992b, Dirkes 1993	35900	µg/L	302000	µg/L
CHLORIDE	8690, 860 (SW) ppb	DOE 1992b, Dirkes 1993	870	µg/L	122000	µg/L
CHLOROFORM	ND (SW)	Dirkes et al. 1993			42	µg/L
CHROMIUM	< 30, <20 (SW) ppb	DOE 1992b, Dirkes 1993	22	µg/L	1950	µg/L
COBALT	ND (SW)	Dirkes et al. 1993			9	µg/L
COPPER	< 30, <20 (SW) ppb	DOE 1992b, Dirkes 1993	22	µg/L	940	µg/L
CYANIDE					21.1	µg/L
DICHLOROETHYLENE, 1,2-	ND (SW)	Dirkes et al. 1993			200	ug/L
DICHLOROETHYLENE, 1,2-trans-					72	µg/L
FLUORIDE	775, 160 (SW) ppb	DOE 1992b, Dirkes 1993	150	µg/L	2080	µg/L



Table A.4. (contd)

Name of Analyte	Background <sup>(a)</sup>	Background Reference	Maximum Concentration in			
			Surface Water	Groundwater		
<b>Chemicals (contd)</b>						
HYDRAZINE					7	µg/L
IRON	86, 72 (SW) ppb	DOE 1992b, Dirkes 1993	463	µg/L	640000	µg/L
LEAD	< 5 ppb	DOE 1992b			900	µg/L
LITHIUM					10	µg/L
MAGNESIUM	16480, 4600 (SW) ppb	DOE 1992b, Dirkes 1993	9860	µg/L	55000	µg/L
MANGANESE	24.5 ppb, ND (SW)	DOE 1992b, Dirkes 1993	22.8	µg/L	1090	µg/L
MERCURY	< 0.1 ppb	DOE 1992b			16	µg/L
METHYL ETHYL KETONE	ND (SW)	Dirkes et al. 1993			18	µg/L
METHYLENE CHLORIDE					3040	µg/L
MOLYBDENUM					25	µg/L
NICKEL	< 30 ppb	DOE 1992b, Dirkes 1993	31	µg/L	479	µg/L
NITRATE	12400, 310 (SW) ppb	DOE 1992b, Dirkes 1993	480	µg/L	90000	µg/L
NITRITE	ND (SW)	Dirkes et al. 1993			60000	µg/L
PHOSPHATE	<1000 ppb	DOE 1992b	3240	µg/L	200	µg/L
PHOSPHORUS	70 ppb	Dirkes et al. 1995			1200	µg/L
POTASSIUM	7975, 1000 (SW) ppb	DOE 1992b, Dirkes 1993	2430	µg/L	11300	µg/L
SELENIUM	< 5 ppb	DOE 1992b			17.2	µg/L
SILICON	26500 ppb	DOE 1992b			17000	µg/L
SILVER	< 10 ppb	DOE 1992b	19	µg/L	10	µg/L
SODIUM	33500, 2000 (SW) ppb	DOE 1992b, Dirkes 1993	13800	µg/L	350000	µg/L
STRONTIUM	264.1 ppb	DOE 1992b			349	µg/L
SULFATE	90500, 8800 (SW) ppb	DOE 1992b, Dirkes 1993	8600	µg/L	600000	µg/L
SULFIDE					3000	µg/L
TETRACHLOROETHYLENE	ND (SW)	Dirkes et al. 1993			39	µg/L
THALLIUM					4	µg/L
TITANIUM					380	µg/L
TOLUENE	ND (SW)	Dirkes et al. 1993	4.7	µg/L	2.9	µg/L
TRICHLOROETHYLENE	ND (SW)	Dirkes et al. 1993			24.1	µg/L
VANADIUM	15 ppb	DOE 1992b			40	µg/L
XYLENE	ND	Dirkes 1993	4	µg/L		
ZINC	< 50, 12 (SW) ppb (b)	DOE 1992b, Dirkes 1993	11	µg/L	8800	µg/L

(a) ND = not detectable; SW = surface water.



**Table A.5.** Maximum Detected Concentrations in Soil and Sediment in the Hanford Site 100, 300, and 1100 Areas, 1980-1994

Name of Analyte	Soil Background	Background Reference	Maximum Concentration in			
			Soil		Sediment	
<b>Radionuclides</b>						
AMERICIUM 241			34	pCi/g		
ANTIMONY 124					1.2	pCi/g
CARBON 14			34	pCi/g		
CESIUM 134	0.002 pCi/g Sed	Blanton et al. 1995	0.04	pCi/g	0.29	pCi/g
CESIUM 137	1.16 pCi/g, 0.57 Sed	DOE 1996a, Blanton et al. 1995	2900	pCi/g	6	pCi/g
COBALT 60	ND, 0.03 pCi/g Sed	DOE 1990a, Blanton et al. 1995	18000	pCi/g	4.9	pCi/g
EUROPIUM 152			59000	pCi/g	2.41	pCi/g
EUROPIUM 154	0.039 pCi/g Sed	Blanton et al. 1995	20000	pCi/g	0.24	pCi/g
EUROPIUM 155	0.085 pCi/g Sed	Blanton et al. 1995	6200	pCi/g	0.32	pCi/g
HYDROGEN 3			1600	pCi/g		
NEPTUNIUM 237					0.606	pCi/g
NICKEL 63			20000	pCi/g		
PLUTONIUM 238	0.0003 pCi/g Sed	Blanton et al. 1995	11	pCi/g	0.00115	pCi/g
PLUTONIUM 239/240	0.0095 pCi/g Sed	Blanton et al. 1995	230	pCi/g	0.071	pCi/g
POTASSIUM 40	17.9 pCi/g, 17.1 Sed	DOE 1996a, Blanton et al. 1995	16	pCi/g	23	pCi/g
RADIUM 226	0.92 pCi/g	DOE 1996a	3.09	pCi/g	1.7	pCi/g
STRONTIUM 90	0.21 pCi/g, 0.021 Sed	DOE 1996a, Blanton et al. 1995	950	pCi/g	207	pCi/g
TECHNETIUM 99			0.67	pCi/g	0.5	pCi/g
THORIUM 228			1.61	pCi/g	3	pCi/g
THORIUM 232	1.46 pCi/g	DOE 1996a	1.1	pCi/g	3.2	pCi/g
THORIUM 234					0.812	pCi/g
URANIUM 233			3.9	pCi/g	2.3	pCi/g
URANIUM 234	1.22 pCi/g	DOE 1996a			3.9	pCi/g
URANIUM 235	0.15 pCi/g, 0.16 Sed	DOE 1996a, Blanton et al. 1995	0.23	pCi/g	0.1	pCi/g
URANIUM 238	1.18 pCi/g, 1.36 Sed	DOE 1996a, Blanton et al. 1995	4.7	pCi/g	3.2	pCi/g
ZINC 65	ND Sed	Blanton et al. 1995			0.24	pCi/g
ZIRCONIUM 95	ND Sed	Blanton et al. 1995	0.56	pCi/g		
<b>Chemicals</b>						
ACENAPHTHENE	ND	DOE 1994a	210	µg/kg		
ALUMINUM	13621 mg/kg	DOE 1994a	26700000	µg/kg	9350000	µg/kg
AMMONIA	16.0 mg/kg	DOE 1994a	12800	µg/kg	12000	µg/kg
ANTHRACENE	ND, 5.09 µg/kg Sed	DOE 1994a, Blanton et al. 1995	430	µg/kg		
AROCOR 1248 (PCB)	ND, ND Sed	DOE 1994a, Blanton et al. 1995	9900	µg/kg		
ARSENIC	7.6 mg/kg, 9.3 Sed	DOE 1994a, Blanton et al. 1995	47000	µg/kg	11000	µg/kg
BARIUM	155.9 mg/kg, 775 Sed	DOE 1994a, Blanton et al. 1995	672000	µg/kg	825,000	µg/kg
BENZENE	ND	DOE 1994a	4500	µg/kg		
BENZO(G,H,I)PERYLENE	ND, 14.6 µg/kg Sed	DOE 1994a, Blanton et al. 1995	410	µg/kg	6.96	µg/kg
BENZO(a)ANTHRACENE	ND, 19.6 µg/kg Sed	DOE 1994a, Blanton et al. 1995	940	µg/kg	7.06	µg/kg
BENZO(a)PYRENE	ND, 15.0 µg/kg Sed	DOE 1994a, Blanton et al. 1995	810	µg/kg	7.77	µg/kg
BENZO(b)FLUORANTHENE	ND, 40.7 µg/kg Sed	DOE 1994a, Blanton et al. 1995	890	µg/kg	11.23	µg/kg
BENZO(k)FLUORANTHENE	ND, 12.6 µg/kg Sed	DOE 1994a, Blanton et al. 1995	760	µg/kg		
BENZOIC ACID	ND	DOE 1994a	1700	µg/kg		
BERYLLIUM	1.6 mg/kg, 1.4 Sed	DOE 1994a, Blanton et al. 1995	8000	µg/kg	1380	µg/kg
BIS(2-ETHYLHEXYL) PHTHALATE	ND	DOE 1994a	68000	µg/kg		
CADMIUM	ND, 6 mg/kg Sed	DOE 1994a, Blanton et al. 1995	1800	µg/kg	2700	µg/kg
CALCIUM	21012 mg/kg	DOE 1994a	40800000	µg/kg	9000000	µg/kg
CHLORDANE	ND	DOE 1990a	4500	µg/kg		
CHLORIDE			1100	µg/kg		



Table A.5. (contd)

Name of Analytes	Soil Background	Background Reference	Maximum Concentration in			
			Soil		Sediment	
<b>Chemicals</b>						
CHROMIUM	24.1 mg/kg, 60 Sed	DOE 1994a, Blanton et al. 1995	259000	µg/kg	122000	µg/kg
CHRYSENE	ND, 42.8 µg/kg Sed	DOE 1994a, Blanton et al. 1995	920	µg/kg	9.69	µg/kg
COBALT	17.6 mg/kg	DOE 1994a	34100	µg/kg	11500	µg/kg
COPPER	25.9 mg/kg, 38 Sed	DOE 1994a, Blanton et al. 1995	14000000	µg/kg	40000	µg/kg
CYANIDE	ND	DOE 1990a	1050	µg/kg		
DIBENZOFURAN	ND	DOE 1994a	130	µg/kg		
DIESEL FUEL			2800000	µg/kg		
ENDRIN ALDEHYDE	ND, ND Sed	DOE 1994a, Blanton et al. 1995	3.3	µg/kg		
ETHYL BENZENE	ND	DOE 1994a	32000	µg/kg		
FLUORANTHENE	ND, 21.7 µg/kg Sed	DOE 1994a, Blanton et al. 1995	1800	µg/kg	13	µg/kg
FLUORENE	ND	DOE 1994a	190	µg/kg		
FLUORIDE			4700	µg/kg		
INDENO(1,2,3-CD)PYRENE	ND, 11.5 µg/kg Sed	DOE 1994a, Blanton et al. 1995	520	µg/kg	5.82	µg/kg
IRON	35746 mg/kg	DOE 1994a	33500000	µg/kg	1.71E+08	µg/kg
KEROSENE	ND	DOE 1994a	3085000	µg/kg		
LEAD	12.6 mg/kg, 50 Sed	DOE 1994a, Blanton et al. 1995	540000	µg/kg	76000	µg/kg
MAGNESIUM	8169 mg/kg	DOE 1994a	11600000	µg/kg	7600000	µg/kg
MANGANESE	548 mg/kg, 900 Sed	DOE 1994a, Blanton et al. 1995	839000	µg/kg	578000	µg/kg
MERCURY	0.61 mg/kg, 0.1 Sed	DOE 1994a, Blanton et al. 1995	4300	µg/kg	0.073	µg/kg
METHYL-2-PENTANONE, 4-	ND	DOE 1994a	22000	µg/kg		
METHYLENE CHLORIDE	ND	DOE 1994a	120	µg/kg		
METHYLNAPHTHALENE, 2-	ND	DOE 1994a	42	µg/kg		
NICKEL	22.2 mg/kg, 35 Sed	DOE 1994a, Blanton et al. 1995	221000	µg/kg	28300	µg/kg
NITRATE			30400	µg/kg		
PHENANTHRENE	ND, 9.7 µg/kg Sed	DOE 1994a, Blanton et al. 1995	1500	µg/kg	9.22	µg/kg
POTASSIUM	2676 mg/kg	DOE 1994a	4980000	µg/kg	1900000	µg/kg
PYRENE	ND, 17.6 µg/kg Sed	DOE 1994a, Blanton et al. 1995	1200	µg/kg	14.33	µg/kg
SELENIUM	ND	DOE 1994a	4200	µg/kg		
SILVER	1.48 mg/kg	DOE 1994a	18000	µg/kg	2500	µg/kg
SILVER CHLORIDE			17300000	µg/kg		
SODIUM	969 mg/kg	DOE 1994a	1770000	µg/kg	920000	µg/kg
STRONTIUM			67000	µg/kg		
STRONTIUM CHLORIDE			1	µg/kg		
SULFATE (SULFUR)			131000	µg/kg		
TOLUENE	ND	DOE 1994a	350000	µg/kg		
TOTAL PETROLEUM HYDROCARBONS			1.26E+08	µg/kg		
VANADIUM	96.7 mg/kg	DOE 1994a	389000	µg/kg	82200	µg/kg
XYLENE	ND	DOE 1994a	1800000	µg/kg		
ZINC	74.7 mg/kg, 620 Sed	DOE 1994a, Blanton et al. 1995	520000	µg/kg	533000	µg/kg



**Table A.6.** Maximum Detected Concentrations in Groundwater in the Hanford Site 100, 200, and 600 Areas Away from the Columbia River, 1980-1994

Contaminant	Number of Plumes	Max. Conc.	Units
<b>100 Areas</b>			
Tritium (Hydrogen-3)	4	80,000	pCi/L
Strontium-90	8	1,800	pCi/L
Nitrate	10	130,000	ppb
Chromium (+6)	3	1,570	ppb
<b>200 West Area</b>			
Arsenic	4	24	ppb
Chromium	5	323	ppb
Fluoride	3	10,067	ppb
Nitrate	5	1,322,000	ppb
Carbon Tetrachloride	1	6,559	ppb
Chloroform	2	1,595	ppb
Trichloroethylene	3	32	ppb
Tritium	3	6,193,000	pCi/L
Technetium-99	5	26,602	pCi/L
Iodine-129	2	30	pCi/L
Uranium	4	1,616	pCi/L
<b>200 East Area</b>			
Arsenic	4	24	ppb
Chromium	4	288	ppb
Cyanide	2	893	ppb
Nitrate	7	397,000	ppb
Chloroform	1	7	ppb
Tritium	5	4,126,000	pCi/L
Cobalt-60	2	440	pCi/L
Strontium-90	5	5,149	pCi/L
Technetium-99	2	22,163	pCi/L
Iodine-129	3	20	pCi/L
Cesium-137	1	1,326	pCi/L
Uranium	1	27	pCi/L
Plutonium-239/240	1	69	pCi/L
<b>600 Area (Solid Waste Landfill Site)</b>			
1,1,1-trichloroethane	1	50	ppb
trichloroethylene	1	7	ppb
tetrachloroethene	1	12	ppb
1,1-dichloroethane	1	7	ppb
chloroform	1	0.5	ppb



### A.3 Screening Approach

Review of the available data indicated that concentrations of various radionuclides, carcinogenic chemicals, and toxic chemicals had been measured in Columbia River water (includes Columbia River, springs, and seeps), groundwater, river sediment, and near-river soil. A multi-stage screening process was developed to identify those various contaminants in terms of risk to human health and the ecosystem. Each stage of the process identified contaminants of interest. The combined results of the entire screening process then makes up the total list of contaminants to be evaluated in the screening assessment of potential risk.

Because the conceptual model for human health risk is associated with a scenario of a dedicated river user, such a scenario was used to screen for the contaminants of interest. The scenario used is an adaptation and expansion of the Hanford Site Risk Assessment Methodology (DOE 1995). Once the contaminants of interest were determined, a suite of scenarios (Section 5.1) was developed for assessing potential risk. Although similar to the scenarios for the risk assessment, the scenario for the contaminant assessment has slightly different parameters.

The reference screening exposure scenario for the contaminant assessment involves a person who frequents the shores of the river, drinks 2 liters (about 2 quarts)/day of untreated river water, consumes about 0.27 kilograms (0.6 pounds)/day (100 kilograms [220 pounds]/year) (CRITFC 1994) of freshwater fish, ingests 200 milligrams/day of incidental sediment (DOE 1995), inhales 100  $\mu\text{grams}/\text{m}^3$  of resuspended material at a breathing rate of 20  $\text{m}^3/\text{day}$  (DOE 1995), and eats 45 kilograms (99 pounds)/year of irrigated fruits and vegetables (DOE 1995). Other pathways are not included in the selection equations.

The conceptual models for ecosystem risk used to identify the contaminants of interest are simpler. They rely on the EPA Ambient Water Quality Criteria (EPA 1992) (threshold concentrations of contaminants in water at which effects begin to be seen), on the concentrations that result in mortality for fish or other aquatic species if data were available, and on the concentrations that have adverse consequences for developing fish eggs, embryos, or juveniles. In addition, potential radiation doses to fish were evaluated.

All analytes found in the reviewed literature (which related to the 100, 300, and 1100 Areas, regions along the banks of the Columbia River, or inland contaminant plumes) were compiled (see Section A.2). Initial screening eliminated the contaminants on the list that showed no detectable levels of activity or

**To determine which of the contaminants should be included in the screening assessment, we created a series of theoretical screens. A screen is a test used to identify potentially critical materials, such as contaminants. Each contaminant that had been detected was subjected to each of the screens. We used three screens to measure relative risk to humans from radionuclides, carcinogenic chemicals, and toxic chemicals. We used five screens to measure relative risk to the environment based on water quality, threshold toxicity of animals and plants, LC<sub>50</sub> (chemical concentration reported to be lethal to 50 percent of the exposed organisms after some period of exposure, usually a few hours to a few days), toxicity to fish eggs, and radiation dose to fish.**



concentration. In addition, analytes that were present only in tank wastes and not in environmental media were eliminated from the study.

The screening process operated on one portion of the available data at a time. Separate screenings were used for contaminants measured in Columbia River water, groundwater near the river, river sediment, near-river soil, and groundwater distant from the river. For each of these media, further subdivisions addressed radionuclides, human carcinogens, human toxins, and a range of ecological benchmarks including multiple measures of toxicity to adult and developing fish and radiation dose to fish. Procedures for determining the screening rankings are described in the following sections.

### **A.3.1 Screening Based on Columbia River Measurements**

The screening process was based on relative measures of risk for three screens related to human risk (radionuclides, carcinogenic and toxic chemicals) and five screens related to ecological risk (water quality, threshold toxicity,  $LC_{50}$ , toxicity to fish eggs, and radiation dose to fish).

#### **A.3.1.1 Screening for Radionuclides**

The first human risk screen was based on a scenario of exposure to a dedicated river user (see definition above). Risk from internal exposure was quantified using the EPA slope factor for ingestion (EPA 1994a). The EPA slope factor represents the lifetime excess total cancer risk per unit of intake. Risk from external exposure to contaminated sediment was addressed by assuming that the parameters associated with the EPA slope factor for external exposure are appropriate.

A relationship was required between the concentration of the contaminant in the water and the concentration in the sediment. For the screening, this relationship was assumed to be described by the sorption parameter,  $K_d$ . The sorption parameter is a measure of the ratio of contaminant concentration in sediment to that in water.

A second relationship was required between the concentration in river water and that in fish consumed by the individual. For the screening, this was defined using a bioaccumulation factor (BAF), which is a ratio between the contaminant concentration in fish and the water in which the fish live. These are linear relationships that can be expressed as a simple multiple of the water concentration times the appropriate factor.

A third relationship was that between the contaminant concentration in irrigation water and the resulting concentration in irrigated crops. This relationship has two terms, addressing both the deposition of the irrigation water on the leaves of the plants and the uptake of the contaminant through the roots of the plants. Irrigation was assumed to be 5 liters per  $m^2$ /day over 6 months (a total of 36 inches). For foliar deposition (deposition on leaves), an initial retention of 25 percent was assumed, with a long-term weathering half-time of 14 days and an assumed translocation of 100 percent of the retained deposition to the edible portions of the plant. These are standard assumptions that tend to maximize the overall exposure (see, for example, Napier et al. 1988). The contaminants mixed in the rooting zone soil were assumed to be



15 centimeters deep (6 inches). Uptake via the roots was parameterized with a plant-to-soil concentration ratio (CR). Using equilibrium assumptions (the plants have reached a steady state with regard to the incoming concentration), the concentration in the plants was calculated as

$$C_{\text{leaf}} = \frac{0.25 C_w I T}{Y \ln(2)/T_w} = 12.6 C_w \quad (\text{A.1})$$

$$C_{\text{root}} = \frac{365}{2} C_w CR I / D = 4.02 C_w CR \quad (\text{A.2})$$

$$C_{\text{plant}} = C_{\text{leaf}} + C_{\text{root}} = C_w (12.6 + 4.02 CR) \quad (\text{A.3})$$

where

- $C_{\text{leaf}}$  = calculated concentration of contaminant in plants via foliar deposition (pCi/kg)
- $C_w$  = measured concentration in Columbia River water (pCi/L)
- $I$  = irrigation rate (5 L/m<sup>2</sup>/day for 6 months/year, 36 inches/year)
- $Y$  = above ground plant yield available for interception taken to be 2 kg/m<sup>2</sup>
- $\ln(2)/T_w$  = weathering removal constant, where  $T_w$  is the weathering half-time of 14 days
- $C_{\text{root}}$  = calculated concentration in plants via root uptake (pCi/kg)
- $CR$  = plant-to-soil concentration ratio
- $T$  = translocation factor from leaves to edible parts of the plant (assumed to be 1.0)
- $D$  = soil surface density (224 kg/m<sup>2</sup>)
- $C_{\text{plant}}$  = calculated concentration in edible plants (pCi/kg)

For an individual contaminant, the screening score for human risk resulting from radionuclides in Columbia River water was derived from the following equation:

$$\text{Score} = \text{River water concentration} * [(\text{External exposure} * \text{External Slope Factor}) + (\text{Drinking} + \text{Fish consumption} + \text{Sediment ingestion/inhalation} + \text{Crop ingestion}) * \text{Internal slope factor}]$$

Using the terms and parameters described above, the individual contaminant scores can be written as

$$\text{Score} = C_w \left[ \frac{Kd * SS}{1000} + (730 + 100 * BAF + Kd * (0.072 + 0.0007) + 45 * (12.6 + 4.02 * CR)) * IS \right] \quad (\text{A.4})$$

where

- $C_w$  = measured concentration in Columbia River water (pCi/L)
- $Kd$  = sediment/water ratio (L/kg)
- $SS$  = radionuclide slope factor for external exposure (risk/year per pCi/g)
- 1000 = unit conversion (g/kg)
- 730 = water consumption of 2 L/day for 365 days/year giving 730 L/year



- 100 = fish consumption of 100 kg/year  
 BAF = bioaccumulation factor for fish (L/kg)  
 0.072 = sediment consumption of 200 mg/day for 365 days/year giving 0.072 kg/year  
 0.0007 = sediment inhalation based on 100  $\mu\text{grams}/\text{m}^3$  and breathing rate of 20  $\text{m}^3/\text{day}$  giving 0.0007 kg/year  
 45 = irrigated fruit and vegetable consumption (kg/year)  
 CR = plant-to-soil concentration ratio  
 IS = radionuclide slope factor for ingestion (risk/pCi)

The values used for all parameters in this screening are provided in Table A.7 (on diskette). The individual scores for all contaminants of the same type (for example, radionuclides) were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.1.2 Screening for Human Carcinogens

The second human risk screen was for carcinogenic chemicals. The conceptual exposure patterns for carcinogens in river water are the same as those for radionuclides. However, there is no factor for external exposure. Because the chemical cancer potency parameters for oral exposure are in units of inverse milligram per kilogram per day, the consumption terms are put in daily, rather than annual, units (EPA 1994a) in the initial scoring equation. The individual contaminant scoring equation is parallel to that for radionuclides:

$$\begin{aligned} \text{Score} = C_w [2 + 0.27 * \text{BAF} + \text{Kd} * (2 \times 10^{-4} + 2 \times 10^{-6}) \\ + 0.12 * (12.6 + 4.02 * \text{CR})] (0.001) \frac{\text{CPF}}{70} \end{aligned} \quad (\text{A.5})$$

where

- $C_w$  = measured concentration of contaminant in Columbia River water ( $\mu\text{g}/\text{L}$ )  
 2 = water consumption of 2 L/day  
 0.27 = fish consumption of 100 kg/year giving 0.27 kg/day  
 BAF = bioaccumulation factor for fish (L/kg)  
 Kd = sediment/water ratio (L/kg)  
 $2 \times 10^{-4}$  = sediment consumption of 200 mg/day (kg/day)  
 $2 \times 10^{-6}$  = sediment inhalation based on a mass loading of 100  $\mu\text{g}/\text{m}^3$  and a breathing rate of 20  $\text{m}^3/\text{day}$  (kg/day)  
 0.12 = irrigated fruit and vegetable consumption (kg/day)  
 CR = plant-to-soil concentration ratio  
 0.001 = conversion factor (micrograms to milligrams)  
 CPF = cancer potency factor,  $(\text{mg}/\text{kg}/\text{day})^{-1}$   
 70 = assumed weight of an adult (kg)



The values used for all parameters in this screening are provided in Table A.7 (on diskette). The individual scores for all contaminants of the same type were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.1.3 Screening for Toxic Chemicals

The third human risk screen was for toxic (hazardous but noncarcinogenic) chemicals. For toxic chemicals, the ranking was based on a ratio of the estimated daily intake to the EPA chronic oral reference dose (EPA 1994a). The conceptual scenario is the same as for radionuclides or carcinogens. The individual contaminant scoring was

$$\begin{aligned} \text{Score} = C_w [2 + 0.27 * \text{BAF} + \text{Kd} * (2 \times 10^{-4} + 2 \times 10^{-6}) + \\ + 0.12 * (12.6 + 4.02 * \text{CR})] \frac{(0.001)}{70 * \text{RfD}} \end{aligned} \quad (\text{A.6})$$

where

- $C_w$  = measured concentration of contaminant in Columbia River water ( $\mu\text{g/L}$ )
- 2 = water consumption of 2 L/day
- 0.27 = fish consumption of 100 kg/year giving 0.27 kg/day
- BAF = bioaccumulation factor for fish (L/kg)
- Kd = sediment/water ratio (L/kg)
- $2 \times 10^{-4}$  = sediment consumption of 200 mg/day (kg/day)
- $2 \times 10^{-6}$  = sediment inhalation based on a mass loading of  $100 \mu\text{g/m}^3$  and a breathing rate of  $20 \text{ m}^3/\text{day}$  (kg/day)
- 0.12 = irrigated fruit and vegetable consumption per day (kg)
- CR = plant-to-soil concentration ratio
- 0.001 = conversion factor (micrograms to milligrams)
- 70 = assumed weight of an adult (kg)
- RfD = EPA chronic oral reference dose (mg/kg/day)

The values used for all parameters in this screening are provided in Table A.7 (on diskette). The individual scores for all contaminants of the same type were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.1.4 Screening for Ambient Water Quality Criteria

The first ecological risk screen was for ambient water quality criteria. For aquatic biota, the measured concentration of the contaminant in Columbia River water was compared with the applicable EPA chronic



water quality criterion for fresh water (EPA 1992). The ambient water quality criteria are values of the concentrations of chemicals in water that are considered by the EPA to be protective of aquatic life. The screening equation was

$$\text{Score} = \frac{C_w}{\text{AWQC}} \quad (\text{A.7})$$

where

$C_w$  = measured concentration of contaminant in Columbia River water ( $\mu\text{g/L}$ )  
 AWQC = ambient water quality criterion ( $\mu\text{g/L}$ )

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

#### A.3.1.5 Screening for Aquatic Biota Threshold Toxicity

The second ecological risk screen was for aquatic biota threshold toxicity. Some data are available that identify the concentrations of certain chemicals that result in toxic effects to aquatic life. Where possible, the threshold concentration for fresh water at which any effect was noted was used. The equation to generate ranking scores for individual contaminants was

$$\text{Score} = \frac{C_w}{\text{TLM}} \quad (\text{A.8})$$

where

$C_w$  = measured concentration of contaminant in Columbia River water ( $\mu\text{g/L}$ )  
 TLM = threshold limit for fresh water (the concentration at which effects are first observed; also called a lowest observed effect level, LOEL) ( $\mu\text{g/L}$ )

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

#### A.3.1.6 Screening for Aquatic Biota LC<sub>50</sub>

The third ecological risk screen used aquatic biota LC<sub>50</sub> (concentration lethal to 50 percent of the test species). Limited data were available on the threshold concentrations of chemicals that result in toxic effects to aquatic life used in the preceding screen. Although it would have been preferable to use information that related directly to the initiation of distress in aquatic life rather than mortality, such



information (for example, the threshold limit value for the medium) was available for only a few chemicals. Therefore, the lowest concentration lethal to 50 percent of the small, freshwater fish tested (for example, guppies, mosquito fish, rainbow trout) was also used (EPA 1985). For a few analytes for which fish data were not available, test results for crayfish or insects were used as a surrogate. In this screen, it is implicitly assumed that a relationship exists between the concentration levels at which stress is initiated in fish and the concentration levels that result in fatality. Thus, although both this and the prior screen address similar endpoints, the absolute values of the two cannot be related. However, the relative rankings should be similar. The equation was

$$\text{Score} = \frac{C_w}{LC_{50}} \quad (\text{A.9})$$

where

- $C_w$  = measured concentration of contaminant in Columbia River water ( $\mu\text{g/L}$ )  
 $LC_{50}$  = concentration of contaminant lethal to 50 percent of the tested fish population in time periods ranging from 48 to 96 hours ( $\mu\text{g/L}$ )

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.1.7 Screening for Embryonic/Juvenile Fish Toxicity

The fourth ecological risk screen was for embryonic/juvenile fish toxicity. A concern has been raised that groundwater, filtering through gravel beds into the waters of the Columbia River without prior dilution by the river water, could directly impact fish eggs laid in the gravel and developing young fish. Sources of data related to the impact of the listed contaminants on fish eggs were sought. Only a few reports about research on fish egg survival and contaminant concentrations were found (for example, EPA 1985), but a screen identical in structure to that for the  $LC_{50}$  screen for the adult fish was constructed and used. The equations and parameters are identical to those in Equation (A.9) above, but the toxicity is directly related to fish egg survival rather than adult mortality.

### A.3.1.8 Screening for Radiation Dose to Fish

The fifth ecological risk screen was for radiation dose to fish. The aquatic biota screens for ambient water quality criteria, threshold effects, lethal effects, and developmental effects used data available only for chemical not radiological contaminants. To rank potentially hazardous radionuclides, a screen involving the radiation dose to fish was developed. Only the internal dose to pelagic fish is considered in the screen because for this type of fish the external dose generally contributes only a small additive increment if the BAF is greater than 1.0. The dose to a fish depends on the radionuclides it has internally incorporated. These concentrations were calculated using the water concentration and bioaccumulation factor in a manner analogous to that used in determining the concentrations in fish eaten by people. The



only additional parameter required was the effective absorbed energy per unit of activity, which is defined by the individual decay characteristics of each radionuclide. These effective energies have been tabulated by Baker and Soldat (1992). The individual radionuclide scoring equation was then

$$\text{Score} = 5.12 \times 10^{-8} C_w \text{BAF EE} \quad (\text{A.10})$$

where

- $5.12 \times 10^{-8}$  = unit conversion factor (disintegration-kg-rad per pCi-day-MeV)
- $C_w$  = measured concentration of contaminant in Columbia River water (pCi/L)
- BAF = bioaccumulation factor for fish (L/kg)
- EE = effective absorbed energy rate per unit activity in fish (MeV/disintegration)

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.2 Screening Based on Near-River Groundwater Measurements

The screening process for selecting contaminants was based on relative measures of risk for the same three screens related to human risk and five screens related to ecological risk as used for Columbia River water.

Groundwater adjacent to the Columbia River can flow into the river, and Columbia River water can flow into the groundwater, depending on the stage of the river. Therefore, concentrations of contaminants in groundwater near the river are difficult to predict, and concentrations measured near the shore differ from those measured further inland. Flow rates from groundwater to the Columbia vary from location to location. Individual springs may have very low flow rates. An average groundwater discharge to the Columbia River of 3 ft<sup>3</sup>/second was modeled by Kipp et al. (1976) for a 8.3-kilometer (5-mile) length of the river near the old Hanford townsite. Raymond et al. (1976) and Cline et al. (1985) report an estimated discharge of 100 ft<sup>3</sup>/second over the entire Hanford Reach. More recent research (Wurstner and Devary 1993) indicates that an annual average of 100 ft<sup>3</sup>/second is an upper bound.

#### A.3.2.1 Screening for Radionuclides

The first human risk screen was based on a scenario of exposure to a dedicated river user (see definition above). Risk from internal exposure was quantified using the EPA slope factor for ingestion (EPA 1994a). The EPA slope factor represents the lifetime excess total cancer risk per unit of intake. Risk from external exposure to contaminated sediment was addressed by assuming the parameters associated with the EPA slope factor for external exposure are appropriate (EPA 1994a). The same relationships used above for estimating contaminant concentrations in sediment, fish, and irrigated crops were used in these screens. The only difference was the use of groundwater instead of river water as the source of contaminants.



Conceptually, a relationship is needed between the concentration of the contaminant in the groundwater and the concentration in the water the individual is exposed to. This can be thought of as an effective dilution factor (DIL). Depending on the location of the individual (for instance, at the site of a groundwater seep or miles downstream), this dilution factor may vary over a large range. However, for screening on relative importance, it turned out that the dilution factor was immaterial because it applied equally to all contaminants at any consistent location and to the sum of scores for all contaminants and disappeared from the final equations. This is demonstrated below.

For an individual contaminant, the screening score for human risk resulting from radionuclides in groundwater was derived from the following equation:

$$\begin{aligned} \text{Score} = & \text{Groundwater concentration} * \text{Dilution factor} * \\ & [(\text{External exposure} * \text{External slope factor}) + \\ & (\text{Drinking} + \text{Fish consumption} + \text{Sediment ingestion/inhalation} + \\ & \text{Crop ingestion}) * \text{Internal slope factor}] \end{aligned}$$

Using the various terms and parameters described above, the individual screening scores for contaminants can be written as

$$\begin{aligned} \text{Score} = C_{\text{gw}} \text{ DIL} \left[ \frac{\text{Kd} * \text{SS}}{1000} + (730 + 100 * \text{BAF} \right. \\ \left. + \text{Kd} * (0.072 + 0.0007) + 45 * (12.6 + 4.02 * \text{CR})) * \text{IS} \right] \end{aligned} \quad (\text{A.11})$$

where

- $C_{\text{gw}}$  = measured concentration of contaminant in groundwater (pCi/L)
- DIL = dilution factor (dimensionless)
- Kd = sediment/water ratio (L/kg)
- SS = radionuclide slope factor for external exposure (risk/year per pCi/g)
- 1000 = unit conversion (g/kg)
- 730 = water consumption of 2 L/day for 365 days/year giving 730 L/year
- 100 = fish consumption of 100 kg/year
- BAF = bioaccumulation factor for fish (L/kg)
- 0.072 = sediment consumption of 200 mg/day for 365 days/year giving 0.072 kg/year
- 0.0007 = sediment inhalation based on 100  $\mu\text{grams}/\text{m}^3$  and breathing rate of 20  $\text{m}^3/\text{day}$  giving 0.0007 kg/year
- 45 = irrigated fruit and vegetable consumption (kg/year)
- CR = plant-to-soil concentration ratio
- IS = radionuclide slope factor for ingestion (risk/pCi)



The values used for all parameters in this screening are provided in Table A.7 (on diskette). The individual scores for all contaminants of the same type were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores (each containing DIL)} * 100 \text{ percent}$$

Notice that both the numerator and denominator of this final ranking equation contain the factor DIL. This factor can be removed from the assessment without disrupting the relative positions of the rankings. In effect, this makes knowledge of the location of the exposure unnecessary. The relative impact of each contaminant is the same whether the individual is exposed to a riverbank spring or to contaminants fully mixed in the flow of the river downstream.

### A.3.2.2 Screening for Human Carcinogens

The conceptual exposure patterns for carcinogens in groundwater are the same as those for radionuclides. However, there is no factor for external exposure. Because the chemical cancer potency parameters for oral exposure are in units of inverse milligram per kilogram per day, the consumption terms are put in daily rather than annual units (EPA 1994a) in the initial scoring equation. The individual contaminant scoring equation is parallel to that for radionuclides:

$$\begin{aligned} \text{Score} = C_{\text{gw}} [2 + 0.27 * \text{BAF} + \text{Kd} * (2 \times 10^{-4} + 2 \times 10^{-6}) \\ + 0.12 * (12.6 + 4.02 * \text{CR})] (0.001) \frac{\text{CPF}}{70} \end{aligned} \quad (\text{A.12})$$

where

- $C_{\text{gw}}$  = measured concentration of contaminant in groundwater ( $\mu\text{g/L}$ )
- 2 = water consumption of 2 L/day
- 0.27 = fish consumption of 100 kg/year giving 0.27 kg/day
- BAF = bioaccumulation factor for fish (L/kg)
- Kd = sediment/water ratio (L/kg)
- $2 \times 10^{-4}$  = sediment consumption of 200 mg/day (kg/day)
- $2 \times 10^{-6}$  = sediment inhalation based on a mass loading of  $100 \mu\text{g/m}^3$  and a breathing rate of  $20 \text{ m}^3/\text{day}$  (kg/day)
- 0.12 = irrigated fruit and vegetable consumption (kg/day)
- CR = plant-to-soil concentration ratio
- 0.001 = conversion factor (micrograms to milligrams)
- CPF = cancer potency factor ( $\text{mg/kg/day}$ )<sup>-1</sup>
- 70 = assumed weight of an adult (kg)

The values used for all parameters in this screening are provided in Table A.7 (on diskette). The individual scores for all contaminants of the same type were then combined, and an overall rank for each contaminant was generated as



$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

The effective dilution factor was neglected in these equations because it canceled out.

### A.3.2.3 Screening for Toxic Chemicals

For hazardous, but non-carcinogenic chemicals, the ranking was based on a ratio of the estimated daily intake to the EPA chronic oral reference dose (EPA 1994a). The conceptual scenario is the same as for the radionuclides or carcinogens. The individual contaminant scoring was

$$\begin{aligned} \text{Score} = C_{\text{gw}} [2 + 0.27 * \text{BAF} + \text{Kd} * (2 \times 10^{-4} + 2 \times 10^{-6}) \\ + 0.12 * (12.6 + 4.02 * \text{CR})] \frac{(0.001)}{70 * \text{RfD}} \end{aligned} \quad (\text{A.13})$$

where

- $C_{\text{gw}}$  = measured concentration of contaminant in groundwater ( $\mu\text{g/L}$ )
- 2 = water consumption of 2 L/day
- 0.27 = fish consumption of 100 kg/year giving 0.27 kg/day
- BAF = bioaccumulation factor for fish (L/kg)
- Kd = sediment/water ratio (L/kg)
- $2 \times 10^{-4}$  = sediment consumption of 200 mg/day (kg/day)
- $2 \times 10^{-6}$  = sediment inhalation based on a mass loading of  $100 \mu\text{g/m}^3$  and a breathing rate of  $20 \text{ m}^3/\text{day}$  (kg/day)
- 0.12 = irrigated fruit and vegetable consumption (kg/day)
- CR = plant-to-soil concentration ratio
- 0.001 = conversion factor (micrograms to milligrams)
- 70 = assumed weight of an adult (kg)
- RfD = EPA chronic oral reference dose (mg/kg/day)

The values used for all parameters in this screening are provided in Table A.7 (on diskette). The individual scores for all contaminants of the same type were combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

Again, the effective dilution factor was neglected in these equations because it canceled out.

### A.3.2.4 Screening for Ambient Water Quality Criteria

For aquatic biota, the measured concentration of the contaminant in groundwater was compared with the applicable EPA water quality criterion (EPA 1992). The ambient water quality criteria are values of the concentrations of chemicals in water that are considered by the EPA to be protective of aquatic life.



While some effective dilution factor would be required to find the actual risk, in finding relative risk this term may be neglected as shown above. The screening equation was

$$\text{Score} = \frac{C_{\text{gw}}}{\text{AWQC}} \quad (\text{A.14})$$

where

$$\begin{aligned} C_{\text{gw}} &= \text{measured concentration of contaminant in groundwater } (\mu\text{g/L}) \\ \text{AWQC} &= \text{ambient water quality criterion } (\mu\text{g/L}) \end{aligned}$$

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

#### A.3.2.5 Screening for Aquatic Biota Threshold Toxicity

Some data are available that identify the concentrations of certain chemicals that result in toxic effects to aquatic life. Where possible, the threshold concentration used was for fresh water at which any effect was noted. While some effective dilution factor is required to find the actual risk, in finding relative risk, this term may be neglected as shown above. The equation to generate ranking scores for individual contaminants in groundwater was

$$\text{Score} = \frac{C_{\text{gw}}}{\text{TLM}} \quad (\text{A.15})$$

where

$$\begin{aligned} C_{\text{gw}} &= \text{measured concentration of contaminant in groundwater } (\mu\text{g/L}) \\ \text{TLM} &= \text{threshold limit for fresh water } (\mu\text{g/L}) \end{aligned}$$

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

#### A.3.2.6 Screening for Aquatic Biota LC<sub>50</sub>

Limited data were available on the threshold concentrations of chemicals that result in toxic effects to aquatic life used in the preceding screen. Although using information that related directly to the initiation of distress in aquatic life would have been preferable to using mortality information, such information (for example, the threshold limit value for the medium) was available for only a few chemicals. Therefore, the lowest concentration lethal to 50 percent of small, freshwater fish tested (for example, guppies, mosquito



fish, rainbow trout) was also used (EPA 1985). For a few analytes for which fish data were not available, test results for crayfish or insects were used as a surrogate. In this screen, it is implicitly assumed that a relationship exists between the concentration levels at which stress is initiated in fish and the concentration levels that result in fatality. Thus, although both this and the prior screen address similar endpoints, the absolute values of the two cannot be related. However, the relative rankings should be similar. The equation was

$$\text{Score} = \frac{C_{\text{gw}}}{LC_{50}} \quad (\text{A.16})$$

where

- $C_{\text{gw}}$  = measured concentration of contaminant in groundwater ( $\mu\text{g/L}$ )
- $LC_{50}$  = concentration of contaminant lethal to 50 percent of the tested fish population in time periods ranging from 48 to 96 hours ( $\mu\text{g/L}$ )

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

#### **A.3.2.7 Screening for Embryonic/Juvenile Fish Toxicity**

A concern has been raised that groundwater, filtering through gravel beds into the waters of the Columbia River without prior dilution by the river water, could directly impact fish eggs laid in the gravel and developing young fish. Sources of data related to the impact of the listed contaminants on fish eggs were sought. Only a few reports about research on fish egg survival and contaminant concentrations were found (for example, EPA 1985), but a screen identical in structure to that for the adult fish  $LC_{50}$  screen was constructed and used. The equations and parameters are identical to those in Equation (A.16), above, but the toxicity is directly related to fish survival rather than adult mortality.

#### **A.3.2.8 Screening for Radiation Dose to Fish**

The aquatic biota screens for ambient water quality criteria, threshold effects, lethal effects, and developmental effects used data available only for chemical, not radiological, contaminants. To rank potentially hazardous radionuclides, a screen involving the radiation dose to fish was developed. The dose to a fish depends on the radionuclides it has internally incorporated. These concentrations were estimated using the water concentration and bioaccumulation factor in a manner analogous to that used in determining the concentrations in fish eaten by people. For screening groundwater, some dilution is to be expected before sufficient free surface water could exist to support life. This additional dilution was



neglected in the screen. The only additional parameter required was the effective absorbed energy per unit of activity, which is defined by the individual decay characteristics of each radionuclide. These effective energies have been tabulated by Baker and Soldat (1992). The individual radionuclide scoring equation was then

$$\text{Score} = 5.12 \times 10^{-8} C_{\text{gw}} \text{BAF EE} \quad (\text{A.17})$$

where

- $5.12 \times 10^{-8}$  = unit conversion factor (disintegration-kg-rad per pCi-day-MeV)
- $C_{\text{gw}}$  = measured concentration of contaminant in groundwater (pCi/L)
- BAF = bioaccumulation factor for fish (L/kg)
- EE = effective absorbed energy rate per unit activity in fish (MeV/disintegration)

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.3 Screening Based on Columbia River Sediment Measurements

Sediment within the river is both a reservoir of contaminants and a source of contamination of the river water as the material desorbs or resuspends into the water column. Accurate representation of this process requires detailed knowledge of the chemical interactions of the contaminant and the water. Information at this level of detail is not available for most of the contaminants considered in the screening assessment.

The screening process was based on relative measures of risk for the same three screens related to human risk and five screens related to ecological risk as used for Columbia River water and groundwater.

#### A.3.3.1 Screening for Radionuclides

The first human risk screen was based on a scenario of exposure to a dedicated river user (see definition above). Risk from internal exposure was quantified using the EPA slope factor for ingestion (EPA 1994a). Risk from external exposure to contaminated sediment was addressed by assuming that the parameters associated with the EPA slope factor for external exposure are appropriate (EPA 1994a). The same relationships used above for estimating contaminant concentrations in sediment, fish, and irrigated crops were used in these screens. Sediment was used instead of river water as the source of contaminants.

Conceptually, a relationship is needed between the concentration of the contaminant in the sediment and the concentration in the water to which the individual is exposed. This can be thought of as a combination of sorption and an effective dilution factor. However, for screening on relative importance, the dilution factor turned out to be immaterial because it applied equally to all contaminants and to the sum of scores for all contaminants and disappeared from the final equations, as demonstrated in Section A.3.2. All that remained was the sorption correction.



For an individual contaminant, the screening score for human risk resulting from radionuclides in sediment was derived from the following equation:

$$\text{Score} = \text{Sediment concentration/Sorption} \times \text{Dilution factor} * \\ [(\text{External exposure} * \text{External slope factor}) + \\ (\text{Drinking} + \text{Fish consumption} + \text{Sediment ingestion/inhalation} + \\ \text{Crop ingestion}) * \text{Internal slope factor}]$$

Using the various terms and parameters described above, the individual screening scores for a single contaminant can be written as

$$\text{Score} = \frac{C_{\text{sed}} \text{ DIL}}{Kd} \left[ \frac{Kd * SS}{1000} + (730 + 100 * \text{BAF} + Kd \right. \\ \left. * (0.072 + 0.0007) + 45 * (12.6 + 4.02 * \text{CR})) * \text{IS} \right] \quad (\text{A.18})$$

where

- $C_{\text{sed}}$  = measured concentration of contaminant in sediment (pCi/kg)
- DIL = dilution factor (dimensionless)
- Kd = sediment/water ratio (L/kg)
- SS = radionuclide slope factor for external exposure (risk/year per pCi/g)
- 1000 = unit conversion (g/kg)
- 730 = water consumption of 2 L/day for 365 days/year giving 730 L/year
- 100 = fish consumption of 100 kg/year
- BAF = bioaccumulation factor for fish (L/kg)
- 0.072 = sediment consumption of 200 mg/day for 365 days/year giving 0.072 kg/year
- 0.0007 = sediment inhalation based on 100  $\mu\text{grams}/\text{m}^3$  and breathing rate of 20  $\text{m}^3/\text{day}$  giving 0.0007 kg/year
- 45 = irrigated fruit and vegetable consumption (kg/year)
- CR = plant-to-soil concentration ratio
- IS = radionuclide slope factor for ingestion (risk/pCi)

The values used for all parameters in this screening are provided in Table A.8 (on diskette). The individual scores for all radionuclides were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score}/\text{Sum of all scores (each containing DIL)} * 100 \text{ percent}$$

Notice that both the numerator and denominator of this final ranking equation contain the factor DIL. This factor can be removed from the assessment without disrupting the relative positions of the rankings.



### A.3.3.2 Screening for Human Carcinogens

The conceptual exposure patterns for carcinogens in sediment are the same as those for radionuclides. However, there is no factor for external exposure. Because the chemical cancer potency parameters for oral exposure are in units of inverse milligram per kilogram per day, the consumption terms were put in daily rather than annual units (EPA 1994a) in the initial scoring equation. The individual contaminant scoring equation is parallel to that for radionuclides:

$$\text{Score} = \frac{C_{\text{sed}}}{Kd} [2 + 0.27 * \text{BAF} + Kd * (2 \times 10^{-4} + 2 \times 10^{-6}) + 0.12 * (12.6 + 4.02 * \text{CR})] (0.001) \frac{\text{CPF}}{70} \quad (\text{A.19})$$

where

- $C_{\text{sed}}$  = measured concentration of contaminant in sediment ( $\mu\text{g}/\text{kg}$ )
- 2 = water consumption of 2 L/day
- 0.27 = fish consumption of 100 kg/year giving 0.27 kg/day
- BAF = bioaccumulation factor for fish (L/kg)
- Kd = sediment/water ratio (L/kg)
- $2 \times 10^{-4}$  = sediment consumption of 200 mg/day (kg/day)
- $2 \times 10^{-6}$  = sediment inhalation based on a mass loading of  $100 \mu\text{g}/\text{m}^3$  and a breathing rate of  $20 \text{ m}^3/\text{day}$  (kg/day)
- 0.12 = irrigated fruit and vegetable consumption (kg/day)
- CR = plant-to-soil concentration ratio
- 0.001 = conversion factor (micrograms to milligrams)
- CPF = cancer potency factor ( $\text{mg}/\text{kg}/\text{day}$ )<sup>-1</sup>
- 70 = assumed weight of an adult (kg)

The values used for all parameters in this screening are provided in Table A.8 (on diskette). The individual scores for all carcinogens were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

The effective dilution factor was neglected in these equations because it canceled out.

### A.3.3.3 Screening for Toxic Chemicals

For hazardous but non-carcinogenic chemicals, the ranking was based on a ratio of the estimated daily intake to the EPA chronic oral reference dose (EPA 1994a). The conceptual scenario was the same as for the radionuclides or carcinogens. The individual contaminant scoring was



$$\text{Score} = \frac{C_{\text{sed}}}{Kd} [2 + 0.27 * \text{BAF} + Kd * (2 \times 10^{-4} + 2 \times 10^{-6}) + 0.12 * (12.6 + 4.02 * \text{CR})] \frac{(0.001)}{70 * \text{RfD}} \quad (\text{A.20})$$

where

- $C_{\text{sed}}$  = measured concentration of contaminant in sediment ( $\mu\text{g}/\text{kg}$ )
- 2 = water consumption of 2 L/day
- 0.27 = fish consumption of 100 kg/year giving 0.27 kg/day
- BAF = bioaccumulation factor for fish (L/kg)
- Kd = sediment/water ratio (L/kg)
- $2 \times 10^{-4}$  = sediment consumption of 200 mg/day (kg/day)
- $2 \times 10^{-6}$  = sediment inhalation based on a mass loading of  $100 \mu\text{g}/\text{m}^3$  and a breathing rate of  $20 \text{m}^3/\text{day}$  (kg/day)
- 0.12 = irrigated fruit and vegetable consumption (kg/day)
- CR = plant-to-soil concentration ratio
- 0.001 = conversion factor (micrograms to milligrams)
- 70 = assumed weight of an adult (kg)
- RfD = EPA chronic oral reference dose (mg/kg/day)

The values used for all parameters in this screening are provided in Table A.8 (on diskette). The individual scores for all toxic contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

Again, the effective dilution factor was neglected in these equations because it canceled out.

#### A.3.3.4 Screening for Ambient Water Quality Criteria

For aquatic biota, the measured concentration of the contaminant in sediment was used to generate an equivalent concentration in surface water, which was then compared with the applicable EPA water quality criterion (EPA 1992). The ambient water quality criteria are values of the concentrations of chemicals in water that are considered by the EPA to be protective of aquatic life. The screening equation was

$$\text{Score} = \frac{C_{\text{sed}}}{Kd \text{ AWQC}} \quad (\text{A.21})$$

where

- $C_{\text{sed}}$  = measured concentration of contaminant in sediment ( $\mu\text{g}/\text{kg}$ )
- Kd = sediment/water ratio (L/kg)
- AWQC = ambient water quality criterion ( $\mu\text{g}/\text{L}$ )



The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.3.5 Screening for Aquatic Biota Threshold Toxicity

Some data are available that identify the concentrations of certain chemicals that result in toxic effects to aquatic life. Where possible, the threshold concentration used was for fresh water at which any effect was noted. The equation to generate ranking scores for individual contaminants measured in sediment is

$$\text{Score} = \frac{C_{\text{sed}}}{Kd \text{ TLM}} \quad (\text{A.22})$$

where

- $C_{\text{sed}}$  = measured concentration of contaminant in sediment ( $\mu\text{g}/\text{kg}$ )
- $Kd$  = sediment/water ratio ( $\text{L}/\text{kg}$ )
- $\text{TLM}$  = threshold limit for fresh water ( $\mu\text{g}/\text{L}$ )

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.3.6 Screening for Aquatic Biota $\text{LC}_{50}$

Limited data were available on the threshold concentrations of chemicals that result in toxic effects to aquatic life used in the preceding screen. Although using information that related directly to the initiation of distress in aquatic life would have been preferable to using mortality information, such information (for example, the threshold limit value for the medium) was available for only a few chemicals. Therefore, the lowest concentration lethal to 50 percent of small, freshwater fish tested (for example, guppies, mosquito fish, rainbow trout) was also used (EPA 1985). For a few analytes for which fish data were not available, test results for crayfish or insects were used as a surrogate. In this screen, it is implicitly assumed that a relationship exists between the concentration levels at which stress is initiated in fish and the concentration levels that result in fatality. Thus, although both this and the prior screen address similar endpoints, the absolute values of the two cannot be related. However, the relative rankings should be similar. The equation was

$$\text{Score} = \frac{C_{\text{sed}}}{Kd \text{ LC}_{50}} \quad (\text{A.23})$$

where

- $C_{\text{sed}}$  = measured sediment concentration ( $\mu\text{g}/\text{L}$ )



- $K_d$  = sediment/water ratio (L/kg)  
 $LC_{50}$  = concentration of contaminant lethal to 50 percent of the tested fish population in time periods ranging from 48 to 96 hours ( $\mu\text{g/L}$ )

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.3.7 Screening for Embryonic/Juvenile Fish Toxicity

A concern has been raised that groundwater, filtering through gravel beds into the waters of the Columbia River without prior dilution by the river water, could directly impact fish eggs laid in the gravels and developing young fish. Sources of data related to the impact of the listed contaminants on fish eggs were sought. Only a few reports about research on fish egg survival and contaminant concentrations were found (for example, EPA 1985), but a screen identical in structure to that for the adult fish  $LC_{50}$  screen was constructed and used. The equations and parameters are identical to those in Equation (A.23), above, but the toxicity is directly related to fish egg survival, rather than adult mortality.

### A.3.3.8 Screening for Radiation Dose to Fish

The aquatic biota screens for ambient water quality criteria, threshold effects, lethal effects, and developmental effects used data available only for chemical, not radiological, contaminants. To rank potentially hazardous radionuclides, a screen involving the radiation dose to fish was developed. The dose to a fish depends on the radionuclides it has internally incorporated. These concentrations were estimated using the water concentration and bioaccumulation factor in a manner analogous to that used in determining the concentrations in fish eaten by people. The only additional parameter required was the effective absorbed energy per unit of activity, which is defined by the individual decay characteristics of each radionuclide. These effective energies have been tabulated by Baker and Soldat (1992). The individual radionuclide scoring equation was then

$$\text{Score} = 5.12 \times 10^{-8} \frac{C_{\text{sed}} \text{ BAF EE}}{K_d} \quad (\text{A.24})$$

where

- $5.12 \times 10^{-8}$  = unit conversion factor (disintegration-kg-rad per pCi-day-MeV)  
 $C_{\text{sed}}$  = measured sediment concentration (pCi/kg)  
 BAF = bioaccumulation factor for fish (kg)  
 EE = effective absorbed energy rate per unit activity in fish (MeV/disintegration)  
 $K_d$  = sediment/water ratio (L/kg)

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as



$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.4 Screening Based on Near-River Soil Measurements

Contaminants in waste sites or other sites adjacent to the Columbia River may not pose a current hazard to down-river users of the river, but they may pose a threat of future contamination of the river. The possibility also exists that such sources may be contributing contamination that has not yet been observed in the river. One of the goals of the CRCIA is to tie Hanford cleanup activities to the potential for river contamination. In this spirit, contaminated soil near the river is included as a possible source of contaminants. Adequate consideration of these contaminants must include site-specific details about how they could be transported from their current locations into the groundwater and hence into the Columbia River. For the screening to determine which contaminants require attention, all contaminants are assumed to be potentially environmentally mobile and potentially available for transport in groundwater. Based on this assumption, the potential groundwater contamination is treated in a manner parallel to the actual measured groundwater in Section A.3.2.

The screening process for the near-river soil measurements was based on relative measures of risk for the same three screens related to human risk and five screens related to ecological risk as used for Columbia River water and groundwater.

#### A.3.4.1 Screening for Radionuclides

The first human risk screen was based on a scenario of exposure to a dedicated river user (see definition above). Risk from internal exposure was quantified using the EPA slope factor for ingestion (EPA 1994a). Risk from external exposure to contaminated sediment was addressed by assuming the parameters associated with the EPA slope factor for external exposure are appropriate (EPA 1994a). The same relationships used above for estimating contaminant concentrations in sediment, fish, and irrigated crops were used in these screens. Soil was used instead of river water as the source of contaminants.

Conceptually, a relationship is needed between the concentration of the contaminant in the soil and the concentration in the water the individual is exposed to. This can be thought of as a combination of sorption and an effective dilution factor. However, for screening on relative importance, the dilution factor turned out to be immaterial because it applied equally to all contaminants and to the sum of scores for all contaminants and disappeared from the final equations, as demonstrated in Sections A.3.2 and A.3.3. All that remained was the sorption correction.

For an individual contaminant, the screening score for human risk resulting from radionuclides in soil was derived from the following equation:

$$\begin{aligned} \text{Score} = & \text{Soil concentration} / \text{Sorption} \times \text{Dilution factor} * \\ & [(\text{External exposure} * \text{External slope factor}) + \\ & (\text{Drinking} + \text{Fish consumption} + \text{Sediment ingestion/inhalation} + \\ & \text{Crop ingestion}) * \text{Internal slope factor}] \end{aligned}$$



Using the various terms and parameters described above, the individual screening scores for a single contaminant can be written as

$$\text{Score} = \frac{C_{\text{soil}} \text{ DIL}}{Kd} \left[ \frac{Kd * SS}{1000} + (730 + 100 * \text{BAF} + Kd \right. \quad (\text{A.25})$$

$$\left. * (0.072 + 0.0007) + 45 * (12.6 + 4.02 * \text{CR})) * \text{IS} \right]$$

where

- $C_{\text{soil}}$  = measured concentration of contaminant in soil (pCi/kg)
- DIL = dilution factor (dimensionless)
- Kd = sediment/water ratio (L/kg)
- SS = radionuclide slope factor for external exposure (risk/year per pCi/g)
- 1000 = unit conversion (g/kg)
- 730 = water consumption of 2 L/day for 365 days/year giving 730 L/year
- 100 = fish consumption of 100 kg/year
- BAF = bioaccumulation factor for fish (L/kg)
- 0.072 = sediment consumption of 200 mg/day for 365 days/year giving 0.072 kg/year
- 0.0007 = sediment inhalation based on 100  $\mu\text{g}/\text{m}^3$  and breathing rate of 20  $\text{m}^3/\text{day}$  giving 0.0007 kg/year
- 45 = irrigated fruit and vegetable consumption (kg/year)
- CR = plant-to-soil concentration ratio
- IS = radionuclide slope factor for ingestion (risk/pCi)

The values used for all parameters in this screening are provided in Table A.8 (on diskette). The individual scores for all radionuclides were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores (each containing DIL)} * 100 \text{ percent}$$

Notice that both the numerator and denominator of this final ranking equation contain the factor DIL. This factor can be removed from the assessment without disrupting the relative positions of the rankings.

#### A.3.4.2 Screening for Human Carcinogens

The conceptual exposure patterns for carcinogens in sediment are the same as those for radionuclides; however, there is no factor for external exposure. Because the chemical cancer potency parameters for oral exposure are in units of inverse milligrams per kilogram per day, the consumption terms were put in daily rather than annual units (EPA 1994a) in the initial scoring equation. The individual contaminant scoring equation is parallel to that for radionuclides:



$$\text{Score} = \frac{C_{\text{soil}}}{Kd} [2 + 0.27 * \text{BAF} + Kd * (2 \times 10^{-4} + 2 \times 10^{-6}) + 0.12 * (12.6 + 4.02 * \text{CR})] (0.001) \frac{\text{CPF}}{70} \quad (\text{A.26})$$

where

- $C_{\text{soil}}$  = measured concentration of contamination in soil ( $\mu\text{g}/\text{kg}$ )
- 2 = water consumption of 2 L/day
- 0.27 = fish consumption of 100 kg/year giving 0.27 kg/day
- BAF = bioaccumulation factor for fish (L/kg)
- Kd = sediment/water ratio (L/kg)
- $2 \times 10^{-4}$  = sediment consumption of 200 mg/day (kg/day)
- $2 \times 10^{-6}$  = sediment inhalation based on a mass loading of  $100 \mu\text{g}/\text{m}^3$  and a breathing rate of  $20 \text{ m}^3/\text{day}$  (kg/day)
- 0.12 = irrigated fruit and vegetable consumption (kg/day)
- CR = plant-to-soil concentration ratio
- 0.001 = conversion factor (micrograms to milligrams)
- CPF = cancer potency factor ( $\text{mg}/\text{kg}/\text{day}$ )<sup>-1</sup>
- 70 = assumed weight of an adult (kg)

The values used for all parameters in this screening are provided in Table A.8 (on diskette). The individual scores for all carcinogens were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

The effective dilution factor was neglected in these equations because it canceled out.

#### A.3.4.3 Screening for Toxic Chemicals

For hazardous, but non-carcinogenic chemicals, the ranking was based on a ratio of the estimated daily intake to the EPA chronic oral reference dose (EPA 1994a). The conceptual scenario was the same as for the radionuclides or carcinogens. The individual contaminant scoring is

$$\text{Score} = \frac{C_{\text{soil}}}{Kd} [2 + 0.27 * \text{BAF} + Kd * (2 \times 10^{-4} + 2 \times 10^{-6}) + 0.12 * (12.6 + 4.02 * \text{CR})] \frac{(0.001)}{70 * \text{RfD}} \quad (\text{A.27})$$

where

- $C_{\text{soil}}$  = measured concentration of contaminant in soil ( $\mu\text{g}/\text{kg}$ )
- Kd = sediment/water ratio (L/kg)
- 2 = water consumption of 2 L/day



- 0.27 = fish consumption of 100 kg/year giving 0.27 kg/day
- BAF = bioaccumulation factor for fish (L/kg)
- $2 \times 10^{-4}$  = sediment consumption of 200 mg/day (kg/day)
- $2 \times 10^{-6}$  = sediment inhalation based on a mass loading of  $100 \mu\text{g}/\text{m}^3$  and a breathing rate of  $20 \text{ m}^3/\text{day}$  (kg/day)
- 0.12 = irrigated fruit and vegetable consumption (kg/day)
- CR = plant-to-soil concentration ratio
- 0.001 = conversion factor (micrograms to milligrams)
- 70 = assumed weight of an adult (kg)
- RfD = EPA chronic oral reference dose (mg/kg/day)

The values used for all parameters in this screening are provided in Table A.8 (on diskette). The individual scores for all toxics were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

Again, the effective dilution factor was neglected in these equations because it canceled out.

#### A.3.4.4 Screening for Ambient Water Quality Criteria

For aquatic biota, the measured concentration of the contaminant in soil was used to generate an equivalent concentration in surface water, which was then compared with the applicable EPA water quality criterion (EPA 1992). The ambient water quality criteria are values of the concentrations of chemicals in water that are considered by the EPA to be protective of aquatic life. The screening equation was

$$\text{Score} = \frac{C_{\text{soil}}}{K_d \text{ AWQC}} \quad (\text{A.28})$$

where

- $C_{\text{soil}}$  = measured concentration of contaminant in soil ( $\mu\text{g}/\text{kg}$ )
- $K_d$  = sediment/water ratio (L/kg)
- AWQC = ambient water quality criterion ( $\mu\text{g}/\text{L}$ )

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$



### A.3.4.5 Screening for Aquatic Biota Threshold Toxicity

Some data are available that identify the concentrations of certain chemicals that result in toxic effects to aquatic life. Where possible, the threshold concentration for fresh water at which any effect was noted was used. The equation to generate ranking scores for individual contaminants measured in sediment is

$$\text{Score} = \frac{C_{\text{soil}}}{K_d \text{ TLM}} \quad (\text{A.29})$$

where

- $C_{\text{soil}}$  = measured concentration of contaminant in soil ( $\mu\text{g}/\text{kg}$ )
- $K_d$  = sediment/water ratio ( $\text{L}/\text{kg}$ )
- $\text{TLM}$  = threshold limit for fresh water ( $\mu\text{g}/\text{L}$ )

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

### A.3.4.6 Screening for Aquatic Biota $\text{LC}_{50}$

Limited data were available on the threshold concentrations of chemicals that result in toxic effects to aquatic life used in the preceding screen. Although using information that related directly to the initiation of distress in aquatic life would have been preferable to using mortality information, such information (for example, the threshold limit value for the medium) was available for only a few chemicals. Therefore, the lowest concentration lethal to 50 percent of small, freshwater fish tested (for example, guppies, mosquito fish, rainbow trout) was also used (EPA 1985). For a few analytes for which fish data were not available, test results for crayfish or insects were used as a surrogate. In this screen, it is implicitly assumed that a relationship exists between the concentration levels at which stress is initiated in fish and the concentration levels that result in fatality. Thus, although both this and the prior screen address similar endpoints, the absolute values of the two cannot be related. However, the relative rankings should be similar. The equation was

$$\text{Score} = \frac{C_{\text{soil}}}{K_d \text{ LC}_{50}} \quad (\text{A.30})$$

where

- $C_{\text{soil}}$  = measured concentration of contaminant in soil ( $\mu\text{g}/\text{kg}$ )
- $K_d$  = sediment/water ratio ( $\text{L}/\text{kg}$ )
- $\text{LC}_{50}$  = concentration of contaminant lethal to 50 percent of the tested fish population in time periods ranging from 48 to 96 hours ( $\mu\text{g}/\text{L}$ )



The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$

#### A.3.4.7 Screening for Embryonic/Juvenile Fish Toxicity

A concern has been raised that groundwater, filtering through gravel beds into the waters of the Columbia River without prior dilution by the river water, could directly impact fish eggs laid in the gravel and developing young fish. Sources of data related to the impact of the listed contaminants on fish eggs were sought. Only a few reports about research on fish egg survival and contaminant concentrations were found (for example, EPA 1985), but a screen identical in structure to that for the adult fish LC<sub>50</sub> screen was constructed and used. The equations and parameters are identical to those in Equation (A.30), above, but the toxicity is directly related to fish egg survival, rather than adult mortality.

#### A.3.4.8 Screening for Radiation Dose to Fish

The aquatic biota screens for ambient water quality criteria, threshold effects, lethal effects, and developmental effects used data available only for chemical, not radiological, contaminants. To rank potentially hazardous radionuclides, a screen involving the radiation dose to fish was developed. The dose to a fish depends on the radionuclides it has internally incorporated. These concentrations were estimated using the water concentration and bioaccumulation factor in a manner analogous to that used in determining the concentrations in fish eaten by people. The only additional parameter required was the effective absorbed energy per unit of activity, which is defined by the individual decay characteristics of each radionuclide. These effective energies have been tabulated by Baker and Soldat (1992). The individual radionuclide scoring equation was then

$$\text{Score} = 5.12 \times 10^{-8} \frac{C_{\text{soil}} \text{ BAF EE}}{Kd} \quad (\text{A.31})$$

where

- $5.12 \times 10^{-8}$  = unit conversion factor (disintegration-kg-rad per pCi-day-MeV)
- $C_{\text{soil}}$  = measured concentration of contaminant in soil (pCi/kg)
- BAF = bioaccumulation factor for fish (L/kg)
- EE = effective absorbed energy rate per unit activity in fish (MeV/disintegration)
- Kd = sediment/water ratio (L/kg)

The individual scores for all contaminants were then combined, and an overall rank for each contaminant was generated as

$$\text{Rank} = \text{Individual score} / \text{Sum of all scores} * 100 \text{ percent}$$



### A.3.5 Screening Based on Distant Groundwater Measurements

The screening process was based on relative measures of risk for the same three screens related to human risk and five screens related to ecological risk as used for near-river groundwater. The equations and parameters are the same as presented in Section A.3.2.

## A.4 Analytes Evaluated, Parameter Values, and Numerical Results

The tables of data for this section are Microsoft Excel 5.0 files on diskette.<sup>(a)</sup> Table A.1 (diskette file “con-apa1.xls”) lists all radionuclides and chemicals for which monitoring has been reported in the reviewed literature of samples from the Columbia River and groundwater in the Hanford Site 100, 300, 1100 Areas, and other areas within 150 meters (500 feet) of the Columbia River. For contaminants that had a detected level, the highest concentration reported is listed. A total of 568 analytes are listed. The 73 analytes for which detected levels were reported are listed in Table A.4.

Table A.2 (diskette file “con-apa2.xls”) lists all radionuclides and chemicals for which monitoring has been reported in the reviewed literature of samples from soil and sediment in the Hanford Site 100, 300, and 1100 Areas. For contaminants that had a detected level, the highest concentration reported is listed. A total of 560 analytes are listed. The 86 analytes for which detected levels were reported are listed in Table A.5.

The data depicted in Tables A.1 and A.2 are from a variety of documents containing different measurements. Whereas the measurements can at times appear contradictory, they reflect the data as they appear in the documents reviewed.

The equations detailed in Appendix A.3 require parameters for each radionuclide and chemical evaluated. The parameters used to screen samples from the Columbia River and groundwater within 150 meters (500 feet) of the Columbia River are provided in Table A.7 (diskette file “con-apa3.xls”). The parameters used to screen samples of soil and sediment are provided in Table A.8 (diskette file “con-apa4.xls”). The parameters used to screen samples of groundwater farther than 150 meters (500) feet from the Columbia River are provided in Table A.3 (diskette file “con-apa5.xls”). For those contaminants lacking a risk-related parameter (such as fish LD<sub>50</sub> or Water Quality Criterion), using multiple screens was assumed to identify important contaminants.

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(a) Because the data on the diskette for this appendix have not changed since the diskette was issued in the April 1997 draft report, the diskette is not being reissued to those who already have it from the April 1997 version. However, since April 1997, a large portion of the text and three tables in Section 2 were moved to Appendix I-A. Therefore, some of the table **callouts and numbers** for the diskette tables have changed in the text. Tables A.1 and A.2 (on diskette) remain the same in the text and on the diskette. However, Table A.3 (on diskette) is now called out as Table A.7 in the text; Table A.4 (on diskette) is now called out as Table A.8 in the text, and Table A.5 (on diskette) is now called out as Table A.3 in the text.



This appendix also provides the numerical results of applying the screening equations in Appendix A.3 to the detected analytes described in Appendix A.2 and A.5. Table A.7 (diskette file “con-apa3.xls”) presents the numerical results of screening samples from the Columbia River and groundwater within 150 meters (500 feet) of the Columbia River. Table A.8 (diskette file “con-apa4.xls”) presents the numerical results of screening soil and sediment samples. Table A.3 (diskette file “con-apa5.xls”) presents the numerical results of screening samples from groundwater farther than 150 meters (500 feet) from the Columbia River. Application of the equations and assumptions defined in Appendix A.3 results in a series of complementary, but not necessarily intercomparable, screening values for each contaminant. The varying numbers of assumptions and associated varying degrees of conservatism require that each screening be evaluated separately. The results of the combined screenings, however, then define the overall list of contaminants to be analyzed in the screening assessment.

The following abbreviations are used in the Microsoft Excel tables on diskette for this appendix. All units are as reported in the reviewed literature. The column headings, such as 100-KR-4, refer to sampling locations at operable units, described in Section A.1.

aCi/L	=	attocuries per liter (one one-millionth of a pCi/L)
AWQC	=	ambient water quality criteria
Bkg	=	background denotes that the highest concentration found was at background level so eliminated from consideration
CAS#	=	Chemical Abstract Service number, a unique numerical identifier for chemicals
EPA-10	=	eliminated from the human risk assessment based on the guidance in EPA Region 10 Supplemental Risk Assessment Guidance for Superfund (EPA 1991)
GW	=	groundwater
HEIS	=	Hanford Environmental Information System database
Kd	=	sediment/water equilibrium partitioning coefficient
Koc	=	carbon matter partitioning coefficient
Kow	=	octanol/water partitioning coefficient
L/kg	=	liters per kilogram
LC <sub>50</sub>	=	lowest concentration reported to be lethal to 50 percent of the organisms 100 days after exposure (EPA 1985)
LD	=	near limit of detection
µg/kg	=	micrograms per kilogram
µg/L	=	micrograms per liter
MeV	=	million electron volts
mg/kg	=	milligrams per kilogram
mg/L	=	milligrams per liter
ml/g	=	milliliters per gram
ND	=	not detected in sample; not all data compilers used this convention; some analytes show no entry where an ND is appropriate
pCi/g	=	picocuries per gram
pCi/kg	=	picocuries per kilogram
pCi/L	=	picocuries per liter



- ppb = parts per billion  
SD = sediment  
SL = soil  
Suspect = noted in the source database as being unreliable (see Section I.-3.4)  
SW = surface water (Columbia River water)  
SW-LD = reported sample in surface water very near the limit of detection and, therefore, unreliable  
TLM = lowest concentration below which no effects on aquatic life are observed (EPA 1985)  
w/Pu239 = concentration included in the value reported for plutonium-239  
w/U233 = concentration included in the value reported for uranium-233  
\* = laboratory results marked as suspect data (see Section I.-2.1.5)