2.1 Over view of Hanford Site Groundwater

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This section provides a broad picture of groundwater flow and contaminant distribution on the Hanford Site. Details for specific locations are included in Sections 2.2 through 2.14.

The uppermost aquifer beneath most of the Hanford Site in unconfined and is composed of unconsolidated to semiconsolidated sediment of the Hanford and Ringold formations, which were 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.

2.1.1 Groundwater Flow

The Hanford Groundwater Monitoring Project measures water-level elevations in aquifers beneath the Hanford Site annually. Water-level elevations indicate the potential for groundwater movement, because groundwater flows from areas of high potential (high water-level elevations) to areas of low potential (low water-level elevations). Contour maps indicate the general direction of groundwater movement, because water generally flows perpendicular to the contour lines from high to low potential. Water-level gradients are used to estimate the rate of groundwater flow.

Beginning in fiscal year 1999 water levels are measured during March because the March water table is expected to represent the annual average water table.

Water-level maps are used to interpret contaminant plume patterns and to support the calibration of groundwater flow models. The Hanford/Ringold aquifer system is the primary focus because it is the most likely groundwater pathway for migration of contaminants off the Hanford Site. However, measurements also are taken annually in the upper basalt-confined aquifer system (Section 2.14) and in the deep basalt aquifers to support modeling activities and to provide a data archive in the event that contamination is discovered in these systems. The *Water-Level Monitoring Plan for the Hanford Groundwater Monitoring Project* (PNNL-13021) contains a detailed description of the water-level monitoring activities.

In past years, the groundwater project collected annual water-level measurements during June. However, beginning in fiscal year 1999, the annual measurements were taken during March, because the March water table is expected to be more representative of the annual average water table (PNNL-13021).

The following sections describe groundwater flow in the unconfined aquifer and changes in the water table during the past year. Flow in a confined aquifer in the Ringold Formation is described in Section 2.9.3. Groundwater flow in the basalt-confined aquifer is discussed in Section 2.14.

2.1.1.1 Current Water Table

Groundwater in the unconfined aquifer flows from areas where the water table is higher (west of the Hanford Site) to areas where it is lower, near the Columbia River (Figure 2.1-1 and Plate 2). Steep gradients in the western region of the Hanford Site are caused by

- groundwater recharge
- lower hydraulic conductivity than in the eastern region of the site
- a decrease in the aquifer thickness from west to east.

Possible sources of recharge include infiltration of rain and snowmelt at higher elevations, primarily in the Cold Creek and Dry Creek Valleys, as well as irrigation of offsite agricultural land in the Cold Creek Valley. Steep gradients north and east of the Columbia River (see Figure 2.1-1) are attributed to recharge associated with irrigation of agricultural land. Regionally, water-table elevations decrease while approaching the Columbia River from either side, indicating that groundwater flow converges and ultimately discharges to the river.

Wastewater discharged to the ground on the Hanford Site resulted in groundwater mounding and significantly affected the flow system. Past discharges at U Pond and lesser discharges to other 200 West Area facilities still are apparent from the shape of the water-table contours passing through the 200 West Area. The steep gradient just east of the 200 West Area results partially from this mounding and partially from the relatively low transmissivity. The hydraulic gradient decreases abruptly between the 200 West and 200 East areas, corresponding to an increase in transmissivity. The steep gradient between Umtanum Ridge and Gable Butte results partially from recharge coming from Cold Creek Valley, mounding in the 200 West Area, and restriction of the Hanford/Ringold aquifer system by the underlying basalt to a thin, narrow zone in the gap.

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

The water table in the central portion of the Hanford Site, south of Gable Mountain, 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. There is a groundwater mound associated with B Pond, where process cooling water and other liquid waste were discharged to the ground up until fiscal year 1997, but currently it occurs mainly within the Ringold Formation mud units and is considered to be part of the Ringold Formation confined aquifer (Section 2.9.3). The mud units of the Ringold Formation at the water table east and northeast of the 200 East Area are represented differently in the June 1998 (PNNL-12086) and March 1999 water-table maps. This is due to evolving interpretation of the hydrogeology of this region.

North of Gable Butte and Gable Mountain, groundwater also generally flows from west to east and discharges to the Columbia River. Recharge to the aquifer in this region comes primarily from the Columbia River west of the 100 B/C Area. Recharge also comes from groundwater flowing north through the gaps between Umtanum Ridge and Gable Butte and between Gable Butte and Gable Mountain.

A local groundwater mound exists ~2 kilometers north of Gable Mountain (between Gable Mountain and the 100 F Area). Long before the Hanford Site was established, Jenkins (1922) reported elevated groundwater levels in this area, which have persisted to the present. Data suggest that this mound is associated with a subsurface topographic "high" of Ringold Formation sediment having a low hydraulic conductivity (primarily clay). One possible source of recharge is past seasonal use of the Hanford irrigation canal, which traverses the groundwater mound area and was active between 1908 and 1943. Other potential sources of recharge include upwelling from the upper basalt-confined aquifer system and infiltration from surface runoff. The slow dissipation of the recharge water is attributed to the presence of a significant thickness of clay in the Ringold Formation sediment. There is insufficient information to distinguish whether the groundwater in this area is locally perched or is part of the regional, unconfined flow system.

The elevation of the water table in the region between the Yakima and Columbia Rivers is lower than

the Yakima River stage elevation, which is ~122 meters above mean sea level at Wanawish (formerly Horn Rapids) Dam. This implies that infiltration from the Yakima River recharges the Hanford/Ringold aquifer system in this area. During the summer, leakage from the Horn Rapids Ditch and Columbia Canal, which originate from the Yakima River at Wanawish Dam, and irrigation in areas east of the Yakima River also may recharge the Hanford/Ringold aquifer system. Operation of the city of Richland's North Well Field recharge ponds results in a groundwater mound in the Richland North Area.

2.1.1.2 Water-Table Changes from June 1998 to March 1999

A contour map of the change in the water table from June 1998 to March 1999 is shown in Figure 2.1-2. The water table declined over much of the Hanford Site during this period. This is due to the decline in wastewater discharges to the ground that have occurred since the peak discharge in 1984. Over the 9-month period, the water table declined by an average of 0.19 meter (equivalent to 0.25 meter per year) in the 200 East Area and 0.34 meters (0.45 meter per year) in the 200 West Area (outside of the 200-ZP-1 and 200-UP-1 Operable Units groundwater pump-and-treat regions).

The water table declined beneath the central Hanford Site in fiscal year 1999, causing some wells to go dry.

The decline in the water table along the Columbia River from west of the 100 B/C Area to the Old Hanford Townsite is due to seasonal differences in river discharge caused by changing the month in which the measurements are collected from June to March. The largest water-level decline (1.87 meters) on the Hanford Site occurred in well 699-68-105 (west of the 100 B/C Area).

The water-table elevation increased in a broad region adjacent to the Rattlesnake Hills and Yakima River. This may be caused by higher than normal precipitation in fiscal years 1993 through 1997, along with higher than normal Yakima River discharge in fiscal years 1995 through 1998.

The water-table elevation increased along the Columbia River in the 300 Area. The 300 Area water-level measurements are collected at the end of the month in which the annual measurements are taken. The increase in the water table in the 300 Area is attributed to a higher river stage in late March 1999 as compared to late June 1998. The largest water table increase on the Hanford Site (0.38 meter) occurred in well 399-4-10, which is located adjacent to the Columbia River in the 300 Area.

Changes in the water table also occurred beneath active facilities (e.g., the State-Approved Land Disposal Site, near the 200 West Area, and the Richland North Well Field) and within groundwater pump-and-treat areas. These changes are attributed to operation of these facilities. The largest water-table increase in the unconfined aquifer (0.58 meter) occurred in well 1199-41-15 at the Richland North Well Field.

2.1.2 Groundwater Contaminants

During fiscal year 1999, Hanford Site staff sampled 623 wells for radiological and chemical constituents. Of the wells sampled, 253 were sampled once, 178 were sampled twice, 20 were sampled three times, 117 were sampled four times, and 55 were sampled more frequently. Well locations for the Hanford Site are shown on Plate 1. A number of wells are sampled to meet *Resource Conservation and Recovery Act of 1976* (RCRA) or *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) requirements. More detailed maps of well locations are included in Appendix A for RCRA units and other sites regulated under the Washington Administrative Code.

Tritium, nitrate, and iodine-129 are the most widespread contaminants associated with past Hanford Site operations. Their distribution in the unconfined aquifer are shown in Figures 2.1-3, 2.1-4, and 2.1-5. The distribution of tritium also is shown in Plate 3. The

most prominent portions of these plumes derive from waste sites in the 200 Areas and spread toward the southeast. Nitrate and tritium also have significant sources in the 100 Areas.

Chromium contamination is widespread in several of the 100 Areas and extends into the surrounding 600 Area. Strontium-90 contamination is present in the 100 Areas, but the plumes are smaller. Other extensive contaminant plumes include carbon tetrachloride and associated chloroform and trichloroethylene in the 200 West Area, chromium in the 600 Area south of the 200 Areas, technetium-99 and uranium that extend eastward from the 200 West Area, and technetium-99 with minor amounts of cyanide and cobalt-60 northwest of the 200 East Area. Several other constituents are detected outside the boundaries of the operational areas but the contamination is clearly linked to operations in the specific areas and is discussed with the source areas. A few smaller sources within the 600 Area are discussed in Section 2.11. Table 2.1-1 lists contaminants and refers to the sections in this report where they are discussed. The table highlights contaminants that exceed water quality standards. All analytical results for fiscal year 1999 are included on the data diskette included with this report.

The major sources of groundwater contamination on the Hanford Site are inactive liquid waste facilities in the 100, 200, and 300 areas.

Available data indicate that the vast majority of contamination on the Hanford Site remains near the water table, but information on the depth of the contaminant plumes is lacking for much of the site. Contamination in deeper aquifers of the Hanford/Ringold sediment is discussed for the 200 East Area in Section 2.9.3. Contamination in the upper basalt-confined aquifer is discussed in Section 2.14.

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. Groundwater operable unit boundaries are illustrated in Figure 2.1-6.

A number of Hanford waste sites have specific RCRA monitoring requirements (Appendix A, Figure A.1). The results of monitoring at these facilities are integrated into the following discussions, and specific RCRA reporting requirements, such as indicator parameter evaluations, are included as needed. Appendix A discusses issues related to regulatory compliance and describes results of statistical evaluations for RCRA monitoring requirements. Appendix A also summarizes analytical results for wells monitoring RCRA- and state-permitted facilities that exceeded maximum contaminant levels or interim drinking water standards.

Table 2.1-1. Maximum Concentrations of Groundwater Contaminants in Fiscal Year 1999 (data on diskette included with this report)

Contaminant (alphabetical order)	DWS or MCL [DCG][a]	Units	100 B/C Section 2.2		100 K Section 2.3		100 N Section 2.4		100 D Section 2.5		100 H Section 2.6	
			Wells	Shore[b]	Wells	Shore[b]	Wells	Shore[b]	Wells	Shore[b]	Wells	Shore[b]
Carbon tetrachloride	5	µg/L										
Carbon-14	2,000 [70,000]	pCi/L			15,600	680						
Cesium-137	200 [3,000]	pCi/L										
Chloroform	100	µg/L										
Chromium (filtered)	100	µg/L	108	50	606	112	176		2,155	783	259	73
Cobalt-60	100 [5,000]	pCi/L										
Cyanide	200	µg/L										
cis-1,2 Dichloroethylene	70	µg/L										
Fluoride	4,000	µg/L									309	
Gross alpha	15	pCi/L									42	
Gross beta	50	pCi/L	141	52	23,800	55		2.3	255	23	260	97
Iodine-129	1 [500]	pCi/L										
Manganese (filtered)	50	µg/L					5,780					
Nitrate (as NO_3^-)	45	mg/L	50	43	175	29	150	21	91	49	216	50
Nitrite (as NO_2)	3,300	µg/L							4,640			
Plutonium	NA [30]	pCi/L			[c]							
Strontium-90	8 [1,000]	pCi/L	135	5.7	5,660	0.03	19,500	13,100	32		45	
Sulfate	250	mg/L					390		735			
Technetium-99	900 [100,000]	pCi/L									561	56
Tetrachloroethylene	5	µg/L										
Trichloroethylene	5	µg/L			23							
Tritium	20,000 [2,000,000]	pCi/L	86,900	66,000	2,360,000	11,900	51,600	24,400	35,500	4,100	6,630	3,800
Uranium	20 [790]	µg/L									57	

Table 2.1-1. (contd)

Contaminant (alphabetical order)	DWS or MCL [DCG][a]	Units	100 F Section 2.7 Wells	100 F Section 2.7 Shore[b]	200 West Section 2.8 Wells	200 East Section 2.9 Wells	200 East Section 2.9 Shore[b]	400 Section 2.10 Wells	600 Section 2.11 Wells	300 Section 2.12 Wells	300 Section 2.12 Shore[b]	Richland North Section 2.14 Wells
Carbon tetrachloride	5	µg/L			7,000				0.5			
Carbon-14	2,000 [70,000]	pCi/L										
Cesium-137	200 [3,000]	pCi/L			undetected	1,840						
Chloroform	100	µg/L			140				1			
Chromium (filtered)	100	µg/L	96	29	433	2,820			NS[d]			
Cobalt-60	100 [5,000]	pCi/L				62						
Cyanide	200	µg/L				291						
cis-1,2 Dichloroethylene	70	µg/L								180		
Fluoride	4,000	µg/L			4,960							5,000
Gross alpha	15	pCi/L			1,380	37	3.22		8	67	55.6	77
Gross beta	50	pCi/L	553	7.4	5,490	20,800	23.3		17		21	50
Iodine-129	1 [500]	pCi/L			47	12.5	0.22					
Manganese (filtered)	50	µg/L			1,380	152			9.2			
Nitrate (as NO_3^-)	45	mg/L	198	49	823	514	36	92	402	112		168
Nitrite (as NO_2)	3,300	µg/L			1,862			154	4,340			
Plutonium	NA [30]	pCi/L			undetected	65.8						
Strontium-90	8 [1,000]	pCi/L	329		1	10,800			948	4		
Sulfate	250	mg/L							56			
Technetium-99	900 [100,000]	pCi/L			8,540	6,850	105					
Tetrachloroethylene	5	µg/L								7		
Trichloroethylene	5	µg/L	18		33				0.8	6		6
Tritium	20,000 [2,000,000]	pCi/L	32,700	1,100	1,970,000	3,870,000	120,000	68,400	1,860,000	13,000	9,590	516
Uranium	20 [790]	µg/L	20		2,800	69			99	322	[e]	12

Note: Table lists highest concentration for fiscal year 1999 in each geographic region. Concentrations in blue exceed drinking water standards. Concentrations in red exceed derived concentration guides. Blank spaces indicate the constituent is not of concern in the given area.

(a) DWS = drinking water standard; MCL = maximum contaminant level; DCG = derived concentration guide. See PNNL-13080 for more information on these standards.
(b) Shoreline sampling includes aquifer sampling tubes, seeps, and shoreline wells from fall 1998. 200 East Area plumes monitored at Old Hanford Townsite.
(c) A special study using ultra-low detection limits detected plutonium at levels far below standard detection limits.
(d) Has had MCL exceedances in the past; well not sampled in fiscal year 1999.
(e) Uranium-234 at 26.2 pCi/L. Uranium-238 at 26.2 pCi/L.

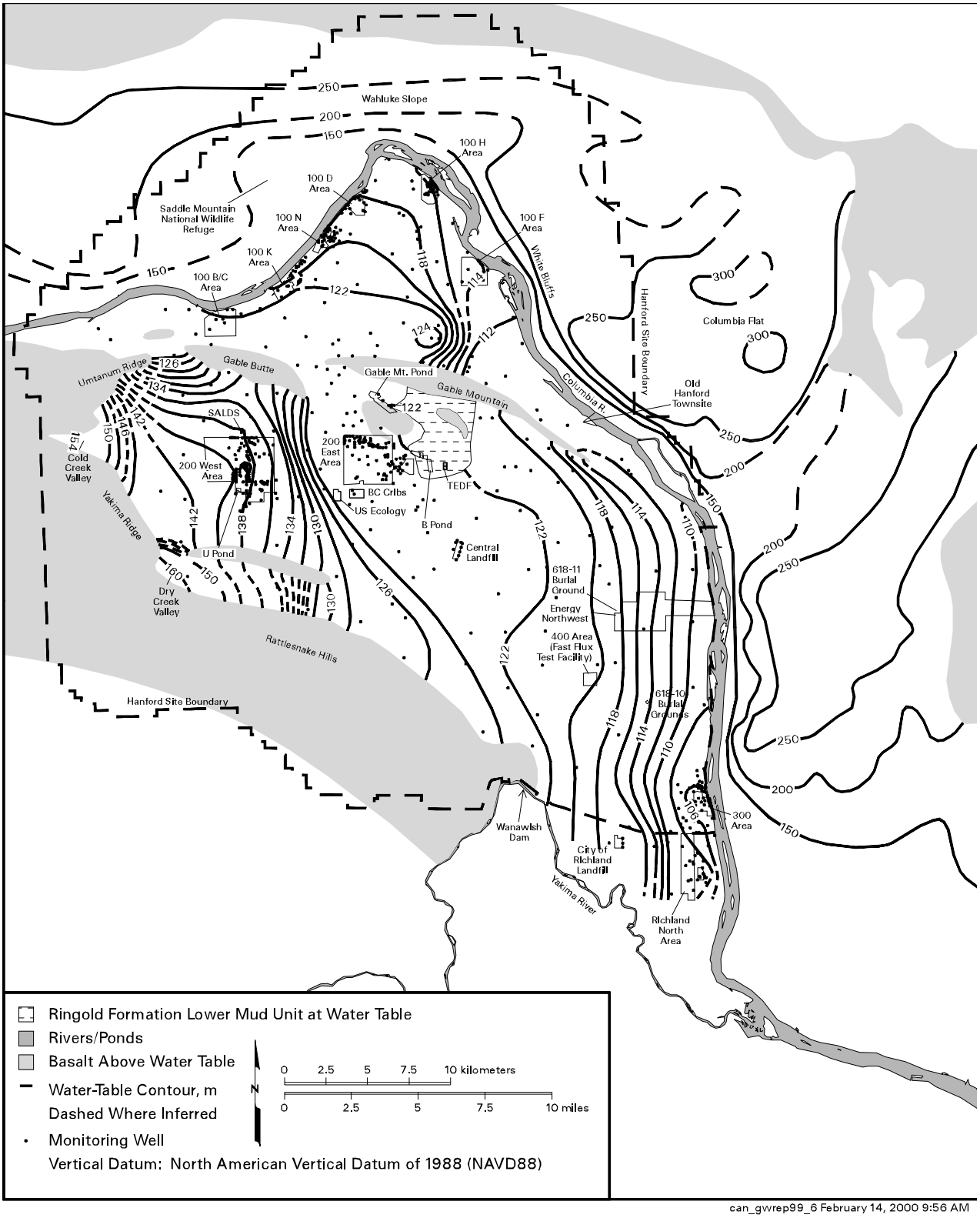

Figure 2.1-1. Hanford Site and Outlying Areas Water-Table Map, March 1999

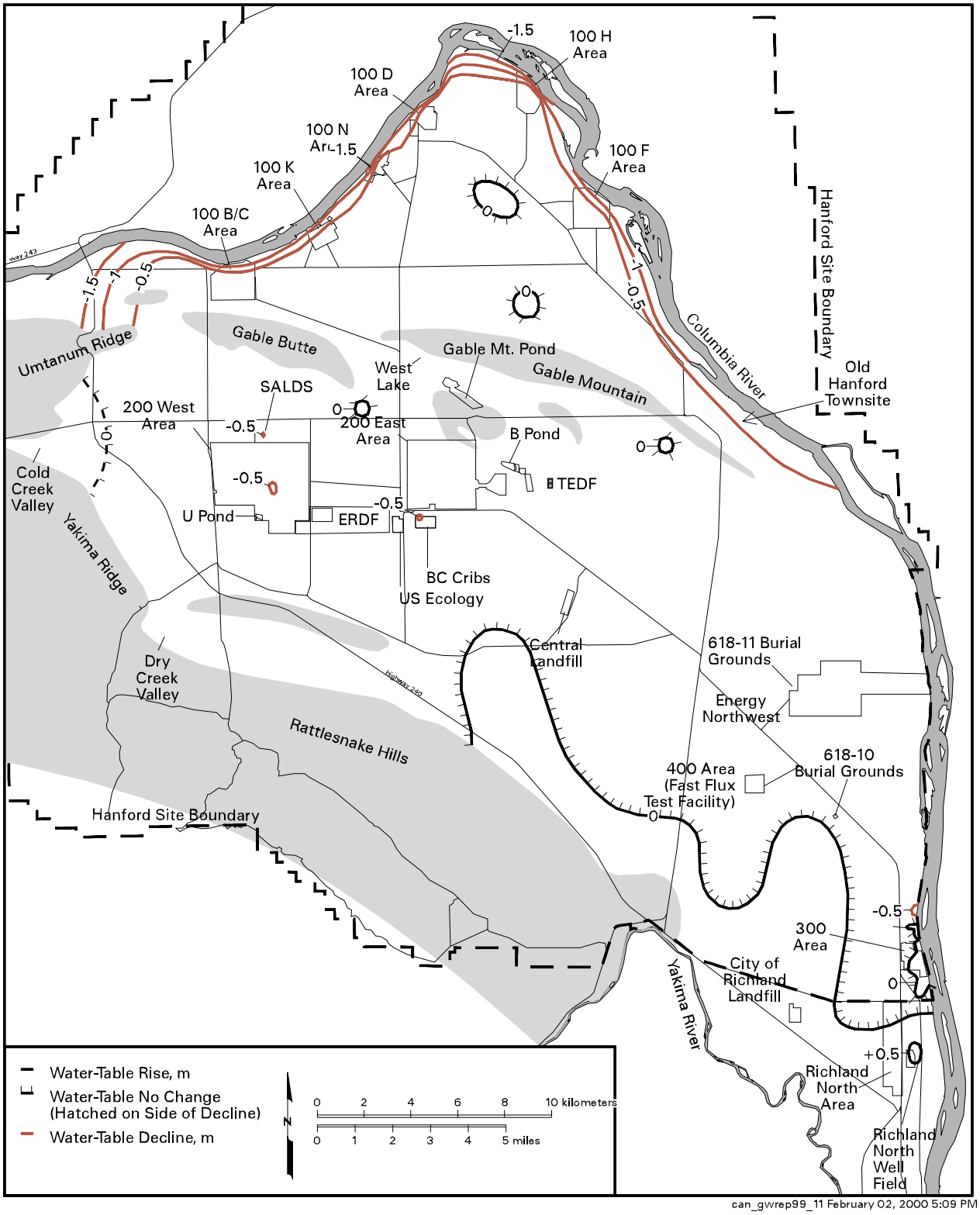

Figure 2.1-2. Changes in Water-Table Elevations Between June 1998 and March 1999

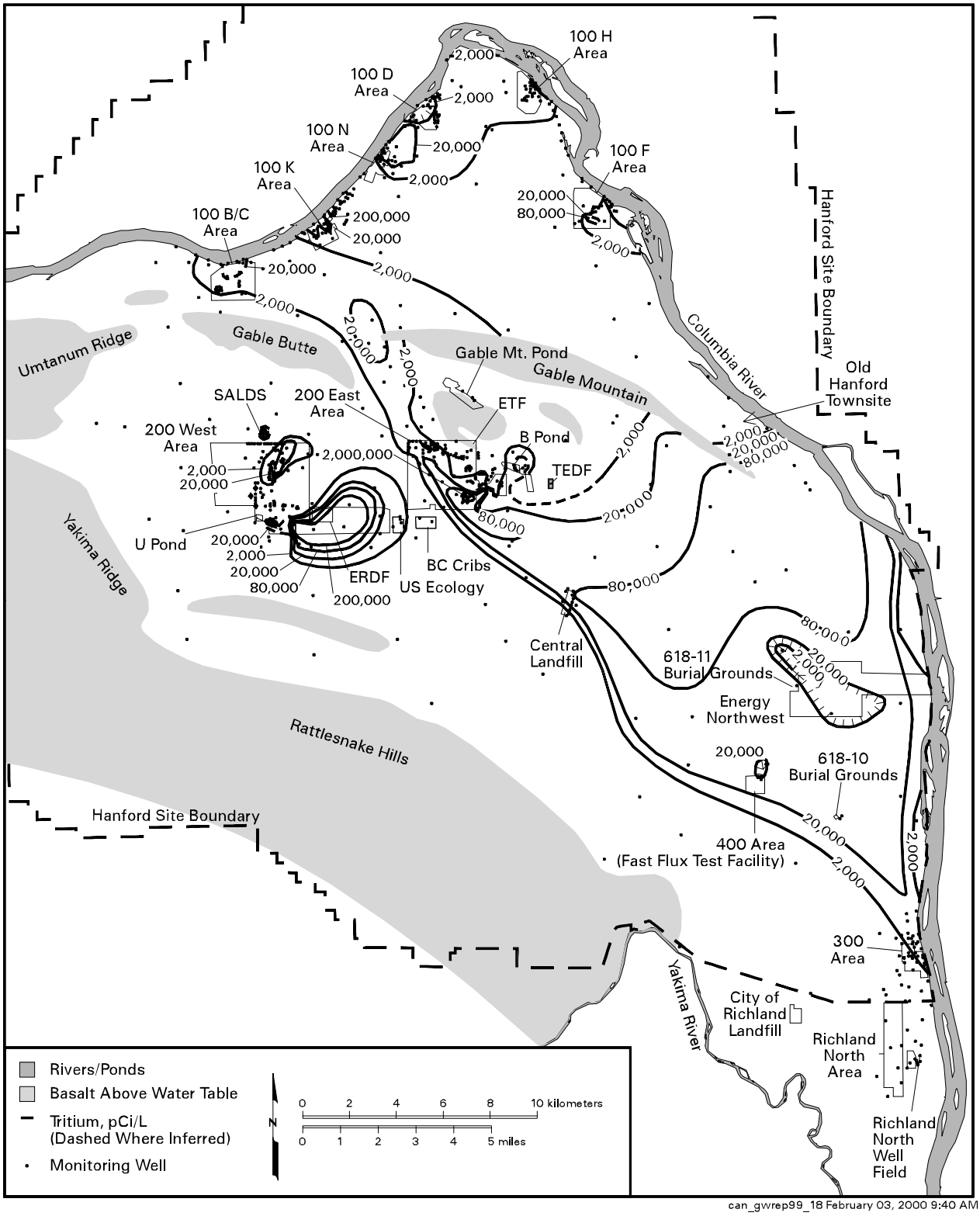

Figure 2.1-3. Average Tritium Concentrations on the Hanford Site, Top of Unconfined Aquifer

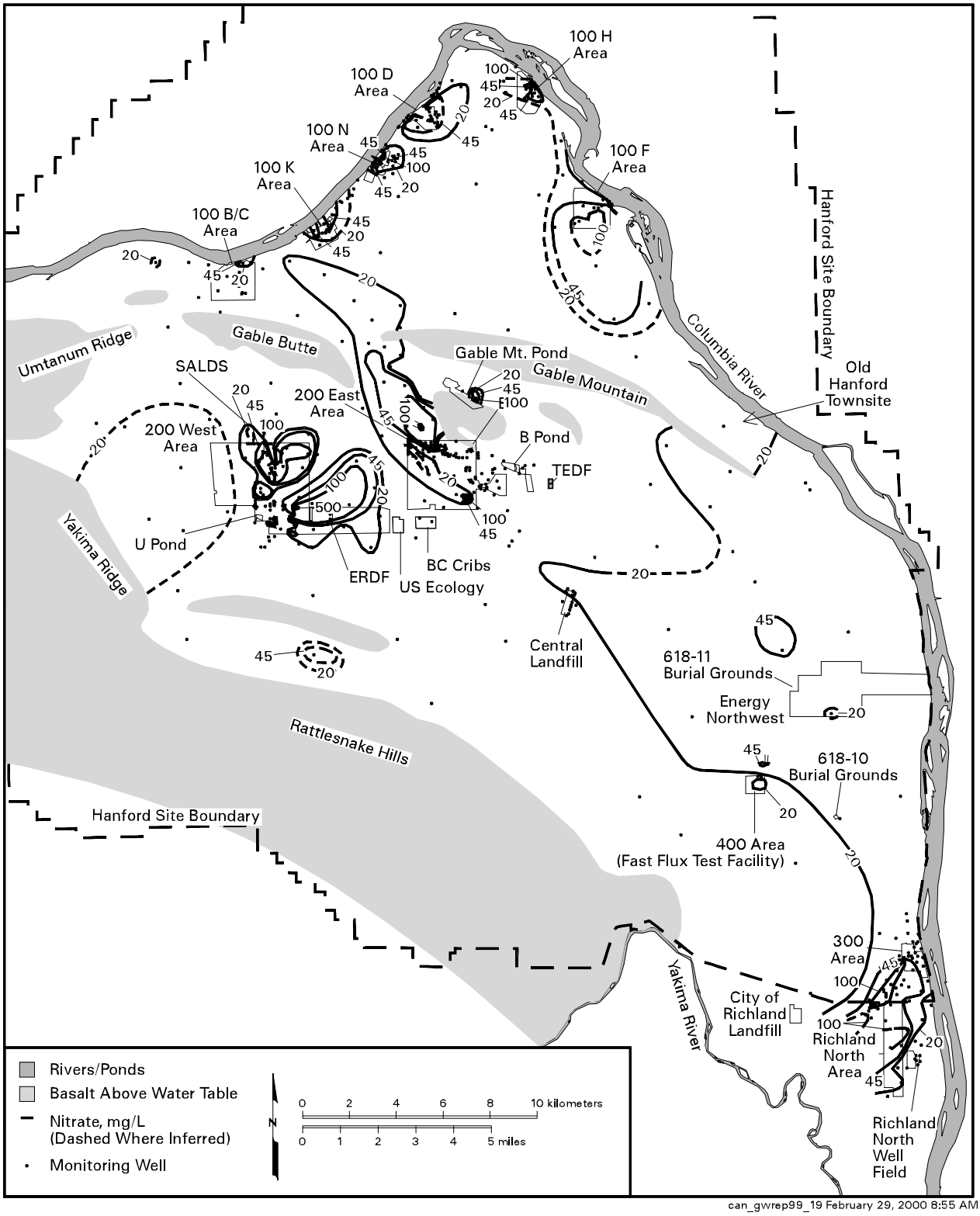

Figure 2.1-4. Average Nitrate Concentrations on the Hanford Site, Top of Unconfined Aquifer

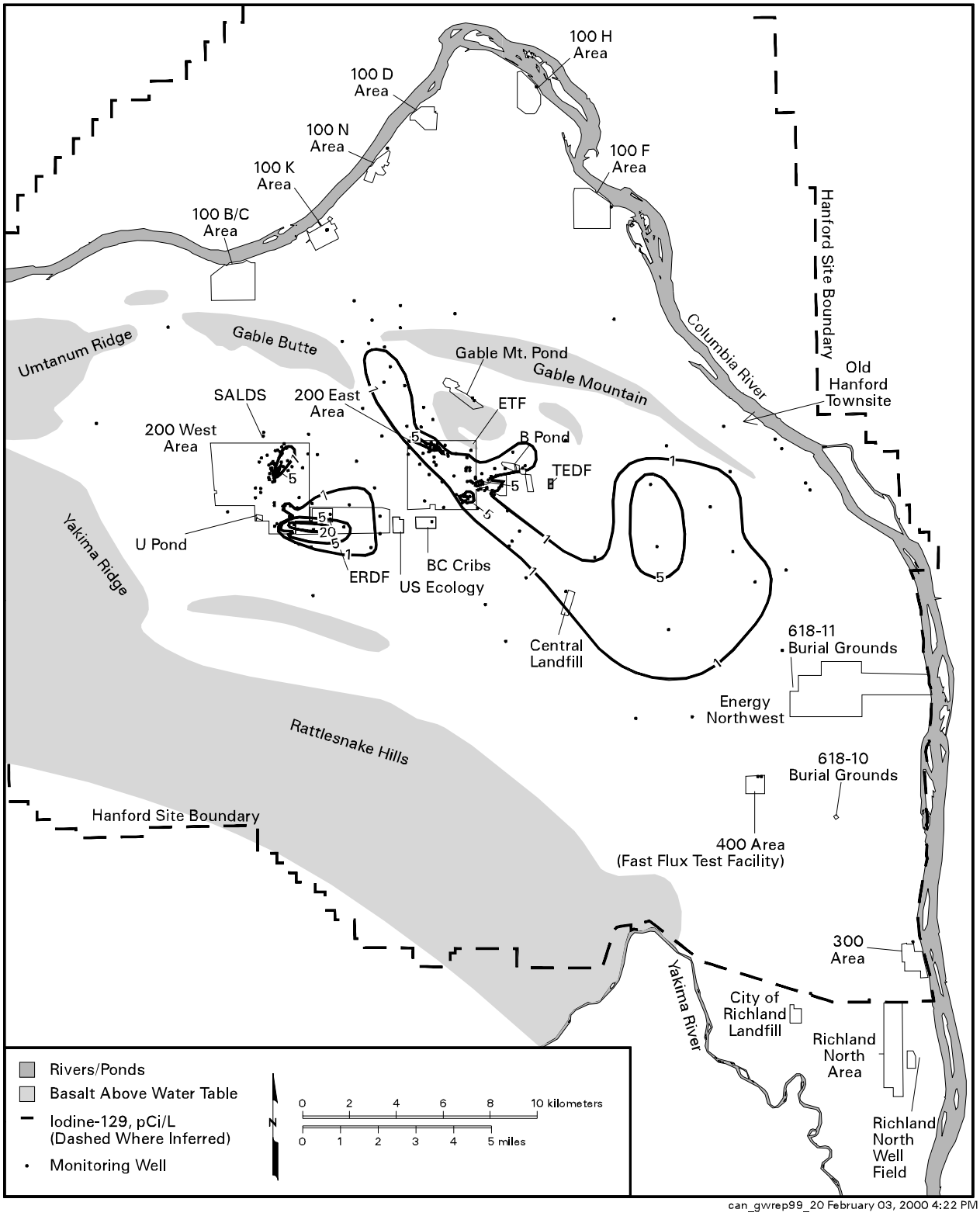

Figure 2.1-5. Average Iodine-129 Concentrations on the Hanford Site, Top of Unconfined Aquifer

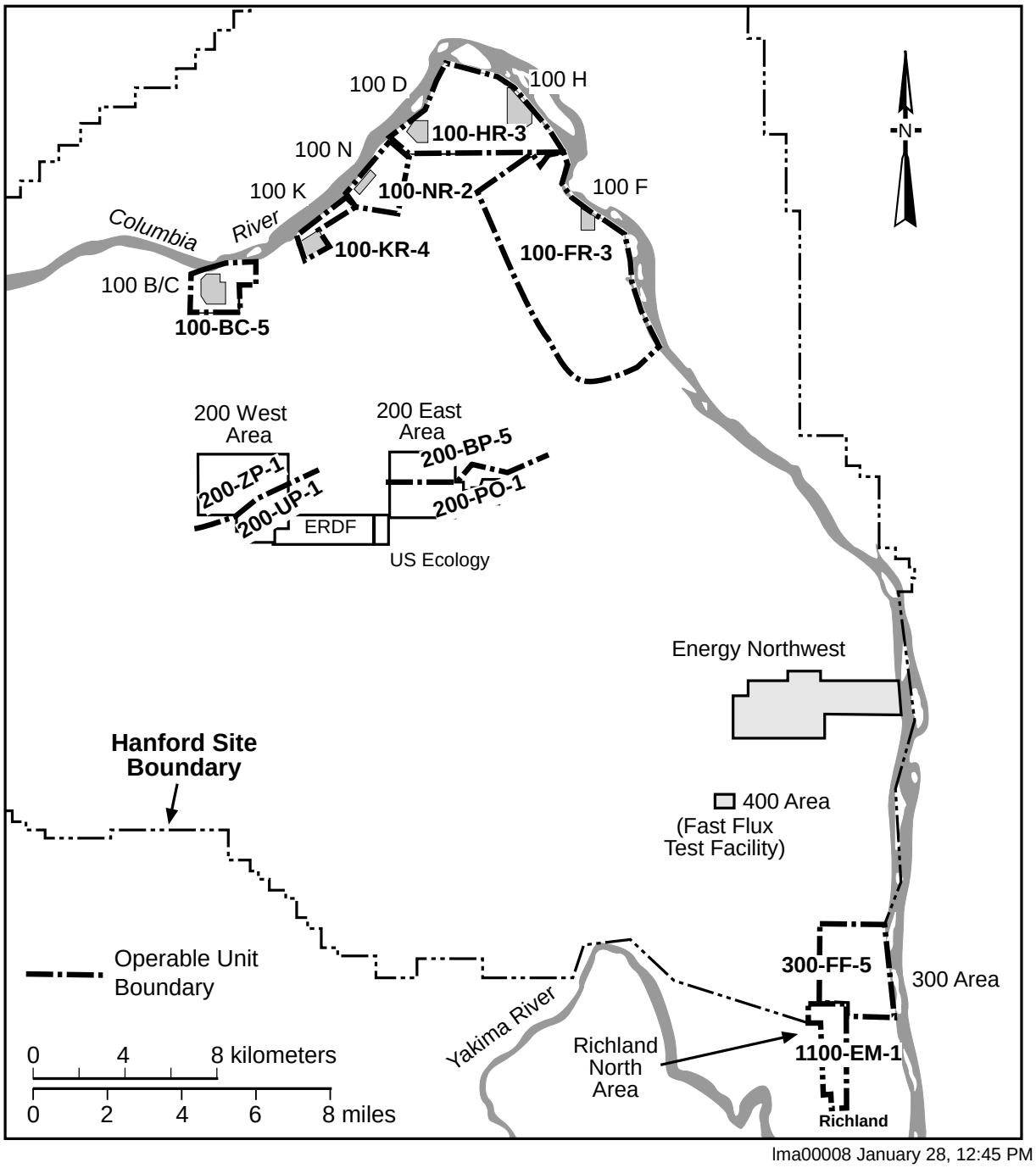

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Figure 2.1-6. Groundwater Operable Units on the Hanford Site