



4.2 SURFACE WATER AND SEDIMENT SURVEILLANCE

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Samples of surface water and sediment on and near the Hanford Site were collected and analyzed to determine the potential impact to the public and to the aquatic environment from radiological and chemical contaminants that originated at Hanford. Surface-water bodies included in routine surveillance were the Columbia River and associated riverbank springs, onsite ponds, and irrigation sources (Figure 4.2.1). Sediment surveillance was conducted for the Columbia River and riverbank springs. Tables 4.2.1 and 4.2.2 summarize the sampling locations, types, frequencies, and analyses included in surface water and sediment surveillance during 2002. This section describes the surveillance efforts and summarizes the results for these aquatic environments. Detailed analytical results are reported in PNNL-14295, APP. 1.

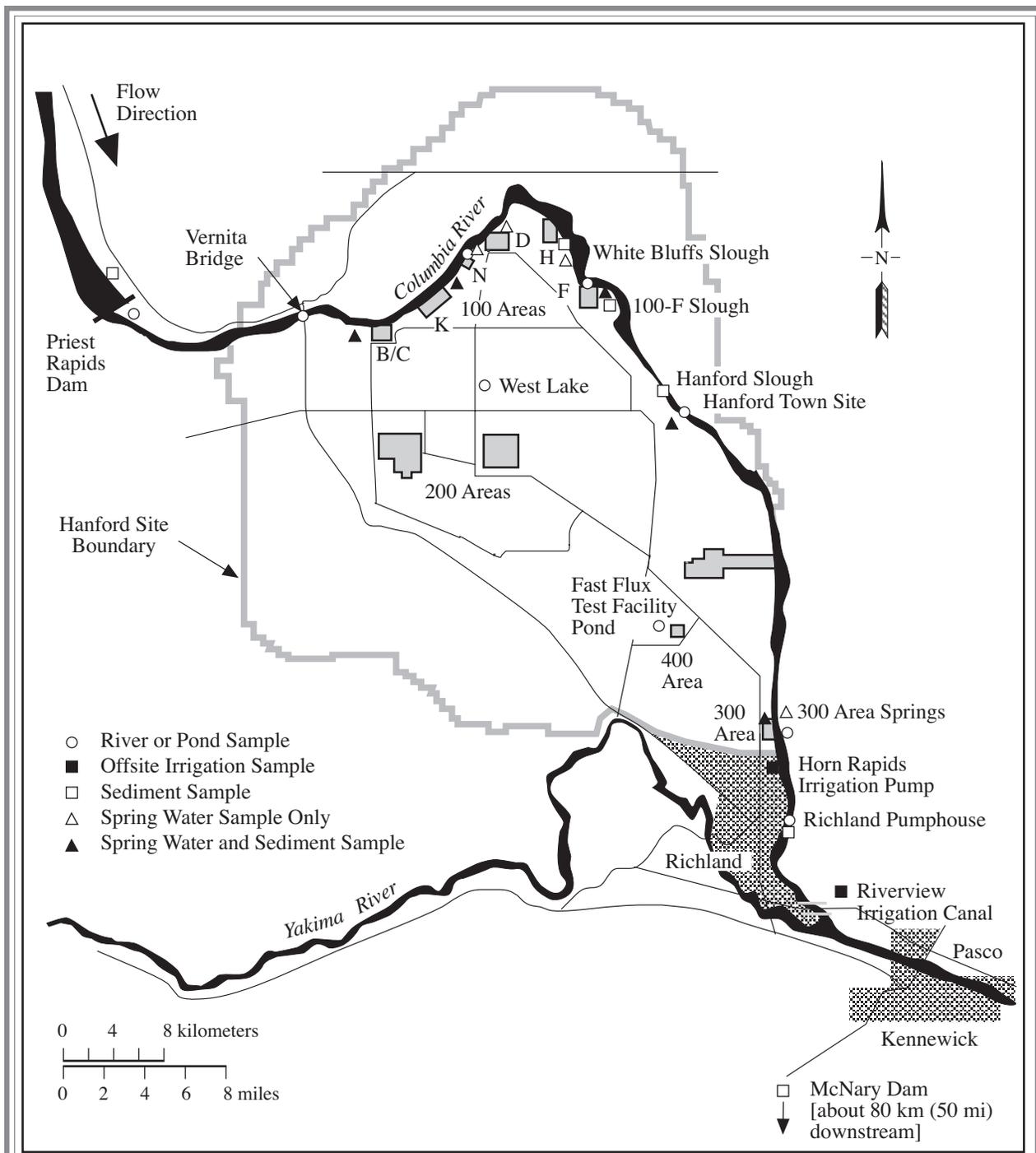
4.2.1 COLUMBIA RIVER WATER

The Columbia River is the second largest river in the continental United States in terms of total flow and is the dominant surface-water body on the Hanford Site. The original selection of the Hanford Site for plutonium production was based, in part, on the abundant water supply offered by the river. The river flows through the northern edge of the site and forms part of the site's eastern boundary. The river is used as a source of drinking water for onsite facilities and communities located downstream from the Hanford Site. Water from the river downstream of the site also is used for crop irrigation. In addition, the Hanford Reach of the Columbia River is used for a variety of recreational activities, including hunting, fishing, boating, water-skiing, and swimming.

Originating in the mountains of eastern British Columbia, the Columbia River and its tributaries drain an area of ~670,000 square kilometers (260,000 square miles) en route to the Pacific Ocean. The flow of the river is regulated by

three dams in Canada and eleven dams in the United States, seven upstream and four downstream of the Hanford Site. Priest Rapids Dam is the nearest upstream dam and McNary Dam is the nearest downstream dam from the site. The Hanford Reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula (created by McNary Dam) near Richland, Washington. The Hanford Reach is the last stretch of the Columbia River in the United States upstream of Bonneville Dam that remains unimpounded.

River flow through the Hanford Reach fluctuates significantly and is controlled primarily by operations at Priest Rapids Dam. Annual average flows of the Columbia River downstream of Priest Rapids Dam are usually around 3,400 cubic meters (120,000 cubic feet) per second (WA-94-1). In 2002, the Columbia River had normal flows; the average daily flow rate downstream of Priest Rapids Dam was 3,340 cubic meters (118,000 cubic feet) per second. The peak monthly average flow rate occurred during June (6,220 cubic meters [220,000 cubic feet] per second) (Figure 4.2.2). The lowest monthly average flow rate occurred during March (2,080 cubic meters [73,400 cubic feet] per second). Daily flow rates varied from 1,320 to 7,620 cubic meters (46,700 to 269,000 cubic feet) per second during 2002. As a result of fluctuation in discharges, the depth of the river varies significantly over time. River stage (water surface level) may change along the Hanford Reach by up to 3 meters (10 feet) within a few hours (see Section 3.3.7 in PNL-10698). Seasonal changes of approximately the same magnitude are also observed. River-stage fluctuations measured at the 300 Area are approximately half the magnitude of those measured near the 100 Areas because of the effect of the pool behind McNary Dam (PNL-8580) and the relative distance of each area from Priest Rapids Dam. The width of the river varies from ~300 to 1,000 meters (~980 to 3,300 feet) through the Hanford Site.



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Figure 4.2.1. Hanford Site Environmental Surveillance Project Sampling Locations for Water and Sediment, 2002

Table 4.2.1. Surface Water Surveillance On and Near the Hanford Site, 2002

Location	Sample Type	Frequency ^(a)	Analyses
Columbia River - Radiological			
Priest Rapids Dam and Richland Pumphouse	Cumulative	M Comp ^(b) Q Comp ^(e)	Alpha, beta, lo ³ H, ^(c) ⁹⁰ Sr, ⁹⁹ Tc, U ^(d) ¹²⁹ I
	Particulate (filter)	M Cont ^(f) Q Cont ^(g)	Gamma energy analysis Pu ^(h)
	Soluble (resin)	M Cont Q Cont	Gamma energy analysis Pu
Vernita Bridge and Richland Pumphouse	Grab (transects)	Quarterly	lo ³ H, ⁹⁰ Sr, U
100-F, 100-N, 300, and Hanford town site	Grab (transects)	Annually	lo ³ H, ⁹⁰ Sr, U
Columbia River - Chemical			
Vernita Bridge and Richland Pumphouse ⁽ⁱ⁾	Grab	Quarterly	Temperature, dissolved oxygen, turbidity, pH, alkalinity, anions, suspended solids, dissolved solids, specific conductance, hardness (as CaCO ₃), Ca, P, Cr, Mg, N-Kjeldahl, Fe, NH ₃ , NO ₃ + NO ₂ , ICP ^(j) metals (filtered and unfiltered), anions
	Grab (transects) Grab (transects)	Quarterly Annually	VOA ^(k)
100-F, 100-N, 300, and Hanford town site	Grab (transects)	Annually	ICP metals (filtered and unfiltered), anions
Onsite Ponds			
West Lake	Grab	Quarterly	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis
Fast Flux Test Facility pond	Grab	Quarterly	Alpha, beta, ³ H, gamma energy analysis
Offsite Irrigation Water			
Riverview irrigation canal	Grab	3/year	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis
Horn Rapids	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis
Riverbank Springs			
100-H Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis, ICP metals (filtered and unfiltered), anions
100-F Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, U, gamma energy analysis, ICP metals (filtered and unfiltered), anions, VOA
100-B Area	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, ⁹⁹ Tc, gamma energy analysis, ICP metals (filtered and unfiltered), anions, VOA
100-D, 100-K, and 100-N Areas	Grab	Annually	Alpha, beta, ³ H, ⁹⁰ Sr, gamma energy analysis, ICP metals (filtered and unfiltered), anions, VOA (100-K Area only)
Hanford town site	Grab	Annually	Alpha, beta, ³ H, ¹²⁹ I, ⁹⁰ Sr, ⁹⁹ Tc, U, gamma energy analysis, ICP metals (filtered and unfiltered), anions
300 Area	Grab	Annually	Alpha, beta, ³ H, ¹²⁹ I, ⁹⁰ Sr, U, gamma energy analysis, ICP metals (filtered and unfiltered), anions, VOA

(a) M = Monthly; Q = Quarterly; Comp = Composite; Cont = Continuous.

(b) M Comp indicates river water was collected hourly and composited monthly for analysis.

(c) lo ³H = Low-level tritium analysis (10-pCi/L detection limit), which includes an electrolytic preconcentration.

(d) U = Isotopic uranium-234, uranium-235, and uranium-238.

(e) Collected weekly and composited for quarterly analysis.

(f) M Cont = River water was sampled for 2 wk by continuous flow through a filter and resin column and multiple samples were composited monthly for analysis.

(g) Q Cont = River water was sampled for 2 wk by continuous flow through a filter and resin column and multiple samples were composited quarterly for analysis.

(h) Pu = Isotopic plutonium-238 and plutonium-239/240.

(i) Numerous water quality analyses are performed by the U.S. Geological Survey under contract to Pacific Northwest National Laboratory.

(j) ICP = Inductively coupled plasma analysis method.

(k) VOA = Volatile organic compounds.

Table 4.2.2. Columbia River Sediment Surveillance from Priest Rapids Dam to McNary Dam, 2002

<u>Location</u> ^(a)	<u>Frequency</u>	<u>Analyses</u>
River		All river sediment analyses included gamma energy analysis, ⁹⁰ Sr, U ^(b) , Pu ^(c) , ICP ^(d) metals, SEM/AVS ^(e)
Priest Rapids Dam: 2 locations near the dam	Annually	
White Bluffs Slough	Annually	
100-F Slough	Annually	
Hanford Slough	Annually	
Richland	Annually	
McNary Dam: 2 locations near the dam	Annually	
Springs ^(f)		All springs sediment analyses included gamma energy analysis, ⁹⁰ Sr, U, ICP metals
100-B Area	Annually	
100-K Area	Annually	
100-N Area	Annually	
100-F Area	Annually	
Hanford town site springs	Annually	
300 Area	Annually	

(a) See Figure 4.2.1.

(b) U = Uranium-235 and uranium-238 analyzed by low-energy photon analysis.

(c) Pu = Isotopic plutonium-238 and plutonium-239/240.

(d) ICP = Inductively coupled plasma analysis method.

(e) SEM/AVS = Simultaneously extracted metals and acid-volatile sulfide.

(f) Sediment is collected when available.

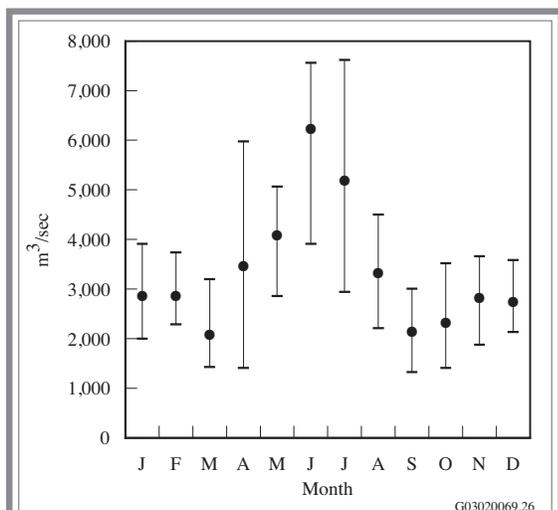


Figure 4.2.2. Mean, Maximum, and Minimum Monthly Columbia River Flow Rates at Priest Rapids Dam, Washington, 2002

Hanford pollutants, both radiological and chemical, enter the Columbia River along the Hanford Reach. Effluent from each direct discharge point is monitored routinely and reported by the responsible operating contractor (Section 3.1). Direct discharges are identified and regulated for non-radiological constituents under the National Pollutant Discharge Elimination System in compliance with the *Clean Water Act* (Section 2.2.8). In addition to permitted direct discharges of liquid effluent from Hanford facilities, contaminants in groundwater from past operational discharges to the ground seep into the river (DOE/RL-92-12; PNL-5289; PNL-7500; WHC-SD-EN-TI-006).

Washington State has classified the stretch of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, as Class A, Excellent (WAC 173-201A). Water quality criteria and

water use guidelines have been established in conjunction with this designation and are provided in Appendix D (Table D.1).

4.2.1.1 COLLECTION OF RIVER-WATER SAMPLES AND ANALYTES OF INTEREST

During 2002, samples were collected from fixed-location monitoring stations at Priest Rapids Dam and the Richland Pumphouse and from Columbia River transects and near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site, 300 Area, and Richland Pumphouse (Figure 4.2.1). Samples were collected upstream from Hanford Site facilities at Priest Rapids Dam and Vernita Bridge to provide background data from locations unaffected by site operations. Samples were collected from all other locations to identify any increase in contaminant concentrations attributable to Hanford operations. The Richland Pumphouse is the first downstream point of Columbia River water withdrawal for a municipal drinking water supply.

The fixed-location monitoring stations at Priest Rapids Dam and the Richland Pumphouse consisted of both an automated sampler and a continuous flow system. Using the automated sampler, unfiltered samples of Columbia River water (cumulative samples) were obtained hourly and collected weekly. Weekly samples were combined into monthly composite samples for radiological analyses (Table 4.2.1). Using the continuous flow system, particulate and soluble constituents in Columbia River water were collected by passing water through a filter and then through a resin column. Filter and resin samples were exchanged approximately every 14 days and were combined into quarterly composite samples for radiological analyses. The river sampling locations and the methods used for sample collection are discussed in detail in DOE/RL-91-50.

Radionuclides of interest were selected for analysis based on

- their presence in effluent discharged from site facilities or in near-river groundwater underlying the Hanford Site
- their importance in determining water quality, verifying effluent control and monitoring systems, and determining compliance with applicable standards

Analytes of interest in water samples collected from Priest Rapids Dam and the Richland Pumphouse included gross

alpha, gross beta, selected gamma emitters, tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240. Gross alpha and beta measurements are indicators of the general radiological quality of the river and provide a timely indication of change. Gamma energy analysis provides the ability to detect numerous specific radionuclides (Appendix F). Sensitive radiochemical analyses were used to determine the concentrations of tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, uranium-238, plutonium-238, and plutonium-239/240 in river water during the year. Analytical detection levels for all radionuclides were <12% of their respective water quality criteria levels (Appendix D, Tables D.1 and D.2). Unless otherwise noted in this section, the statistical tests for differences are paired sample comparisons and two-tailed t-tests, 5% significance level.

Transect sampling (multiple samples collected along a line across the Columbia River) was initiated as a result of findings of a special study conducted during 1987 and 1988 (PNL-8531). That study concluded that, under certain flow conditions, contaminants entering the river from the Hanford Site are not completely mixed when sampled at routine monitoring stations located downriver. Incomplete mixing results in a slightly conservative (high) bias in the data generated using the routine, single-point, sampling system at the Richland Pumphouse. During 1999, the transect sampling strategy was modified, with some of the mid-river sampling points shifted to near-shore locations in the vicinity of the transect. For example, at the 100-N Area instead of collecting ten evenly-spaced cross-river transect samples, only six cross-river samples were collected, and the other four samples were obtained at near-shore locations. This sampling pattern was used during 2002 and allowed the cross-river concentration profile to be determined and also provided information over a larger portion of the Hanford shoreline where the highest contaminant concentrations would be expected. The Vernita Bridge and the Richland Pumphouse transects and near-shore locations were sampled quarterly during 2002. Annual transect and near-shore sampling were conducted at the 100-N Area, 100-F Area, Hanford town site, and 300 Area locations in late summer when river flows were low.

Columbia River transect water samples collected during 2002 were analyzed for both radiological and chemical contaminants (Table 4.2.1). Metals and anions were selected for analysis following reviews of existing surface-water and groundwater data, various remedial investigation/feasibility study work plans, and preliminary Hanford Site risk assessments (DOE/RL-92-67; PNL-8073; PNL-8654; PNL-10400; PNL-10535). All radiological and chemical analyses of transect samples were performed on grab samples of unfiltered water, except for metals analyses, which were performed on both filtered and unfiltered samples.

In addition to radiological monitoring conducted, water quality monitoring was performed by the U.S. Geological Survey for the Pacific Northwest National Laboratory. Samples were collected along Columbia River transects quarterly at the Vernita Bridge and the Richland Pump-house (Appendix B, Table B.5). Sample analyses were performed at the U.S. Geological Survey laboratory in Denver, Colorado, for numerous physical parameters and chemical constituents.

4.2.1.2 RADIOLOGICAL RESULTS FOR RIVER-WATER SAMPLES

Fixed Location Sampling. Results of the radiological analyses of Columbia River water samples collected at Priest Rapids Dam and the Richland Pump-house during 2002 are reported in PNNL-14295, APP. 1 and summarized in Appendix B (Tables B.1 and B.2). These tables also list the maximum and average concentrations of selected radionuclides detected in Columbia River water in 2002 and during the previous 5 years. All radiological contaminant concentrations measured in Columbia River water during 2002 were less than DOE derived concentration guides (DOE Order 5400.5) and Washington State ambient surface-water quality criteria (WAC 173-201A and 40 CFR 141; Appendix D, Tables D.2, D.3, and D.5). Significant results are discussed in the following paragraphs, and comparisons to previous years are provided.

Radionuclide concentrations monitored in Columbia River water were low throughout the year. During 2002, the radionuclides tritium, strontium-90, iodine-129, uranium-234, uranium-238, plutonium-239/240, and naturally occurring beryllium-7 and potassium-40 were

consistently detected in river water at levels greater than two times their associated total propagated analytical uncertainty. The concentrations of all other radionuclides were typically below detection limits. Tritium, strontium-90, iodine-129, and plutonium-239/240 exist in worldwide fallout from historical nuclear-weapons testing, as well as in effluent from Hanford facilities. Tritium and uranium occur naturally in the environment, in addition to being present in Hanford Site effluent.

The 2002 average gross alpha and gross beta concentrations measured upstream and downstream of the Hanford Site were similar to those observed during recent years. Statistical comparisons for gross alpha and gross beta concentrations at Priest Rapids Dam and the Richland Pump-house were not performed because the majority of the concentrations were below the 1 pCi/L (0.037 Bq/L) detection limit (Figures 4.2.3 and 4.2.4). The average alpha concentration in Columbia River water at the Richland Pump-house during 2002 was less than the state ambient surface-water quality criteria level of 15 pCi/L (0.56 Bq/L).

The 2002 annual average tritium concentrations measured upstream and downstream of the Hanford Site were similar to concentrations measured in previous years. Statistical analyses indicated that monthly tritium

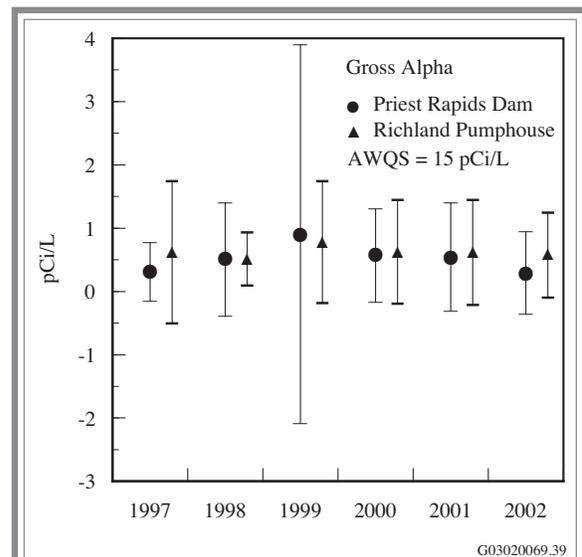
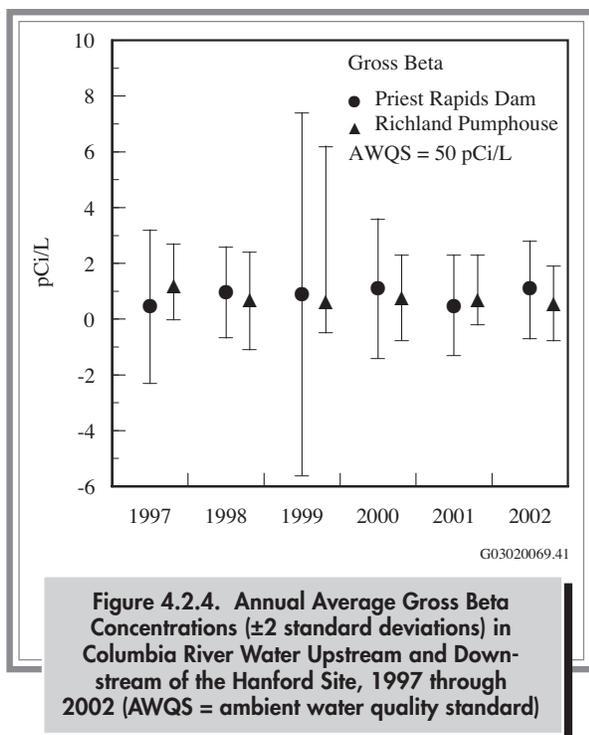
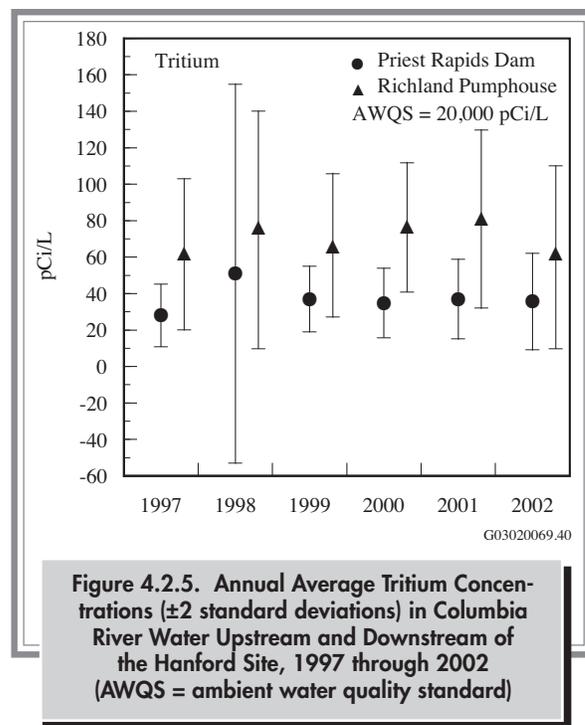


Figure 4.2.3. Annual Average Gross Alpha Concentrations (± 2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1997 through 2002 (AWQS = ambient water quality standard)



concentrations in river water samples at the Richland Pumphouse were higher than concentrations in samples from Priest Rapids Dam (Figure 4.2.5). However, 2002 average tritium concentrations in Columbia River water collected at the Richland Pumphouse were only 0.3% of the state ambient surface-water quality criteria level of 20,000 pCi/L (740 Bq/L). Onsite sources of tritium entering the river include groundwater seepage and direct discharge from the 100-K Area permitted outfall (Sections 3.1 and 7.1). Tritium concentrations measured at the Richland Pumphouse, while representative of river water used by the city of Richland for drinking water, tend to overestimate the average tritium concentrations across the river at this location (PNL-8531). This bias is attributable to the contaminated 200 Areas' groundwater plume entering the river along the portion of shoreline extending from the Hanford town site to below the 300 Area, which is relatively close to the Richland Pumphouse sample intake. This plume is not completely mixed within the river at the Richland Pumphouse. Sampling along cross-river transects at the pumphouse during 2002 confirmed the existence of a concentration gradient in the river under certain flow conditions and is discussed subsequently in this section. The extent to which samples taken from the Richland Pumphouse overestimate the average tritium concentrations in the Columbia River at this location is variable



and appears to be related to the flow rate of the river just before and during sample collection.

Strontium-90 levels measured in Columbia River water collected upstream and downstream of the Hanford Site during 2002 were similar to those reported previously (Figure 4.2.6). Groundwater plumes containing strontium-90 enter the Columbia River throughout the 100 Areas (Section 6.2). Some of the highest strontium-90 levels that have been found in onsite groundwater are the result of past discharges to the 100-N Area liquid waste disposal facilities. Despite the Hanford Site source, there was no statistical difference between monthly strontium-90 concentrations at Priest Rapids Dam and the Richland Pumphouse during 2002. Average strontium-90 concentrations in Columbia River water at the Richland Pumphouse were less than 0.7% of the state ambient surface-water quality criteria level (8 pCi/L [0.30 Bq/L]).

Annual average total uranium concentrations (i.e., the sum of uranium-234, uranium-235, uranium-238) observed in water samples collected upstream and downstream of the Hanford Site during 2002 were similar to those observed during recent years (Figure 4.2.7). Monthly total uranium concentrations measured at the Richland Pumphouse during 2002 were statistically higher than those measured

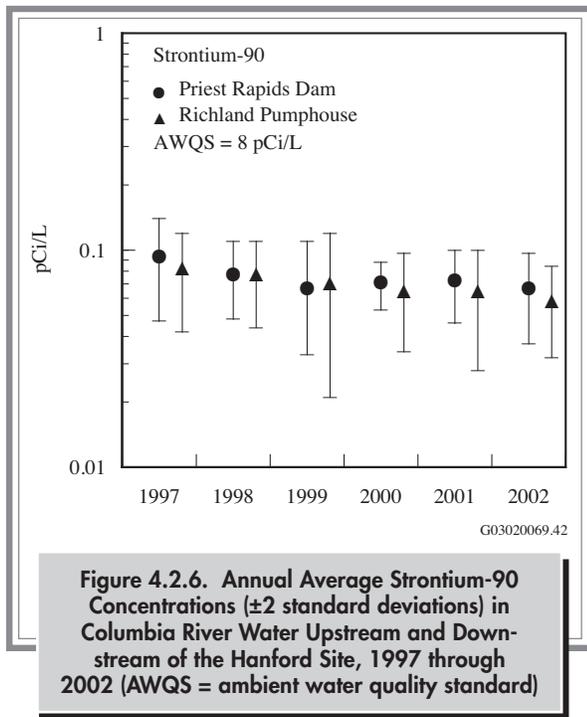


Figure 4.2.6. Annual Average Strontium-90 Concentrations (± 2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1997 through 2002 (AWQS = ambient water quality standard)

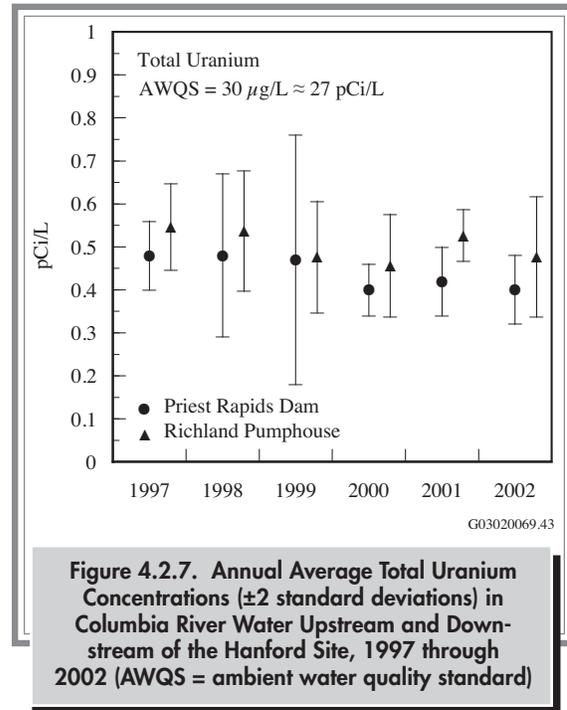


Figure 4.2.7. Annual Average Total Uranium Concentrations (± 2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1997 through 2002 (AWQS = ambient water quality standard)

at Priest Rapids Dam. Although there is no direct process discharge of uranium to the river, uranium is present in the groundwater beneath the 300 Area as a result of past Hanford operations (Section 6.2). Groundwater contaminants have been detected at elevated levels in riverbank springs at the 300 Area (Section 4.2.3 and PNNL-13692). Uranium is also known to enter the river across from the Hanford Site via irrigation return water and groundwater seepage associated with extensive irrigation north and east of the Columbia River (PNL-7500). There are no ambient surface-water quality criteria levels directly applicable to uranium. However, total uranium levels in the river during 2002 were well below the EPA drinking water standard of $30 \mu\text{g/L}$ ($\sim 27 \text{ pCi/L}$ [1.0 Bq/L], Appendix D, Table D.2).

The average iodine-129 concentration in Columbia River water measured downstream of the Hanford Site at the Richland Pumphouse was extremely low during 2002 (0.007% of the state ambient surface-water quality criteria level of 1 pCi/L [0.037 Bq/L]) and similar to levels observed during recent years (Figure 4.2.8). The onsite source of iodine-129 to the Columbia River is the discharge of contaminated groundwater along the portion of shoreline downstream of the Hanford town site (Section 6.2). The iodine-129 plume originated in the 200 Areas from past

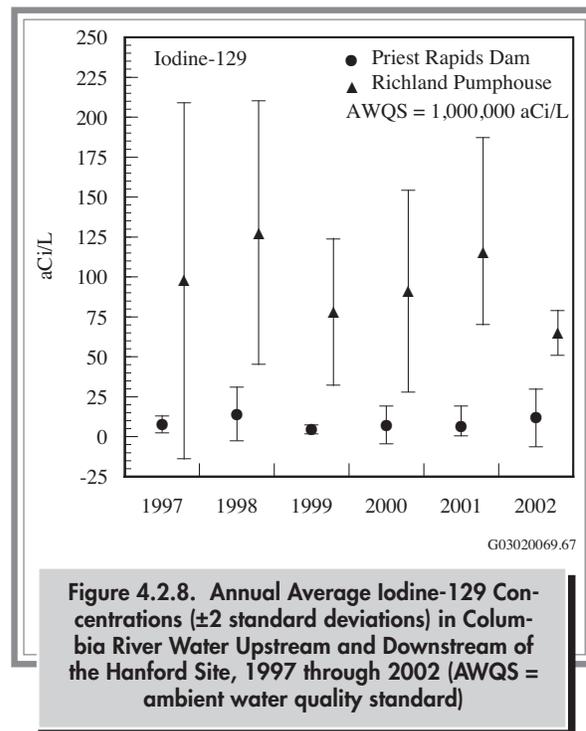


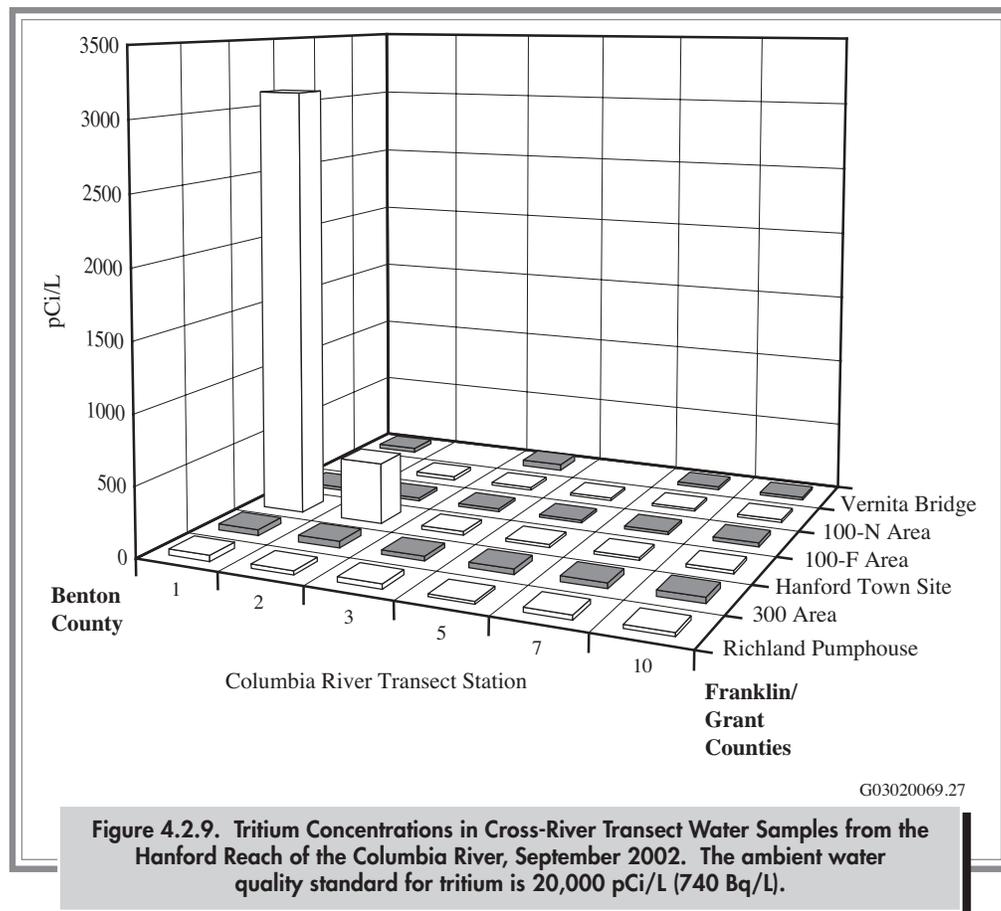
Figure 4.2.8. Annual Average Iodine-129 Concentrations (± 2 standard deviations) in Columbia River Water Upstream and Downstream of the Hanford Site, 1997 through 2002 (AWQS = ambient water quality standard)

waste disposal practices. Quarterly iodine-129 concentrations in Columbia River water at the Richland Pumphouse were statistically higher than those at Priest Rapids Dam.

Plutonium-239/240 concentrations were at or near the detection limit for some filter (particulate) and all resin (dissolved) components. Average plutonium-239/240 concentrations on filter samples at Priest Rapids Dam and the Richland Pumpouse were 0.000022 ± 0.000024 pCi/L ($0.00000081 \pm 0.00000089$ Bq/L) and 0.000011 ± 0.000015 pCi/L ($0.00000041 \pm 0.00000056$ Bq/L), respectively. Plutonium was only detected for the particulate fraction of the continuous water sample (i.e., detected on the filters but not detected on the resin column). All concentrations were below the DOE derived concentration guide of 30 pCi/L (1.1 Bq/L) (Appendix D, Table D.5). No state ambient surface-water quality criteria level exists for plutonium-239/240. Results for filter samples for plutonium-239/240 were statistically higher at Priest Rapids Dam compared to the Richland Pumpouse; thus, there was no observed Hanford Site contribution. Statistical comparisons for dissolved plutonium concentrations at Priest Rapids Dam and the Richland Pumpouse were not performed because the majority of the concentrations were below the detection limit.

River Transect and Near-Shore Sampling. Radiological results from samples collected along Columbia River transects and at near-shore locations near the Vernita Bridge, 100-N Area, 100-F Area, Hanford town site, 300 Area, and Richland Pumpouse during 2002 are presented in Appendix B (Tables B.3 and B.4) and PNNL-14295, APP. 1. Sampling locations were documented using a global positioning system. Radionuclides consistently detected at concentrations greater than two times their associated total propagated analytical uncertainty included tritium, strontium-90, uranium-234, and uranium-238. All measured concentrations of these radionuclides were less than applicable state ambient surface-water quality criteria levels.

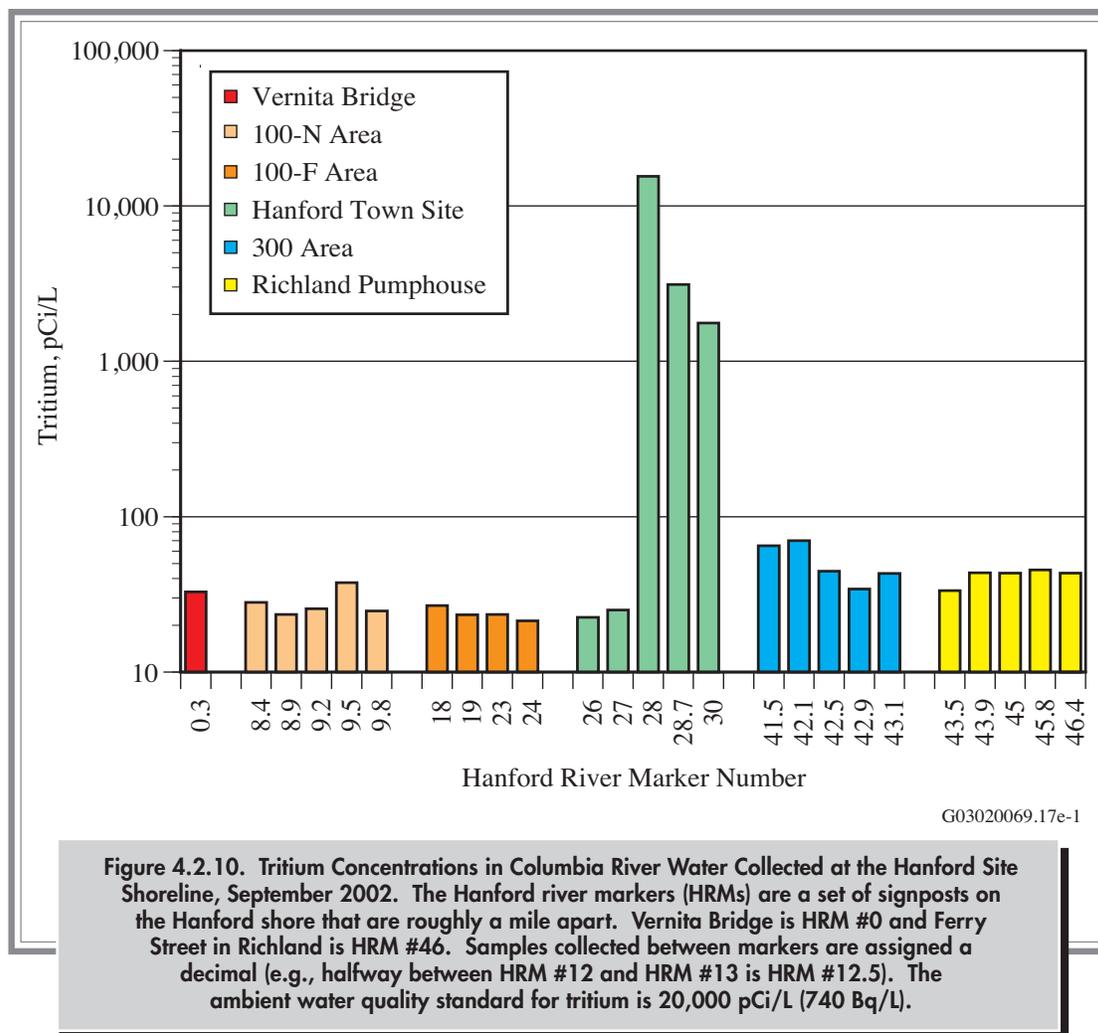
Tritium concentrations measured along Columbia River transects during September 2002 are depicted in Figure 4.2.9. The results are displayed such that the observer's view is upstream from the Richland Pumpouse. Vernita Bridge is the most upstream transect. Stations 1 and 10 are located along the Benton County and Franklin/Grant Counties



Counties shorelines, respectively. The 100-N Area, Hanford town site, 300 Area, and Richland Pumphouse transects have higher tritium concentrations at the Hanford (Benton County) shore compared to the opposite shore. The presence of a tritium concentration gradient in the Columbia River at the Richland Pumphouse supports previous conclusions made in HW-73672 and PNL-8531 that contaminants in the 200 Areas' groundwater plume entering the river at, and upstream of, the 300 Area are not completely mixed at the Richland Pumphouse. The gradient is most pronounced during periods of relatively low river flow. Since transect sampling began during 1987, the average tritium concentration measured along the Richland Pumphouse transect has been less than that measured in monthly composited samples from the pumphouse, illustrating the conservative bias (i.e., overestimate) of the fixed-location monitoring station. The highest tritium concentration detected in 2002 samples of cross-river

transect water was $3,100 \pm 160$ pCi/L (120 ± 5.9 Bq/L) (Appendix B, Table B.3), which was detected along the shoreline of the Hanford town site. This is a location where groundwater containing tritium levels over the state ambient surface-water quality criterion (20,000 pCi/L [740 Bq/L]) is known to discharge to the river (Section 6.2).

Tritium concentrations for near-shore water samples collected at the Hanford (Benton County) shoreline during September 2002 are shown in Figure 4.2.10. The near-shore sampling locations are identified according to Hanford river markers, which are a series of signpost markers (~1.6 kilometers [~1 mile] apart) that originate at Vernita Bridge (Hanford river marker #0) and end just upriver from the Richland Pumphouse (Hanford river marker #46). The concentrations of tritium in near-shore water samples collected at the 100-N Area, Hanford town site, and 300 Area were elevated compared to concentrations in



samples collected near the Vernita Bridge. There was a wide range of tritium concentrations measured for the shoreline samples with the concentrations increasing near discharge points for the groundwater tritium plume (Chapter 6, Figures 6.1.11, 6.1.12, and 6.1.19). The tritium concentrations in near-shore samples collected from the Richland shore were only slightly higher than those measured at Vernita Bridge. During 2002, the highest tritium concentration observed in near-shore water samples was $16,000 \pm 490$ pCi/L (590 ± 18 Bq/L) (Appendix B, Table B.4), which was detected along the shoreline of the Hanford town site at Hanford river marker #28. This location is roughly 1 kilometer (0.6 mile) upriver from the cross-river transect sampling location where the maximum tritium level was $3,100 \pm 160$ pCi/L (120 ± 5.9 Bq/L).

During 2002, strontium-90 concentrations in Hanford Reach river water for both transect and near-shore samples were similar to background concentrations for all locations, except for the 100-N Area. The 100-N Area had elevated strontium-90 concentrations in some samples obtained at near-shore locations. The average strontium-90 concentration found during transect sampling at the Richland Pump house was similar to those measured in monthly composite samples from the pump house, indicating that strontium-90 concentrations in water collected from the fixed-location monitoring station are representative of the average strontium-90 concentrations in the river at this location.

Total uranium concentrations in Hanford Reach water during 2002 were elevated along the Franklin County shoreline in both the 300 Area and Richland Pump house transects. The highest total uranium concentration was measured in March near the Franklin County shoreline of the Richland Pump house transect (1.5 ± 0.21 pCi/L [0.056 ± 0.0078 Bq/L]) (Appendix B, Table B.3) and likely resulted from groundwater seepage and water from irrigation return canals on the Franklin County side of the river that contained naturally occurring uranium (PNL-7500).

4.2.1.3 CHEMICAL AND PHYSICAL RESULTS FOR RIVER-WATER SAMPLES

The U.S. Geological Survey and Pacific Northwest National Laboratory compiled chemical and physical

water quality data for the Columbia River during 2002. A number of the parameters measured have no regulatory limits; however, they are useful as indicators of water quality and contaminants of Hanford origin. Potential sources of pollutants not associated with Hanford include irrigation return water and groundwater seepage associated with extensive irrigation north and east of the Columbia River (PNL-7500).

U.S. Geological Survey. Figure 4.2.11 shows U.S. Geological Survey results for the Vernita Bridge and Richland Pump house for 1997 through 2002 (2002 results are preliminary) for several water quality parameters with respect to their applicable standards. The complete list of preliminary results obtained through the U.S. Geological Survey National Stream Quality Accounting Network program is documented in PNNL-14295, APP. 1 and is summarized in Appendix B (Table B.5). Final results are published annually by the U.S. Geological Survey (e.g., WA-99-1). The 2002 U.S. Geological Survey results were comparable to those reported during the previous 5 years. Applicable standards for a Class A-designated surface-water body were met. During 2002, there was no indication of any deterioration of water quality resulting from site operations along the Hanford Reach of the Columbia River (Appendix D, Table D.1).

River Transect and Near-Shore Samples. Results of chemical sampling conducted by Pacific Northwest National Laboratory along transect and near-shore locations of the Columbia River in 2002 at the Vernita Bridge, 100-F Area, 100-N Area, Hanford town site, 300 Area, and Richland Pump house are provided in PNNL-14295, APP. 1. The concentrations of metals and anions observed in river water during 2002 were similar to those observed in the past and remain below regulatory limits. Several metals and anions were detected in Columbia River transect samples both upstream and downstream of the Hanford Site. Arsenic, antimony, cadmium, chromium, lead, nickel, thallium, and zinc were detected in the majority of samples, with similar levels at most locations. Beryllium, selenium, and silver were detected occasionally. Nitrate concentrations for water samples from the Benton County shoreline near the Richland Pump house were similar to mid-river samples. Nitrate, sulfate, and chloride concentrations were slightly elevated, compared to mid-river samples, along the Franklin County shoreline at the Richland Pump house and 300 Area transects and likely resulted from

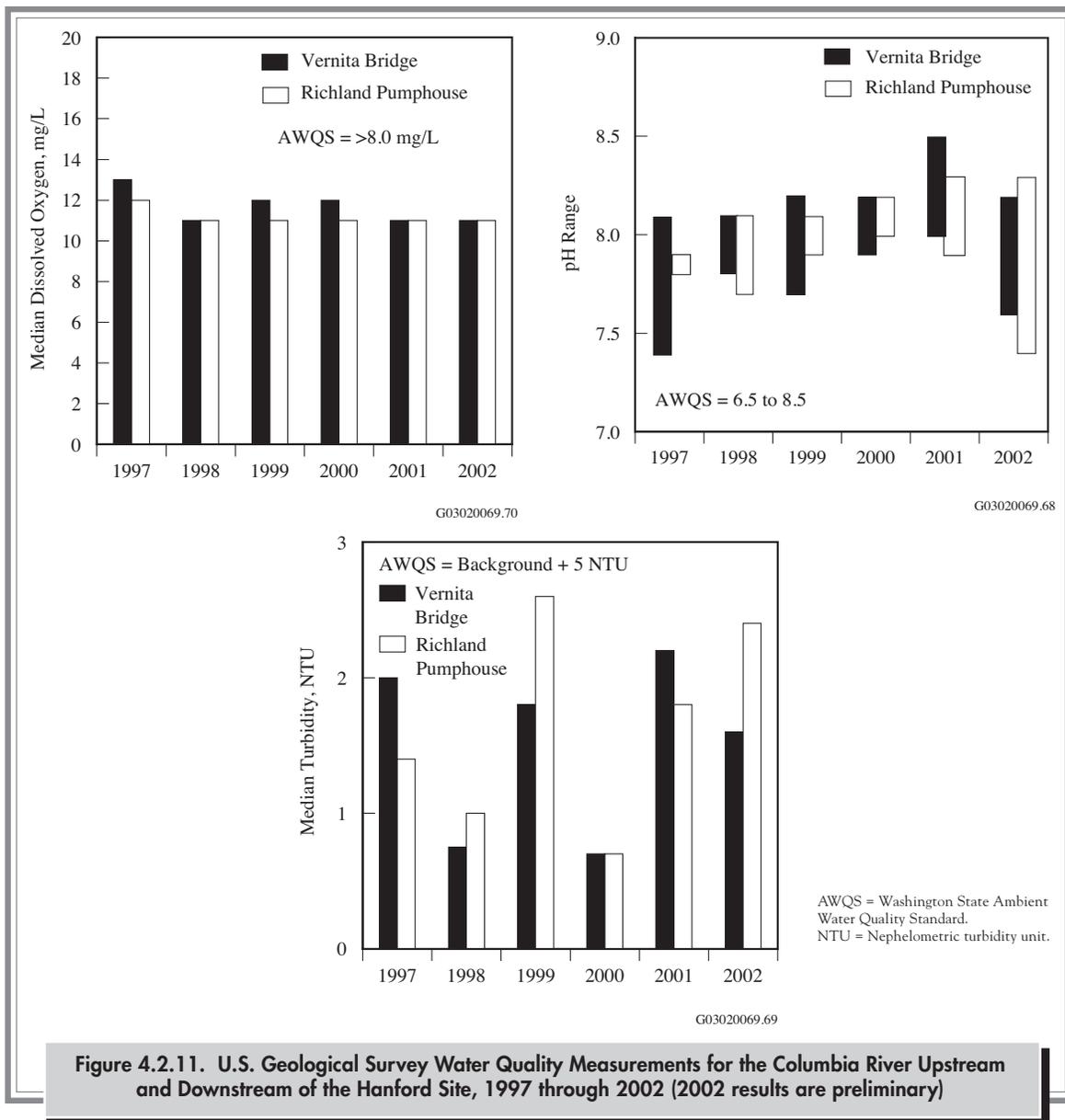


Figure 4.2.11. U.S. Geological Survey Water Quality Measurements for the Columbia River Upstream and Downstream of the Hanford Site, 1997 through 2002 (2002 results are preliminary)

groundwater seepage associated with extensive irrigation north and east of the Columbia River. Nitrate contamination of some Franklin County groundwater has been documented by the U.S. Geological Survey (1995) and is associated with high fertilizer and water usage in agricultural areas. Numerous wells in western Franklin County exceed the EPA maximum contaminant level for nitrate (40 CFR 141; USGS Circular 1144). Average chloride, nitrate, and sulfate results were slightly higher for quarterly concentrations at the Richland Pumphouse transect compared to the Vernita Bridge transect. The only apparent

concentration gradients near the Hanford shoreline for anions measured in transect samples were at the Hanford town site.

Washington State ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; Appendix D, Table D.3). Criteria for Columbia River water were calculated using a total hardness of 47 mg/L as calcium carbonate, the limiting value based on U.S. Geological Survey monitoring of Columbia River water near Vernita Bridge and the Richland Pumphouse over the past years. The total

hardness reported by the U.S. Geological Survey at those locations from 1992 through 2002 ranged from 47 to 77 mg/L as calcium carbonate. All metal and anion concentrations in river water were less than the state ambient surface-water quality criteria levels for the protection of aquatic life from both acute and chronic toxicity levels (Appendix B, Table B.6 and Appendix D, Table D.3). Arsenic concentrations exceeded the EPA standard for the protection of human health for the consumption of water and organisms; however, this EPA value is ~10,500 times lower than the state chronic toxicity value and similar concentrations were found at the Vernita Bridge and the Richland Pumphouse (Appendix D, Table D.3). The concentrations of volatile organic compounds in Columbia River water samples (e.g., chlorinated solvents, benzene) were below detection limits in most samples, with no indication of a Hanford source.

4.2.2 RIVERBANK SPRING WATER

The Columbia River is the primary discharge area for the unconfined aquifer underlying the Hanford Site (Section 6.1.2). Groundwater provides a means for transporting Hanford-associated contaminants, which have leached into groundwater from past waste disposal practices, to the Columbia River (DOE/RL-92-12; PNL-5289; PNL-7500; WHC-SD-EN-TI-006). Contaminated groundwater enters the Columbia River via surface and subsurface discharge. Discharge zones located above the water level of the river are identified in this report as riverbank springs. Routine monitoring of riverbank springs offers the opportunity to characterize the quality of groundwater being discharged to the river and to assess the potential human and ecological risk associated with the spring water.

The seepage of groundwater into the Columbia River has occurred for many years. Riverbank springs were documented along the Hanford Reach long before Hanford Site operations began during World War II (Jenkins 1922). During the early 1980s, researchers walked the 66-kilometer (41-mile) stretch of the Benton County shoreline of the Hanford Reach and identified 115 springs (PNL-5289). They reported that the predominant areas of groundwater discharge at that time were in the vicinity of the 100-N

Area, Hanford town site, and 300 Area. The predominance of the 100-N Area may no longer be valid because of declining water-table elevations in response to the cessation of liquid waste discharges to the ground from Hanford Site operations and the pump-and-treat operations to decontaminate groundwater at the 100-N Area. In recent years, it has become increasingly difficult to locate riverbank springs in the 100-N Area.

The presence of riverbank springs also varies with river stage. Groundwater levels in the 100 and 300 Areas are heavily influenced by river stage fluctuations (Section 6.2). Water levels in the Columbia River fluctuate greatly on annual and daily cycles and are controlled by the operation of Priest Rapids Dam upstream of the site. Water flows into the aquifer (as bank storage) as the river stage rises and then flows in the opposite direction as the river stage falls. Following an extended period of low river flow, groundwater discharge zones located above the water level of the river may cease to exist once the level of the groundwater comes into equilibrium with the level of the river. Thus, springs are most readily identified immediately following a decline in river stage. Bank storage of river water also affects the contaminant concentration of the springs. Spring water discharge immediately following a river stage decline generally consists of river water or a mixture of river water and groundwater. The percentage of groundwater in the spring water discharge is believed to increase over time following a drop in river stage. Measuring the specific conductivity of the spring water discharge provides an indicator of the extent of bank storage because Hanford Site groundwater has a higher specific conductivity than Columbia River water.

Because of the effect of bank storage on groundwater discharge and contaminant concentration, it is difficult to estimate the volume of contaminated groundwater discharged to the Columbia River within the Hanford Reach. Studies of riverbank springs conducted during 1983 (PNL-5289), 1988 (PNL-7500), and a near-shore study (PNNL-11933) noted that discharges from the springs had only localized effects on river contaminant concentrations. These studies reported that the volume of groundwater entering the river at these locations was very small compared to the flow of the river and that the impact of groundwater discharges to the river was minimal.

4.2.2.1 COLLECTION OF WATER SAMPLES FROM RIVERBANK SPRINGS AND ANALYTES OF INTEREST

Routine monitoring of selected riverbank springs was initiated during 1988. Currently, riverbank spring water samples are collected for environmental surveillance and to support groundwater operable unit investigations (Figure 4.2.1; DOE/RL-91-50). Analytes of interest for samples from riverbank springs were selected based on findings of previous investigations, reviews of contaminant concentrations observed in nearby groundwater monitoring wells, and results of preliminary risk assessments. Sampling is conducted annually when river flows are low, typically in late summer or early fall.

All samples collected during 2002 were analyzed for gamma-emitting radionuclides, gross alpha, gross beta, and tritium. Samples from selected springs were analyzed for strontium-90, technetium-99, iodine-129, and uranium-234, uranium-235, and uranium-238. All samples were analyzed for metals and anions, with volatile organic compounds analyzed at selected locations. All analyses were conducted on unfiltered samples, except for metals analyses, which were conducted on both filtered and unfiltered samples (Appendix B, Table B.9; PNNL-14295, APP. 1).

Hanford-origin contaminants continued to be detected in water from riverbank springs entering the Columbia River along the Hanford Site during 2002. The locations and extent of contaminated discharges were consistent with recent groundwater surveys. Tritium, strontium-90, technetium-99, iodine-129, uranium-234, uranium-235, and uranium-238, metals, and anions (chloride, fluoride, nitrate, and sulfate) were detected in spring water. Volatile organic compounds were near or below the detection limits for most samples. The contaminant concentrations in water from riverbank springs are typically lower than those found in near-shore groundwater wells because of bank storage effects. In the following discussion, radiological and chemical results are addressed separately. Contaminant concentration trends are illustrated for selected locations.

4.2.2.2 RADIOLOGICAL RESULTS FOR WATER SAMPLES FROM RIVERBANK SPRINGS

All radiological contaminant concentrations measured in riverbank springs during 2002 were less than the DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.5). However, the spring near well 199-N-8T at the 100-N Area that has historically exceeded the DOE derived concentration guide for strontium-90 only had observed flow during one (1997) sampling attempt in the last 6 years; thus, an alternative spring was sampled in the 100-N Area.

Gross beta concentrations in riverbank spring water at the 100-H Area, Hanford town site, and 300 Area were elevated compared to other riverbank spring water locations.

Tritium concentrations varied widely with location. The highest tritium concentration detected in riverbank springs was at the Hanford town site ($58,000 \pm 1,900$ pCi/L [$2,100 \pm 70$ Bq/L]), which exceeded the state ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L) (WAC 173-201A; 40 CFR 141), followed by the 300 Area ($8,100 \pm 690$ pCi/L [300 ± 26 Bq/L]), and the 100-N Area ($7,100 \pm 320$ pCi/L [260 ± 12 Bq/L]). Tritium concentrations in all riverbank spring samples were elevated compared to the 2002 average Columbia River concentration at Priest Rapids Dam (35 ± 26 pCi/L [1.3 ± 0.96 Bq/L]).

Samples from riverbank springs in the 100-B, 100-K, 100-H Areas, and the Hanford town site were analyzed for technetium-99. All results for technetium-99 were below the EPA drinking water standard of 900 pCi/L (33 Bq/L) (Appendix D, Table D.2). The highest technetium-99 concentration was found in riverbank spring water from the Hanford town site (75 ± 4.7 pCi/L [2.8 ± 0.17 Bq/L]), which was higher than the observed gross beta concentrations (24 ± 4.4 pCi/L [0.89 ± 0.16 Bq/L]).

Samples from riverbank springs at the Hanford town site and 300 Area were analyzed for iodine-129. The highest concentration was measured in a water sample from the Hanford town site spring (0.19 ± 0.019 pCi/L [0.007 ± 0.0007 Bq/L]). This value was elevated compared to the

2002 average measured at Priest Rapids Dam (0.000012 ± 0.000018 pCi/L [$0.00000044 \pm 0.00000067$ Bq/L]) but was below the 1-pCi/L (0.037-Bq/L) surface-water quality criteria level (Appendix D, Table D.2).

Uranium was sampled in riverbank spring water in the 100-H Area, 100-F Area, Hanford town site, and 300 Area in 2002. The highest total uranium level was found in 300 Area spring water (99 ± 11 pCi/L [3.7 ± 0.41 Bq/L]), which was collected from a spring located downgradient from the retired 300 Area process trenches. The total uranium concentration in this spring exceeded the EPA drinking water standard of 30 $\mu\text{g/L}$ (~ 27 pCi/L [~ 1.0 Bq/L]). The 300 Area spring had an elevated gross alpha concentration (81 ± 19 pCi/L [3.0 ± 0.70 Bq/L]), which paralleled that of uranium. The gross alpha level in 300 Area spring water also exceeded the state ambient surface-water quality criterion of 15 pCi/L (0.56 Bq/L) (Appendix D, Table D.2).

Samples from riverbank springs were analyzed for strontium-90 in the 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F Areas. The highest strontium-90 concentration detected in riverbank spring water was at the 100-H Area (3.3 ± 0.71 pCi/L [0.12 ± 0.026 Bq/L]). This value was 41% of the ambient surface-water quality criterion of 8 pCi/L (0.30 Bq/L).

Concentrations of selected radionuclides in riverbank spring water near the Hanford town site (spring 28-2) from 1997 through 2002 are provided in Figure 4.2.12. Annual fluctuations in these values may reflect the influence of bank storage during the sampling period.

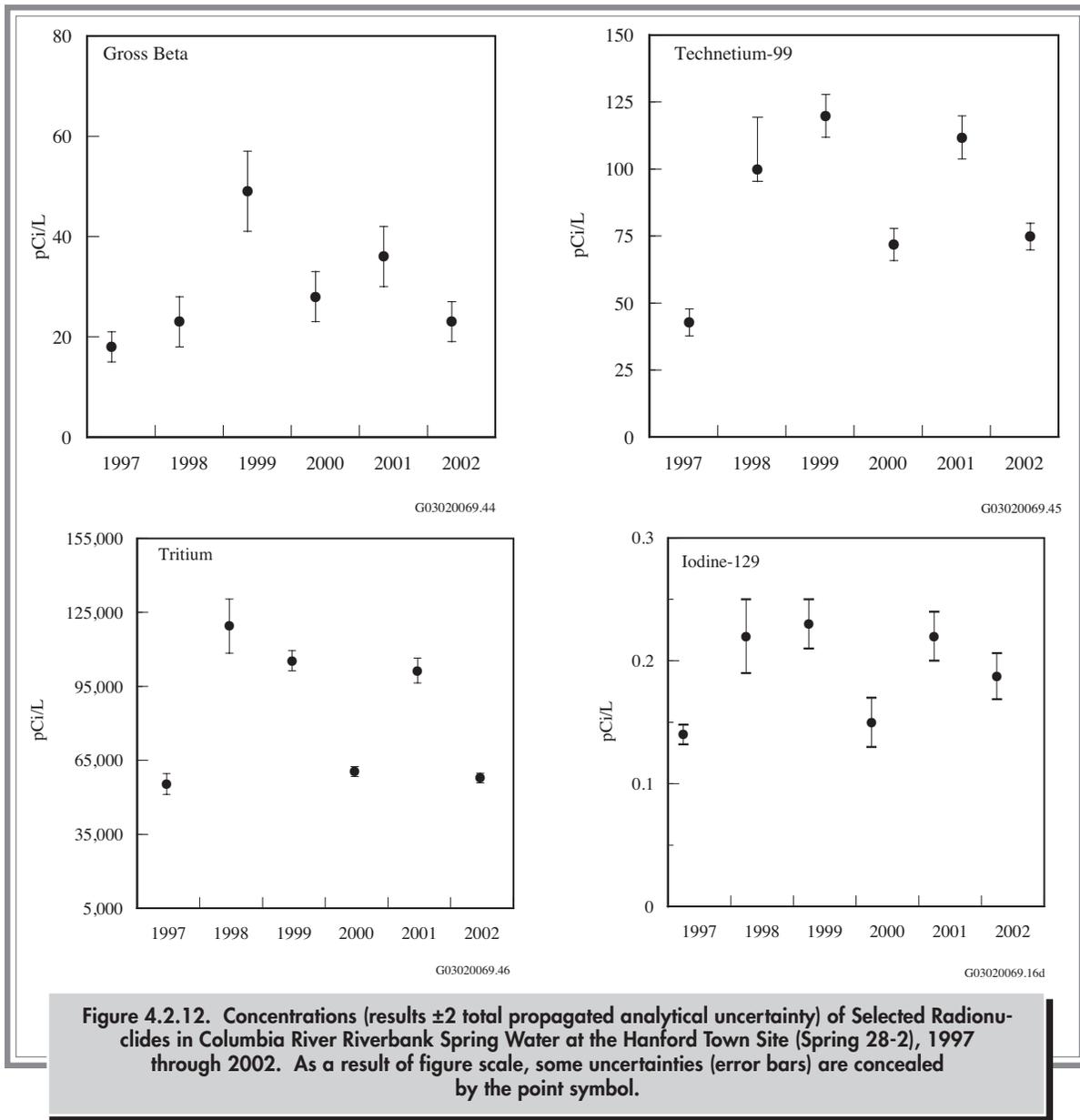
Figure 4.2.13 depicts concentrations of selected radionuclides in the 300 Area riverbank spring water (spring 42-2 and spring DR 42-2) from 1997 through 2002. The elevated tritium levels measured in the 300 Area riverbank springs are indicators of the contaminated groundwater plume from the 200 Areas (Section 5.9 in PNL-10698). Elevated uranium concentrations exist in the unconfined aquifer beneath the 300 Area in the vicinity of the former uranium fuel fabrication facilities and inactive waste sites. The gross alpha and gross beta concentrations in 300 Area riverbank springs water from 1997 through 2002 parallel uranium and are likely associated with its presence.

Historically, riverbank seepage in the 100-N Area has been monitored for contaminants by sampling from well

199-N-8T, which is located close to the river; well 199-N-46 (caisson), which is slightly inland from well 199-N-8T (see PNNL-11795, Figure 3.2.4); or riverbank springs. Since 1993, 100-N Area seepage samples for the Surface Environmental Surveillance Project have been collected only from riverbank springs. The Near-Facility Environmental Monitoring Program (Section 3.2.2) also collects water samples along the 100-N shoreline at monitoring well 199-N-46 and at shoreline seepage wells. The Near-Facility Environmental Monitoring Program reported all strontium-90 concentrations during 2002 samples from shoreline seepage wells located near monitoring well 199-N-46 were below the 1,000-pCi/L (37-Bq/L) DOE derived concentration guide (Table 3.2.4). From 1993 to 2002, there were no visible riverbank springs directly adjacent to wells 199-N-8T or 199-N-46 during the Surface Environmental Surveillance Project sampling periods, with the exception of one sample collected during 1997. The samples collected from 100-N Area riverbank springs during those years were, therefore, collected from a downstream riverbank spring. Contaminant concentrations measured in water from the downstream spring were distinctly different from concentrations in the springs located near the shoreline wells (Table 4.2.3). Historically, the concentrations of strontium-90 and gross beta were considerably higher in the riverbank spring directly adjacent to well 199-N-8T than for the downstream spring. Tritium levels in water from riverbank springs are typically elevated at both locations, and the 2002 tritium result for the 100-N riverbank spring was similar to those seen in previous years at the same location (Table 4.2.3). Tritium was the only specific radionuclide detected in 100-N Area riverbank spring water during 2002.

4.2.2.3 CHEMICAL RESULTS FOR WATER SAMPLES FROM RIVERBANK SPRINGS

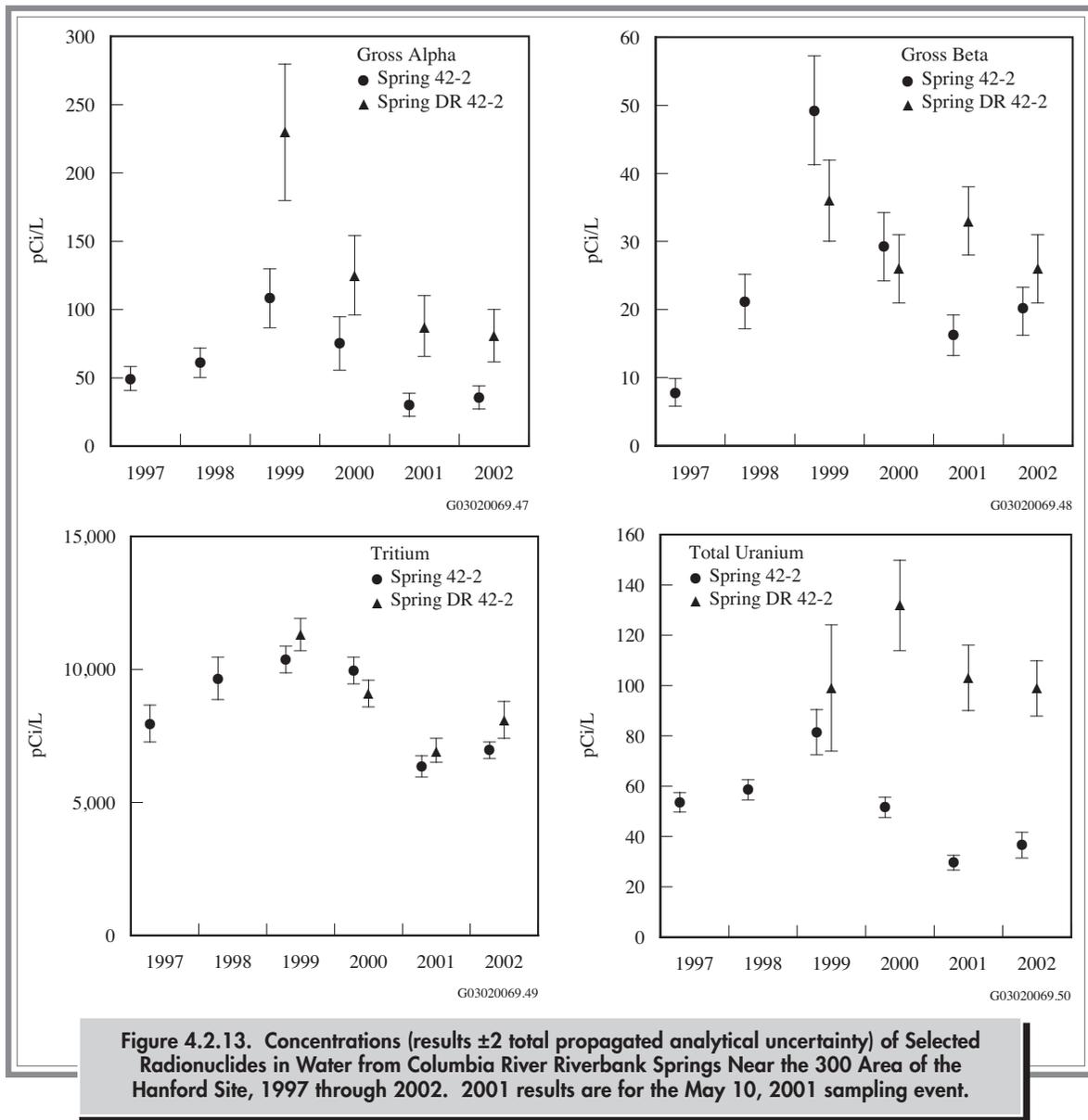
Concentration ranges of selected chemicals measured in riverbank springs water during 1999 through 2002 are presented in Table 4.2.4. For most locations, the 2002 chemical sample results were similar to those reported previously (PNNL-12088). Nitrate concentrations were highest in the 300 Area. Chromium concentrations were generally highest in the 100-K, 100-D, and 100-H Areas' riverbank springs. Hanford groundwater monitoring



results for 2002 indicated similar contaminant concentrations in shoreline areas (Section 6.2).

The ambient surface-water quality criteria for cadmium, copper, lead, nickel, silver, and zinc are total-hardness dependent (WAC 173-201A; Appendix D, Table D.3). For comparison purposes, spring water criteria were calculated using the same 47-mg calcium carbonate per liter hardness given in Appendix D, Table D.3. Most metal concentrations measured in water collected from riverbank springs along the Hanford Site shoreline during 1999 through 2002 were below ambient surface-water acute

toxicity levels (WAC 173-201A). However, concentrations of chromium in 100-B, 100-K, 100-N, 100-D, 100-H, and 100-F, and 300 Areas spring water were above state ambient surface-water acute toxicity levels (Appendix D, Table D.3). Arsenic concentrations in riverbank spring water were well below state ambient surface-water chronic toxicity levels, but concentrations in all samples (including upriver Columbia River water samples) exceeded the federal limit for the protection of human health for the consumption of water and organisms; however, this EPA value is more than 10,500 times lower than



the state chronic toxicity standard (40 CFR 141; Appendix D, Table D.3). Nitrate concentrations at all spring water locations were below the drinking water standard (Appendix D, Table D.2).

4.2.3 COLUMBIA RIVER AND RIVERBANK SPRINGS SEDIMENT

Upon release to the Columbia River, radioactive and non-radioactive materials were dispersed rapidly, sorbed onto detritus and inorganic particles, incorporated into aquatic

biota, deposited on the riverbed as sediment (particularly in upstream areas of a dam), or flushed out to sea. The concentrations of the radioactive material decreased as it underwent radioactive decay. Fluctuations in the river flow, as a result of the operation of hydroelectric dams, annual spring freshets, and occasional floods, have resulted in the resuspension, relocation, and subsequent redeposition of the sediment (DOE/RL-91-50). Sediment in the Columbia River contains low concentrations of radionuclides and metals of Hanford Site origin as well as radionuclides from nuclear weapons testing fallout (Beasley et al. 1981; BNWL-2305; PNL-8148; PNL-10535). Potential public exposure is well below the level at which

Table 4.2.3. Selected Radionuclide Concentrations in 100-N Area Riverbank Spring Water at the Hanford Site, 1997 through 2002

Year	Concentration, pCi/L ^(a)		
	Tritium	Gross Beta	Strontium-90
1997 ^(b)	19,000 ± 1,500	3.5 ± 1.6	0.59 ± 0.13
1997 ^(c)	14,000 ± 1,100	16,000 ± 1,400	9,900 ± 1,800
1998 ^(b)	24,000 ± 1,900	2.3 ± 2.1	^(d)
1999 ^(b)	14,000 ± 670	2.9 ± 1.7	0.026 ± 0.034 ^(e)
2000 ^(b)	18,000 ± 800	5.9 ± 2.1	-0.0026 ± 0.037 ^(e)
2001 ^(b)	17,000 ± 800	3.7 ± 1.8	0.013 ± 0.043 ^(e)
2001 ^(b)	6,500 ± 430	5.5 ± 2.0	0.039 ± 0.044 ^(e)
2002 ^(b)	7,100 ± 320	4.8 ± 1.7	0.0042 ± 0.0034 ^(e)

- (a) Concentrations are ±2 total propagated analytical uncertainty. To convert to international metric system, multiply pCi/L by 0.037 to obtain Bq/L.
- (b) Sample collected from riverbank spring downstream of well 199-N-8T (Spring 8-13).
- (c) Samples collected from spring below well 199-N-8T (see PNNL-11795, Figure 3.2.4).
- (d) Sample was lost during processing at the analytical laboratory.
- (e) Value below the detection limit.

routine surveillance of Columbia River sediment is required (PNL-3127; Wells 1994). However, periodic sampling is necessary to confirm the low concentrations and to assure that no significant changes have occurred for this pathway. The accumulation of radioactive materials in sediment can lead to human exposure by ingestion of aquatic organisms associated with the sediment, sediment resuspension into drinking water supplies, or as an external radiation source irradiating people who are fishing, wading, sunbathing, or participating in other recreational activities associated with the river or shoreline (DOE/EH-0173T).

Since the shutdown of the last single-pass reactor at Hanford during 1971, the contaminant concentrations in the surface sediment have been decreasing as a result of radioactive decay and the subsequent deposition of uncontaminated material (Cushing et al. 1981). However, discharges of some pollutants from the Hanford Site to the Columbia River still occur via permit-regulated liquid effluent discharges at the 100-K Area (Section 3.1) and via contaminated groundwater seepage (Section 4.2.3).

Several studies have been conducted on the Columbia River to investigate the difference in sediment grain-size composition and total organic carbon content at routine monitoring sites (Beasley et al. 1981; PNL-10535; PNNL-13417). Physical and chemical sediment characteristics were found to be highly variable among monitoring sites along the Columbia River. Samples containing the highest percentage of silts, clays, and total organic carbon were generally collected from the upstream pools at the dams and from White Bluffs Slough.

4.2.3.1 COLLECTION OF SEDIMENT SAMPLES AND ANALYTES OF INTEREST

During 2002, samples of the surface layer of Columbia River sediment were collected at depths of 0 to 15 centimeters (0 to 6 inches) from six river locations that were permanently (some Hanford Reach sampling locations may not be submerged during extremely low river stage) submerged and six riverbank springs that were periodically inundated (Figure 4.2.1 and Table 4.2.2). Sediment sampling locations were documented using a global positioning system.

Samples were collected upstream of Hanford Site facilities from the Priest Rapids Dam pool (the nearest upstream impoundment) to provide background data from an area unaffected by site operations. Samples were collected downstream of the Hanford Site above McNary Dam (the nearest downstream impoundment) to identify any increase in contaminant concentrations. Any increases in contaminant concentrations found in sediment above McNary Dam compared to that found above Priest Rapids Dam do not necessarily reflect a Hanford Site source. The confluences of the Columbia River with the Yakima, Snake, and Walla Walla Rivers lie between the Hanford Site and McNary Dam. Several towns, irrigation water returns, and factories in these drainages also may contribute to the contaminant load found in McNary Dam sediment; thus, sediment samples are periodically taken at Ice Harbor Dam (the first dam on the Snake River upstream of the river mouth) to assess Snake River inputs (the most recent samples were collected during 2001). Sediment samples also were collected along the Hanford Reach of the Columbia River from areas close to contaminant discharges (e.g., riverbank springs), from

Table 4.2.4. Concentration Ranges for Selected Chemicals in Water from Columbia River Springs at the Hanford Site, 1999 through 2002

	Ambient Water Quality Criterion Level ^(a)	Concentration, µg/L							
		100-B Area	100-K Area	100-N Area	100-D Area	100-H Area	100-F Area	Hanford Town Site	300 Area
No. of Samples		6	8	5	6	12	5	6	7
Dissolved Metals (µg/L)									
Antimony	NA	0.081 - 0.28	0.14 - 0.24	0.16 - 0.24	0.18 - 0.22	0.23 - 0.42	0.096 - 0.23	0.13 - 0.39	0.20 - 0.36
Arsenic	190	0.93 - 1.6	0.32 - 2.1	1.4 - 3.4	0.66 - 1.3	0.30 - 3.0	1.5 - 2.6	2.6 - 4.8	0.95 - 2.9
Cadmium	0.59	0.010 - 0.021	0.0044 - 0.051	0.011 - 0.031	0.017 - 0.093	0.0044 - 0.034	0.0091 - 0.023	0.010 - 0.089	0.012 - 0.078
Chromium	10 ^(b)	7.5 - 20	2.1 - 82	5.6 - 12	24 - 150	4.0 - 88	14 - 22	1.8 - 4.6	2.2 - 3.9
Copper	6	0.20 - 2.1	0.38 - 1.1	0.25 - 0.40	0.38 - 1.4	0.29 - 5.6	0.32 - 0.45	0.20 - 0.62	0.38 - 0.60
Lead	1.1	0.011 - 0.16	0.0078 - 0.016	0.0050 - 0.016	0.0073 - 0.020	0.0050 - 0.57	0.0078 - 0.033	0.0049 - 0.075	0.0050 - 0.062
Nickel	83	0.028 - 1.6	0.12 - 1.7	0.027 - 1.0	0.22 - 1.8	0.070 - 1.2	0.070 - 2.2	0.62 - 1.7	0.055 - 2.1
Silver	0.94 ^(c)	0.0012 - 0.021	0.0012 - 0.021	0.0012 - 0.021	0.0043 - 0.021	0.0050 - 0.021	0.0012 - 0.042	0.0043 - 0.053	0.0049 - 0.021
Thallium	NA	0.0035 - 0.020	0.0035 - 0.023	0.0071 - 0.016	0.026 - 0.098	0.0059 - 0.026	0.0035 - 0.011	0.013 - 0.028	0.013 - 0.038
Zinc	55	0.94 - 5.0	0.76 - 3.7	1.5 - 3.7	1.7 - 12	0.35 - 5.0	1.1 - 2.5	1.3 - 3.1	1.7 - 3.0
No. of Samples		7	8	5	6	11	5	10	7
Total Recoverable Metals (µg/L)									
Chromium	96 ^(d)	7.2 - 20	2.2 - 93	7.6 - 14	24 - 190	4.0 - 99	17 - 33	1.8 - 5.4	1.9 - 24
Mercury	0.012	0.00048 - 0.0013 ^(e)	0.00098 - 0.014 ^(f)	0.00044 - 0.0062 ^(g)	0.00086 - 0.020 ^(e)	0.00056 - 0.002 ^(h)	0.0017 - 0.0038 ^(g)	0.00079 - 0.0028 ⁽ⁱ⁾	0.00074 - 0.0047 ^(e)
Selenium	5	0.60 - 2.2	0.11 - 2.2	0.41 - 0.96	0.67 - 2.7	0.39 - 2.9	0.94 - 2.3	0.56 - 2.3	1.7 - 4.1
No. of Samples		8	7	4	10 ^(j)	12	5	8	7
Anions (mg/L)									
Nitrate	45 ^(k)	1.5 - 3.4	0.29 - 4.9	2.0 - 4.9	0.84 - 6.3	0.10 - 20	0.58 - 33	3.0 - 8.1	3.2 - 6.4

(a) Ambient Water Quality Criteria Values (WAC 173-201A-040) for chronic toxicity unless otherwise noted.

(b) Value for hexavalent chromium.

(c) Value for acute toxicity; chronic value not available.

(d) Value for trivalent chromium.

(e) n=5.

(f) n=4.

(g) n=3.

(h) n=7.

(i) n=8.

(j) One nitrate result of 295 mg/L for riverbank spring (SD-110-2) on October 17, 2000 was not included in the range because it was considered an anomalously high value.

(k) Drinking water standard (WAC 246-290).

NA = Not available.

slackwater areas where fine-grained material is known to deposit (e.g., the White Bluffs, 100-F Area, and Hanford Sloughs), and from the publicly accessible Richland shoreline that lies within the influence of the McNary Dam impoundment.

Monitoring sites at McNary and Priest Rapids Dams consisted of two stations spaced equidistant (approximately) on a transect line crossing the Columbia River; the samples were collected near the boat exclusion buoys at each dam. All other monitoring sites consisted of a single sampling location. Samples of permanently inundated river sediment were collected using a clam-shell style sediment dredge. Samples of periodically inundated (covered by water) river sediment (riverbank springs sediment) were collected using a large plastic spoon, immediately following the collection of riverbank springs water samples. Sampling methods are discussed in detail in DOE/RL-91-50. All sediment samples were analyzed for gamma-emitting radionuclides (Appendix F), strontium-90, uranium-234, uranium-235, uranium-238, and metals (DOE/RL-91-50). Selected river sediment samples were also analyzed for plutonium-238 and plutonium-239/240. The specific analytes selected for sediment samples were based on findings of previous Columbia River sediment investigations, reviews of past and present effluent discharged from site facilities, and reviews of contaminant concentrations observed in groundwater monitoring wells near the river.

4.2.3.2 RADIOLOGICAL RESULTS FOR SEDIMENT SAMPLES FROM COLUMBIA RIVER

Radionuclides consistently detected in river sediment adjacent to and downstream of the Hanford Site during 2002 included potassium-40, cesium-137, uranium-238, plutonium-238, and plutonium-239/240 (Appendix B, Table B.7). The concentrations of all other radionuclides were below detection limits for most samples (PNNL-14295, APP. 1). Cesium-137 and plutonium isotopes exist in worldwide fallout, as well as in effluent from Hanford Site facilities. Potassium-40 and uranium occur naturally in the environment, and uranium is also present in Hanford Site effluent. No federal or state freshwater sedi-

ment criteria are available to assess the sediment quality of the Columbia River (EPA 822-R-96-001).

Radionuclide concentrations reported in river sediment during 2002 were similar to those reported for previous years (Appendix B, Table B.7). Cesium-137, plutonium-239/240, and uranium isotopes were the only radionuclides detected in sediment samples, and there were no obvious differences between locations. Median, maximum, and minimum concentrations of selected radionuclides measured in Columbia River sediment (1996 through 2001) are presented in Figure 4.2.14.

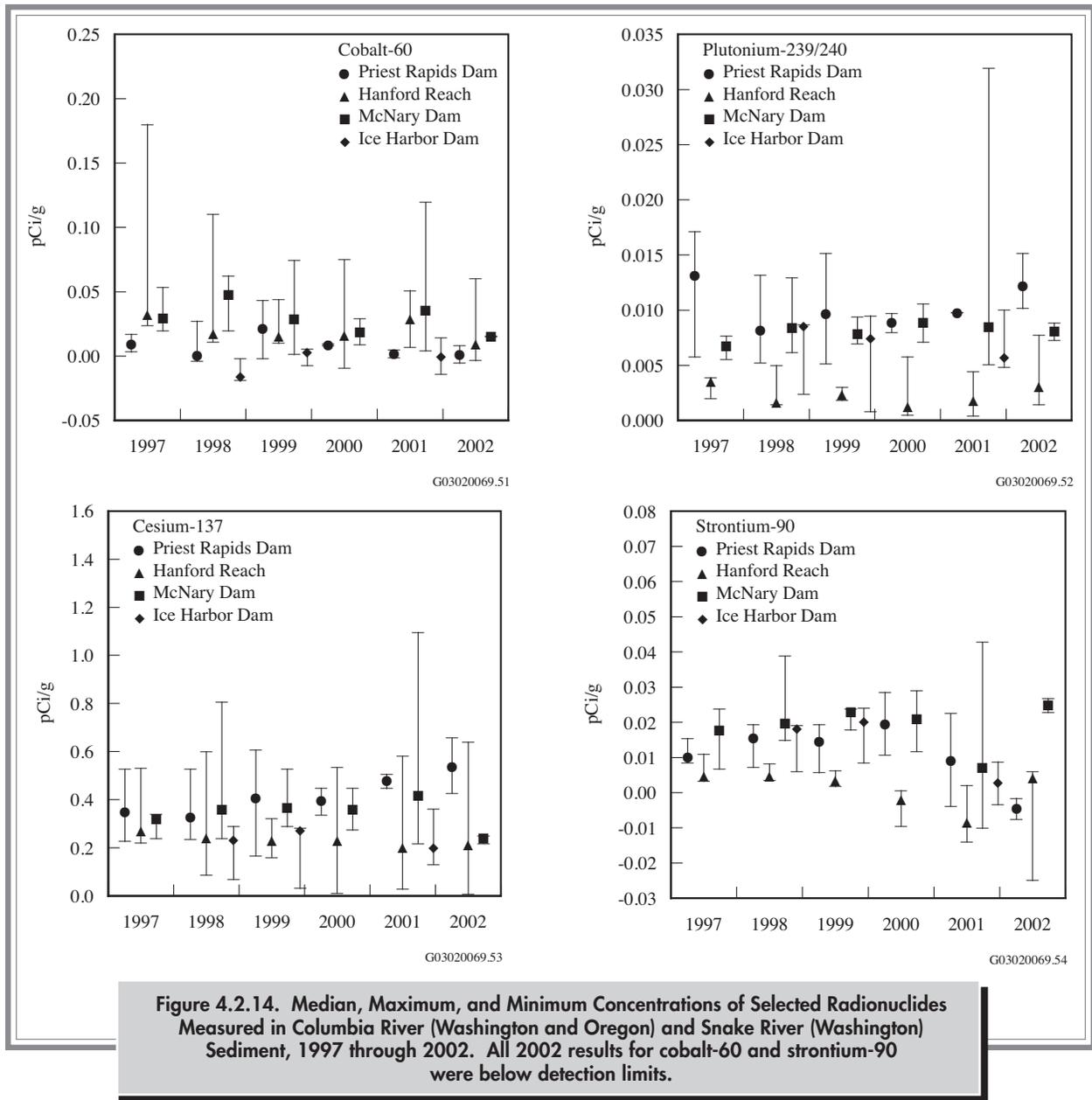
4.2.3.3 RADIOLOGICAL RESULTS FOR SEDIMENT SAMPLES FROM RIVERBANK SPRINGS

Sampling of sediment from riverbank springs began during 1993 at the Hanford town site and the 300 Area. Sampling of the riverbank springs in the 100-B, 100-K, and 100-F Areas began during 1995. Substrates at riverbank springs sampling locations in the 100-N, 100-D, and 100-H Areas consist of predominantly large cobble and are unsuitable for sample collection.

During 2002, sediment samples were collected at riverbank springs in the 100-B, 100-F, and 300 Areas. No sediment was available for sampling at the 100-K and 100-N Area locations. Results for 2002 samples were similar to those observed for previous years (PNNL-14295; APP. 1; Appendix B, Table B.7). Cesium-137 and uranium isotopes were the only radionuclides reported above the detection limits. During 2002, radionuclide concentrations in riverbank spring sediment were similar to those observed in river sediment, with the exception of the 300 Area where elevated uranium concentrations were observed (PNNL-13692).

4.2.3.4 CHEMICAL RESULTS FOR SEDIMENT SAMPLES FROM THE COLUMBIA RIVER AND RIVERBANK SPRINGS

Detectable amounts of most metals were found in all river sediment samples (Figure 4.2.15; Appendix B, Table B.8;



PNNL-14295, APP. 1). Maximum and median concentrations of most metals were higher for sediment collected at Priest Rapids Dam compared to either Hanford Reach or McNary Dam sediment. The concentrations of cadmium, mercury, silver, and zinc had the largest differences between locations. Metal concentrations in riverbank spring sediment samples during 2002 were similar to concentrations in Hanford Reach Columbia River sediment samples. Currently, there are no Washington State freshwater sediment quality criteria for comparison to the measured values.

From 1997 to 2000 and for 2002, Columbia River sediment was analyzed for simultaneously extracted metals/acid volatile sulfide (SEM/AVS). This analysis involves a cold acid extraction of the sediment followed by analysis for sulfide and metals. The SEM/AVS ratios are an indicator of potential sediment toxicity (DeWitt et al. 1996; Hansen et al. 1996; PNNL-13417). Acid volatile sulfide is an important binding phase for divalent metals (i.e., metals with a valence state of 2+, such as Pb^{2+}) in sediment. Metal sulfide precipitates are typically very insoluble, and this limits the amount of dissolved metal available in the

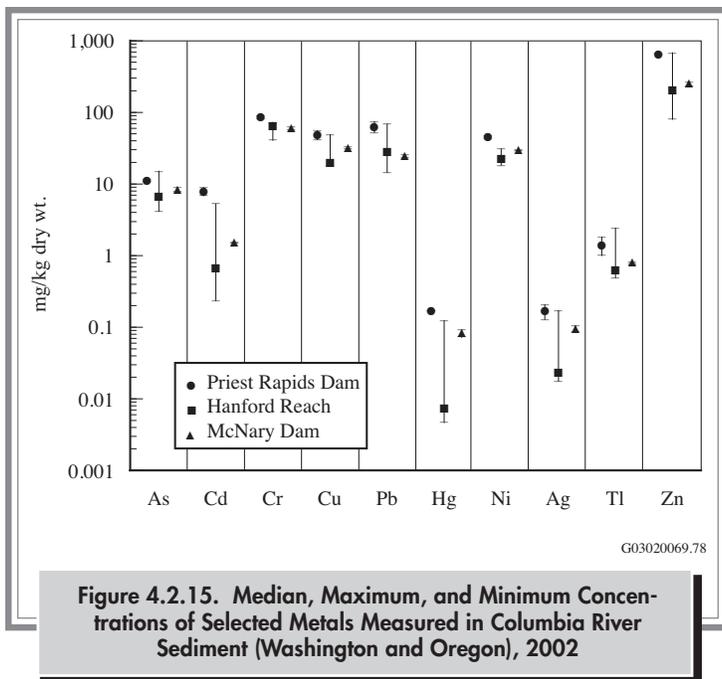


Figure 4.2.15. Median, Maximum, and Minimum Concentrations of Selected Metals Measured in Columbia River Sediment (Washington and Oregon), 2002

sediment porewater. For an individual metal, when the amount of acid volatile sulfide exceeds the amount of the metal (i.e., the SEM/AVS molar ratio is below 1), the dissolved metal concentration in the sediment porewater will be low because of the limited solubility of the metal sulfide. For a suite of divalent metals, the sum of the simultaneously extracted metals must be considered, with the assumption that the metal with the lowest solubility will be the first to combine with the acid volatile sulfide.

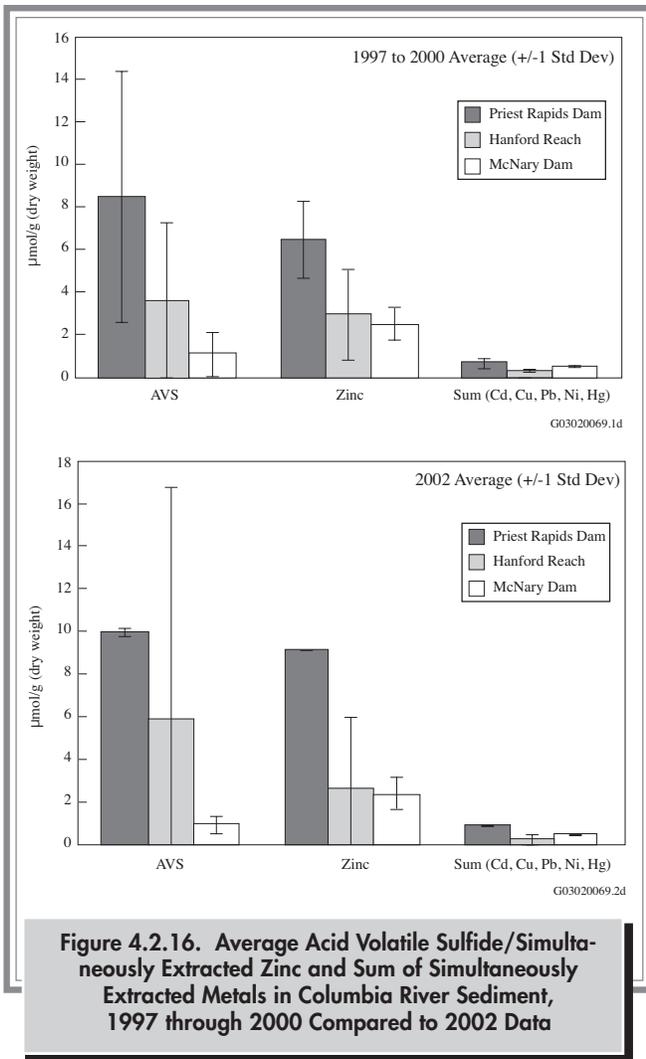
The SEM/AVS results for the sediment collected during 2002 near Priest Rapids Dam and McNary Dam were similar to previous years (Figure 4.2.16). The average SEM/AVS results for the Hanford Reach sediment collected during 2002 were similar but the concentrations varied over a wider range (0.024 to 22 $\mu\text{mol/g}$). The sediment deposition locations in the Hanford Reach are more subject to annual variations in sediment parameters that can influence SEM/AVS results (e.g., sediment deposition rate, scouring by floods, changes in total organic carbon concentrations, and potential exposure to air during dry periods) than the sediment deposition areas upstream of the dams. For 2002, the acid volatile sulfide values in sediment from the Priest Rapid Dam reservoir had concentrations ranging from 9.8 to 10 $\mu\text{mol/g}$. Sediment from the Hanford Reach and McNary Dam reservoir had lower concentrations of acid volatile sulfide, with values ranging from 0.024 to 1.2 $\mu\text{mol/g}$, excluding the White

Bluffs Slough result of 22 $\mu\text{mol/g}$. For 2002, the SEM/AVS molar ratios were near 1.0 for Priest Rapids Dam. For 2002, SEM/AVS molar ratios for sediment from the Hanford Reach and McNary Dam were above 1.0, indicating a potential for some dissolved metals to be present in the sediment porewater; excluding the White Bluffs Slough that had SEM/AVS molar ratio below one (i.e., low potential for dissolved metals in sediment porewater). For all locations, zinc was the primary SEM metal present.

These results reveal an apparent difference in the acid volatile sulfide concentrations in sediment from Priest Rapids Dam reservoir, which had higher concentrations than Hanford Reach and McNary Dam. An apportionment of acid volatile sulfide by divalent metals according to solubility values revealed that sufficient acid volatile sulfide should exist in all locations to limit the porewater concentrations of cadmium, copper, lead, and mercury. In Priest Rapids Dam sediment, average zinc values were of similar magnitude as the average acid volatile sulfide concentrations. In Hanford Reach and McNary Dam sediment, the average zinc concentrations were higher than the available mean acid volatile sulfide pool, indicating the potential for zinc and possibly other dissolved metals to be present in the sediment porewater.

4.2.4 ONSITE POND WATER AND SEDIMENT

Two onsite ponds (Figure 4.2.1), located near operational areas, were sampled periodically during 2002. The ponds are inaccessible to the public and, therefore, did not constitute a direct offsite environmental impact during 2002. However, they were accessible to migratory waterfowl and deer, creating a potential biological pathway for the dispersion of contaminants (PNL-10174). The Fast Flux Test Facility pond is a disposal site for process water (primarily cooling water drawn from groundwater wells). West Lake, the only naturally occurring pond on the site, is located north of the 200-East Area (ARH-CD-775). West Lake has not received direct effluent discharges from Hanford Site facilities but is influenced by changing water-table elevation as a result of previous discharge of water to the ground in the 200 Areas.



4.2.4.1 COLLECTION OF POND WATER AND SEDIMENT SAMPLES AND ANALYTES OF INTEREST

During 2002, grab samples were collected quarterly from the Fast Flux Test Facility pond (water) and from West Lake (water and sediment). All water samples were analyzed for tritium. Water samples from the Fast Flux Test Facility pond were also analyzed for gross alpha and gross beta concentrations, and gamma-emitting radionuclides. The groundwater table in the 200-East Area has decreased in recent years (Section 6.1) and this has decreased the size of West Lake and caused the suspended sediment loading to increase. During 2002, it was no longer practical for the analytical laboratory to process West Lake water

samples for gross alpha, gross beta, strontium-90, technetium-99, and uranium-234, uranium-235, and uranium-238 because of the high sediment load; thus, sediment samples were submitted for these analytes. Constituents were chosen for analysis based on their known presence in local groundwater, effluent discharged, and their potential to contribute to the overall radiation dose to biota that frequent the ponds.

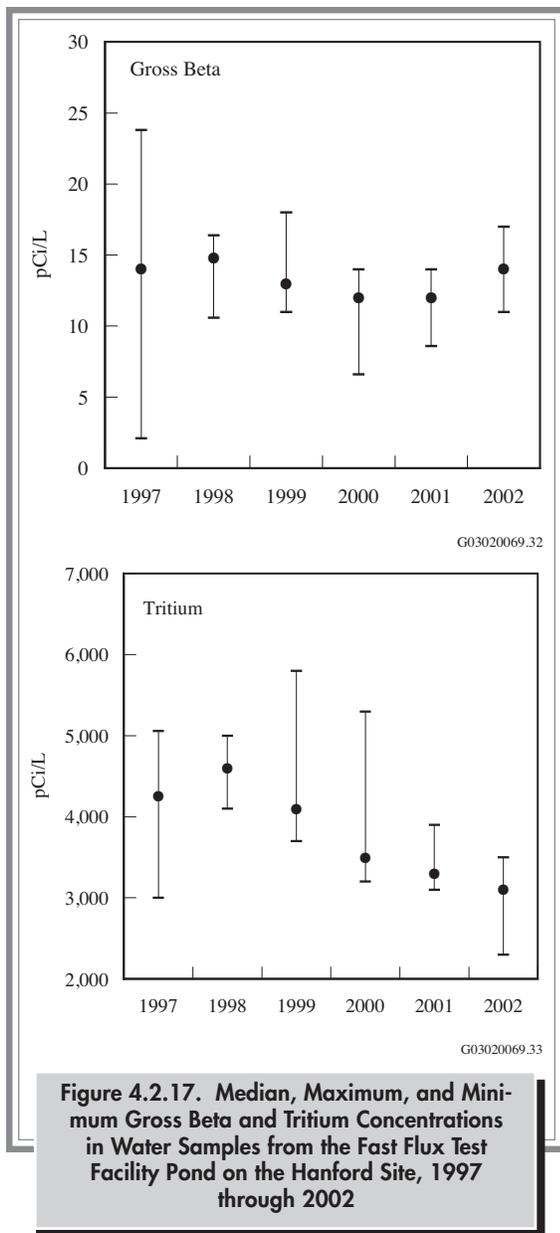
4.2.4.2 RADIOLOGICAL RESULTS FOR POND WATER AND SEDIMENT SAMPLES

All radionuclide concentrations in onsite pond water were less than applicable DOE derived concentration guides (DOE Order 5400.5; Appendix D, Table D.5) and state ambient surface-water quality criteria levels (WAC 173-201A; 40 CFR 141; PNNL-14295, APP. 1; Appendix D, Tables D.1 and D.2).

Figure 4.2.17 shows the annual gross beta and tritium concentrations in Fast Flux Test Facility pond water from 1997 through 2002. Median levels of both constituents have remained stable in recent years. The median tritium concentration in Fast Flux Test Facility pond water during 2002 was 15% of the state ambient surface-water quality criterion of 20,000 pCi/L (740 Bq/L).

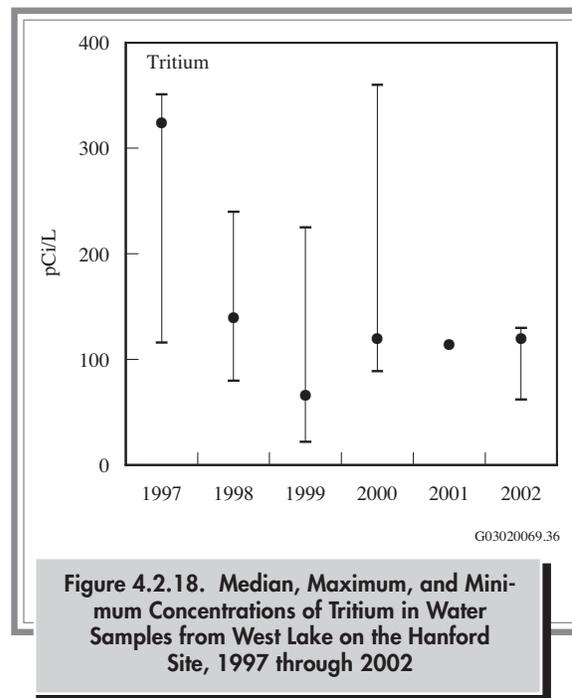
Median tritium concentrations in West Lake water during 2002 were similar to those observed in the past (Figure 4.2.18). The median concentration of tritium in West Lake water in 2002 was 0.6% of the state ambient surface-water quality criterion level (20,000 pCi/L [740 Bq/L]) and reflected local groundwater concentrations.

Samples of West Lake sediment in 2002 had detectable values for gross alpha (2.6 to 11 pCi/g [0.096 to 0.41 Bq/g]), gross beta (24 to 34 pCi/g [0.89 to 1.3 Bq/g]), potassium-40 (14 to 19 pCi/g [0.52 to 0.70 Bq/g]), strontium-90 (0.11 to 0.70 pCi/g [0.0041 to 0.026 Bq/g]), cesium-137 (0.28 to 1.8 pCi/g [0.010 to 0.067 Bq/g]), uranium-234 (0.29 to 4.8 pCi/g [0.011 to 0.16 Bq/g]), uranium-235 (0.0099 to 0.18 pCi/g [0.00037 to 0.0067 Bq/g]), and uranium-238 (0.29 to 4.3 pCi/g [0.011 to 0.16 Bq/g]). These levels of radionuclides are similar to previous measurement (PNL-7662) and are believed to result from high levels of naturally occurring uranium in the surrounding soil (BNWL-1979).



4.2.5 IRRIGATION WATER

During 2002, water samples were collected from an irrigation canal located across the Columbia River and downstream from the Hanford Site at Riverview, and from an irrigation water supply on the Benton County shoreline near the southern boundary of the Hanford Site (Horn Rapids irrigation pumping station). As a result of public concerns about the potential for Hanford-associated contaminants in offsite water, sampling was conducted to document the levels of radionuclides in water used by



the public. Consumption of vegetation irrigated with Columbia River water downstream of the site has been identified as one of the primary pathways contributing to the potential dose to the hypothetical maximally exposed individual and any other member of the public (Chapter 5).

COLLECTION, ANALYSIS, AND RESULTS FOR IRRIGATION WATER

Water from the Riverview irrigation canal and the Horn Rapids irrigation pumping station was sampled three times during 2002 during the irrigation season. Unfiltered samples were analyzed for gross alpha, gross beta, gamma emitters, tritium, strontium-90, and uranium-234, uranium-235, and uranium-238. During 2002, radionuclide concentrations measured in irrigation water were at the same levels detected in the Columbia River (PNNL-14295, APP. 1). All radionuclide concentrations were below their respective DOE derived concentration guides and state ambient surface-water quality criteria levels (DOE Order 5400.5; WAC 173-201A; 40 CFR 141). Strontium-90 levels in all irrigation water samples during 2002 ranged from 0.055 ± 0.028 to 0.077 ± 0.034 pCi/L (0.0020 ± 0.0010 to 0.0028 ± 0.0013 Bq/L).