2.1 Overview of Hanford Site Groundwater

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DOE monitors groundwater quality all across the Hanford Site to know what contaminants are present and how they are moving.

This section provides a broad picture of groundwater flow and contaminant distribution beneath the Hanford Site. Details for specific locations are included in Sections 2.2 through 2.14. Supporting information for *Resource Conservation and Recovery Act* (RCRA), *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), and other regulated units is compiled in Appendices A, B, and C.

The uppermost aquifer beneath most of the Hanford Site is unconfined and is composed of unconsolidated to semiconsolidated sediment of the Hanford and Ringold Formations, which was deposited on the basalt bedrock. In some areas, deeper parts of the aquifer are confined locally by layers of silt and clay. Confined aquifers occur within the underlying basalt and associated sedimentary interbeds.

For site characterization and cleanup, waste sites are grouped into source operable units, and the groundwater beneath the sites is divided into groundwater operable units. For the purposes of this report and for data review and interpretation in fiscal year 2003, the Groundwater Performance Assessment Project (groundwater project) divides the Hanford Site into geographic areas of interest for groundwater monitoring. Figure 2.1-1 illustrates these areas of interest and the operable units boundaries.

Well location maps for each geographic region are included in Sections 2.2 through 2.14. Wells in the 600 Area (i.e., portions of the Hanford Site other than the former operational areas) are shown in Figure 2.1-2.

Monitoring points near the river, called aquifer sampling tubes (or simply aquifer tubes), provide additional information on water quality near the Columbia River. Most of the aquifer tubes are located in the 100 Areas and the Hanford town site. Their locations are shown on well location maps in Sections 2.2 through 2.7.

2.1.1 Groundwater Flow

During March and early April 2003, 887 water-level measurements were collected from the unconfined aquifer system and the underlying confined aquifers beneath the Hanford Site. These data are used to (1) prepare contour maps that indicate the general direction of groundwater movement within an aquifer; (2) determine hydraulic gradients, which in conjunction with the hydraulic properties of the aquifer, are used to compute groundwater flow velocities; (3) support groundwater model calibration; and (4) interpret sampling results. This section describes the results of a regional-scale analysis of these data for the unconfined aquifer, which is the aquifer most affected by Hanford operations. Flow in the

Groundwater is the water that fills the pores or cracks between grains in a layer of sediment or rock. Monitoring the groundwater helps determine what contamination exists beneath the Hanford Site. This information will help regulators and DOE make cleanup decisions based on scientific information and technical capabilities.

DOE has monitored groundwater on the Hanford Site since the 1940s to help determine what chemical and radiological contaminants have made their way to groundwater and how they have migrated in groundwater. Groundwater monitoring is a part of the cleanup mission and will remain a component of long-term stewardship after remediation is completed.

confined aquifer in the lower Ringold Formation and the upper basalt-confined aquifer is discussed in Section 2.14. For more information regarding water-level monitoring activities, see PNNL-13021.

Groundwater in the unconfined aquifer generally flows west to east beneath the Hanford Site and discharges to the Columbia River.

2.1.1.1 March 2003 Water Table

Figure 2.1-3 presents the March 2003 water-table map for the Hanford Site. Groundwater in the unconfined aquifer generally flows from west to east and discharges to the Columbia River. Steep gradients occur in the west, east, and north regions of the site. Shallow gradients occur southeast of the 100-F Area, and in a broad arc extending from west of the 100-B/C Area trending southeast between Gable Butte and Gable Mountain (Gable Gap), and through the 200 East Area into the central portion of the Hanford Site. The steep gradients in the west and east are due to the presence of the relatively low permeability sediment of the Ringold Formation at the water table, while the low gradient areas are associated with the highly permeable sand and gravel of the Hanford formation.

North of Gable Butte and Gable Mountain, groundwater generally flows from west to east and discharges to the Columbia River. Groundwater enters this region from the Columbia River west of the 100-B/C Area, through Gable Gap, and through the gap between Umtanum Ridge and Gable Butte. An apparent groundwater mound exists ~2 kilometers north of Gable Mountain, and is associated with low conductivity Ringold Formation muds at the water table.

Past effluent discharges at U Pond and other facilities caused a groundwater mound to form beneath the 200 West Area. These discharges had largely ceased by the mid-1990s, but a remnant mound remains, which is apparent from the shape of the water-table contours passing through the 200 West Area. Currently, this mound is ~12 meters above the estimated pre-Hanford water table. Scientists predict that when equilibrium conditions are established, the water table may be ~5 to 7 meters higher than the pre-Hanford water table because of artificial recharge from offsite irrigation (PNNL-11801).

Over much of the Hanford Site, the water table continued to decline. The declining water table caused some monitoring wells to go dry; new wells are planned.

Groundwater flow in the central portion of the Hanford Site, encompassing the 200 East Area, is significantly affected by the presence of a buried flood channel, which lies in a northwest to southeast orientation (PNNL-12261). The water table in this area is relatively flat because of the presence of highly permeable sediment of the Hanford formation at the water table. Groundwater flow in this region also is significantly affected by the presence of low permeability sediment of the Ringold Formation at the water table east and northeast of the 200 East Area, as well as basalt above the water table. The water table beneath the 200 East Area is ~2.4 meters higher than pre-Hanford conditions. Scientists estimate that when equilibrium conditions are established in the 200 East Area, the water table will be near its pre-Hanford elevation (PNNL-11801).

2.1.1.2 Water-Table Changes from Fiscal Year 2002

In the 200 East Area, the water table decline from March 2002 to March 2003 averaged 0.04 meter. This is significantly smaller than the decline measured in previous years (e.g., 0.19 meter in fiscal year 2002; PNNL-14187). The region affected by this smaller than normal decline extends from Gable Gap through the 200 East Area to the Central Landfill, i.e., in the highly conductive sediment of the Hanford formation. The water-table elevation actually increased in the south part of the 200 East Area and into the surrounding 600 Area. This fluctuation in the water table is demonstrated by the hydrograph for well 299-E32-8 in the northwest part of the 200 East Area (Figure 2.1-4). The cause of this fluctuation remains unclear.

Over much of the rest of the Hanford Site, the long-term decline in the water-table elevation continued, although increases did occur in some areas. North of Gable Butte and Gable Mountain, the water-table elevation increased in many areas along the Columbia River, and in the highly permeable sediment from the 100-B/C Area to Gable Gap. These increases are attributed to changes in river stage. In the 200 West Area, the water table declined by an average of 0.26 meter (in those areas not influenced by pump-and-treat remediation systems). The largest water-table elevation increase was 1.33 meters in well 1199-39-16E at the city of Richland North Well Field, and the largest decrease was 0.72 meter in well 399-4-10 in the 300 Area.

Tritium, nitrate, and iodine-129 are the most widespread contaminants on the Hanford Site.

2.1.2 Groundwater Contaminants

During fiscal year 2003, Hanford Site staff sampled 710 wells and 79 aquifer tubes for radiological and chemical constituents. Many of the wells were sampled multiple times, for a total of 1,788 well trips.

Chromium (total or hexavalent) was the most frequently analyzed constituent, analyzed 1,723 times. Anions, iodine-129, metals, technetium-99, strontium-90, and volatile organic compounds were other commonly analyzed constituents (Table 2.1-1). The data from many wells on the Hanford Site are used to meet the objectives of multiple regulations, including RCRA, CERCLA, and the *Atomic Energy Act of 1954*. Sampling and analysis are coordinated to avoid unnecessary costs.

Monitoring water quality along the river is accomplished by collecting samples from (a) aquifer sampling tubes having sample ports at several depths beneath the shoreline, (b) riverbank springs, and (c) near-shore river water. Use of aquifer sampling tubes at riverbank springs is included in CERCLA monitoring plans for groundwater operable units in the 100 and 300 Areas. Representatives from the U.S. Environmental Protection Agency and Washington State Department of Ecology meet annually with the U.S. Department of Energy (DOE) and its contractors to plan the annual aquifer sampling tube event, which usually occurs during the fall months (DOE/RL-2000-59).

Tritium, nitrate, and iodine-129 are the most widespread contaminants associated with past Hanford Site operations. Their distribution in the unconfined aquifer is shown in Figures 2.1-5, 2.1-6, and 2.1-7. The most prominent portions of these plumes originated at waste sites in the 200 Areas and spread toward the southeast. Nitrate and tritium also had significant sources in the 100 Areas.

Although some contaminants exceed drinking water standards in groundwater samples, the concentrations measured in river water remained far below standards.

Other contaminant plumes include:

- Carbon tetrachloride and associated trichloroethene in the 200 West Area.
- Chromium in the 100 Areas.
- Chromium in the 600 Area south of the 200 Areas.
- Strontium-90 in the 100 Areas.
- Technetium-99 and uranium that extend eastward from the 200 West Area.
- Technetium-99 and uranium with minor amounts of cyanide and cobalt-60 in the northwest 200 East Area.
- Uranium in the 300 Area.

The distribution of hexavalent chromium in aquifer tubes along the 100 Areas is illustrated in Figure 2.1-8. The highest concentrations are detected along the south 100-D Area shoreline. In most cases, concentrations have decreased in recent years.

Table 2.1-2 lists contaminants and refers to the sections in this report where they are discussed. The table highlights contaminants that exceed water quality standards. Analytical results including fiscal year 2003 and historical data are included in the data files accompanying this report.

Available data indicate that the vast majority of contamination on the Hanford Site remains near the water table. Relatively few wells are completed deeper in the aquifer, but in most cases, these detect lower levels of contamination than their shallow counterparts.

A confined aquifer in the Ringold sediment east of the 200 East Area is contaminated with tritium at levels near those in the unconfined aquifer. However, tritium levels drop sharply a short distance downgradient, as discussed in Section 2.14. Deeper still, in the upper basalt-confined aquifer ~25 meters below the water table, contamination has been detected in only two wells, both near the 200 East Area (see Section 2.14).

DOE is working to clean up groundwater contamination that may pose a risk to human health or the environment. Remedial actions reduce the movement of contaminants until final cleanup decisions are made.

The discharge of the Columbia River along the Hanford Reach is controlled by releases from the Priest Rapids Dam, located upstream of the Hanford Site. Daily discharge cycles can cause river elevation changes of up to several meters along the reactor areas. These fluctuations create a bank storage zone containing highly variable water movement patterns. The influx of river water may dilute contamination carried toward the river by groundwater, prior to its discharge through the riverbed sediment and river bank springs. Seasonal discharge cycles also influence the release of groundwater into the river environment.

2.1.3 Groundwater Remediation

DOE is working to clean up groundwater contamination that may pose a risk to human health or the environment. Decision-making efforts are organized by groundwater operable unit. The text below summarizes the status of remediation in each operable unit. Additional detail is provided elsewhere in Chapter 2 and Appendix A.

The regulators have created records of decision for seven groundwater operable units:

- **100-HR-3 (100-D and 100-H Areas) and 100-KR-4 (100-K Area)** – Chromium may pose a threat to aquatic organisms in the Columbia River. In the 100-K, 100-D, and 100-H Areas, interim action pump-and-treat systems reduce the amount of chromium reaching the river. Also in the 100-D Area, an innovative treatment method immobilizes chromium in the aquifer. In fiscal year 2003, chromium concentrations at all these interim action sites remained above remediation goals (ROD 1996a, 1999a).
- **100-NR-2 (100-N Area)** – Strontium-90 concentrations remained much higher than the drinking water standard in wells at the river shore in fiscal year 2003. DOE has operated a pump-and-treat system for strontium-90 as an interim action since 1995 and is investigating alternative remediation methods (ROD 1999b).
- **200-UP-1 (200 West Area)** – DOE has operated an interim action pump-and-treat system for technetium-99 and uranium since 1995. In fiscal year 2003, some concentrations of uranium remained above remediation goals. Many of the wells monitoring this area have gone dry, so the sizes of the current plumes are uncertain (ROD 1997).
- **200-ZP-1 (200 West Area)** – DOE has operated an interim action pump-and-treat system to prevent carbon tetrachloride from spreading since 1994. In fiscal year 2003, the system continued to limit migration of the heart of the plume (ROD 1995a).
- **300-FF-5 (300 Area and satellite areas to the north)** – The interim action involves natural attenuation of the cis-1,2-dichloroethene, trichloroethene, and uranium plumes in the 300 Area. In fiscal year 2003, concentrations of the organic contaminants were low, but uranium remained elevated (ROD 1996b).
- **1100-EM-1 (Richland North Area)** – DOE and regulators have determined that the final cleanup action will be monitored attenuation of the contaminant plumes (ROD 1993).

At four operable units, there is no imminent threat to human health or the environment, so no interim remedial actions are required.

- **100-BC-5 (100-B/C Area)**
- **100-FR-3 (100-F Area)**

- **200-BP-5 (north 200 East Area)**
- **200-PO-1 (south 200 East Area and southeast tritium plume)**

Waste sites and plumes will continue to be monitored until there are final records of decision, which may stipulate active remediation or rely on natural processes.

Table 2.1-1. Number of Groundwater Analyses by Groundwater Interest Area, Fiscal Year 2003

Constituent	Site Total	100-BC-5	100-KR-4	100-NR-2	100-HR-3-D	100-HR-3-H	100-FR-3	200-ZP-1	200-UP-1	200-BP-5	200-PO-1	300-FF-5	1100-EM-1
Carbon tetrachloride	565	0	2	1	0	0	18	241	71	8	73	117	35
Chromium (total + hexavalent)	1,723	27	211	48	435	191	38	219	143	202	181	22	7
Iodine-129	278	0	0	0	0	1	0	97	62	52	51	11	4
Nitrate	1,181	15	65	43	72	58	21	264	173	214	159	55	43
Strontium-90	301	16	57	43	16	24	22	20	11	35	48	9	0
Technetium-99	655	1	12	1	9	39	0	218	148	195	21	9	3
Tritium	908	18	92	34	49	36	18	206	121	180	66	71	18
Uranium	583	0	0	0	43	38	0	59	121	165	9	134	14

Table 2.1-2. Maximum Concentrations of Selected Groundwater Contaminants in Fiscal Year 2003

Contaminant, units (alphabetical order)	DWS [DCG][a]	100-BC-5 Section 2.2 Wells	100-BC-5 Section 2.2 Aquifer Tubes	100-KR-4 Section 2.3 Wells	100-KR-4 Section 2.3 Aquifer Tubes	100-NR-2 Section 2.4 Wells	100-HR-3-D Section 2.5 Wells	100-HR-3-D Section 2.5 Aquifer Tubes	100-HR-3-H Section 2.6 Wells	100-HR-3-H Section 2.6 Aquifer Tubes	100-FR-3 Section 2.7 Wells	100-FR-3 Section 2.7 Aquifer Tubes
Antimony (filtered), µg/L[b]	6						**30.8**				**31.5**	
Arsenic (filtered), µg/L	10											
Cadmium (filtered), µg/L	5	3.3				3.1	3.4				3.9	
Carbon tetrachloride, µg/L	5											
Carbon-14, pCi/L	2,000 [70,000]			**20,900**	67.2	15.4						
Cesium-137, pCi/L	200 [3,000]					ND						
Chloroform, µg/L	100			1		7.2					1.1	
Chromium (dissolved), µg/L	100	46	38	**542**	52	**168**	**5,440**	**295**	**154**	43	90	
cis-1,2-dichloroethene, µg/L	70											
Cobalt-60, pCi/L	100 [5,000]					ND						
Cyanide, µg/L	200											
Fluoride, mg/L	4	0.51		0.49		1	0.45		0.45		0.72	
Gross alpha, pCi/L	15	2.99		7.14		3.07	3.94		**72.4**		10.1	
Gross beta, pCi/L	50	**221**		**3,590**		**16,000**	**466**		**183**		**51.1**	
Iodine-129, pCi/L	1 [500]											
Methylene chloride, µg/L[c]	5					0.37					0.31	
Nickel (filtered), µg/L	100			28.8		17	**416**		21.6			
Nitrate, mg/L	45	27.9		**195**	3.6	**228**	**107**		**474**		**177**	
Nitrite, mg/L	3.3			0.135		0.299	**7.55**					
Plutonium-239/240, pCi/L	NA[d] [30]											
Strontium-90, pCi/L	8 [1,000]	**98.9**	**15**	***2,440***	ND	***8,000***	7.06		23.2		**27.8**	
Technetium-99, pCi/L	900 [100,000]	46.7		85.4					**986**	ND		
Trichloroethene, µg/L	5			**11**							**9.8**	
Tritium, pCi/L	20,000 [2,000,000]	**21,900**	**32,200**	**1,270,000**	ND	**31,400**	**23,700**	**29,700**	6,210		11,500	
Uranium, µg/L	30						3.58		**119**			

Table 2.1.2. (contd)

Contaminant, units (alphabetical order)	DWS [DCG][a]	200-ZP-1 Section 2.8 Wells	200-UP-1 Section 2.9 Wells	200-BP-5 Section 2.10 Wells	200-PO-1 Section 2.11 Wells	300-FF-5 Section 2.12 Wells	1100-EM-1 Section 2.13 Wells
Antimony (filtered), µg/L[b]	6	**29.2**	**31.1**	**51.1**	**44.8**		**29.8**
Arsenic (filtered), µg/L	10	4.1	8.7	7.6	9.2		
Cadmium (filtered), µg/L	5	3.2	3.1	4.6	3.3		
Carbon tetrachloride, µg/L	5	**6,200**	**690**		0.29	0.35	
Carbon-14, pCi/L	2,000 [70,000]						
Cesium-137, pCi/L	200 [3,000]			**1,170**			
Chloroform, µg/L	100	31	20		0.46	3	4.4
Chromium (dissolved), µg/L	100	**592**	**209**	54.9	**6,250**	7.3	
cis-1,2-dichloroethene, µg/L	70	0.09				**160**	48[e]
Cobalt-60, pCi/L	100 [5,000]			48.4			
Cyanide, µg/L	200	6.4		**275**			
Fluoride, mg/L	4	**4.3**	0.7	0.98	1.3	0.52	**4.3**[f,g]
Gross alpha, pCi/L	15	6.73	13.9	**324**	10.7	**43.9**	**77**[f,g]
Gross beta, pCi/L	50	**4,390**	**71,200**	**12,100**	**79.7**	**97.5**	34.7[f,g]
Iodine-129, pCi/L	1 [500]	**36.7**	**35.3**	**3.65**	**11.9**		
Methylene chloride, µg/L[c]	5	**18**	**7**		4.2	1.8	**5.4**
Nickel (filtered), µg/L	100	**328**	**120**	**133**	**864**	41.6	
Nitrate, mg/L	45	**2,160**	**1,930**	**735**	**170**	**134**	**261**[f,g]
Nitrite, mg/L	3.3	0.361	0.46	1.12	0.233	0.069	0.043
Plutonium-239/240, pCi/L	NA[d] [30]			***74.8***			
Strontium-90, pCi/L	8 [1,000]	1.29	**53.6**	***5,680***	**21.4**	4.03	
Technetium-99, pCi/L	900 [100,000]	**11,117**	***188,000***	**10,600**	287	319	27
Trichloroethene, µg/L	5	**18**	**11**		0.88	**7.2**	**27**[e,f]
Tritium, pCi/L	20,000 [2,000,000]	***2,170,000***	**634,000**	**27,600**	***5,570,000***	***3,670,000***	251
Uranium, µg/L	30	**367**	**1,190**	**554**	7.19	**235**	18[f]

Note: Table lists highest concentration for fiscal year 2003 in each groundwater interest area. Concentrations in **bold** exceed drinking water standards. Concentrations in ***bold italic*** exceed DOE derived concentration guides. Blank space indicates the constituent was undetected or not analyzed.

(a) DWS = Drinking water standard; DCG = DOE derived concentration guide. See PNNL-13080 for more information on these standards.
(b) Detection limit is higher than DWS. Not a known contaminant of interest on the Hanford Site.
(c) Common laboratory contaminant.
(d) There is no drinking water standard for plutonium-239/240.
(e) City of Richland date; not in HEIS.
(f) From offsite contaminant source.
(g) Framatome ANP data; not in HEIS.

HEIS = Hanford Environmental Information System.
NA = Not applicable.
ND = Not detected.

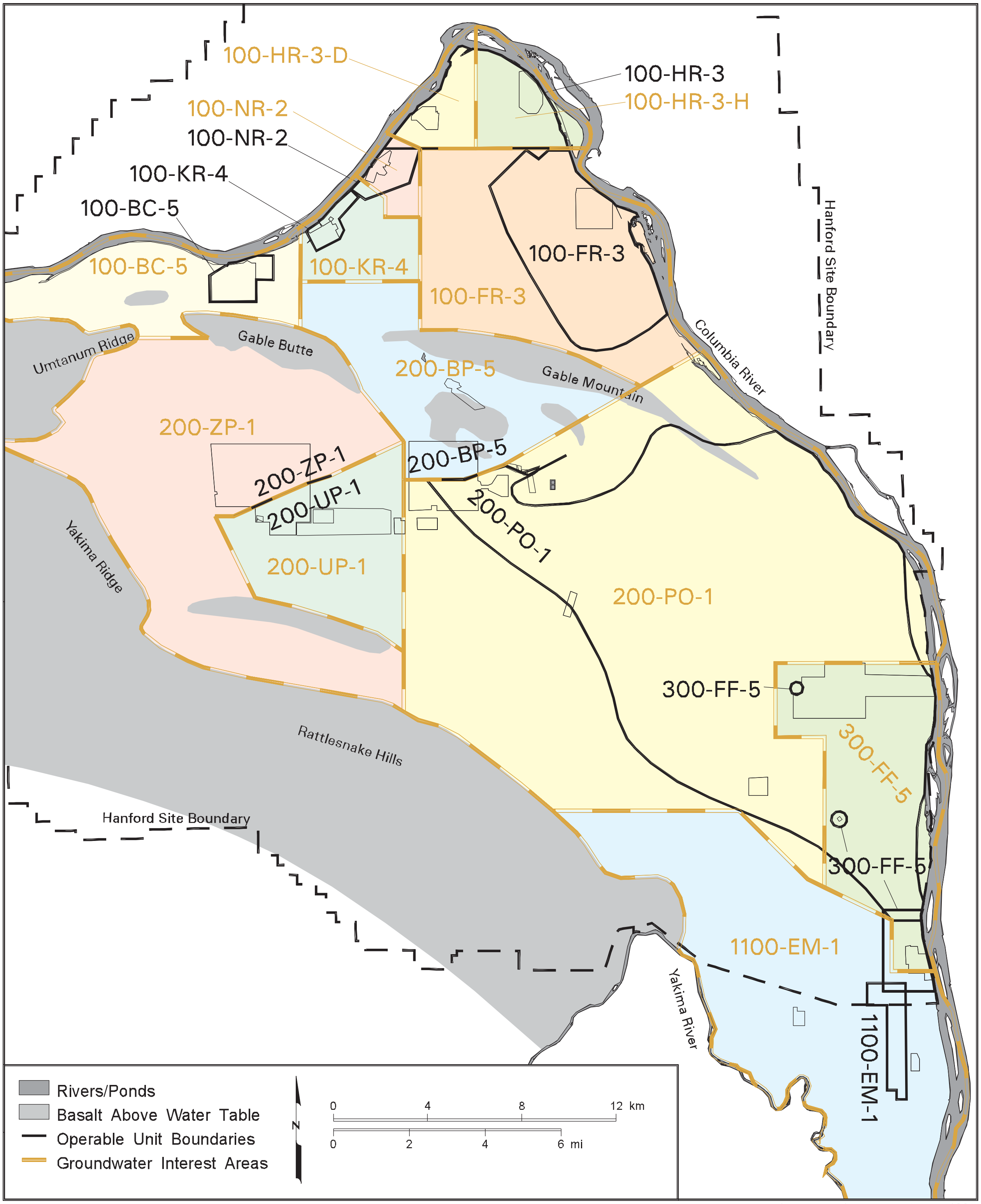

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Figure 2.1-1. Groundwater Operable Units and Groundwater Interest Areas on the Hanford Site

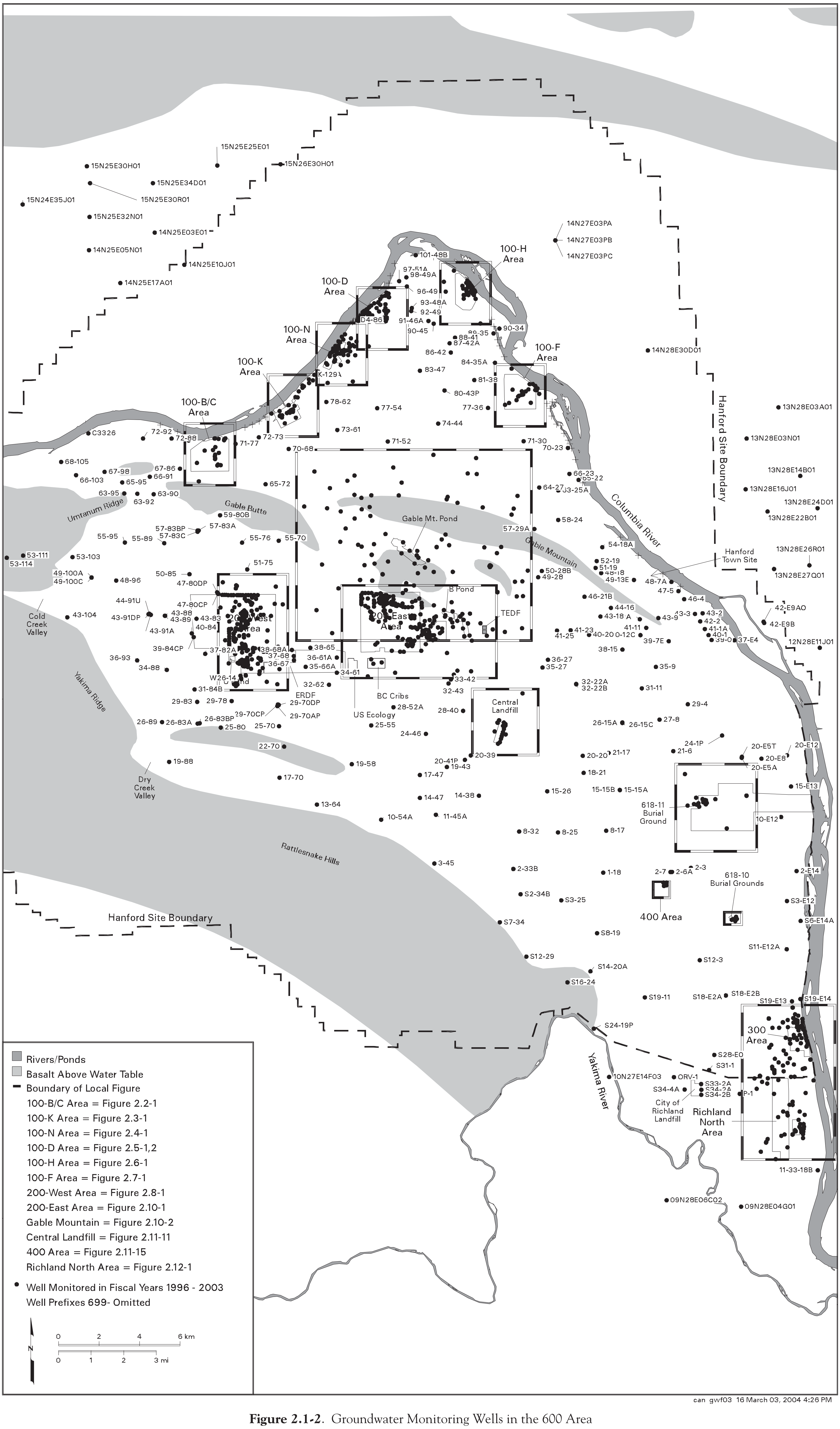

Figure 2.1-2. Groundwater Monitoring Wells in the 600 Area

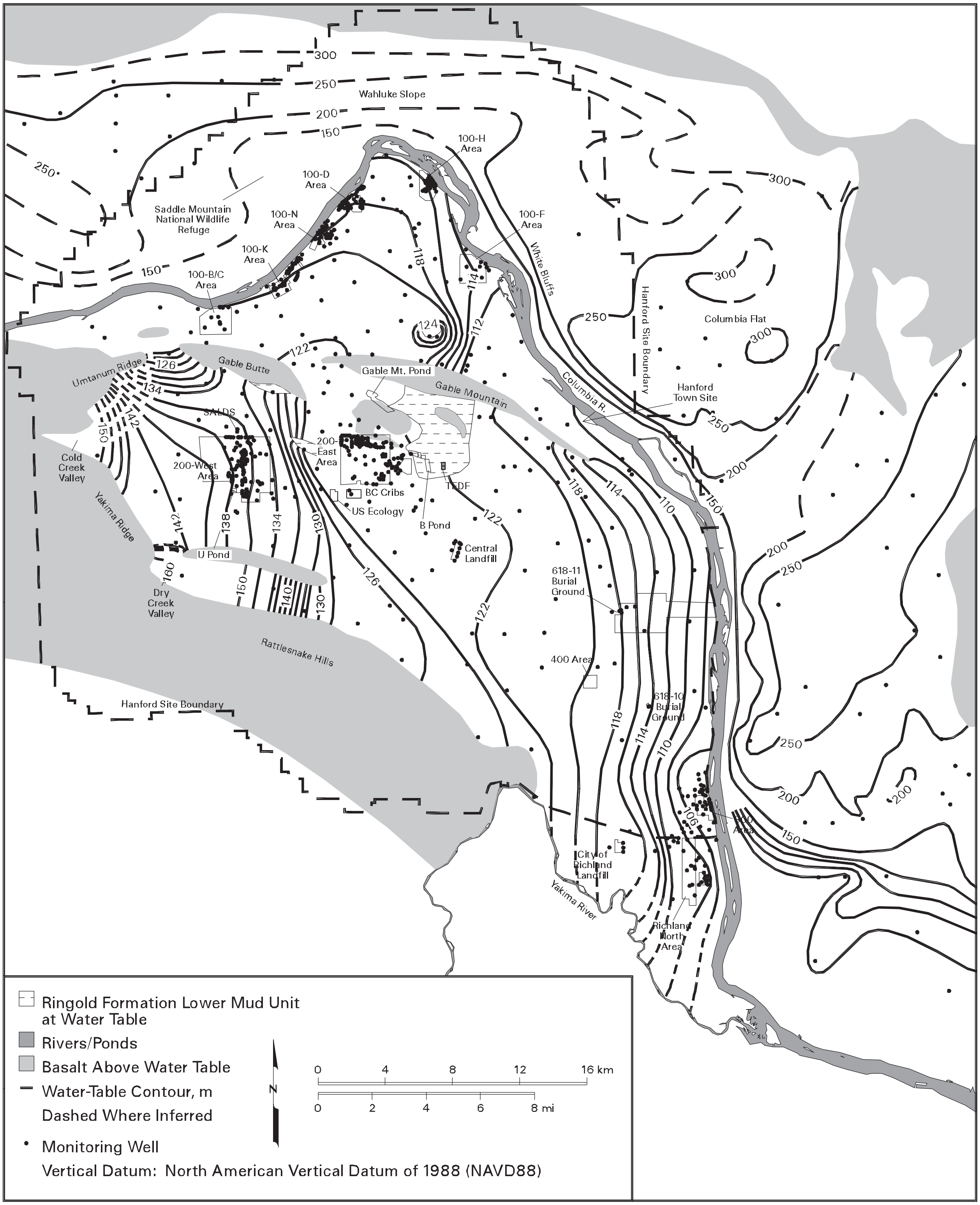

Figure 2.1-3. Hanford Site and Outlying Areas Water-Table Map, March 2003

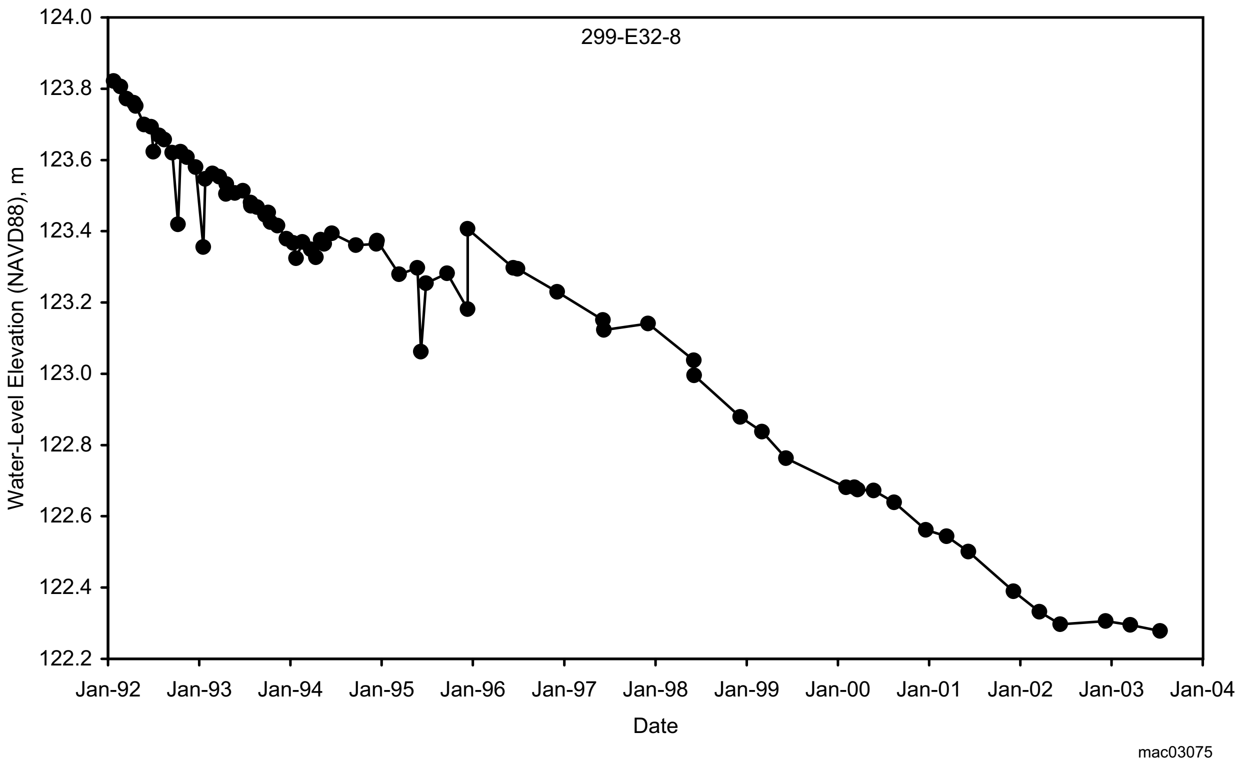

Figure 2.1-4. Water Level in Well 299-E32-8, Northwest 200 East Area

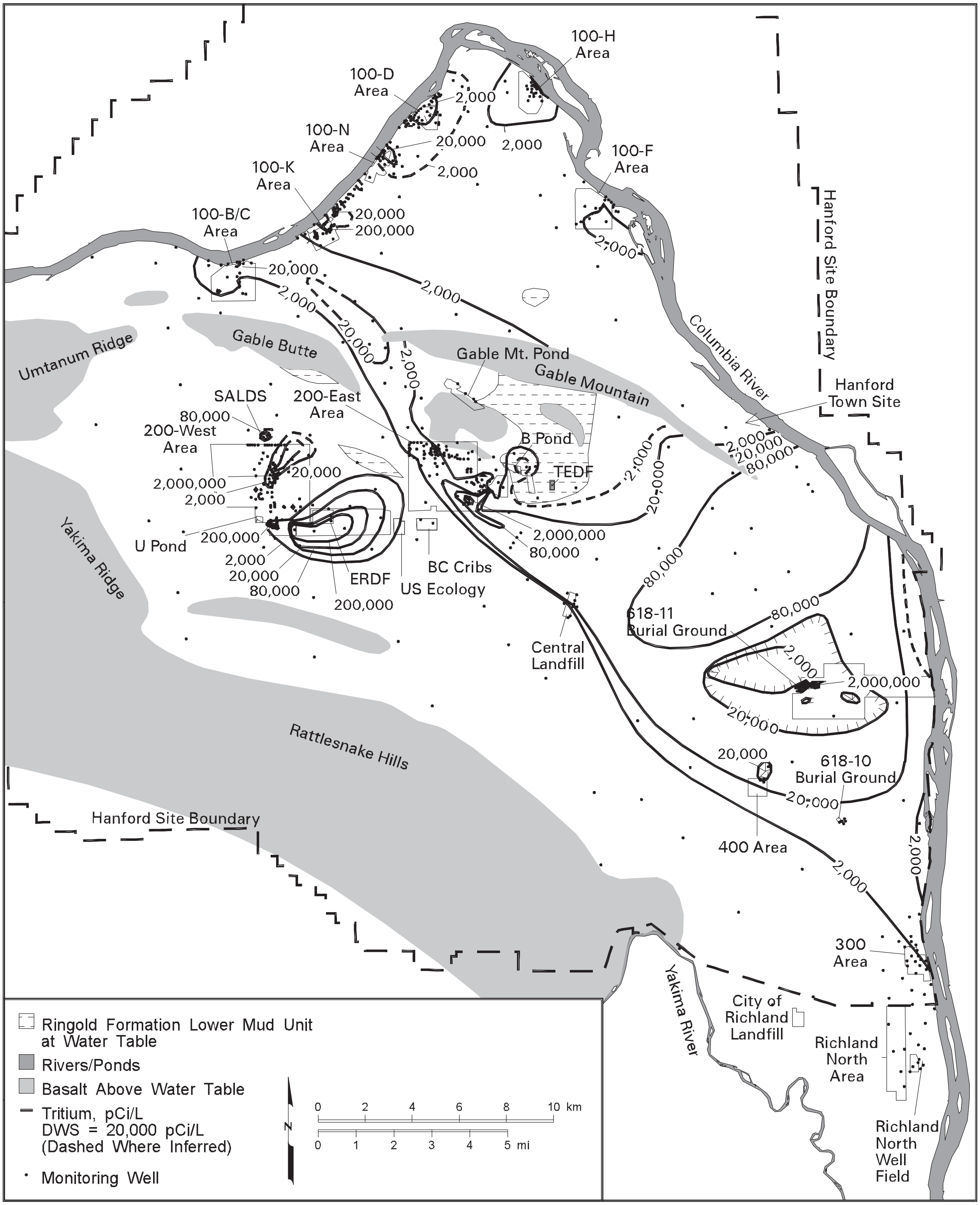

Figure 2.1-5. Average Fiscal Year 2003 Tritium Concentrations on the Hanford Site, Top of Unconfined Aquifer

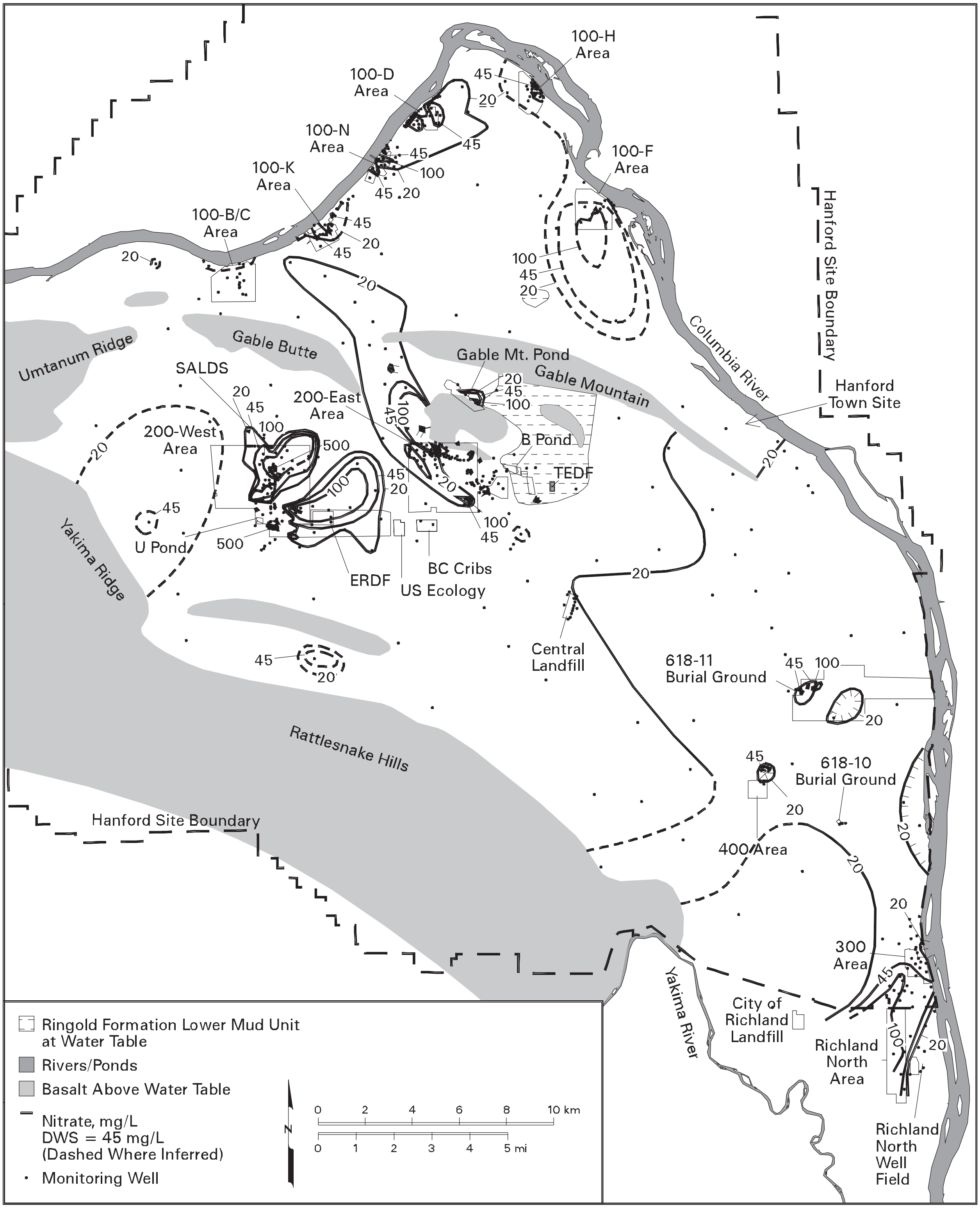

Figure 2.1-6. Average Fiscal Year 2003 Nitrate Concentrations on the Hanford Site, Top of Unconfined Aquifer

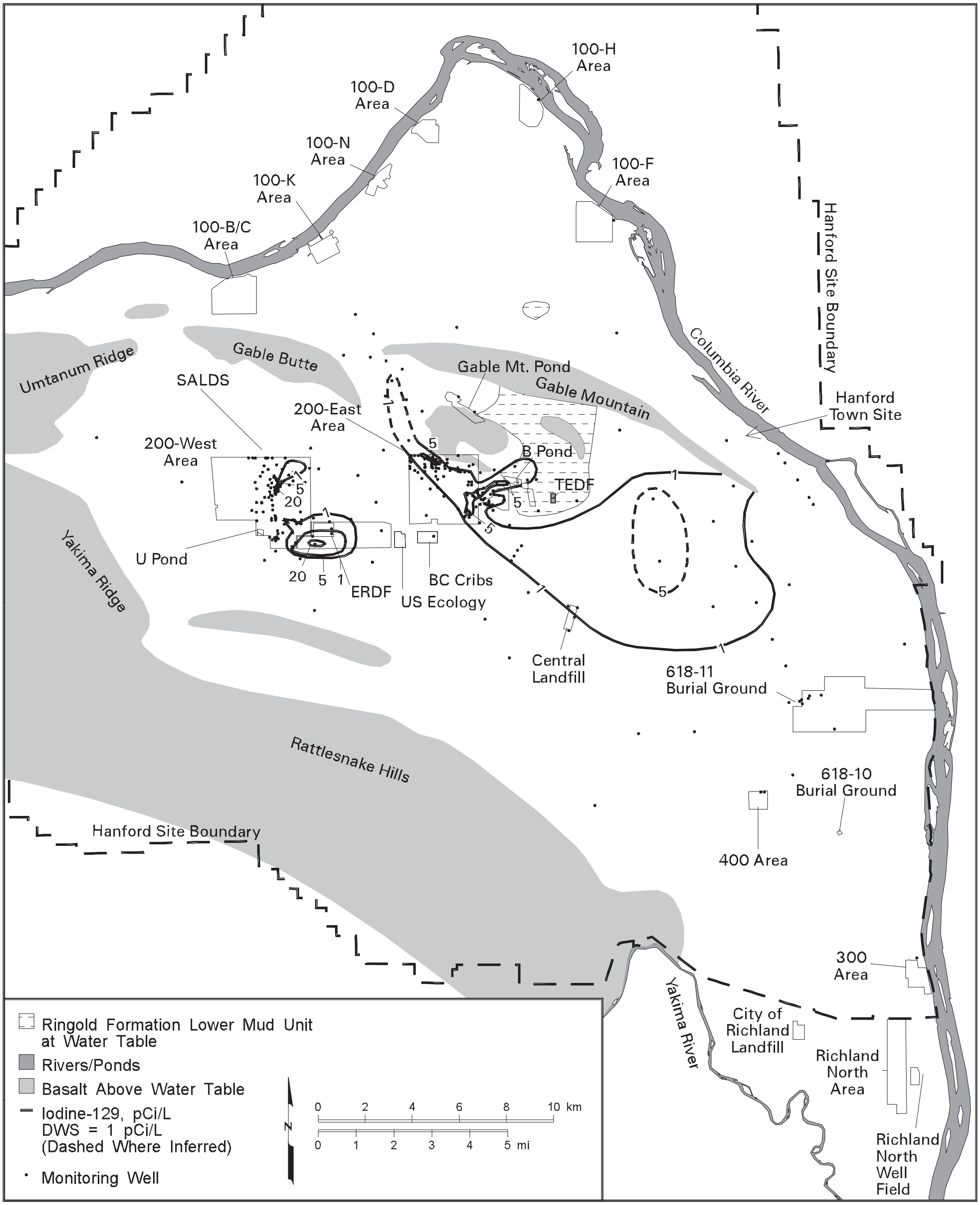

Figure 2.1-7. Average Fiscal Year 2003 Iodine-129 Concentrations on the Hanford Site, Top of Unconfined Aquifer

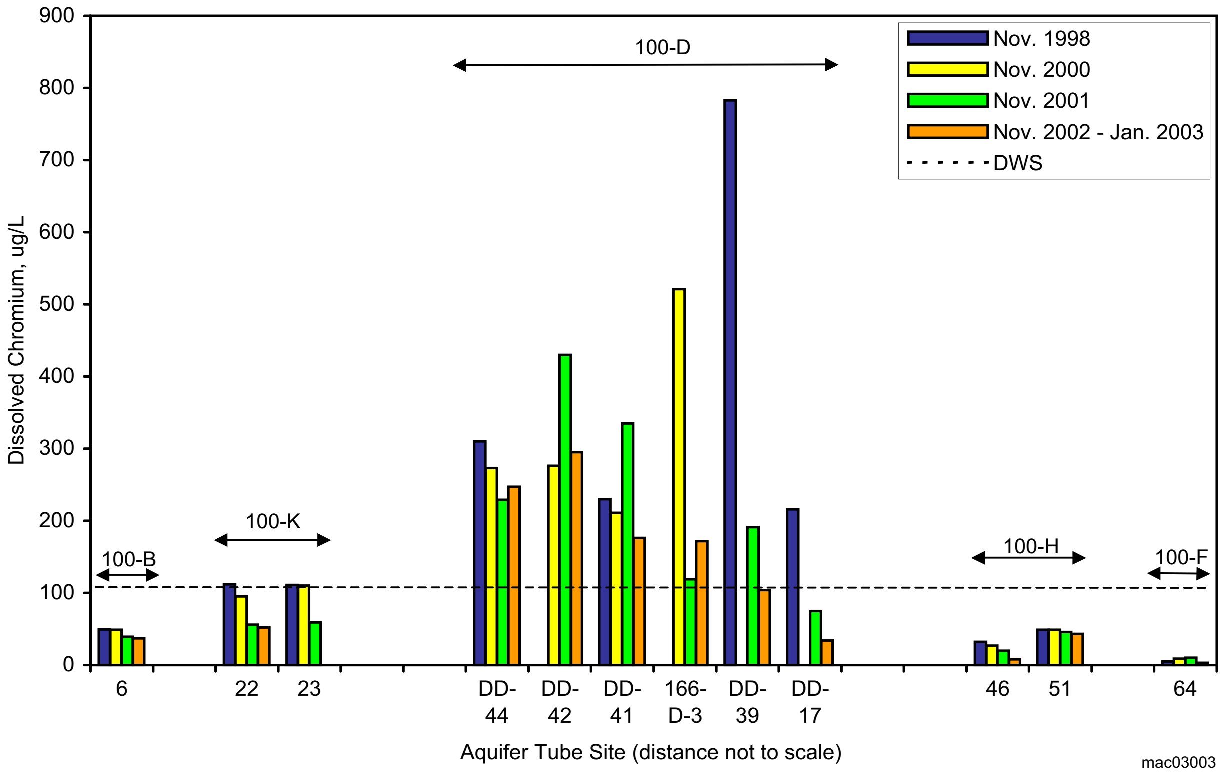

Figure 2.1-8. Dissolved Chromium at Selected Aquifer Tube Sites for Selected Years, 100 Areas (PNNL-14444)