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Pacific Northwest National Laboratory

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Results of RCRA Groundwater Quality Assessment Program at the 216-U-12 Crib

B. A. Williams
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May 1997

Prepared for the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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DISCLAIMER

Summary

The 216-U-12 crib has been in a *Resource Conservation and Recovery Act of 1976* (RCRA) interim-status groundwater quality assessment program since the first quarter of 1993. Specific conductance measured in downgradient wells 299-W22-41 and 299-W22-42 exceeds its critical mean. This report presents the results and findings of Phases I and II of the assessment monitoring program, as required by 40 CFR 265.93.

The elevated levels of specific conductance in the downgradient "triggering" wells are attributed to nitrate, the mobile anion released when nitric acid is diluted in water, and calcium which is released from the sediments as acid is neutralized. Technetium-99 levels have been elevated in these same downgradient wells since 1991. The source of these constituents is the 216-U-12 crib.

Downward migration of nitrate and technetium-99 from the vadose zone (and continued elevated specific conductance in the two downgradient wells) is still occurring because the driving force is still present.

Also, tritium and iodine-129 have been detected at levels above background and/or the interim drinking water standards in both upgradient and downgradient monitoring wells. Their patterns are similar, and probably reflect a common upgradient source caused by past disposal of process condensate waste from the nuclear fuel dissolution and extraction activities at the Reduction-Oxidation (REDOX) Plant located near the southern end of the 200-West Area.

Even though the 216-U-12 crib is the source of elevated nitrate, the State of Washington Department of Ecology and the U.S. Environmental Protection Agency determined in the interim remedial measures for the 200-UP-1 Operable Unit that nitrate and tritium will not be remediated until practical treatment options are available.

Based on the results of the investigation, the site must remain in interim-status assessment monitoring because of continuing elevated levels of nitrate and technetium-99. However, the objective of groundwater monitoring, rather than delineating the existing known plumes, should be focused on 1) continued groundwater monitoring to determine whether the flux of constituents out of the vadose zone into the groundwater is increasing, staying the same, or decreasing; 2) monitoring the known contaminants until a near-term interim corrective action is defined; and 3) monitoring under interim-status assessment until a final-status monitoring plan is implemented during closure of the facility.

The RCRA groundwater monitoring activities should be integrated with the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and/or sitewide surveillance programs and a revised groundwater-monitoring plan should be prepared and implemented to ensure that only necessary data are collected in accordance with the initiative to combine all groundwater-monitoring requirements under a single groundwater project.

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1.0 Introduction

This report presents the results and findings of the assessment monitoring program established for the 216-U-12 crib as required by 40 CFR 265.93 and conducted by Pacific Northwest National Laboratory[a]. The crib is a small, currently inactive, unlined percolation pit located ~610 m (2,000 ft) south of U Plant in the 200-West Area in the central portion of the Hanford Site (Figure 1). The crib is regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA). Wastewater disposed to the crib has contained corrosive hazardous waste and dangerous radioactive materials. RCRA groundwater monitoring at the crib began in 1991. In January 1993, specific conductance in two downgradient wells, 299-W22-41 and 299-W22-42 (Chou and Williams 1993) significantly exceeded upgradient concentrations, promoting the initiation of an interim-status groundwater quality assessment program to determine if the crib has affected the quality of the groundwater in the uppermost aquifer beneath it.

This report discusses the detected constituents and the source (as Phase I); the concentration, rate, and extent of constituent migration in the aquifer (Phase II); and the conditions supporting the recommendation to revise the assessment monitoring program. Results of groundwater assessment indicate that no RCRA hazardous (dangerous) waste constituents from the crib have entered the groundwater. However, nitrate continues to be elevated at concentrations above the drinking water standard and technetium-99 is elevated above background levels. Based on this assessment, the source of the elevated nitrate and technetium-99 has been shown to be the 216-U-12 crib.

Because this crib is not expected to receive additional hazardous effluent, it is scheduled to be closed in 2003 under RCRA final status according to provisions of the Hanford Site RCRA Facility Permit (DOE 1996a). This closure will be coördinated and integrated with the *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) 200-UP-1 Groundwater Operable Unit remedial action plan.

This report is composed of five chapters, including this introduction. Chapter 2.0 gives a brief description of the facility, including the waste inventory disposed to the crib and the groundwater-monitoring program. Chapter 3.0 outlines in detail the Phase I assessment, followed by Chapter 4.0 that gives the Phase II assessment. Chapter 5.0 is a list of the references cited in the text. The appendix to this report contains supporting information.

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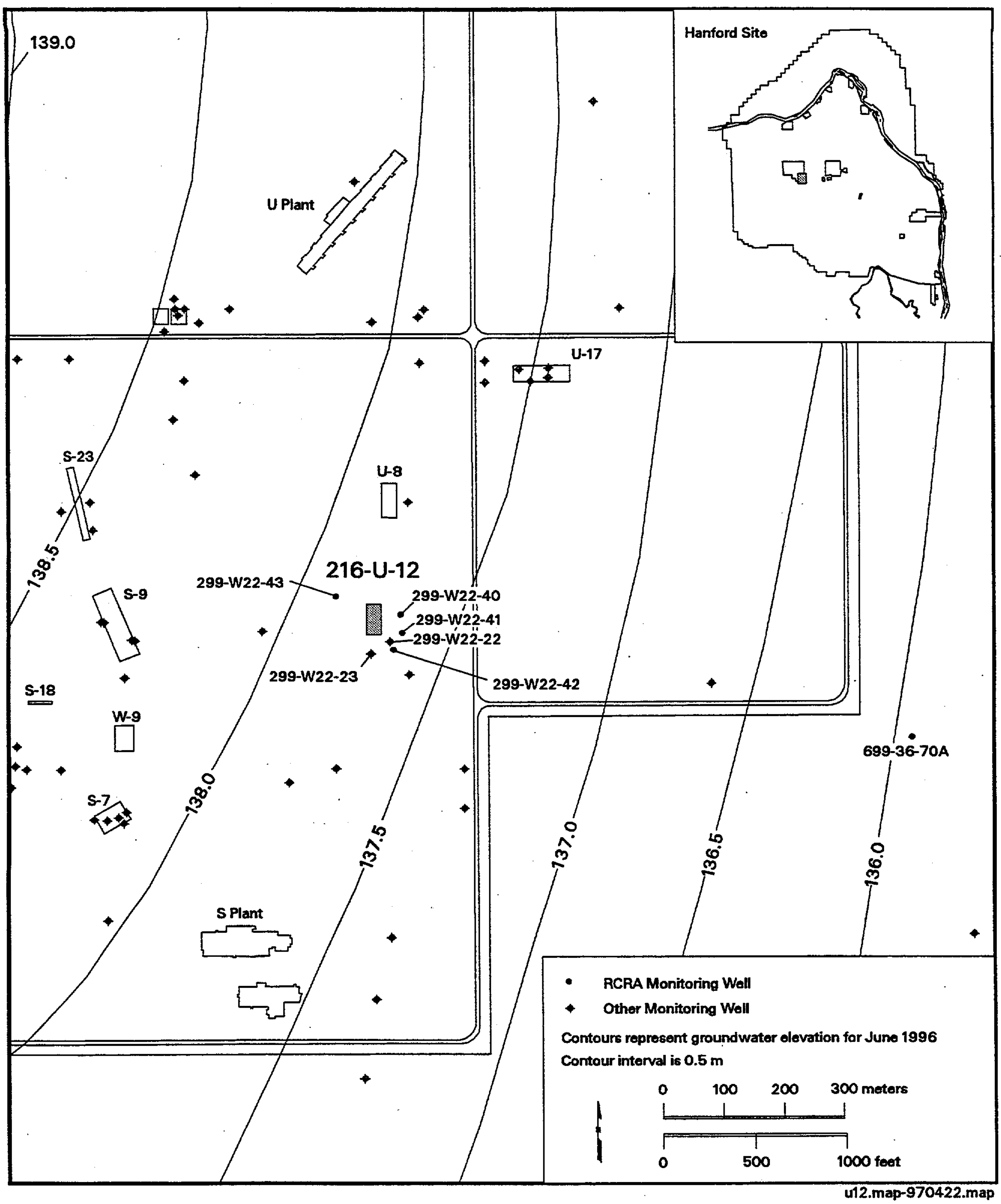


Figure 1. Location Map of 216-U-12 Crib and Surrounding Facilities in 200-West Area

2.0 Facility Description

Information about the 216-U-12 crib and its underlying geology and hydrology have been provided in Jensen et al. (1990) and is condensed below.

This crib was a liquid waste-disposal facility composed of an unlined, gravel-bottomed, percolation crib, 3 x 30 m (10 x 100 ft), 4 m (13 ft) deep. The crib has a plastic barrier cover and is backfilled with the original excavated gravel. A vitrified clay distributor pipe, buried in the gravel, dispersed the effluent across the bottom of the crib. This crib was used to dispose (neutralize) dangerous and corrosive wastes composed of effluent and process condensate from the 224-U Building (UO_3 Plant) and included 291-U-1 stack drainage. The crib received this waste stream from April 1960 until 1972 when it was deactivated. The crib was reactivated in November 1981 and received waste until it was permanently retired in February 1988.

In 1985, physical controls and operating procedures were modified to avoid inadvertent discharge of hazardous chemicals to the wastewater stream. A yearly average of over 1.33×10^8 L/yr (3.5×10^7 gal/yr) of effluent was disposed to the crib from 1960 through 1978 (Maxfield 1979). The crib has received nitric acid waste and low-level radioactive waste known to have included plutonium, ruthenium, cesium, strontium, and uranium.

The crib is located near several other crib sites in the 200-West Area that introduced large volumes of liquid effluent containing radioactive and hazardous waste to the soil at various times during the operational history of the U and S Plants (see Figure 1). Details of all the facilities are provided in the Waste Information Data System (WIDS) database, managed by Bechtel Hanford, Inc.

2.1 Waste Characteristics

The waste inventory documented for the crib is given in Table 1. The documented inventory is composed mainly of radioisotopes. During the early operations, the chemicals that were disposed were not typically monitored. Most of the total beta (773 Ci) and strontium-90 (104 Ci) was discharged to the crib in October 1965 as contaminated water originating from the 244-WR vault (McMurray 1966). This waste also contained 3.14 kg of thorium. The relative volumes of process condensate, stack drainage, and storm runoff discharged to the crib are not known. According to Smith and Kasper (1983), the process condensate was acidic, composed of 0.077 M nitric acid, with a pH of 1.1. This created an acidic waste stream with the potential to mobilize strontium-90, resulting in downward migration toward the aquifer. It was recommended that the waste stream be neutralized but pH values (see Table 1) for the waste discharge stream suggest that this was not done until after 1987 when the crib was retired and the waste stream was diverted to the 216-U-17 crib. The chemical makeup of the acidic waste stream is not known.

Table 1. Waste Inventory by Year for 216-U-12 Crib

Year[a]	Volume, L	Plutonium, g	Beta, Ci	^{90}Sr, Ci	^{106}Ru, Ci	^{238}U, kg	^{3}H, Ci	Alpha, Ci	Uranium, Ci	pH	Total Organic Carbon, mg/L
1960	9.0×10^6	0.1	4.4			176					
1961	1.4×10^7	0.1	56.3			437					
1962	1.4×10^7	0.1	5.0			417					
1963	1.4×10^7	0.1	11.1			129					
1964	1.7×10^7	0.1	3.0			254					
1965	1.4×10^7	0.1	773	104	80	209					
1966	1.1×10^7	0.1	0.1			103					
1967	1.0×10^7	0.1	0.04			69					
1968	8.9×10^6	0.1	0.02			7.6					
1969	7.2×10^6	0.1	0.03			6.0					
1970	3.1×10^6		0.01			1.4					
1971	6.0×10^6		0.06			2.2					
1972	3.8×10^6		0.013			0.061					
1973	0										
1974	0										
1975	0										
1976	0										
1977	0										
1978	0										
1979	0										
1980	0										
1981	1.6×10^4	2.7×10^{-6}	2.1×10^{-3}			2.1	0.009				
1982[b]											
1983	1.3×10^6		0.007			5.5					
1984	5.5×10^6	0.009				3.3		0.0034		0.8 to 2.3	1,602
1985	4.7×10^6		0.007						0.007	1.4 to 2.5	29,574
1986	3.9×10^6		0.01					0.01	0.02	1.0 to 2.5	?
1987	6.4×10^5	6×10^{-4}						6×10^{-4}	9×10^{-4}		222
1988	1.1×10^5		1.45×10^{-4}					$<9.43 \times 10^{-4}$	1.28×10^{-4}		

(a) Data from 1960 to 1981 from Smith and Kasper (1983); data from 1983 to 1987 from Aldrich (1984 through 1987); data from 1988 from Coony and Thomas (1989).
(b) No data available.

2.2 RCRA Groundwater Monitoring

The RCRA groundwater monitoring plan (Jensen et al. 1990) presents the program to determine the crib's impact on the quality of groundwater in the uppermost aquifer. Background levels for the contaminant indicator parameters (i.e., pH, specific conductance, total organic carbon, and total organic halogens) were established in accordance with 40 CFR 265.92. In accordance with the groundwater monitoring plan (as required by 40 CFR 265.91), four RCRA groundwater-monitoring wells were installed in 1990. The monitoring network consisted of one upgradient and three downgradient wells (Figure 2). Specific conductance data collected during the third quarter of 1992 from downgradient wells 299-W22-41 and 299-W22-42 showed a statistically significant increase over background values [40 CFR 265.93(3)(b)]. Verification sampling results confirmed that the initial exceedances could not be attributed to laboratory error [40 CFR 265.93(2)]. Data obtained in subsequent quarters corroborated these findings.

A RCRA interim-status assessment-level groundwater-monitoring program was implemented for the crib in January 1993. The crib's groundwater-monitoring well network is sampled quarterly in accordance with the groundwater quality assessment plan (Chou and Williams 1993) [40 CFR 265.94(d)(4)]. This plan was developed to determine whether the crib is the source of the contamination (i.e., Phase I) and if so, to determine the concentration, rate, and extent of migration of the contaminant plumes (Phase II).

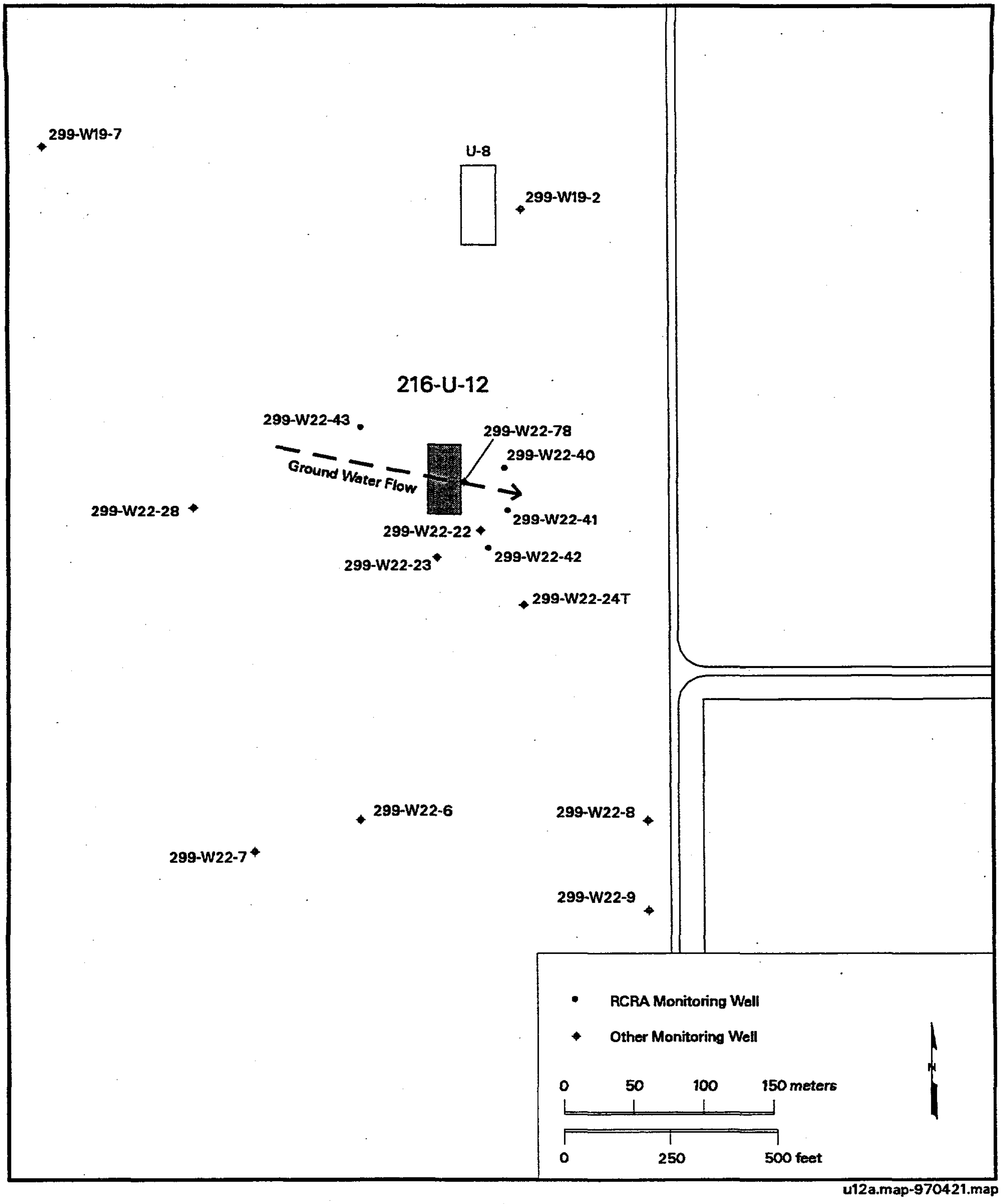


Figure 2. Location Map of 216-U-12 Crib and Monitoring Wells

3.0 Phase I Assessment

The phase I assessment of the 216-U-12 crib is outlined in Chou and Williams (1993). Phase I assessment requires identification of the contributing chemical constituents impacting the groundwater below the crib and the source of the identified contamination.

3.1 Network Design

To support Phase I's source determination, the original RCRA detection-monitoring network was expanded during 1993. Because only one upgradient well was in use, it was difficult to determine or confirm whether the crib was the source or if one of several upgradient disposal facilities could be the source of the contaminants (see Figure 1). Initially, existing older wells were added to enhance the assessment network. Because the number of existing wells around the crib was limited, only two wells proved useful. Well 299-W22-23 was added as an upgradient well, and well 299-W22-22 was included for source delineation. The distance from the crib to the nearest upgradient source (216-S-9 pond) is ~381 m (1,250 ft) and the combination of upgradient wells, 299-W22-43 and 299-W22-23 (located <91 m [300 ft] from the crib), was determined to be adequate spacing for source identification (see Figure 2). The two additions to the network did not meet Washington Administrative Code (WAC) 173-160 (resource protection well) construction requirements and were remediated by brushing to remove corrosion in the carbon steel well casing and by shortening the sampling interval consistent with the other RCRA-compliant network wells.

Constituents and monitoring wells originally selected for the assessment network have been reduced to the current list presented in Table 2.

The original sampling constituent list in Chou and Williams (1993) included the contamination indicator parameters, drinking water standards, and groundwater quality parameters, as well as site-specific parameters that were selected based on published groundwater data and waste stream data reports and from ongoing groundwater studies. This original list has been shortened over the assessment period to include only those that revealed consistently elevated results or that support the assessment of groundwater quality. The nondetected constituents were deleted.

3.1.1 Groundwater-Flow Direction and Velocity

Evaluation of the water-table map (Figure 3) indicates that groundwater flows toward the east, in an east-southeasterly direction beneath the crib. This flow direction is unchanged from previous years and is consistent with the published plume maps for the area that show a flow pattern east to slightly northeast or southeast. The upgradient and downgradient wells are still located appropriately to provide background water quality upgradient and contaminant detection downgradient of the crib.

Table 2. Monitoring Wells and Constituents for 216-U-12 Crib (adapted from Jensen et al. 1990 and Williams and Chou 1993)

Well	Hydrogeologic Unit Monitored	Sampling Frequency	Water-Level Measurements	Well Standard	Other Networks
299-W22-43[90]	Top of unconfined	Quarterly	Quarterly	RCRA	Operational and Sitewide
299-W22-40[90]	Top of unconfined	Quarterly	Quarterly	RCRA	Operational and Sitewide
299-W22-41[90]	Top of unconfined	Quarterly	Quarterly	RCRA	Operational and Sitewide
299-W22-42[90]	Top of unconfined	Quarterly	Quarterly	RCRA	Operational and Sitewide
699-36-70A[94]	Top of unconfined	Quarterly	Quarterly	RCRA	Operational, CERCLA, and Sitewide

Contamination Indicator Parameters	Site-Specific Parameters	
pH	Anions	Iodine-129
Specific conductance	ICP metals	Technetium-99
Total organic carbon	Gross alpha	Turbidity
Total organic halogen	Tritium	Total dissolved solids
	Alkalinity[(a)]	Gross beta

(a) Only analyzed in wells 299-W22-42, 299-W22-43, and 699-36-70A.
Shading = Upgradient well.
Superscript = Year of installation.
RCRA = Well constructed to RCRA standards.

Groundwater levels have been measured at least semiannually since RCRA monitoring began in 1991 and quarterly during assessment of the crib. In the past 6 years, since RCRA groundwater monitoring began, the water table has declined over 3 m (9 ft) (Figure 4). The water table, which is still above the pre-Hanford Site operational elevation, is expected to continue to decline because artificial recharge to the aquifer has been significantly reduced. Effluent disposed to the 216-U-10 pond (decommissioned in 1984) created a radial groundwater-flow pattern that locally affected the regional flow regime.

The rate of groundwater flow beneath the crib in 1996 was estimated based on a form of the Darcy equation (Williams 1996). The estimated average groundwater-flow velocity is 0.06 m/d (0.21 ft/d).

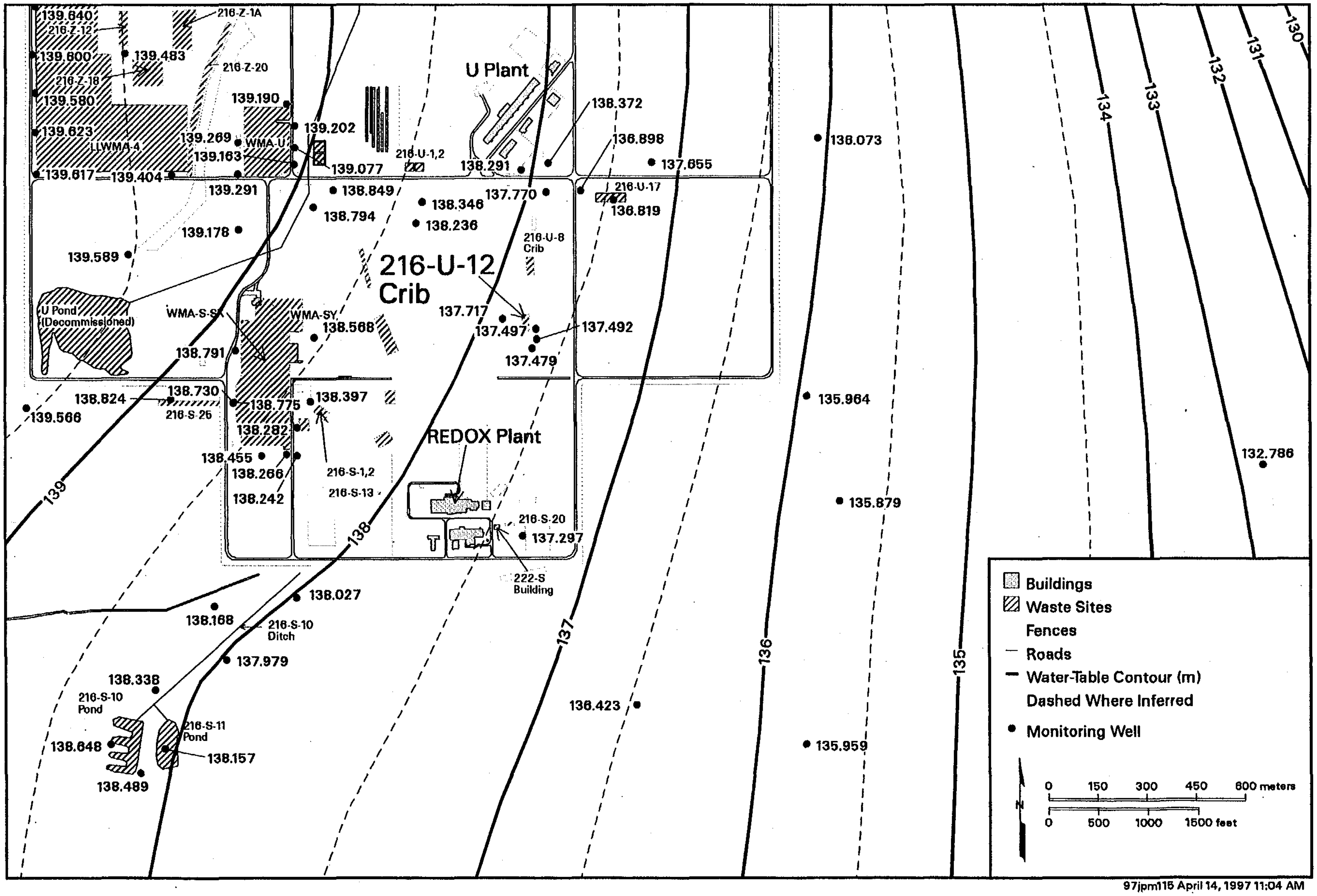


Figure 3. 1996 Water-Table Elevations in Vicinity of 216-U-12 Crib

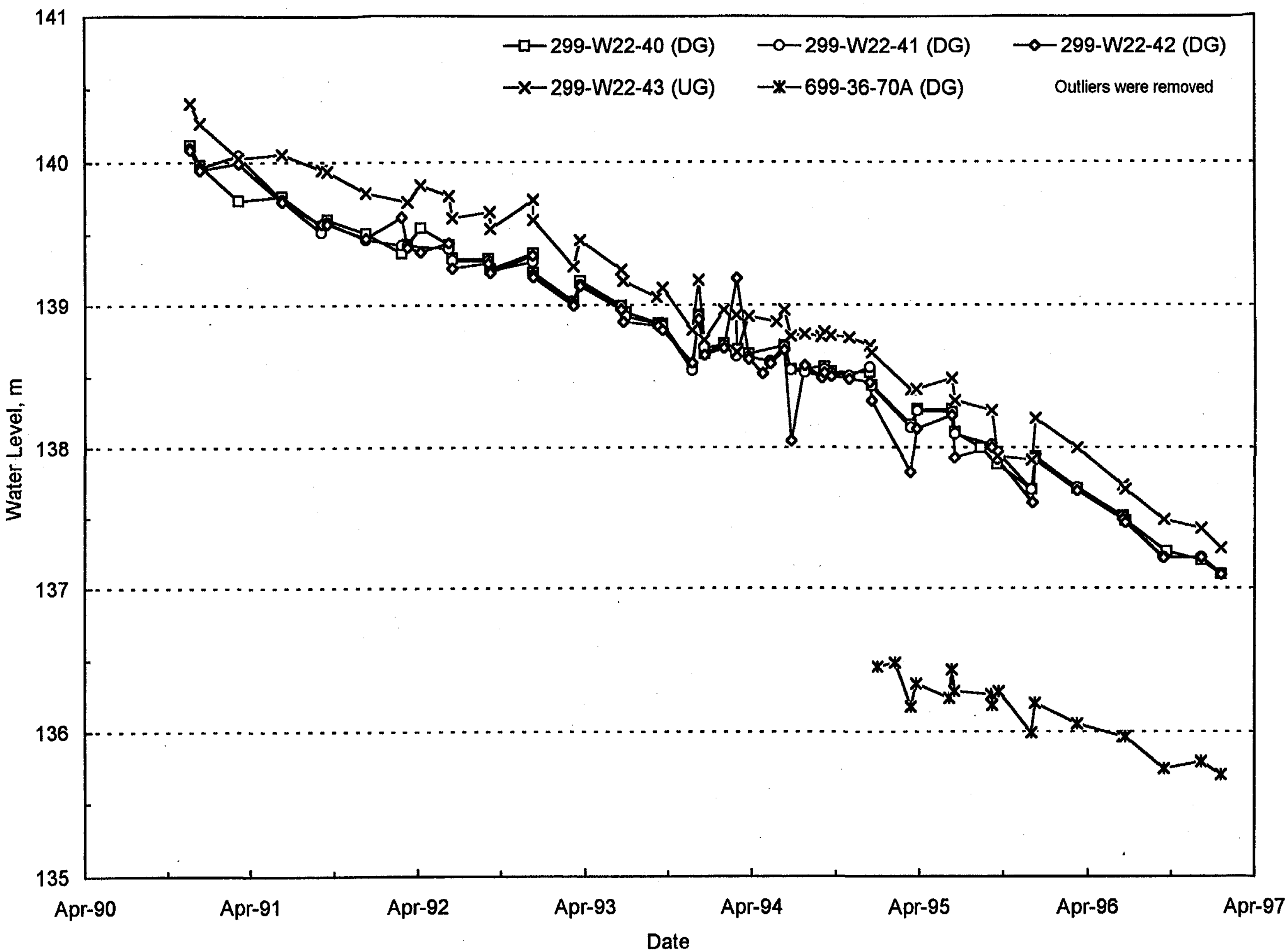


Figure 4. Hydrograph for Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

Average groundwater velocities have also been estimated based on plume-transport velocities in the area just north of the crib. Rates of movement are ~0.15 m/d (0.5 ft/d) in the 200-West Area (DOE 1995). These two calculations are in general agreement and within the range of velocities reported in Trent (1992). Because the gradient has not significantly changed since these estimates were made, it is assumed that they represent the maximum rate at which nitrate and technetium-99 can move in groundwater.

3.2 Monitoring Results

The 216-U-12 crib has been in Phase I assessment groundwater monitoring for hazardous waste or hazardous waste constituents under RCRA assessment monitoring requirements (40 CFR 265.93[d]) since the first quarter of calendar year 1993. Six quarters of groundwater data have been collected. All groundwater results are published in RCRA quarterly reports (e.g., DOE 1996b) and are available electronically through the Hanford Environmental Information System (HEIS). Groundwater-monitoring data have been validated and evaluated in accordance with protocols outlined in the quality assurance project plan (WHC 1995), in procedure manuals (WHC 1989, 1992), and as specified in the regulations (40 CFR 265). Contaminants of concern are those identified based on process knowledge, with concentration trends above background, and/or those exceeding interim drinking water standards or maximum contaminant levels. Anomalous values and spurious data results if not repeated in subsequent data sets are considered as outliers and ignored. Data of suspicious quality were submitted for the RADE process (request for analytical data evaluation) (WHC 1992).

3.2.1 Chemical and Radiological Contaminants

Nitrate and calcium are the only specific chemical constituents that have been identified as the cause of the high specific conductance (see discussions below) measured in downgradient "trigger" wells 299-W22-41 and 299-W22-42. Nitrate comes from the disposal of large quantities of corrosive hazardous waste (i.e., nitric acid). Calcium is released from the sediments when the acidic effluent is neutralized during migration through the calcium carbonate-rich vadose zone (discussed in Section 3.2.3).

The range of specific conductance for the two assessment trigger wells is illustrated on the concentration trend plot (Figure 5). The range of values recorded for these wells is 483 to 1,400 μSm/cm. Background specific conductance measurements average ~400 μSm/cm in the upgradient wells (critical mean = 457.8 μSm/cm). Nitrate concentration trends, illustrated in Figure 6, have exceeded the 45,000-μg/L maximum contaminant levels since RCRA monitoring began in September 1991. The range of nitrate concentrations reported in the two trigger wells is 150,000 to 550,000 μg/L in well 299-W22-42 and 100,000 to 300,000 μg/L in well 299-W22-41. The upgradient concentration ranges from 13,000 to 20,000 μg/L in well 299-W22-43. No other chemical constituents come close to exceeding the maximum contaminant levels.

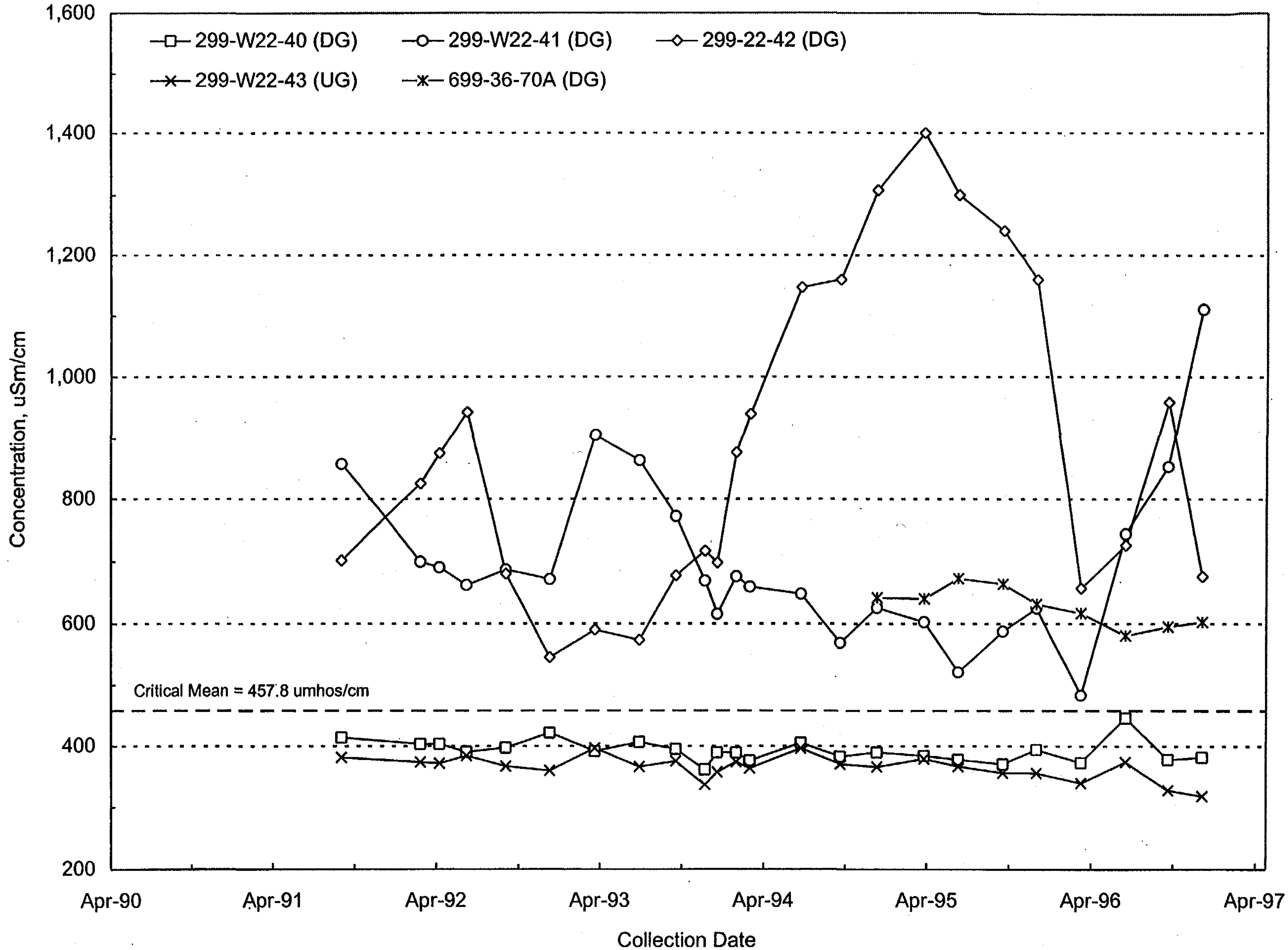


Figure 5. Specific Conductance in Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

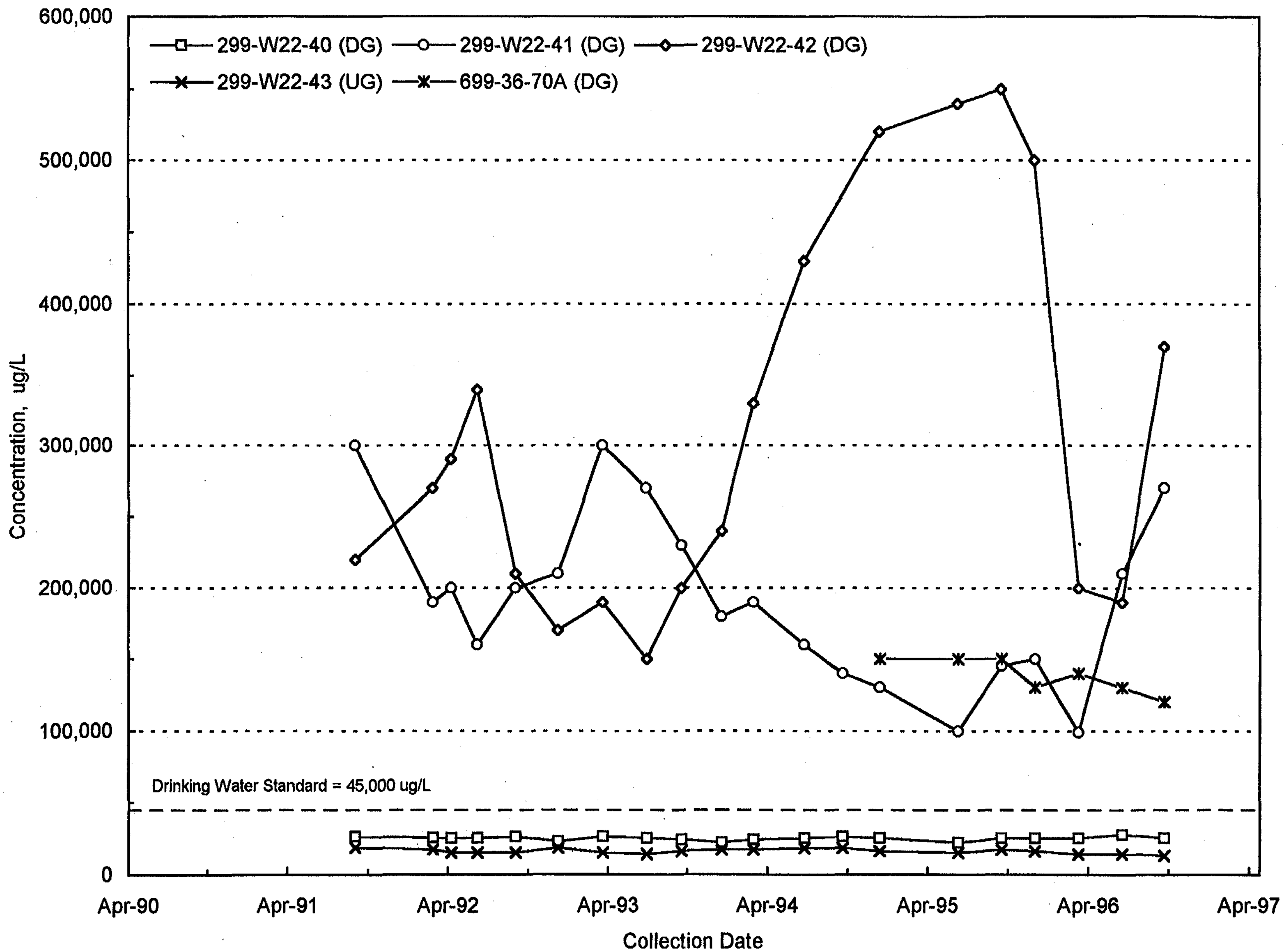


Figure 6. Nitrate in Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

Comparison of the concentration trend plots for specific conductance with the trend plots for nitrate and calcium show the direct relationship between the three (see Figures 5, 6, and 7). Because the calcium is not considered hazardous, it will not be discussed further, but was included in this section for completeness.

Correlations between specific conductance, nitrate, and technetium-99 for the crib-monitoring network were calculated (using all available data) and are presented in Table 3. From the correlations, it can be seen that there is a close relationship (i.e., $R^2 = 93\%$) between specific conductance and nitrate (in the two triggering wells). However, in the upgradient well (299-W22-43) and in the unimpacted downgradient well (299-W22-40) located northeast near the crib, there is little relationship ($R^2 < 14\%$) between specific conductance and nitrate. Similar relationship patterns exist for other analytes of concern (see technetium-99 discussion below). Based on this correlation, it is clear that specific conductance concentrations in the downgradient wells have been impacted directly by nitrate.

Carbon tetrachloride has been detected above the maximum contaminant level (5 μg/L) in all crib-monitoring wells. The source of this contaminant has been well documented (Rohay et al. 1994) and includes several upgradient disposal facilities (i.e., 216-Z-9 trench).

Because carbon tetrachloride is not a known or documented constituent of the effluent waste stream for this crib (and not its source), it will not be discussed further. To identify if any inconsistencies or unidentified chemical contaminants exist in the water analyses, the accuracy of the anion and cation results have been checked by calculating the electrical neutrality (electrochemical equilibrium) of the measured groundwater results. Results balance to within 5%, indicating reasonably good analytical data (i.e., we have not omitted measurement of any major constituents). The data presented reinforce the relationship between specific conductance and nitrate and validate nitrate as the primary chemical constituent impacting the aquifer.

The 216-U-12 crib received over 1.3 x 10^8 L of radioactive effluent, some of which are documented in Jensen et al. (1990) and the Waste Information Data System (WIDS). Three radioisotopes and two indicators (gross alpha and beta) were selected for continued assessment analysis (see Table 2). Gross beta, tritium, technetium-99, and iodine-129 have been detected above background levels and/or interim drinking water standards and are reported here to relate similarities in their concentration trends to the nitrate data. These data support the conclusion that the crib is the source of the nitrate and technetium-99.

Gross beta, a radioisotope indicator, and technetium-99 have been detected above background (below maximum contaminant levels) in downgradient wells 299-W22-41 and 299-W22-42 since monitoring began (Figures 8 and 9). Levels of gross beta in upgradient well 299-W22-43 range from 0 to 50.7 pCi/L. Levels of gross beta in the two trigger wells, 299-W22-41 and 299-W22-42, range from 45.8 to 148 and 65.8 to 222 pCi/L, respectively. The procedure for counting gross beta has an efficiency of ~20% when measuring technetium-99; thus technetium-99 is present at ~5 times

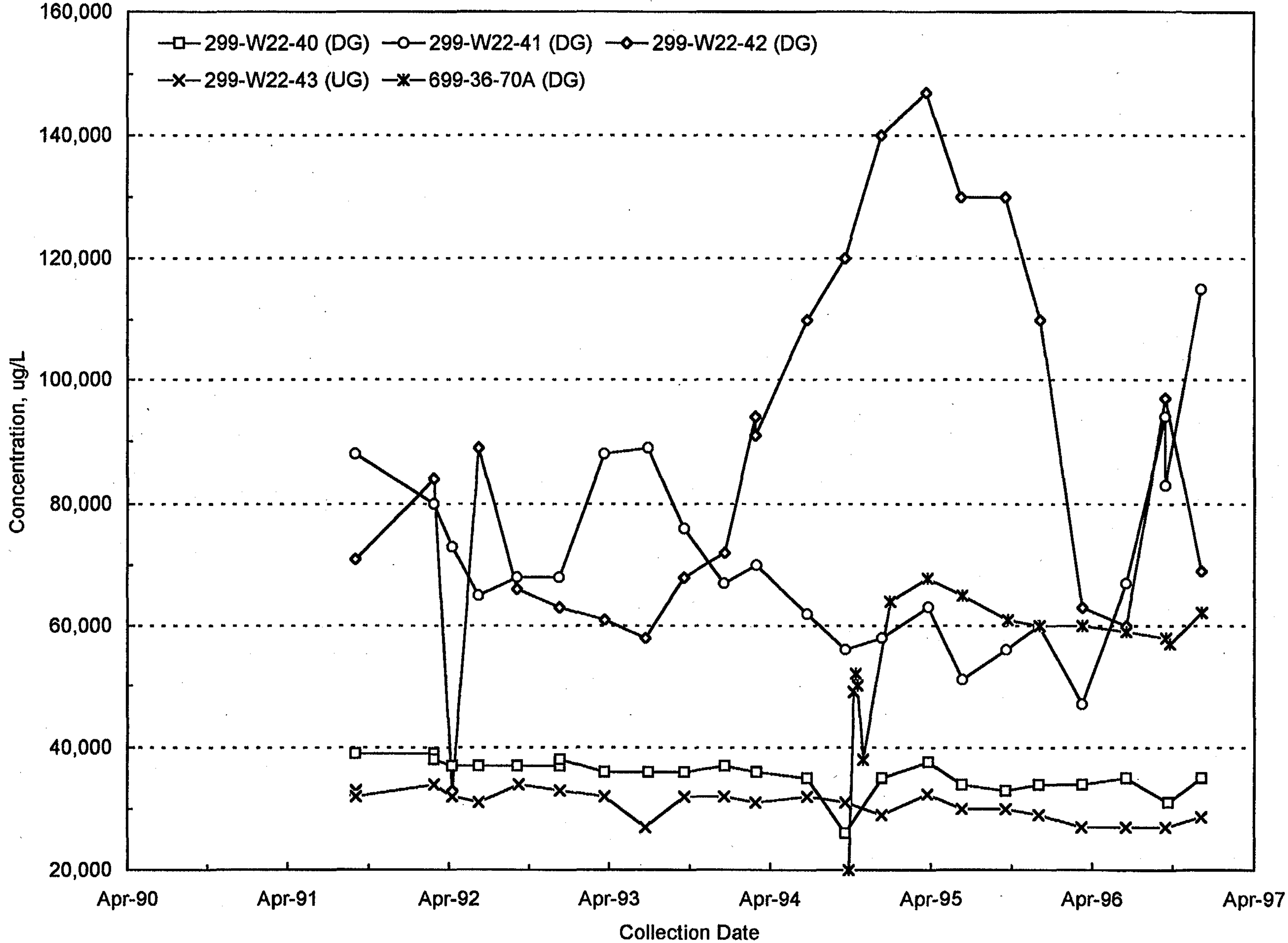


Figure 7. Calcium (filtered) in Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

Table 3. Correlations Between Specific Conductance, Nitrate, and Technetium-99 for 216-U-12 Crib Monitoring Network

		Coefficient of Determination[b]		
Network[a]	Location	Specific Conductance vs Nitrate	Specific Conductance vs Technetium-99	Technetium-99 vs Nitrate
299-W22-40[90]	DG	11.1	1.3	3.9
299-W22-41[90]	DG	93.8	58.1	58.4
299-W22-42[90]	DG	97.0	80.0	71.3
299-W22-43[90]	UG	13.3	30.5	20.6
699-36-70A[94]	DG	68.6	0.5	0.03

(a) Well that showed elevated specific conductance and triggered the 216-U-12 crib into assessment monitoring status.

(b) Coefficient of determination (R^2) is the square of the correlation coefficient between respective analytes of interest.

Superscript = Year of installation.
DG = Downgradient well.
UG = Upgradient well.

the gross beta activity. Based on this relationship, it is determined that the gross beta contamination is predominantly a result of the technetium-99 in the groundwater. No other beta-emitting radioisotopes were detected that would contribute significantly to the gross beta in these trigger wells. Comparing the concentration trend plots for these two reveals the direct relationship between them. Correlations between specific conductance and technetium-99 for the crib were presented in Table 3. From that correlation, >58% (i.e., R^2) of the total variation for specific conductance (in the two triggering wells) can be explained by technetium-99. Technetium-99 is thought to be present as the pertechnetate ion (TcO_4^{-1}), a highly mobile anion with chemical properties similar to nitrate.

Uranium, a documented waste constituent, was analyzed until calendar year 1995 (in Phase I wells) when it was eliminated from the list of analytes for the crib because it did not exceed the sitewide provisional background value (i.e., 3.43 pCi/L) (Johnson 1993a). Therefore, it essentially was not detected (Figure 10). It should be noted that a conversion factor of 0.68 pCi/μg was used to estimate the activity of total uranium measured as mass (μg/L) for the uranium data reported for the crib. This ratio was recommended by the U.S. Environmental Protection Agency (1991).

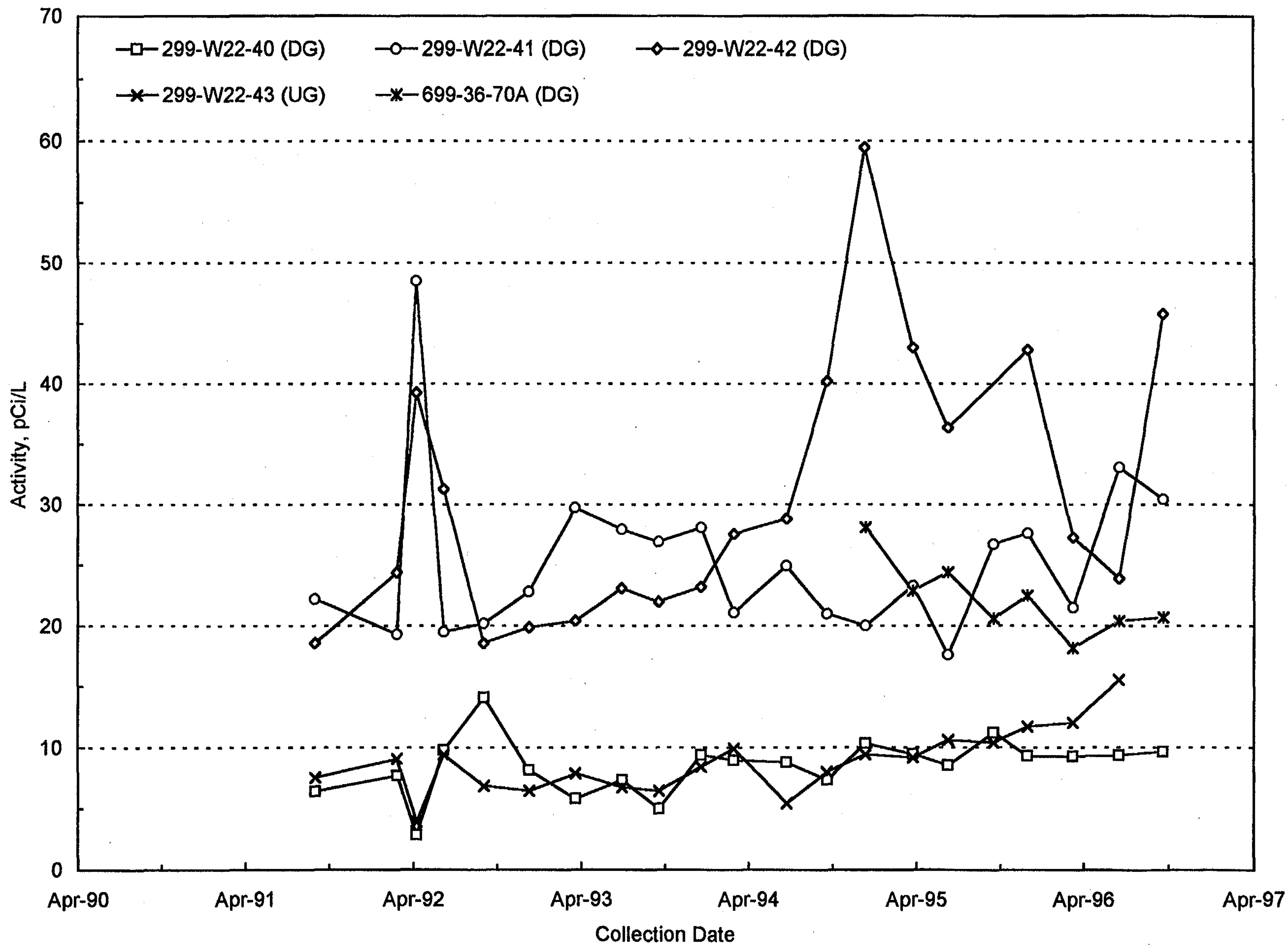


Figure 8. Gross Beta in Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

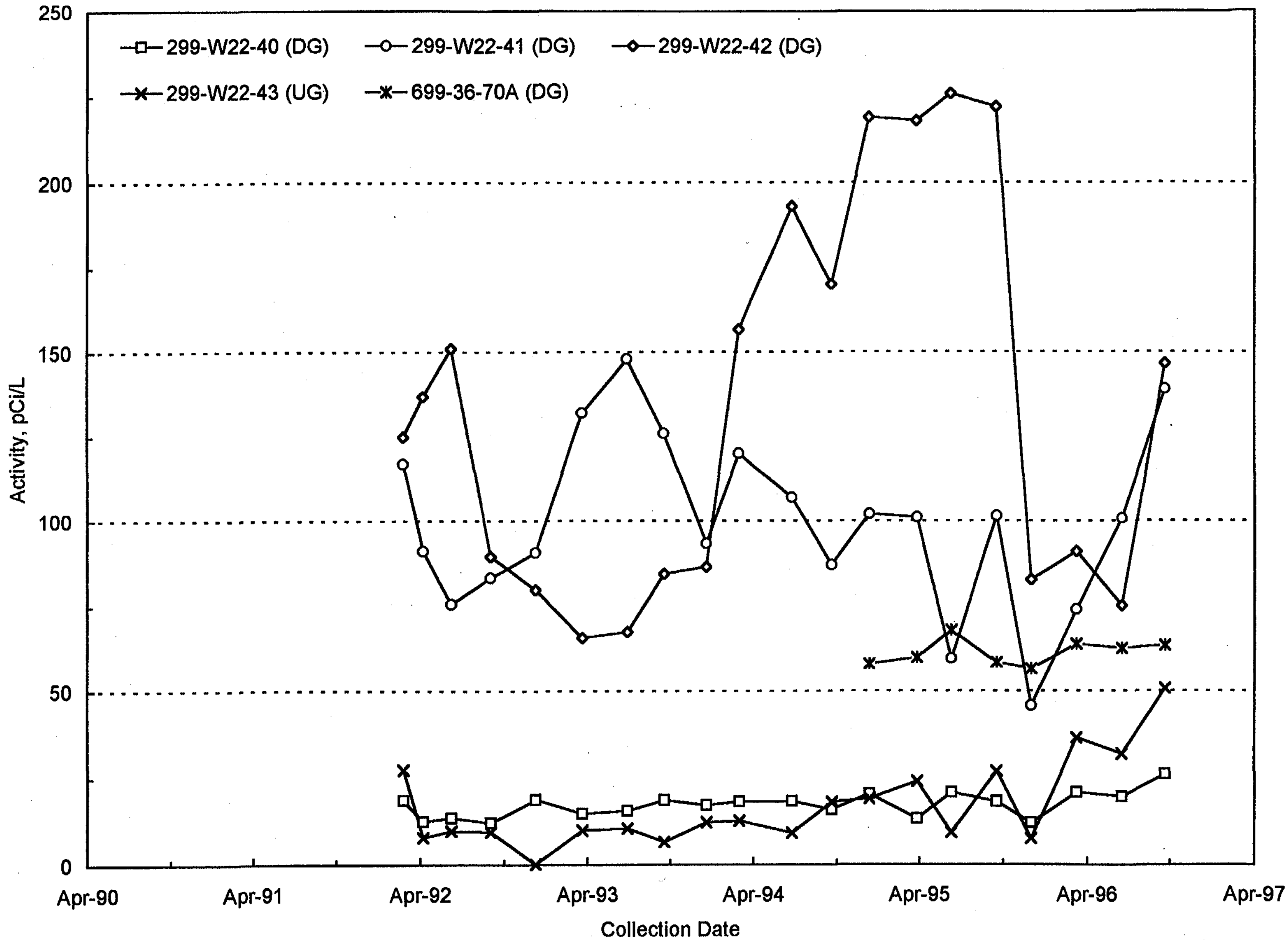


Figure 9. Technetium-99 in Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

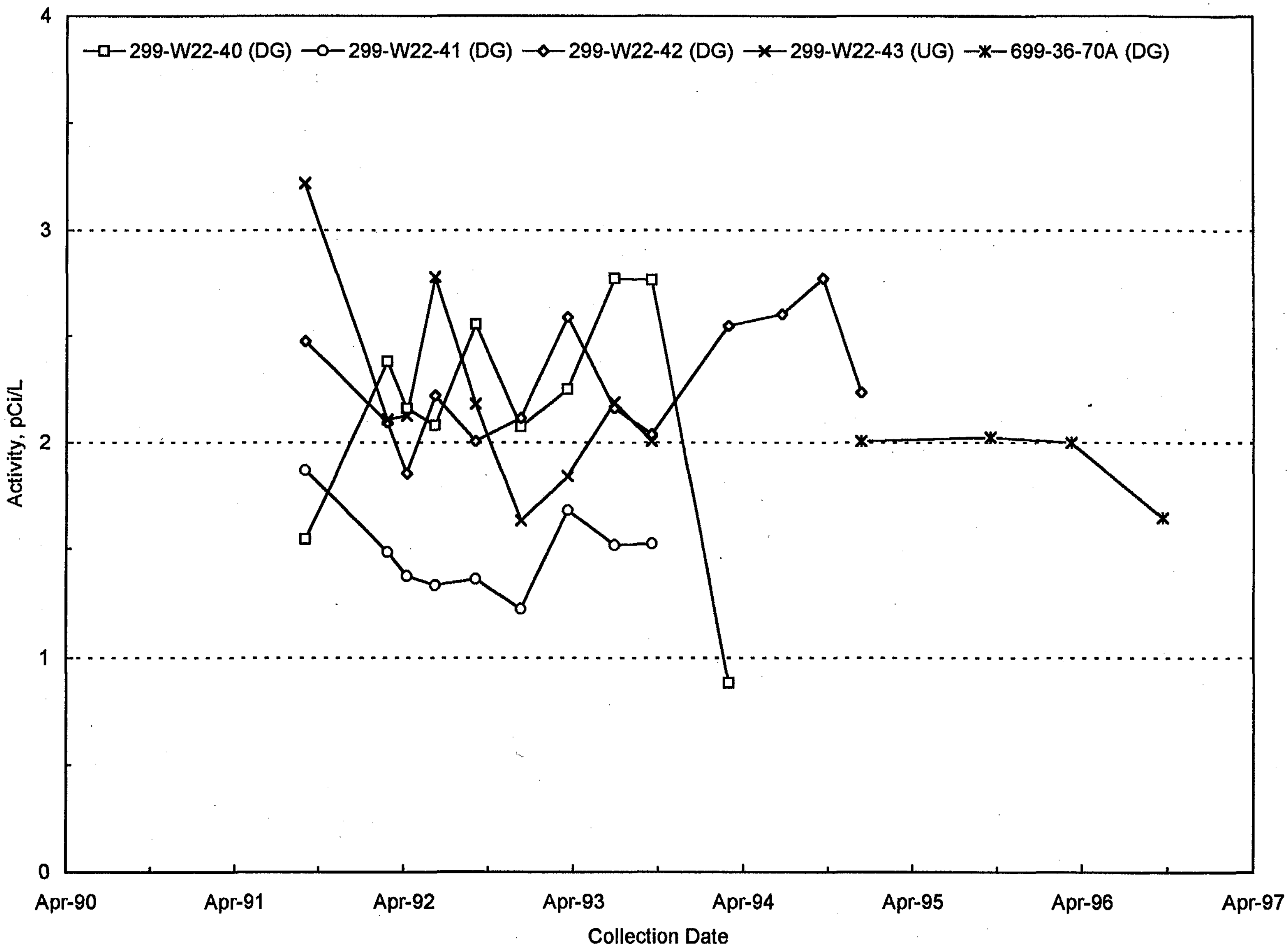


Figure 10. Uranium in Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

Tritium and iodine-129 are two contaminants detected downgradient of the crib. The tritium and iodine-129 trends (Figures 11 and 12) are similar and probably reflect a common source caused by past disposal of process condensate waste from the nuclear fuel dissolution and extraction activities at the REDOX Plant located near the southern end of the 200-West area. Elevated tritium and iodine-129 concentrations in upgradient well 299-W22-23 (see Figures 11 and 12) also support this interpretation. The tritium and iodine-129 activities are highest in well 699-36-70A, located southeast (downgradient based on groundwater flow) of the crib.

3.2.2 Source Determination

The data presented above support 1) the conductance/nitrate relationship, 2) the argument that the two downgradient "trigger" wells are detecting releases from the crib, and 3) the crib as the source for the technetium-99. Other upgradient sources exist, and contaminants have been released to the groundwater but they are not currently detected at or impacting groundwater below the 216 U-12 crib. There are no regional plumes that exhibit the types of correlation discussed for the localized crib-monitoring network.

Many disposal facilities in the surrounding area had similar waste streams and timing. The overlapping plumes from these facilities complicated the assessment of the crib. At least four facilities exist upgradient of the crib that could be potential sources of the detected contaminants (see Figure 1): 216-S-23 crib, 216-S-9 pond (swamp), 216-S-18 crib, and 218-W-9 burial ground. Through a process of elimination, it can be shown that these upgradient facilities are not the source of the constituents detected in wells 299-W22-41 and 299-W22-42.

It can be demonstrated that the breakthrough of constituents migrating between the facilities, as measured in the wells, either does not coincide with the time of contaminant detection at the crib (has significantly higher or lower transport velocities) or is not seen in the key wells at all. This same reasoning demonstrates that other potential upgradient sources (i.e., 216-U-1/2 and 216-U-16) are not impacting the 216-U-12 crib.

The Waste Information Data System (WIDS) provides disposal histories for the four facilities whose hypothetical groundwater flowpaths potentially intersect the 216-U-12 crib.

To confirm that this crib is the source of nitrate (and technetium-99), the gross beta and technetium-99 concentration trend plots are compared to the specific conductance and nitrate plots. These are the only constituents (excluding calcium) found in the effluent waste stream that are detected in both of the downgradient wells that triggered the assessment of the crib.

The correlations between specific conductance, nitrate, and technetium-99 (presented in Table 3) also support the relationship. This relationship is also demonstrated by box and whisker pattern

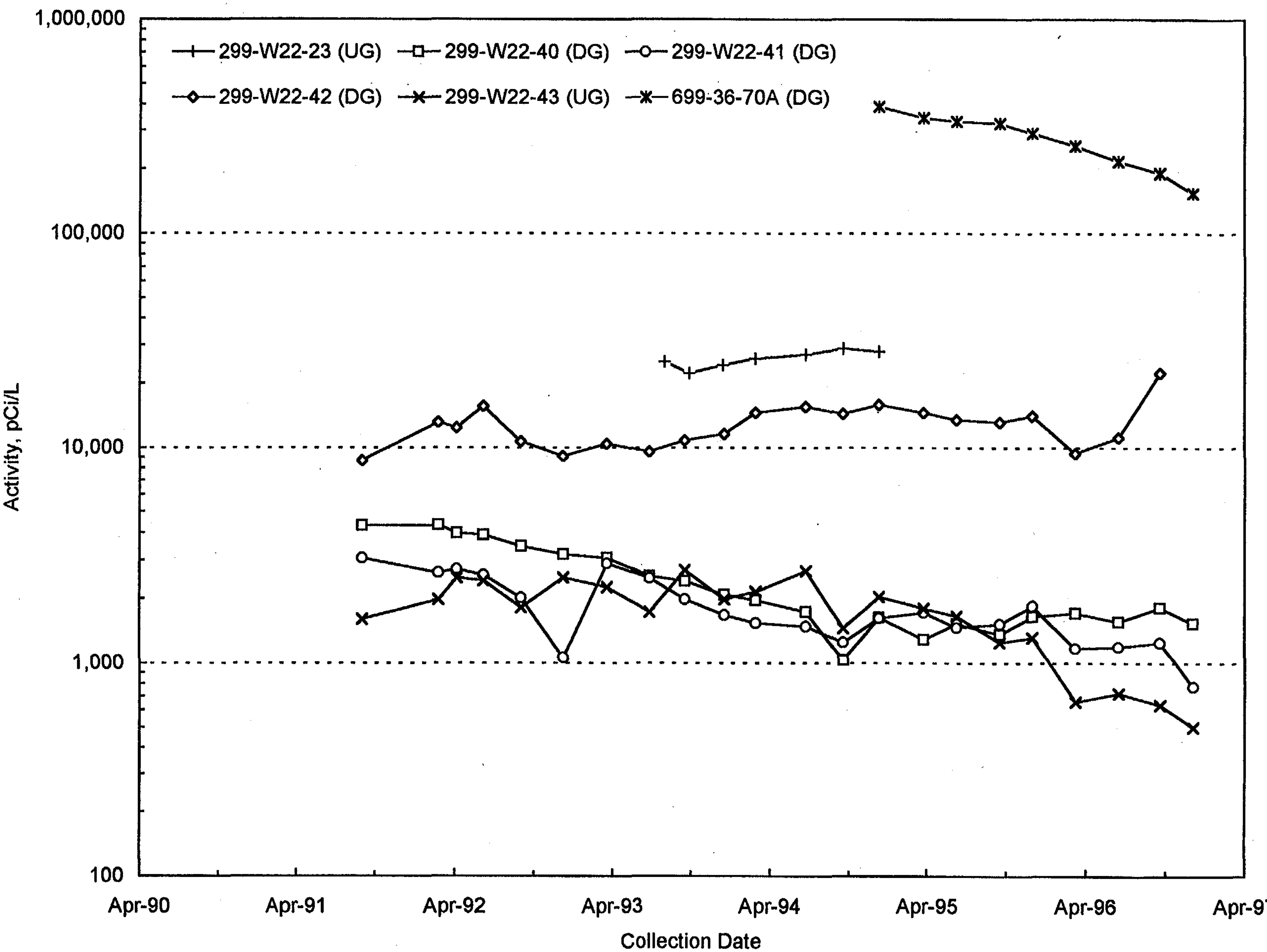


Figure 11. Tritium in Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

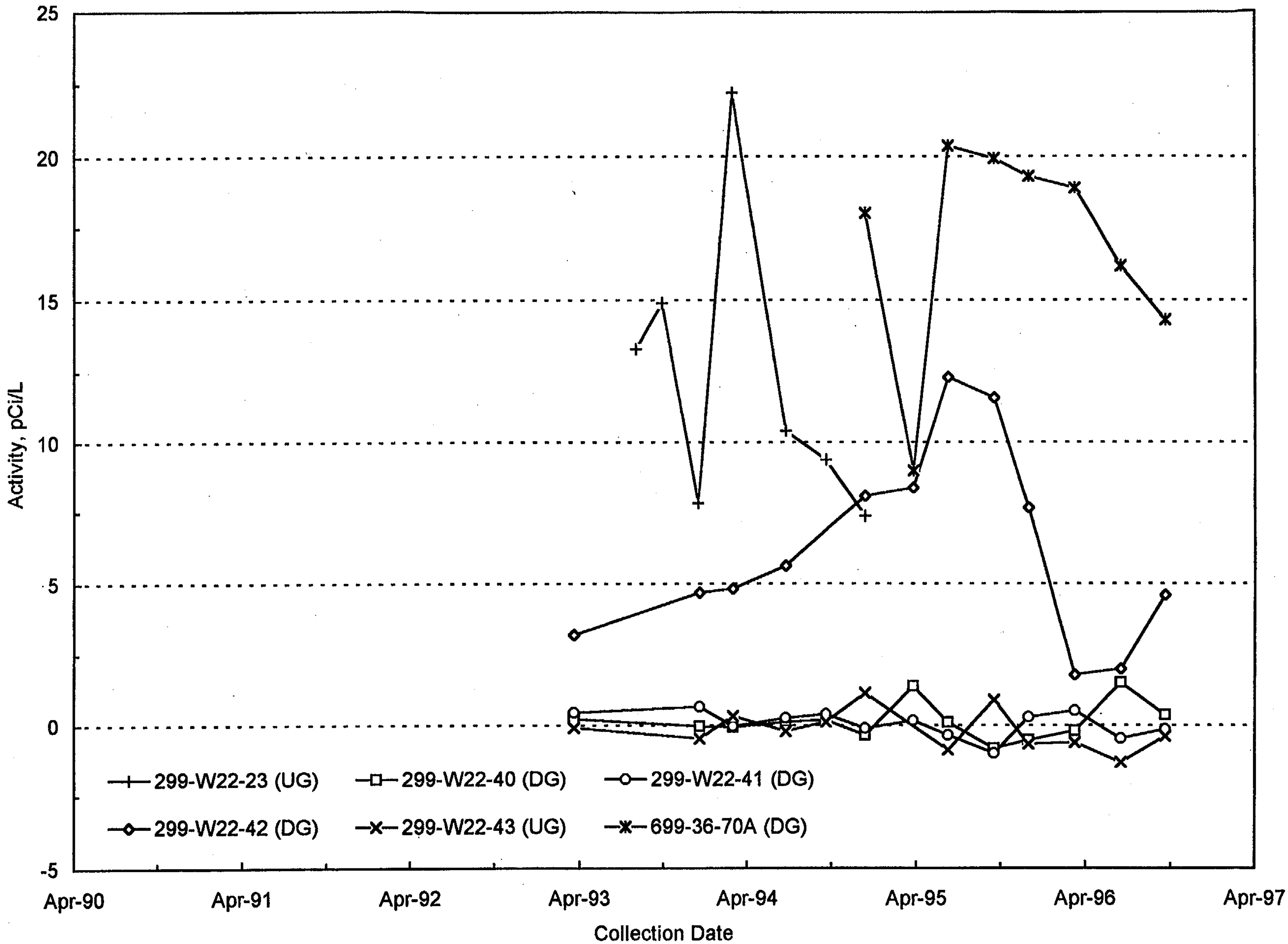


Figure 12. Iodine-129 in Wells Monitoring 216-U-12 Crib (DG = downgradient; UG = upgradient)

comparisons in Figure 13. A comparison of conductance and iodine-129 reveals no relationship and indicates an upgradient site, other than the crib, is likely the source of the iodine-129.

Because technetium-99 has essentially zero retardation, it should travel in groundwater at the same rate as nitrate. Assuming a correlation between concentrations of nitrate and technetium-99 in the liquid effluent, their concentration histories should reflect similar changes in time and relative concentration. A comparison of the trend plots (see Figures 5 through 9) for specific conductance, nitrate, calcium, gross beta, and technetium-99 confirms just that and revealed consistent trends in concentration over time. While the concentrations may be fluctuating, the consistent relationship between the constituents is apparent and indicates that the hydrogeologic processes acting on them and the migration pathway has remained the same.

3.2.3 Hazardous Waste Determination

The strongly acidic, and thus hazardous (corrosive), liquid effluent that went into the crib was composed primarily of nitric acid (Jensen et al. 1990). Nitric acid dissociates into the ions H^+ and NO_3^- when placed in water. The nitrate anion does not interact with the sediment and thus travels at the same rate as the water through the vadose zone. The H^+ cation is quite reactive with the sediments either dissolving sediment aluminum-, silicon-, manganese-, iron-, calcium carbonate-, and titanium-bearing minerals or displacing other cations off exchange sites. The H^+ does not move through the soil with the water. The effects of H^+ are measurable as changes in pore water or groundwater pH. It is expected that the zone of lowered pH was localized in the upper vadose zone near and laterally to the crib bottom.

The nitric acid reacted with, and was neutralized (by design) within, the thick vadose interval (>68 m [225 ft]) below the crib. Neutralization of any residual acidic liquid effluent would occur as the water moved through the calcium carbonate-rich early Palouse soil and Plio-Pleistocene ("caliche") intervals. It can be demonstrated that the acid (H^+) never reached the aquifer. Further, two separate, independent studies discussed below conclude that sufficient calcium carbonate still exists within the vadose zone below the crib to neutralize any residual acid in the crib. This indicates that the hazardous acidic effluent was neutralized before it could migrate into the aquifer and that carbonate-buffering capacity still exists below the crib.

Vadose-Zone Studies

A study completed in November 1987 concluded that, after investigation of deepened crib vadose-zone-monitoring borehole 299-W22-75, the presence of calcium carbonate in the lower portion of the sediment is a strong indication that the crib still retains some buffering capacity. This is an indication that the acidic waste stream did not penetrate to this depth before it was neutralized higher in the soil column.

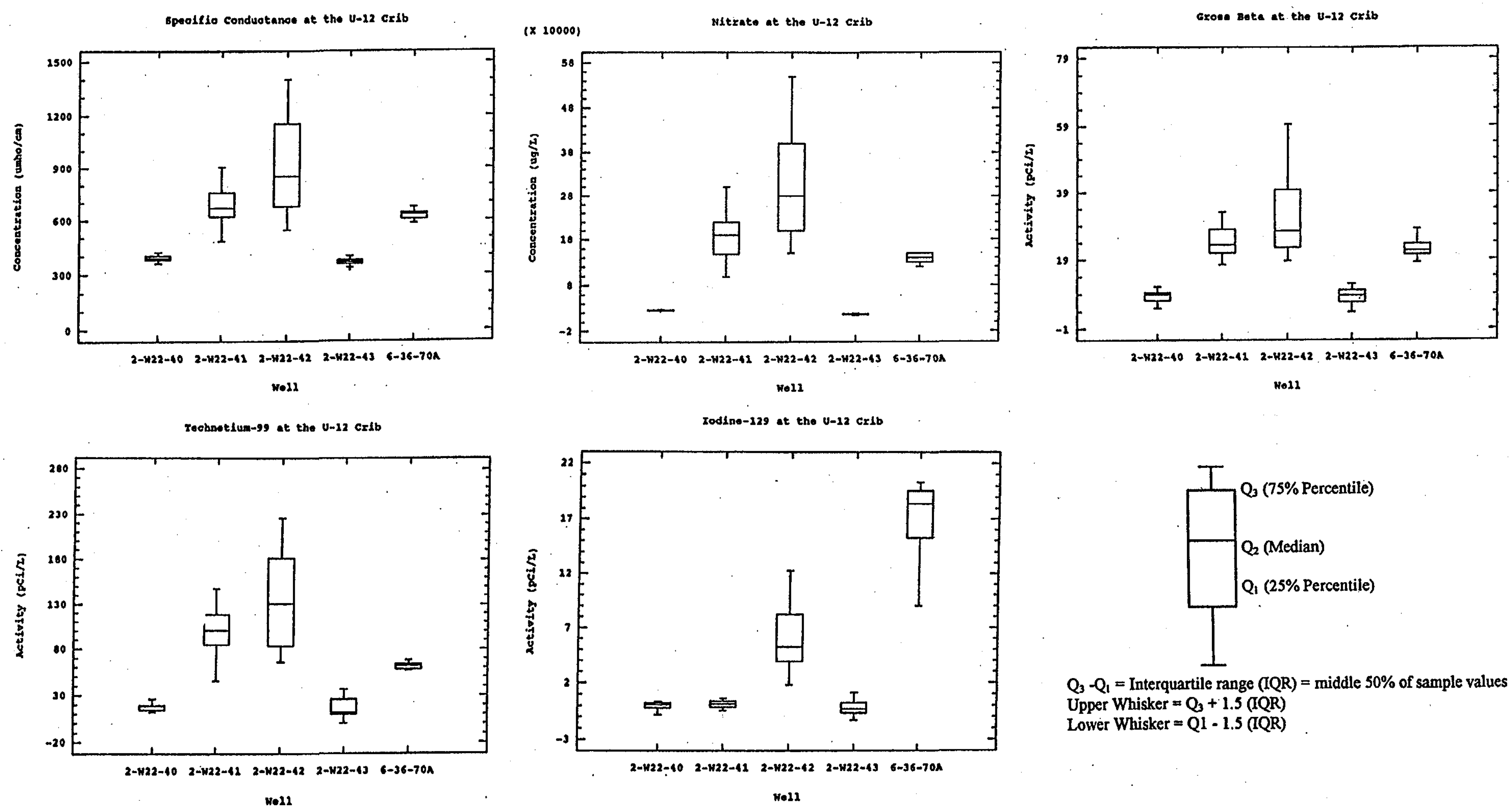


Figure 13. Box and Whisker Plots for Wells Monitoring 216-U-12 Crib

If the acid had reached deeper levels, essentially all the calcium carbonate should have been dissolved. Because the testing was completed in June 1987, only 8 months before the 216-U-12 crib was permanently retired and replaced by the 216-U-17 crib (February 1988), it is concluded that the corrosive component of the waste stream was completely neutralized above the water table.

The second study was completed as part of a CERCLA vadose-zone limited field investigation for the 200-UP-2 Source Operable Unit (Kelty et al. 1994). The purpose of the study was to characterize the vertical and horizontal extent of contaminants within the vadose zone at various disposal sites with the highest probability of significant contamination. The characterization data were used to perform a qualitative risk assessment.

The crib was evaluated for this risk assessment. Limited contaminants were encountered in the single investigative borehole (299-W22-78) drilled at the crib site in October 1994. The borehole was drilled at the edge of the original excavation for the crib (see Figure 2). Analyses for calcium carbonate in the borehole sediment samples confirmed its presence. This study confirms that the area near the crib still retains sufficient carbonate-buffering capacity 6 years after corrosive effluent disposal ceased.

In support of the two studies, a conservative theoretical calculation of the buffering capacity (acid-neutralizing capacity) and chemical reaction potential of calcareous sediments in the vadose zone (Johnson 1993b) was performed. This calculation indicates that there was enough carbonate in the vadose zone to neutralize the acidic effluent.

The chemical reaction for acid neutralization is as follows:

$$2H^+ + CaCO_3 = Ca^{2+} + CO_2 + H_2O$$

The above reaction shows that two moles of acid are consumed for every mole of calcium carbonate. Assuming uniform infiltration of wastewater and lateral spreading of twice the dimensions of the crib (180 m^2 [215 yd^2]) and an average calcium carbonate content of 1.5% in the vadose-zone interval, the moles of calcium carbonate in a 1-m (3-ft) layer of the sediments immediately beneath the crib can be estimated using the following equation:

$$\text{moles } CaCO_3 = \frac{A*Z*D*C}{MW} = \frac{(180\ m^2)*(1\ m)*(2{,}000\ kg/m^3)*(0.015)}{100.08\ kg/kmol} = 54\ kmol$$

where A = area of crib, m^2
Z = soil depth increment, m
D = bulk density of soil, kg/m^3
C = $CaCO_3$ weight fraction (e.g., 1.5% = 0.015)
MW = molecular weight of $CaCO_3$, kg/kmol.

To estimate the total original (predisposal) calcium carbonate content in the vadose zone below the crib, this same calculation is performed using a carbonate content that is assumed equivalent to the carbonate profile for the new assessment well, 699-36-70A (Williams 1995). This well is located in an area near the outer edge of the carbonate depositional facies, which is considered to have less overall carbonate than at the crib. Added incrementally over the Hanford formation/Plio-Pleistocene unit, the estimated total moles of calcium carbonate is:

$$\begin{aligned} \text{total moles } CaCO_3 &= (50.1 \text{ m at } 1.5\% \ CaCO_3) + (9.15 \text{ m at } 6\% \ CaCO_3) + (9.25 \text{ m at } 3\% \ CaCO_3) \\ &= (50.1 \text{ m} * 54 \text{ kmol/m}) + (9.15 \text{ m} * 216 \text{ kmol/m}) + (9.25 \text{ m} * 108 \text{ kmol/m}) \\ &= 2{,}700.0 \text{ kmol} + 1{,}975.0 \text{ kmol} + 987.4 \text{ kmol} = 5.66 * 10^3 \text{ kmol} \end{aligned}$$

The amount of nitric acid disposed to the crib is unknown; however, as reported by Smith and Kasper (1983), the process condensate was known to have an acid molarity of 0.077 mole/L. Using a conservative estimate that assumes that the total molarity is nitric acid and the estimated effluent discharge volume ($1.33 * 10^8$ L) that went to the crib had a molarity equivalent to the process condensate, the calculation for acid equivalent follows:

$$\text{acid equivalent} = V * M = (1.33 * 10^8 \text{ L}) * (0.077 \text{ mole/L}) = 1.024 * 10^7 \text{ moles}$$
$$\text{or } 1.024 * 10^4 \text{ kmol}$$

where V = total estimated effluent volume, L
M = molarity of the acid, mol/L.

Based on this hypothetical chronic acid loading of the soil column, the amount of calcium carbonate that would be consumed, being only half as many moles as the acid equivalent, is $5.12 * 10^3$ kmol. Because the estimated total moles of calcium carbonate available in the vadose zone below the crib is approximately equal to this (conservatively estimated to be $5.66 * 10^3$ kmol), it is concluded that there was a sufficient amount of calcium carbonate to neutralize the estimated amount of nitric acid released to the crib.

Most Probable Scenario

Based on the vadose-zone studies and the consistent near-neutral pH readings (7.72 to 8.19) measured in all the downgradient wells, it is concluded that the vadose zone had sufficient calcium carbonate to neutralize all the acidic effluent waste disposed at the crib before it reached the groundwater. This observation is consistent with the predicted pH (7.3 to 8.2) of an aqueous system in equilibrium with a calcium carbonate phase and ambient or average atmospheric carbon dioxide partial pressures of 10^{-2} to $10^{-3.5}$ atmosphere (Johnson 1993b).

Disposal to the 216-U-12 crib ceased in 1988 and the waste was diverted to the 216-U-17 crib. Based on discussions in Section 3.2.3, it is unlikely that corrosive nitric acid could reach the groundwater and become a health or safety hazard to the public. If any of the residual acidic effluent contacted the aquifer, it would be diluted. However, continued downward migration of neutralized reaction constituents (nitrate and associated radionuclides) is still occurring. This slow leakage into the aquifer may also be enhanced by other liquid sources in the area (i.e., leaking underground utilities, improperly decommissioned or leaking underground disposal lines, and infiltration from large precipitation events).

Continued drainage of mobile contaminants from the vadose zone is expected based on vadose-zone-transport modeling, which has estimated that the travel time for natural (no artificial driving head) moisture within the vadose zone to migrate to the aquifer can take many years (Fayer and Walters 1995).

3.3 Conclusions

Based on the results of the groundwater monitoring conducted for the groundwater quality assessment program Phase I for the 216-U-12 crib, it is concluded:

- that elevated levels of specific conductance in the downgradient triggering wells (299-W22-41 and 299-W22-42) are attributed to nitrate, the mobile anion released when nitric acid is diluted in water, and calcium that is released from the sediments when acid is neutralized
- that technetium-99 levels have been elevated in the downgradient triggering wells since 1991
- that the crib is the source of the elevated nitrate and technetium-99
- that downward migration of nitrate and technetium-99 from the vadose zone is still occurring (further, the driving force that caused the elevation of specific conductance in these two wells is still present [see Figures 6 and 9])
- that tritium and iodine-129 have been detected at levels above background and/or interim drinking water standards in both upgradient and downgradient wells (the patterns are similar [see Figures 11 and 12] and probably reflect a common upgradient source caused by past disposal of process condensate waste from the nuclear fuel dissolution and extraction activities at the REDOX Plant located near the southern end of the 200-West Area).

3.4 Recommendations

Because active effluent disposal at the 216-U-12 crib ended 3 years before RCRA facility groundwater monitoring was initiated, it is presumed that most of the detected nitrate, which still exceeds the drinking water standard, and radioisotopes are remnant contamination or the tail of a larger, higher concentration portion of a plume that migrated beyond the point of the interim-status compliance detection network.

Based on this hypothesis, a Phase II assessment program was initiated to determine if higher concentrations exist downgradient that have not previously been realized and mapped for the region.

4.0 Phase II Assessment

As outlined in the assessment plan supplement (Williams 1994) and as required in 40 CFR 265.93(d)(4)(i), Phase II of the assessment attempts to delineate the location, rate, and extent (including the vertical and horizontal concentration profiles) of the migration of nitrate and associated radioisotopes released to the groundwater from disposal practices at the 216-U-12 crib. In addition, Phase II provides hydrogeologic characterization data necessary to apply and confirm the adequacy of the conceptual hydrogeologic model for the area. This step is important to 1) ensure that there is satisfactory knowledge of site hydrogeologic conditions and the controlling contaminant flow mechanisms, 2) allow informed decisions on how to characterize plume migration, 3) identify the cause of the continued contaminant leakage below the crib for future evaluation, and 4) determine the need for corrective measures at the crib.

Two unknowns to be addressed are whether and to what extent contamination originating from the crib contributes to the regional plume and whether the current well spacing adequately identifies the distribution of contaminants in the groundwater downgradient of the crib.

To determine the unknowns, process knowledge and published information in reports were incorporated into the interpretation to define the major contaminant plumes surrounding the crib. Dresel et al. (1995) provided contaminant plume maps within and surrounding the 200-West Area. Figures 14 through 17 show the areal distribution and concentrations associated with the nitrate, technetium-99, tritium, and iodine-129 plumes. As can be seen from these figures and as discussed previously, many other U Plant and REDOX Plant disposal facilities contributed to these plumes.

Limited well control along with chemically similar waste streams and overlapping timing of effluent disposal complicate the ability to delineate each contributing source. However, it is clearly demonstrated by the asymmetrical nature of the contaminant plumes (see Figures 14 through 17), which extend downgradient of the crib, that this crib contributed to the overall plumes. The regional plumes appear to be a superposition of smaller plumes created from overlapping contaminant plumes from many individual and smaller sources in the area.

One new borehole was located based on strategies and modeling developed both in support of RCRA and the 200-UP-2 Groundwater Operable Unit project (CERCLA), which is providing regional plume mapping and remedial investigation of the U Plant waste-disposal activities in the area. In addition, new well 699-36-70A is integrated to support the needs of the Environmental Restoration Disposal Facility groundwater-detection monitoring network.

4.1 Network Design

The current assessment-monitoring program utilizes an expanded groundwater-monitoring network (Phase II) consisting of 5 wells (see Figure 1), the original 4 RCRA wells (299-W22-40, -41, -42, and

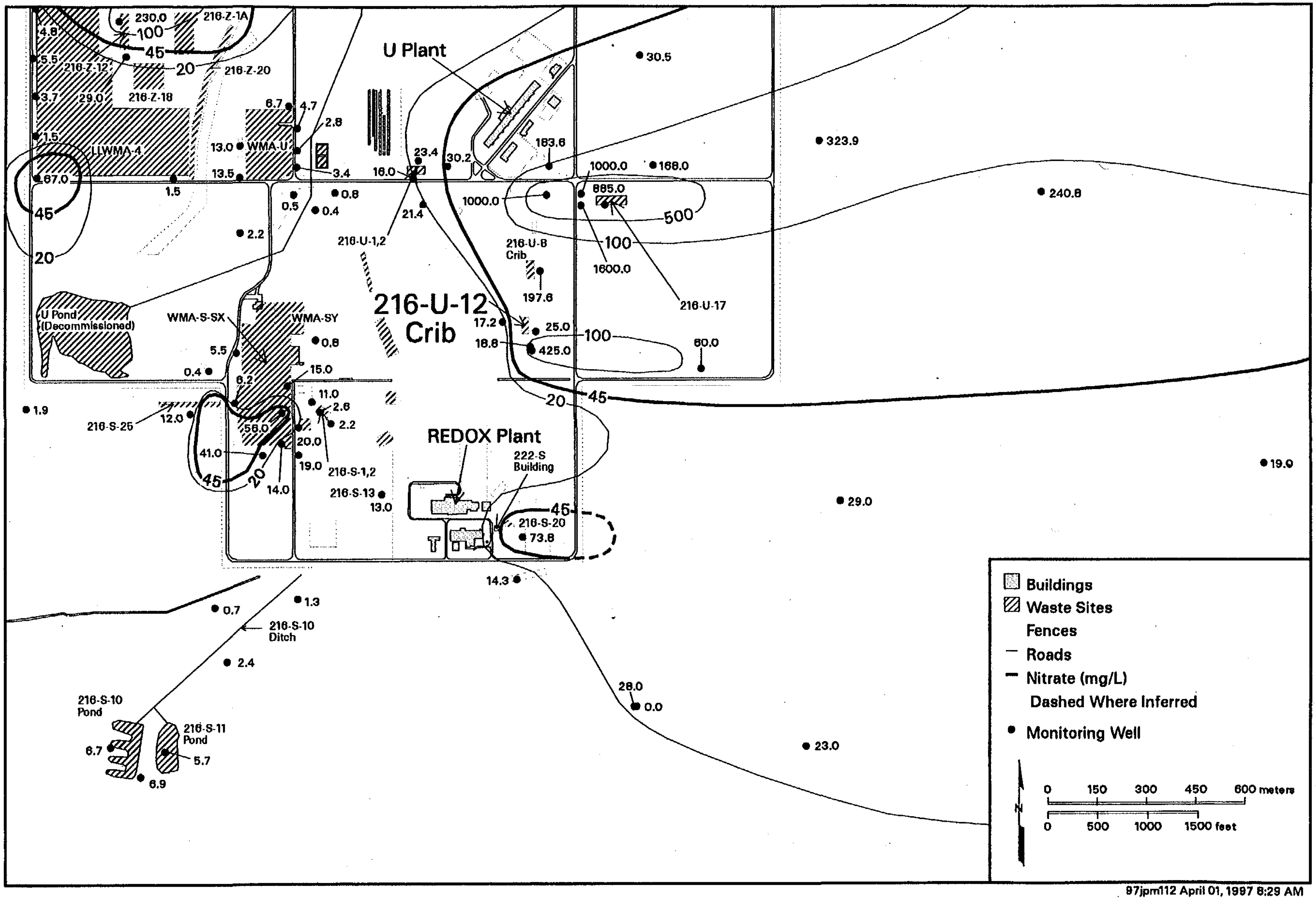


Figure 14. 1994 Nitrate Activity Near 216-U-12 Crib

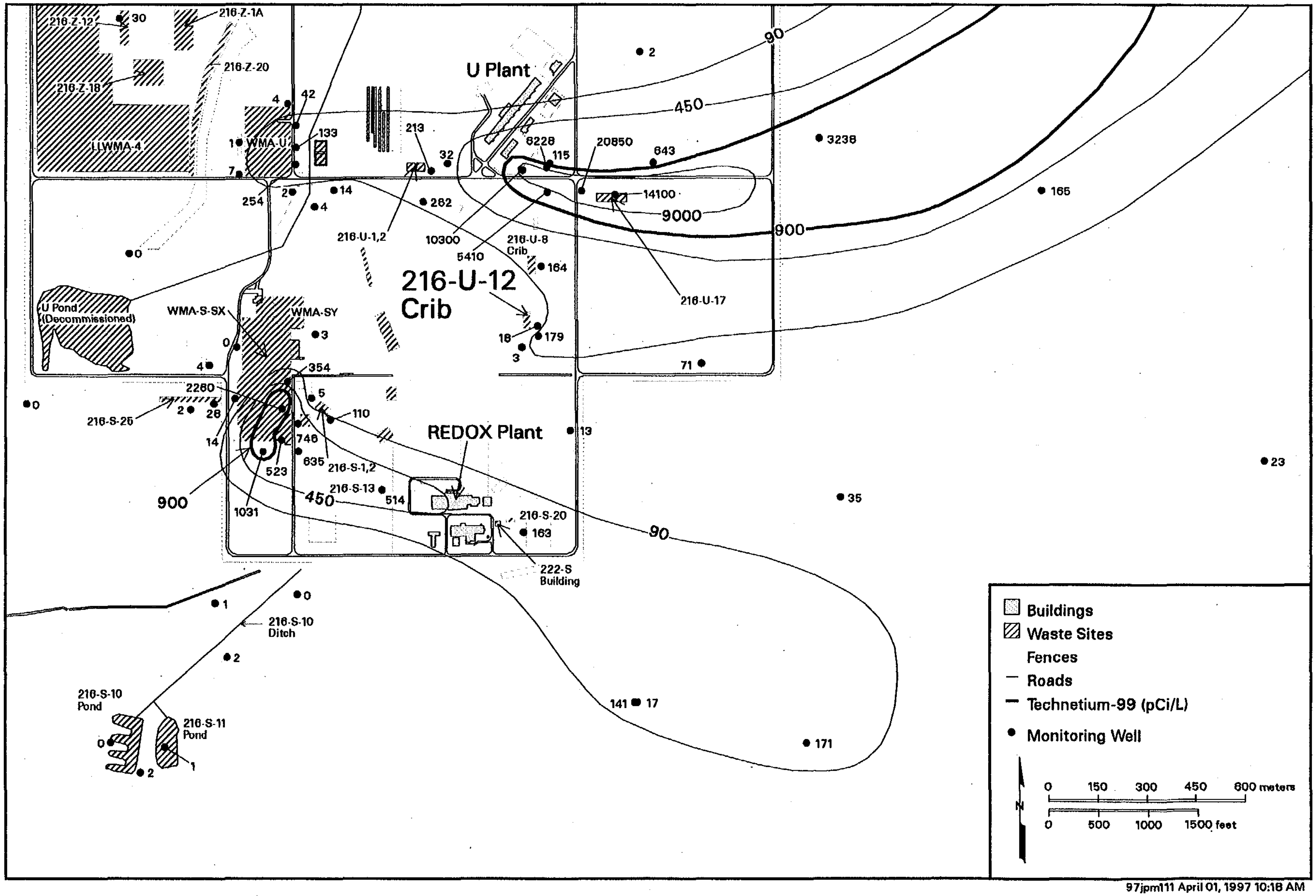


Figure 15. 1994 Technetium-99 Activity Near 216-U-12 Crib

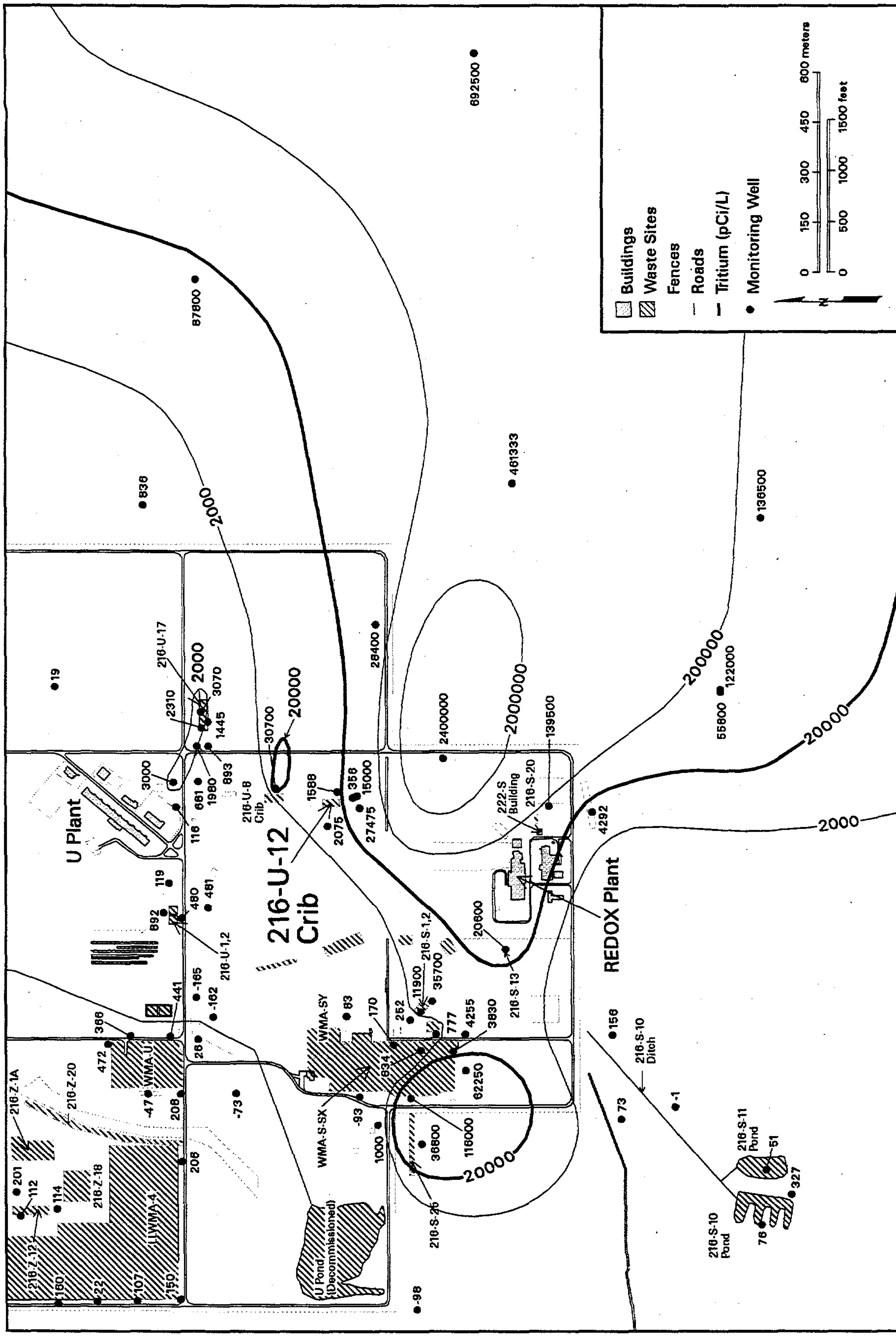


Figure 16. 1994 Tritium Activity Near 216-U-12 Crib

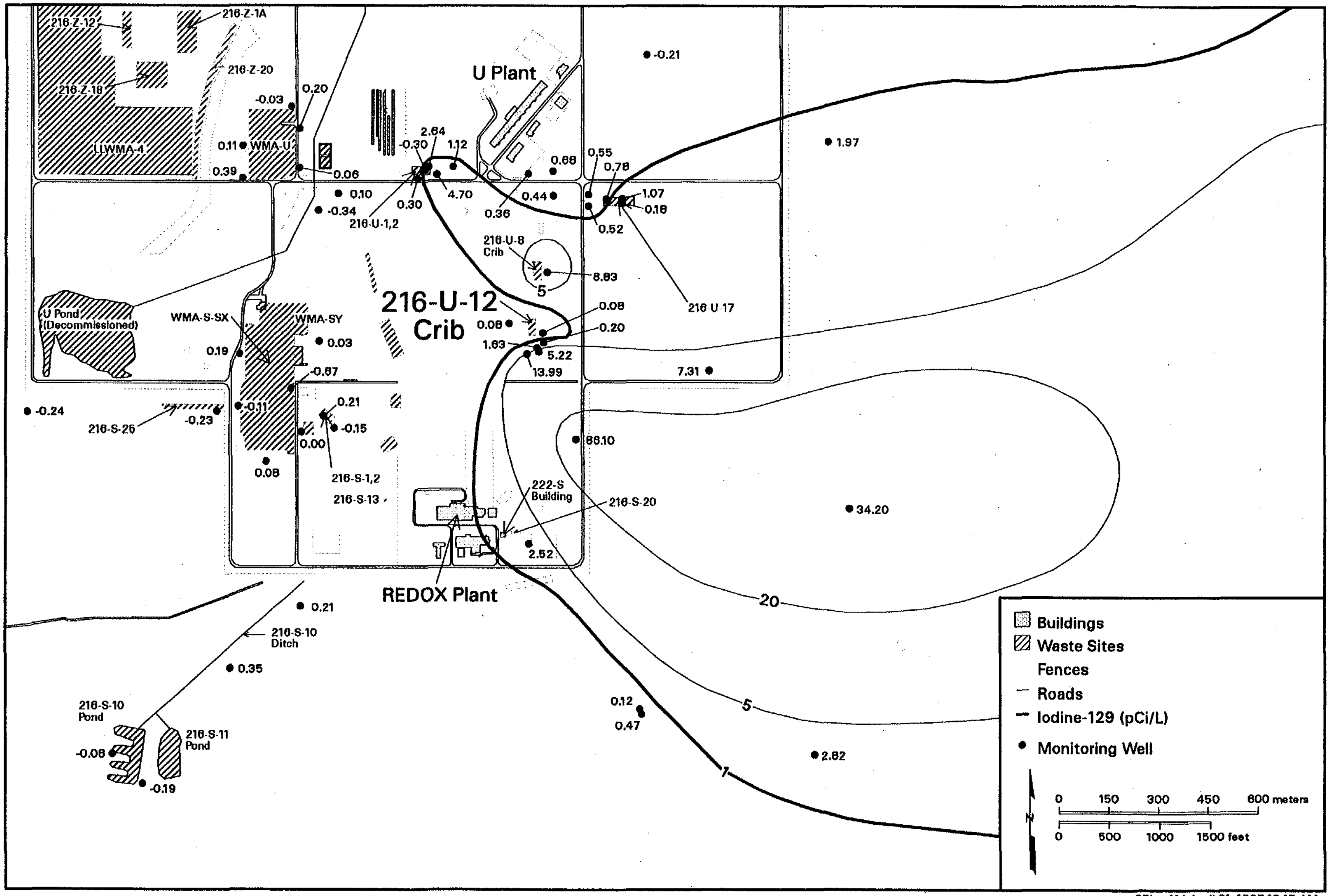


Figure 17. 1994 Iodine-129 Activity Near 216-U-12 Crib

-43) and the new well (699-36-70A). Table 2 listed the current network wells, sampling frequency, construction standards, and selected groundwater constituents. The Appendix contains as-builts for the monitoring well network. The two remediated wells (299-W22-22 and -23) added to the network in support of Phase I assessment have been eliminated from the Phase II network because of problems with excessive turbidity and declining water levels. Well construction information and characterization data results for new well 699-36-70A are documented in Williams (1995).

4.2 Groundwater Monitoring Results

Eight quarters of groundwater data have been collected under Phase II assessment since January 1995. Groundwater results are published in RCRA quarterly reports (e.g., DOE 1996) and/or are available electronically through the Hanford Environmental Information System (HEIS).

Groundwater-monitoring data have been validated and evaluated in accordance with protocols outlined in the quality assurance project plan (WHC 1995), in procedure manuals (WHC 1989, 1992), and as specified in the regulations (40 CFR 265).

4.3 Plume Delineation

Results of the Phase II assessment and the groundwater-sampling results from the new well are included in the plume maps reported in Hartman and Dresel (1997). Comparison of these plumes with those in Figures 14 and 15 indicate that higher concentrations (than the overall region) of nitrate and technetium exist downgradient of the crib. This area of higher nitrate and technetium-99 concentration downgradient of the crib substantiates the crib as the source.

In contrast, groundwater-sampling results for tritium and iodine-129 reveal only minor changes to the regional plume interpretations presented in Figures 16 and 17. This indicates that there has not been a significant contributing source (for tritium and iodine-129) that has gone undetected. This also supports the Phase I conclusion that the source of tritium and iodine-129 is not the crib.

4.4 Conclusions

Based on results of groundwater monitoring conducted for the groundwater quality assessment program Phase II for the 216-U-12 crib, it is concluded:

- that the crib is the source of extended downgradient nitrate and technetium-99 plumes that were not previously recognized because of overlapping and commingling plumes from surrounding disposal activities and limited well control in the area

- that the associated nitrate and technetium-99 plumes have concentrations similar to what is currently being detected in the trigger wells (the nitrate and technetium-99 plume data are currently mapped as part of the overall regional plumes for the 200-West Area).

4.5 Recommendations

Even though the crib is the source of elevated nitrate, the State of Washington Department of Ecology and the U.S. Environmental Protection Agency have decided in the interim remedial measures for the 200 UP-1 Groundwater Operable Unit that nitrate and tritium will not be remediated from the aquifer until practical treatment options are available that will allow cost-effective removal (Swanson 1996). Furthermore, the Tri-Party Agreement (Ecology et al. 1989) has assigned CERCLA as the program that will address the corrective action provisions of RCRA. Therefore, any future cleanup of the crib contaminants will be part of the CERCLA 200 UP-1 Groundwater Operable Unit investigation and subsequent remedial or corrective action decisions.

Based on the information and discussions presented, the following are recommended:

- In accordance with 40 CFR 265.94(7)(i), the site must remain in interim-status assessment monitoring because of continuing elevated levels of nitrate and technetium-99. However, the objective of groundwater monitoring, rather than delineating the existing known plumes, should be focused on 1) continued groundwater monitoring to determine whether the flux of constituents out of the vadose zone into the groundwater is increasing, staying the same, or decreasing; 2) monitoring the known contaminants until a near-term interim corrective action is defined; and 3) monitoring under interim-status assessment until a final-status monitoring plan is implemented during closure of the facility.

- RCRA groundwater-monitoring activities should be integrated with the CERCLA and/or sitewide surveillance programs in accordance with the initiative to combine all groundwater-monitoring requirements under a single groundwater project. Results of RCRA monitoring should provide the inputs for tracking 1) trends at the site and 2) contaminant migration into sitewide plumes from their source at the crib.

- A revised groundwater-monitoring plan should be prepared and implemented as part of the groundwater integration initiative to ensure monitoring activities are integrated with the other groundwater (sitewide) and remediation activities (interim corrective measures), and that only necessary data are collected.

5.0 References

40 CFR 265, Code of Federal Regulations, Title 40, Part 265. *Interim Status Standards for Owners and Operators of Hazardous Water Treatment, Storage, and Disposal Facilities*.

WAC 173-160, Washington Administrative Code. *Minimum Standards for Construction and Maintenance of Wells*. Olympia, Washington.

Aldrich, R. C. 1984. *Radioactive Liquid Wastes Discharged to Ground in the 200 Areas During 1983*. RHO-HS-SR-83-3 4QL1Q P, Rockwell Hanford Operations, Richland, Washington.

Aldrich, R. C. 1985. *Radioactive Liquid Wastes Discharged to Ground in the 200 Areas During 1984*. RHO-HS-SR-84-3 4QL1Q P, Rockwell Hanford Operations, Richland, Washington.

Aldrich, R. C. 1986. *Radioactive Liquid Wastes Discharged to Ground in the 200 Areas During 1985*. RHO-HS-SR-85-3 4QL1Q P, Rockwell Hanford Operations, Richland, Washington.

Aldrich, R. C. 1987. *Radioactive Liquid Wastes Discharged to Ground in the 200 Areas During 1983*. RHO-HS-SR-86-3 4QL1Q P, Rockwell Hanford Operations, Richland, Washington.

Chou, C. J., and B. A. Williams. 1993. *Interim-Status Groundwater Quality Assessment Plan for the 216-U-12 Crib*. WHC-SD-EN-AP-108, Rev. 0, Westinghouse Hanford Company, Richland Washington.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, Public Law 96-510, 94 Stat. 2767, 42 USC 9601 et seq.

Coony, F. M., and S. P. Thomas. 1989. *Westinghouse Hanford Company Effluent Discharges and Solid Waste Management Report for Calendar Year 1988: 200/600 Areas*. WHC-EP-0141-1, Westinghouse Hanford Company, Richland, Washington.

Dresel, P. E., P. D. Thorne, S. P. Luttrell, B. M. Gillespie, W. D. Webber, J. K. Merz, J. T. Rieger, M. A. Chamness, S. K. Wurstner, and B. E. Opitz. 1995. *Hanford Site Ground-Water Monitoring for 1994*. PNL-10698, Pacific Northwest Laboratory, Richland, Washington.

Fayer, M. J., and T. B. Walters. 1995. *Estimated Recharge Rates at the Hanford Site*. PNL-10285, Pacific Northwest Laboratory, Richland, Washington.

Hartman, M. J., and P. E. Dresel (eds). 1997. *Hanford Site Groundwater Monitoring for Fiscal Year 1996*. PNNL-11470, Pacific Northwest National Laboratory, Richland, Washington.

Jensen, E. J., M. A. Chamness, S. M. Goodwin, S. H. Hall, and D. R. Newcomer. 1990. *Interim-Status Ground-Water Monitoring Plan for the 216-U-12 Crib.* WHC-SD-EN-AP-019 Rev. 0, prepared by Pacific Northwest Laboratory for Westinghouse Hanford Company, Richland, Washington.

Johnson, V. G. 1993a. *Westinghouse Hanford Company Operational Groundwater Status Report. 1990-1992.* WHC-EP-0595, Westinghouse Hanford Company, Richland, Washington.

Johnson, V. G. 1993b. *Groundwater Impact Assessment Report for 216-Z-20 Crib, 200 West Area.* WHC-EP-0674, Westinghouse Hanford Company, Richland, Washington.

Kelty, G. G., K. A. Lindsey, S. E. Kos, R. K. Price. 1994. *Borehole Summary Report for the 200-UP-2 Operable Unit, 200 West Area.* BHI-00034, Rev.00, Bechtel Hanford, Inc., Richland, Washington.

Maxfield, H. L. 1979. *Hanford - 200 Area Waste Sites.* RHO-CD-673, Rockwell Hanford Operations, Richland, Washington.

McMurray, B. J. 1966. *Radioactive Contamination in Liquid Wastes Discharged to Ground at the Separations Facilities Through December, 1965.* ISO-98, Isochem Company, Richland, Washington.

Resource Conservation and Recovery Act of 1966, as amended, Public Law 94-580, 90 Stat. 2795, 42 USC 6901 et seq.

Rohay, V. J., K. J. Swett, and G. V. Last 1994. *1994 Conceptual Model of the Carbon Tetrachloride Contamination in the 200 West Area at the Hanford Site.* WHC-SD-EN-TI-248, Rev.0, Westinghouse Hanford Company, Richland, Washington.

Smith, R. M., and R. B. Kasper. 1983. *Serviceability of Cribs Affected by PUREX Startup.* RHO-HS-EV-18, Rockwell Hanford Operations, Richland, Washington.

State of Washington Department of Ecology (Ecology). 1994. *Hanford Facility RCRA Permit.* Permit WA7890008967, effective September 28, 1994, Olympia, Washington.

State of Washington Department of Ecology (Ecology), U.S. Environmental Protection Agency (EPA), and U.S. Department of Energy (DOE). 1989. *Hanford Federal Facility Agreement and Consent Order Between the U.S. Environmental Protection Agency, the U.S. Department of Energy, and the State of Washington Department of Ecology, May 15, 1989,* as amended. Olympia, Seattle, and Richland, Washington.

Swanson, L. C. 1996. *Engineering Evaluation/Conceptual Plan for the 200-UP-1 Groundwater Operable Unit Interim Remedial Measure.* BHI-00187, Bechtel Hanford, Inc., Richland, Washington.

Trent, S. J. 1992. *Hydrogeologic Model for the 200 West Groundwater Aggregate Area*. WHC-SD-EN-TI-014, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

U.S. Department of Energy (DOE). 1995. *Hanford Site Groundwater Remediation Strategy*. DOE/RL-94-95, Rev. 0, Richland Operations Office, Richland, Washington.

U.S. Department of Energy (DOE). 1996a. *Hanford Facility Dangerous Waste Permit Application, General Information Portion*. DOE/RL-91-28, Rev. 2, Richland Operations Office, Richland, Washington.

U.S. Department of Energy (DOE). 1996b. *Quarterly Report of RCRA Groundwater Monitoring Data for Period July 1 through September 30, 1995*. DOE/RL-95-69-3, Richland Operations Office, Richland, Washington.

U.S. Environmental Protection Agency (EPA). 1991. *Proposed Rules for National Drinking Water Regulations: Radionuclides*. Federal Register 56:138, July 18, 1991.

Westinghouse Hanford Company (WHC). 1989. *Environmental Investigations and Site Characterization Manual*. WHC-CM-7-7, Vol. 1, Richland, Washington.

Westinghouse Hanford Company (WHC). 1992. *Environmental Activities*. WHC-CM-7-8, Richland, Washington.

Westinghouse Hanford Company (WHC). 1995. *Quality Assurance Project Plan for RCRA Groundwater Monitoring Activities Managed by Westinghouse Hanford Company*. Westinghouse Hanford Company, Richland, Washington.

Williams, B. A. 1994. Supplemental Engineering Change Notice #602620 for *Interim Status Groundwater Quality Assessment Monitoring Plan for the 216-U-12 Crib*. WHC-SD-EN-AP-108, Rev. 0., Westinghouse Hanford Company, Richland, Washington.

Williams, B. A. 1995. *Borehole Data Package for the 216-U-12 Crib Well 699-36-70A, Calendar Year 1994*. WHC-SD-EN-DP-091, Rev.0, Westinghouse Hanford Company, Richland, Washington.

Williams, B. A. 1996. "4.2 216-U-12 Crib." In *Annual Report for RCRA Groundwater Monitoring Projects at Hanford Site Facilities for 1995*. DOE/RL-96-01, Rev. 0, prepared by Earth and Environmental Technical Services, Westinghouse Hanford Company for U.S. Department of Energy, Richland Operations Office, Richland, Washington.

Appendix

216-U-12 Crib Assessment Well As-Builts

Appendix

216-U-12 Crib Assessment Well As-Builts

This appendix contains the as-built diagrams for all the groundwater monitoring wells utilized for sampling and assessment of the 216-U-12 crib.

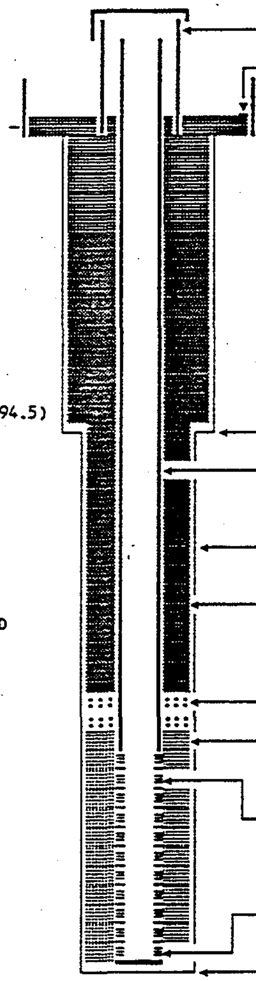
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel Hard tool	WELL NUMBER: 299-W22-40 TEMPORARY WELL NO:
Drilling Fluid Used: Water	Additives Used: None	Hanford Coordinates: N/S N 36,242.3 E/W W 73,041.7
Driller's Name: L. Watkins	WA State Lic Nr: Not documented	State NAD83 Coordinates: N 134,509.99m 441,357 E 567,634.57m 2,222,190
Drilling Company: Kaiser Engineers Han	Company Location: Richland, WA	Start Card #: Not documented T___ R___ S___
Date Started: 01Mar90	Date Complete: 15May90	Elevation Ground surface (ft): 689.22 Brass cap

Depth to water: 228.1-ft Apr90
(Ground surface) 232.4-ft Sep92

GENERALIZED STRATIGRAPHY — Geologist's Log

5: SAND
10: Slightly gravelly, slightly muddy SAND
15: Slightly muddy SAND
20: Muddy SAND
25,30: Slighlty gravelly SAND
35,40: SAND
43: Muddy SAND
45,50,55: SAND
60: Slightly gravelly SAND
64: Slightly muddy SAND
65: Gravelly SAND
70,75,80,85: SAND
87: Slightly muddy SAND
90,95: SAND (Sl muddy 92-93, 94-94.5)
100: Muddy SAND
105: SAND
110,115: Slightly muddy SAND
120-155: SAND
160,165,170: Slightly muddy SAND
175: Muddy SAND
180: Slightly muddy SAND
185: Muddy SAND
190: Slightly gravelly, slightly muddy SAND
195: Slightly muddy gravelly SAND
200: Slightly muddy SAND
205: Slightly gravelly, slightly muddy SAND
210,215,220: Muddy SAND
225: Slightly muddy SAND
230: Muddy SAND
235,240,245: Muddy sandy GRAVEL



Elevation of reference point: (top of casing) [692.23-ft]
Height of reference point above ground surface [3.0-ft]
Depth of surface seal [0-20.5-ft]
Type of surface seal: 4-ft by 4-ft concrete surface pad. Cement grout to 20.5-ft.
10 3/4-in nominal hole to 143.5-ft.
I.D. of riser pipe: [4-in]
Type of riser pipe: Type 304 stainless steel
Diameter of borehole: 143.5-245.0-ft [9-in nom]
Type of filler, 20.5-211.1-ft: Bentonite crumbles 8-20 mesh
Bentonite pellets, 1/2-3/8-in 211.1-218.1-ft
Depth top of sand pack: 40 mesh silica sand to 243.2-ft [218.1-ft]
Depth top of screen: 4-in, #10-slot, Johnson type 304 stainless steel, wire wrapped, with bottom cap and channel pack [224.1-ft]
Depth bottom of screen: [244.5-ft]
Depth bottom of borehole: [245.0-ft]

Drawing By: RKL/2W22-40.ASB Date: 24Nov92
Reference: WHC-MR-0208, October 1990
KEH Survey Data Report, 18Jun90

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W22-40

WELL DESIGNATION	:	299-W22-40
CERCLA UNIT	:	200 Aggregate Area Management Study
RCRA FACILITY	:	216-U-12
HANFORD COORDINATES	:	N 36,242.3 W 73,041.7 [200W-18Jun90]
LAMBERT COORDINATES	:	N 441,357 E 2,222,190 [HANCONV] N 134,509.99m E 567,634.57m [NAD83-18Jun90]
DATE DRILLED	:	May90
DEPTH DRILLED (GS)	:	245.0-ft
MEASURED DEPTH (GS)	:	244.5-ft, 13May91
DEPTH TO WATER (GS)	:	228.1-ft, Apr90; 232.4-ft, 09Sep92
CASING DIAMETER	:	4-in, stainless steel, +ND↔224.1-ft; 6-in, stainless steel, +3.0↔-0.5-ft (not documented)
ELEV TOP CASING	:	692.23-ft, [200W-18Jun90]
ELEV GROUND SURFACE	:	689.22, Brass cap [200W-18Jun90]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	224.1↔244.5-ft, #10-slot, stainless steel
COMMENTS	:	FIELD INSPECTION, 20Jan92; Stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable capped and locked, brass cap in pad with well ID. Not in radiation zone. OTHER:
AVAILABLE LOGS	:	Driller
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	U-12 crib Quarterly water level measurement, 20Nov90↔09Sep92; Not on water sample schedule
PUMP TYPE	:	Hydrostar
MAINTENANCE	:	

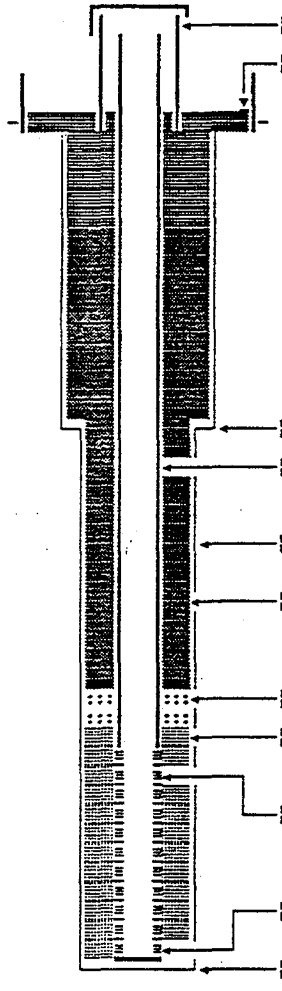
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel Hard tool	WELL NUMBER: 299-W22-41 TEMPORARY WELL NO:
Drilling Fluid Used: Water	Additives Used: None	Hanford Coordinates: N/S N 36,142.1 E/W W 73,033.8
Driller's Name: C. Wamsley	WA State Lic Nr: Not documented	State NAD83 N 134,479.46m E 567,637.04m
Drilling Company: Kaiser Engineers Han	Company Location: Richland, WA	Coordinates: N 441,255 E 2,222,197
Date Started: 07Feb90	Date Complete: 15May90	Start Card #: Not documented T___ R___ S___
		Elevation Ground surface (ft): 688.77 Brass cap

Depth to water: 228.0-ft Apr90
(Ground surface) 231.9-ft Sep92

GENERALIZED STRATIGRAPHY — Geologist's Log

5: Slightly muddy SAND
10–45: SAND
50: Slightly gravelly SAND
55–105: SAND (slightly cemented at 104 ft)
110: Muddy SAND
115–155: SAND
160: Muddy SAND
165–185: Sandy MUD
190–205: Muddy sandy GRAVEL
210–230: Sandy MUD
235–245: Muddy sandy GRAVEL



Elevation of reference point: (top of casing) [691.74-ft]

Height of reference point above ground surface [2.97-ft]

Depth of surface seal [0–18.4-ft]

Type of surface seal:
4-ft by 4-ft concrete pad
Cement grout to 18.4-ft

10 3/4-in nominal hole to 132.1-ft

I.D. of riser pipe: [4-in]
Type of riser pipe:
Type 304 stainless steel

Diameter of borehole: 132.1–244.4-ft [9-in nom]

Type of filler, 18.4–215.4-ft:
Bentonite crumbles
8–20 mesh

Bentonite pellets, 1/2–3/8-in
215.4–220.7-ft

Depth top of sand pack: [220.7-ft]
40–100 mesh silica sand
to 243.7-ft

Depth top of screen: [224.1-ft]
4-in, #5-slot, Johnson type 304 stainless steel, wire wrapped, with bottom cap.

Depth bottom of screen: [245.3-ft]

Depth bottom of borehole: [245.3-ft]

Drawing By: RKL/2W22-41.ASB Date: 30Nov92

Reference: WHC-MR-0208, October 1990
KEH Survey Data Report, 18Jun90

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W22-41

WELL DESIGNATION	:	299-W22-41
CERCLA UNIT	:	200 Aggregate Area Management Study
RCRA FACILITY	:	216-U-12
HANFORD COORDINATES	:	N 36,142.1 W 73,033.8 [200W-18Jun90]
LAMBERT COORDINATES	:	N 441,255 E 2,222,197 [HANCONV] N 134,479.46m E 567,637.04m [NAD83-18Jun90
DATE DRILLED	:	May90
DEPTH DRILLED (GS)	:	245.3-ft
MEASURED DEPTH (GS)	:	245.6-ft, 13May91
DEPTH TO WATER (GS)	:	228.0-ft, Apr90; 231.9-ft, 09Sep92
CASING DIAMETER	:	4-in, stainless steel, +ND–224.1-ft; 6-in, stainless steel, +2.97–¯0.5-ft (not documented)
ELEV TOP CASING	:	691.74-ft, [200W-18Jun90]
ELEV GROUND SURFACE	:	688.77, Brass cap [200W-18Jun90
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	224.1–245.3-ft, #5-slot, stainless steel
COMMENTS	:	FIELD INSPECTION, 13May91; Stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable capped and locked, brass cap in pad with well ID. Not in radiation zone. OTHER:
AVAILABLE LOGS	:	Driller
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	U-12 Crib Quarterly water level measurement, 20Nov90–09Sep92; Not on water sample schedule
PUMP TYPE	:	Hydrostar
MAINTENANCE	:	

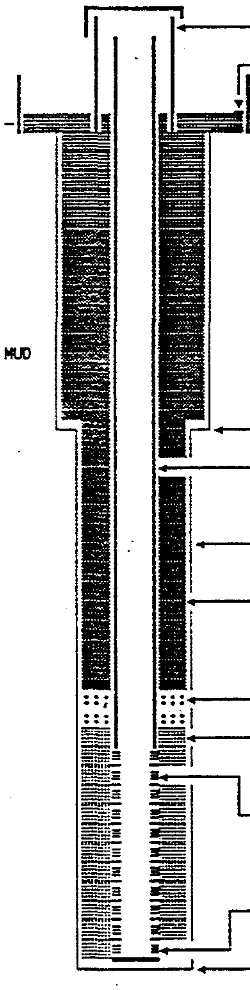
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel Hard tool	WELL NUMBER: 299-W22-42 TEMPORARY WELL NO:
Drilling Fluid Used: Water	Additives Used: None	Hanford Coordinates: N/S N 36,052.7 E/W W 73,079.6
Driller's Name: G. Lydin	WA State Lic Nr: Not documented	State NAD83 N 134,452.20m E 567,623.16m Coordinates: N 441,167 E 2,222,153
Drilling Company: Kaiser Engineers Han	Company Location: Richland, WA	Start Card #: Not documented T___ R___ S___
Date Started: 12Feb90	Date Complete: 15May90	Elevation Ground surface (ft): 688.20 Brass cap

Depth to water: 227.0-ft Apr90
(Ground surface) 231.4-ft Sep92

GENERALIZED STRATIGRAPHY   Geologist's Log

5-30: SAND
35: Slightly muddy SAND
40,45: SAND
50: Gravelly SAND
55-150: SAND
155: Slightly muddy SAND
160: Muddy SAND
165,170: Sandy MUD
175-185: Muddy SAND
190,195: Gravelly muddy SAND
200,205: Muddy SAND
210,215: Slightly gravelly sandy MUD
220,225: Sandy MUD
230: Muddy SAND
235-245: Muddy sandy GRAVEL



- Elevation of reference point: (top of casing) [691.16-ft]
- Height of reference point above ground surface [2.96-ft]
- Depth of surface seal [18.8-ft]
- Type of surface seal: Cement grout
- 10 3/4-in nominal hole to 137.7-ft.
- I.D. of riser pipe: [4-in]
- Type of riser pipe: Type 304 stainless steel
- Diameter of borehole: 137.7-243.4-ft [9-in nom]
- Type of filler, 18.8-215.2-ft: Bentonite crumbles 8-20 mesh
- Bentonite pellets, 1/2-3/8-in 215.2-219.7-ft
- Depth top of sand pack: 40-mesh silica sand to 243.2-ft [219.7-ft]
- Depth top of screen: 4-in, #10-slot, Johnson type 304 stainless steel, wire wrapped, with bottom cap. [223.1-ft]
- Depth bottom of screen: [243.4-ft]
- Depth bottom of borehole: [243.4-ft]

Drawing By: RKL/2W22-42.ASB   Date: 30Nov92

Reference: WHC-MR-0208, October 1990
KEH Survey Data Report 18Jun90

SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W22-42

WELL DESIGNATION	:	299-W22-42
CERCLA UNIT	:	200 Aggregate Area Management Study
RCRA FACILITY	:	216-U-12
HANFORD COORDINATES	:	N 36,052.7 W 73,079.6 [200W-18Jun90]
LAMBERT COORDINATES	:	N 441,167 E 2,222,153 [HANCONV]
		N 134,452.20m E 567,623.16m [NAD83-18Jun90]
DATE DRILLED	:	May90
DEPTH DRILLED (GS)	:	243.4-ft
MEASURED DEPTH (GS)	:	244.3-ft, 13May91
DEPTH TO WATER (GS)	:	227.0-ft, Apr90;
		231.4-ft, 09Sep92
CASING DIAMETER	:	4-in, stainless steel, ~+1.0↔223.1-ft;
		6-in stainless steel, +2.96↔~0.5-ft (not documented)
ELEV TOP CASING	:	691.16-ft, [200W-18Jun90]
ELEV GROUND SURFACE	:	688.20, Brass cap [200W-18Jun90]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	223.1↔243.4-ft, 10-slot, stainless steel
COMMENTS	:	FIELD INSPECTION, 13May91;
		Stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable
		capped and locked, brass cap in pad with well ID.
		Not in radiation zone.
		OTHER:
AVAILABLE LOGS	:	Driller
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	Water levels measured, 20Nov90↔09Sep92
		Not on water sample schedule
PUMP TYPE	:	Hydrostar
MAINTENANCE	:	

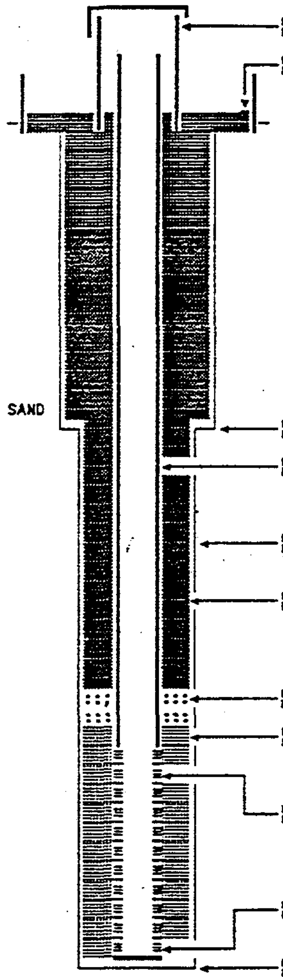
WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Drive barrel Method: Hard tool	WELL NUMBER: 299-W22-43 TEMPORARY WELL NO:
Drilling Fluid Used: Water	Additives Used: None	Hanford Coordinates: N/S N 36,339.1 E/W W 73,376.5
Driller's Name: D. Ludke	WA State Lic Nr: Not documented	State NAD83 N 134,539.24m E 567,532.48m Coordinates: N 441,453 E 2,221,855
Drilling Company: Kaiser Engineers Han	Company Location: Richland, WA	Start Card #: Not documented T___ R___ S___
Date Started: 22Feb90	Date Complete: 15May90	Elevation Ground surface (ft): 688.40 Brass cap

Depth to water: 226.2-ft Apr90
(Ground surface) 230.7-ft Sep92

GENERALIZED STRATIGRAPHY Geologist's Log

5: Slightly muddy SAND
10: Slightly gravelly SAND
15-35: SAND
40: Slightly gravelly SAND
45: Gravelly SAND
50: Slightly gravelly SAND
55-95: SAND
100-110: Slightly muddy SAND
115-135: SAND
140,145: Slightly muddy SAND
150,155: Muddy SAND
160-180: Sandy MUD
185: Sandy MUD, caliche
190: Muddy sandy GRAVEL, caliche
195,200: Slightly gravelly muddy SAND
205-215: Sandy MUD
220-235: Muddy SAND
240: SAND
245: Muddy sandy GRAVEL



Elevation of reference point: [691.35-ft]
(top of casing)

Height of reference point above ground surface [2.83-ft]

Depth of surface seal [0-18-ft]

Type of surface seal:
4-ft by 4-ft concrete pad
Cement grout to 18.0-ft

10 3/4-in nominal hole to 134.9-ft.

I.D. of riser pipe: [4-in]
Type of riser pipe:
Type 304 stainless steel

Diameter of borehole: [9-in nom]
134.9-244.0-ft

Type of filler, 18.0-216.0-ft:
Bentonite crumbles
8-20 mesh

Bentonite pellets, 1/2-3/8-in
216.0-219.4-ft

Depth top of sand pack: [219.4-ft]
40-mesh silica sand
to 242.9-ft

Depth top of screen: [223.7-ft]
4-in, #10-slot, Johnson type 304
stainless steel, wire wrapped,
with bottom cap.

Depth bottom of screen: [244.0-ft]

Depth bottom of borehole: [244.0-ft]

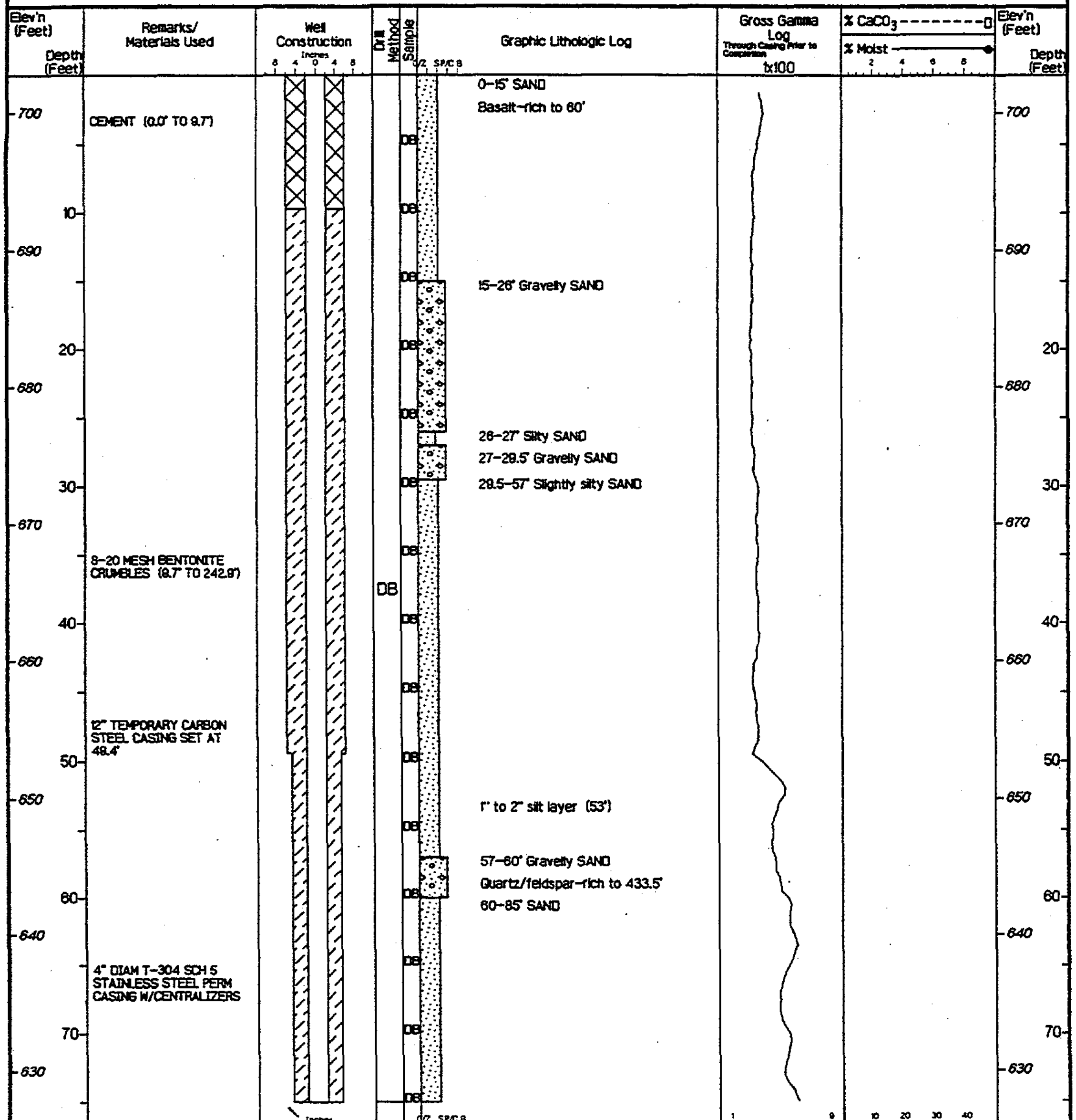
Drawing By: RKL/2W22-43.ASB Date: 07Dec92

Reference: WHC-MR-0208, October 1990
KEH Survey Data Report 18Jun90

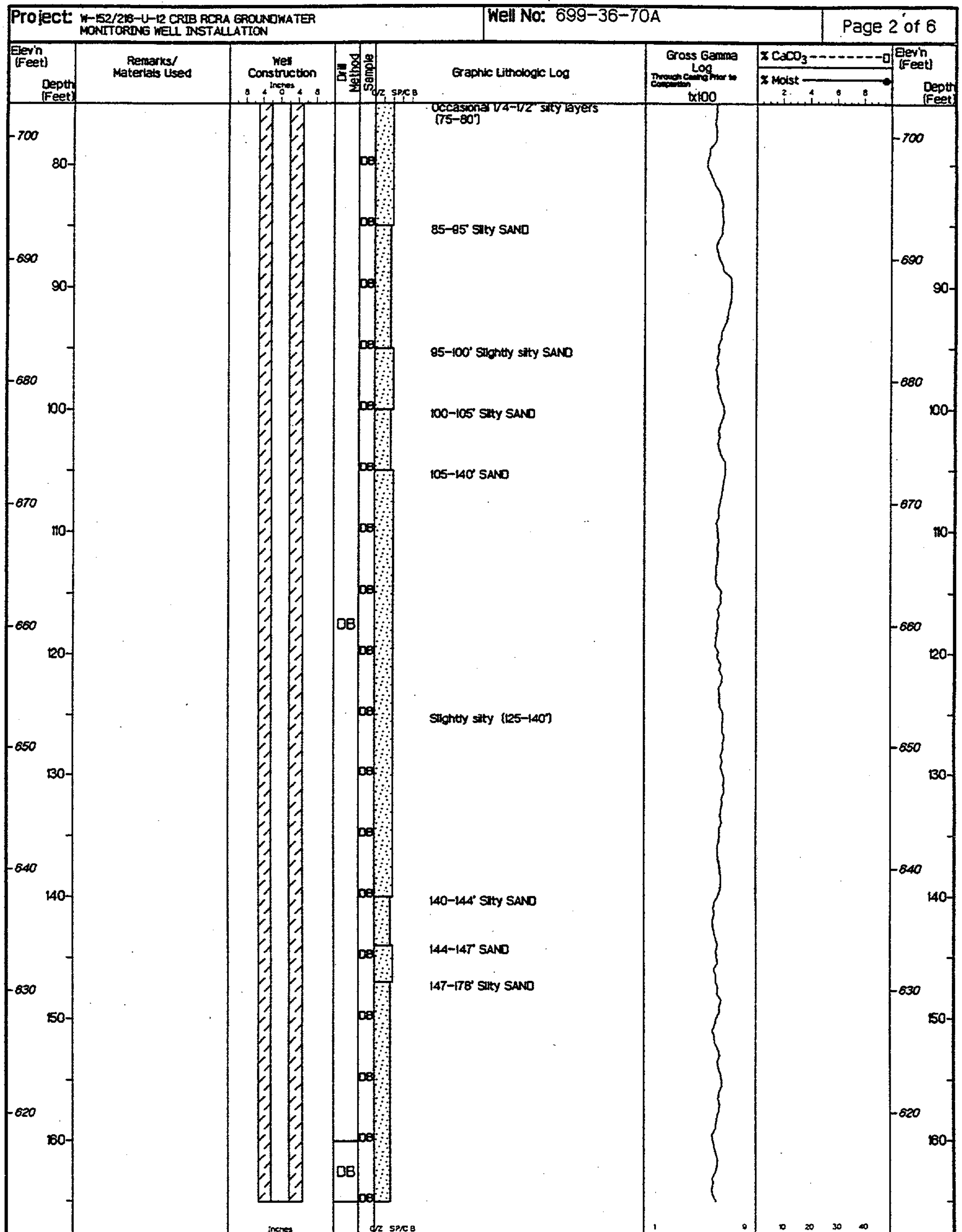
SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
RESOURCE PROTECTION WELL - 299-W22-43

WELL DESIGNATION	:	2-W22-43
CERCLA UNIT	:	200 Aggregate Area Management Study
HANFORD COORDINATES	:	N 36,339.1 W 73,376.5 [200W-18Jun90]
LAMBERT COORDINATES	:	N 441,453 E 2,221,855 [HANCONV] N 134,539.24m E 567,532.48m [NAD83-18Jun90]
DATE DRILLED	:	May90
DEPTH DRILLED (GS)	:	244.0-ft
MEASURED DEPTH (GS)	:	244.9-ft, 13May91
DEPTH TO WATER (GS)	:	226.2-ft, Apr90; 230.7-ft, 09Sep92
CASING DIAMETER	:	4-in, stainless steel, +ND↔223.7-ft; 6-in, stainless steel, +2.83↔~0.5-ft (not documented)
ELEV TOP CASING	:	691.35-ft, [200W-18Jun90]
ELEV GROUND SURFACE	:	688.40-ft, Brass cap [200W-18Jun90]
PERFORATED INTERVAL	:	Not applicable
SCREENED INTERVAL	:	223.7↔244.0-ft, #10-slot, stainless steel
COMMENTS	:	FIELD INSPECTION, 13May91; Stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable capped and locked, brass cap in pad with well ID. Not in radiation zone. OTHER:
AVAILABLE LOGS	:	Driller
TV SCAN COMMENTS	:	Not applicable
DATE EVALUATED	:	Not applicable
EVAL RECOMMENDATION	:	Not applicable
LISTED USE	:	U-12 Crib Quarterly water level measurement, 20Nov90↔09Sep92; Not on water sample schedule
PUMP TYPE	:	Hydrostar
MAINTENANCE	:	

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION		Well No: 699-36-70A	Page 1 of 6
		Total Depth: 440	Static Water Level: 257.85
Date Started: 9-6-94	Date Completed: 5-11-95	Surface Elevation: 702.74	Casing Elevation: 705.43
Location: 200' E OF 200W PERIMETER FENCE		Northing: 134308.839	Easting: 588466.679
Prepared By: CE DEGENHART, et. al.		Hanford N: 35576.56	Hanford W: 70312.20
Drilling Co: KEH	Driller: C WAMSLEY/K OLSON	Drill Meth: CABLE TOOL	Drill Equip: N/A
Screen: 30.26' OF 4" DIAMETER 10-SLOT TYPE 304 STAINLESS STEEL CONTINUOUS WIREWRAP SET FROM 257.48' TO 287.74'			
Filter Pack: 20-40 MESH SILICA SAND FROM 246.9' TO 289.5'			
Permanent Casing: 4" DIAMETER TYPE 304 SCHEDULE 5 STAINLESS STEEL WITH CENTRALIZERS SET TO 257.48'			
Comments:			

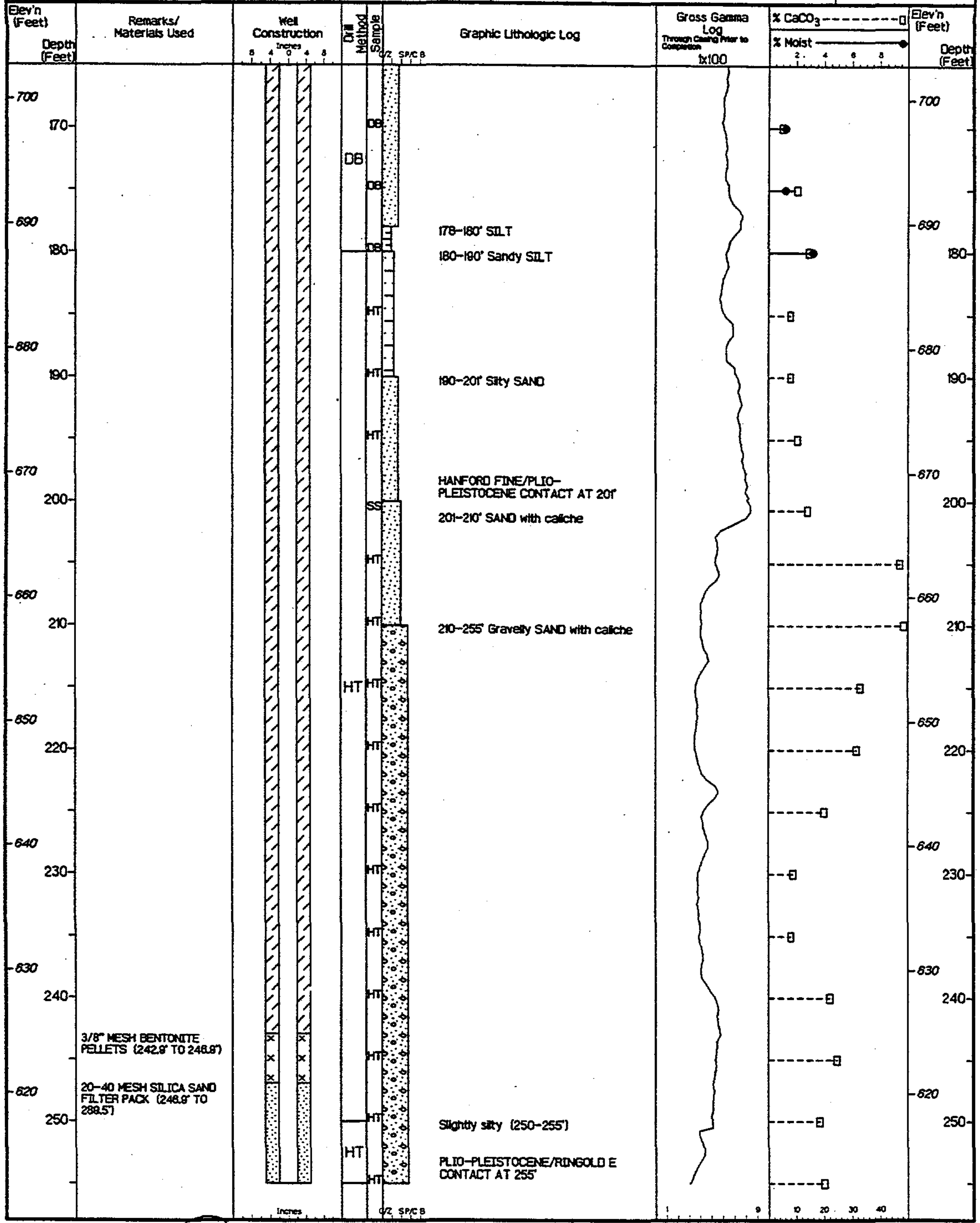


Reviewed By: [signature] Date: 2/5/95



Reviewed By: [signature] Date: 7/5/95

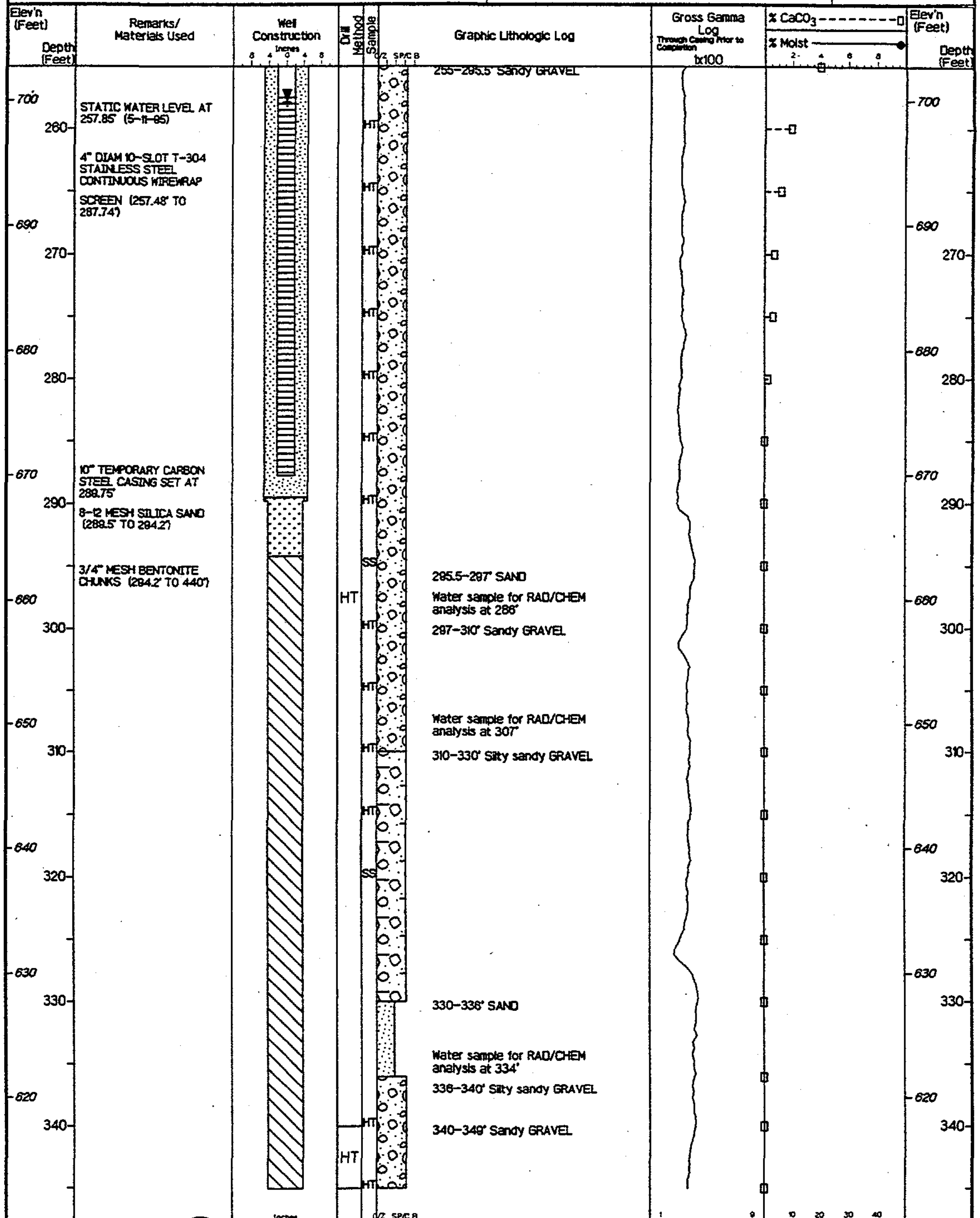
Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION	Well No: 699-36-70A	Page 3 of 6



Reviewed By: [signature]

Date: 7/5/85

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION | **Well No:** 699-36-70A | Page 4 of 6



Reviewed By: [signature] Date: 7/5/95

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION

Well No: 699-36-70A

Elev'n (Feet) / Depth (Feet) | Remarks/ Materials Used | Well Construction (Inches) | Drill Method | Sample | Graphic Lithologic Log | Gross Gamma Log Through Casing Prior to Completion 1x100 | % CaCO3 / % Moist | Elev'n (Feet) / Depth (Feet)

349-380' Silty SAND

360-372' Slightly silty sandy GRAVEL

372-376.5' Silty SAND with gravel
Water sample for RAD analysis at 372'

376.5-433.5' Sandy GRAVEL
Occasional sand lenses

Water sample for RAD analysis at 400'

8" TEMPORARY CARBON STEEL CASING SET AT 430'

Water sample for RAD/CHEM analysis at 430'

RINGOLD E/RINGOLD LOWER MUD CONTACT AT 433.5'

433.5-440' SILT

Drill Method: HT

Reviewed By: [signature]

Date: 7/5/95

Project: W-152/216-U-12 CRIB RCRA GROUNDWATER MONITORING WELL INSTALLATION	Well No: 699-36-70A	Page 6 of 6

Elev'n (Feet)	Depth (Feet)	Remarks/ Materials Used	Well Construction (Inches)	Drill Method	Sample	Graphic Lithologic Log	Gross Gamma Log Through Casing Prior to Completion tx100	% CaCO3 / % Moist	Elev'n (Feet)	Depth (Feet)
700				HT					700	
	440	TOTAL DEPTH = 440'		HT						
690	450								690	450
680	460								680	460
670	470								670	470
660	480								660	480
650	490								650	490
640	500								640	500
630	510								630	510
620	520								620	520

Reviewed By: [signature]

Date: 7/5/95

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