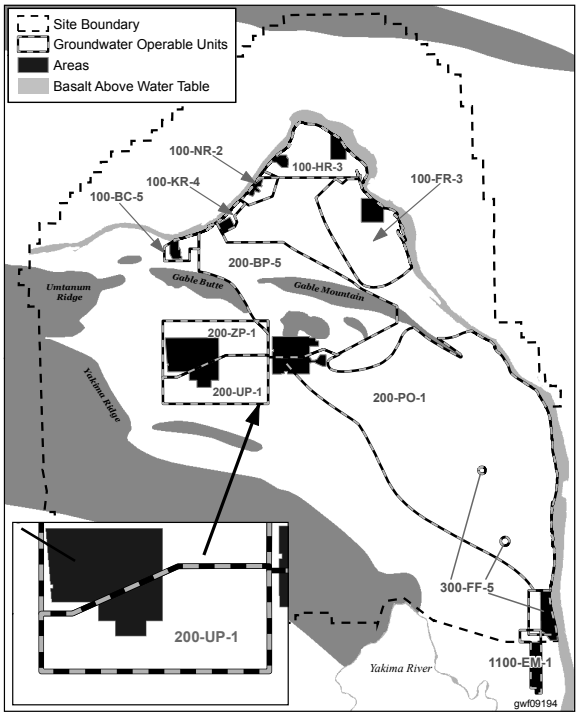
6.0 200-UP-1 Operable Unit

J. P. McDonald



The 200-UP-1 Operable Unit (OU) addresses groundwater contaminant plumes beneath the southern third of the 200 West Area and adjacent portions of the surrounding 600 Area. With the exception of the Environmental Restoration Disposal Facility (ERDF), most of the facilities and waste sites within the OU are associated with former operation of the Reduction-Oxidation (REDOX) Plant and U Plant. The OU lies within the larger 200-UP-1 groundwater interest area, informally defined to facilitate sample scheduling, data review, and interpretation. Figure 6-1 shows facilities and wells in a large portion of the 200-UP-1 interest area. Groundwater wells in the remainder of the interest area are shown in Figure 2-1 in Chapter 2.0. The interest area and OU boundaries are shown in Figure 1-2 in Chapter 1.0. No new groundwater wells were installed within the interest area during the reporting period.

Groundwater monitoring in the 200-UP-1 groundwater interest area is conducted under three regulatory drivers:

- The *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) governs the 200-UP-1 OU and the ERDF. The CERCLA requirements for the OU are further subdivided into monitoring conducted to (1) characterize and track contaminants of concern or potential concern in the OU; and (2) evaluate the performance of a pump-and-treat system that removes technetium-99, uranium, carbon tetrachloride, and nitrate from groundwater near U Plant.
- *Resource Conservation and Recovery Act of 1976* (RCRA) (and *Revised Code of Washington* [RCW] 70.105, "Hazardous Waste Management") interim status assessment monitoring for dangerous constituents is performed at single-shell tank Waste Management Areas (WMAs) U and S-SX. Evaluation monitoring for interim status indicator parameters under RCRA is performed at the 216-S-10 Pond and Ditch (S-10 unit).
- Monitoring of radionuclides at these three sites (i.e., WMA S-SX, WMA U, and the S-10 unit) is governed by the *Atomic Energy Act of 1954* (AEA).

Although previous annual groundwater monitoring reports covered fiscal year time periods, this report describes the groundwater monitoring results for the 15-month period from October 1, 2008, through December 31, 2009. As a result of this change, the following date conventions are used within this chapter:

- Fiscal year (FY) 2009: Refers to the fiscal year named (i.e., October 1, 2008, through September 30, 2009).
- Calendar year (CY) 2009: Refers to the calendar year named (i.e., January 1, 2009, through December 31, 2009).
- Reporting period: Refers to the entire 15-month reporting period covered in this report (i.e., October 1, 2008, through December 31, 2009).

The scope of this chapter is the entire 200-UP-1 groundwater interest area, but the term "operable unit" is used frequently as a spatial reference because most of

the waste disposal operations and groundwater plumes occur within the OU. Unless otherwise noted, the plume maps shown in this chapter are based on groundwater sampling results averaged over CY 2009.

6.1 Conceptual Model

Technetium-99, uranium, tritium, iodine-129, nitrate, and carbon tetrachloride are the contaminants of greatest significance in groundwater and form substantial plumes within the 200-UP-1 OU.

Large-scale waste disposal at the 200-UP-1 OU began during the early 1950s when plutonium-separation operations began at the REDOX Plant and uranium-recovery operations began at U Plant. In general, the high-level radioactive waste was stored in underground storage tanks, and other liquid waste streams were disposed to ponds and cribs. Groundwater plumes of nitrate, tritium, and iodine-129 formed when the pond and crib waste reached the aquifer. These plumes expanded as effluent disposal operations continued. Effluent disposal to the ponds and cribs ceased during the 1990s. The groundwater plumes from these sources are currently dispersing naturally; however, constituents of lower mobility in the vadose zone beneath the ponds and cribs may potentially reach the water table in the future and affect groundwater quality.

Within the tank farms (WMA U and WMA S-SX), some of the underground single-shell storage tanks have leaked, contaminating the vadose zone beneath the tanks. Some of the contamination has migrated downward and reached the water table (e.g., PNNL-11810, *Results of Phase I Groundwater Quality Assessment for Single-Shell Tank Waste Management Area S-SX at the Hanford Site*). Plumes of nitrate, technetium-99, and chromium from the tank farms are currently found in the groundwater, and the plumes are generally growing in areal extent and exhibit increasing constituent concentrations. To prevent future leaks, all of the single-shell tanks at the Hanford Site have been interim stabilized, and the drainable liquid in each tank has been removed and transferred to double-shell tanks.

Plumes of tritium, nitrate, and iodine-129 from ponds and cribs are dispersing naturally, whereas plumes from the tank farms generally exhibit increasing concentrations and are growing in areal extent.

Technetium-99, uranium, tritium, iodine-129, nitrate, and carbon tetrachloride are the contaminants of greatest significance in groundwater and form extensive plumes within the region. These contaminants have sources within the OU, except for carbon tetrachloride which has migrated into the 200-UP-1 OU from the adjacent 200-ZP-1 OU. In addition to these constituents, high-priority contaminants of concern include strontium-90, trichloroethene, chloroform, chromium, cadmium, and arsenic (DOE/RL-92-76, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*).

The Columbia River Basalt Group forms the bedrock beneath the 200-UP-1 OU. The uppermost basalt flow is the Elephant Mountain Member of the Saddle Mountains Basalt. Geologic units above the basalt (in ascending sequence) are as follows:

- Semiconsolidated sand and gravel of the Ringold Formation Unit 9
- Silt and clay of the Ringold lower mud unit
- Semiconsolidated sand and gravel of the Ringold Unit 5
- Fine- to coarse-grained Cold Creek unit
- Unconsolidated sand and gravel of the Hanford formation.

Groundwater within the interest area occurs as an unconfined aquifer, as well as under confining conditions beneath the Ringold lower mud unit (Ringold confined aquifer) and within and between the basalt flows (upper basalt-confined aquifer system and the lower basalt aquifers). The unconfined aquifer is the aquifer directly impacted by waste disposal operations in the southern 200 West Area and, therefore, is the

only aquifer discussed in this chapter. The unconfined aquifer occurs within Ringold Unit 5 and its base is the fine-grained lower mud unit. Depths from land surface to the water table range from 64 to 106 meters, with the largest depths occurring in the northeastern portion of the OU. The thickness of the unconfined aquifer within the OU is variable (PNNL-13858, *Revised Hydrogeology for the Suprabasalt Aquifer System, 200-West Area and Vicinity, Hanford Site, Washington*). The aquifer is ~70 meters thick in the western portion of the OU. The elevation of the top of the lower mud unit increases to the northeast, so a portion of this unit is interpreted to occur above the water table north of the OU boundary (shown on Figure 3-5 in Chapter 3.0). Thus, the aquifer thickness approaches zero in the northeastern corner of the OU.

Groundwater flow in the unconfined aquifer is primarily to the east within the southern 200 West Area and east-northeast in the eastern portion of the interest area (Figure 6-2). Water levels have been declining in this area since the 1980s; within the southern portion of the 200 West Area, flow directions have generally changed from southeast to east since the 1980s. When the 216-U-10 Pond (U Pond) and the 216-U-14 Ditch were active, a groundwater mound formed resulting in radial flow in the northwestern portion of the interest area (e.g., PNNL-16069, *Development of Historical Water Table Maps of the 200 West Area of the Hanford Site [1950-1970]*). Discharges to ground ceased in the mid-1990s, and the groundwater flow has resumed its pre-Hanford flow direction toward the east. Based on water-level measurements in March 2008 and March 2009, the water table elevation declined by an average of 0.31 meters in the southern portion of the 200 West Area.

6.2 Groundwater Contaminants

The following sections provide an overview of the contaminant plumes and contaminants of concern for the 200-UP-1 groundwater interest area. The discussion provides a summary of the combined results of CERCLA, RCRA, and AEA monitoring performed in this area, with focus on the upper portion of the unconfined aquifer. Information on the vertical distribution of contaminants in the aquifer is given where available.

Plume areas (square kilometers) above the drinking water standard at the 200-UP-1 Operable Unit:

Chromium, 100 µg/L — 2.276
Iodine-129, 1 pCi/L — 4.63
Nitrate, 45 mg/L — 5.20
Technetium-99, 900 pCi/L — 0.332
Tritium, 20,000 pCi/L — 8.051
Uranium, 30 µg/L — 0.419

****Carbon tetrachloride included with 200-ZP-1 Operable Unit.***

6.2.1 Technetium-99

Technetium-99 concentrations occur above the drinking water standard (DWS) of 900 pCi/L in three regions of the 200-UP-1 OU: (1) downgradient from the 216-U-1/2 Cribs near U Plant, (2) at WMA S-SX, and (3) at WMA U (Figure 6-3). A technetium-99 plume originates from the 216-U-1/2 Cribs, which were active in the 1950s and 1960s. The plume extends ~1.5 to 2 kilometers east into the 600 Area, but the plume is mostly at levels below the DWS. When wastewater was disposed at the nearby 216-U-16 Crib in the mid-1980s, it migrated north along a caliche layer and mobilized the technetium-99 and uranium in the soil column beneath the 216-U-1/2 Cribs, which added contaminant mass to the groundwater plume (DOE/RL-92-76, *Remedial Investigation/Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit*). This plume is separated into two parts: one downgradient from the 216-U-1/2 Cribs, and one east of the 200 West Area boundary. This separation was caused by capture of the high-concentration portion of this plume by the 200-UP-1 interim remedial action pump-and-treat system while the lower concentration portion that was not captured continued to migrate to the east. Historically, the highest measured technetium-99 concentration in the 216-U-1/2 Cribs plume was 41,000 pCi/L in well 299-W19-24 (west of the 216-U-17 Crib) in October 1989.

The pump-and-treat system operated in the central portion of the 216-U-1/2 Cribs plume from 1995 until a rebound study began in early 2005. Groundwater extraction resumed in April 2007 following the rebound study. The pump-and-treat system has been successful in reducing technetium-99 concentrations in the aquifer. Throughout the reporting period, technetium-99 concentrations were below the 9,000 pCi/L remedial action objective in both extraction wells (299-W19-36 and 299-W19-43) and in all of the compliance wells. Technetium-99 concentrations exceeded the DWS in both extraction wells but were below the DWS at all of the compliance wells. The maximum concentration measured during the reporting period at the pump-and-treat system was 8,000 pCi/L in extraction well 299-W19-36 (November 2008). Section 6.3.2 provides additional discussion of the pump-and-treat activities.

The maximum technetium-99 concentration during the reporting period at S-SX Tank Farm well 299-W23-19 was 75,000 pCi/L

At WMA S-SX, a technetium-99 plume originates from the southwestern corner of the WMA and another plume originates from the northern portion. The highest technetium-99 concentrations within the OU occur in the southern plume at well 299-W23-19 (located inside the SX Tank Farm). During the reporting period, concentrations in this well exhibited a generally increasing trend, peaking at 75,000 pCi/L in June 2009 (Figure 6-4). The southern plume from WMA S-SX represents a growing contamination issue because the plume is increasing in areal extent and concentrations are increasing in many of the downgradient wells. At far downgradient well 299-W22-86, the technetium-99 concentration increased to 9,200 pCi/L during December 2009, exceeding ten times the DWS

The northern plume at WMA S-SX originates from the S Tank Farm. Concentrations began increasing in this plume during FY 2007 and continued to increase during the reporting period (Figure 6-5). In well 299-W22-44, the technetium-99 concentration increased from 13,000 pCi/L in December 2008 to 20,000 pCi/L in December 2009. Concentrations are also increasing in far downgradient well 299-W22-26, where the technetium-99 concentration was 5,600 pCi/L in September 2009. Technetium-99 concentrations were not detectable in upgradient well 299-W23-20 during the reporting period, confirming the S Tank Farm as the source. The recent concentration increases in the northern plume indicate that it is also a growing contamination issue. Section 6.4.1 provides additional information regarding technetium-99 at this WMA. Future remediation of both the northern and southern plumes from WMA S-SX is being addressed by the 200-UP-1 OU CERCLA activities.

Both the northern and southern technetium-99 plumes from WMA S-SX represent growing contamination issues.

Technetium-99 concentrations in the downgradient wells at WMA U are elevated compared to concentrations in the upgradient well. This indicates the U Tank Farm is a source of technetium-99 contamination (PNNL-13282, *Groundwater Quality Assessment for Waste Management Area U: First Determination*); however, concentrations are very low compared to WMA S-SX. The DWS was exceeded in four wells during the reporting period, with peak concentrations occurring in July 2009 of 1,200 pCi/L at 299-W18-30; 2,200 pCi/L at 299-W19-42; 1,800 pCi/L at 299-W19-45; and 2,200 pCi/L at 299-W19-47. Concentrations have been relatively stable in wells 299-W18-30 and 299-W19-47 and slowly increasing in wells 299-W19-42 and 299-W19-45. Section 6.4.2 includes additional discussion regarding technetium-99 at this WMA.

Within the 200-UP-1 OU, depth-discrete groundwater sampling during well installation between FY 2003 and FY 2008 indicated three locations where technetium-99 occurred above the DWS relatively deep below the water table: (1) well 299-W19-46 (southeast of U Plant) had a concentration of 1,360 pCi/L at 19 meters below the water table, with concentrations less than 300 pCi/L above this depth; (2) well 299-W19-49 (south of U Plant) had a concentration of 1,320 pCi/L

at 28 meters below the water table; and (3) well 699-38-70C (east of U Plant in the 600 Area) had concentrations between 970 and 1,600 pCi/L throughout the unconfined aquifer thickness to the Ringold lower mud unit at 33 meters below the water table. At all other locations, technetium-99 concentrations above the DWS did not occur beyond the upper ~20 meters of the aquifer. Maps provided in *Hanford Site Groundwater Monitoring for Fiscal Year 2006* (PNNL-16346) show the depth distribution of technetium-99 (and uranium) in groundwater within the OU.

6.2.2 Uranium

Within the 200-UP-1 OU, uranium primarily occurs in a plume downgradient from the 216-U-1/2 Cribs (Figure 6-6) and is associated with the technetium-99 plume. The plume extends a total of ~1.5 kilometers to the east at levels above the 30 µg/L DWS. Uranium interacts with soil particles and is not as mobile in the aquifer as technetium-99. The uranium originated from the 216-U-1/2 Cribs, which were active in the 1950s and 1960s. As with technetium-99, additional mass was added to the groundwater plume when effluent disposed at the nearby 216-U-16 Crib in the mid-1980s migrated north along a caliche layer in the vadose zone, mobilizing the technetium-99 and uranium in the soil column beneath the 216-U-1/2 Cribs (DOE/RL-92-76).

An interim remedial action pump-and-treat system operated in the central portion of the 216-U-1/2 Cribs plume from 1995 until a rebound study began in early 2005. Groundwater extraction resumed in April 2007 following the rebound study. The remedial action objective was formerly 480 µg/L, but this was revised to 300 µg/L during the reporting period (*Explanation of Significant Differences for the Interim Record of Decision for the 200-UP-1 Groundwater Operable Unit, Hanford Site, Washington* [EPA et al. 2009]).

At the end of the reporting period, all uranium sample results in the 200-UP-1 pump-and-treat area were below the 300 µg/L remedial action objective, although the concentration at well 299-W19-18, upgradient from the remedial action target area, continued to exceed 300 µg/L.

The uranium plume map shown in Figure 6-6 depicts the average conditions during the reporting period, showing a 300 µg/L contour within the pump-and-treat area. However, by the end of the reporting period, all uranium sample results were below the current remedial action objective of 300 µg/L at all wells that have not gone dry within the remedial action target area (i.e., baseline plume area). Concentrations at extraction well 299-W19-43 were above the remedial action objective for most of the reporting period (peak of 333 µg/L in November 2009) but declined to 262 µg/L in August 2009. Well 299-W19-37 had a uranium concentration of 322 µg/L in March 2008, but this well has since gone dry and can no longer be sampled. Concentrations at most wells, however, continue to exceed the DWS of 30 µg/L. Section 6.3.2 provides additional information regarding operation and performance of the pump-and-treat system.

Near the 216-U-1/2 Cribs, uranium continues to be elevated in well 299-W19-18. Concentrations had been declining in this well; however, between August 2008 and August 2009, the uranium concentration increased from 349 to 416 µg/L. The persistence of elevated concentrations in this well over the past 10 years may be due to an ongoing source of uranium to the aquifer. Possible sources include continued leaching from the vadose zone beneath the 216-U-1/2 Cribs or desorption of uranium from the aquifer sediment. However, the uranium concentration may also result from the slow migration of this constituent compared to technetium-99.

Depth-discrete sampling during drilling within the 216-U-1/2 Cribs plume has indicated that the uranium plume is limited to the upper ~20 meters of the aquifer. There were no exceedances of the DWS below 20 meters in depth. Even in those wells (299-W19-46, 299-W19-49, and 699-38-70C) in which technetium-99 was

found above the DWS relatively deep in the aquifer, uranium was not elevated at the same depths. Maps of depth-discrete sampling results for uranium during well installation between FY 2003 and FY 2006 are provided in PNNL-16346.

Uranium concentrations are elevated in wells west and northwest of WMA S-SX in the vicinity of U Pond. Uranium concentrations exceed the DWS in only one well in this area, 299-W23-4 (near the 216-S-21 Crib), which had a peak concentration of 35 µg/L during the reporting period.

6.2.3 Tritium

Disposal facilities associated with REDOX Plant are the primary sources of tritium in the 200-UP-1 OU. The REDOX Plant operated from 1952 until 1967, although effluent releases continued to occur after that time. A large tritium plume from the REDOX Plant cribs originates from the southern portion of the 200 West Area and extends ~5 kilometers toward the east and northeast at levels above the 20,000 pCi/L DWS. Two high-concentration areas occur within this region: a large plume extending to the east and northeast from the 200 West Area, and a smaller plume extending ~550 meters to the east-southeast from the 216-S-25 Crib (Figure 6-7).

The tritium plume originating from the southern 200 West Area is attenuating naturally through dispersion and radiological decay.

Sample results in the eastern high-concentration area ranged from ~130,000 to 1 million pCi/L. Within the 20,000 pCi/L contour, concentrations are generally declining at eight wells, are relatively stable in two wells, and are increasing in one well. The plume has localized high-concentration areas, which may account for increasing trends as these areas pass by wells. However, the plume exhibits declining concentrations overall, and the areal extent has changed little in recent years, indicating natural attenuation by dispersion and radiological decay.

Only limited information is available on the vertical distribution of the large tritium plume. At the southern edge of this plume, depth-discrete tritium sampling was conducted at well 699-30-66 during drilling in 2004. Tritium was found at 18,000 pCi/L in the uppermost sample, 6.3 meters below the water table. The concentration was much lower (570 pCi/L) at 17.6 meters below the water table, and tritium was not detected in deeper samples. Depth-discrete tritium sampling was also conducted at well 699-36-70B when the well was drilled in 2004. This well is located along the western boundary of the ERDF. Concentrations were 8,800 pCi/L at 1.5 meters below the water table; 1,200 pCi/L at 11.9 meters depth; 1,000 pCi/L at 22.9 meters depth; and 325 pCi/L at 46.3 meters depth. This information suggests that tritium occurs largely in the upper ~20 to ~25 meters of the aquifer, but this conclusion is tentative because vertical information is not available within the high-concentration regions of this plume.

Tritium occurs above the DWS in eight wells downgradient of the 216-S-25 Crib. Historically, concentrations fluctuated in a single well (299-W23-9) on the downgradient side of the crib, but this well went dry during FY 2007 and can no longer be sampled. Further downgradient, trends are generally stable in five wells and increasing in two wells. Radioactive liquid effluent was disposed to the 216-S-25 Crib from 1973 through 1980; in 1985, effluent from a pump-and-treat system at the 216-U-1/2 Cribs was disposed to this crib. In the vadose zone beneath this crib, tritium in the residual soil moisture may be migrating slowly to the water table, which would account for the fluctuating tritium concentration trend in well 299-W23-9. The plume has migrated under WMA S-SX, but the tank farms are not considered a direct source of tritium to the groundwater. Tritiated water in the tanks was removed by the 242-S evaporator and disposed to the 216-S-25 Crib. The maximum sample result

in this plume during the reporting period was 80,000 pCi/L in well 299-W23-21, which is upgradient of WMA S-SX.

The tritium concentration in groundwater near the 216-S-21 Crib (west of WMA S-SX) continued to increase during the reporting period, reaching 38,000 pCi/L in well 299-W23-4 (July 2009). This crib has previously been a major source of tritium. The peak tritium concentration in well 299-W23-4 occurred in 1963 and 1964 at 110 million pCi/L.

6.2.4 Iodine-129

Iodine-129 plumes in the 200-UP-1 OU originate from both U Plant and REDOX Plant disposal facilities (Figure 6-8). One plume originates from the 216-U-1/2 Cribs, and a second plume originates from the southern portion of the 200 West Area. At the current level of monitoring detail, these plumes merge downgradient and become indistinguishable. This combined plume (as defined by the 1 pCi/L contour) extends to the east a total distance of ~3.5 kilometers. Sample results near the REDOX Plant cribs are above the DWS (1 pCi/L). For example, well 299-W22-72, near the 216-S-7 Crib, had a maximum concentration during the reporting period of 2.9 pCi/L (December 2008).

The highest concentrations of iodine-129 within the interest area, greater than ten times the DWS, occur in a 2-kilometer region extending eastward from the southeastern 200 West Area.

The highest concentrations of iodine-129 within the OU, greater than 10 times the DWS, occur in a region extending ~2 kilometers east into the 600 Area from the southeastern 200 West Area (Figure 6-8). The peak concentration in this area occurs in well 699-35-70, which is sampled every other year. The most recent sampling was in March 2008, and the iodine-129 result was 37 pCi/L. Within the larger plume (as delineated by the 1 pCi/L contour), concentrations are generally declining or stable, and dispersion is slowly reducing the areal extent of the plume above the DWS. Radiological decay is not a factor in the declining areal extent because iodine-129 has a long half-life (15.7 million years).

Information on the vertical extent of iodine-129 within the OU is limited. Depth-discrete sampling was conducted at well 299-W19-48 in the pump-and-treat area when the well was drilled in 2004. Concentrations were reported at 1.6 pCi/L at 11 meters below the water table, 1.1 pCi/L at 27 meters depth, 0.7 pCi/L at 44.5 meters depth, and 0.05 pCi/L at 48.8 meters depth. All of these results are flagged as non-detects, but the results greater than 1 pCi/L are interpreted to be valid concentrations. The data indicate that concentrations above the DWS occur within the upper ~30 meters of the aquifer at this location. Depth-discrete sampling was also conducted at well 699-30-66 (southern edge of the 600 Area tritium plume), but iodine-129 was not detected at all (the reported values were all less than 0.6 pCi/L). At well 699-36-70B (western boundary of the ERDF), iodine-129 was not detected in depth-discrete samples collected during drilling, but these results are considered suspect because samples from the finished well averaged 3.5 pCi/L during the reporting period.

6.2.5 Nitrate

Nitrate plumes are widespread within the 200-UP-1 interest area and originated from multiple sources.

Nitrate plumes in the 200-UP-1 OU are thought to have originated from both the U Plant and REDOX Plant disposal facilities and are widespread throughout the area. Potential sources of nitrate from U Plant include the 216-U-1/2, 216-U-8, and 216-U-12 Cribs. The nitrate plumes from these and other sources merge downgradient into a single large plume, which extends to the east and northeast a total distance of ~4 kilometers (Figure 6-9). Nitrate sources from REDOX Plant disposal facilities may also have contributed to this plume. With a few exceptions, concentrations throughout the large plume outside the 200 West Area are stable or declining. On the eastern

The highest nitrate concentrations within the 200-UP-1 OU occur within the pump-and-treat area at extraction well 299-W19-43. Concentrations in this well decreased from 1,080 to 668 mg/L during the reporting period.

edge of the plume, concentrations are stable in well 699-36-61A, increasing in well 699-40-62, and are declining in well 699-44-64.

Within the pump-and-treat area, nitrate concentrations are highest in the two extraction wells, 299-W19-43 and 299-W19-36 (Figure 6-9). At well 299-W19-43, nitrate concentrations decreased during the reporting period, from 1,080 mg/L in November 2008 to 668 mg/L in August 2009. Concentrations fluctuate in this well in response to pumping outages, and the pump was not operational during most of the spring and summer of 2008 (DOE/RL-2008-77, *200-UP-1 and 200-ZP-1 Operable Units Pump-and-Treat System Annual Report for Fiscal Year 2008*). The concentration declines are likely the result of reduced contaminant mass in the aquifer combined with the growth of the capture zone. As the capture zone grows in response to pumping, water with a lower nitrate concentration (quite possibly from beneath the plume) may be drawing into the extraction well and diluting the water of higher nitrate concentration. The maximum nitrate concentration values from well 299-W19-43 are higher than concentrations measured historically at the 216-U-1/2 Cribs in the 1970s and 1980s (~100 to ~300 mg/L). Thus, it appears that nitrate may have a local source near the pump-and-treat area.

At the other extraction well (299-W19-36), concentrations increased during the reporting period, from 218 mg/L in November 2008 to 321 mg/L in August 2009 (Figure 6-10). Concentrations have been increasing in this well since the restart of pumping in 2007 after a rebound study. The next highest concentrations in the pump-and-treat area occur in well 299-W19-48, where concentrations increased from 58 mg/L in November 2008 to 105 mg/L in November 2009. Section 6.3.2 provides additional information on the pump-and-treat system.

The occurrence of nitrate above the DWS deep in the unconfined aquifer does not appear to be widespread. The nitrate distribution depicted in Figure 6-9 represents the nitrate concentrations in the upper portion of the unconfined aquifer because most of the wells are screened across the water table. Of the wells actively sampled within the OU, eight are screened deeper in the aquifer, and five of these wells are located within the mapped nitrate plume. Nitrate is found at levels above the DWS in only one of these deeper wells, 699-38-70C. The concentration in this well was 151 mg/L in November 2009, and the trend is slightly declining. Further downgradient to the east, nitrate may occur relatively deep in the unconfined aquifer due to hydrodynamic dispersion.

The WMA U is a source of nitrate to groundwater (Section 6.4.2). Nitrate concentrations in four of the downgradient wells were above the DWS at the end of the reporting period. The maximum measured nitrate concentration at the U Tank Farm during the reporting period was 85 mg/L (January 2009) in well 299-W19-44.

Nitrate occurs in two small plumes associated with REDOX Plant disposal facilities: one plume near the 216-S-20 Crib, and the second plume near the 216-S-25 Crib and S-SX Tank Farms. Well 299-W22-20 (downgradient of the 216-S-20 Crib) had a nitrate concentration of 104 mg/L in September 2007. The concentration in this well has been declining since a maximum value occurred in December 2005 (144 mg/L). At new well 699-34-72 (located ~320 meters downgradient from the 216-S-20 Crib), the nitrate concentration was 31 mg/L in March 2009. From 1952 through 1972, this crib received waste from laboratory hoods and decontamination sinks in the 222-S Building, as well as laboratory waste from the 300 Area.

The nitrate plume originating from the 216-S-25 Crib merges with a nitrate plume from WMA S-SX (Section 6.4.1). Nitrate concentrations from the tank farm correlate with technetium-99 and chromium concentrations. In well 299-W23-19 in the southwestern corner of WMA S-SX, the nitrate concentration exhibited a generally increasing trend, with a maximum value of 540 mg/L (June 2009) during the reporting period. In addition, the downgradient extent of this plume, as delineated by the 45 mg/L contour, increased to beyond the far downgradient well 299-W22-86 during the reporting period. A nitrate plume also originates from the S Tank Farm; the maximum concentration in this plume during the reporting period was 280 mg/L in well 299-W22-44 (Figure 6-5). Depth-discrete sampling during drilling of well 299-W22-47 indicated that concentrations above the DWS in the southern plume are limited to the upper 21 meters of the aquifer.

6.2.6 Chromium

High concentrations of dissolved chromium are found in two regions of the 200-UP-1 OU: WMA S-SX and in the 600 Area (east and southeast of the 200 West Area). During the reporting period, samples from five wells at WMA S-SX exceeded the 100 µg/L DWS. The highest concentrations occurred at well 299-W23-19, where dissolved chromium exhibited a generally increasing trend during the reporting period (average of 949 µg/L in filtered samples) (Figure 6-4). This well is near the source of a chromium, technetium-99, and nitrate plume originating from the SX Tank Farm.

High concentrations of chromium are found in two regions of the 200-UP-1 OU: at WMA S-SX and in the 600 Area (east and southeast of the 200 West Area).

A second plume occurs in the northern portion of WMA S-SX, downgradient from the S Tank Farm. At near-field downgradient well 299-W22-44, dissolved chromium has continued to trend generally upward since October 2006 (Figure 6-5). During the reporting period, the maximum concentration in this well for a filtered sample was 668 µg/L in March 2009. The other mobile tank waste constituents (technetium-99 and nitrate) have also increased substantially in this well. In general, chromium concentrations are increasing at WMA S-SX and the areal extent of both the northern and southern plumes is growing. Section 6.4.1 provides additional information on chromium at WMA S-SX.

Dissolved chromium is frequently detected in wells east and southeast of the 200 West Area. The dissolved chromium concentration in well 699-32-62 was 144 µg/L in April 2009, similar to the previous sample result of 152 µg/L in September 2007. Chromium concentrations have declined slowly since the constituent was first analyzed at this well in 1992. Dissolved chromium is also elevated at well 699-30-66 (108 µg/L in December 2009), which is completed deep in the aquifer, just above the Ringold lower mud unit. This indicates that chromium may occur throughout the aquifer thickness in this region. The location of this plume is consistent with effluent disposal to the 216-S-20 Crib and/or the REDOX Plant ponds and ditches to the south of the 200 West Area during the 1950s. Chromium concentrations remain elevated in groundwater near both of these potential source locations. In well 699-34-72, downgradient from the 216-S-20 Crib, a chromium concentration of 30 µg/L was detected in a filtered sample collected during July 2008. In well 299-W26-13 at the 216-S-10 Pond, chromium was detected at 39 µg/L in a filtered sample in June 2009.

6.2.7 Chlorinated Hydrocarbons

Carbon tetrachloride occurs above the DWS (5 µg/L) in numerous wells within the 200-UP-1 OU, and the maximum concentration in 23 wells during the reporting period exceeded 10 times the DWS. The highest concentrations occur within and

Carbon tetrachloride concentrations exceed the 5 µg/L DWS in numerous wells within the 200-UP-1 OU. This constituent originates from disposal sites in the 200-ZP-1 OU.

near the 200 West Area, with concentrations decreasing toward the east. At the water table, the plume is widespread in the southern portion of the 200 West Area and extends ~1 kilometer east into the 600 Area (Figure 7-3 in Chapter 7.0). The plume originated from waste disposal sites associated with the Plutonium Finishing Plant in the 200-ZP-1 OU. Concentration trends vary, with different wells exhibiting increasing trends, stable trends, or declining trends, and no clear spatial pattern is evident among the wells with increasing or decreasing trends.

Depth-discrete sampling during well drilling in the eastern portion of the plume has shown that concentrations generally increase with depth in the unconfined aquifer. This indicates that the plume occurs at greater depths as it migrates east, possibly because of plume density, vertical dispersion, or aquifer heterogeneity/anisotropy. The highest carbon tetrachloride concentration measured during the reporting period was 1,300 µg/L in well 299-W14-71, which is screened from 40.9 to 45.4 meters below the water table, just above the Ringold lower mud unit. Chapter 7.0 provides additional information regarding carbon tetrachloride in the 200 West Area.

Within the 200-UP-1 pump-and-treat area, carbon tetrachloride concentrations at all wells exceeded the 5 µg/L DWS. The maximum concentration within the baseline plume area was 400 µg/L in extraction well 299-W19-36 (December 2008). Given the size of the carbon tetrachloride plume and the relatively low pumping rates, groundwater extraction is not having any discernable effect on carbon tetrachloride concentrations in this area.

Carbon tetrachloride and chloroform concentrations generally increase with depth in the eastern portion of the 200-UP-1 OU.

Chloroform is a degradation product of carbon tetrachloride and tends to occur in the same wells with carbon tetrachloride. Thus, some natural degradation of carbon tetrachloride may be occurring, although chloroform was likely introduced to the aquifer from the 2607-Z Tile Field as well (Chapter 7.0). During the reporting period, 158 chloroform analyses were performed on samples from 52 wells within the 200-UP-1 groundwater interest area, and no exceedances of the DWS (80 µg/L for total trihalomethanes) were observed. The maximum concentration measured was 18 µg/L in well 299-W15-37, located north of the WMA U tank farm. Depth-discrete sampling during new well installation has indicated that concentrations tend to increase with depth, similar to carbon tetrachloride.

Trichloroethene is found in the 200-UP-1 OU above the DWS (5 µg/L) near the pump-and-treat system, as well as to the north at well 299-W14-71. Depth-discrete sampling results during well drilling have shown that concentrations tend to increase with depth. During the reporting period, 158 trichloroethene analyses were performed on samples from 52 wells within the interest area, and the DWS was exceeded in only two wells (299-W14-71 and 699-38-70B). Both of these wells are screened deep within the unconfined aquifer, just above the Ringold lower mud unit. In previous years, trichloroethene was detected in well 699-38-70C above the DWS, but the concentration declined to below the DWS during the reporting period. None of the wells monitoring the upper portion of the aquifer exceeded the DWS. The maximum concentration measured was 9.4 µg/L in well 299-W14-71. The areal extent of trichloroethene does not coincide with the distribution of carbon tetrachloride, which suggests a localized source in the U Plant area.

6.2.8 Strontium-90

Strontium-90 in groundwater occurs in only one location within the OU (well 299-W22-10, downgradient from the 216-S-1/2 Cribs). This well was last sampled in FY 2006 with a result of 27 pCi/L, which was above the DWS (8 pCi/L). The 216-S-1/2 Cribs received highly acidic waste from the REDOX Plant between

1952 and 1956. In 1955, the waste is believed to have corroded the casing of nearby well 299-W22-3 (not shown in Figure 6-1, but the well is located ~25 meters south-southeast of the 216-S-1/2 Cribs), which allowed the effluent to bypass the soil column and flow down the well directly into groundwater (based on information from the Waste Information Data System database). This is the postulated pathway by which strontium-90 may have reached groundwater at this location.

During the reporting period, 37 analyses for strontium-90 were performed on samples collected from 14 wells within the groundwater interest area. Only one detection was noted (6.1 pCi/L in well 299-W23-21), but this result is flagged as suspect in the Hanford Environmental Information System (HEIS) database because strontium-90 was not detected in the duplicate sample and has not been detected in any of the historical samples from this well.

6.2.9 Other Constituents

Arsenic and cadmium are listed as contaminants of concern for the 200-UP-1 OU (DOE/RL-92-76). During the reporting period, over 60 analyses were performed for arsenic in more than 15 wells, and over 380 analyses were performed for cadmium in more than 45 wells. No confirmed detections above the DWS (10 µg/L for arsenic and 5 µg/L for cadmium) were observed in either filtered or unfiltered samples.

Well 299-W22-20, near the 216-S-20 Crib, was sampled in August 2009, and 1,4-dioxane was detected at 39 µg/L. This was a decline from the previous sample result of 120 µg/L in August 2006. Between 2002 and 2009, this constituent was detected during four sample events at well 299-W22-20, with concentrations ranging from 39 to 160 µg/L. This well has gone dry, so no further samples will be collected. New well 699-34-72 was installed ~230 meters east-southeast of well 299-W22-20 in 2008. There were no detections of 1,4-dioxane in this well during the reporting period, but sampling for this constituent will continue in future years.

The contaminants of concern for the 200-UP-1 OU were classified into an initial list of high-priority constituents (i.e., strontium-90, iodine-129, technetium-99, uranium, tritium, carbon tetrachloride, chloroform, trichloroethene, chromium, arsenic, cadmium, and nitrate) to support integrated CERCLA and AEA long-term monitoring, as well as additional contaminants of concern specifically identified to support the remedial investigation/feasibility study. These additional contaminants of concern are documented in the remedial investigation/feasibility study work plan (DOE/RL-92-76) and include an extended list of volatile organic compounds, metals, anions, ammonium ion, ammonia, cyanide, sulfide, cresols, phenols, total petroleum hydrocarbons (kerosene range), beta emitters (carbon-14 and selenium-79), alpha emitters (neptunium-237 and protactinium-231), and gamma emitters (cesium-137 and cobalt-60).

Wells 299-W19-105, 299-W19-107, 299-W22-69, 299-W22-72, 299-W22-86, and 699-33-76 were specifically sampled for the additional contaminants of concern during the reporting period. Other than those constituents that are naturally present in groundwater above laboratory detection limits (e.g., ammonium ion, magnesium, manganese, vanadium, etc.), only two constituents were persistently detected in a monitoring well (carbon-14 in well 299-W22-72, and selenium-79 in well 299-W22-86). Carbon-14 was detected in two samples collected from well 299-W22-72 but was at levels far below the 2,000 pCi/L DWS (maximum concentration of 24 pCi/L). In addition, carbon-14 was detected in one sample from well 299-W22-86 at a concentration of 8.3 pCi/L. Selenium-79 was detected in all five samples collected from well 299-W22-86 during the reporting period, with a

maximum concentration of 26 pCi/L. There is no established DWS for selenium-79, but the U.S. Department of Energy (DOE) established a derived concentration guide of 20,000 pCi/L (100 mrem/year dose). The concentration equivalent to a 4 mrem/year dose (comparable to a DWS) is 800 pCi/L; the reported concentrations at well 299-W22-86 are below both of these values. Additional sampling in the WMA S-SX monitoring wells has confirmed that selenium-79 is present in the groundwater (Section 6.4.1), with the maximum concentration of 311 pCi/L in well 299-W23-19 (below the 4 mrem/year dose equivalent).

Additional constituents of concern (silver and tetrachloroethene) were sporadically detected in one or more wells at low levels. Tetrachloroethene may be present in the groundwater at low concentrations, but the silver detections are likely false positives because of their sporadic nature and low concentrations (with six detections all less than or equal to 13 µg/L).

6.3 CERCLA Groundwater Activities

This section describes activities involving the remedial investigation, the status of the interim action pump-and-treat system just southeast of U Plant, extended well purging for technetium-99 in the SX Tank Farm plume, and closeout of actions related to the 2006 CERCLA 5-year review (DOE/RL-2006-20, *The Second CERCLA Five-Year Review Report for the Hanford Site*) for the 200-UP-1 OU. Monitoring within the OU is controlled by a sampling and analysis plan, which is incorporated into the remedial investigation/feasibility study work plan for the 200-UP-1 OU (DOE/RL-92-76, Rev. 1). The work plan integrates CERCLA and AEA monitoring and is a revision of the original integrated plan issued in June 2002 (DOE/RL-2002-10, *Sampling and Analysis Plan for the 200-UP-1 Groundwater Monitoring Well Network*). Appendix A, Table A-12, presents the monitoring information for the 200-UP-1 OU, including a well list, sampling frequency, and a list of analytes.

An explanation of significant differences was issued that modified the interim Record of Decision for the 200-UP-1 OU. The remedial action objective for uranium was lowered from 480 µg/L to 300 µg/L.

The second CERCLA 5-year review was published in November 2006 (DOE/RL-2006-20). Only one issue and associated action were identified for the 200-UP-1 OU:

- ***Issue 18.*** The remedial action objective for uranium was ten times the *Washington Administrative Code* (WAC) 173-340 ("Model Toxics Control Act – Cleanup") cleanup standard of 48 µg/L. Since that time, the U.S. Environmental Protection Agency has established a DWS of 30 µg/L. Other issues remain to be addressed in the Record of Decision, including the limited quarterly pumping requirement at well 299-W23-19, adjusting the pumping requirement for 200-UP-1 because of limited flow within the extraction well network, and technetium-99 groundwater contamination at other locations within the OU.

  Action 18-1: Prepare an explanation of significant difference for 200-UP-1 OU interim action Record of Decision.

- ***Response***. An explanation of significant differences was issued in February 2009 (EPA et al. 2009), and the interim action Record of Decision was modified as follows:
  - The remedial action objective for uranium was reduced to 300 µg/L.
  - The requirement to extract groundwater at a rate of 190 liters per minute from existing extraction wells was replaced by a requirement to extract groundwater from existing or new extraction wells in accordance with an

approved remedial design/remedial action work plan until the concentration of uranium and technetium-99 are less than or equal to their respective remedial action objectives for four consecutive quarters.

- A requirement was added to sample well 299-W23-19 at WMA S-SX for technetium-99 quarterly, and to purge a minimum of 3,785 liters of water during each sample event until the technetium-99 concentration is less than or equal to 9,000 pCi/L for four consecutive quarters.
- The national primary DWS of 30 µg/L for uranium was added as an applicable or relevant and appropriate requirement for the treatment of the extracted groundwater.
- Institutional controls were revised.
- The cost estimate for the remedial action was revised.

The revised *200-UP-1 Groundwater Remedial Design/Remedial Action Work Plan* (DOE/RL-97-36, Rev. 3) was prepared to address these changes. In addition, the work plan also included the design for a pump-and-treat system targeting the technetium-99 plumes at the S and SX Tank Farms, with treatment anticipated to occur at the 200 West Area treatment facility. The final work plan was published in January 2010.

6.3.1 CERCLA Decision Document

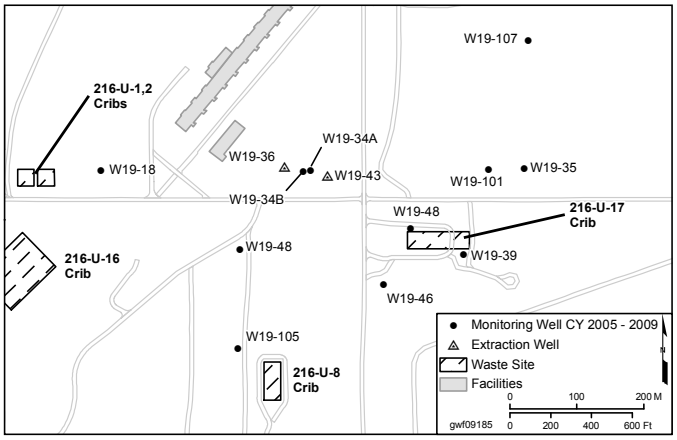
Preparation of the remedial investigation/feasibility study and proposed plan reports began in February 2009 and was ongoing at the end of the reporting period. Although DOE/RL-92-76 called for the collection of 2 years of monitoring data from each well for use in the remedial investigation, DOE and the Washington State Department of Ecology (Ecology) agreed that no further remedial investigation data were needed beyond that available by January 2009 so work on the remedial investigation/feasibility study report could begin (TPA-CN-252, *Change Notice for Modifying Approved Documents/Workplans in Accordance with the Tri Party Agreement Action Plan, Section 9.0, Documentation and Records, DOE/RL-92-76 Revision 1, Remedial Investigation Feasibility Study Work Plan for the 200-UP-1 Groundwater Operable Unit* [issued January 15, 2009]). At the start of the reporting period, all new well installations identified for the OU in DOE/RL-92-76 had been completed. Well 699-33-76 (UP-10) was the last well installed (March 27, 2008) and is an upgradient well for the S-10 unit.

The interim remedial action objectives for the 200-UP-1 pump-and-treat system are as follows (EPA/ROD/R10-97/048, as modified by EPA et al. 2009):

- ***Reduce contamination in the area of highest concentrations of uranium and technetium-99 to below 300 µg/L for uranium and 9,000 pCi/L for technetium-99.***
- ***Reduce potential adverse human health risks through reduction of contaminant mass.***
- ***Prevent further movement of these contaminants from the highest concentration area.***
- ***Provide information that will lead to development and implementation of a final remedy that will be protective of human health and the environment.***

6.3.2 200-UP-1 Pump-and-Treat System

E. J. Freeman, G. L. Kasza, and M. J. Tonkin



The 200-UP-1 pump-and-treat system continued operations during the reporting period. The operation of the system and monitoring results are presented in this section.

The 200-UP-1 pump-and-treat system is intended to reduce uranium and technetium-99 concentrations within the groundwater plume from the 216-U-1/2 Cribs (Figure 6-11). The *Record of Decision for the 200-UP-1 Interim Remedial Measure* (EPA/ROD/R10-97/048), as modified by the recently issued explanation of significant differences (EPA et al. 2009), identifies remedial action objectives that address plume concentrations and target locations for remediation.

The primary contaminants of concern for the 200-UP-1 pump-and-treat system are uranium and technetium-99, and the co-contaminants are carbon tetrachloride and nitrate. Groundwater pumped from the two active 200-UP-1 extraction wells (299-W19-36 and 299-W19-43) is transported by pipeline to the Liquid Effluent Retention Facility (LERF) and is then processed at the Effluent Treatment Facility (ETF).

The pump-and-treat system began operation in 1995, and in July 2003 after 8 years of operation, the system successfully reached the then-current remedial action objectives for uranium and technetium-99 concentrations (480 µg/L for uranium, and 9,000 pCi/L for technetium-99). Following a year of optimized operation, the system was shut down to conduct a year-long rebound study from January 2005 and January 2006. The system remained in hot-standby status until April 19, 2007, when it was then restarted. Except for minor unplanned equipment malfunctions and regular planned outages, the system operated until August 6, 2008, at which time both extraction wells were shut down to support ETF system modifications and upgrades. The wells were restarted on November 17, 2008, and were operational except for minor unplanned and planned service outages until October 14, 2009, when the wells were again shut down due to work at the ETF.

Throughout the reporting period, technetium-99 concentrations were below the remedial action objective of 9,000 pCi/L. Within the baseline plume area (i.e., the area originally targeted for remediation), uranium concentrations were above the remedial action objective of 300 µg/L at a few wells during much of the reporting period, but concentrations were below the remedial action objective in all wells by the end of the reporting period. Concentrations were above the remedial action objective at well 299-W19-18, which is upgradient from the baseline plume area. The production metrics and operational results of the pump-and-treat activities are discussed in Sections 6.3.2.1 through 6.3.2.5. Detailed background information, discussion of the contaminant sources, and operational results from earlier years are presented in *200-UP-1 and 200-ZP-1 Operable Units Pump and Treat System Annual Report for Fiscal Year 2008* (DOE/RL-2008-77) and earlier annual reports.

6.3.2.1 Changes in 2009

System upgrades at the ETF, which began during the latter part of FY 2008, were completed early in the reporting period and the pump-and-treat system returned to operational status in November 2008. Additional work at the ETF required shutdown of the extraction wells from October 14, 2009, through the end of the reporting period (December 31, 2009).

In February 2009, an explanation of significant differences (EPA et al. 2009) was issued to provide notice on changes to the February 1997 interim action Record of Decision. The significant changes to the remedial action objectives are discussed in Section 6.3, but the major change was the reduction of the uranium cleanup level from 480 µg/L to 300 µg/L.

During the reporting period, no configuration changes were made to the extraction wells and no new wells were drilled to supplement the monitoring network.

6.3.2.2 Extraction System Performance

Figure 6-12 presents the system hours and online operational percentages for both extraction wells, and Table 6-1 summarizes the system availability. During the period of system operation (i.e., between November 17, 2008, and October 14, 2009), the predominant impact to the operational productivity for each extraction well were the 12- to 36-hour scheduled outages for leachate transfer from ERDF to the LERF. During the reporting period, well 299-W19-36 was online a total of 7,740 hours, with an average monthly operational percentage of 66.76%. Well 299-W19-43 was online a total of 7,524 hours and had an average monthly operational percentage of 65.71%. Well 299-W19-36 had a total of 3,252 hours of downtime, while well 299-W19-43 had a total of 3,444 hours of downtime during the reporting period. As mentioned previously, much of the downtime was due to ETF outages.

During the reporting period, the quarterly combined average groundwater extraction rate for the two extraction wells was as follows:

- Quarter 1, October through December 2008 (actual November 17 through December 31, 2008): 16.27 liters per minute.
- Quarter 2, January through March 2009: 28.4 liters per minute.
- Quarter 3, April through June 2009: 23.5 liters per minute.
- Quarter 4, July through September 2009: 34 liters per minute.
- Quarter 5, October through December 2009 (actual October 1-14, 2009): 23.1 liters per minute.

During the reporting period, 12.5 million liters of water were extracted from the aquifer by the 200-UP-1 pump-and-treat system.

Extraction well 299-W19-36 had a monthly average pumping rate ranging from 9.1 to 19.3 liters per minute and a yearly average rate of 14.8 liters per minute during the period of operation (i.e., excluding the last ~3 months of the reporting period, when the system did not operate). Extraction well 299-W19-43 had a monthly average pumping rate of 6.8 to 13.2 liters per minute and a yearly average rate of 9.8 liters per minute during the period of operation. A total of 12.5 million liters of water was extracted by both 200-UP-1 extraction wells during the reporting period and transferred to the LERF Basin 43 (Table 6-1), which is a lesser volume than the 13.4 million liters reported in FY 2008. The total volume of water removed since startup of operations in March 1994 is estimated to be 881.4 million liters. Quarterly production data for the reporting period and production summary data since startup of operations are presented in Table 6-2.

6.3.2.3 Capture Zone Analysis

This section describes groundwater flow in the vicinity of the 200-UP-1 pump-and-treat system, and presents an estimate of the extent of capture developed by the system during CY 2009. Groundwater levels are measured throughout the 200 West Area continuously at some wells using pressure transducers with data loggers, and on a regular basis at other wells using manual (depth-to-water) measurements. Groundwater elevations indicate that flow is generally west to east throughout the area, but the flow rates and direction are affected by pumping at three remedies, which include 200-UP-1, 200-ZP-1, and 241-T.

Water-level mapping and capture zone estimation method. Flow rates and directions are affected by pumping related to remedial activities. As a result, water-level maps and estimates of the extent of capture are prepared using a method that incorporates drawdown (or mounding) in response to extraction (or injection) at wells. This technique is an alternative to the use of a numerical model for interpreting capture using measured water levels and pumping rates. The technique is detailed in *Collection and Mapping of Water Levels to Assist in the Evaluation of Groundwater Pump-and-Treat Remedy Performance* (SGW-42305). Estimating capture using water-level mapping follows the three-step process, as described below. Derivations for the equations presented, and additional equations that describe expected changes in water levels near rivers and ponds, are presented in "Kriging Water Levels with a Regional-Linear and Point-Logarithmic Drift" (Tonkin and Larson 2002); "A Simple Approach to Account for Radial Flow and Boundary Conditions When Kriging Hydraulic Head Fields for Confined Aquifers" (Brochu and Marcotte 2003); and SGW-42305.

In the first step, water-level maps are prepared using universal kriging (*Geostatistics: Modeling Spatial Uncertainty* [Chiles and Delfiner 1999]; "On the Use of a Main Trend for the Kriging Technique in Hydrology" [Volpi and Gambolati 1978]), which allows a trend to be incorporated in the map. The form of the trend is defined by the analyst, and the trend coefficients are estimated automatically through kriging. For example, where planar groundwater flow exists, a linear trend is appropriate, leading to the following estimate of the water level, H, at any location (x,y) (Equation 6-1):

$$H(x,y) = A + Bx + Cy + \varepsilon(x,y) \qquad \textbf{(Equation 6-1)}$$

where A, B, and C are regression coefficients and $\varepsilon(x,y)$ is the residual from the linear trend. Because the objective is to estimate the extent of capture, the trend must also reflect the expected response of water levels to pumping at wells. This is accomplished using a term that can be derived from the Thiem equation or the Cooper-Jacob equation. These equations state that under quasi, steady-state conditions, water-level changes due to pumping are centered on the pumped well and are proportional to the logarithm of the radial distance (r) from the pumped well, the pumping rate (Q), and the aquifer transmissivity. If superposition is used to sum the effects of multiple pumped wells, these pumping effects can be combined with the linear trend to provide the following water-level estimator (Equation 6-2):

$$H(x,y) = A + Bx + Cy + D\sum_{1}^{n} Q_i \log_{10}(r_i) + \varepsilon(x,y) \qquad \textbf{(Equation 6-2)}$$

where n is the number of pumped wells, $Q_i \log_{10}(r_i)$ describes the effect of pumping at well i, and D is the regression coefficient corresponding to the pumping effects.

Particle tracking is then used in the second step to estimate flow directions and the extent of capture using the mapped water levels. Particle tracking on a single

water-level map provides an instantaneous depiction of capture corresponding to the water levels and pumping rates used to prepare that map. Because data loggers provide essentially continuous water-level data with corresponding pumping rates, maps depicting water levels and capture can be produced on any frequency. However, determining a best estimate of capture on the basis of numerous maps can be difficult. This is accomplished in the third step of the analysis.

In the third analysis step, a capture frequency map is used to depict the capture estimated on the basis of numerous water-level maps. A capture frequency map depicts the frequency with which each released particle terminates at a pumped well, calculated over all water-level maps. A frequency of 1.0 indicates that the particle is captured on every map, a frequency of 0.0 (zero) indicates that a particle is not captured on any map, and intermediate frequencies indicate that the particle is captured using some maps and not on others. Since each individual water-level map is instantaneous, there is no explicit consideration for the time taken for contaminants to be recovered. Thus, a capture frequency map is most appropriately interpreted as an ensemble estimate for the monitoring period. Causes for frequencies below 1.0 include changing pumping rates and occasional violations of the underlying assumptions. Because low capture frequencies can be misleading, only frequencies of 0.5 and higher are depicted in the figures.

When interpreting the results of this analysis, the following should be considered:

- A capture frequency map typically provides a reasonable estimate of remedy-wide capture within the footprint of the measured data, but distinguishing the capture zones of individual wells within a multi-well remedy can be prone to error. Therefore, inferences based on a capture frequency map should focus on area-wide capture and the relative distribution of low and high frequencies.
- Results presented on the basis of water-level mapping assume that vertical flow is negligible compared to horizontal flow, which is usually a reasonable assumption at some distance from pumping wells.

Approximate flow patterns and extent of capture. Figure 6-13 summarizes pumping rates at the 200-UP-1 pump-and-treat system and clearly indicates two distinct periods of operation. The system operated reasonably continuously during a single period (identified as "UP-1 Period 1" in Figure 6-13) in the first three quarters of 2009, and the system was not operational for the last quarter of 2009. The nearby 200-ZP-1 pump-and-treat system operated reasonably continuously during three periods (identified as "ZP-1 Period 1," "ZP-1 Period 2," and "ZP-1 Period 3" in Figure 7-17 in Chapter 7.0), and intermittently at other times.

Figure 6-14 depicts the water-level contours in the vicinity of the 200-UP-1 pump-and-treat system on (a) March 19 and (b) August 6, 2009, at which times the 200-UP-1 system (and the nearby 200-ZP-1 and 241-T pump-and-treat systems) were operating. Figure 6-14 illustrates the impact of pumping at 200-ZP-1 and, to a lesser extent, depicts local inflections in the water levels due to pumping at 200-UP-1. Multiple maps analogous to that presented in Figure 6-14, constructed using weekly average water levels (obtained throughout CY 2009 with transducers and corresponding pumping rates) were used to develop an estimate of the extent of capture by the 200-UP-1 pump-and-treat system.

Figure 6-15 depicts the estimated extent of hydraulic capture developed by the system calculated from the weekly average water-level maps using a capture frequency map. This figure was generated using data only for the period when the system was operational. Figure 6-16 depicts the same estimated extent of hydraulic

capture as presented in Figure 6-15, together with contours depicting the extent of groundwater contaminated by technetium-99.

Conclusions. The overlay of the capture frequency map with contours depicting the extent of the technetium-99 plume (Figure 6-16) suggests that pumping is well situated to recover technetium-99 from the groundwater. However, the extent of capture shown in Figure 6-16 does not encompass the full extent of the mapped plume above the 900 pCi/L DWS. In addition, the 200-UP-1 extraction wells penetrate a small fraction of the total saturated thickness of the unconfined aquifer. As a result, the most reasonable assumption is that the capture frequency map is valid for that upper portion of the unconfined aquifer that is intercepted by the majority of the extraction wells and, in this case, the validity of the capture frequency map diminishes with increasing depth below the bottom of the screened intervals for the majority of extraction wells. In addition, the relatively low extraction rates and relatively low density of monitoring wells in the vicinity of the pumped wells results in uncertainty in estimates of the capture zone dimensions and orientation. Efforts are underway in regard to performance of the 200-UP-1 recovery wells to rehabilitate these wells to improve performance. These conclusions indicate that current operations at the 200-UP-1 pump-and-treat system are insufficient to contain and ultimately recover all of the technetium-99 at concentrations above the DWS, but the system has been effective in capturing the portion of the plume above the RAO concentration of 9,000 pCi/L.

6.3.2.4 Treatment System Performance

During the reporting period, the 200-UP-1 pump-and-treat system removed 2.86 kilograms of uranium, 0.0024 kilograms (0.041 curies) of technetium-99, 2.48 kilograms of carbon tetrachloride, and 5,805 kilograms of nitrate from the aquifer.

During the reporting period, the system removed 2.98 kilograms of uranium, 0.0025 kilograms (0.042 curies) of technetium-99, 2.58 kilograms of carbon tetrachloride, and 6,044 kilograms of nitrate from the aquifer. Since startup in March 1994, a total of 219.5 kilograms of uranium, 0.126 kilograms (2.14 curies) of technetium-99, 40.3 kilograms of carbon tetrachloride, and 47,585 kilograms of nitrate have been removed (Table 6-2). Concentrations in the treated effluent from the ETF were below laboratory detection limits for uranium, technetium-99, carbon tetrachloride, and nitrate.

6.3.2.5 Compliance Monitoring

The locations of wells monitoring concentrations within the baseline plumes are shown in Figure 6-11. Figures 6-17 through 6-20 show the uranium, technetium-99, carbon tetrachloride, and nitrate groundwater monitoring results for the reporting period, as well as the long-term concentration trends from the 200-UP-1 pump-and-treat system wells. This section discusses the contaminant monitoring results and plume changes.

At the end of the reporting period, all uranium concentrations within the baseline plume area were below the 300 µg/L remedial action objective.

Uranium monitoring results. The annual average uranium plume for CY 2009 (Figure 6-21) showed little change from the FY 2008 average plume. The area bounded by the current 300 µg/L uranium remedial action objective contour does not differ appreciably from the earlier 480 µg/L remedial action objective contour. The area of highest uranium concentration continues to be defined by extraction wells 299-W19-36 and 299-W19-43, and monitoring wells 299-W19-48 and 299-W19-18 (upgradient from the baseline plume area). More uncertainty exists in the location of the 300 µg/L remedial action objective contour since the loss of monitoring well 299-W19-37, which went dry in FY 2008.

During the reporting period, only wells 299-W19-43 and 299-W19-18 exhibited maximum sample results above the 300 µg/L remedial action objective, with concentrations of 333 and 416 µg/L, respectively. By the end of the reporting period,

the concentration at well 299-W19-43 had declined to 262 µg/L (Figure 6-17). For the CY 2009 average plume, the area with a concentration greater than 300 µg/L is estimated to be ~2.1 hectares. However, at the end of the reporting period, all uranium sample results within the baseline plume area were below the remedial action objective.

The persistent uranium plume immediately downgradient of the 216-U-1/2 Cribs may be the result of residual drainage from the vadose zone or continuing releases from the aquifer sediments. Mobilization of contaminants in the vadose zone may have resulted from discharges to the 2607-W5 septic tank and tile field. This system was active into 2005 and received washroom and restroom wastewater, estimated at 4,000 liters per day (DOE/RL-2008-77). Only well 299-W19-18 is currently used to monitor the area immediately downgradient of the 216-U-1/2 Cribs. The declining concentration trend in this well since 2004 suggests that the main mass of mobile uranium has already passed this location. However, the persistent to slowly diminishing uranium concentrations in the extraction wells and adjacent monitoring wells since that time indicates that uranium continues to be present in the downgradient portion of the unconfined aquifer.

Technetium-99 monitoring results. Technetium-99 concentrations were below the 9,000 pCi/L remedial action objective for all of the pump-and-treat system monitoring wells (Figure 6-18). Consistent with previous reporting periods, extraction wells 299-W19-43 and 299-W19-36 were the only wells with concentrations above the 900 pCi/L DWS. Both wells continued to exhibit declining technetium-99 trends, with the concentration at well 299-W19-36 decreasing from 8,000 pCi/L in November 2008 to 4,900 pCi/L in August 2009, and well 299-W19-43 decreasing from 1,600 pCi/L in November 2008 to 1,000 pCi/L in August 2009. The plume continues to decrease in size, as illustrated in DOE/RL-2008-77 and earlier annual reports. Since the end of the rebound study, well 299-W19-36 has shown the largest variability in technetium-99 concentrations. Technetium-99 concentrations remained essentially stable at most other wells.

Technetium-99 concentrations within the baseline plume area were below the 9,000 µg/L remedial action objective throughout the reporting period.

Carbon tetrachloride monitoring results. Carbon tetrachloride concentrations exceeded the 5 µg/L DWS for all monitoring wells in the baseline plume area (Figure 6-19). Average annual concentrations for CY 2009 ranged from 58 to 593 µg/L. Historically, wells 299-W19-36, 299-W19-49, and 699-38-70B have exhibited the highest concentrations and greatest quarterly sampling variability. Carbon tetrachloride originates from disposal facilities associated with the Plutonium Finishing Plant. Given the size of this plume and the relatively low pumping rates, groundwater extraction is not having any discernable effect on carbon tetrachloride concentrations in this area.

Nitrate monitoring results. Nitrate concentrations exceed the 45 mg/L DWS at most wells within the baseline plume area (Figure 6-20). Extraction wells 299-W19-43 and 299-W19-36 had the highest nitrate concentrations, with maximum sample results of 1,080 mg/L and 321 mg/L, respectively. Monitoring well 299-W19-37 also had historically high nitrate concentrations, but this well went dry during FY 2008. The majority of wells have shown stable or decreasing trends from FY 2008. Only wells 299-W19-36 and 299-W19-48 continue to exhibit increasing nitrate concentrations since the restart of extraction in FY 2007.

Deep well sampling results. Most wells in the uranium and technetium-99 baseline plume areas are screened within the upper 12.2 meters of the unconfined aquifer. Deep wells near the pump-and-treat area constructed with screened intervals located within the lower portion of the unconfined aquifer include 299-W19-34A, 299-W19-34B,

and downgradient well 699-38-70B (Figure 6-11). Well 299-W19-34B is sampled every other year and was not sampled during this reporting period.

The uranium, technetium-99, and nitrate concentrations were all below their respective DWSs at the deep wells sampled, and the trends are stable. Carbon tetrachloride concentrations were above the DWS in the deep wells sampled, and their long-term trends are more variable. Well 299-W19-34A exhibited a minor decrease for carbon tetrachloride (Figure 6-19), while well 699-38-70B exhibited a generally increasing trend and the highest concentration (593 µg/L) among all the pump-and-treat system wells sampled. Historically, well 299-W19-34B has exhibited a variable carbon tetrachloride concentration trend, with sample results ranging from 85 to 190 µg/L since CY 2002. As discussed in Section 6.2.7, carbon tetrachloride concentrations generally increase with depth in the eastern portion of the 200 West Area.

6.3.3 Extended Purging of Well 299-W23-19

The feasibility of using well 299-W23-19 as a pump-and-treat extraction well to remediate the southern plume from the SX Tank Farm was investigated in 2001. After aquifer testing in this well, it was concluded that the production capacity was too small for a pump-and-treat system (RPP-10757, *Technetium-99 in Groundwater at Hanford Well 299-W23-19: Options Analysis and Recommended Action Report*). To perform some remediation of the technetium-99, the practice of extended purging during sampling at well 299-W23-19 was agreed to by DOE and Ecology and began in 2003. This agreement was formalized in the explanation of significant differences for the 200-UP-1 OU (EPA et al. 2009) (see Section 6.3). After samples are collected from this well each quarter, well purging is continued at a higher flow rate until a minimum of 3,785 liters of water are removed from the aquifer. This water is transferred to the ETF for treatment and disposal. This practice has the objective of reducing the technetium-99 concentration in the aquifer, and is to continue until four consecutive quarterly sample results are below 9,000 pCi/L.

Table 6-3 presents the date, amount of water collected, and a calculation of the mass and activity of technetium-99 removed from the aquifer. A total of ~0.0020 curies (~0.12 grams) of technetium-99 was recovered during the reporting period. Since the start of this treatment in 2003, ~0.0084 curies (~0.49 grams) of technetium-99 have been recovered.

6.4 Facility Monitoring

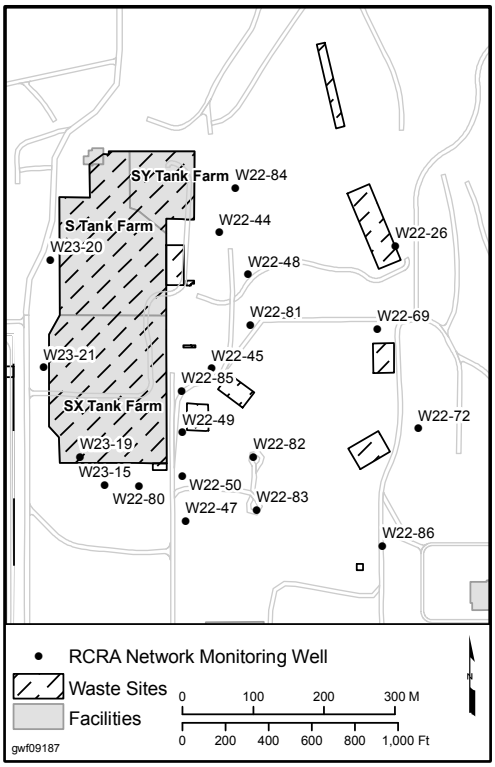
This section describes the results of monitoring for individual waste management or disposal facilities. Some of these facilities are monitored under RCRA requirements for dangerous waste constituents and AEA for source, special nuclear, and byproduct materials. Data from facility-specific monitoring also are integrated into the CERCLA groundwater investigations. Dangerous constituents and radionuclides are discussed jointly in this section to provide comprehensive interpretations of groundwater contamination for each facility. As discussed in Chapter 1.0 pursuant to RCRA, the source, special nuclear, and byproduct material components of radioactive mixed waste are not regulated under RCRA but are regulated by DOE, acting pursuant to its AEA authority.

Detailed groundwater monitoring is conducted at four facilities in the 200-UP-1 OU. Three of these sites are monitored in accordance with RCRA regulations. Interim status groundwater quality assessment monitoring was

conducted at WMA U and WMA S-SX, and interim status indicator parameter evaluation monitoring was conducted at the 216-S-10 Pond and Ditch (S-10 unit). Groundwater monitoring at the ERDF is conducted in accordance with a CERCLA Record of Decision (EPA/ROD/R10-95/110, *Record of Decision: U.S. DOE Hanford Environmental Restoration Disposal Facility, Hanford Site, Benton County, Washington*). Groundwater data for these facilities are available from the HEIS database and the data files accompanying this report.

6.4.1 Waste Management Area S-SX

The WMA S-SX consists of two tank farms: the S Tank Farm and the SX Tank Farm. The S Tank Farm consists of twelve tanks, each with a capacity of 2.9 million liters (total of 34.4 million liters). The SX Tank Farm consists of fifteen tanks, each with a capacity of 3.8 million liters (total of 56.8 million liters) (RPP-7884, *Field Investigation Report for Waste Management Area S SX*). The WMA also includes ancillary equipment consisting of three catch tanks, one receiver tank, six diversion boxes, associated piping, valve pits, and pumps (RPP-7884; DOE/RL-91-60, *S Plant Aggregate Area Management Study Report*). Both tank farms received waste generated from the reduction-oxidation process (REDOX Plant) in the 1950s and 1960s.



Groundwater monitoring is conducted at WMA S-SX in accordance with WAC 173-303-400 ("Dangerous Waste Regulations; Interim Status Facility Standards") and, by reference, 40 *Code of Federal Regulations* (CFR) 265, Subpart F ("Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities; Ground-Water Monitoring"), which requires monitoring to determine whether dangerous waste or dangerous waste constituents from the waste site have entered the groundwater. The WMA was placed into assessment status (40 CFR 265.93[d], "Preparation, Evaluation, and Response," as referenced by WAC 173-303-400) in 1996 at the direction of Ecology due to elevated specific conductance in downgradient monitoring wells. The first determination assessment of the WMA found that multiple sources within the WMA had affected groundwater quality with elevated concentrations of nitrate and chromium in wells downgradient of the WMA (PNNL-11810). The current objective of RCRA monitoring at WMA S-SX is to assess the nature and extent of groundwater contamination with dangerous constituents and determine their rate of movement in the aquifer. Groundwater monitoring under the AEA tracks radionuclides in the vicinity of the WMA.

6.4.1.1 Constituent List and Sample Frequency

Groundwater is monitored in accordance with the *RCRA Assessment Plan for Single-Shell Tank Waste Management Area S-SX at the Hanford Site* (PNNL-12114, Interim Change Notice 4). During the reporting period, quarterly sampling was conducted in the monitoring wells for the RCRA constituents chromium and nitrate, as well as the AEA constituent technetium-99. Alkalinity, as well as major anions and cations, are also sampled quarterly as supporting constituents. The monitoring wells are sampled annually for the AEA constituent tritium. Annual sampling is also conducted in well 299-W23-19 for gross alpha and gross beta. During the reporting period, the AEA constituent selenium-79 was sampled quarterly in the monitoring wells for one year only as a special study. Sampling for this constituent will be reduced to an annual frequency in six wells for 2010.

The planned sampling for all but two wells in the monitoring network was completed as scheduled during the reporting period. The last quarter sampling of wells 299-W22-26 and 299-W23-21 was delayed until January 6, 2010. Appendix C includes a well location map (Figure C-16) and lists of wells and constituents monitored for WMA S-SX (Table C-33).

6.4.1.2 Network Evaluation

The monitoring network at WMA S-SX consists of nineteen wells (two upgradient wells, sixteen downgradient wells, and one well within the WMA). One additional well (299-W22-26), located downgradient from the S Tank Farm, was informally added to the network in March 2008. The well network is adequate for monitoring the distribution of contamination, except for the southern extent of the plumes from the SX Tank Farm. Bounding the southern extent was the objective in locating well 299-W22-47, which was installed during 2005. Instead of finding constituent concentrations in the aquifer consistent with the edge of the plumes, concentrations of chromium, nitrate, and technetium-99 in this well were higher than in any other intermediate downgradient well. Thus, well 299-W22-47 is closer to the centerline of the plumes than the edge, which resulted in a reinterpretation of the southern extent of the plumes (PNNL-15070, *Hanford Site Groundwater Monitoring for Fiscal Year 2004*; PNNL-15670, *Hanford Site Groundwater Monitoring for Fiscal Year 2005*). A new monitoring well, 299-W22-89, is planned to be installed during CY 2010, ~50 meters south of well 299-W22-47 with the objective of determining the southern extent of the plumes.

During the reporting period, the water table elevation declined at an average rate of 0.22 meters per year in the monitoring wells, which was similar to the long-term rate of decline since 2005 of 0.26 meters per year. Analysis of water-level data collected during March 2009 indicated that the hydraulic gradient is 1.9×10^{-3} m/m nearly due east (88 degrees azimuth), and the groundwater flow rate (i.e., average linear velocity) ranges from 0.012 to 0.30 meters per day (5 to 110 meters per year), depending on the hydraulic conductivity and effective porosity. Using values of 6.1 meters per day for the hydraulic conductivity and 0.12 for the effective porosity (average values from multiple constant-rate pumping tests in wells at the WMA [PNNL-13514, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2000*; PNNL-14113, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2001*; PNNL-14186, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 2002*]), the groundwater flow rate most representative for this site is 0.095 meters per day (35 meters per year). This is consistent with previous estimates of 0.07 to 0.14 meters per day (25 to 50 meters per year) based on the movement of tritium between wells (PNNL-12114; PNNL-13441, *RCRA Groundwater Quality Assessment Report for Waste Management Area S-SX [November 1997 through April 2000]*).

Concentrations of mobile tank waste constituents in well 299-W22-44 at the S Tank Farm increased during the reporting period, with maximum values of 280 mg/L for nitrate, 668 µg/L for chromium, and 20,000 pCi/L for technetium-99.

6.4.1.3 Groundwater Contaminants

Groundwater beneath WMA S-SX is contaminated primarily with nitrate, chromium, and technetium-99, attributed to two general source areas within the WMA: (1) a source area in the S Tank Farm, and (2) a source area located to the south in the SX Tank Farm. Nitrate also has other sources in the vicinity, most notably the 216-S-25 Crib. Figures 6-22, 6-23, and 6-24 show the nitrate, chromium, and technetium-99 plumes using average concentrations for CY 2009. Carbon tetrachloride also is present in groundwater beneath the WMA (Figure 7-3 in Chapter 7.0), but the sources are waste sites outside the 200-UP-1 OU in the vicinity of the Plutonium Finishing Plant (PNNL-13441). Although tritium is also present

beneath the WMA (Figure 6-7), its source is the 216-S-25 Crib, located just west (upgradient) of the SX Tank Farm (PNNL-13441).

In the plume downgradient from the S Tank Farm, concentrations of mobile tank waste constituents nitrate, chromium, and technetium-99 increased substantially in well 299-W22-44 during FY 2007. After appearing to stabilize and/or decline near the end of FY 2008, concentrations increased again during the current reporting period (Figure 6-5). Peak concentrations in this well during the reporting period were 280 mg/L for nitrate (June 2009), 668 µg/L for dissolved chromium (March 2009), and 20,000 pCi/L for technetium-99 (December 2009). The DWSs for these constituents are 100 µg/L for chromium, 45 mg/L for nitrate, and 900 pCi/L for technetium-99. Concentrations of these constituents are also increasing in well 299-W22-26 (further downgradient from the S Tank Farm). In this well, nitrate and technetium-99 have exceeded their DWSs at 84 mg/L and 5,600 pCi/L, respectively. Dissolved chromium remains below the DWS at 78 µg/L. Concentrations of these constituents in upgradient well 299-W23-20 for the S Tank Farm were either not detected or were below the DWSs, indicating that the S Tank Farm is the source. Tank S-104 is the only tank within the S Tank Farm known to have leaked (from an overfill event). A surface electrical-resistivity survey conducted during FY 2006 indicated that a portion of the vadose zone plume beneath tank S-104 at the 2- to 5-ohmmeter level had apparently reached groundwater (RPP-RPT-30976, *Surface Geophysical Exploration of S Tank Farm at the Hanford Site*). This is the presumed source of the S Tank Farm groundwater plume.

Concentrations of mobile tank waste constituents in well 299-W23-19 at the SX Tank Farm increased during the reporting period, with maximum values of 540 mg/L for nitrate, 1,020 µg/L for chromium, and 75,000 pCi/L for technetium-99.

Groundwater beneath the SX Tank Farm in the southern portion of the WMA is also contaminated with nitrate, chromium, and technetium-99. These plumes extend from the source area (near well 299-W23-19) toward the east-southeast ~300 to 500 meters at levels above the DWSs (Figures 6-22, 6-23, and 6-24). Low-concentration areas are depicted in these plumes around wells 299-W22-80 and 299-W23-15. An in-well tracer test at well 299-W22-80 and time-series sampling during extensive purging indicated that relatively clean water may be migrating into the bottom of the well, moving up the wellbore, and diluting plume concentrations in the upper portion of the plume (PNNL-15070). A similar process is assumed to be occurring at well 299-W23-15. In the source area, concentrations of all three constituents generally increased in well 299-W23-19 during the reporting period, with peak concentrations of 540 mg/L for nitrate; 1,020 µg/L for dissolved chromium; and 75,000 pCi/L for technetium-99, all during June 2009 (Figure 6-4). Extended purging during quarterly sampling is conducted in this well as a remedy for technetium-99. This CERCLA action is described in Section 6.3.3.

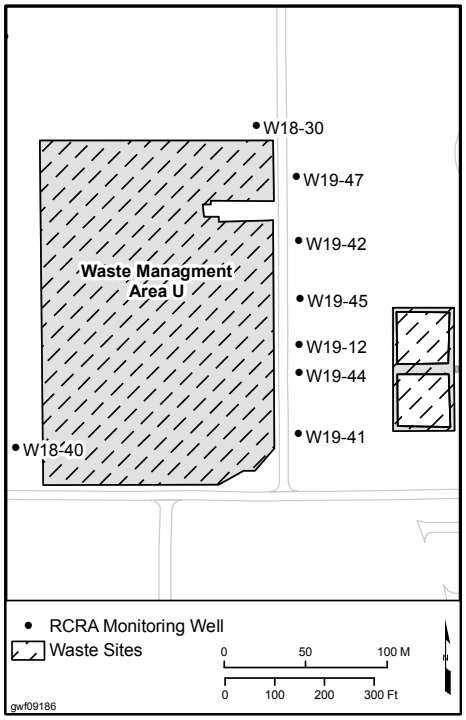
During CERCLA sampling of well 299-W22-86 (~350 meters downgradient from the SX Tank Farm), selenium-79 was detected in two samples collected in January and March 2008 (22 pCi/L and 26 pCi/L, respectively). In September 2008, all of the WMA S-SX network wells were sampled for selenium-79, with sampling continuing during the reporting period. A total of nine network monitoring wells had at least one detection during the reporting period, ranging from 5.5 to 311 pCi/L; the maximum concentration occurred in well 299-W23-19. There is no established DWS for selenium-79, but DOE has established a derived concentration guide at 20,000 pCi/L (100 mrem/year dose). The concentration equivalent to a 4 mrem/year dose (comparable to a DWS) is 800 pCi/L. All of the wells that had detectable selenium-79 are near-field downgradient wells within either the northern plume (from the S Tank Farm) or the southern plume (from the SX Tank Farm). Selenium-79 was not detected in upgradient wells. The sample results for selenium-79 correlated

with the technetium-99 results, indicating that selenium-79 occurs in association with technetium-99 and the other tank waste constituents in groundwater. Due to the low concentrations, sampling for this constituent was reduced to an annual frequency in the four downgradient wells with the highest concentrations (299-W22-44, 299-W22-47, 299-W22-50, and 299-W23-19) and the two upgradient wells (299-W23-20 and 299-W23-21) beginning in FY 2010.

6.4.1.4 Compliance Status

The WMA S-SX remains in interim status groundwater quality assessment monitoring in accordance with 40 CFR 265.93(d), as referenced by WAC 173-303-400.

6.4.2 Waste Management Area U



The WMA U contains sixteen underground single-shell tanks constructed between 1943 and 1944. Twelve of the single-shell tanks have capacities of 2 million liters and four have capacities of 210,000 liters (RPP-35485, *Field Investigation Report for Waste Management Area U*). The WMA also contains a variety of ancillary equipment used to manage tank waste during operations, including six diversion boxes, the 271-UR control house, the 244-UR process vault, the 244-U double-contained receiver tank, waste transfer lines, pits, and junction boxes.

The tank farm received waste from the bismuth phosphate process between 1946 and 1948, and from the reduction-oxidation process between 1954 and 1957 (WHC-MR-0132, *History of the 200 Area Tank Farms*). In 1952, some waste was retrieved and pumped to the 242-T evaporator, and between 1952 and 1957, the metal wastes (stored in nine of the 2-million-liter capacity tanks) were transferred to U Plant to facilitate uranium recovery.

Groundwater monitoring is conducted at WMA U in accordance with WAC 173-303-400, and by reference 40 CFR 265, Subpart F, which requires monitoring to determine whether dangerous waste or dangerous waste constituents from the unit have entered the groundwater. The WMA U was placed into assessment status in 2000 when specific conductance in groundwater monitoring wells downgradient of the WMA exceeded upgradient levels (PNNL-13185, *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U at the Hanford Site*). An assessment of that finding determined that the WMA had affected groundwater quality based on elevated concentrations of nitrate and possibly chromium in wells downgradient of the WMA (PNNL-13282, *Groundwater Quality Assessment for Waste Management Area U: First Determination*). Contaminant concentrations did not exceed their respective DWSs, and the affected area appeared to be limited to the southeastern corner of the WMA. The current objective of RCRA monitoring at this WMA is to assess the nature and extent of groundwater contamination with dangerous constituents and determine their rate of movement in the aquifer (40 CFR 265.93[d], as referenced by WAC 173-303-400). Groundwater monitoring under the AEA tracks radionuclides in the WMA and surrounding area.

6.4.2.1 Constituent List and Sample Frequency

Groundwater quality is assessed at WMA U according to the *Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U* (PNNL-13612, Interim Change Notice 2). During the reporting period, quarterly sampling was conducted in the monitoring wells for the RCRA constituents chromium and nitrate, as well as the AEA constituent technetium-99. Alkalinity, as well as major anions

and cations, are also sampled quarterly as supporting constituents. The monitoring wells are sampled annually for gross alpha, gross beta, and gamma emitters. During the reporting period, the AEA constituent selenium-79 was sampled as a special study once in July 2009. All monitoring wells were sampled as scheduled during the reporting period. Appendix C includes a well location map (Figure C-16) and lists of wells and constituents monitored for WMA U (Table C-36).

6.4.2.2 Network Evaluation

The monitoring network at WMA U consists of eight wells sampled quarterly: one upgradient well and seven wells downgradient of the WMA. The well network is adequate for monitoring the distribution of contamination from the WMA.

Groundwater flow conditions at WMA U have varied over the past several decades due to changing wastewater disposal in areas surrounding the WMA, but flow has been generally to the east since 1996 (~080 degrees azimuth). The decline in monitoring well water levels has averaged 0.28 meters per year since 2005. Water levels increased temporarily in the monitoring wells between March and July 2009 due to a shutdown of the 200-ZP-1 pump-and-treat system. Analysis of water-level data collected during the reporting period indicated an average hydraulic gradient of 2.0×10^{-3} m/m in a direction of 81 degrees azimuth (east). The groundwater flow rate (i.e., average linear velocity) ranged from 0.017 to 0.19 meters per day (6 to 68 meters per year), depending on the hydraulic conductivity and effective porosity. Using values believed to be most representative, 6.12 meters per day for the hydraulic conductivity and 0.17 for the effective porosity from a constant-rate pumping test conducted in well 299-W19-42 (PNNL-13378, *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 1999*), the groundwater flow rate most representative for this site is 0.071 meters per day (26 meters per year).

6.4.2.3 Groundwater Contaminants

The WMA U has been identified as the source of groundwater contamination limited to the downgradient (east) side of the site (PNNL-13282). Constituents found in the groundwater originally included chromium, nitrate, and technetium-99, but monitored chromium concentrations have decreased in the past to near the analytical detection limit, where concentrations remained during the reporting period. Nitrate and technetium-99 appear to have different sources within the WMA, because nitrate concentrations are the highest along the southern half of the site and technetium-99 concentrations are highest along the northern half of the site (Figure 6-25). These constituents are both mobile in groundwater and would be expected to travel together if they were from the same source.

Sources within WMA U have contaminated the groundwater with nitrate and technetium-99.

During the reporting period, measured technetium-99 concentrations exceeded the DWS (900 pCi/L) in at least one sample from each well along the north downgradient side of the WMA (299-W18-30, 299-W19-42, 299-W19-45, and 299-W19-47). Concentrations are increasing in each of these four wells. The concentration trend at well 299-W19-45 had been relatively stable since 2005 (~1,000 to ~1,200 pCi/L); however, during the reporting period, the technetium-99 concentration in this well increased from 1,200 pCi/L in August 2008 to 1,800 pCi/L in July 2009. The maximum technetium-99 concentration measured in a quarterly sample was 2,200 pCi/L in wells 299-W19-42 and 299-W19-47, both in July 2009.

During the reporting period, nitrate concentrations were above the DWS (45 mg/L) in at least one sample from five downgradient wells: 299-W19-12, 299-W19-42, 299-W19-44, 299-W19-45, and 299-W19-47. The maximum nitrate concentration measured in a quarterly sample was 86 mg/L in well 299-W19-44 in January 2009.

Technetium-99 concentrations are highest in the northern wells at WMA U, while nitrate concentrations are higher in the southern wells.

The concentration at well 299-W19-42 exceeded the DWS for the first time, with a value of 45 mg/L in October 2009. Concentrations at well 299-W19-41 declined to below the DWS during the reporting period. Concentrations are higher in the downgradient wells compared to the upgradient well, confirming that the WMA is a source of nitrate to the aquifer. However, nitrate from an upgradient source is also affecting the groundwater quality. During the reporting period, the maximum concentration measured in upgradient well 299-W18-40 was 43 mg/L in October 2009, nearly exceeding the DWS.

The AEA constituent selenium-79 was detected in groundwater downgradient from WMA S-SX (Section 6.4.1.3). To determine whether this constituent is present in groundwater at WMA U, all of the network monitoring wells were sampled for selenium-79 in July 2009. This constituent was not detected in any of the network monitoring wells, and it was concluded that selenium-79 is not present in groundwater downgradient from WMA U at detectable concentrations (the minimum detectable activity in July sampling averaged 6.0 pCi/L).

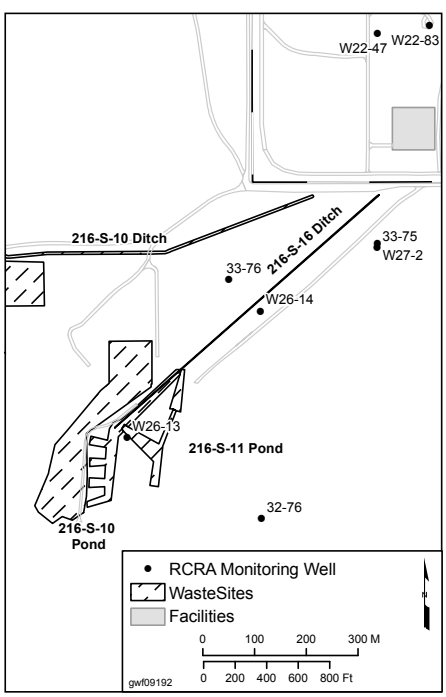
Carbon tetrachloride is found in groundwater beneath WMA U at concentrations above the DWS of 5 µg/L. Well 299-W18-30 is the only well with samples analyzed for carbon tetrachloride (CERCLA sampling). Duplicate samples collected in July 2009 yielded results of 130 and 200 µg/L (exhibiting poor precision, with a relative percent difference of 42%); the previous sample result was 145 µg/L in August 2008. The regional carbon tetrachloride distribution (Figure 7-3 in Chapter 7.0) indicates that the carbon tetrachloride found in the groundwater beneath WMA U originates from liquid waste disposal sites at the Plutonium Finishing Plant.

6.4.2.4 Compliance Status

The WMA U remains in interim status groundwater quality assessment monitoring, in accordance with 40 CFR 265.93(d), as referenced by WAC 173-303-400.

6.4.3 216-S-10 Pond and Ditch

C. J. Martin



The 216-S-10 Pond and Ditch (referred to as the S-10 unit) is located off the southwestern corner of the 200 West Area, directly outside the perimeter fence (Figure 6-1). The site was active from 1951 through 1991 and received effluent primarily from the REDOX Plant chemical sewer. The groundwater beneath the S-10 unit is monitored under interim status regulations (40 CFR 265.93[b], as referenced by WAC 173-303-400) to determine if dangerous waste constituents have impacted groundwater. A factor that complicates groundwater monitoring is adjacent waste disposal sites that have similar hydrogeologic controls and received similar waste streams during their operational life as at the S-10 unit. Hence, distinguishing between contamination contributions from these waste sites and the S-10 unit is difficult.

The S-10 unit was initially a single, open, unlined ditch (216-S-10 Ditch), ~1.2 meters wide at its base and 686 meters long. Discharge to the ditch was through a vitrified clay pipeline from the REDOX Plant. The 216-S-10 Pond was added to the southwest end of the 216-S-10 Ditch in 1954 to increase wastewater capacity. The 216-S-10 Pond covered ~2 hectares, and the shape resembled a backwards "E" with an extra leg, where each leg was a separate leaching trench. Wastewater discharged into the 216-S-10 Ditch flowed into the 216-S-10 Pond and evaporated or infiltrated into the ground.

This infiltration created perched water in the vadose zone and created a groundwater mound on the underlying aquifer. In May 1954, increases in discharge to the S-10 unit necessitated the excavation of two additional ponds on the southeastern side of the 216-S-10 Ditch (i.e., 216-S-11 leach ponds). Wastewater flowed into the 216-S-11 Pond when levels in the 216-S-10 Ditch reached the elevation of the connecting ditch.

The conceptual model assumes that the large volume of wastewater discharged to the S-10 unit during its operational lifetime (6.6 x 10^9 liters) was sufficient to saturate the soil column down to groundwater beneath both the unlined ditch and the pond. Saturated conditions, combined with the fact that many of the contaminants of concern are known to be mobile (because they are anions or are non-charged chemical species), lead to contaminants contained in wastewater discharged to the S-10 unit migrating through the soil column to groundwater. In addition, it is believed that several multi-valent metals (e.g., chromium and copper) were mobile via complexing agents or as oxymetallic anions (e.g., chromate and cuprate) and may have also migrated to the groundwater.

In September 1983, a documented dangerous waste discharge to the S-10 unit occurred (PNNL-15731, *Post-Closure RCRA Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch*). This waste was discharged to the pond and ditch and allowed to percolate into the soil column underlying the unit. In this incident, 416.4 liters of synthetic, double-shell tank slurry were discharged to the S-10 unit from the Chemical Engineering Laboratory. The waste consisted largely of sodium nitrate (46%) and sodium hydroxide (41%), with small quantities of sodium phosphate, sodium fluoride, sodium chloride, and potassium chromate.

6.4.3.1 Constituent List and Sample Frequency

Groundwater is monitored at the S-10 unit in accordance with the *Groundwater Monitoring Plan for the 216-S-10 Pond and Ditch* (PNNL-14070). The network wells are monitored semiannually for the contamination indicator parameters total organic halides, total organic carbon, pH, and specific conductance. Major dissolved anions, metals, phenols, alkalinity, turbidity, and temperature are sampled annually as indicators of sample and analytical quality, as well as general aquifer/well background conditions. Additional groundwater monitoring for gross alpha and gross beta under the AEA is used to track the radionuclides beneath the WMA and surrounding area. Groundwater samples from three of the newly installed wells (699-32-76, 699-33-75, and 699-33-76) were collected quarterly during CY 2009 to obtain data and establish baseline conditions. Appendix C includes a well location map (Figure C-6) and lists of wells and constituents monitored for the S-10 unit (Table C-14). During the reporting period, all groundwater samples were collected as scheduled.

6.4.3.2 Network Evaluation

The declining water table in the 200 West Area has resulted in many wells going dry. Water levels in all of the original wells monitoring the upper aquifer at the S-10 unit have declined below their screened intervals. Prior to 2008, the monitoring network consisted of only two shallow downgradient wells and one deep downgradient well; all former upgradient wells were dry. The RCRA requirements for interim status monitoring specify a minimum of one upgradient and three downgradient monitoring wells for monitoring the site. One new upgradient well (699-33-76) and two new downgradient wells (699-32-76 and 699-33-75) were installed in 2008 as planned. All three wells are screened across the upper portion of the aquifer. These three wells were informally added to the network and underwent

initial quarterly sampling in CY 2009; however, the wells were not used for statistical comparisons during this reporting period. The new wells will be formally added to the monitoring well network (to be used for statistical comparisons) in the revised groundwater monitoring plan, which will be released in early 2010.

Groundwater flow conditions beneath the S-10 unit have varied greatly over the past several decades due to changing wastewater disposal practices on the site. Using the water table map for the 200-UP-1 OU (Figure 6-2) and measured head differences between network wells, the direction of groundwater flow near the S-10 unit is estimated to be to the southeast, which is consistent with flow over the past several years. Using an average hydraulic gradient of 1.33×10^{-3} m/m, a hydraulic conductivity range of 1.5 to 52 meters per day (range of hydrologic testing results), and an assumed effective porosity range of 0.1 to 0.2, the range of average linear velocities is 0.010 to 0.69 meters per day (3.6 to 250 meters per year). Using a best hydraulic conductivity value of 10.4 meters per day (constant-rate discharge test from well 299-W27-2 near the water table [WHC-SD-EN-DP-052, *Borehole Completion Data Package for the 216-S-10 Facility, CY 1992*]) and an assumed effective porosity of 0.15, the best-estimate average linear velocity is 0.092 meters per day (34 meters per year). The rate at which the water table is declining has remained constant at ~0.3 meters per year in all of the monitoring wells during 2009.

With the new wells installed at the 216-S-10 Pond and Ditch, the monitoring well network will be adequate for detecting potential releases from the site.

The revised well network will be evaluated annually to determine if it is adequate to meet the groundwater monitoring needs of the S-10 unit through the post-closure period. Based on the most recent determinations of groundwater flow direction, the revised network will be adequate for detecting potential releases from the S-10 unit in CY 2010.

6.4.3.3 Groundwater Contaminants

As required by RCRA regulations (40 CFR 295.93[b], as referenced by WAC 173-303-400), the required indicator parameters (pH, specific conductance, total organic carbon, and total organic halides) are statistically compared between the upgradient and downgradient wells of the formal monitoring network using the most recent data. However, since the formal network does not include an upgradient well, the most recent data from the former upgradient well 299-W26-7 (before it went dry in 2003) was used to provide background values of contaminant indicator parameters in 2009. At the completion of the CY 2009 monitoring cycle, data from the new upgradient well 699-33-76 will be used to calculate new critical means for use in the required upgradient/downgradient comparisons beginning in CY 2010.

No exceedances of an indicator parameter occurred during 2009 at the 216-S-10 Pond and Ditch, so the site will remain in detection monitoring.

No indicator parameter exceedances occurred during 2009 at the S-10 unit, but several constituents detected in nearby wells are being tracked by the monitoring network. Chromium is being tracked because it is a potential contaminant of concern associated with releases to the S-10 unit. Elevated total chromium concentrations at well 299-W26-7 exceeded the DWS (100 µg/L) before the well went dry. The elevated total chromium may have been caused by short-term releases migrating through the vadose zone from past effluent releases to the pond or from upgradient sources.

Although well 299-W26-7 was designated as an upgradient well, it is located very close to one lobe of the pond system and may have been affected by drainage spreading laterally in the vadose zone or by a mound on the water table when the facility was in operation. Although historical records document that the release in 1983 to the 216-S-10 Ditch contained hexavalent chromium, the assignment of chromium to the S-10 unit is complicated by the fact that a REDOX Plant disposal

pond (located immediately upgradient of the S-10 unit) is also a potential source of chromium contamination. Because the S-10 unit cannot currently be ruled out as the source of the contamination, chromium remains a dangerous waste constituent for the unit. More recently, concentrations of total chromium have been increasing rapidly in well 299-W26-13, downgradient of the 216-S-10 Pond (up to 39 µg/L dissolved total chromium during June 2009). Both total chromium and hexavalent chromium are also measured above the detection limit in new well 699-32-76, which is downgradient of well 299-W26-13 and the 216-S-10 Pond (less than 20 µg/L).

Concentrations of total chromium and hexavalent chromium have been increasing in well 299-W26-13, which is downgradient of the 216-S-10 Pond.

Nitrate concentrations were covariate with chromium concentrations in older network wells 299-W26-7, 299-W26-9, 299-W26-10, and 299-W26-12 before the wells went dry. Upgradient well 299-W26-7 had the highest nitrate concentrations. These and other data presented in PNNL-14070 suggest that the 216-S-10 Pond could be the source of the nitrate and chromium increase. Although chromium and nitrate were elevated in upgradient well 299-W26-7 before the well went dry, substantial concentrations of these constituents have not been detected in downgradient wells. Well 299-W26-13 (which replaced well 299-W26-9 and is located downgradient of the pond) shows the same covariate increases in total chromium; chromium concentrations increased from 28.4 µg/L in January 2008 to 37.9 µg/L in January 2009 at the same time that nitrate increased from 12.2 to 17.2 mg/L. Neither constituent exceeds the DWSs (i.e., 100 µg/L for chromium and 45 mg/L for nitrate). By comparison, chromium in well 299-W26-14 (located away from the pond and centered along the ditch portion of the facility) remains essentially undetected. This difference may indicate a localized source near the pond.

Concentrations of nickel in deep monitoring well 299-W27-2 continued to be significantly higher than in shallow wells during the reporting period. Because nickel has not been detected in the shallow monitoring wells, the S-10 unit is not believed to be the source of this constituent.

Carbon tetrachloride continued to be detected in all wells in the S-10 unit monitoring network. Concentrations in well 299-W27-2 have averaged above the DWS (5 µg/L) since 2001, and the well had a concentration this reporting period of 6.9 µg/L. New well 699-33-75, located near 299-W27-2, has the highest carbon tetrachloride results of any well in the S-10 unit network, with an average concentration of 27.5 µg/L during the reporting period. Chloroform is also detected in this well at concentrations averaging ~1.3 µg/L. The source of these constituents is believed to be liquid waste disposal sites at the Plutonium Finishing Plant. New upgradient well 699-33-76 also has measurable concentrations of carbon tetrachloride (average of 3.9 µg/L), supporting the assertion of an upgradient source.

6.4.3.4 Compliance Status

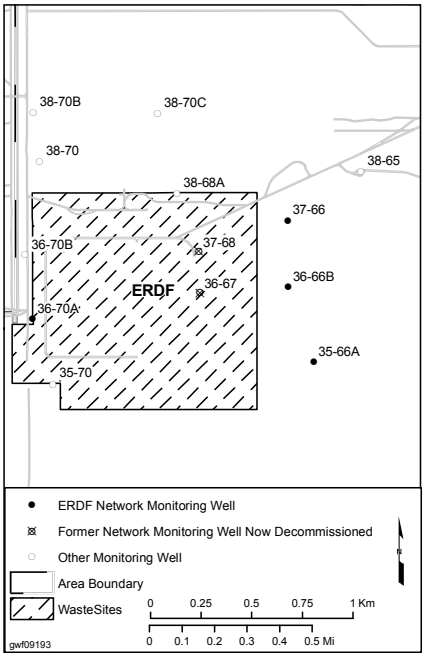
The monitoring well network is sufficient for determining the hydraulic gradient, which allows for distinguishing between upgradient and downgradient wells and performing the required statistical comparisons.

Required statistical evaluations of the RCRA contamination indicator have been conducted since 1992, immediately after background values were established. Since then, background values have been revised several times to reflect the changes in site conditions (e.g., wells that are dry). The most recent collected background values of listed contaminant indicator parameters are from well 299-W26-7 before it went dry in 2003. The completion of four quarters of RCRA-compliant data collected from the new upgradient well occurred in CY 2009. Thus, new background values will be calculated for use in CY 2010 for the required upgradient/downgradient comparisons.

To date, no dangerous waste subject to WAC 173-303 from the S-10 unit has affected groundwater quality in the uppermost aquifer beneath the unit. Therefore, the site remains in detection monitoring for indicator parameters, as specified in 40 CFR 265.93(b). The current monitoring plan (including the well network, constituents of concern, sampling and analysis procedure, and a conceptual model), as detailed in PNNL-13047, is being revised and is scheduled to be completed in early CY 2010.

6.4.4 Environmental Restoration Disposal Facility

R. L. Weiss



The ERDF is a low-level radioactive mixed waste facility used for disposal of waste from surface remedial actions on the Hanford Site. The location of the ERDF is shown in Figure 6-1. Groundwater monitoring is regulated under a CERCLA Record of Decision (EPA/ROD/R10-95/110), which states that groundwater monitoring will be conducted in accordance with RCRA regulations. The site was designed to meet RCRA standards, although it is not actually permitted as a RCRA facility. The ERDF began operation in July 1996. During CY 2009, ~635,000 tons of remediation waste were disposed at the facility.

6.4.4.1 Leachate Monitoring

In 2009, *Groundwater and Leachate Monitoring and Sampling at the ERDF, CY 2008* (WCH-315) was published. This section provides a summary of the leachate monitoring described in WCH-315 and any impact the vadose zone might have on groundwater. The groundwater monitoring results for 2009 are discussed in Section 6.4.4.2.

The ERDF currently operates six disposal cells. Each disposal cell was constructed with a double-liner system to collect leachate from natural precipitation and water added as a dust suppressant. The collected leachate is sent to the ETF. The liners deliver the leachate to sumps beneath the cells where the leachate is sampled. Composite samples of leachate were collected in June and December 2008 from the sumps associated with the upper liners of cells 1 through 6. The samples were analyzed for selected metals, anions, selected organic compounds, total dissolved solids, gross alpha, gross beta, and selected radionuclides. Sampling in December 2008 included an expanded list of analytes (primarily for organic compounds) specified to be performed every 2 years. This expanded list is required to ensure that delisting criteria (necessary for the disposal path to the ETF) continue to be met. The analyses provide data for leachate delisting analyses and to assess whether additional analytes should be added to the routine ERDF groundwater monitoring program.

The results of leachate monitoring at the ERDF for 2008 indicated that no additional analytes need to be added to the groundwater monitoring program.

The composite leachate samples contained detectable concentrations of common metals, anions, and mobile radionuclides. Constituents generally increasing in concentration include gross alpha and uranium. Evaluation of the reported constituents for the expanded analyte lists found no impact to the delisting criteria. The following is a summary of the analytes discussed in WCH-315:

- Bromide, which had been detected in recent years, was not detected in leachate samples in CY 2008.
- Chromium concentrations began declining during CY 2007. The chromium

concentration averaged 29 µg/L in December 2006, but the 2008 average was less than 20 µg/L.

- Potassium concentrations were steady at ~26,000 µg/L through December 2008.
- Uranium concentrations, which have increased over the previous 3 years, reached a new maximum concentration of 2,820 µg/L in December 2008.
- Nitrate concentrations remained steady in CY 2008, averaging ~380 mg/L.
- Specific conductance remained steady during CY 2008.
- Total dissolved solids, which had been increasing throughout 2006, remained steady during CY 2008, averaging ~2,100,000 µg/L.
- Gross-alpha concentrations continued to increase, reaching a new maximum concentration of 3,380 pCi/L in December 2008.
- Gross-beta concentrations, which had been increasing through CY 2006, remained steady in 2007 and then reached a new maximum concentration of 1,500 pCi/L in December 2008.

Gross alpha and gross beta in groundwater will be closely monitored in the future. However, based on the CY 2008 leachate concentrations, no additional analytes were recommended for the groundwater monitoring program.

6.4.4.2 Groundwater Monitoring

This section summarizes the 2009 groundwater monitoring results at the ERDF, which will be described more fully in the upcoming ERDF 2009 annual groundwater and leachate monitoring report. The groundwater flow direction beneath the ERDF is toward the east-northeast (Figure 6-2). During 2008, former downgradient wells 699-36-67 and 699-37-68 were decommissioned to allow for expansion of ERDF to the east, and two new downgradient wells (699-37-66 and 699-36-66B) were constructed as replacements.

Groundwater at the ERDF is monitored in accordance with the *Groundwater Protection Plan for the Environmental Restoration Disposal Facility* (WCH-198). One upgradient well (699-36-70A) and three downgradient wells (699-37-66, 699-36-66B, and 699-35-66A) are sampled semiannually, typically in March and September. All monitoring wells were sampled as planned during the reporting period. Appendix C includes a well location map (Figure C-21) and lists of the wells and constituents monitored for the ERDF (Table C-39).

The results of groundwater monitoring at the ERDF continued to indicate that the facility has not adversely affected groundwater quality.

The results of groundwater monitoring at the ERDF continued to indicate that the facility has not adversely affected groundwater quality. Several constituents (tritium, iodine-129, nitrate, and carbon tetrachloride) are present in the groundwater near or above DWSs, but these constituents are elevated in both the upgradient and downgradient wells. Figure 7-3 in Chapter 7.0, and Figures 6-7, 6-8, and 6-9 in this chapter indicate that these plumes originated in the 200 West Area and have migrated toward the ERDF.

Both filtered and unfiltered samples are collected for metals (except for uranium analyses, which are performed on unfiltered samples only). None of the sampling results were significantly out of trend during 2009. To better establish new trending information for the replacement wells, these wells were sampled in June 2008 and December 2008, in addition to regular semiannual sampling. Except as noted below, contaminant concentrations in the replacement wells were similar to the results from the recently decommissioned wells or bounded by the sampling results from wells 699-36-70A and 699-35-66A.

The uranium concentrations in wells 699-36-70A and 699-35-66A are consistent with Hanford Site background levels. Both technetium-99 and gross beta are trending downward in upgradient well 699-36-70A. The technetium-99 concentration is an order of magnitude below the DWS (900 pCi/L), and gross beta is approximately one-half the DWS (50 pCi/L). Previous indications that technetium-99 activities may have peaked in downgradient well 699-35-66A in FY 2007 were not confirmed. The CY 2009 values exceeded the CY 2007 maximum for this well. Nitrate levels are decreasing in upgradient well 699-36-70A and downgradient well 699-36-66B, but the levels remain stable in downgradient wells 699-37-66 and 699-35-66A. These trends will continue to be monitored.

Barium results for new downgradient well 699-37-66 remain greater than in the other monitoring wells but are below the maximum concentrations encountered early in the monitoring program. Nitrate concentrations in this well remained more than twice the concentrations observed in the other monitoring wells and near the highest concentrations encountered in the monitoring program. However, these values are below the 226 mg/L tolerance limit established in the monitoring plan (WCH-198) and appear to be trending downward.

In the previous annual report (DOE/RL-2008-66), it was noted that concentrations reported by the ion chromatographic method for nitrate/nitrite were not consistent with results from the colorimetric method, with some colorimetric analyses reporting lower values. This issue has been resolved, and no new analytical issues were identified during the CY 2009 sampling.

6.5 Conclusions and Recommendations

Within the 200-UP-1 groundwater interest area, groundwater monitoring is conducted under CERCLA to track contaminants throughout the OU, to assess potential impact to groundwater from the ERDF, and to monitor the performance of the 200-UP-1 pump-and-treat system. Interim status groundwater quality assessment monitoring under RCRA is conducted at WMA S-SX and WMA U, and interim status indicator parameter evaluation monitoring is conducted at the S-10 unit. Monitoring of radionuclides at the RCRA sites is conducted under CERCLA and the AEA.

Within the OU, technetium-99, uranium, tritium, iodine-129, nitrate, and carbon tetrachloride are the contaminants of greatest significance in groundwater and form extensive plumes within the region. Groundwater plumes of tritium, nitrate, and iodine-129 that originated from ponds and cribs are dispersing naturally, whereas plumes originating from the tank farms are generally growing in areal extent and exhibit increasing concentrations. The carbon tetrachloride plume has migrated into the 200-UP-1 OU from the adjacent 200-ZP-1 OU. Groundwater flow in the unconfined aquifer is primarily to the east within the interest area, and the water table declined by an average of 0.31 meters between March 2008 and March 2009.

An interim action pump-and-treat system continued to operate on the uranium and technetium-99 plumes downgradient from the 216-U-1/2 Cribs. During the reporting period, an explanation of significant differences was released (EPA et al. 2009) that modified the interim action Record of Decision (EPA/ROD/R10-97/048) by reducing the uranium remedial action objective from 480 µg/L to 300 µg/L. Within the baseline plume area (i.e., the area targeted for remediation under the interim action), all technetium-99 sample results were below the 9,000 pCi/L remedial action objective throughout the reporting period, and all uranium sample results were

below the 300 µg/L remedial action objective by the end of the reporting period. The highest uranium concentrations downgradient from the 216-U-1/2 Cribs occurred at well 299-W19-18 (average of 412 µg/L), which is located upgradient of the baseline plume area.

At WMA S-SX, concentrations of the mobile tank waste constituents in well 299-W22-44 (downgradient of the S Tank Farm) increased during the reporting period, with maximum values of 280 mg/L for nitrate, 668 µg/L for chromium, and 20,000 pCi/L for technetium-99. At well 299-W23-19 (near the source of the SX Tank Farm plume), concentrations of the mobile tank waste constituents also increased during the reporting period, with maximum values of 540 mg/L for nitrate; 1,020 µg/L for chromium; and 75,000 pCi/L for technetium-99. All of the WMA S-SX monitoring wells were sampled for selenium-79. This constituent was detected in nine of the twenty network wells, with concentrations ranging from 5.5 to 311 pCi/L; the maximum concentration occurred in well 299-W23-19. These values are well below the 20,000 pCi/L DOE derived concentration guide and the 800 pCi/L, 4 mrem dose equivalent.

The results of monitoring at WMA U, the S-10 unit, and the ERDF were similar to those of previous years. Results for WMA U continued to indicate that technetium-99 concentrations are the highest in the northern wells and nitrate concentrations are higher in the southern wells. This suggests two different sources for these constituents within the WMA. There were no exceedances of an indicator parameter during the reporting period at the S-10 unit. The new upgradient well (699-33-76) and two new downgradient wells (699-32-76 and 699-33-75) installed in 2008 will be used for statistical evaluations in CY 2010. Sampling results at the ERDF have continued to indicate that the facility has not affected groundwater quality.

Table 6-1. 200-UP-1 Treatment System Summary.

Total hours in the reporting period	10,992
Scheduled outages (hours)	3,588
Total time online (hours)	7,404
Total processed groundwater:	
Total groundwater processed in reporting period (millions of liters)	12.5
Total groundwater processed since startup (March 1994) (millions of liters)	881.4
Summary of fiscal year 2008 operational parameters:	
Removal efficiency % by mass for uranium, average for year – [(influent – effluent) / (influent)] x 100	99.9%

Table 6-2. 200-UP-1 Pump-and-Treat System Volume of Groundwater Treated and Mass of Contaminants Removed During Calendar Year 2009 and Since Startup of Operation.

Reporting Period	Liters Treated	Mass Technetium-99 Removed (g)	Mass Total Uranium Removed (g)	Mass Carbon Tetrachloride Removed (g)	Mass Nitrate Removed (kg)
October 1 through December 31, 2008	2,115,130	0.58	608	552	1,132
January 1 through March 31, 2009	3,668,017	0.64	911	668	1,805
April 1 through June 30, 2009	3,059,143	0.56	703	601	1,469
July 1 through September 30, 2009	3,066,717	0.61	639	660	1,399
October 1 through December 31, 2009	550,960	0.10	118	102	238
Reporting period totals	12,459,967	2.49 g (0.00249 kg)	2,979 g (2.979 kg)	2,584 g (2.584 kg)	6,044 kg
Previous reporting period totals (fiscal year 2008)	13,463,380	4.53 g (0.00453 kg)	3,470 g (3.470 kg)	3,024 g (3.024 kg)	6,415 kg
Totals since startup of operations	881,360,762	126.1 g (0.1 kg)	219,489 g (219.5 kg)	40,329 g (40.3 kg)	47,575 kg

Table 6-3. Quantity of Treated Groundwater and Technetium-99 Mass Removed from the Aquifer During Extended Purging at Well 299-W23-19.

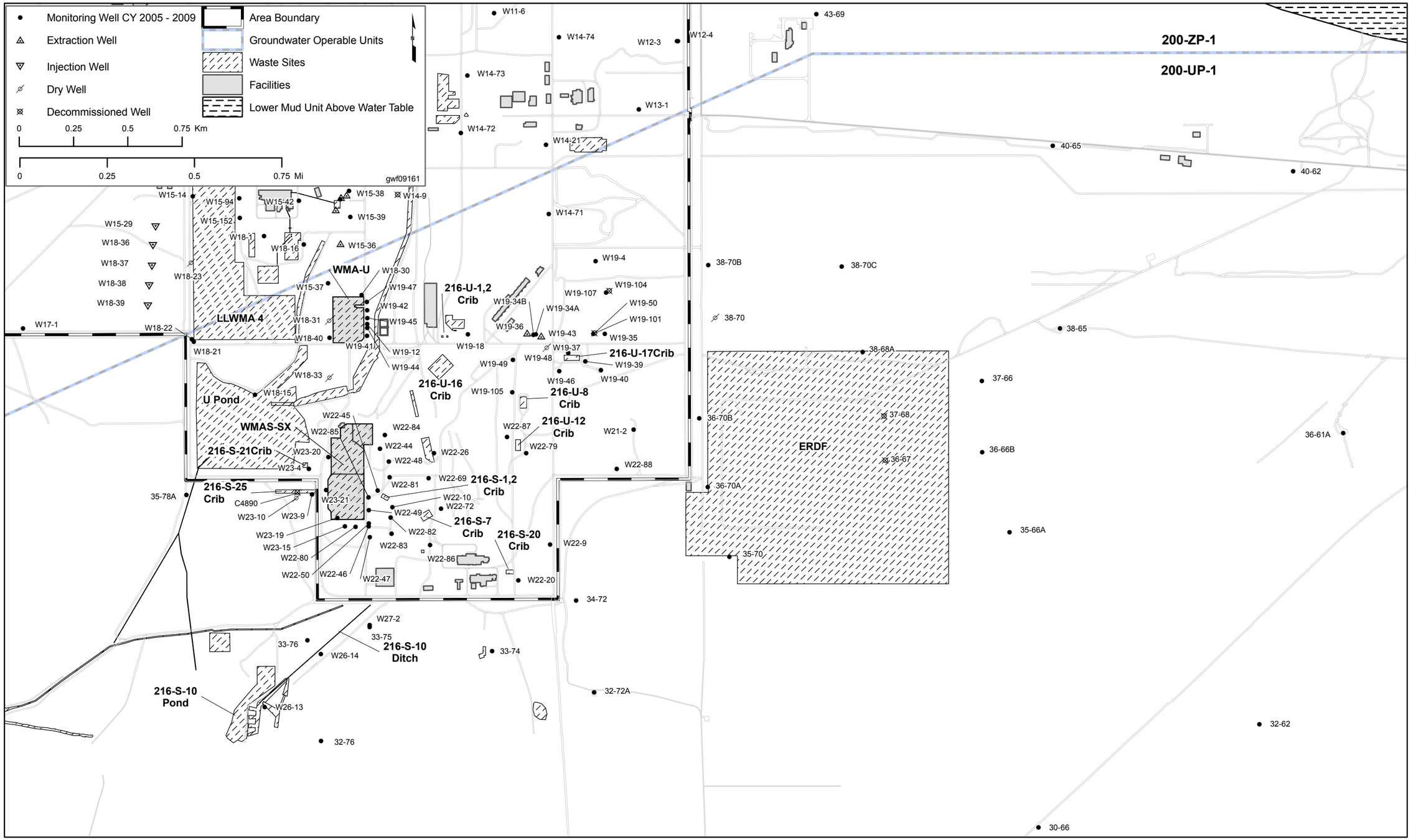
Sample Date	Volume of Water Treated L (gal)	Technetium-99 Concentration (pCi/L)	Activity of Technetium-99 Removed (Ci)	Mass of Technetium-99 Removed (g)
1/6/2009	5,708 (1,508)	52,000	3.0×10^{-4}	0.017
4/1/2009	6,359 (1,680)	71,500	4.5×10^{-4}	0.027
6/17/2009	5,648 (1,492)	75,000	4.2×10^{-4}	0.025
8/27/2009	6,814 (1,800)	54,000	3.7×10^{-4}	0.022
12/7/2009	6,057 (1,600)	69,000	4.2×10^{-4}	0.025
Totals	**30,586 (8,080)**	**N/A**	**2.0×10^{-3}**	**0.116**
Totals since startup*	**134,469 (35,524)**	**N/A**	**8.4×10^{-3}**	**0.495**

Notes:
* Totals for all quarterly events since startup of extended purging in March 2003.

N/A = not applicable

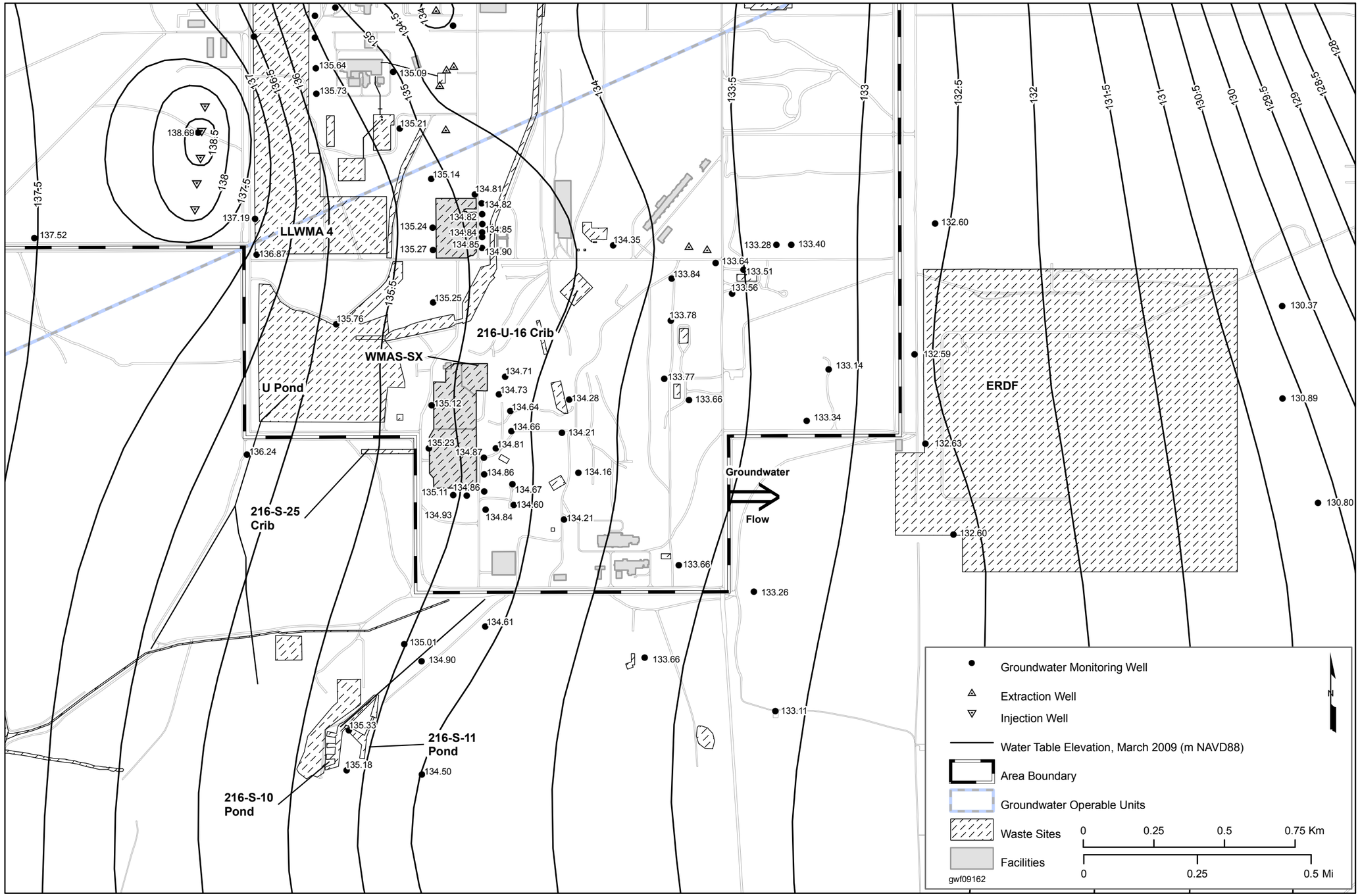
This page intentionally left blank.

Figure 6-1. Facilities and Groundwater Monitoring Wells in the 200-UP-1 Groundwater Interest Area.



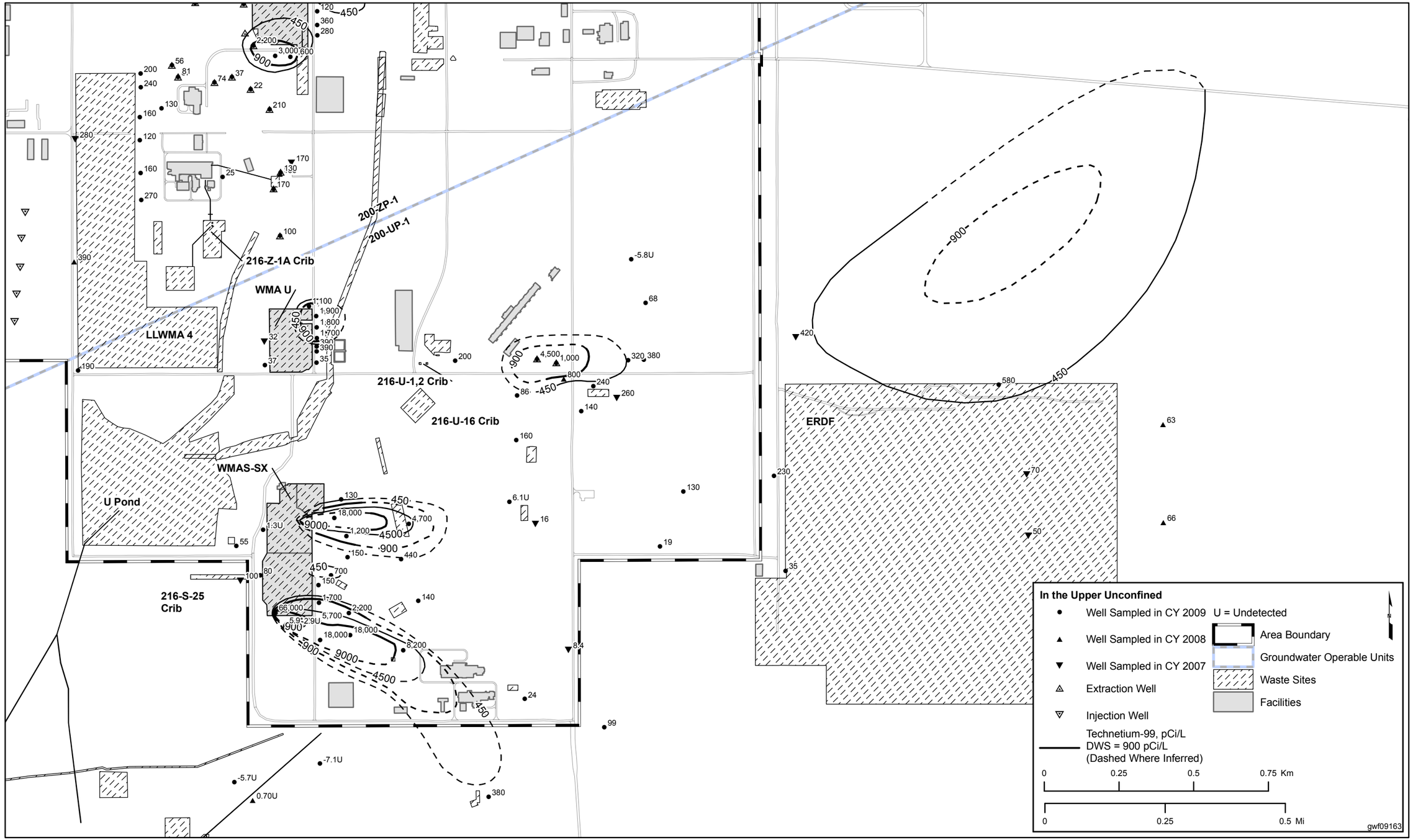
This page intentionally left blank.

Figure 6-2. Water Table Map for the 200-UP-1 Groundwater Interest Area, March 2009.



This page intentionally left blank.

Figure 6-3. Average Technetium-99 Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer.



This page intentionally left blank.

Figure 6-4. Chromium and Technetium-99 Concentrations in Well 299-W23-19, Southern Portion of Waste Management Area S-SX.

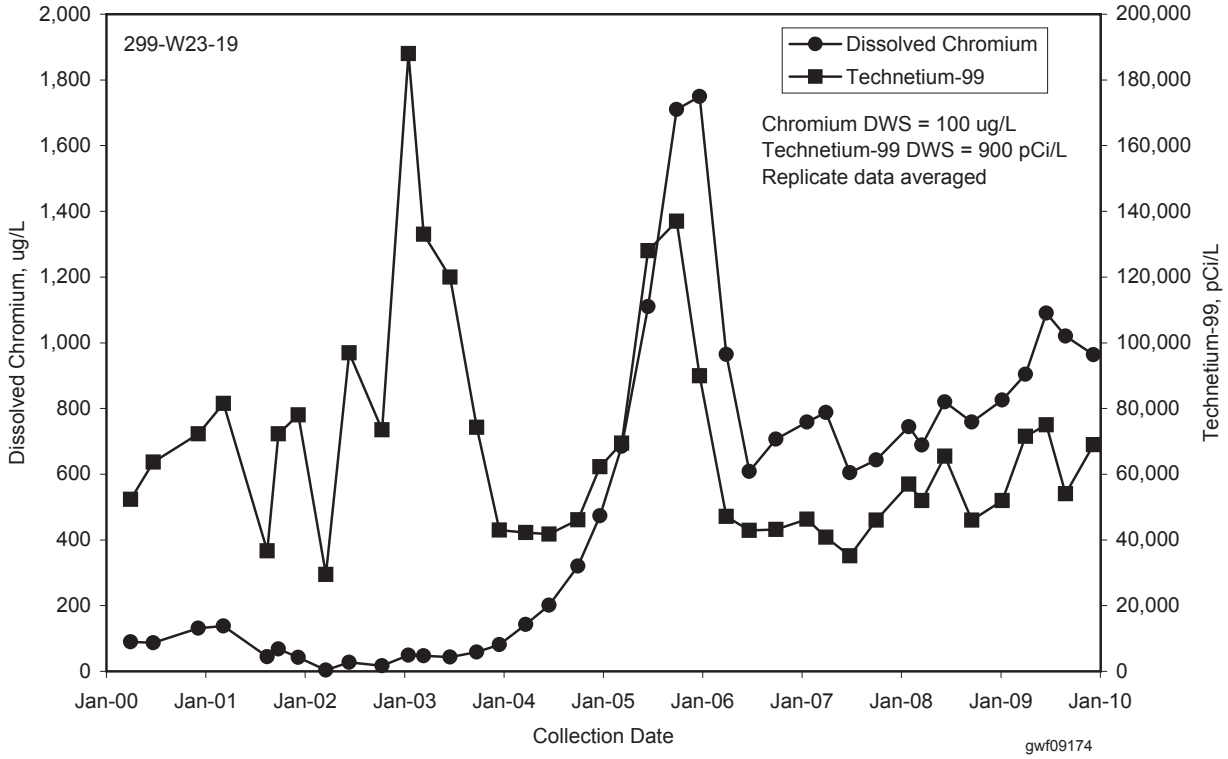
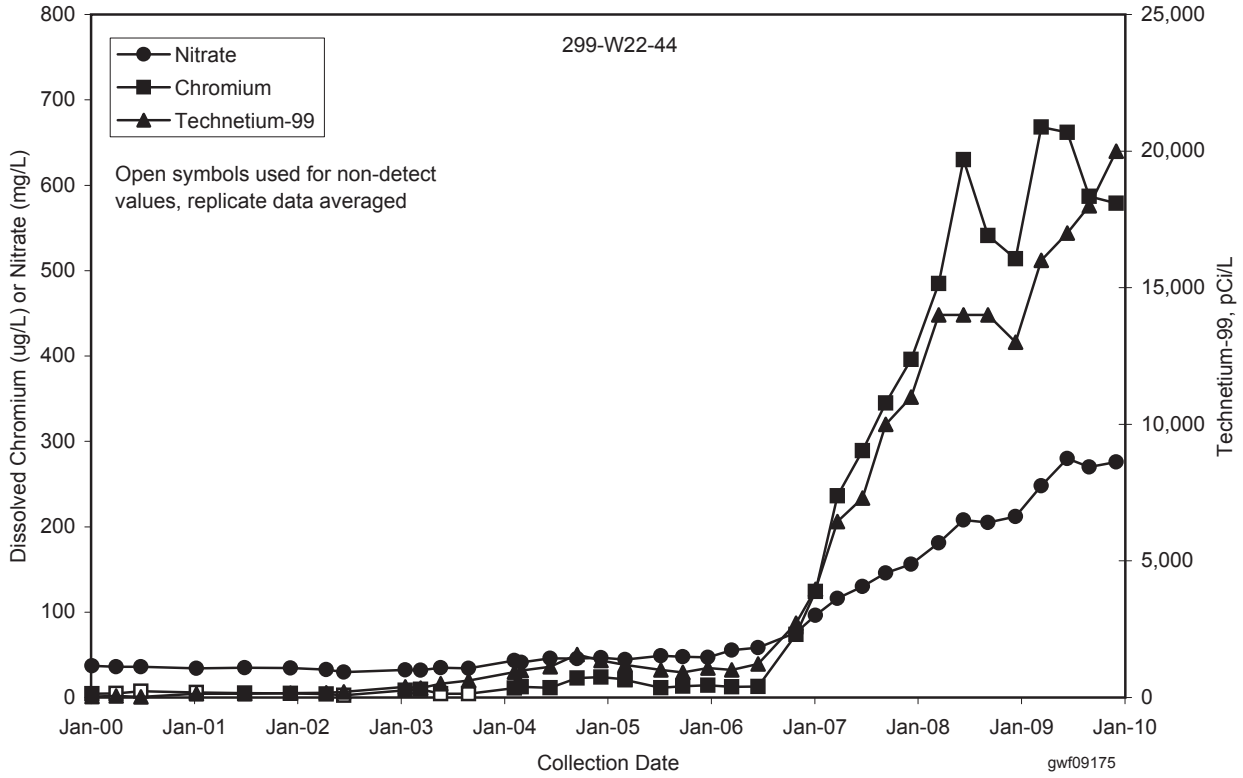


Figure 6-5. Nitrate, Chromium, and Technetium-99 Concentrations Downgradient from S Tank Farm.



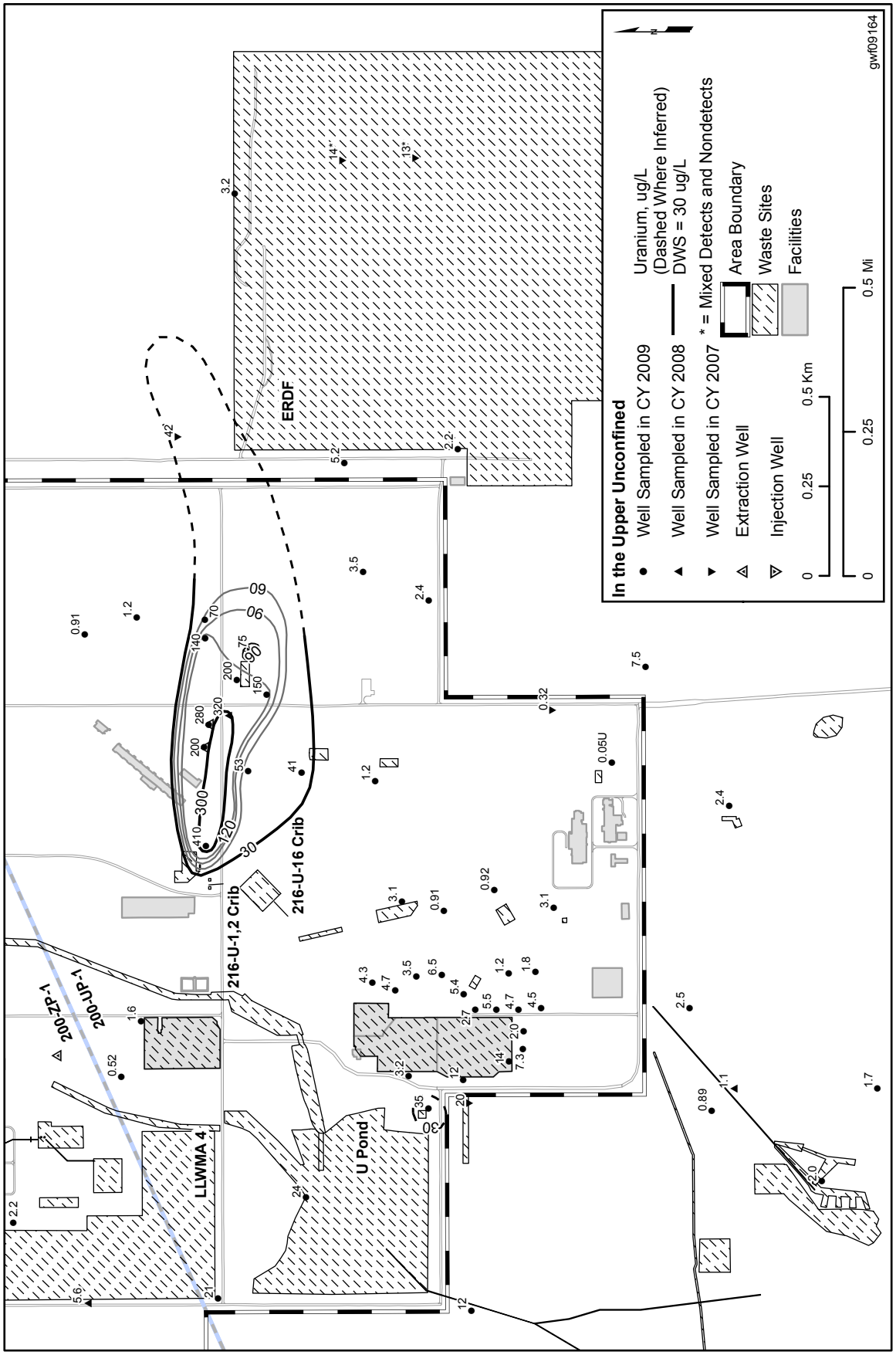
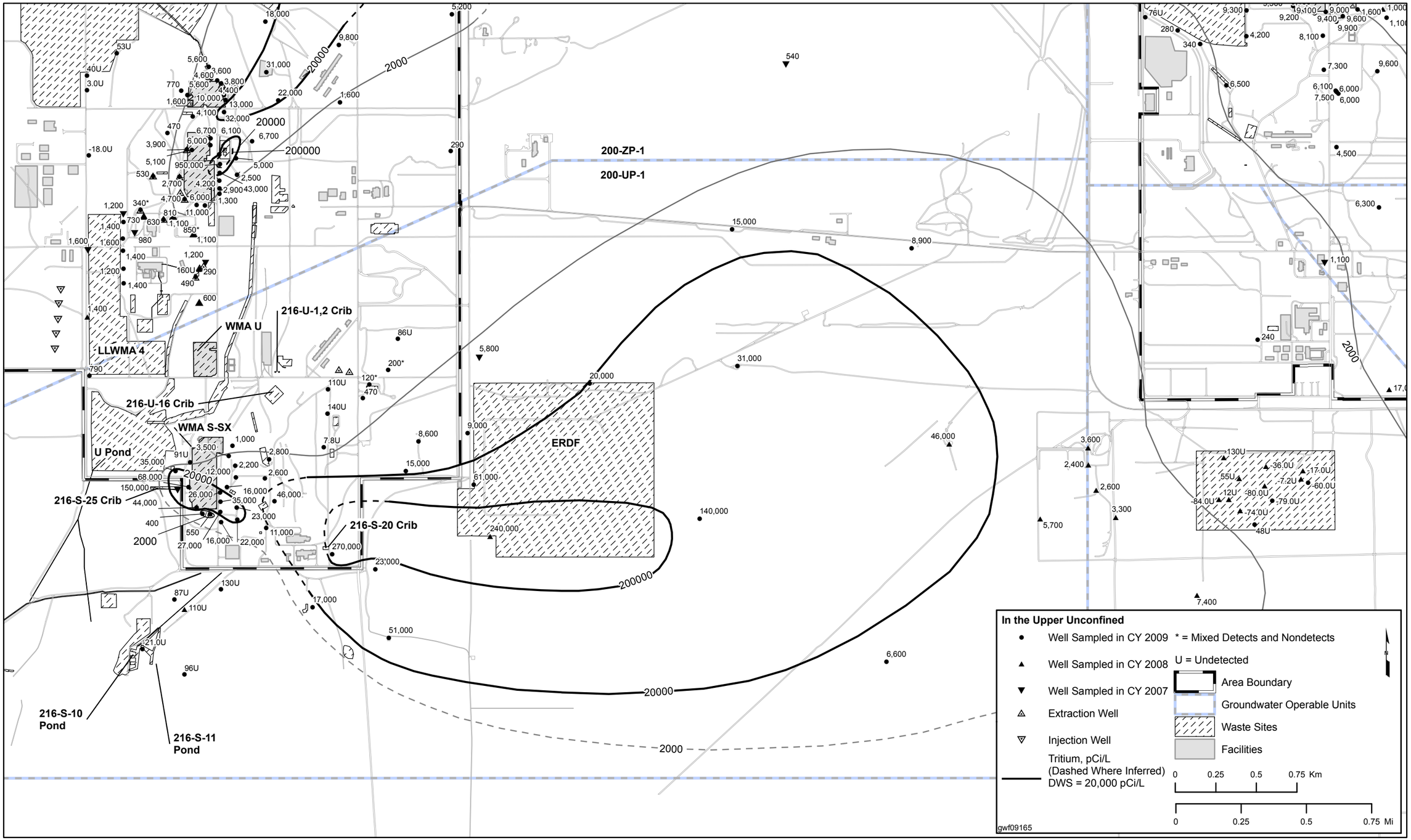


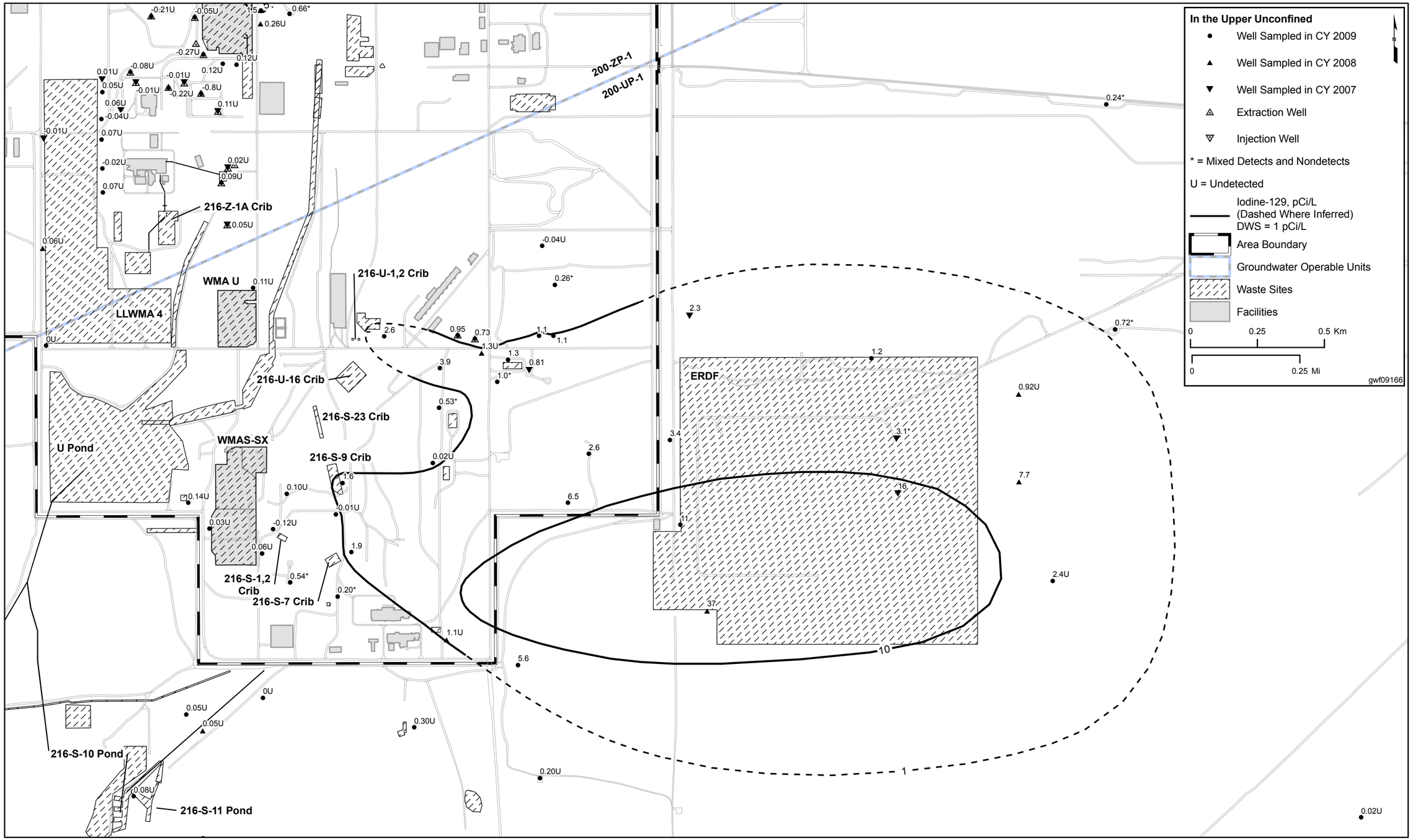
Figure 6-6. Average Uranium Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer.

Figure 6-7. Average Tritium Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer.



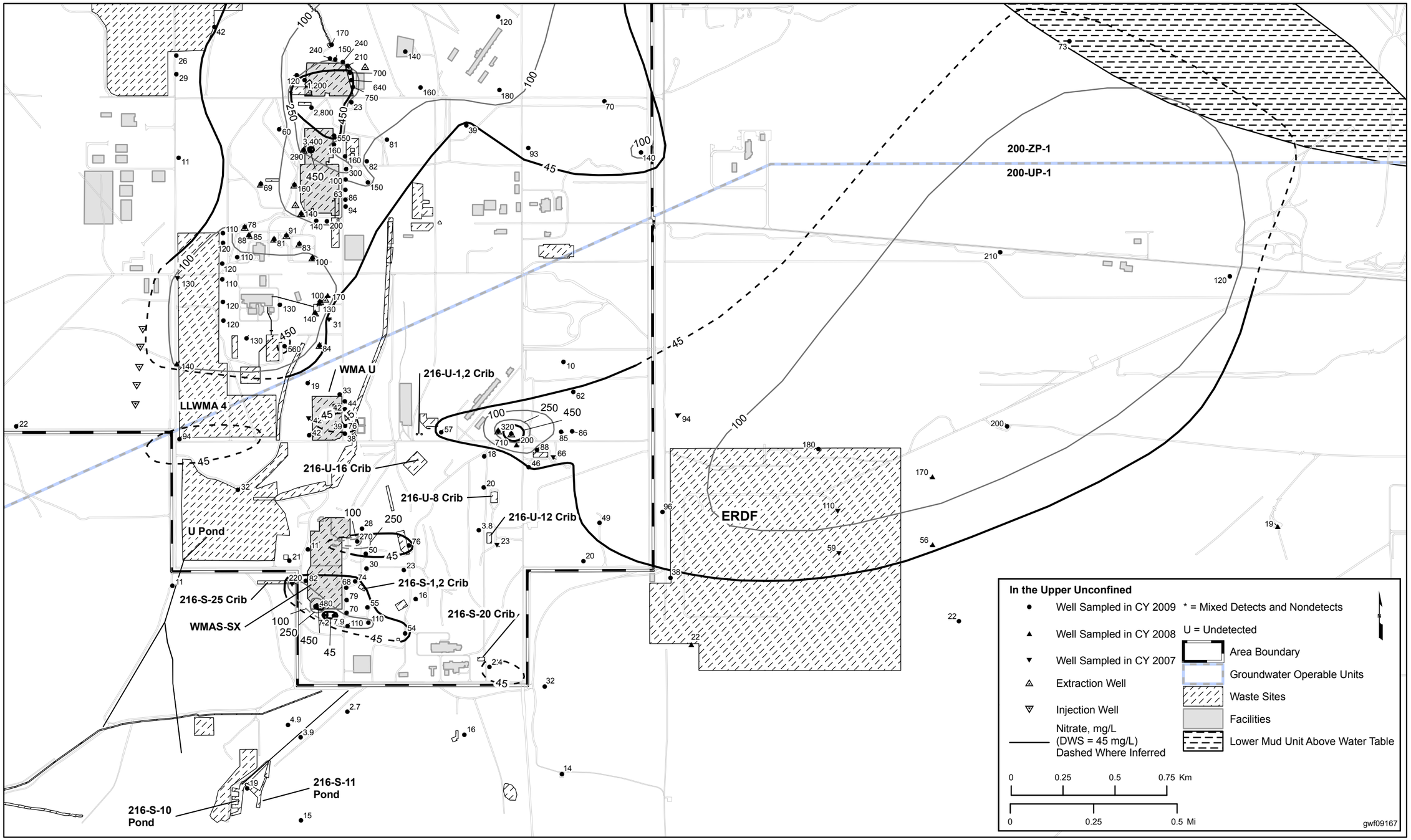
This page intentionally left blank.

Figure 6-8. Average Iodine-129 Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer.



This page intentionally left blank.

Figure 6-9. Average Nitrate Concentrations in the 200-UP-1 Groundwater Interest Area, Upper Portion of Unconfined Aquifer.



This page intentionally left blank.

Figure 6-10. Nitrate Concentrations in the 200-UP-1 Pump-and-Treat System Extraction Wells.

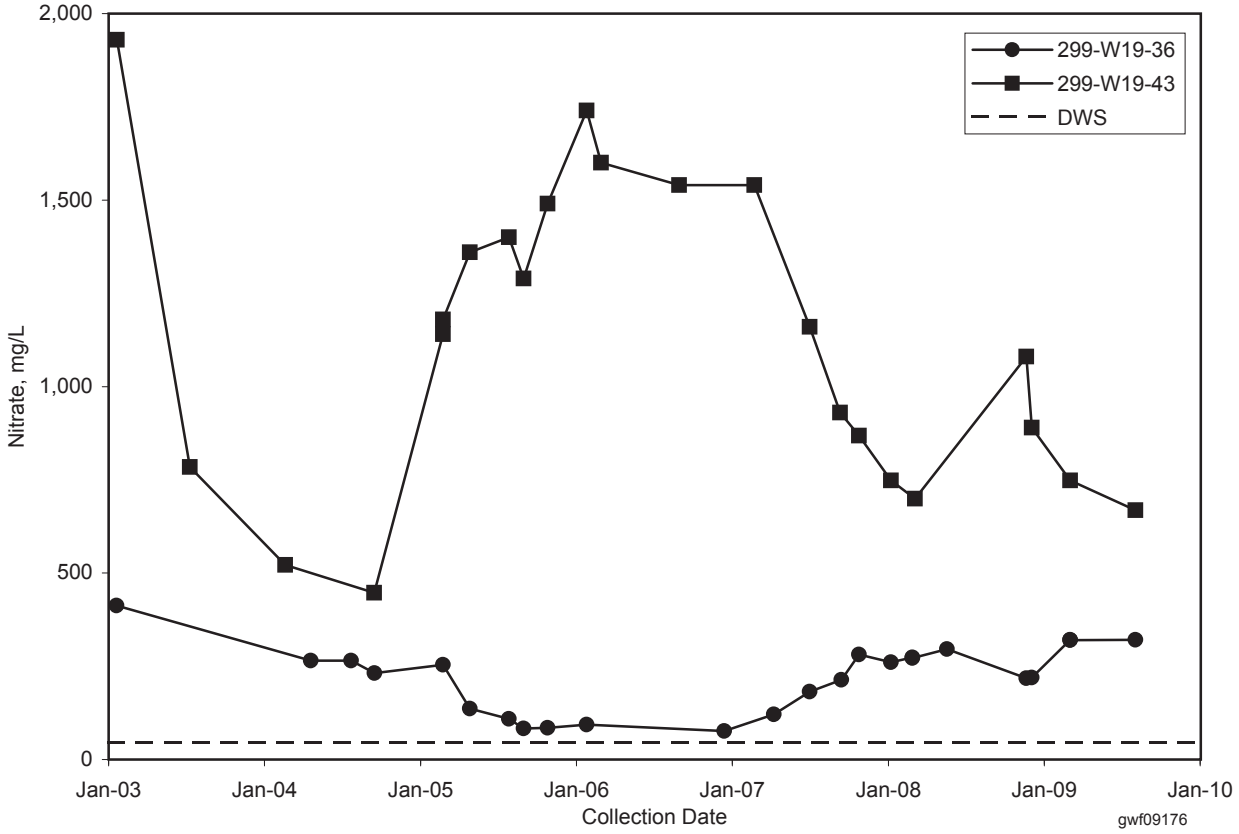


Figure 6-11. 200-UP-1 Pump-and-Treat System Location Map and Monitoring Wells.

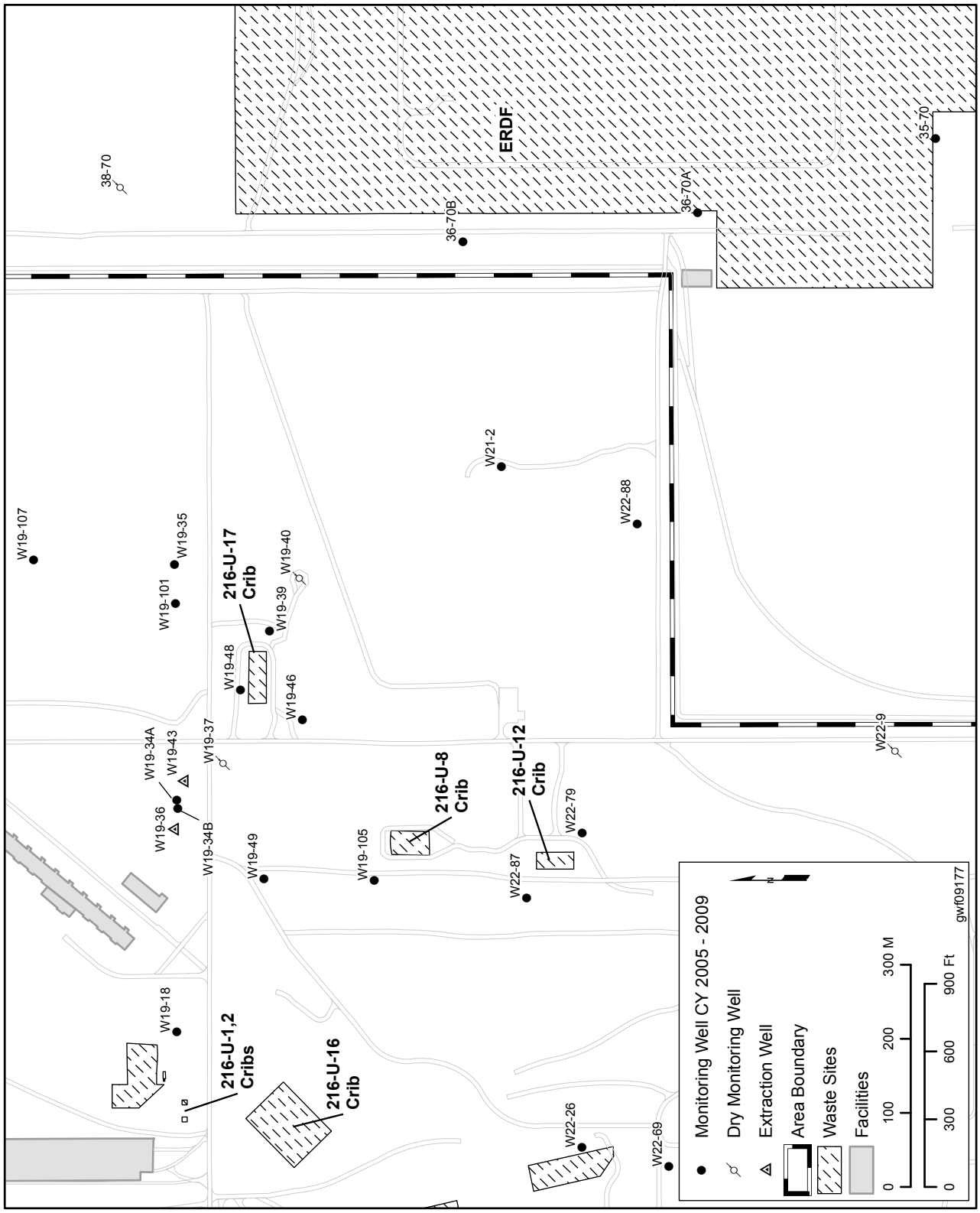


Figure 6-12. 200-UP-1 Extraction Well On-Line Operational Percentages and Hours of Operation.

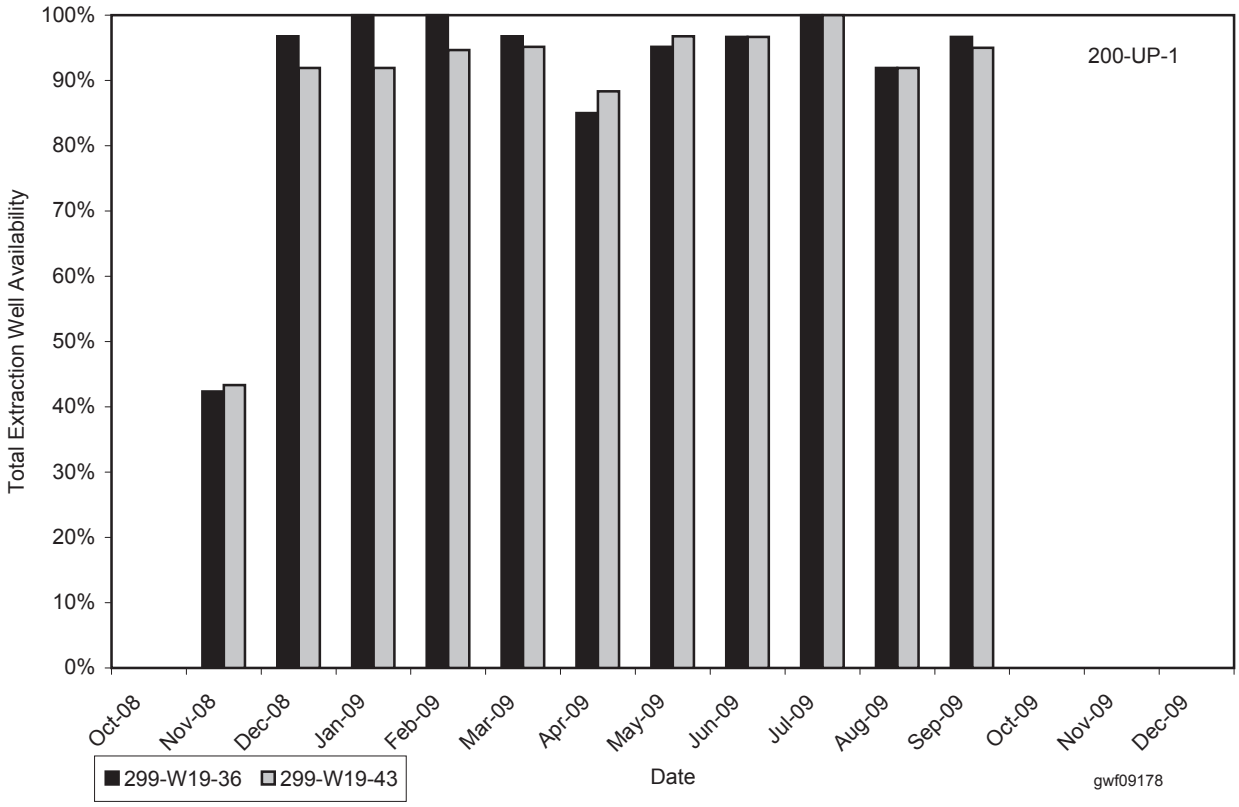
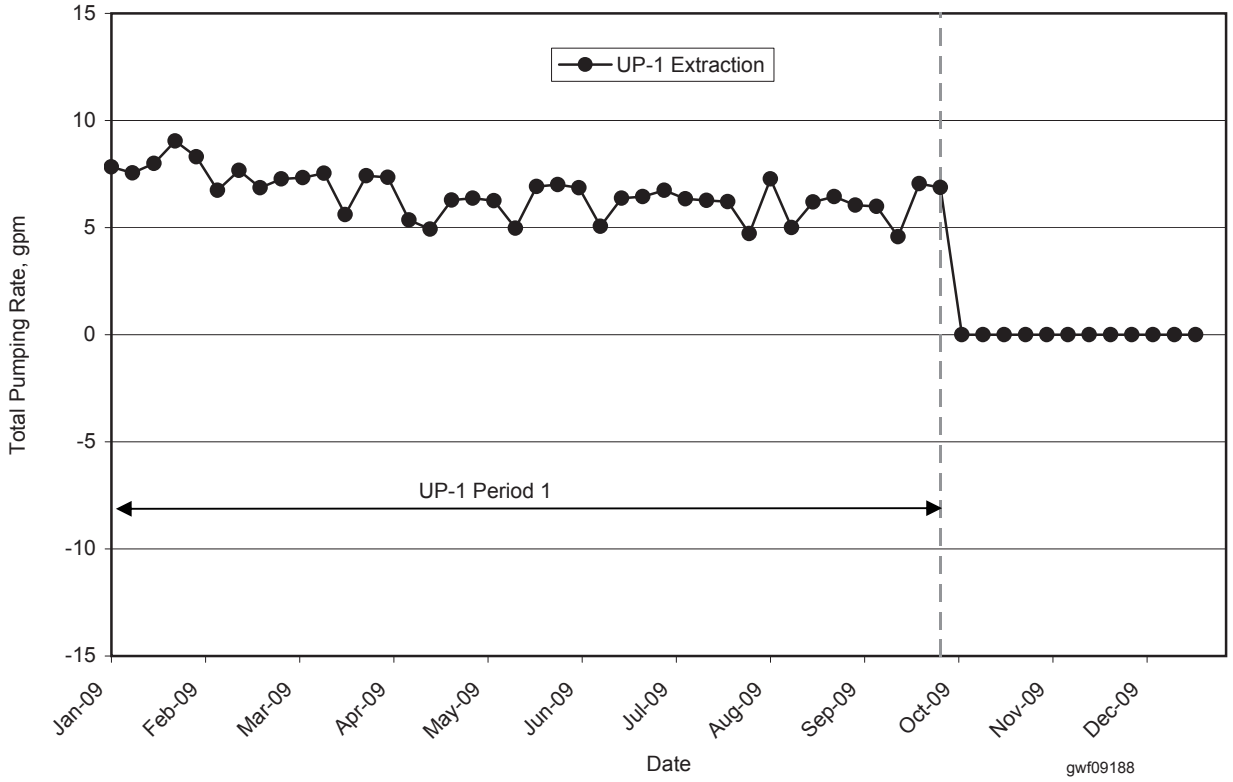


Figure 6-13. Pumping Rates and Periods for the 200-ZP-1, 200-UP-1, and WMA T Tank Farm Pump-and-Treat Systems.



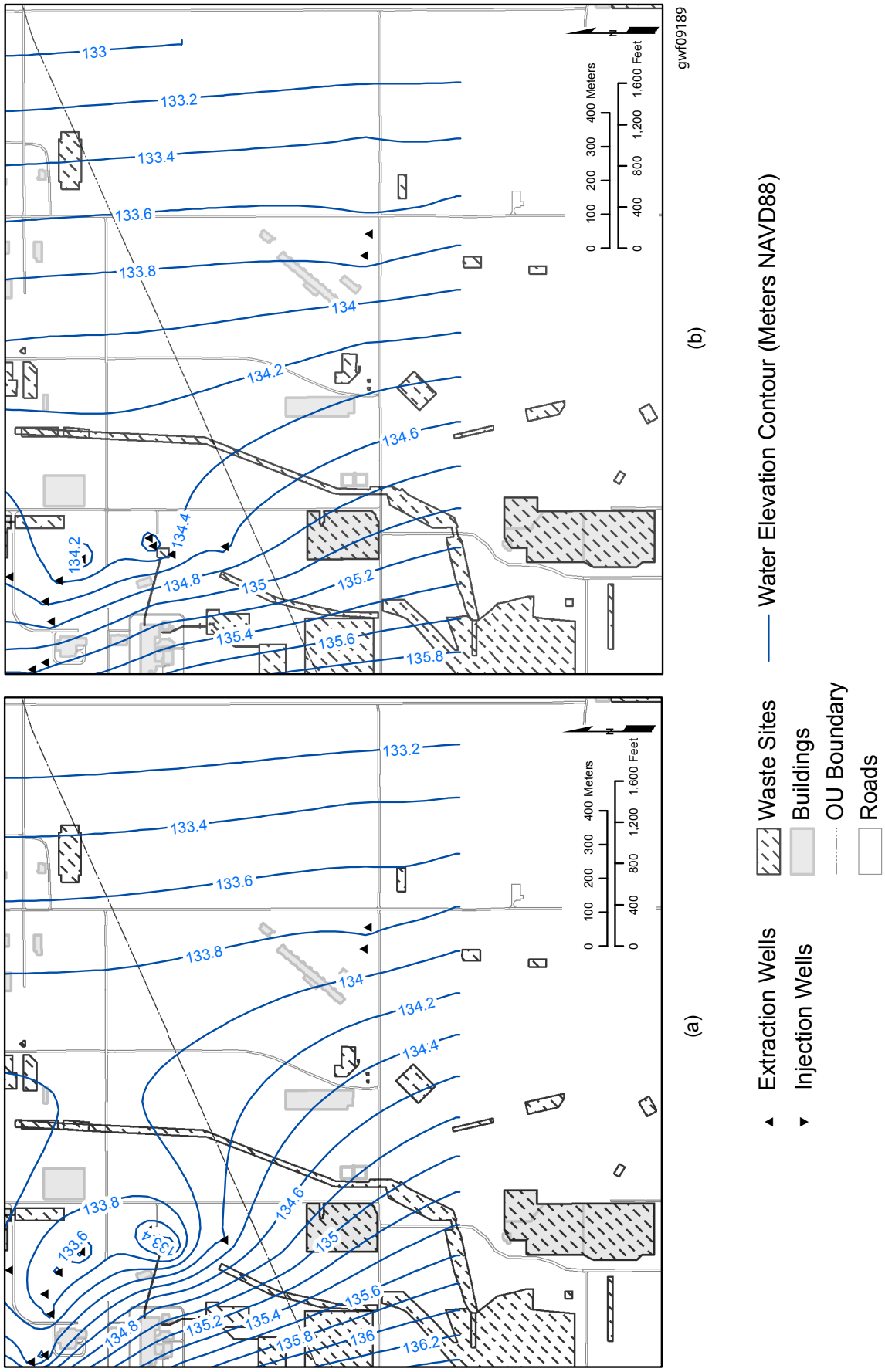


Figure 6-14. Example Water Table Elevation Contours Throughout the 200 West Area (a) March 19, 2009 and (b) August 6, 2009.

Figure 6-15. 200-UP-1 Pump-and-Treat System Capture Frequency, Calendar Year 2009.

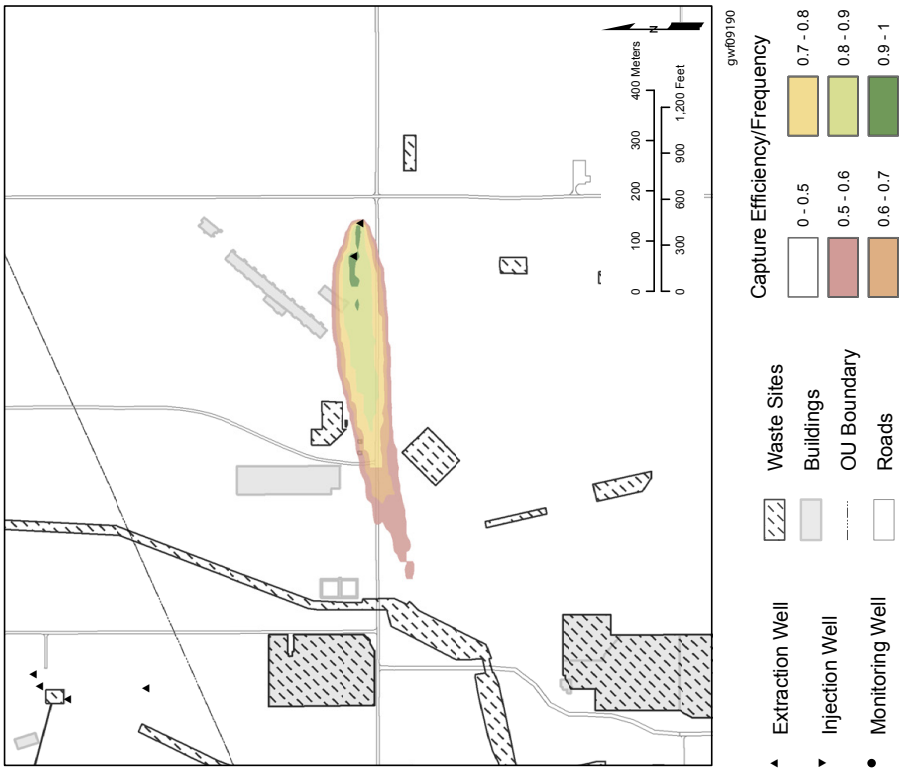


Figure 6-16. 200-UP-1 Pump-and-Treat System Capture Frequency, Calendar Year 2009, with Technetium 99 Plume Contours.

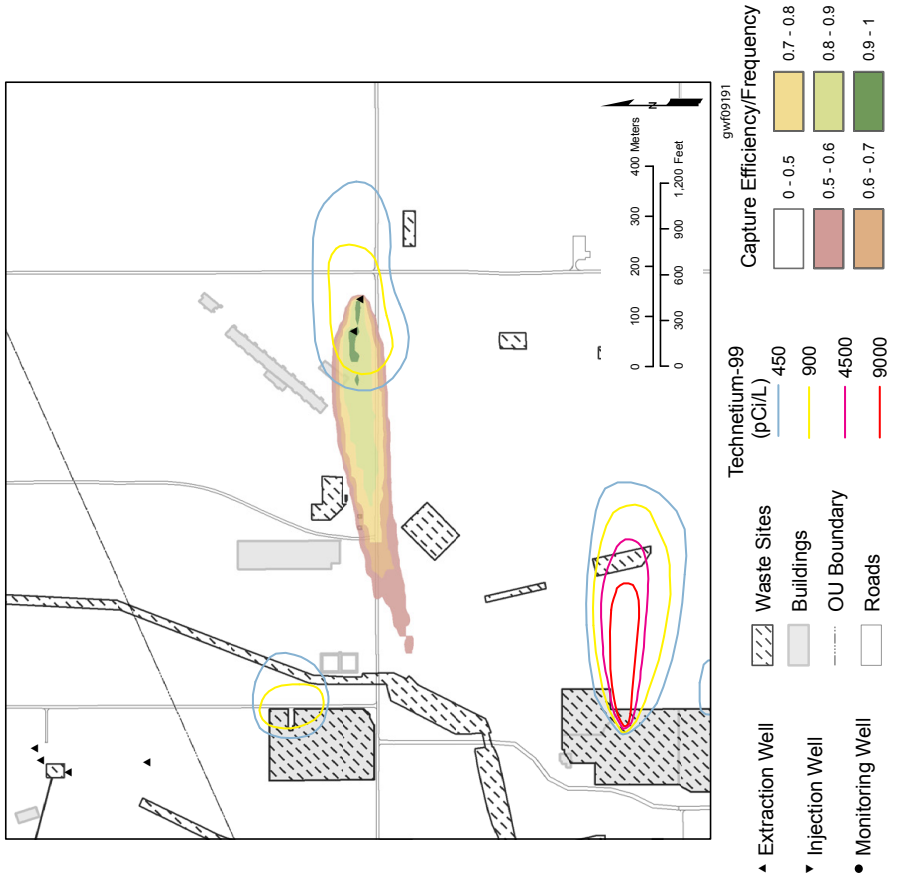


Figure 6-17. Uranium Concentrations in the 200-UP-1 Pump-and-Treat System Wells.

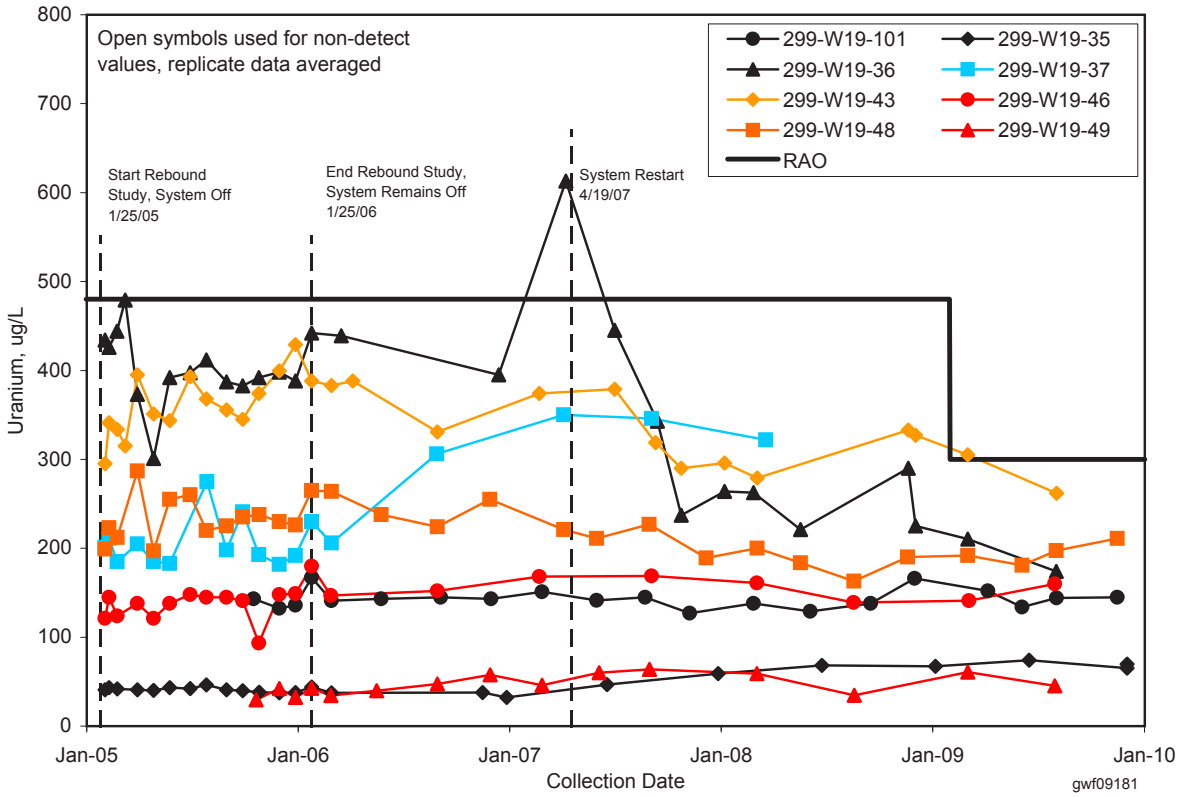


Figure 6-18. Technetium-99 Concentrations in the 200-UP-1 Pump-and-Treat System Wells.

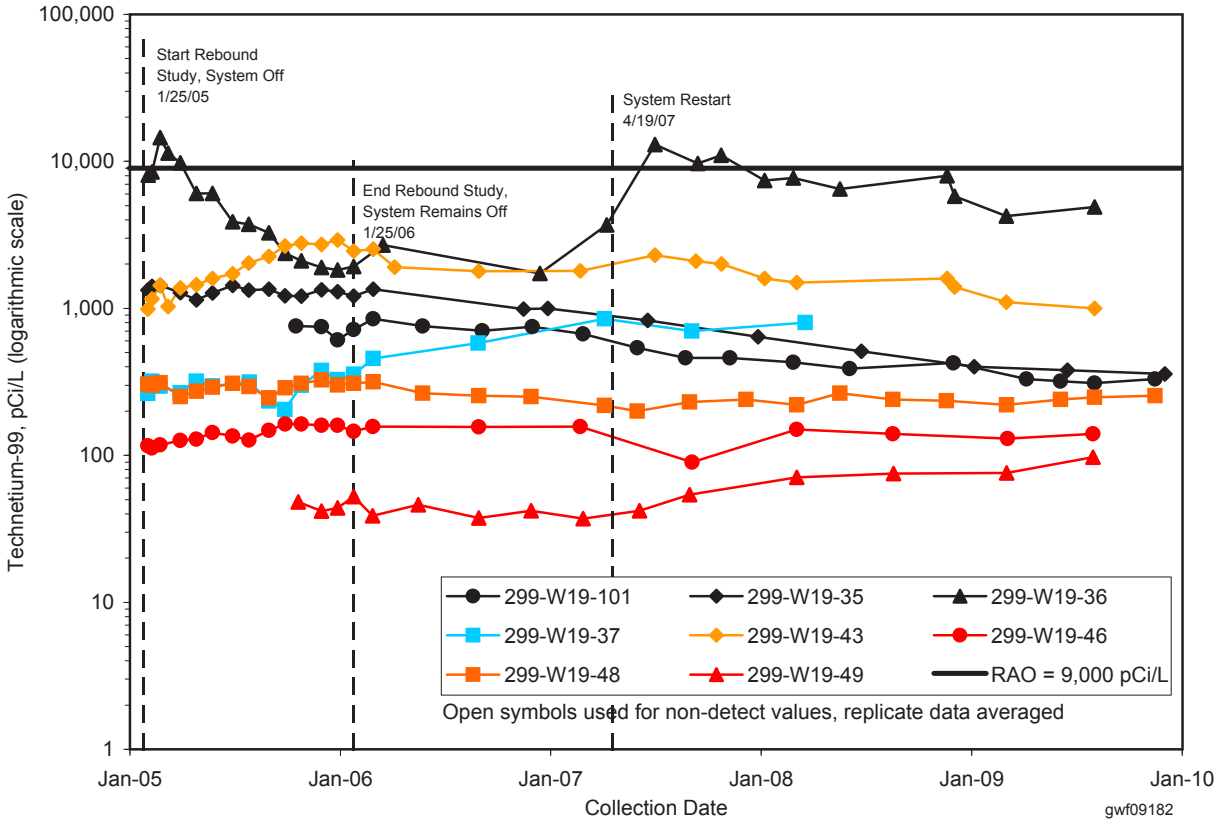


Figure 6-19. Carbon Tetrachloride Concentrations in the 200-UP-1 Pump-and-Treat System Wells.

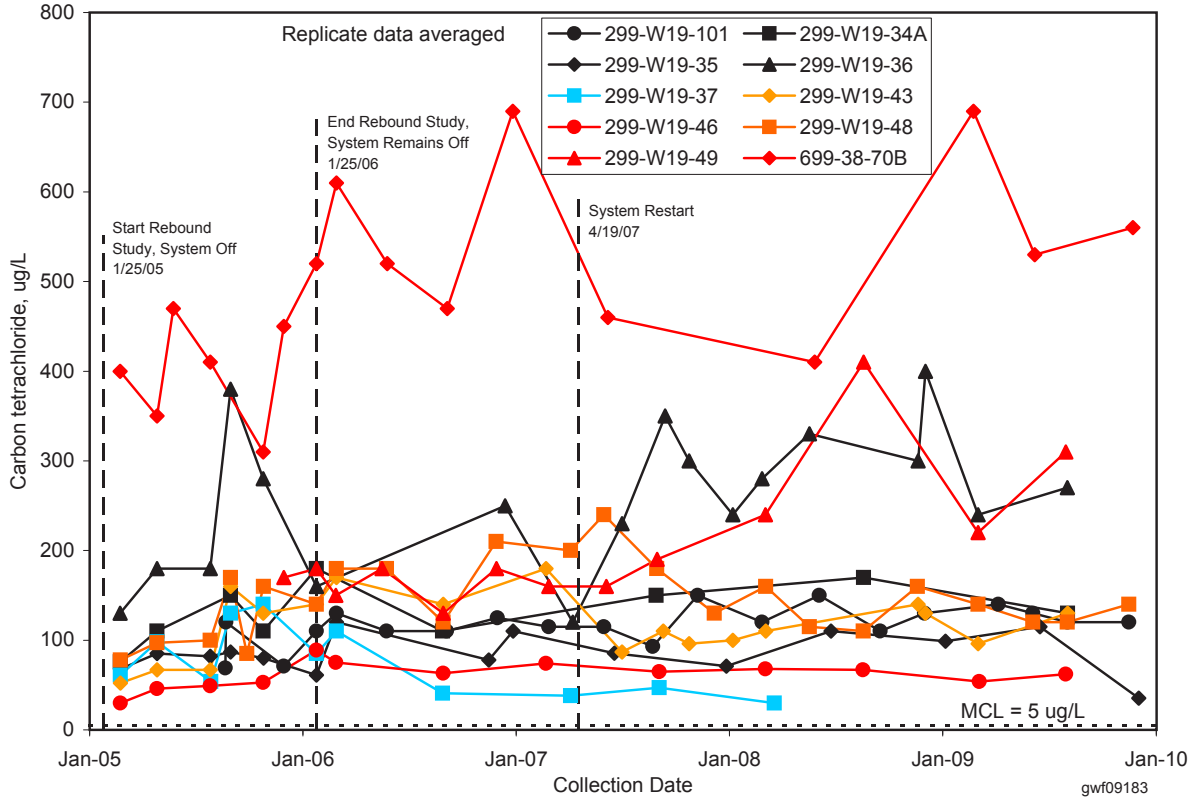
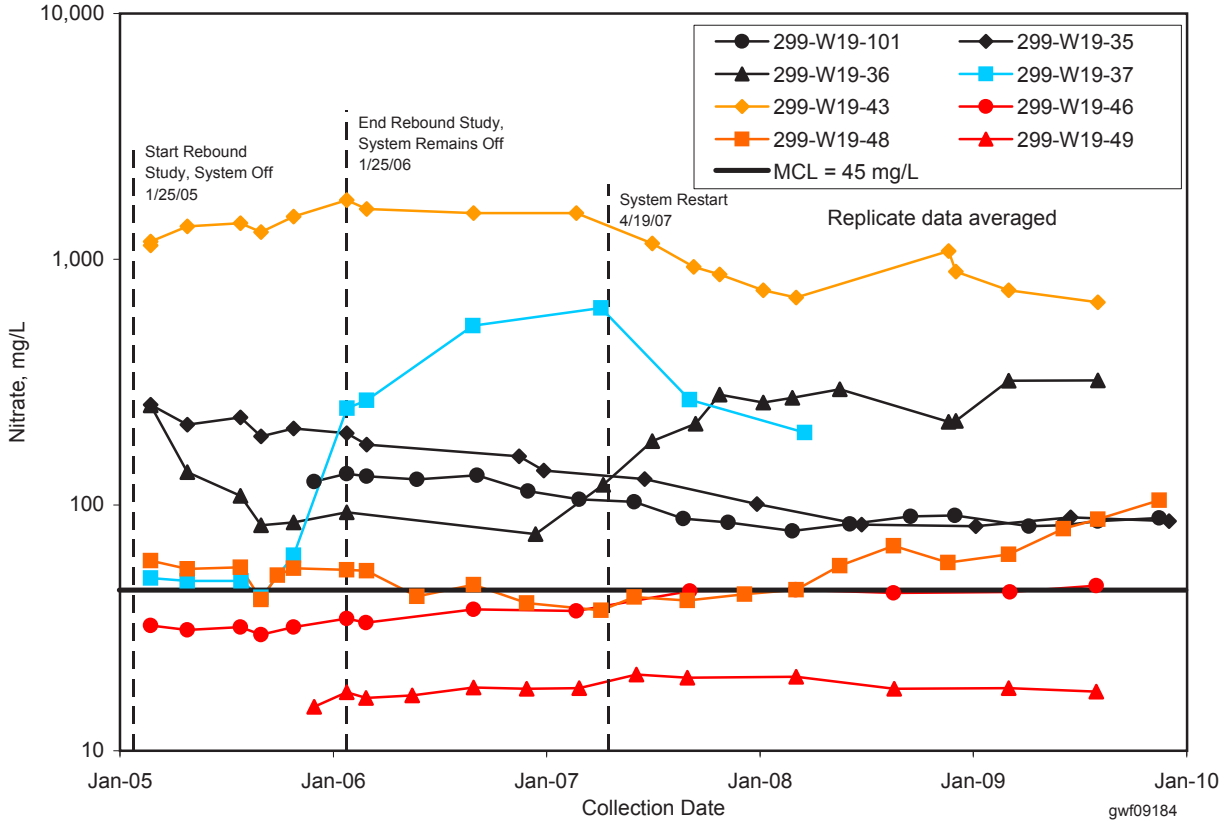


Figure 6-20. Nitrate Concentrations in the 200-UP-1 Pump-and-Treat System Wells.



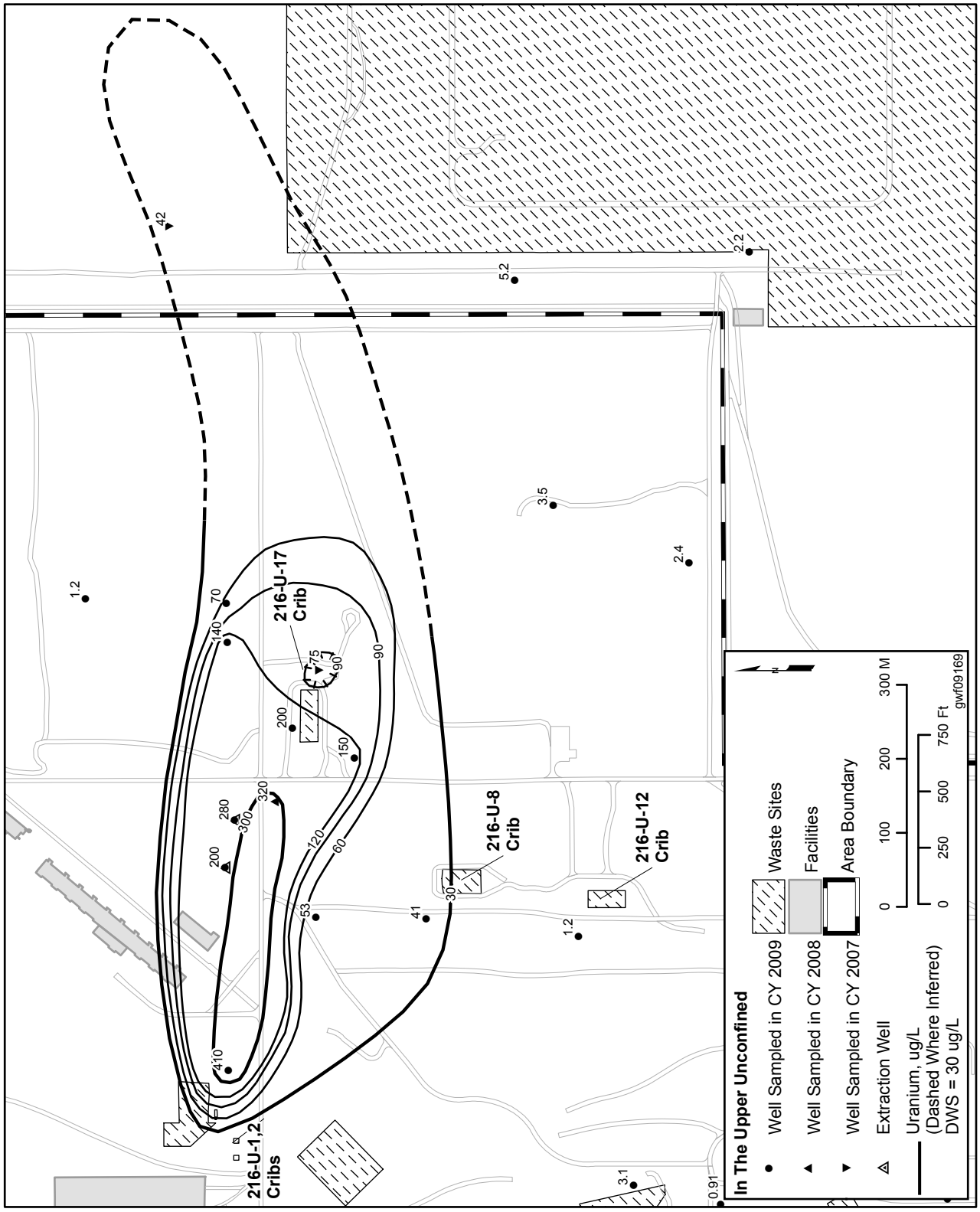


Figure 6-21. Average Uranium Concentrations in the 200-UP-1 Pump-and-Treat System Area, Upper Portion of Unconfined Aquifer.

Figure 6-22. Average Nitrate Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer.

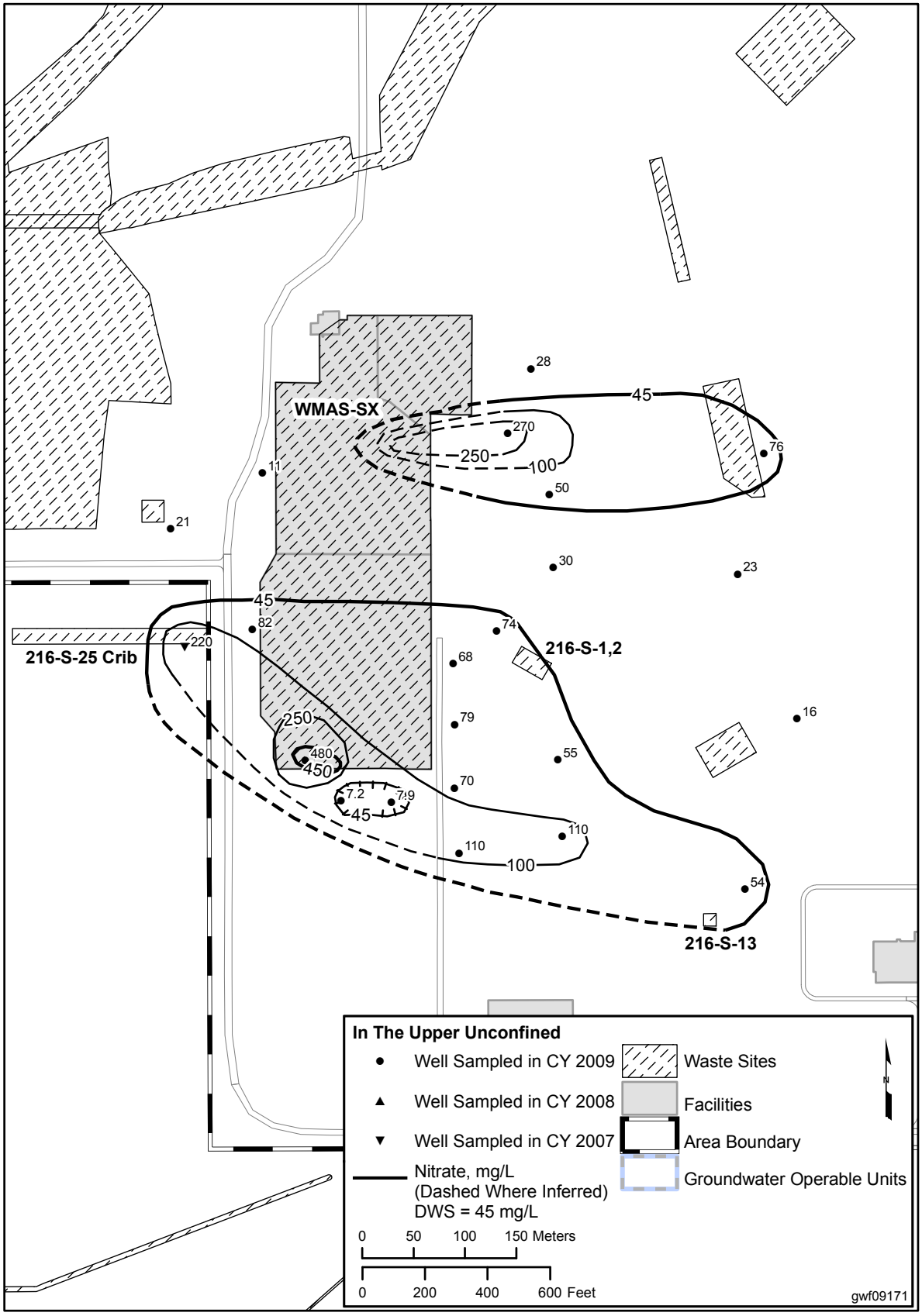


Figure 6-23. Average Chromium Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer.

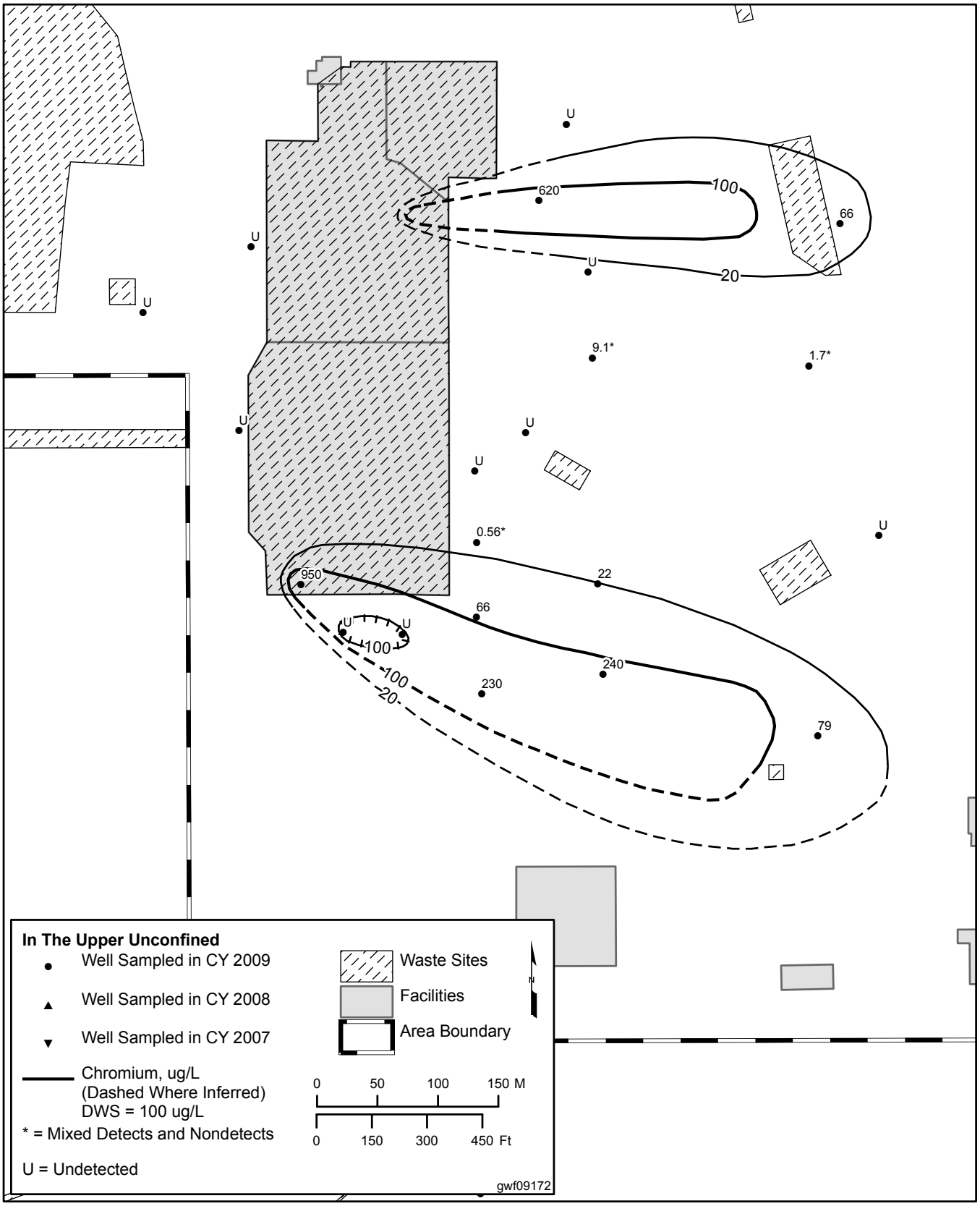


Figure 6-24. Average Technetium-99 Concentrations in Waste Management Area S-SX, Upper Portion of Unconfined Aquifer.

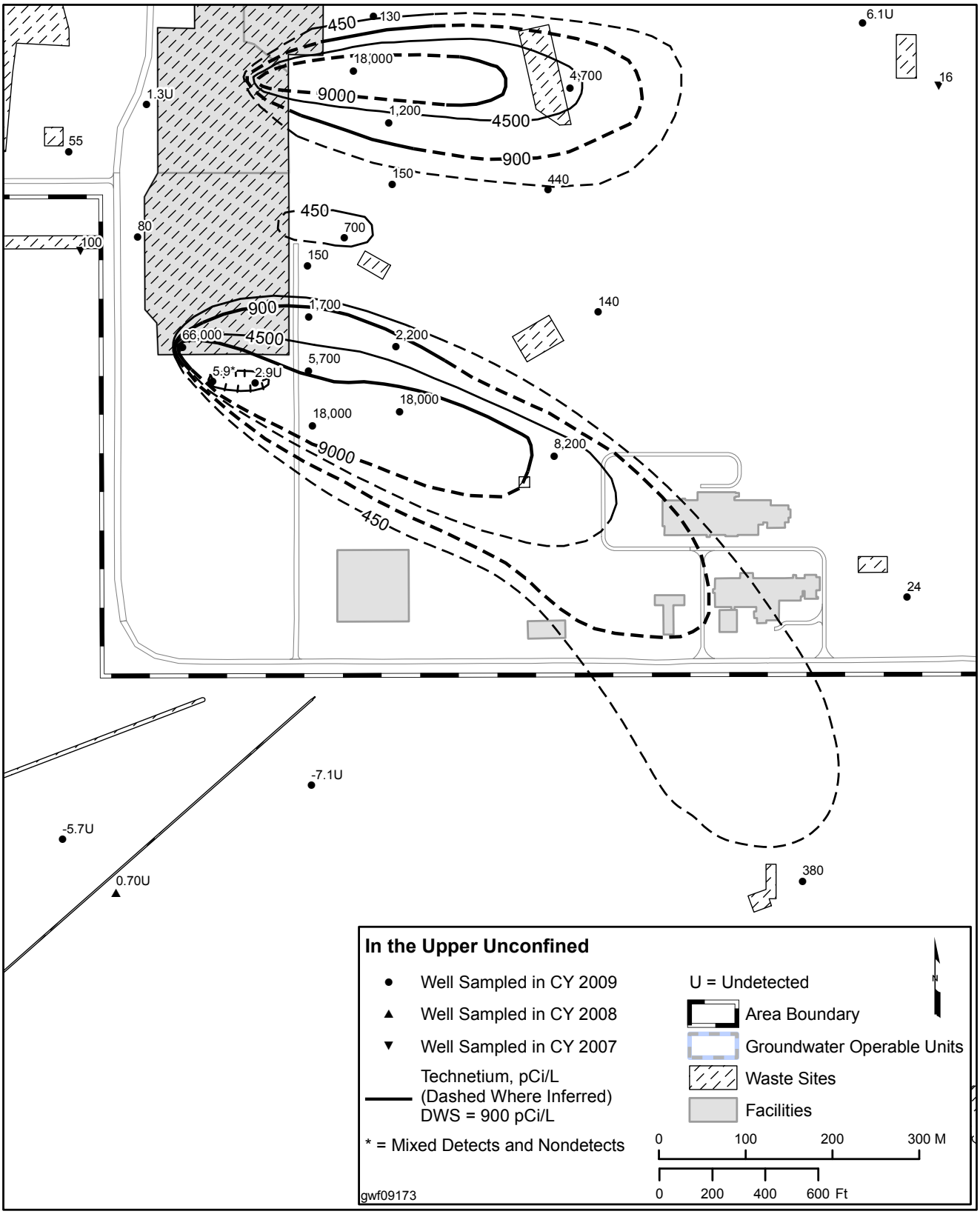
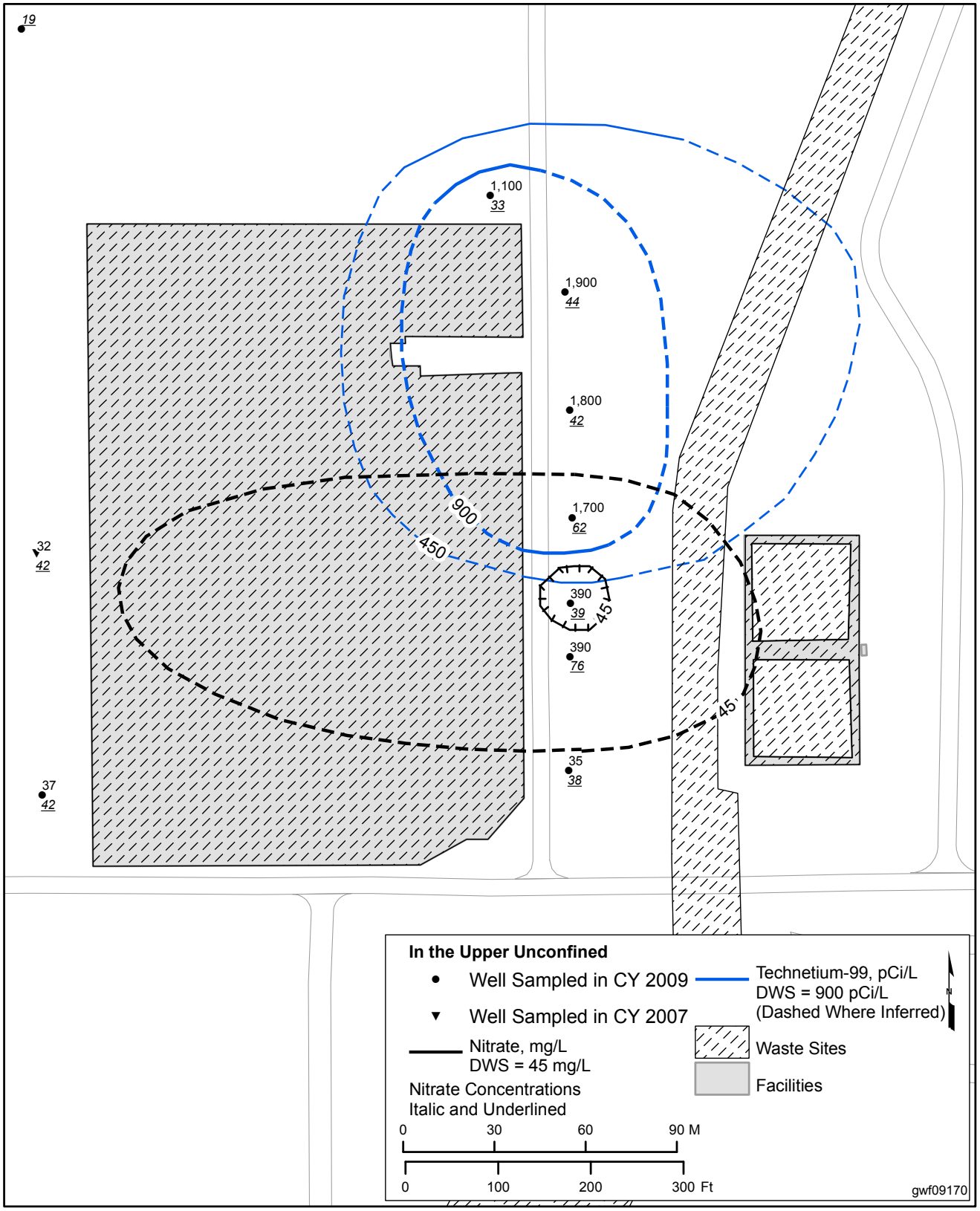


Figure 6-25. Average Nitrate and Technetium-99 Concentrations in Waste Management Area U, Upper Portion of Unconfined Aquifer.



This page intentionally left blank.