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RCRA Assessment Plan for Single-Shell Tank Waste Management Area T

D. G. Horton

May 2006

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830



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Pacific Northwest National Laboratory
Richland, Washington 99352

Summary

Waste Management Area (WMA) T is regulated under the *Resource Conservation and Recovery Act* (RCRA) as modified in 40 CFR Part 265, Subpart F and Washington State's Hazardous Waste Management Act (HWMA, RCW 70.105 and its implementing requirements in the Washington State dangerous waste regulations [WAC 173-303-400]). WMA T was placed in assessment monitoring in 1993 because of elevated *specific conductance*. A groundwater quality assessment plan was written in 1993 (Caggiano and Chou 1993) describing the monitoring activities to be used in deciding whether WMA T had affected groundwater. That plan was updated in 2000 (Hodges and Chou 2001) for continued RCRA groundwater quality assessment as required by 40 CFR 265.93 (d)(7). This document further updates the assessment plan for WMA T by including (1) information obtained from seven new wells installed at the WMA after 1999 and (2) information from routine quarterly groundwater monitoring during the last five years. Also, this plan describes activities for continuing the groundwater assessment at WMA T.

This plan describes the data quality objectives process used to guide information gathering to further the assessment at WMA T. The general approach of the assessment is to (1) determine the optimum locations for new monitoring wells to improve the assessment of and the probability of detecting contaminants from the WMA, (2) determine the depth distribution of contaminants within the uppermost aquifer, (3) improve estimates of hydraulic properties that influence the distribution of contaminants in the aquifer, (4) delineate the lateral extent and the concentrations of contaminants and their relationship to potential sources within the study boundary, and (5) continue routine quarterly groundwater sampling and analysis to comply with RCRA regulatory requirements.

This assessment plan includes a sampling and analysis plan (Appendix A) consisting of a field sampling plan and an quality assurance project plan. The sampling and analysis plan is used as the principal controlling document for conducting the work identified by the data quality assessment process.

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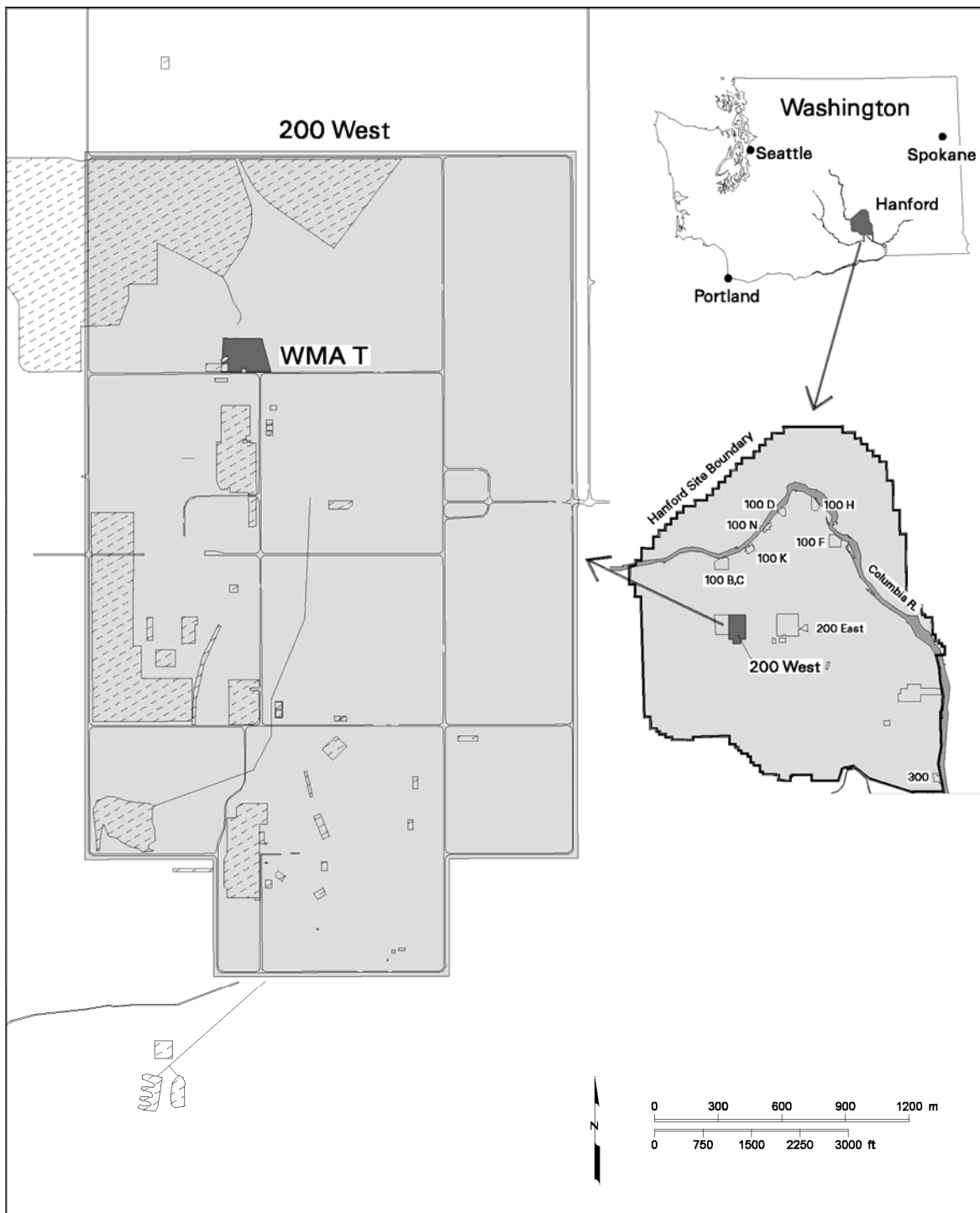
1.0 Introduction

Waste Management Area (WMA) T, containing the T Tank Farm, is located in the northern portion of the 200 West Area (Figure 1.1) and was used for the interim storage of radioactive waste from chemical processing of reactor fuel for plutonium production. The WMA is regulated under the *Resource Conservation and Recovery Act* (RCRA) as modified in 40 CFR Part 265, Subpart F and Washington State's *Hazardous Waste Management Act* (HWMA, RCW 70.105 and its implementing requirements in the Washington State dangerous waste regulations [WAC 173-303-400]). WMA T was placed in assessment monitoring in 1993 because of elevated *specific conductance*, a RCRA indicator parameter, in one downgradient well. A groundwater quality assessment plan was written in 1993 (Caggiano and Chou 1993) describing the monitoring activities to be used in deciding whether WMA T had affected groundwater. That plan was updated in 2000 (Hodges and Chou 2001) for continued RCRA groundwater quality assessment as required by 40 CFR 265.93 (d)(7). This document further updates the assessment plan for WMA T by including (1) information obtained from seven new wells installed at the WMA since the previous plan was issued and (2) information from routine, quarterly groundwater monitoring during the last five years. Also, this plan describes activities for continuing the groundwater assessment at WMA T. All information pertinent to the WMA T groundwater assessment available through October 2005 is considered in this plan.

1.1 Background

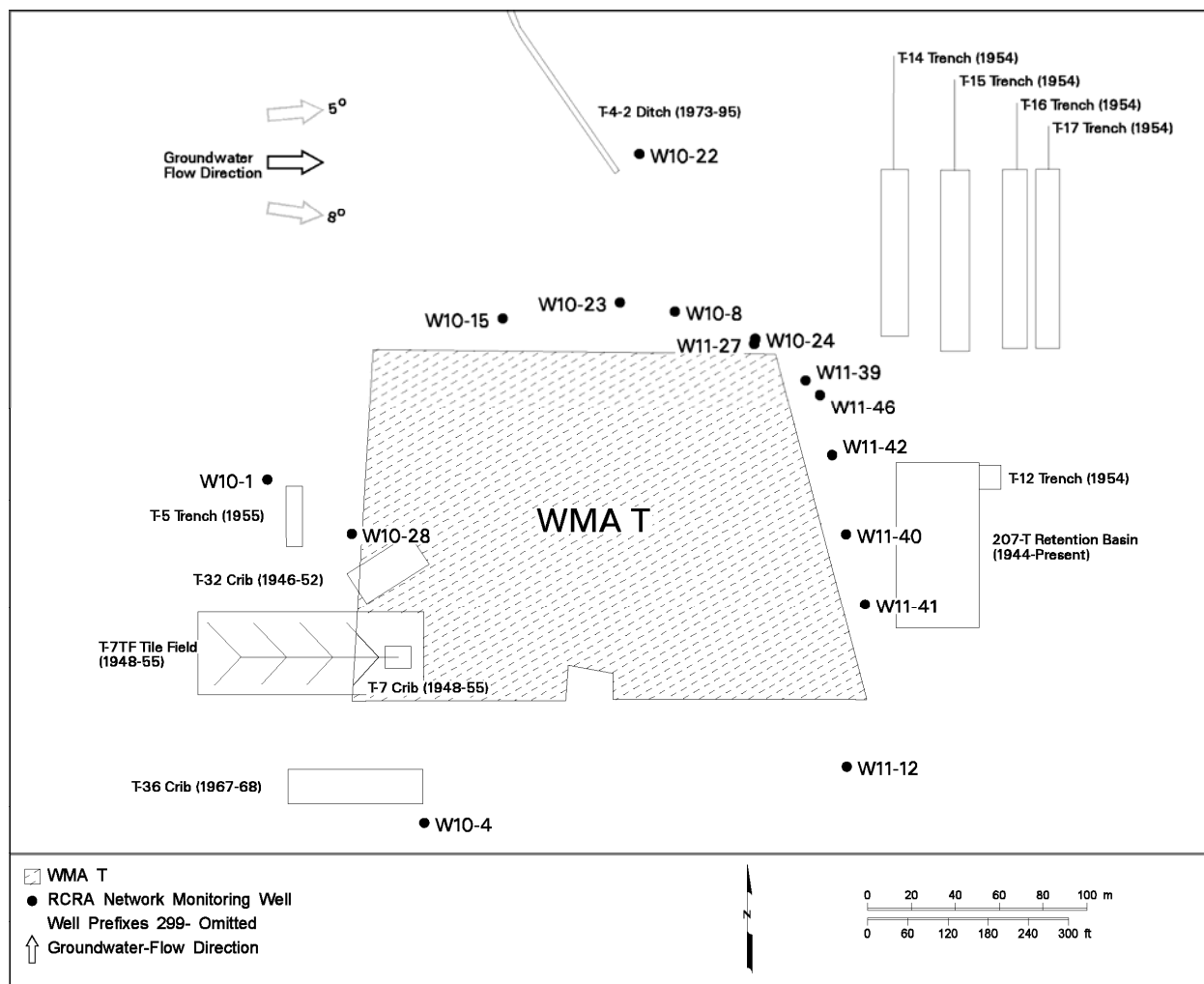
Figure 1.2 shows the general layout of WMA T. A detection level RCRA groundwater monitoring program for WMA T was initiated in 1989 (Jensen et al. 1989; Caggiano and Goodwin 1991). The WMA was placed into assessment monitoring in 1993 because specific conductance values in down-gradient well 299-W10-15 exceeded the upgradient background value (critical mean) of 1,175 $\mu\text{S}/\text{cm}$ (Caggiano and Chou 1993). Elevated specific conductance values in well 299-W10-15, principally a result of elevated sodium and nitrate from an upgradient source, dropped below the critical mean in 1994. However, before the WMA could be returned to a detection level monitoring program, specific conductance in well 299-W11-27 started a rapid increase in late 1995 and exceeded the critical mean in early 1996. In the case of well 299-W11-27, the increased specific conductance was accompanied by elevated technetium-99, tritium, nitrate, calcium, magnesium, sulfate, chromium, cobalt-60, and total organic carbon. In February 1997, technetium-99, the principal contaminant, reached a maximum concentration of 21,700 pCi/L, 24 times the drinking water standard of 900 pCi/L.

The first assessment report (Hodges 1998) did not identify an upgradient source for the contamination observed in monitoring well 299-W11-27, and indeed found evidence linking the contaminants in groundwater to the WMA. Accordingly, continuation of the groundwater assessment is required. This plan describes the activities for the continued assessment.



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Figure 1.1. Location Map for Waste Management Area T



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Figure 1.2. General Layout of Waste Management Area T including Locations of Nearby Past-Practice Facilities and Monitoring Wells

1.2 Objectives

The objectives for the continued assessment of groundwater quality at WMA T, as required by 40 CFR 265.93(d)(7)(i), are to determine

- (i) *the rate and extent of migration of the hazardous waste or hazardous waste constituents in the groundwater and*
- (ii) *the concentration of hazardous waste or hazardous waste constituents in the groundwater.*

These objectives are related to the *Comprehensive Environmental Resource Conservation Act* (CERCLA) 200-ZP-1 operable unit remedial investigation/ feasibility study and the RCRA vadose zone RCRA facility investigation/corrective measures study (RFI/CMS) at WMA T as described in the Hanford Federal Facility Agreement and Consent Order Change Request M-45-98-03 (Tri-Party Agreement, Ecology et al. 1989). In accordance with the agreement between the U.S. Department of

Energy (DOE), and the Washington State Department of Ecology (Ecology) concerning this change request, the continuing RCRA groundwater quality assessment and the RFI/CMS work will be conducted under separate but coordinated plans. Data from the RCRA groundwater quality assessment will be used in RFI/CMS planning and will be included either by reference or directly with the vadose zone data from the RFI/CMS efforts in a field investigation report due July 2005 (milestone M-45-55-T03).

Key questions related to the above objectives are:

1. What is the vertical and horizontal concentration profile of all dangerous waste constituents in vadose zone and groundwater released from WMA T?
2. What is the rate and extent of contaminant migration in the groundwater?
3. What are the likely source(s) for the observed groundwater contamination at WMA T?
4. What are the likely driving forces for observed groundwater contamination at WMA T?
5. What are the groundwater flow rate and flow direction?

The groundwater quality assessments for the single-shell tank WMAs are conducted by Pacific Northwest National Laboratory (PNNL) for DOE. Also, in accordance with the cleanup objective for Hanford Site tank farms, the groundwater investigations will be planned and implemented to support decisions on interim measures, corrective measures, waste retrieval, and eventual closure of the tank farms.

1.3 Scope

The scope of this plan is to acquire the necessary groundwater data to reach the above objectives and integrate the RCRA groundwater quality assessment with the 200-ZP-1 groundwater operable unit and the vadose zone RFI/CMS.

Groundwater monitoring objectives of RCRA, CERCLA, and the *Atomic Energy Act* (AEA) often differ slightly and the contaminants monitored are not always the same. For RCRA regulated units, monitoring focuses on non-radioactive dangerous waste constituents. Radionuclides (source, special nuclear and by-product materials) may be monitored in some RCRA unit wells to support objectives of monitoring under the AEA and/or CERCLA. Please note that pursuant to RCRA, the source, special nuclear and by-product material component of radioactive mixed wastes are not regulated under RCRA and are regulated by DOE acting pursuant to its AEA authority. Therefore, while this report may be used to satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA permit.

1.4 General Approach

The data quality objectives (DQO) process was used to guide information gathering to further the assessment at WMA T. The resulting, general approach to meet the specific or immediate objectives for

the continued assessment (i.e., to determine the concentration, rate of movement and extent of contamination) includes the following major components:

- Determine optimum locations for new monitoring wells to improve the assessment of and the probability of detecting contaminants from the WMA. A reliable detection network is also important to demonstrate the effectiveness of any interim corrective measures undertaken as a result of the RFI/CMS process.
- Determine depth distribution of contaminants within the aquifer by discrete depth sampling during drilling of new wells and by sampling multiple depths within the screened intervals of existing wells.
- Conduct hydrologic testing on selected wells to obtain estimates of hydraulic conductivity, effective porosity, and preferential flow zones within the screened interval of monitoring wells. This information will be used in concert with new water-level data to determine groundwater flow velocities and to determine optimal locations of sampling intervals within the well screen intervals.
- Use spatial and temporal mapping of the contaminant plumes to delineate the extent and concentration of contaminants and their relationship to potential sources within the study boundary. In concert with hydrogeologic data, estimate the approximate rate, direction, and extent of contaminant migration.
- Use the results of special isotopic studies to aid the identification of contaminant sources (e.g., differentiation of tank leaks, distinguish cribs versus tanks, etc.) affecting groundwater quality.
- Continue routine, quarterly groundwater sampling and analysis to comply with RCRA regulatory requirements.

1.5 Plan Organization

A review of existing data including waste characteristics, geology and hydrology, and vadose zone and aquifer contamination are presented in Chapter 2.0. The DQO process for this groundwater assessment is given in Chapter 3.0. An updated conceptual model is given as part of the DQO chapter. References cited are listed in Chapter 4.0. A sampling and analysis plan (including a field sampling plan and a quality assurance plan) for the groundwater quality assessment at WMA T is included in Appendix A. Appendix B gives pertinent hydrogeologic and monitoring well information.

2.0 Background

2.1 Facility Description

WMA T occupies an area of about 32,000 m² and contains 16 underground single-shell tanks constructed in 1943 and 1944 (Figure 1.2). Twelve tanks (T-101 through T-112) have capacities of 2,006,286 liters and four tanks (T-201 through T-204) have capacities of 208,200 liters. In addition to the tanks, six diversion boxes and ancillary pumps, valves and pipes are included in the *Hanford Facility Dangerous Waste Part A Permit Application* (DOE 2000b) for single-shell tank farm system T. Two cribs, 216-T-7 and 216-T-32, are within the tank farm fence but are not included in the single-shell tank Part A permit application.

The single shell tanks are constructed of carbon steel (ASTM A283 Grade C) lining the bottom and sides of a reinforced concrete shell. The concrete dome top is unlined. The larger tanks are 22.9 meters in diameter and are about 9 meters in height. The bottoms of the tanks are about 11 meters below grade with approximately 2.1 meters of fill over the top. Various ports in the tank tops are available for waste transfer and monitoring. In addition, vadose zone monitoring wells (drywells) are located around the tanks and extend generally to 22 to 45 meters depth to allow monitoring of radionuclide and moisture migration outside the tanks by geophysical methods.

The smaller tanks are 6.1 meters in diameter and 7.8 meters in height. The bottoms of the smaller tanks are at about 11.4 meters below grade with about 3.6 meters of fill over the top. Numerous buried waste transfer lines run into the tank farm to diversion boxes where wastes were routed to various tanks through valve boxes.

The routing of liquid waste from the operations buildings to the tank farms was done with underground lines and diversion boxes. The diversion boxes are concrete boxes that were designed to contain any waste that leaked from the high-level waste transfer line connections. Diversion boxes generally drained to nearby catch tanks where any spilled waste was stored and then pumped to single-shell tanks. It is estimated that each diversion box contains 23 kilograms of lead (DOE 2000b).

2.2 Operational History

The tanks in WMA T began receiving waste in 1944 and were more-or-less in continual use from that time until 1980, at which time all tanks in the waste management area had been removed from service. The single-shell tanks received predominantly high-level metal and first cycle waste from chemical processing of uranium-bearing spent fuel rods. Lesser amounts of other waste types were also stored in the tanks at WMA T. After fuel rod dissolution, metal waste was the first waste stream generated in the bismuth phosphate process. Metal waste contained about 60 g/L of uranium and about 90% of the fission product radionuclides originally present in the irradiated fuel rods (Jones et al. 2000). First cycle waste was generated from the first precipitation step after the generation of metal waste. The composition of first cycle waste should be similar to the metal waste, but without the uranium (Jones et al. 2000).

Waste management operations have created a complex intermingling of the tank wastes. Non-radioactive chemicals have been added to the tanks and varying amounts of waste- and heat-producing

radionuclides have been removed. In addition, natural processes have caused settling, stratification, and segregation of waste components. Waste was also cascaded (allowed to flow by gravity from one tank to another) through a series of tanks; cooling and precipitation of radionuclides and solids occurred in each tank of the cascade. Some of the supernatant from the last tank in a cascade was sent to cribs because of shortage of tank storage capacity. As a result, it is very difficult to estimate the composition of the wastes remaining in the tanks through operational records. A detailed history of tank farm operations is given by Anderson (1990).

The 216-T-7 crib operated between April 1948 and November 1955. During that time, the crib received 110 million liters of a combination of second-cycle, T-Plant cell drainage waste, and plutonium concentrator waste (Williams 2000). The 216-T-32 crib operated between 1946 and 1952. During that time, it received 29 million liters of “224 waste” (defined as low-level waste containing plutonium in Williams 2000) from the 224-T building by way of the 241-T-201 single-shell tank.

In addition to the above two cribs, several other liquid disposal facilities are located adjacent to the tank farm but outside the tank farm fence. About 785,000 to 1 million liters of first-cycle waste were discharged to each of the 216-T-14 through 216-T-17 specific retention trenches northeast of the T Tank Farm in 1954. In 1967 and 1968, about 522,000 liters of decontamination waste and condensate were discharged to the 216-T-36 crib southwest of the T Tank Farm. The 216-T-5 crib, located just west of the T Tank Farm, received about 2.6 million liters of second cycle waste in 1955 (Williams 2000).

Initial corrective actions have been implemented at WMA T. Berms were constructed around the T Tank Farm in 2001 to stop run-on of natural precipitation. Also, all known water lines have been tested or cut off. Finally, an interim surface barrier is planned to be tested at tank T-106. The barrier will consist of a ground cover consisting of about 1.3 centimeters of polyurethane.

2.3 Tank Leaks and Unplanned Releases

Seven of the tanks at WMA T have been declared leakers based on liquid losses (Hanlon 2004). Information about these leaks is given in Table 2.1. Although Hanlon gives estimated leak volumes for tanks T-107, T-108, T-109, and T-111 based on observed liquid levels in the tanks, neither the spectral gamma logging data (GJO-99-101-TAR) nor tank waste transfer records provide evidence of leaks from these tanks (Jones et al. 2000). Contamination associated with these tanks may be from waste pipeline leaks or from nearby tanks that are known to have leaked.

All seven of the tanks listed by Hanlon as “assumed leakers” have been interim stabilized. Interim stabilized means that the tank now contains less than 189,250 liters of drainable interstitial liquid and less than 18,925 liters supernatant liquid (Hanlon 2004). The volume contents of each tank in WMA T are given in Table 2.2.

Tank T-101 was overfilled in the 1960s and lost between about 28,000 and 38,000 liters of reduction/oxidation (REDOX) cladding waste through a defective spare inlet port in 1969 (Jones et al. 2000). Spectral gamma logs are consistent with waste loss through a spare inlet port. Also, waste transfer records suggest a waste loss of between 3,700 and 11,400 liters through a spare inlet port when tank T-103 was overfilled in 1972 and 1973.

Table 2.1. Tank Leak Volume Estimates

Tank Number	Date Declared or Confirmed, or Assumed Leaker ^(a)	Volume Leaked (L) ^(a)	Volume Leaked (L) ^(b)	Interim Stabilized Date
241-T-101	1992	28,400	37,850	04/93
241-T-103	1974	<3,785	11,355	11/83
241-T-106	1973	435,275	435,275	08/81
241-T-107	1984	~30,280	No basis for estimate	05/96
241-T-108	1974	<3,785	3,785	11/78
241-T-109	1974	<3,785	3,785	12/84
241-T-111	1979 and 1994	<3,785	3,785	02/95
(a) From Hanlon (2004).				
(b) From Field and Jones (2005).				

Table 2.2. Inventory by Tank (Hanlon 2004)

Tank	Tank Integrity	Drainable Liquid Remaining (L)	Sludge (L)	Salt Cake (L)
241-T-101	Assumed Leaker	79,500	140,060	242,270
241-T-102	Sound	60,560	71,920	0
241-T-103	Assumed Leaker	26,500	87,060	0
241-T-104	Sound	117,350	1,199,980	0
241-T-105	Sound	18,930	370,970	0
241-T-106	Assumed Leaker	7,570	71,920	0
241-T-107	Assumed Leaker	128,700	654,880	0
241-T-108	Assumed Leaker	18,930	79,500	87,060
241-T-109	Assumed Leaker	37,850	0	219,550
241-T-110	Sound	181,700	1,393,030	0
241-T-111	Assumed Leaker	143,850	1,688,290	0
241-T-112	Sound	41,640	227,120	0
241-T-201	Sound	18,930	105,990	0
241-T-202	Sound	11,360	79,500	0
241-T-203	Sound	18,930	132,490	0
241-T-204	Sound	18,930	143,850	0

The largest tank leak at WMA T is associated with tank T-106. The leak was about 435,300 liters of tank waste that is suspected to have started in May 1973 but was not detected until June 1973. The waste lost from this leak originated from B Plant isotope recovery processes. Approximately 25,000 m³ of soil were contaminated to a depth of 33 meters, based on the estimated 1 µCi/L ruthenium isopleth obtained from gamma energy analyses of vadose zone samples (ARH 1973). The leak was investigated in 1973

(ARH 1973), in 1979 (Routson et al. 1979), and in 1992 (Freeman-Pollard et al. 1994). The conclusion of the latter investigation was that contaminants in the leading edge of the vadose zone plume had penetrated to the contact between the Ringold Formation unit E and the overlying Taylor Flats member of the Ringold Formation at about 37 meters below ground surface. However, that same report states that a small amount of technetium-99 had penetrated into the Ringold Formation unit E to a depth of 44 meters.

Most recently, Serne et al. (2004) made an extensive analytical characterization of sediment samples from two boreholes cored near tank T-106. They concluded that nitrate had migrated about 1.8 meters and cobalt-60 had migrated about 3 to 4.6 meters deeper in 2003 than in 1993. The deepest cobalt-60 was at 34.4 meters and the deepest nitrate was at about 38.7 meters below ground surface. Serne et al. 2004 also concluded that there was no vertical migration of actinides between 1993 and 2003. Data for determining the extent of subsurface movement of other contaminants were inconclusive.

In addition to leaks, nine unplanned releases have been documented. The following information about those releases is from DOE (1991).

- Unplanned release UN-200-W-7 occurred in 1950 at the 241-T-151 and 241-T-152 diversion boxes. The material and amount released are not documented. Contaminated soil was partly removed and the remainder of contaminated soil was covered with approximately 0.3 meter of clean soil.
- Unplanned release UN-200-W-14 occurred in October 1952 along the waste line connecting the 242-T building and the 207-T retention basin. The release was detected when contaminated water rose to the ground surface above the waste line. The waste line was repaired and the contaminated soil was covered with approximately 0.3 meter of soil. The specific contaminant and the amount of contaminant released are not documented in DOE/RL-91-61 or in the Waste Information Data System.
- Unplanned release UN-200-W-29 occurred in November 1954 at a cave-in approximate 23 meters east of Camden Avenue and 23 meters south of 23rd Street, between the 241-T-152 and 241-TX-153 diversion boxes. The unplanned release resulted from failure of an uncased line connecting the diversion boxes. First-cycle supernatant waste from the 241-T-105 single-shell tank was released with dose rates of 11.5 R/hour at 5 centimeters. The area was hosed down with water and back-filled. A second spill occurred at the same location in May 1966 due to reuse of the same line. The amount of material released is not documented in DOE (1991) or the Waste Information Data System (WIDS).
- Unplanned release UN-200-W-62 occurred in May 1966 at the corner of 23rd Street and Camden Avenue. Second-cycle waste was released to the ground from a ruptured transfer line during transfer of bismuth phosphate waste from the 241-T-107 tank to the 242-T evaporator feed. Readings ranged from 20 to 5,000 mR/hour. Liquid was dispersed over an approximate 22-by-440-meter area which was isolated and covered with sand and gravel.
- Unplanned release UN-200-W-63 occurred in September 1966 along 23rd Street at diversion box 241-TX-153. Approximately 1 curie of strontium-90 was released from a used diversion box jumper that was in transit in a truck along the road. Contamination was removed from the road and the area covered with 15 centimeters of soil.

- Unplanned release UN-200-W-64 occurred in February 1969 along Camden Avenue and 23rd Street. Six hundred counts per minute of cesium-137 were discovered in mud samples in an area cordoned off as a radiation zone. The cause may have been snow melt runoff from nearby radiation zones.
- Unplanned release UN-200-W-97 occurred in May 1966 at the southeast corner of 23rd Street and Camden Avenue south to near 22nd Street. Liquid waste was released from a broken underground line, surfaced, and crossed Camden Avenue but did not run down the side of the road. Surface contamination at 600 counts per minute was detected. Surface contamination was removed to a depth of 0.9 meter.
- Unplanned release UPR-200-W-147 occurred in 1973 at the southeast side of single-shell tank 241-T-103. Contamination was encountered while monitoring wells were being drilled to track a tank leak. The leak may have resulted from a failed grout seal in a spare entry line to the tank. The spill was approximately 5 m³.
- Unplanned release UPR-200-W-148 occurred in April 1973 at 7 meters from single-shell tank 241-T-106. This is the well known leak from tank 241-T-106 (Routson et al. 1979; Freeman-Pollard 1994; Serne et al. 2004).

2.4 Waste Characteristics

Three basic chemical processing operations were the source of most of the hazardous waste transferred to the T Tank Farm. These were the bismuth phosphate process, the tributyl phosphate process, and the REDOX process. The bismuth phosphate and REDOX processes were chemical separations programs for recovery of plutonium from irradiated reactor fuels. The tributyl phosphate process recovered uranium metal in waste generated by the bismuth phosphate process. Waste from all three processes was made alkaline for storage in the tanks (Anderson 1990).

Table 2.3 lists the specific wastes and volumes transferred to each tank in WMA T. Anderson (1990) gives approximate chemical compositions for the major waste types sent to the T Tank Farm single-shell tanks.

Jones et al. (2000) have recently given estimates for the composition of the leaked fluids from tanks T-101, T-103, and T-106. Table 2.4 gives a partial leak inventory from their data.

2.5 Geology and Hydrogeology

This section updates the description of the geology beneath the single-shell tanks WMA T with new information from seven wells drilled since 1999. This information assists decisions concerning well location and well construction if new wells are added to the monitoring network. The geologic interpretation is also used to evaluate pathways to groundwater through the vadose zone and groundwater flow properties.

The regional geologic setting of the Pasco Basin and the Hanford Site has been described previously by Delaney et al. (1991), Reidel et al. (2002), Tallman et al. (1979), and Lindsey et al. (1992). Most recently, Williams et al. (2002) have described the geology of the 200 West Area. The reader is referred to these references for descriptions of the regional geology.

Table 2.3. Tank Contents and Waste Received for the T Tank Farm Single-Shell Tanks (Agnew et al. 1997)

Tank	Source Description/Waste Type ^(a)
241-T-101	Bismuth phosphate metal waste, tributyl phosphate waste, cladding waste from bismuth phosphate, cladding waste from REDOX, B Plant HLW, ion exchange from cesium recovery, evaporator bottoms, REDOX ion exchange, REDOX HLW, B Plant LLW, decontamination waste, Battelle Northwest Laboratory waste, 224 waste (lanthanum fluoride finishing waste), non-complexed waste
241-T-102	Bismuth phosphate metal waste, cladding waste from bismuth phosphate, B Plant LLW, ion exchange waste, evaporator bottoms, REDOX ion exchange, REDOX HLW, non-complexed waste
241-T-103	Bismuth phosphate metal waste, cladding waste, B Plant LLW, ion exchange from cesium recovery, evaporator bottoms, REDOX ion exchange, REDOX HLW, non-complexed waste
241-T-104	First cycle decontamination waste from bismuth phosphate process, non-complexed waste
241-T-105	First and second cycle waste from bismuth phosphate process, REDOX cladding waste, cladding waste, Hanford laboratory operations waste, decontamination waste, B Plant LLW, ion exchange waste from cesium recovery, decontamination waste and B Plant ion exchange, non-complexed waste
241-T-106	First and second cycle waste from bismuth phosphate process, cladding waste, B Plant LLW, ion exchange waste from cesium recovery, decontamination waste, non-complexed waste
241-T-107	First cycle waste from bismuth phosphate process, tributyl phosphate waste from uranium recovery, cladding waste, B Plant LLW, ion exchange waste from cesium recovery, evaporator feed, non-complexed waste
241-T-108	First cycle waste from bismuth phosphate process, tributyl phosphate waste from uranium recovery, evaporator bottoms, Hanford laboratory operations waste, Battelle Northwest laboratory waste, ion exchange waste from cesium recovery, B Plant low level ion exchange, non-complexed waste
241-T-109	First cycle waste from bismuth phosphate process, tributyl phosphate waste from uranium recovery, evaporator bottoms, B Plant LLW, ion exchange waste from cesium recovery, Battelle Northwest Laboratory waste, non-complexed waste
241-T-110	Second cycle waste from bismuth phosphate process, lanthanum fluoride finishing waste, non-complexed waste
241-T-111	Second cycle waste from bismuth phosphate process, lanthanum fluoride finishing waste, non-complexed waste
241-T-112	Second cycle waste from bismuth phosphate process, lanthanum fluoride finishing waste, decontamination waste, cladding waste, B Plant LLW, ion exchange waste from cesium recovery, evaporator feed, non-complexed waste
241-T-201	Lanthanum fluoride finishing waste, evaporator feed, non-complexed waste
241-T-202	Lanthanum fluoride finishing waste, non-complexed waste
241-T-203	Lanthanum fluoride finishing waste, evaporator feed, non-complexed waste
241-T-204	Lanthanum fluoride finishing waste, non-complexed waste
(a) Does not include between tank transfers. HLW = High-level waste. LLW = Low-level waste. REDOX = Reduction/oxidation.	

Table 2.4. Partial Inventory Estimates for Tank Leak Fluids from Tanks in Waste Management Area T
(data from Jones et al. 2000)

Element or Radionuclide ^(a)	Concentration (mol/L for elements or Ci/L for radionuclides)		
	T-101	T-103	T-106
Sodium	3.04	4.00	4.34
Chromium	0.0122	3.91E-2	4.27E-2
Calcium	0.00789	7.73E-3	9.16E-3
Nitrate	0.925	1.13	1.25
Nitrite	0.925	7.9E-1	8.36E-1
Sulfate	0.0142	7.99E-2	8.89E-2
Fluoride	0.000353	2.9E-3	5.43E-3
Uranium	0.0035	2.78E-3	3.01E-3
Tritium	0.0000236	1.03E-4	1.08E-4
Cobalt-60	0.00000114	2.06E-5	2.25E-5
Strontium-90	0.00603	4.5E-2	4.97E-2
Technetium-99	0.0000101	1.27E-4	1.38E-4
Ruthenium-106	2.61E-10	3.47E-9	3.78E-9
Iodine-129	1.91E-8	2.45E-7	2.66E-7
Cesium-137	2.34E-2	4.6E-2	4.84E-2
(a) Radionuclides are decayed to January 1, 1994.			

The geology specific to WMA T was first described by Price and Fecht (1976) and then by Caggiano and Goodwin (1991). More recently the WMA T geology was summarized by Lindsey and Reynolds (1998) and by Wood et al. (2001). Most recently, Reidel et al. (2005) updated previous work to include observations from four new downgradient and one new upgradient wells at the WMA. Their geologic description is comparable to recent, regional studies (Williams et al. 2002; Wood et al. 2001) and assures coherence within the larger framework of stratigraphic interpretations of the Hanford Site. Any small differences that exist between the geologic description given in Reidel et al. (2005) and descriptions in previous reports result primarily from differences in survey elevations used to interpret lithologic contacts. These are small differences and do not represent any major change or discrepancy. The geologic description give below is summarized from Reidel et al. (2005).

Figure 2.1 shows the locations of all wells in the vicinity of WMA T that were used for geologic interpretation. The quality of data obtained from these wells varies and is a function of when they were drilled, drilling methods, and their purpose. Pertinent information about the wells is given in Appendix C. In general, data from RCRA standard boreholes is of higher quality than data from the older (pre-1989) boreholes.

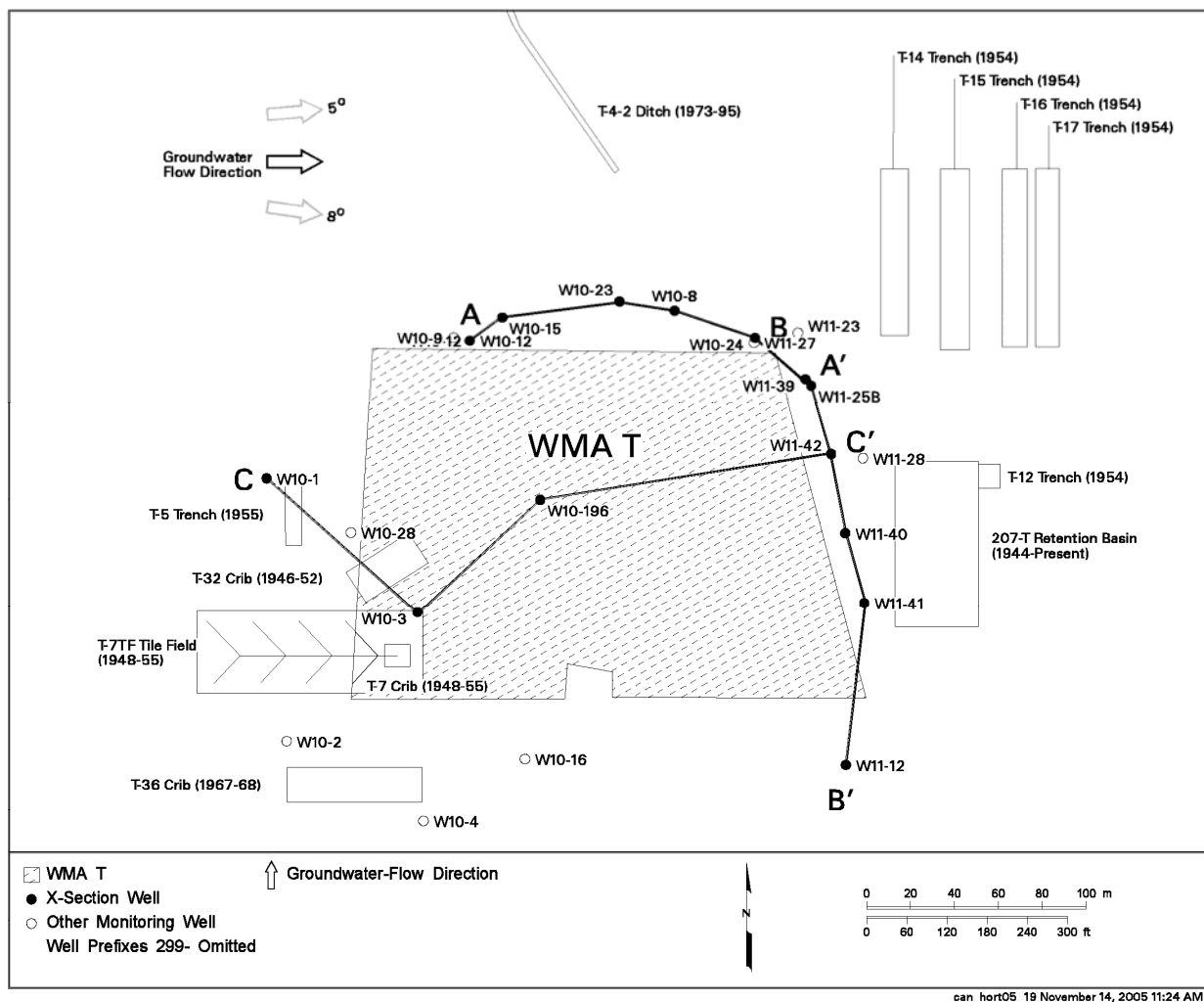


Figure 2.1. The Locations of Wells and Cross-Section at Waste Management Area T

Geologic interpretations were made from the well-site geologist's (or driller's) logs. Geophysical logs, particle size distributions, and laboratory moisture data were then compared with the lithologic logs. In some cases, geophysical logs (e.g., gross gamma-ray) allowed refinement of the data by permitting more precise placement of geologic contacts than when lithologic logs alone were used. This was particularly true for wells where only older, driller's logs and no geologist's logs were available.

2.5.1 Stratigraphy and Lithology at Waste Management Area T

The vadose zone beneath WMA T is between about 68 and 74 meters thick and consists of the Hanford formation, the Cold Creek unit, the Taylor Flats member of the Ringold Formation, and the upper part of unit E of the Wooded Island member of the Ringold Formation. The water table is at about 136.5 meters elevation and the unconfined aquifer beneath WMA T is estimated to be about 53 meters thick based on March 2004 water levels and the depth of the Ringold Formation lower mud unit in well 299-W10-24.

The geology beneath WMA T consists of basalt basement overlain by nine sedimentary sequences distinguished mainly by texture (particle size), mineralogy, responses to natural gamma logs, and stratigraphic position. These sequences are (from top to bottom):

- Holocene eolian sediments and/or backfill material
- Hanford formation gravel-dominated sequence
- Hanford formation sand-dominated sequence
- Cold Creek unit silts and sands
- Cold Creek unit calcic paleosols
- Ringold Formation, member of Taylor Flats
- Ringold Formation, member of Wooded Island unit E
- Ringold Formation, member of Wooded Island lower mud
- Ringold Formation, member of Wooded Island unit A

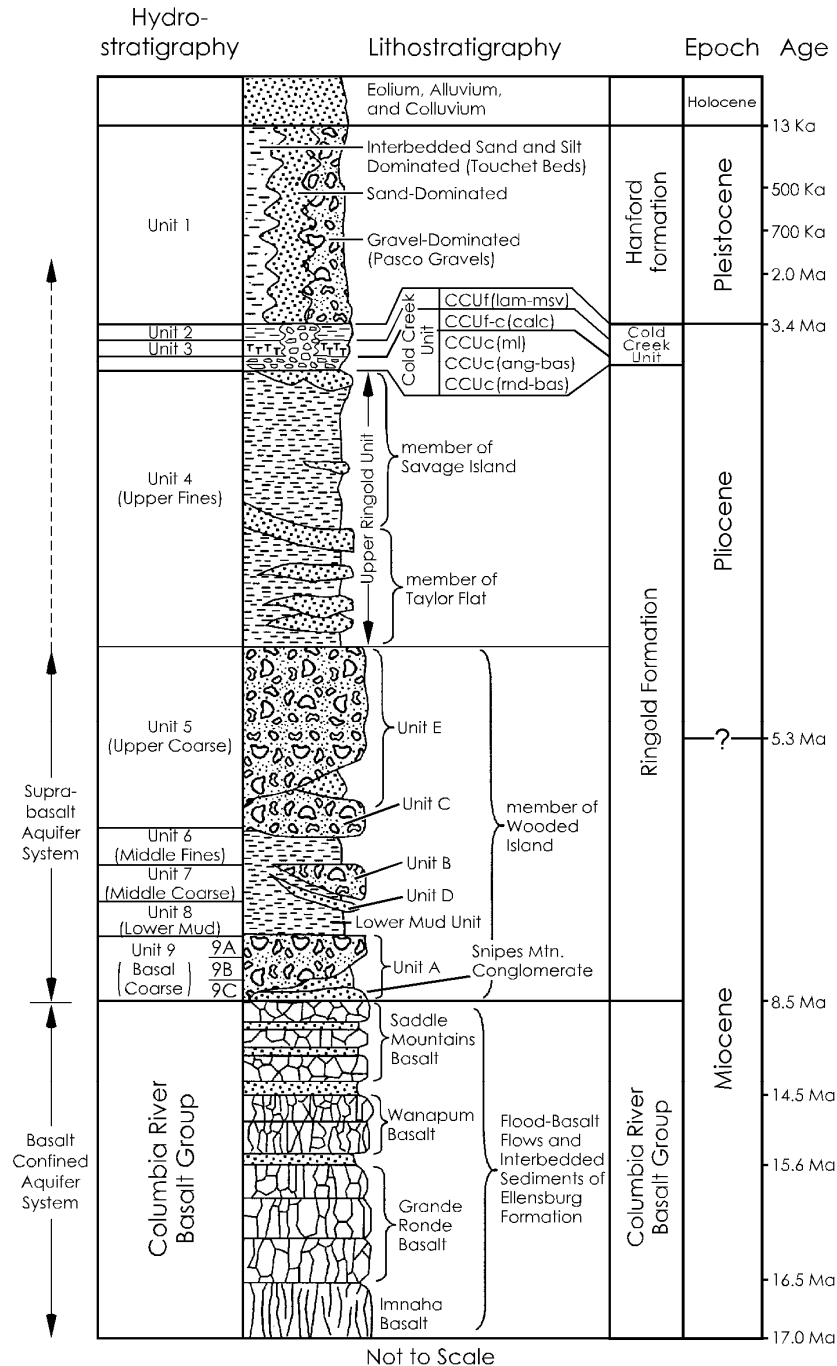
Figure 2.2 shows a generalized stratigraphic column for the WMA T area. The site specific stratigraphic information used to construct geologic cross-sections, thickness maps and structure contour maps at WMA T is given in Appendix B. The cross-sections are shown in Figures 2.3 through 2.5. (See Figure 2.1 for locations of cross-sections).

The Elephant Mountain Member of the Saddle Mountains Basalt is the base of the suprabasalt aquifers in the area. The Elephant Mountain Member was not encountered in any boreholes in the WMA T area. Based on driller's logs from nearby deep well 299-W11-26, located about 130 meters southeast of the T Tank Farm, the elevation of the top of the Elephant Mountain Member is at about 60 meters above sea level. The Elephant Mountain Member dips gently to the southwest into the Cold Creek syncline.

The Ringold Formation, member of Wooded Island unit A overlies the Elephant Mountain Member beneath WMA T. Unit A is described on borehole logs of cuttings and samples from wells near the WMA T area as pebble to cobble gravel with up to 15% sand and very little silt. Some interstratified sand horizons exist within the gravel and there are some highly cemented zones. Unit A was completely penetrated in only one borehole in the area of WMA T (well 299-W11-26) where it was found to be 23 meters thick.

The Ringold Formation, member of Wooded Island lower mud unit overlies unit A. The lower contact of the lower mud unit is usually sharp and easy to distinguish from drill cuttings and natural gamma logs. The lower mud unit is described as laminated to massive clay, silt, and sandy silt. Sediments in the lower mud unit are consolidated and generally contain no calcium carbonate. The lower mud unit was completely penetrated in two wells near WMA T; well 299-W10-24 where it was found to be 1.25 meters thick and well 299-W11-26 where it was found to be 5.2 meters thick.

The lower mud unit is equivalent to hydrogeologic unit 8 of Williams et al. (2002). They describe hydrogeologic unit 8 as separating the suprabasalt aquifer into an upper unconfined aquifer in the sediments above the lower mud unit and a lower, confined aquifer in the Ringold Formation unit A. Groundwater in the unconfined aquifer and the confined Ringold Formation unit A aquifer does not flow vertically through hydrogeologic unit 8 (Williams et al. 2002).



After Reidel et al. (1992), Thorne et al. (1993), Lindsey (1995), Williams et al. (2000), DOE (2002)

2004/DCL/TX-TY/004 (03/23)

Figure 2.2. Generalized Stratigraphic Column for the Hanford Site (modified from Lindsey 1996). The column is not to scale. The member of Savage Island, the member of Wooded Island units C, B, and D, and the Snipes Mountain Conglomerate are not present at Waste Management Area T.

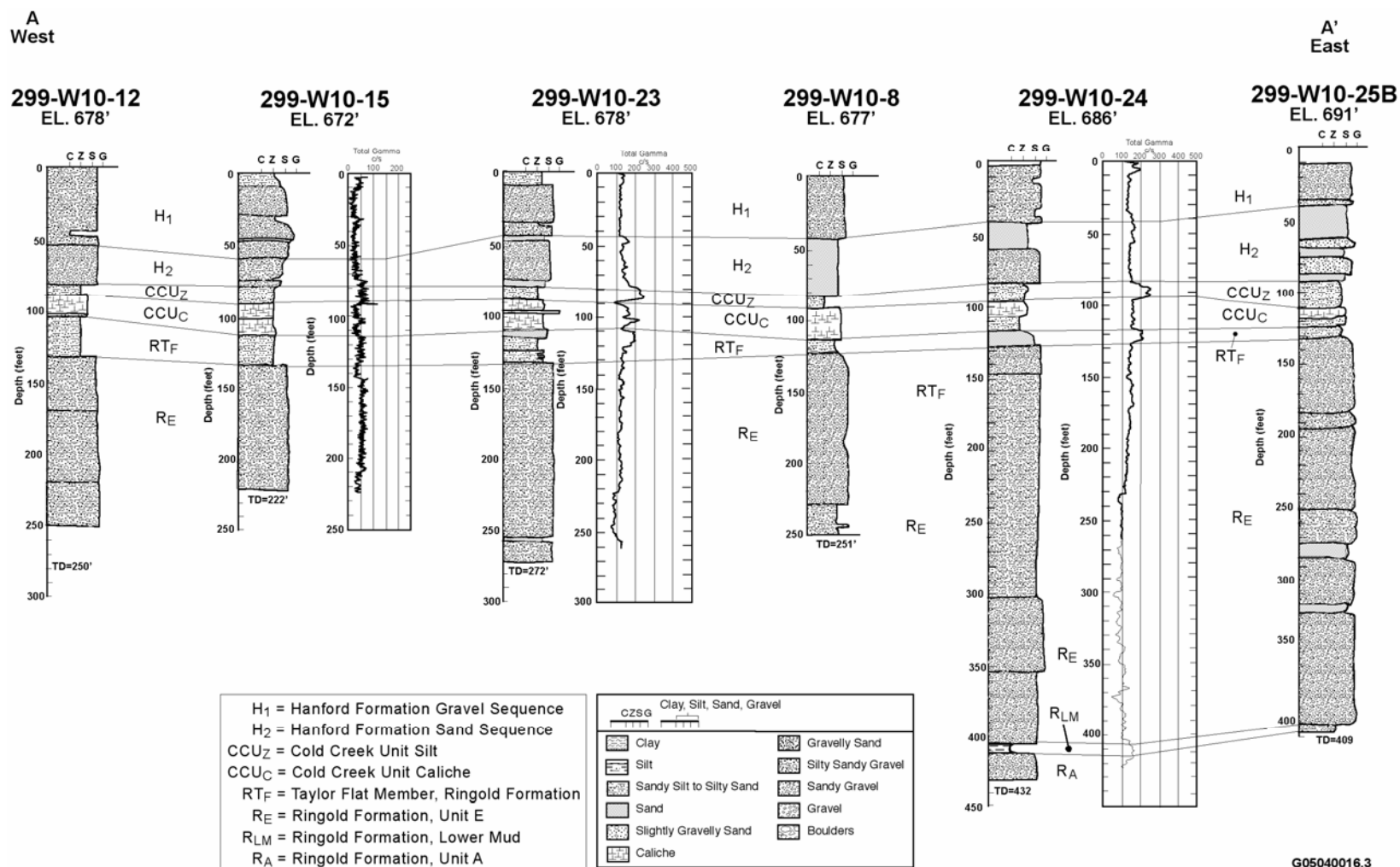


Figure 2.3. Cross-Section of the Geology North of Waste Management Area T (See Figure 2.1 for the location of the cross-section; multiply feet by 0.3048 to change to meters.)

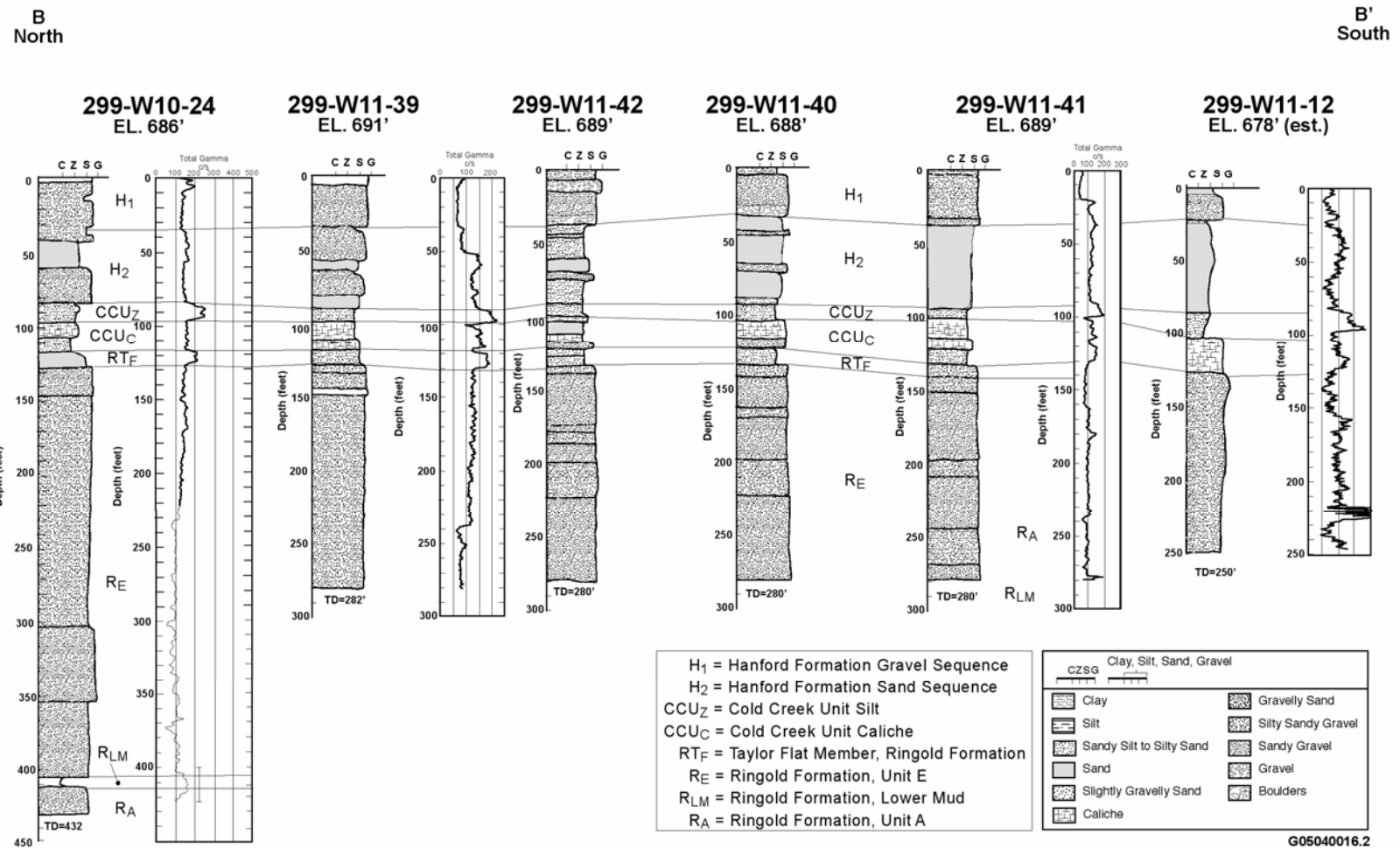


Figure 2.4. Cross-Section of the Geology East (downgradient) of Waste Management Area T (See Figure 2.1 for the location of the cross-section; multiply feet by 0.3048 to change to meters.)

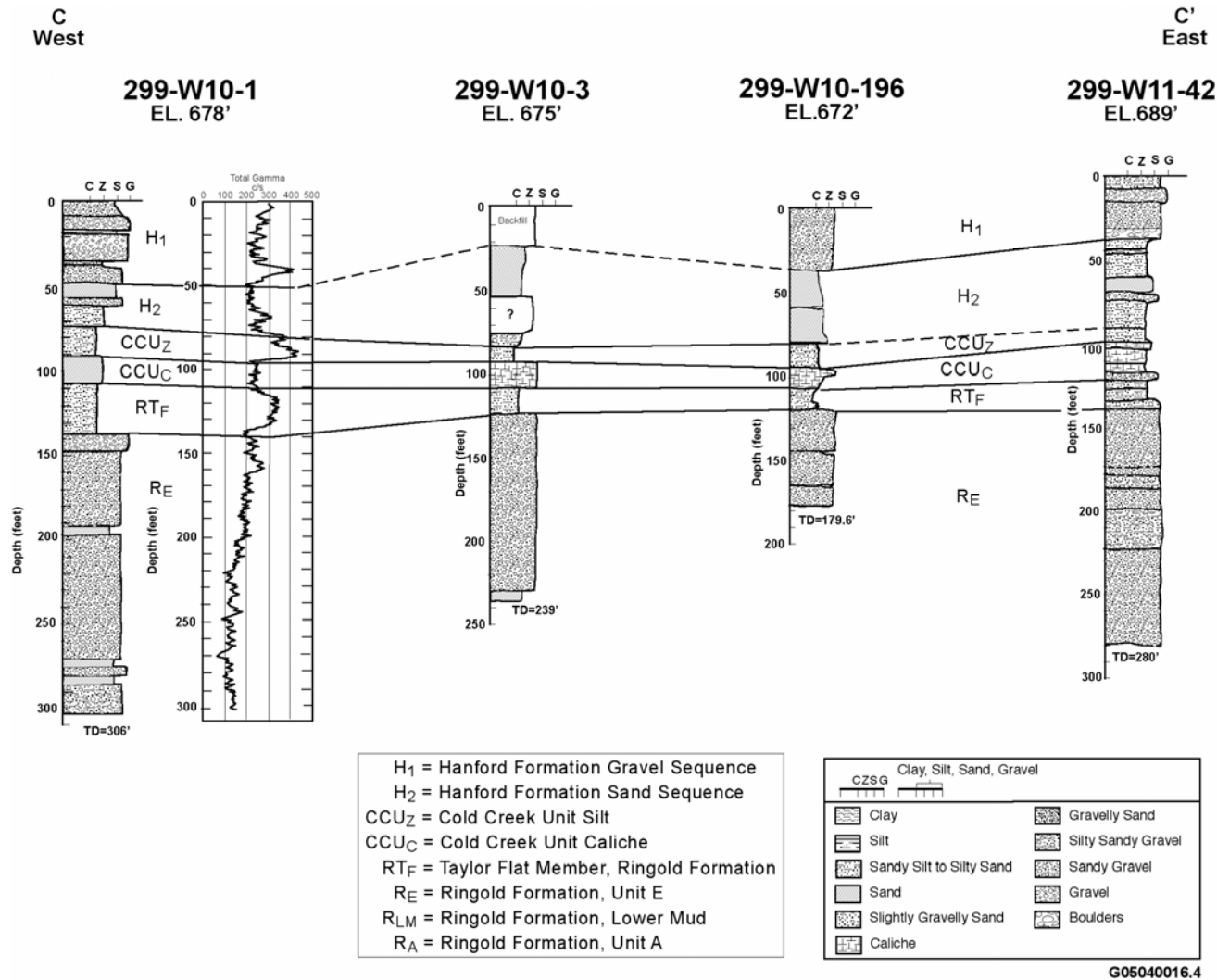


Figure 2.5. Cross-Section of the Geology Beneath Waste Management Area T (See Figure 2.1 for the location of the cross-section; multiply feet by 0.3048 to change to meters.)

Where the lower mud unit is not present, the suprabasalt aquifer is a single system. The limited data available from the WMA T area suggests that the lower mud unit extends laterally beneath the entire WMA.

Overlying the lower mud unit is the Ringold Formation, member of Wooded Island unit E. The contact between the two is easily distinguished on natural gamma logs by a considerable drop in gamma activity in going from the lower mud unit into unit E. Unit E is described on borehole logs of cuttings and samples from wells near the WMA T area as a pebble to cobble gravel with a fine- to coarse-grained sand matrix. Gravel content is usually greater than 60 to 70%. Occasionally, what are interpreted as large boulders are encountered during drilling. The sediments are variably consolidated, usually poorly sorted and show variable amounts of calcium carbonate. Iron oxide staining is common. "Slow drilling," "hard drilling," and "switched to hard tool" are common comments on the geologists' logs when drilling in unit E sediments.

Unit E was fully penetrated by three wells in the WMA T area: well 299-W10-24 where it was found to be 86 meters thick, 299-W11-26 where it was 83 meters thick, and well 299-W11-25B where it was 84 meters thick. Many wells in the WMA T area penetrate the top of unit E. Based on the elevation of the upper boundary of unit E, the unit dips slightly toward the west or southwest beneath WMA T (Figure 2.6).

Unit E is overlain by bedded sandy silt, sand, and silty sand of the Ringold Formation, member of Taylor Flats. These sediments are unconsolidated to consolidated and poorly to well sorted. Local pebbly areas occur. In places, calcium carbonate occurs as stingers and nodules whereas in other places no calcium carbonate exists. The lower boundary of the member of Taylor Flats is easily recognized by the difference in texture between this fine-grained member and the underlying unit E gravels.

The member of Taylor Flats ranges in thickness from 1.2 to 10.3 meters beneath WMA T, but is generally thicker than 3 meters, and averages 5.5 meters (Figure 2.7). Like the underlying units, the member of Taylor Flats has a general, gentle dip toward the southwest (Figure 2.6).

The Cold Creek unit calcic paleosol sequence (formerly known as the Plio-Pleistocene caliche) overlies the member of Taylor Flats. The contact between the two is marked by a substantial increase in calcium carbonate in the paleosol sequence and a substantial decrease in the natural gamma log going from the underlying sands and silts into the paleosol sequence. The Cold Creek paleosol sequence consists of calcium carbonate-cemented silt, silty sand, and sandy silt with some gravel in places. In most wells the calcium carbonate is fairly continuous throughout the unit, but in others there are caliche-rich and caliche-poor zones. In one well (299-W11-38), three distinct caliche zones were recognized. In places, the sediment becomes extremely cemented with calcium carbonate so that the driller changes from drive barrel to hard tool in order to continue drilling.

The Cold Creek unit calcic paleosol sequence occurs in all wells at WMA T. The sequence ranges in thickness from 2.4 to 9.8 meters with an average thickness of 5.3 meters under the WMA.

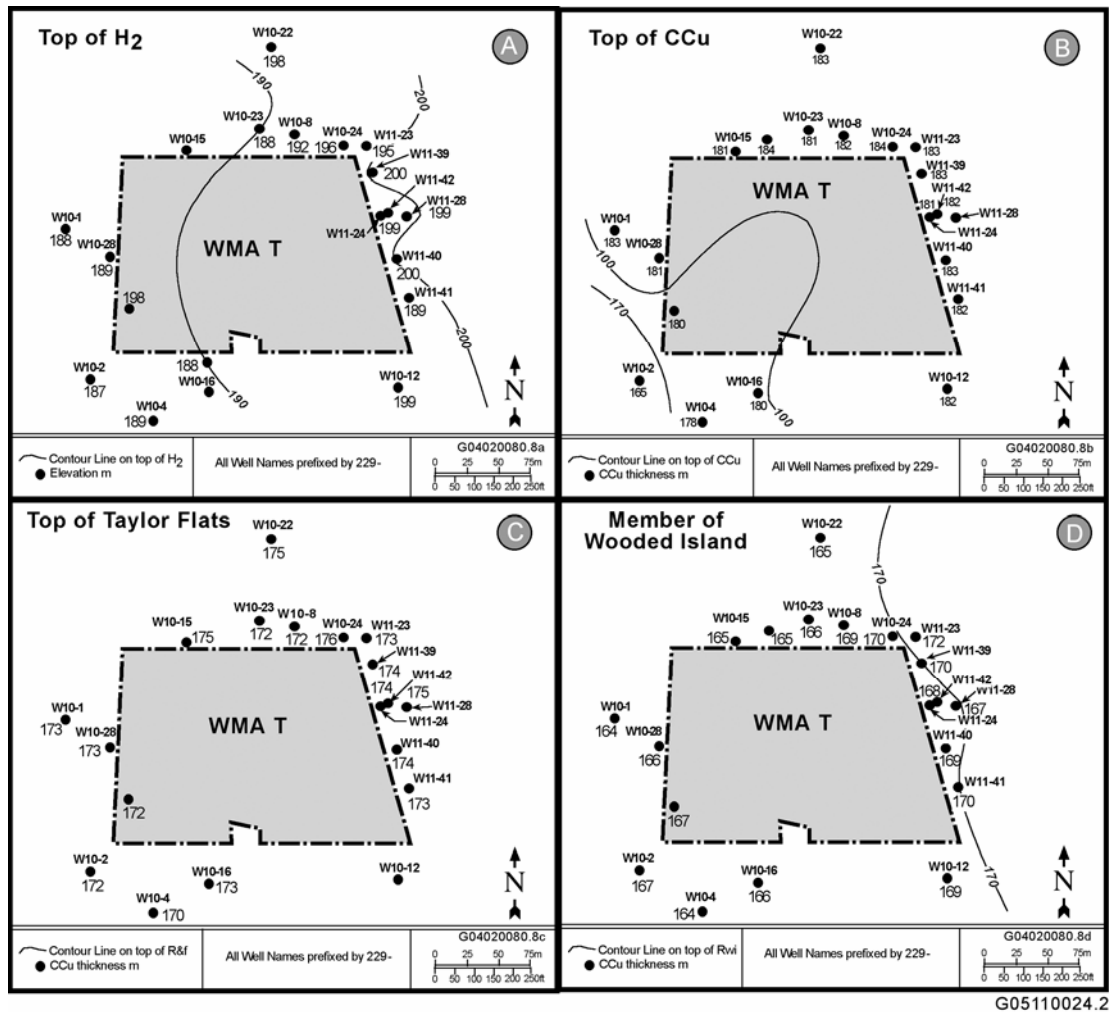


Figure 2.6. Structure Contour Maps for Selected Units Under Waste Management Area T (from Reidel et al. 2005)

Cold Creek unit fluvial and/or eolian sediments overlie the calcic paleosol sequence at WMA T. These sediments are slightly to well consolidated, moderately to well sorted silt and sandy silt. They may contain calcium carbonate but lack the extensive cementation found in the underlying calcic paleosols.

The driller's log for well 299-W10-2, located about 35 meters southwest of T Tank Farm, noted perched water from 26 to 31 meters depth. This closely corresponds to the top and bottom of the Cold Creek fluvial and eolian sequence in the well. Perched water also was found just above the contact of the Cold Creek fluvial sediments and the overlying Hanford formation in well 299-W10-22, north of the WMA. Although perched water has not been found beneath the WMA, the Cold Creek fluvial sediments extend throughout the area so that perched water may occur locally in areas that have not been drilled.

The Cold Creek fluvial and/or eolian sequence is between 1.8 and 6.7 meters in thickness and averages 3.6 meters thick at WMA T (Figure 2.7). The surface of the unit dips gently to the southwest (Figure 2.6).

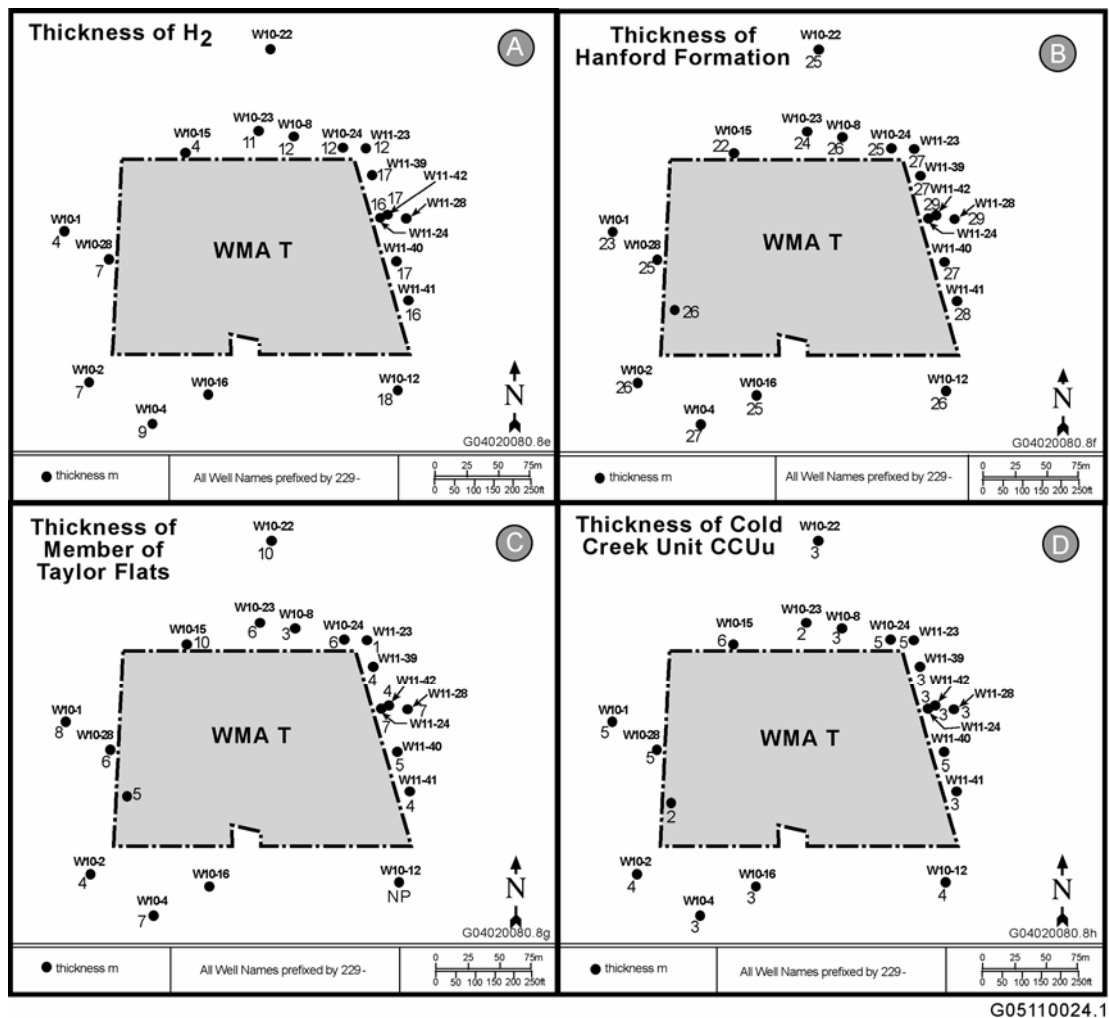


Figure 2.7. Thickness Maps for Selected Units Under Waste Management Area T (from Reidel et al. 2005)

A Hanford formation sand-dominated sequence overlies the Cold Creek fluvial sediments beneath WMA T. The sequence is equivalent to the sandy sequence of Lindsey et al. (1992), the Hanford formation H2 sequence of Lindsey et al. (1994), and to Qfs of Reidel and Fecht (1994).

The Hanford formation sand-dominated sequence (H2) is described on borehole logs of cuttings in the WMA T area as variably bedded silty sand, sand, and slightly gravelly to gravelly sand. The sediments are poorly to well sorted and unconsolidated. Fine-grained, silt-rich lenses are common and range from about 5 to 10 centimeters up to about 30 centimeters in thickness. Based on observations of outcrop and intact core, the sand-dominated sequence is interpreted to have been deposited during the waning stages of glacial flooding.

The Hanford formation sand sequence ranges from about 4 to 18 meters and averages 13 meters in thickness beneath the WMA (Figure 2.7). The sandy beds are “salt and pepper” sands ranging from about 30% basaltic and 70% felsic sand to 70% basaltic and 30% felsic sand. The sequence is not cemented but does contain zones with calcium carbonate as small concretions and as coatings on grains.

Thin silt lenses cap some individual beds within the Hanford formation sand-dominated sequence. These lenses are generally 15 centimeters or less in thickness but range up to about 30 centimeters thick. Generally, the silt lenses cannot be correlated among boreholes. However, one thin silt lens can be traced among three boreholes along the north edge of the WMA (Figure 2.3).

The base of the Hanford formation sand-dominated sequence is recognized by a change from the finer-grained silty sand to coarser grained deposits and is reflected by a decrease in natural gamma activity when going upward from the sediments of the Cold Creek unit into the Hanford formation. The top of the sand-dominated sequence is more difficult to distinguish and is usually chosen at the top of the shallowest sand bed that is greater than 3 meters thick, beneath gravel-dominated deposits. In some wells, this corresponds to a decrease in natural gamma activity when going from the sand-dominated sequence upward into the gravel-dominated sequence. The Hanford formation sand-dominated sequence tends to be thicker beneath the eastern part of the WMA (Figure 2.7) and has a slight dip toward the west or southwest (Figure 2.6).

A Hanford formation gravel-dominated sequence overlies the sand-dominated sequence. The gravel-dominated sequence is described on borehole logs of cuttings as consisting of silty sandy gravel and sandy gravel with some interbedded sand and silty sand. This sequence is equivalent to the Hanford formation upper gravel sequence of Lindsey et al. (1992), the Hanford formation H1 sequence of Lindsey et al. (1994), and Qfg of Reidel and Fecht (1994). Caggiano and Goodwin (1991), in the original ground-water monitoring plan for single-shell tanks, did not differentiate this sequence and the underlying Hanford formation sand-dominated sequence. The upper gravel-dominated sequence was deposited by high-energy, glacial flood waters.

The Hanford formation gravel-dominated sequence varies from 6 to 17 meters thick in the WMA T area and averages about 11 meters thick. Much or the entire unit was removed from most, if not all, of the tank farm during construction and replaced as backfill after construction was complete. The base of the gravel-dominated sequence was chosen at the top of the first sand or silty sand sequence that is at least 3 meters thick. This contact may be somewhat arbitrary, particularly in boreholes with only a driller's log and no natural gamma log.

Holocene deposits overlie the Hanford formation at WMA T. These deposits are limited to wind blown silt and sand. Eolian sheet sands occur sporadically at the surface and generally are less than 1 to 2 meters thick. Eolian sediments do not occur in the tank farm where they were removed during construction. Backfill material occurs to about 15 meters depth in the tank farm. The backfill is poorly sorted, gravelly sand to sandy gravel (Price and Fecht 1976) from the gravel-dominated sequence of the Hanford formation.

Price and Fecht (1976) state that clastic dikes were detected in the T Tank Farm during construction although they could not be mapped. Clastic dikes have not been recognized during drilling of the RCRA wells at WMA T although they have been identified in recent wells drilled at WMA TX-TY and WMA S-SX.

2.5.2 Aquifer Properties

This section provides information on the properties of the unconfined aquifer in the immediate region of WMA T. Aquifer properties were determined from stratigraphic interpretations, current water level elevations, and aquifer testing. Most of the information given in this section is summarized from Serne et al. (2004) and Reidel et al. (2005).

Currently, the water table at WMA T is at about 136.5 meters above sea level. The suprabasalt aquifer system beneath WMA T is estimated to be about 80 meters thick based on the depth to top of basalt in well 299-W11-26, located about 130 meters southeast of the WMA. The suprabasalt aquifer system consists of the Ringold confined aquifer, which is about 28 meters thick and lies between the top of basalt and the bottom of the lower mud unit, and the unconfined aquifer, which is about 52 meters thick and lies above the lower mud unit. All wells in the WMA T monitoring network are screened in the unconfined aquifer, hydrogeologic unit 5 of Williams et al. (2002) (the Ringold Formation unit E).

Water levels in the unconfined aquifer were raised as much as 13.5 meters (above the pre-Hanford Site natural water table) beneath WMA T because of artificial recharge from liquid waste disposal operations active between the mid 1940s and 1995. The largest volumes of discharge were to the 216-T pond system and the 216-U-10 pond system.

Figure 2.8 shows the groundwater elevations in the north part of 200 West Area since the late 1940s. The figure shows that the increase in water-table elevation was most rapid from 1949 to 1956 and was somewhat stable between the late 1960s and the late 1980s. Water levels began to decline in the late 1980s beneath WMA T when wastewater discharges in the 200 West Area were reduced. The decline in water levels may have implications for the groundwater monitoring network at the WMA T as will be discussed later.

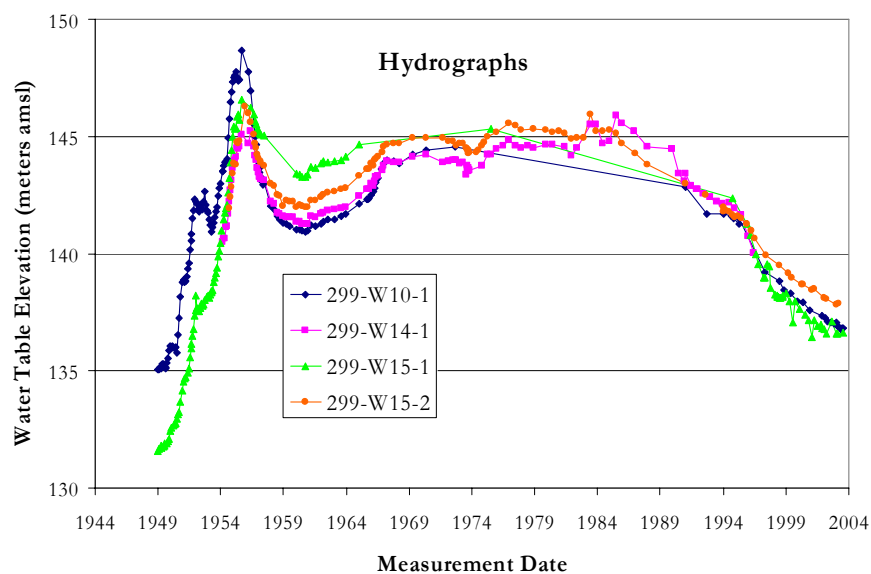


Figure 2.8. Hydrographs of Selected Wells in North 200 West Area

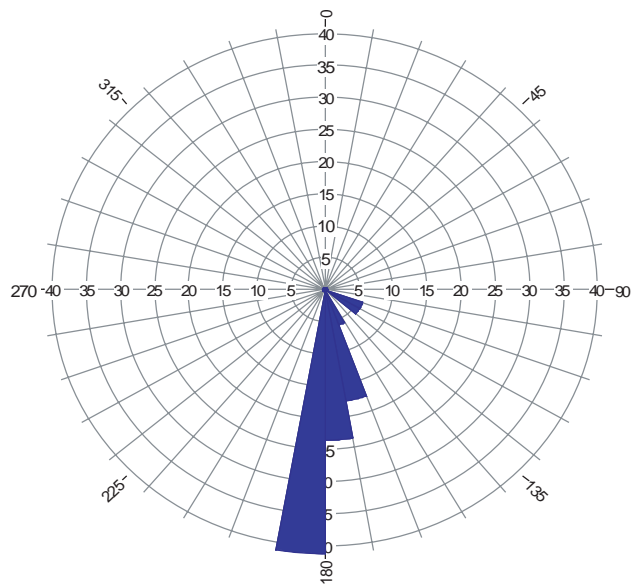
Accompanying the changes in water level were changes in groundwater flow direction. Histograms (rose diagrams) showing groundwater flow directions beneath the T Tank Farm during different time periods are shown in Figure 2.9. The rose diagrams plot the solutions to numerous three-point analyses using water level information from various well triplets in the north central part of 200 West Area. The petals of the rose diagrams point in the direction of groundwater flow and the length of the petals represent the percentage of measurements showing that groundwater flowed in the indicated direction. It should be noted that the apparent abrupt shifts in groundwater flow directions did not occur. Instead, the large changes in flow directions most likely took place over a period of months.

Pre-Hanford Site (circa 1942) groundwater flow direction was toward the east (Kipp and Mudd 1974). The rose diagram in Figure 2.9A shows that groundwater flow had changed toward the south in the area by the early 1950s. This shift resulted from disposal of large volumes of liquid to the 216-T pond system, located north of WMA T. In 1956, groundwater flow direction changed again and started flowing towards the northeast due to the increasing influence of the groundwater mound under 216-U pond and a decreasing influence of the mound under 216-T pond (Figure 2.9B). Discharges to 216-T pond ended in 1976 but continued at 216-U pond until 1984. As discharges to the 216-U pond declined in the early 1980s, groundwater flow shifted to a more northward direction as the groundwater mound began to decrease and discharges to the 216-U-14 ditch continued. The slight westward component to the groundwater flow direction between early 1980s and mid 1990s (Figure 2.9C) is probably a result of the discharges to the 216-U-14 ditch, located southwest of WMA T, influencing water levels in some of the wells used in the analysis. All non-permitted discharges to the ground ceased and the influence of the 216-U pond mound on the groundwater beneath the T Tank Farm diminished in 1995. Consequently, the flow direction changed again in about 1996 and began to return toward an eastward direction where it is expected to stabilize (Figure 2.9D).

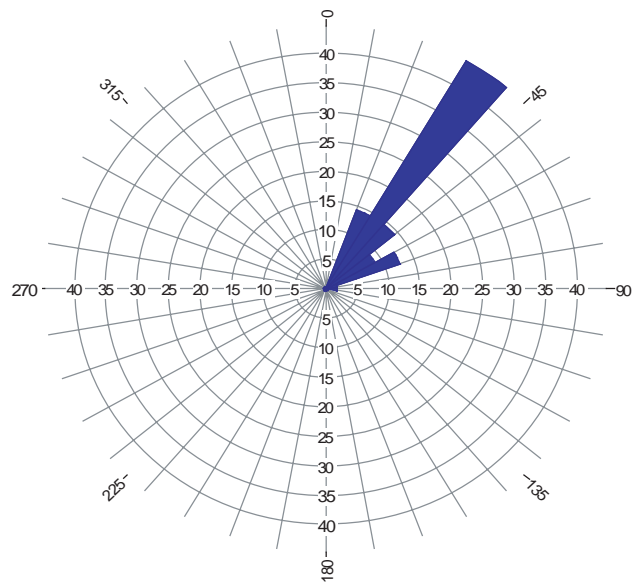
These large shifts in groundwater flow direction have large implications for contaminant distribution in the uppermost aquifer beneath WMA T. In the late 1940s and early 1950s, contamination was spread south in the aquifer. Then, in the late 1950s and until the mid-1990s that same contamination returned to the north along with any new contamination that entered the aquifer after the 1950s. Today, groundwater contamination beneath WMA T and surrounding area is generally migrating east.

Recently, two trend-surface analyses, done in August and September 2002, yielded groundwater flow directions of 6° to 8° south of east and a water-table gradient between of 0.00114 and 0.00132 (Spane et al. 2002). An earlier trend-surface analysis yielded a flow direction of 5° north of east and a water-table gradient of 0.00172 (Spane et al. 2001). Although the flow direction may differ slightly from well to well due to heterogeneous aquifer sediments, the groundwater flow direction at WMA T as determined by the trend surface analyses is consistent with the current regional groundwater map (Hartman et al. 2005). A current groundwater map for WMA T (and WMA TX-TY) is shown in Figure 2.10.

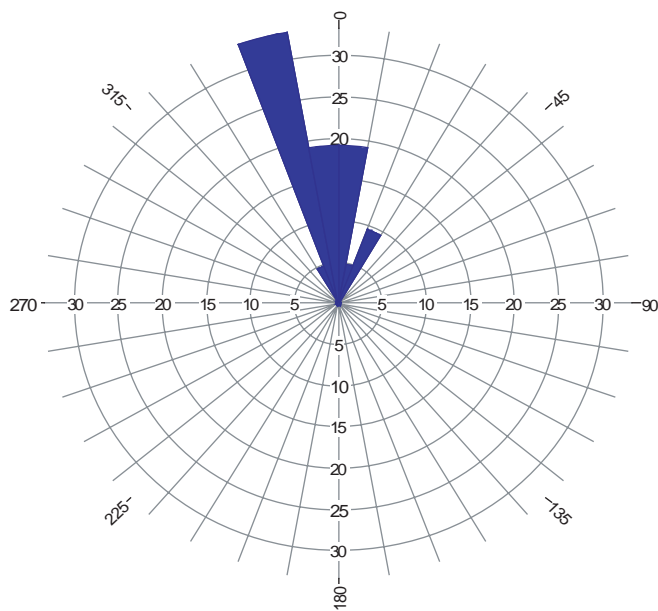
Borehole tracer dilution and tracer pumpback tests were conducted in three new RCRA monitoring wells at the T Tank Farm between fiscal years 1999 and 2001. These tests permitted some inferences about flow rate and aquifer homogeneity. The tests allowed direct observation of the effect of lateral groundwater flow through the well screens and, thus, provided an indication of the variability of flow through the screened intervals. Details of the test methods, computations, and results are included in Spane et al. (2001 and 2002).



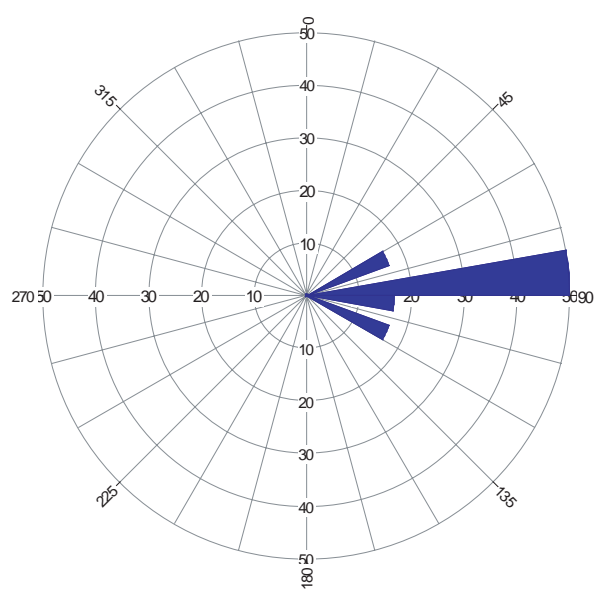
(A) 1954-1956



(B) 1957-1982



(C) 1983-1995



(D) 1997-2003

Figure 2.9. Groundwater Flow Directions in the North Part of 200 West Area. (A) 1954 to 1956, 1 well triplet, 17 measurements; (B) 1957 to 1982, 2 well triplets, 56 measurements; (C) 1983 to 1995, 4 well triplets, 21 measurements; (D) 1997 to 2003, 3 well triplets, 6 measurements.

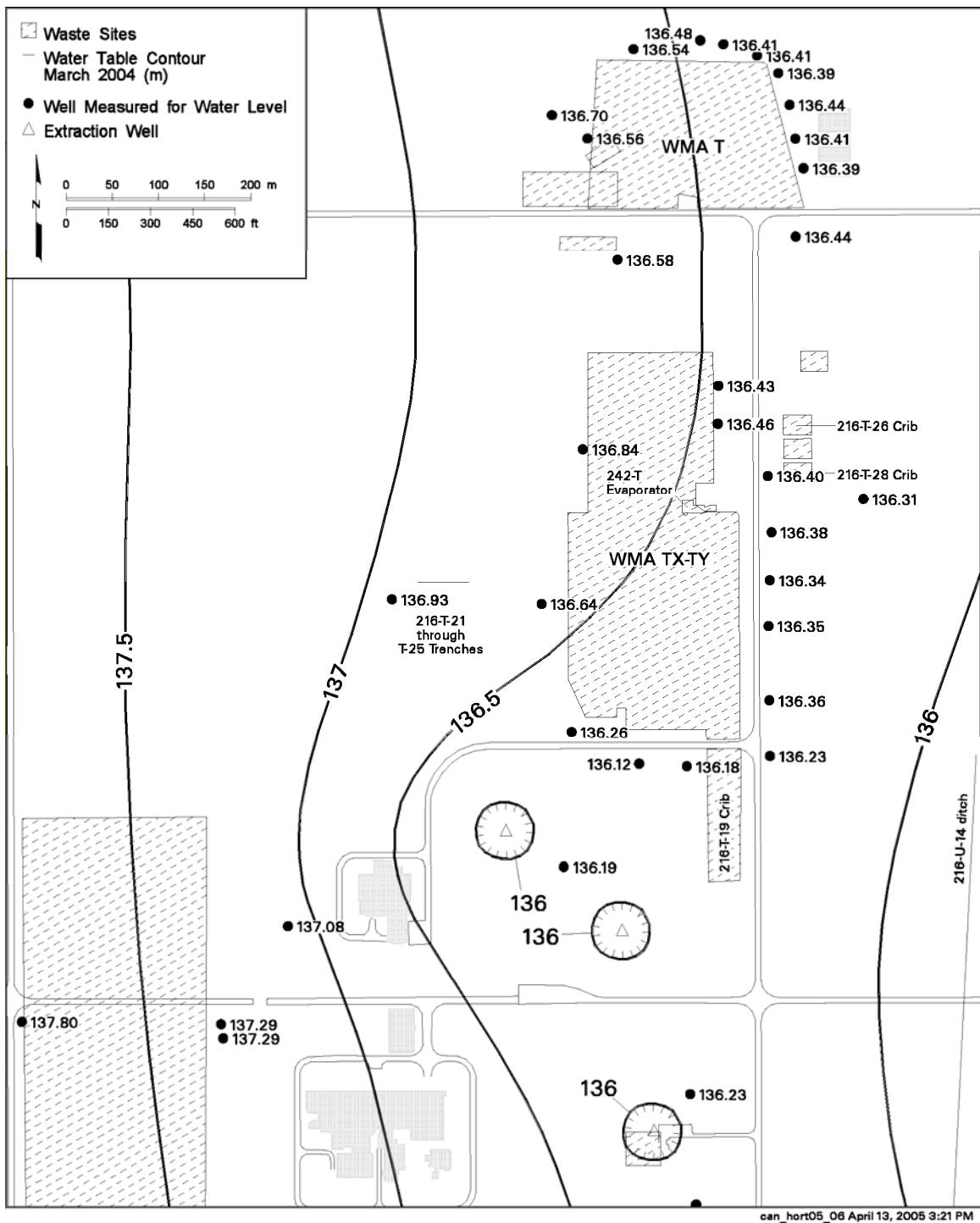


Figure 2.10. March 2004 Water-Table Map for the Area Around Waste Management Area T

A significant feature of the tracer dilution test results is evidence for downward, vertical hydraulic gradients within the upper portion of the aquifer in wells 299-W11-39 and 299-W11-40. Table 2.5 summarizes the test results for these wells.

Table 2.5. In-Well, Downward Vertical, Flow-Velocity Summary for Wells 299-W11-39 and 299-W11-40 at Waste Management Area T (Spane et al. 2002)

Test Well	Tracer Dilution Profile	
	Range (m/min)	Average (m/min)
299-W11-39	0.0003 – 0.002	0.001
299-W11-40	0.011 – 0.020	0.017

The existence of vertical flow in a well does not necessarily reflect actual groundwater flow conditions within the surrounding aquifer, but its presence implies a vertical flow gradient in the well bore and has implications pertaining to how representative the groundwater samples collected from the wells are. Also, the vertical gradient in some wells along the downgradient edge of WMA T may have an impact on contaminant distribution in the aquifer.

A second feature of the hydrologic test data is the suggestion of higher or lower hydraulic conductivity at certain depths within the screened interval of some wells relative to other depths. For example, tracer tests indicate that the upper 3 to 4 meters of the screened interval of well 299-W10-24 is less permeable than the lower part of the screened interval. However, a tracer test in nearby well 299-W11-39 indicated that the lower 1.8 meters of the screened interval are relatively impermeable compared to the rest of the interval. Thus, apparent differences in permeability do not appear to correlate from well to well.

For the WMA T groundwater assessment, new hydraulic conductivity data were obtained from slug tests and drawdown tests conducted in nine new wells drilled since 1999. Effective porosities were determined from tracer drift and tracer pumpback tests. Hydraulic properties are discussed in detail by Spane et al. 2001, 2002; and Spane et al. 2003 and are presented in Tables 2.6 and 2.7.

Table 2.6. Results from Tracer-Dilution and Tracer-Pumpback Tests in Wells at Waste Management Area T (Spane et al. 2001, 2002)

Well	Effective Porosity ^(a)	Horizontal Groundwater ^(a) Flow Velocity (m/d)	Average In-Well Horizontal Flow Velocity ^(b)
299-W10-24	0.072	0.029	0.012
299-W11-39 ^(c)	0.022	0.045	0.014
299-W11-40 ^(d)	0.002	1.1	0.176
(a) Data from tracer pump back tests. (b) Data from tracer dilution tests. (c) Slight downward vertical flow, data uncertain. (d) Strong downward vertical flow, data highly uncertain.			

Table 2.7. Hydraulic Properties from Slug and Constant Rate Pumping Tests and Calculated Horizontal Flow Velocities at New Wells at Waste Management Area T

Well	Hydraulic ^(a,b) Conductivity (m/d)	Hydraulic ^(a,c) Conductivity (m/d)	Transmissivity ^(a,c) (m ² /d)	Specific ^(a,c) Yield	Calculated Flow Velocity (m/d)
299-W10-23	1.62 – 2.35	ND	ND	ND	0.024 ^(e)
299-W10-24	1.04 – 1.68	1.22	66	0.11	0.023 ^(f)
299-W10-28	27.9 ^(g)	ND	ND	ND	0.23 ^(e)
299-W11-39	1.31 – 1.69	0.85	44	0.1	0.017 ^(d)
299-W11-40	3.56 – 4.58	2.02	103	0.1	0.046 ^(d)
299-W11-41	7.57 – 7.78	ND	ND	ND	0.078 ^(e)
299-W11-42	28.1 ^(g)	ND	ND	ND	0.28 ^(e)
(a) Data from Spane et al. 2001a, 2002, and 2003. (b) Slug test data. (c) Constant rate pumping test data. (d) Estimated using maximum hydraulic conductivity value, a gradient of 0.001, and specific yield from this table. Specific yield was used because downward flow in the well resulted in uncertain effective porosity. (e) Estimated using maximum hydraulic conductivity value, a gradient of 0.001 and effective porosity values of 0.1. (f) Estimated using maximum hydraulic conductivity value, a gradient of 0.001, and effective porosity value from Table 2.6. (g) Indicates average hydraulic conductivity obtained from high-permeability, non-linear type-curve analysis method. ND = Not determined.					

The horizontal groundwater flow velocities determined from tracer pump back tests (Table 2.6) are greater than the calculated velocities (Table 2.7) for wells which have downward vertical flow in the well bore (299-W11-39 and 299-W11-40). The vertical flow in these wells probably resulted in overestimation of the measured flow velocity. Both the measured and calculated velocities are about the same for well 299-W10-24, which has no vertical flow.

Overall, there is about an order of magnitude difference in the horizontal flow velocities in Table 2.7. The horizontal velocity in wells 299-W10-28 and 299-W11-42 are substantially greater than the velocities calculated for the other wells. Very rapid recoveries during slug testing were noted (90% recovery within 4 seconds for both wells), which suggests fairly permeable formations (Spane et al. 2002, 2003). However, there is nothing in the geologist's logs or the geophysical logs to suggest that the formation in the screened interval of these wells is significantly different than the formation at other, nearby wells.

Taken as a whole, the geologist's logs, geophysical logs, development pumping data, and the hydrologic testing data all indicate heterogeneity in the aquifer properties within the screened intervals of several individual wells and among wells at WMA T. No widespread trends have been identified.

The hydrographs in Figure 2.11 show that water levels have declined by about 6.5 meters since 1991 beneath the T Tank Farm. This decline, resulting from decreasing effluent discharge in the 200 West Area, became much steeper in 1995 with the effective cessation of discharge to all non-permitted facilities in this area. Between 1998 and 2004 the average rate of water table decline has been between about 0.3 to 0.4 meter/year in all monitoring wells at WMA T. The rapid decrease in water levels after 1995 has resulted in monitoring wells going dry more quickly than previously predicted and has necessitated the drilling of seven new monitoring wells since 1999. The life expectancy for all wells in the WMA T monitoring network is shown in Table 2.8.

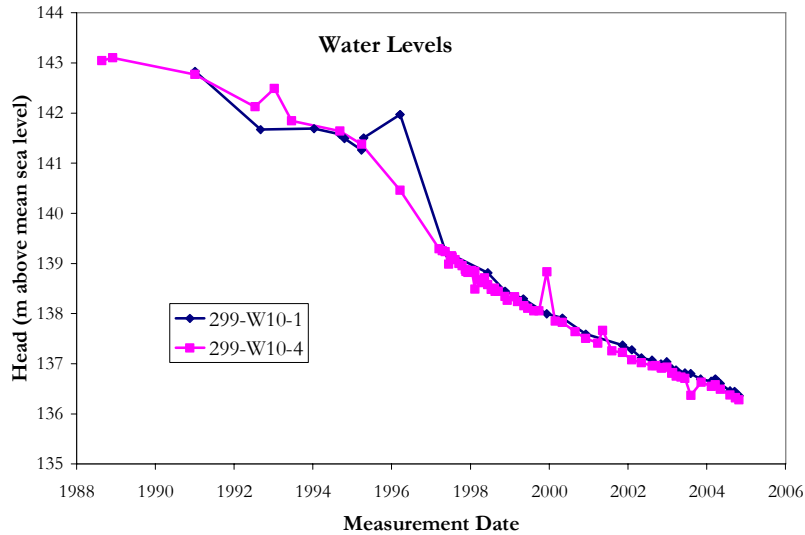


Figure 2.11. Hydrographs for Two Wells at Waste Management Area T

Table 2.8. Calculated Life Expectancy for Wells in the Waste Management Area T Monitoring Network

Well Name	Length of Saturated Screened Interval (m) ^(a)	Year Expected to Go Dry ^(b)
299-W10-1	12.8 ^(c)	2033
299-W10-4	5.4 ^(c)	2017
299-W10-8	4.7	2015
299-W10-22	2.6	2011
299-W10-23	8.6	2024
299-W10-24	8.5	2024
299-W10-28	9.5	2026
299-W11-7	7.2 ^(c)	2021
299-W11-12	4.3 ^(c)	2015
299-W11-39	9.6	2026
299-W11-40	9.5	2026
299-W11-41	9.1	2025
299-W11-42	8.6	2024
(a) Based on second quarter FY 2005 water levels except 299-W10-22, 299-W10-28, and 299-W11-7 which is based on first quarter FY 2005 data.		
(b) Assuming an average of 0.45 m/yr water-table decline.		
(c) Perforated well.		

2.6 Contamination at Waste Management Area T

This section summarizes the current and historical groundwater contamination at WMA T. Vadose zone contamination is also discussed because any residual vadose zone contamination is a potential source for future groundwater contamination.

As stated in Section 1.3, groundwater monitoring objectives of RCRA, CERCLA, and the AEA often differ slightly and the contaminants monitored are not always the same. For RCRA regulated units, monitoring focuses on non-radioactive dangerous waste constituents. Radionuclides (source, special

nuclear and by-product materials) may be monitored in some RCRA unit wells to support objectives of monitoring under the AEA and/or CERCLA. Please note that pursuant to RCRA, the source, special nuclear and by-product material component of radioactive mixed waste are not regulated under RCRA and are regulated by DOE acting pursuant to its AEA authority. Therefore, while this report may be used to satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA permit.

2.6.1 Groundwater Contamination

Most of the information presented in this section is from Horton et al. (2002), Hartman et al. (2000, 2001, 2002, 2003, 2004, 2005), and Serne et al. (2004).

Chromium, carbon tetrachloride, and trichloroethene are the only dangerous waste constituents found in the groundwater beneath WMA T. Carbon tetrachloride and trichloroethene are monitored as part of the 200-ZP-1 Operable Unit. Nitrate and fluoride are also found in groundwater beneath the facility. In addition to the dangerous waste constituents, the non-RCRA-regulated constituents technetium-99 and tritium are found in groundwater at the WMA.

Groundwater chemistry in the vicinity of WMA T is dominated by high sodium, high nitrate groundwater containing varying concentrations of chromium, tritium, technetium-99, fluoride, carbon tetrachloride, and trichloroethene. These contaminants are a result of over 50 years of waste management activities in the 200 West Area.

Carbon tetrachloride is present in the unconfined aquifer beneath most of the 200 West Area (Figure 2.12). (Note that all plume maps in this document represent conditions in the upper approximately 9 to 10 meters of the unconfined aquifer.) The highest carbon tetrachloride concentration near WMA T in fiscal year 2004 was 1,800 µg/L in well 299-W10-4, south of the waste management area. High concentrations were also found north (299-W10-23) of the waste management area. The carbon tetrachloride is believed to be from pre-1973 waste from the Plutonium Finishing Plant and not from WMA T.

The major sources for trichloroethene are disposal sites associated with the Plutonium Finishing Plant. A second potential source is disposal near T Plant (Hartman et al. 2003). The maximum trichloroethene concentration found near WMA T in 2004 was about 10 µg/L in the north (well 299-W10-23) and south (well 299-W10-4) of the WMA (Figure 2.13). The waste management area is not considered a source for trichloroethene.

A tritium plume lies beneath WMA T and much of the north half of the 200 West Area (Figure 2.14). The plume geometry suggests that the major tritium source is to the south near WMA TX-TY, the 242-T evaporator, and nearby cribs (Hartman et al. 2004). Other contributing sources are likely present in the vicinity of the T Tank Farm and include associated cribs and trenches and, potentially, tank leaks. The highest tritium concentration near WMA T in 2004 was 51,000 pCi/L in well 299-W11-12, located at the southeast corner of the waste management area. Waste Management Area T is not thought to be a major contributor of tritium to the groundwater plume in the area.



2.26

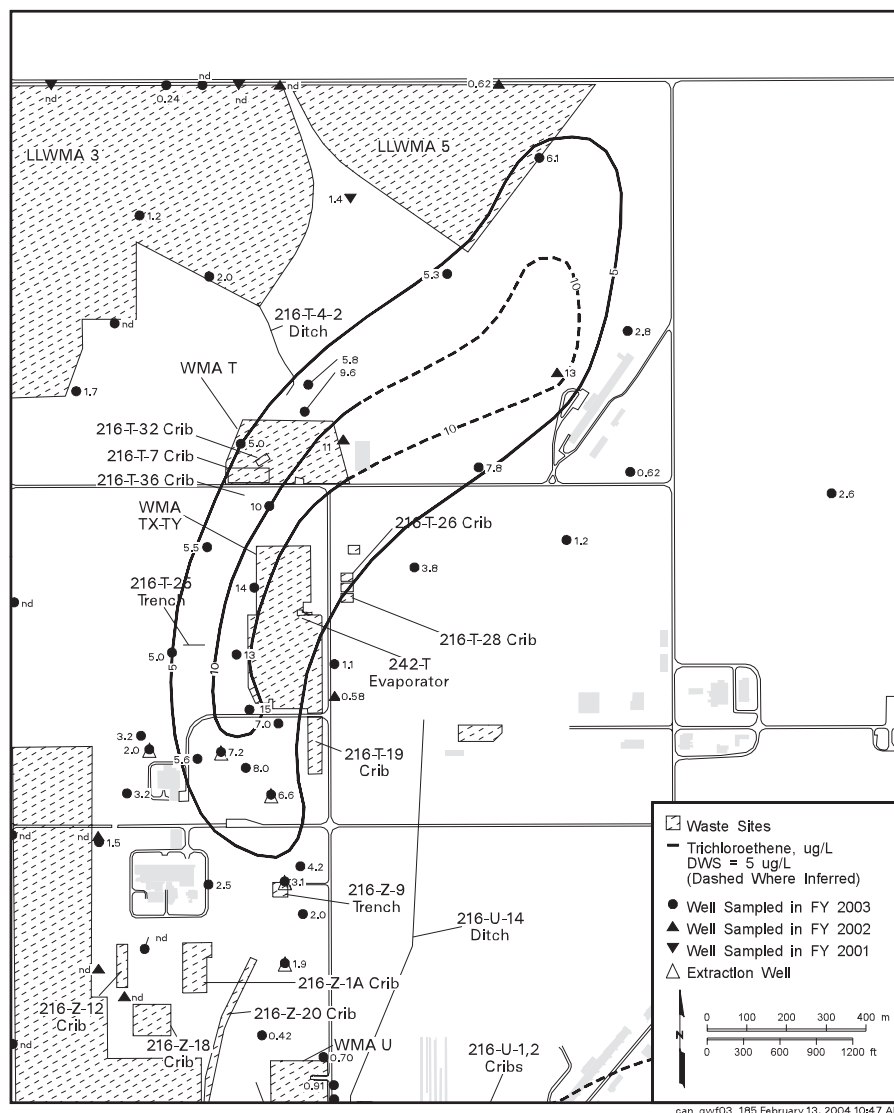


Figure 2.13. Average Concentrations of Trichloroethene in the North Part of the 200 West Area, Top of the Unconfined Aquifer (from Hartman et al. 2005)

A regional nitrate plume underlies WMA T and much of the north part of the 200 West Area (Figure 2.15). However, unlike, carbon tetrachloride, trichloroethene, and tritium, there also appears to be a source of nitrate local to, but upgradient of, WMA T. All monitoring wells in the WMA T monitoring network have nitrate concentrations in excess of the 45,000 $\mu\text{g/L}$ maximum contaminant level in all monitoring wells.

The highest nitrate concentrations at the Hanford Site in fiscal year 2004 were from two upgradient wells at WMA T: 3,430,000 $\mu\text{g/L}$ in well 299-W10-4 and 2,000,000 $\mu\text{g/L}$ in well 299-W10-28. The nitrate concentration began to increase in well 299-W10-4 in about 1997 when the groundwater flow direction changed from northerly to easterly. Concentrations have continued to rise since that time. The nitrate concentration in well 299-W10-28 has always been greater than 1.12 million $\mu\text{g/L}$ since it was

Fluoride concentrations exceeded the drinking water standard of 4,000 µg/L in two wells at WMA T in 2004 and exceeded the secondary drinking water standard of 2,000 µg/L in five additional wells. Currently, the highest concentrations are in wells north of the WMA (Figure 2.16) but historically, the highest concentration was in well 299-W10-4 in late 1999 (5,250 µg/L). A fluoride plume appears to have passed well 299-W10-4 between mid-1997 and late 2000.

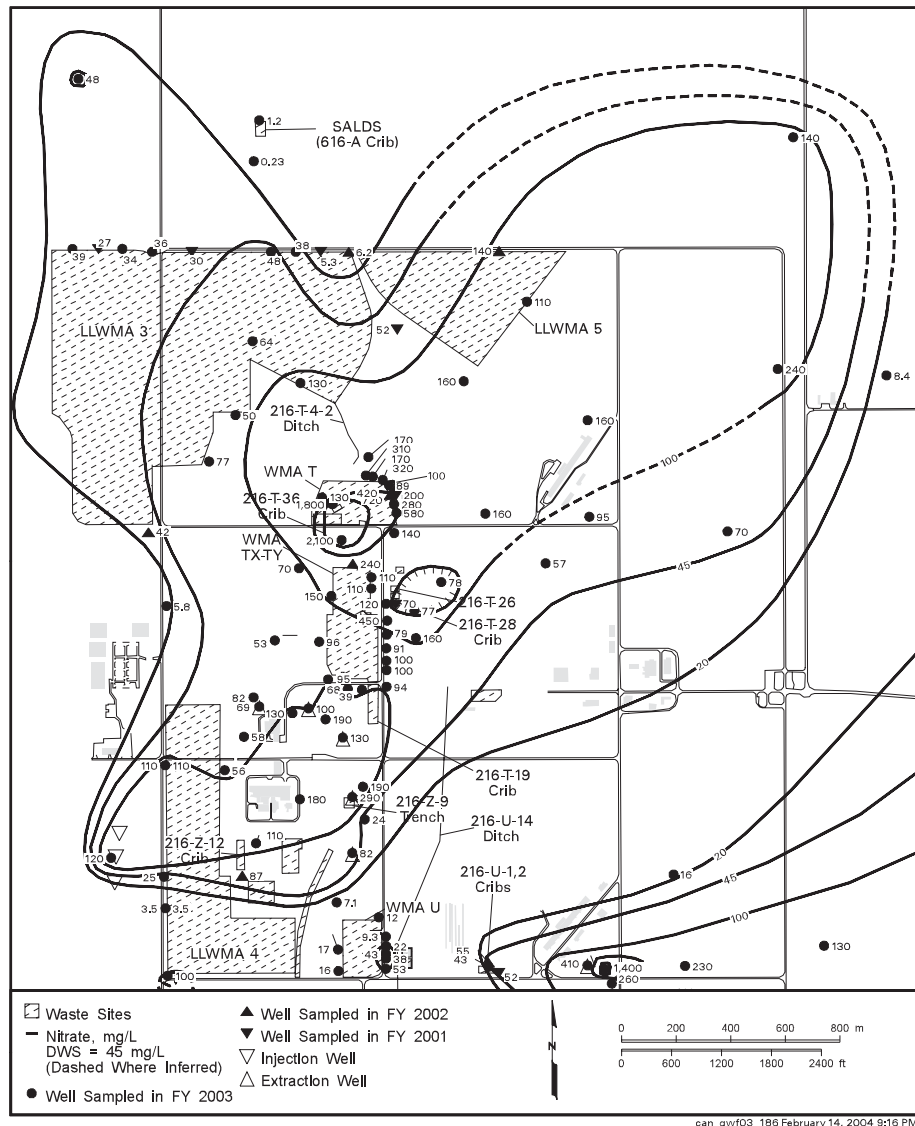


Figure 2.15. Average Concentrations of Nitrate in the North Part of 200 West Area, Top of the Unconfined Aquifer (from Hartman et al. 2005)

Although a tank farm source for the fluoride contamination has not been ruled out, one or more of the nearby cribs are believed to be a more likely source for much of the fluoride for two reasons. First, the highest concentrations of fluoride historically have been in upgradient wells located near potential fluoride sources (19,000 kilograms of fluoride disposed to the 216-T-7 crib and 16,000 kilograms of fluoride disposed to the 216-T-32 crib [Simpson et al. 2001]). Second, the fluoride/technetium-99 ratios vary from well to well at WMA T and with time in some individual wells (see Figure 2.17 for an example). If the technetium-99 has a source within the waste management area, as suggested below, the variation in the fluoride/technetium-99 ratios suggest a different source for most of the fluoride. However, some of the fluoride as well as some of the nitrate, chromium, and tritium in the groundwater is probably from tank waste in amounts proportional to their relative concentrations with respect to technetium-99.

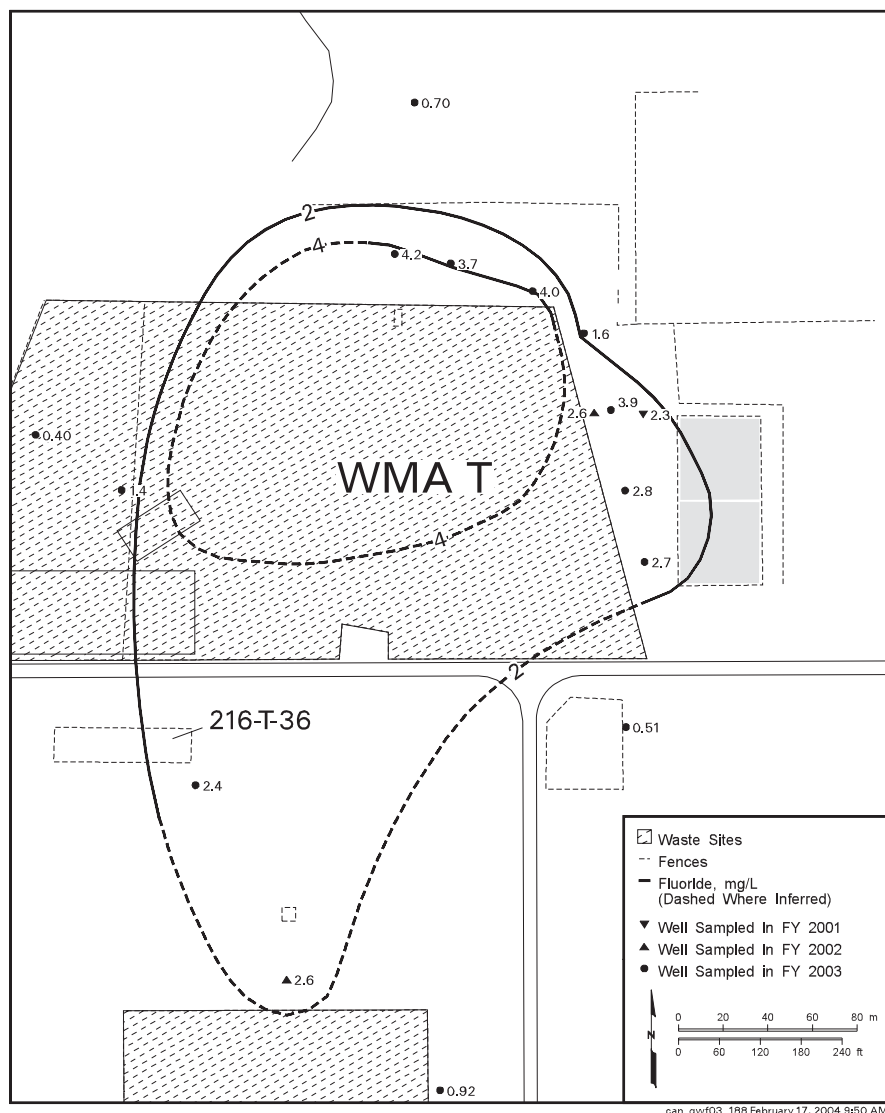


Figure 2.16. Average Concentrations of Fluoride in the Area of Waste Management Area T, Top of the Unconfined Aquifer (from Hartman et al. 2005)

A plume map for technetium-99 in the groundwater in the area of WMA T is shown in Figure 2.18. Technetium-99 began to increase in well 299-W11-27, located at the northeast corner of T Tank Farm, in late 1995, coincident with the cessation of surface water disposal in the 200 West Area. Concentrations reached a peak level of 21,700 pCi/L in February 1997 (Figure 2.18). Technetium-99 concentrations in well 299-W11-27 subsequently decreased to 6,000 pCi/L in March 1999 when the well went dry. Hodges (1998) suggested that technetium-99 had arrived at well 299-W11-27 by the early 1990s, but was diluted with water from a leaking water line located immediately adjacent to the well. The water line carried cooling and ventilation steam condensate, process cooling water, and evaporator condensate from the 207-T retention basin to the 216-T-4-2 ditch (DOE 1991) until 1995. Elimination of water discharge to the 216-T-4-2 ditch in June 1995 allowed contaminants to reach the well. The subsequent decrease in technetium-99 in well 299-W11-27 since 1997 may be a result of changing groundwater flow direction.

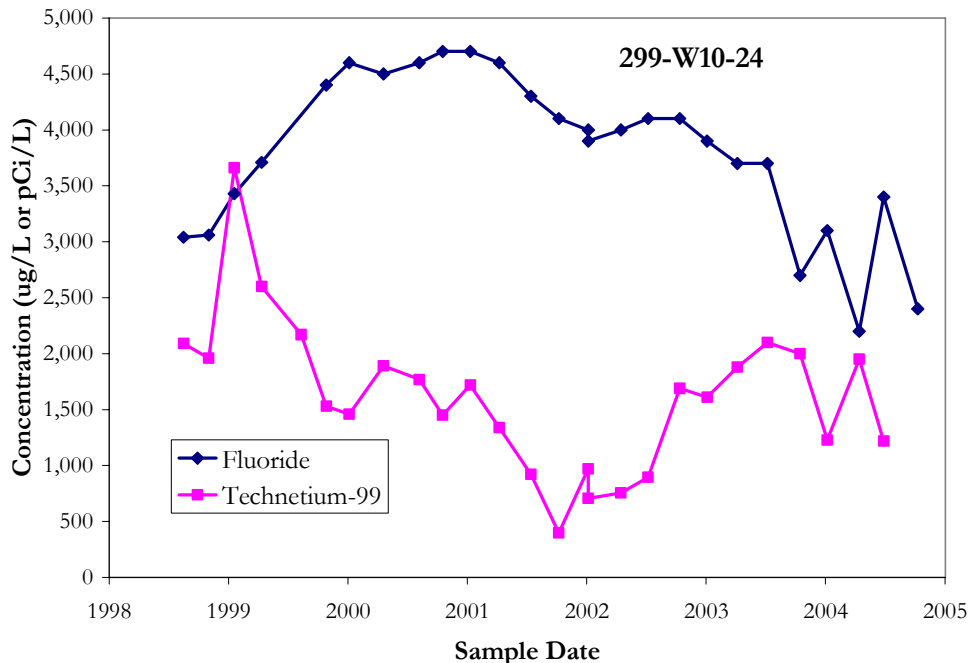


Figure 2.17. Technetium-99 and Fluoride Concentrations in Downgradient Well 299-W-10-24

Technetium-99 began to increase in well 299-W11-23, located east of well 299-W11-27, in November 1997 coincident with the change in groundwater flow to a more eastward direction. It increased to a high of 8,540 pCi/L in November 1998 (Figure 2.19). Subsequently, technetium-99 values fluctuated between 7,110 and 840 pCi/L. The last sample from this well, taken in December 2000, indicated a technetium-99 concentration of 4,470 pCi/L. Sampling of replacement well 299-W11-39 in 2001 detected technetium-99 concentrations between 4,160 and 5,010 pCi/L, indicating contamination of the upper portion of the aquifer at this well. The technetium-99 concentration in this well rose to a high of 21,400 pCi/L in August 2004.

In early 2002, technetium-99 concentration began to increase in well 299-W11-42, south of well 299-W11-39 and, in early 2003, technetium-99 began to increase in well 299-11-41, south of 299-W11-42 (Figure 2.20). These increases suggest that a second technetium-99 plume or a portion of the technetium-99 plume first detected in the northeast corner of T Tank Farm is being detected along the entire east and downgradient side of the WMA.

Sampling during drilling of well 299-W10-24, in 1998, showed that the highest technetium-99 concentrations were at or very near the water table, at the northeast corner of the WMA, and concentrations decreased rapidly with increasing depth in the aquifer at the time the well was drilled. This suggested a nearby source for the technetium-99 because the contaminant had not traveled far enough to disperse vertically in the aquifer (Hodges 1998).

However, in February and March 2005, well 299-W11-25B was drilled to the Ringold Formation lower mud unit and encountered extremely high concentrations of technetium-99, nitrate, and chromium at 10.7 meters below the water table and deeper (Figure 2.21). (Well 299-W11-25B was damaged during construction and was replaced by well 299-W11-46.) Such high levels of contaminants at these depths

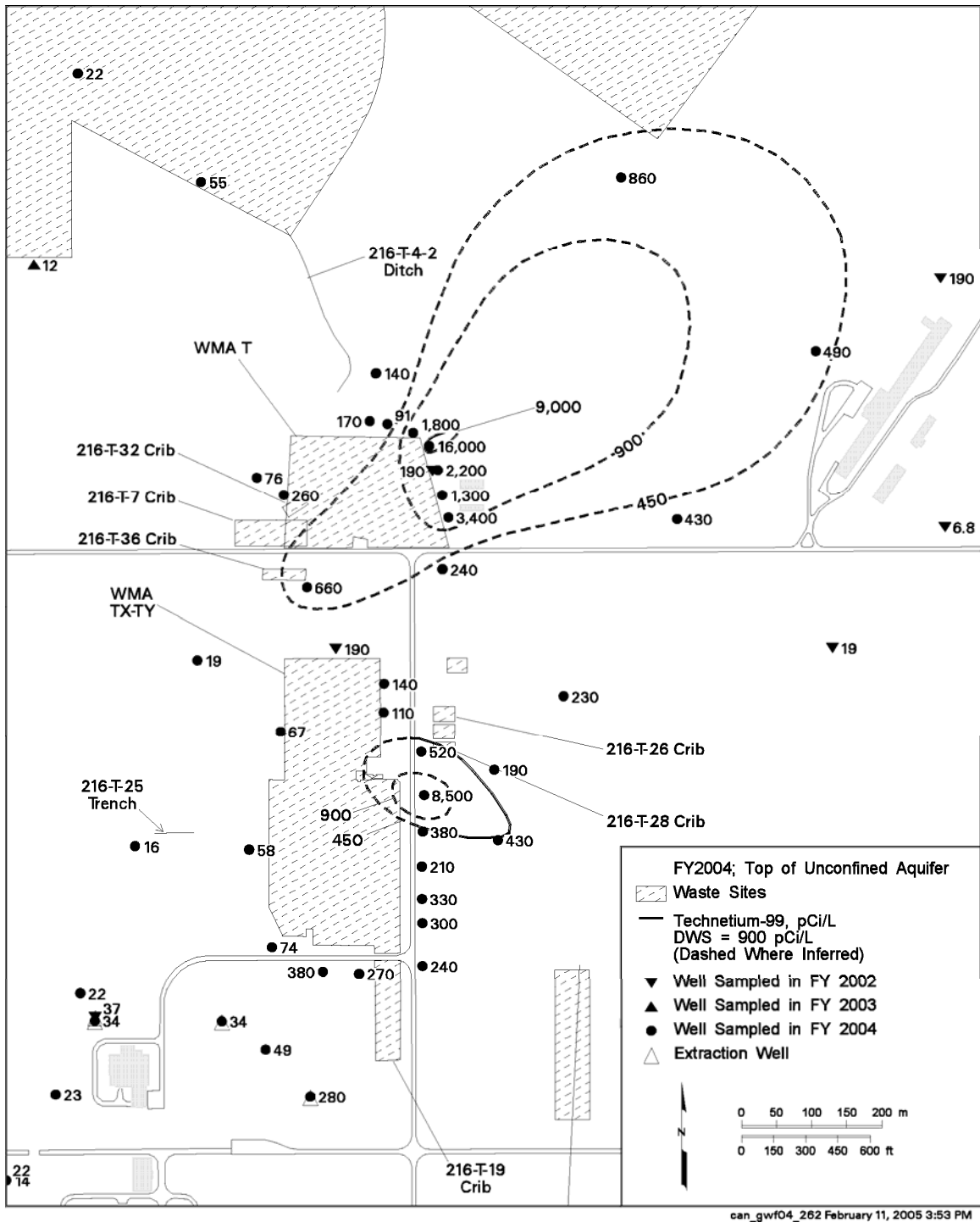


Figure 2.18. Average Concentrations of Technetium-99 in the Area of Waste Management Area T, Top of the Unconfined Aquifer (from Hartman et al. 2005)

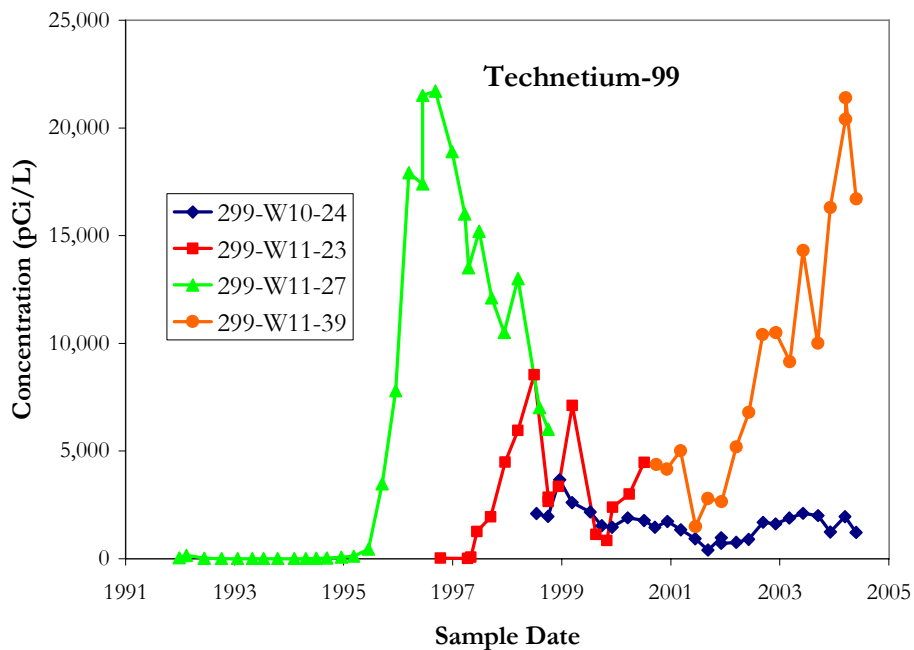


Figure 2.19. Technetium-99 Concentrations in Wells at the Northeast Corner of Waste Management Area T

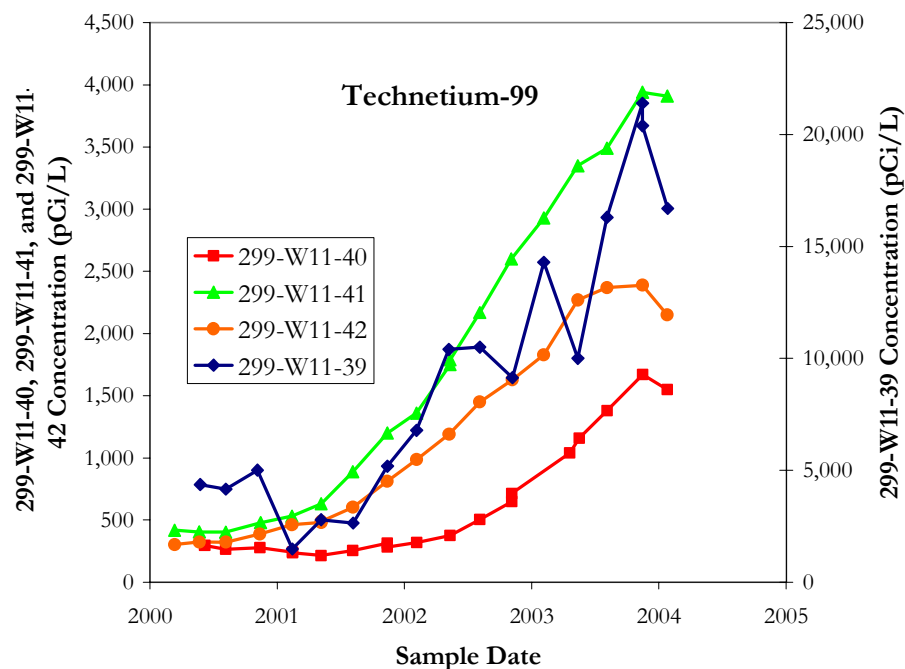


Figure 2.20. Technetium-99 Concentrations in Selected Downgradient Wells at Waste Management Area T

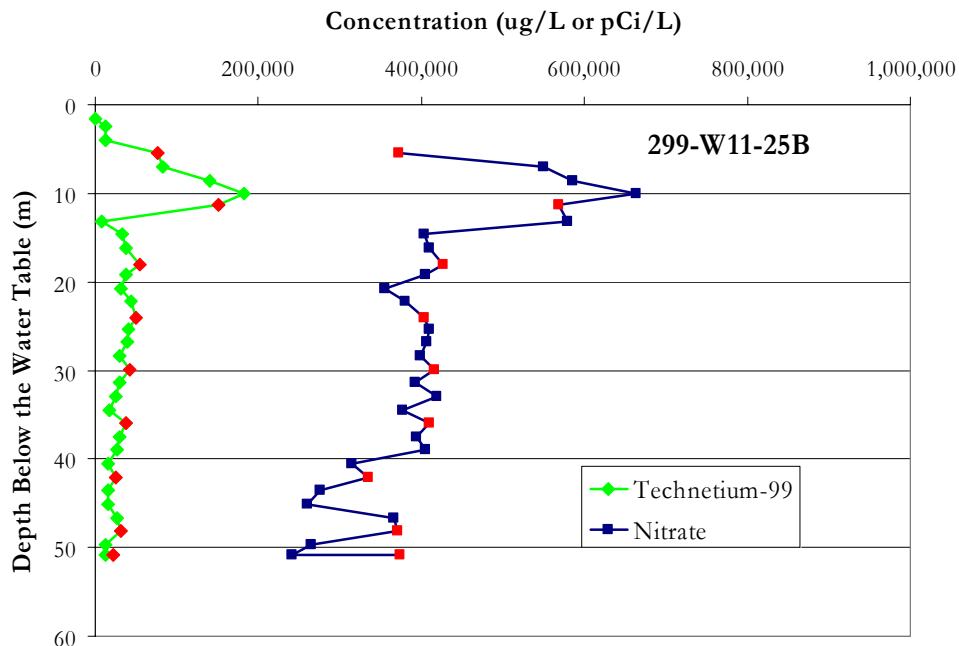


Figure 2.21. Concentrations of Technetium-99 and Nitrate Versus Depth Below the Water Table in Well 299-W11-25B. Red dots are pumped samples; all others are air lifted samples.

below the water table is contrary to what had been observed at well 299-W10-24 and at well 299-W14-13 at the WMA TX-TY (Hartman et al. 2004) where the highest concentrations of technetium-99 were at or near the water table. The reason for the high concentrations at depth in well 299-W11-25B is not fully understood. Part of the explanation may be the broken pipeline near well 299-W11-27. Data in Alexander et al. (1995) allow for an estimated maximum leakage of 1,800,764 liters of water between November 1992, when well 299-W11-27 was drilled, and June 1995 when discharge of all non-permitted effluent was stopped. This volume of water may have influenced the distribution of contamination in the aquifer. Further characterization is needed to fully understand the vertical distribution of contaminants in the area.

Also unknown is the lateral extent of the contamination at depth within the aquifer. Characterization to delineate the lateral extent is addressed in the DQOs in Chapter 3.0 of this plan.¹

Figures 2.21 and 2.22 show the concentrations of selected constituents with depth in the aquifer in well 299-W11-25B. Figure 2.21 shows that the technetium-99 concentration near the water table is relatively low (238 pCi/L) but rapidly increases to a maximum of 181,600 pCi/L at 10 meters below the water table. The technetium-99 concentration decreases below the 10-meter depth but remains elevated at between 20,000 and 50,000 pCi/L to total depth of the well. The maximum nitrate concentrations also are at the 10-meter depth below the water table. The concentrations of nitrate and technetium-99 appear to track each other with depth in the aquifer.

¹ At the time this document was prepared, two new wells were under construction to help delineate the vertical and horizontal extent of contamination at WMA T (see Section 3.4.3).

The chromium and manganese concentrations in well 299-W11-25B are shown in Figure 2.22. Two types of samples were collected during drilling of the well. The blue points on the figure represent air lifted samples of drill cutting and groundwater. The red points represent samples collected by pumping after extensive purging of the well. There is a substantial difference between the air lifted and pumped results. The groundwater associated with the air lifted samples was in contact with the drill cuttings for at least 24 hours before analysis. It is probable that the soluble Cr^{6+} was reduced to insoluble Cr^{3+} by being in contact with pulverized rock in the drill cuttings. Extensive purging of the well before collection of the pumped samples removed most or all of the groundwater affected by drilling so that the resulting chromium concentrations were unaffected by reducing conditions created during drilling. The highest chromium concentration in the pumped samples was 1,033 $\mu\text{g/L}$ at 5.5 meters below the water table.

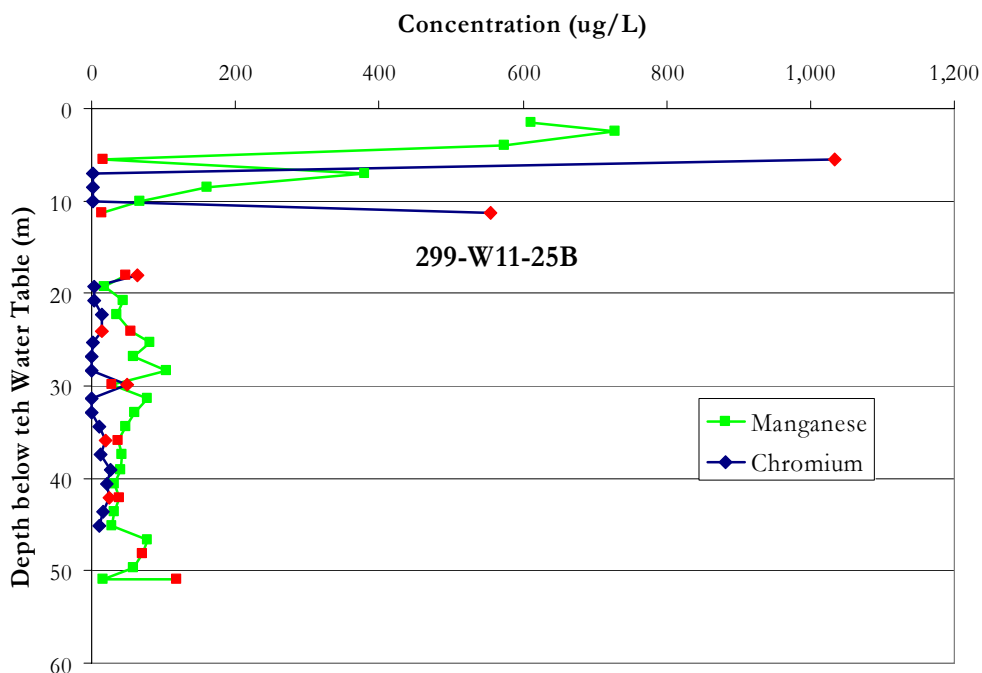


Figure 2.22. Concentrations of Chromium and Manganese Versus Depth Below the Water Table in Well 299-W11-25B. Red dots are pumped samples; all others are air lifted samples.

The distribution of manganese (Figure 2.22) supports the reduction of chromium in the air lifted samples. Soluble Mn^{2+} is expected to be released from the basaltic sediments during drilling and it is this manganese that is measured during analysis of the air lifted samples. Purging the well before collecting the pumped samples removes the artificially introduced manganese and more natural, background manganese concentrations result.

Because of the high technetium-99 concentrations found in well 299-W11-25B, two new wells were proposed to help delineate the vertical and horizontal extent of the contamination (see Section 3.4.3 and Appendix A). Both wells were under construction at the time this plan was being written and groundwater samples collected during drilling of one of them, well T-2 (299-W11-45), had been analyzed. A brief discussion of the preliminary results is give here. The location of the well is shown on Figure 2.23.

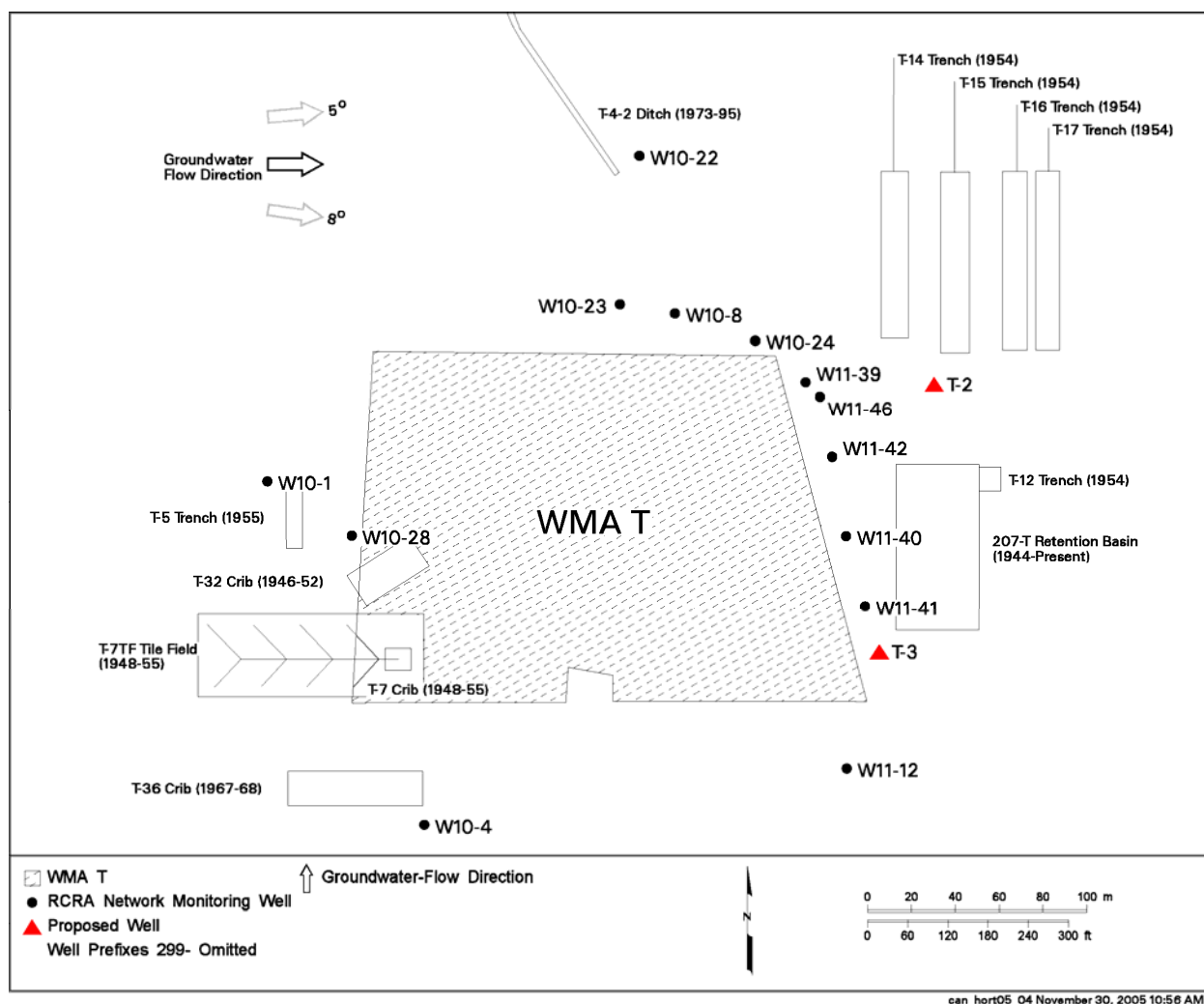


Figure 2.23. Current Groundwater Monitoring Network for Waste Management Area T. Proposed wells are indicated by red triangles.

Drilling began on well 299-W11-45, located ~80 meters downgradient of well 299-W11-25B, in September 2005. Groundwater from the well was sampled every 1.5 meters throughout the upper 56 meters of the aquifer. The technetium-99 and nitrate concentrations found during drilling are shown on Figure 2.24.

The maximum technetium-99 concentration found during drilling of well 299-W11-45 was 15,646 pCi/L at 9.1 meters below the water table. The depths of the maximum concentrations are similar in wells 299-W11-25B and 299-W11-45. Although the technetium-99 concentration is very high in well 299-W11-45, it is much less than the 181,000 pCi/L maximum found in well 299-W11-25B. This suggests that, if the technetium-99 found in the two wells is from the same plume, the front edge of the plume is probably a short distance east of well 299-W11-45.

The nitrate and technetium-99 concentrations tracked each other in well 299-W11-25B. This does not seem to be the case in well 299-W11-45 (Figure 2.24). The maximum nitrate concentration (590,000 µg/L) roughly coincides with the maximum technetium-99 concentration, but the nitrate has a

much broader high concentration interval before gradually decreasing. Both wells are located in the regional nitrate plume and, perhaps, the regional nitrate masks the nitrate associated with the technetium-99 at lower technetium-99 concentrations (and presumably lower associated nitrate concentrations).

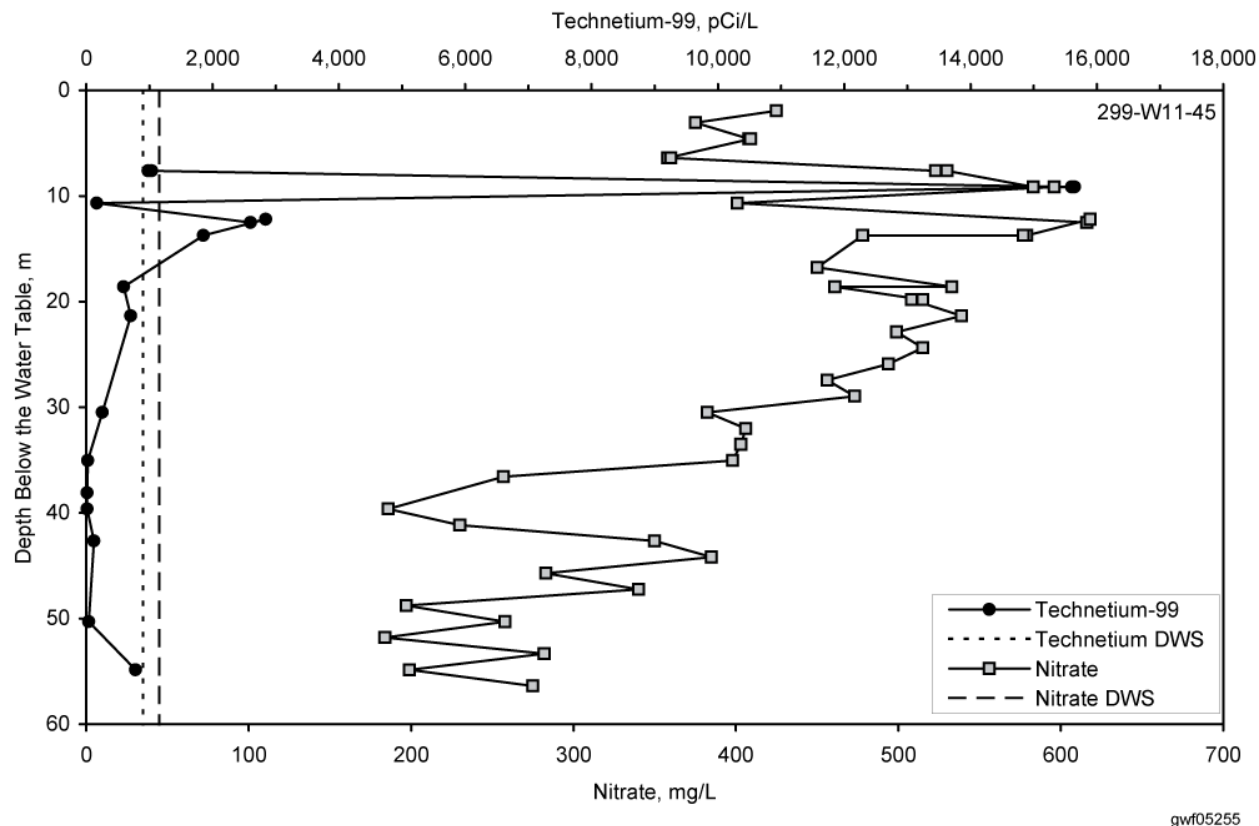


Figure 2.24. Technetium-99 and Nitrate Concentrations Encountered During Drilling of Well 299-W11-45

A plume map depicting the fiscal year 2004 average chromium concentration in wells near WMA T is shown in Figure 2.25. The highest chromium concentrations are in wells 299-W10-28 and 299-W10-4 where chromium reached 316 and 772 $\mu\text{g/L}$, respectively, in 2004. Prior to about 1997 when groundwater flow direction was toward the north, several wells on the north (then downgradient) side of the waste management area had relatively high chromium concentrations. Also, prior to 1997, well 299-W10-1, which was lateral to the tank farm with respect to groundwater flow direction but downgradient of the 216-T-5 trench, the 216-T-7 crib and tile field, and the 216-T-32 crib, had chromium concentrations exceeding 200 $\mu\text{g/L}$. After flow direction changed toward the east in about 1997, chromium concentrations dropped to <40 $\mu\text{g/L}$ in well 299-W10-1, decreased in all of the northern wells, and began increasing in well 299-W10-4 (see the chromium trend plots in Figure 2.26). The most likely source for the chromium west and north of WMA T is one or more of the disposal facilities upgradient of the WMA. (The 216-T-5 crib received 3,920 kilograms of chromium and the 216-T-32 crib received 2,490 kilograms of chromium [Simpson et al. 2001].) Chromium from these facilities would have been moving north across well 299-W10-1 prior to 1997 and then east across the northern wells and the rest of the waste management area after 1997.

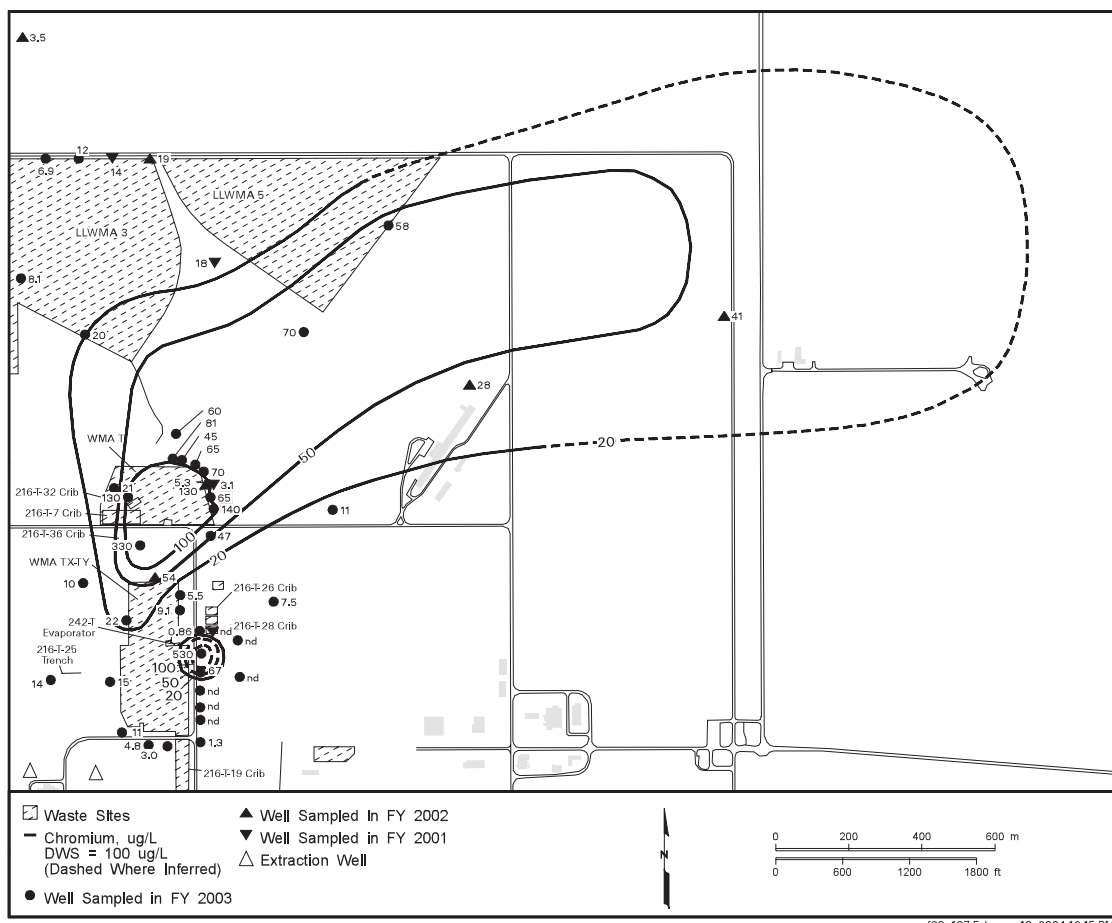


Figure 2.25. Average Concentrations of Chromium in the Area of Waste Management Area T, Top of the Unconfined Aquifer (from Hartman et al. 2005)

Figure 2.26 shows the concentrations of chromium and technetium-99 in selected wells at WMA T. The relative concentrations of technetium-99 and chromium track each other through time in upgradient wells at the WMA (Figure 2.26A) and the same relationship holds for wells north of the WMA (Figure 2.26B) where groundwater contamination is most likely from the disposal facilities west of the T Tank Farm.

The technetium-99 – chromium concentration relationship is different in wells located at the north-east corner (Figure 2.26C) and east of the WMA (Figure 2.26D) than it is to the west and north. On the east and northeast sides, the concentrations of the two constituents do not appear to track each other. This is especially evident in wells to the east. The trends in Figures 2.26C and 2.26D suggest that there are two different sources for either the technetium-99 or the chromium or both.

In 2004, the technetium-99/chromium concentration ratios in groundwater was compared to the estimated concentration ratios of single-shell tank leaks from tanks T-101 and T-106 and to the concentration ratios of some cribs and trenches in the area of WMA T (Hartman et al. 2005; Serne et al 2004). The conclusion was made that crib waste had impacted the groundwater in the southwest, north, and east of

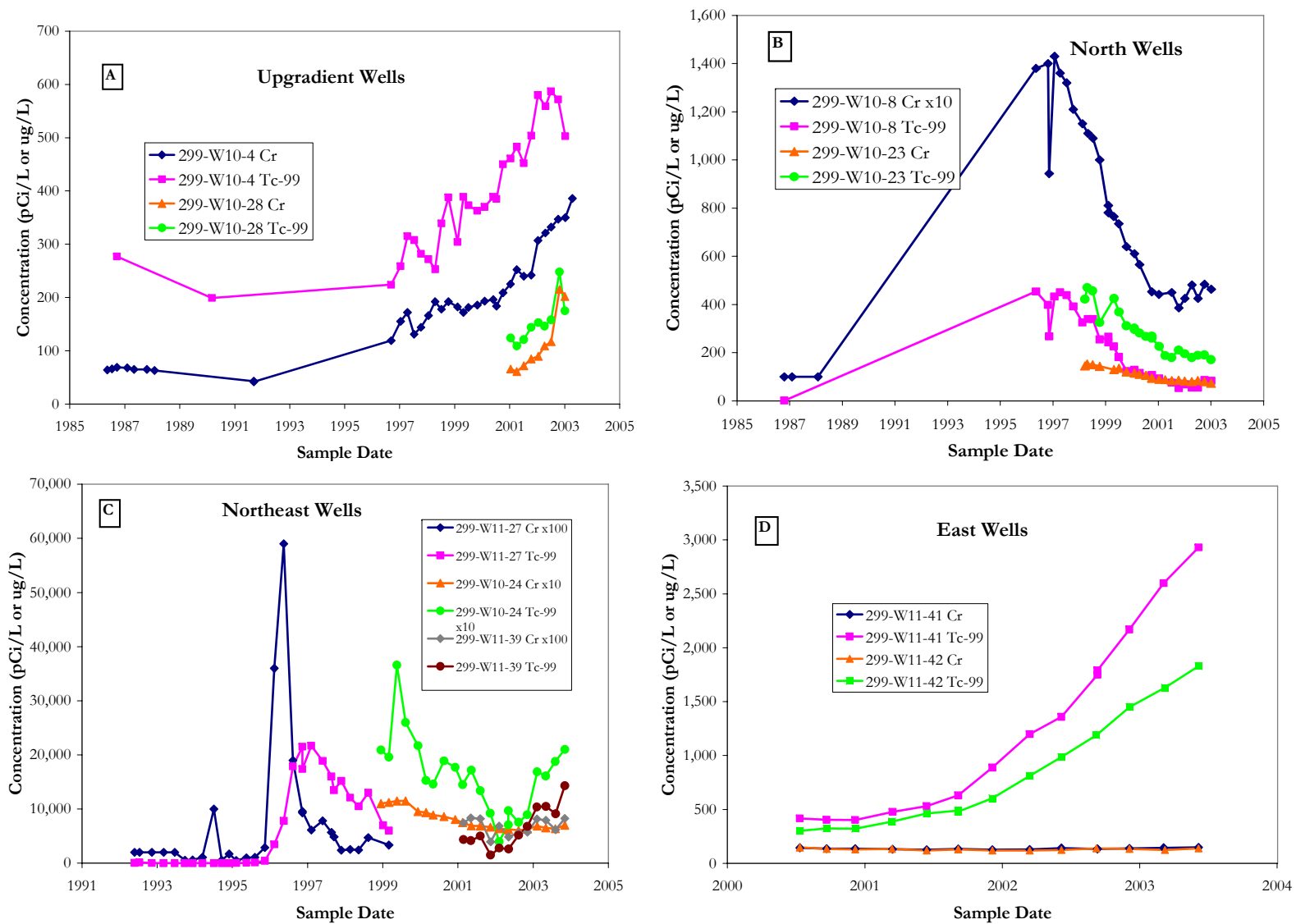


Figure 2.26. Technetium-99 and Chromium Concentrations in Selected Wells at Waste Management Area T

the WMA and tank waste has impacted the recent groundwater in the east and northeast of the WMA. Those conclusions were based on 2001 estimates for the tank leaks and discharges to past-practice disposal facilities (Jones et al. 2000; Simpson et al. 2001). Leak and discharge inventory estimates were updated in fiscal year 2005 (Corbin et al. 2005), and the new data necessitate a reinterpretation of the groundwater data.

Figure 2.27 shows the technetium-99/chromium composition ratios in samples of groundwater from selected wells at WMA T compared to the estimated compositions for two tank leaks and several past-practice disposal facilities in the area. As was previously concluded (Hartman et al. 2005, Serne et al. 2004), the figure shows that, after about 1995, groundwater in the northeast part of the WMA (Figure 2.27C), and probably the more recent samples from wells east of the WMA (Figure 2.27D) was impacted by tank waste. However, groundwater in the southwest, west, and north parts of the WMA do not appear to have been influenced to any great extent by waste disposed to the nearby cribs and trenches, east of the WMA, as was previously concluded (Figure 2.27A and B).

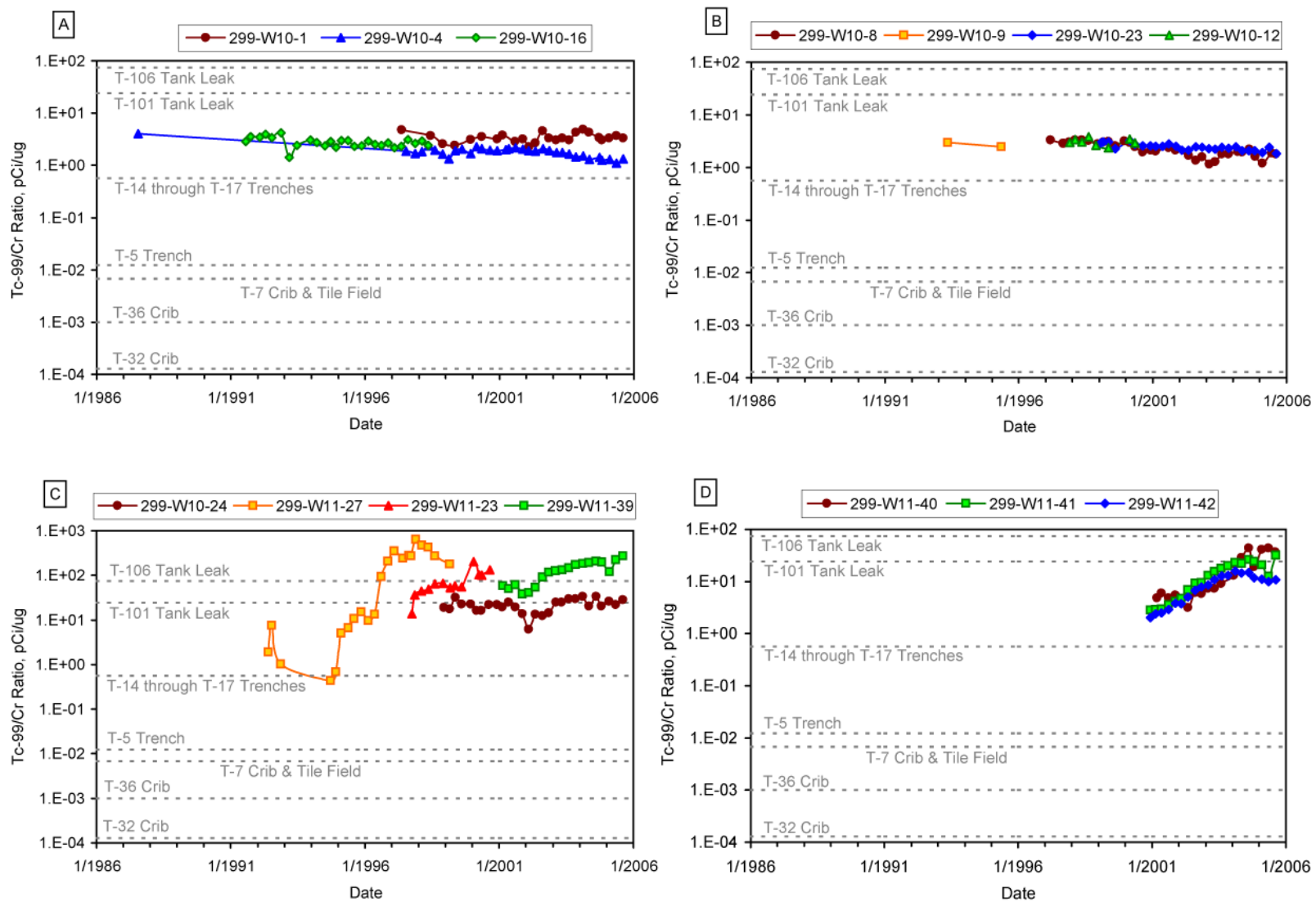
Figure 2.28A shows the technetium-99/chromium composition ratios estimated for two tank leaks and several past-practice facilities² with ratios from 1:1 water:sediment extracts (vadose zone pore water) collected from two boreholes drilled through the tank T-106 leak (Serne et al. 2004b). Supposedly, the pore water collected from the two T-106 characterization boreholes represents the fluid leaked from the tank. The vadose zone data show several orders of magnitude variation but are more similar to the estimated tank leaks than to the estimated composition of the past-practice waste.

The technetium-99/chromium composition ratios for borehole C4105 are generally larger than those from borehole C4104. The differences may be because borehole C4104 is located closer to the actual leak and any retardation of chromium relative to technetium-99 will increase the ratio in the more distant borehole C4105.

Figure 2.28B compares estimated technetium-99/chromium ratios with ratios in groundwater collected during drilling of boreholes 299-W11-25B and 299-W11-45. The technetium-99/chromium composition ratios from the groundwater samples are closer to the estimated composition of the tank fluids in the pore water collected from the characterization boreholes than they are to the estimated composition of the past practice facilities. However, the groundwater ratios vary by up to about three orders of magnitude within the same well (299-W11-25B).

Figure 2.29 compares the technetium-99/nitrate ratios in samples of groundwater from selected wells at WMA T with estimated compositions for two tank leaks and several past-practice disposal facilities in the area. The technetium-99/nitrate concentration ratios suggest the same conclusions reached with the technetium-99/chromium ratios. That is, groundwater from wells at the northeast corner of WMA T has a technetium/nitrate composition similar to estimated tank leak fluids.

² Estimated tank leaks and past-practice facility waste compositions are from the *Hanford Soil Inventory Model*, Rev. 1 (Corbin et al. 2005) as presented by C Kincaid in a November 16, 2005, T-Area Technetium-99 Data Quality Objectives workshop.



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Figure 2.27. Technetium-99/Chromium Concentration Ratios in Samples from Selected Wells at Waste Management Area T. (A) = upgradient (West) wells; (B) = northern wells; (C) = northeastern wells; (D) = eastern (downgradient wells).

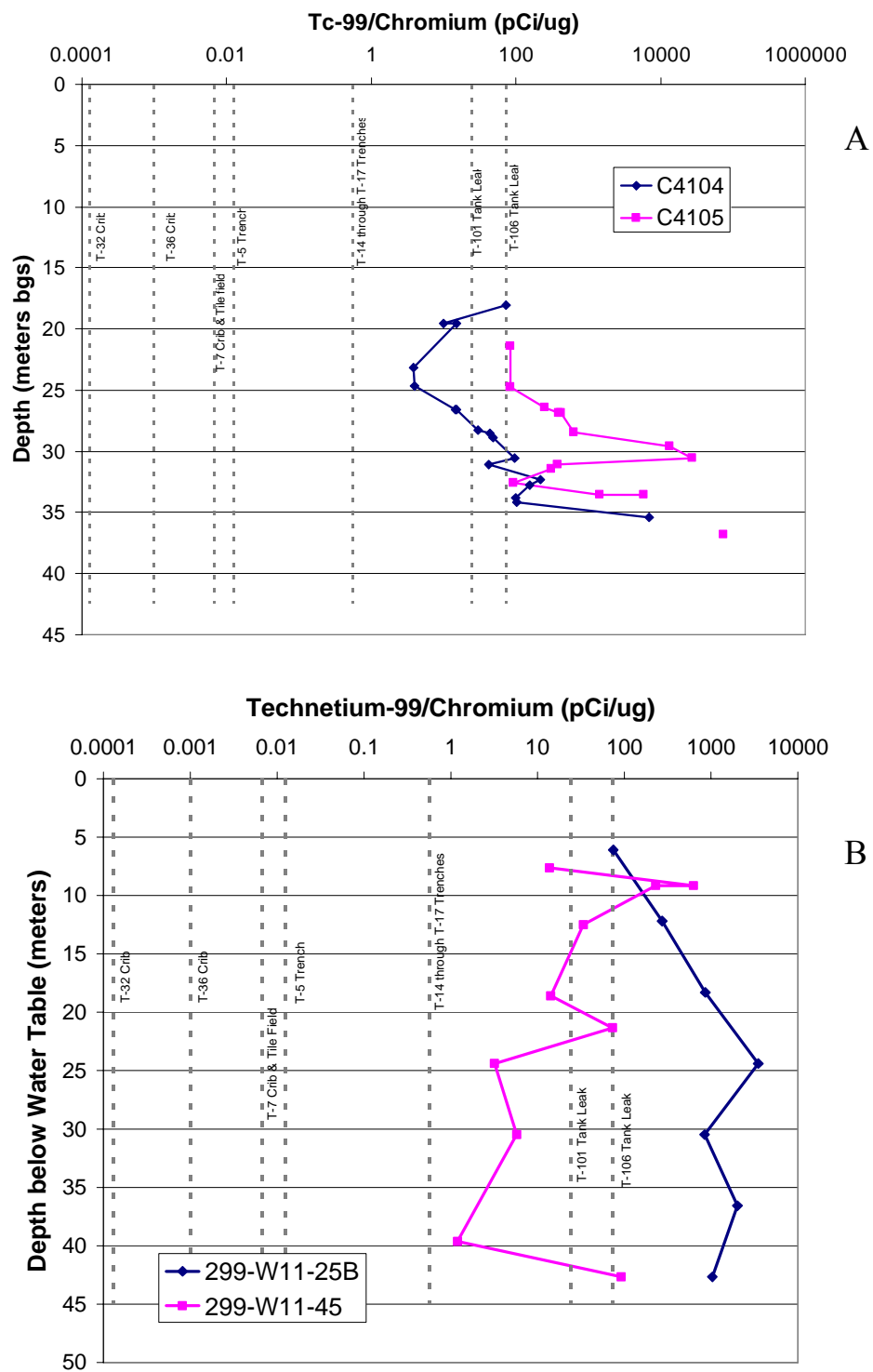
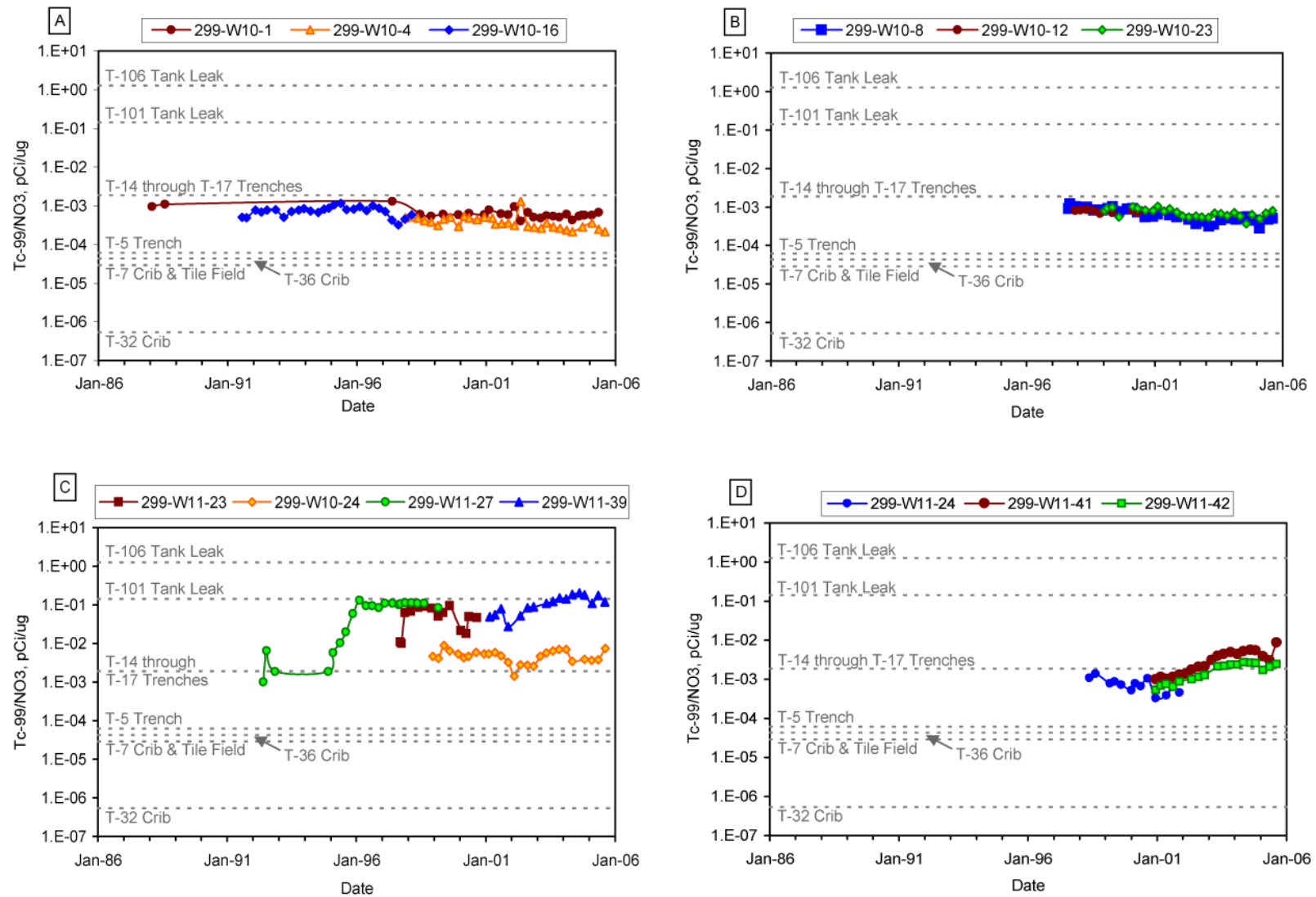


Figure 2.28. Technetium-99/Chromium Composition Ratios for A: Pore Water at the Tank T-106 Leak (Serne et al. 2004b) and B: Two New Monitoring Wells at Waste Management Area T



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Figure 2.29. Technetium-99/Nitrate Concentration Ratios in Samples from Selected Wells at Waste Management Area T. (A) = upgradient (West) wells; (B) = northern wells; (C) = northeastern wells; (D) = eastern (downgradient wells).

Figure 2.30A shows the technetium-99/nitrate composition ratios estimated for the two tank leaks with ratios measured from vadose zone pore water associated with the tank T-106 leak (Serne et al. 2004). Figure 2.30B compares the technetium-99/nitrate ratios estimated for two tank leaks with the compositions of groundwater samples from wells 299-W11-25B and 299-W11-45. The technetium-99/nitrate concentrations ratios are within the same order of magnitude range as are the estimated tank leak ratios and, more importantly, the sampled pore water. The tie between the technetium-99/nitrate groundwater data and the vadose zone pore water data is much tighter than for the technetium-99/chromium data. This may be the results of some retardation of chromium relative to technetium-99 in the vadose zone and aquifer.

2.6.2 Vadose Zone Contamination

Contaminants that reach the water table must pass through the vadose zone. Knowing the location of current vadose zone contamination provides a basis for focusing groundwater monitoring on a specific area of the WMA and may provide an explanation for groundwater contamination if it is detected. Spectral gamma logging in boreholes drilled around the single-shell tanks in WMA T is conducted to delineate the location of gamma emitting radionuclides in the vadose zone (DOE 2000a). Whereas the radioactive contaminants detectable by gamma logging are considered fairly immobile in the Hanford Site sediments, their identification provides a minimum indication of how deep the more mobile constituents may have migrated.

Figure 2.31 contains selected figures from the addendum (DOE 2000a) to the T Tank Farm spectral gamma logging report. These figures show the general distribution of gamma contamination around the tanks. The actual gamma logs are included in the logging report (DOE 2000a). The addendum and the original report can be viewed at <http://www.doejpo.com/programs/hanf/HTFVZ.html>.

Figure 2.31 shows a general representation of detected contamination at progressively deeper positions beneath the ground surfaced ranging from 1.8 to 21.6 meters deep. Contaminant distribution at the 1.8-meter depth illustrates the extent of contamination at and near the surface (Figure 2.31A) and only cesium-137 was identified at this depth. At about 6 meters depth (not shown on Figure 2.31) europium-154 is detected around tank T-103 and at 7.3 meters depth and cobalt-60 is detected in the same area (Figure 2.31B). Also, the cesium-137 between tanks T-104 and T-107 is the deepest cesium-137 associated with a surface source.

Figure 2.31C shows the distribution of gamma emitting contamination at 11.9 meters depth which is approximately the depth of the base of the tanks. DOE (2000a) suggests that the contamination east of tanks T-103 and T-101 is the result of leaks in fill lines and that contamination west of T-101 is the result of leaks from a cascade overfill line. The contamination at tank T-106 is associated with a leak from that tank and the contamination between tanks T-102 and T-105 is probably the result of a leak from one of those tanks. The deepest slice is from 21.6 meters depth and is about 3 meters above the contact between the Hanford formation and underlying Cold Creek unit. The Figure 2.31D shows that all of the plumes have merged at this depth and cover approximately one-third of the tank farm.

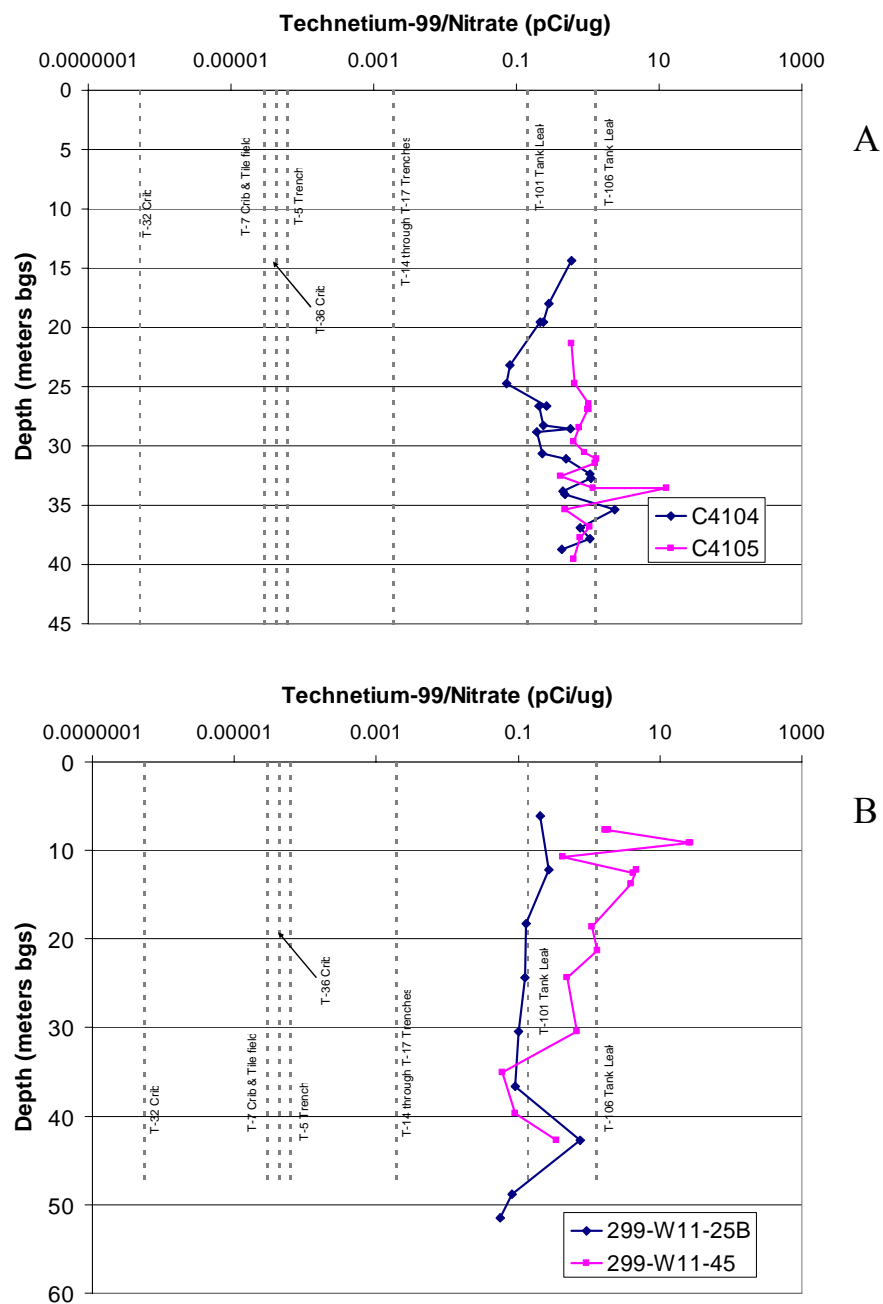


Figure 2.30. Technetium-99/Nitrate Composition Ratios for A: Pore Water at the Tank T-106 Leak and B: Two New Monitoring Wells at Waste Management Area T

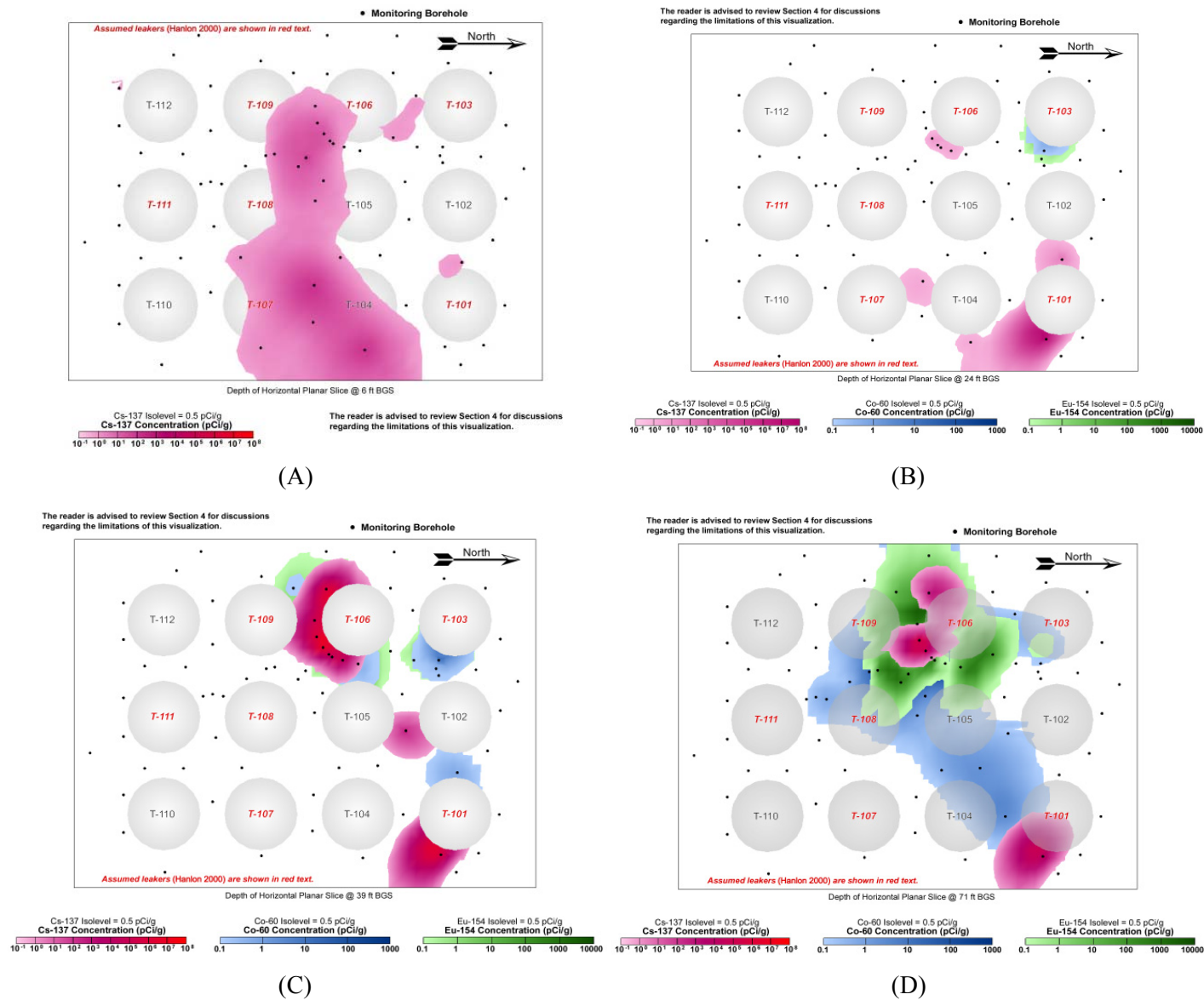


Figure 2.31. Vadose Zone Contamination in the T Tank Farm (from DOE 2000a). Note depths are given in feet below ground surface. Multiply by 0.3048 to change feet to meters.

Repeated logging events and analysis of historical gross gamma logs both show possible contaminant movement in the subsurface between 1975 and 1994 and between 1998 and 1999. (There was no logging between 1994 and 1998.) Possible movement occurred adjacent to drywells west of tank T-101 and northeast and southeast of tank T-105. This movement may be associated with the contamination found in the groundwater at the northeast corner of the WMA. Possible movement was also found northwest of tank T-109 and west and southeast of tank T-106. The vertical extent of vadose zone contamination at WMA T is not well known because contamination extends deeper than the bottom of the drywells in which it was detected.

Several drywells and groundwater wells at the 216-T-7 crib and tile field have been periodically monitored in the past. Fecht et al. (1977) state that on the basis of scintillation logs obtained in well 299-W10-3 between 1959 and 1976, breakthrough of contaminants to groundwater could have occurred at the 216-T-7 crib.

The 216-T-32 crib is monitored by eight drywells. Fecht et al. (1977) found no measurable migration of radionuclides in the vadose zone after comparing scintillation logs obtained in 1963 and 1976 and concluded that breakthrough to groundwater had not occurred at that site in 1976.

3.0 Data Quality Objectives

This chapter applies the relevant components of the general DQO process as an aid in designing a cost-effective data collection plan to support decision making for the RFI/CMS and for the groundwater assessment at WMA T. The process was originally designed by the U.S. Environmental Protection Agency (EPA) to expedite cleanup activities at RCRA corrective action or superfund sites (EPA 2000). Thus, not all of the steps apply to a groundwater quality assessment. The important or essential aspects of the DQO process are that key decisions are identified in the form of questions or statements and that data acquired are appropriate to make the necessary decisions.

The process for developing DQOs involves the following seven primary steps:

1. State the problem (Section 3.1)
2. Identify the decision and expected action (Section 3.2)
3. Identify decision inputs (Section 3.3)
4. Define the study boundaries (Section 3.4)
5. Develop decision rules (Section 3.5)
6. Specify limits on decision errors (not applicable to groundwater monitoring plans)
7. Optimize the sampling design (Section 3.6).

3.1 Statement of the Problem

The problem addressed by this DQO is the uncertainties in the conceptual model pertaining to determination of (1) contaminant source, (2) groundwater flow rate and flow direction, (3) lateral and vertical contaminant distributions, (4) driving forces to move contaminants to groundwater, and (5) contaminant pathways to groundwater.

These uncertainties in the conceptual model of WMA T are discussed in this section.

3.1.1 Scoping Process

The scoping process gathers the information that will be used to develop the conceptual model of WMA T. Such information includes the following items:

- History of operations at WMA T
- Waste characteristics
- Characterization of existing vadose zone and groundwater contamination
- Site geology and hydrology

This information was discussed in Chapter 2.0 as background information to refine the conceptual model and define problem statements and key issues.

3.1.2 Regulatory Drivers

WMA T is regulated under RCRA interim-status regulations (40 CFR 265, Subpart F) and Washington's HWMA (RCW 70.105). Implementing requirements are provided in Washington's Dangerous Waste Regulations (WAC 173-303). The site was originally placed in groundwater assessment monitoring status (40 CFR 265.93 [d]) in 1993 because specific conductance values in downgradient well 299-W10-15 exceeded the upgradient background value of 1,175 $\mu\text{S}/\text{cm}$ (Caggiano and Chou 1993). In 1996, specific conductance exceeded the critical mean in well 299-W11-27 and was accompanied by increases in the concentrations of nitrate, calcium, magnesium, sulfate, chromium, technetium-99, and cobalt-60.

The first assessment report (Hodges 1998) did not identify an upgradient source for the contamination observed in monitoring well 299-W11-27 and did find evidence linking the contaminants in groundwater to the WMA. As a result, a revised assessment plan was written (Hodges and Chou 2001) to guide the investigation of the rate and extent of aquifer contamination beneath the WMA. This plan updates the revised assessment plan (Hodges and Chou 2001).

This DQO considers both RCRA regulated dangerous waste constituents and certain non-RCRA regulated constituents to satisfy the integration of the RCRA groundwater quality assessment with the CERCLA 200-ZP-1 groundwater operable unit remedial investigation and the RCRA vadose facility investigation/corrective measures study. This provides comprehensive interpretations of groundwater contamination.

Groundwater monitoring objectives of RCRA, CERCLA, and the AEA often differ slightly and the contaminants monitored are not always the same. For RCRA regulated units, monitoring focuses on non-radioactive dangerous waste constituents. Radionuclides (source, special nuclear and by-product materials) may be monitored in some RCRA unit wells to support objectives of monitoring under the AEA and/or CERCLA. Please note that pursuant to RCRA, the source, special nuclear and by-product material component of radioactive mixed waste are not regulated under RCRA and are regulated by DOE acting pursuant to its AEA authority. Therefore, while this report may be used to satisfy RCRA reporting requirements, the inclusion of information on radionuclides in such a context is for information only and may not be used to create conditions or other restrictions set forth in any RCRA permit.

3.1.3 Conceptual Model for Waste Management Area T

This section describes the current conceptual model for WMA T. This model will be modified as new data become available and new understanding is developed. The current conceptual model for WMA T illustrates the complexity and the spatial and temporal relationships of five important parameters: contaminant sources, driving forces, migration pathways to groundwater, changes in groundwater flow direction and flow rate, and the current contaminant distributions in the aquifer. The model described in this section is a synthesis of the information given in Chapter 2.0.

3.1.3.1 Contaminant Sources

Several potential sources for groundwater contamination exist in the WMA T area:

- Tank leaks
- Liquid wastes disposed to past-practice facilities located northeast, west, and southwest of the WMA T
- Unplanned releases including leaking pipelines
- Regional contamination from far-field sources (e.g., Plutonium Finishing Plant)

Each of these potential sources is discussed in Chapter 2.0. It currently is not possible to distinguish sources within WMA T from sources outside the WMA in instances where tank waste was purposely discharged to nearby, past practice facilities.

There are regional sources for most of the tritium, carbon tetrachloride, and nitrate found in the groundwater beneath WMA T with the exception of a probable local source for the extremely high nitrate near well 299-W10-4 and the high nitrate concentrations associated with technetium-99 found in well 299-W11-25B. Results shown in Chapter 2.0 indicate that (1) tank waste from the WMA has impacted groundwater at the northeast corner and along the eastern boundary of the WMA and (2) past-practice cribs, trenches, and tile fields, located west of WMA T, have impacted groundwater west and north of the WMA and may be impacting groundwater east of the WMA. The most likely source for the tank waste in groundwater northeast and east of WMA T is the WMA itself and may be the relatively small 1969 leak from tank T-101, although impact from the T-106 leak is possible.

All tanks in WMA T have been interim stabilized, which means each tank contains less than 189,000 liters of drainable liquid and less than 18,900 liters of supernate (Hanlon 2004). Consequently there is little risk that large, new leaks will occur from the tanks. However, a total of 810,000 liters of drainable interstitial liquid and 102,000 liters of supernate remain in all of the tanks with four tanks still containing greater than 114,000 liters of drainable liquid so the possibility of future impacts to groundwater remains.

Spectral gamma ray logging in WMA T has shown that there are substantial amounts of cesium-137, cobalt-60, and europium-152, -154 with minor amounts of tin-126, antimony-125, and uranium-235, -238 in the vadose zone (DOE 2000a). Although these constituents are relatively immobile in the vadose zone environment (except cobalt-60 and possibly uranium), their presence indicates that more mobile (and non-gamma ray emitting) contaminants such as nitrate, chromium, and technetium-99 are probably also present. Therefore, most future tank waste contamination in the groundwater is expected to result from either remobilization of residual vadose zone plumes or leaks associated with liquid waste transfers and single-shell tank remediation.

All non-permitted, liquid discharges were terminated at the Hanford Site in 1995. Therefore, no flushing of contaminants to groundwater will result from future intentional discharges. However, residual vadose zone pore water and associated contaminants remain in the vadose zone beneath

past-practice disposal facilities and WMA T. This residual contamination is expected to slowly bleed into the aquifer for the foreseeable future under the influence of natural infiltration.

Non-tank sources have contributed to groundwater contamination in the past. The earliest evidence of groundwater contamination is high levels of gross beta in wells located at the cribs and trenches west of WMA T in 1955 (Serne et al. 2004). This early groundwater contamination pre-dates any reported tank leak from the T Tank Farm.

3.1.3.2 Driving Forces

In general, there are two ways to transport contaminants to groundwater. The first is associated with very large leaks when the amount of liquid is sufficient to reach groundwater through gravitational forces and capillary action. The second is associated with an external source of water (or other liquid) available to remobilize residual waste in vadose zone plumes. Since most tanks in WMA T no longer contain large amounts of liquid waste and since large volume disposal to cribs and tile fields no longer takes place, it is unlikely that a sufficient source of liquid large enough to reach groundwater unassisted will exist at WMA T.

The second mechanism is to move existing vadose zone contamination to groundwater. This involves an external source of water and is the most likely possibility at WMA T. The most likely external sources are broken water lines and natural precipitation. Broken water lines can produce large volumes of water, however, all known water lines in the area have been pressure tested and all unnecessary water lines have been turned off and capped. It is possible but unlikely that a previously unidentified water line will leak and substantially mobilize existing vadose zone contamination to groundwater in the area.

As discussed in Chapter 2.0, there is evidence that a broken waste water transfer line may have leaked considerable water and locally affected the composition of the groundwater near the northeast corner of the WMA during the first half of the 1990s. This leak may also be partly responsible for the relatively deep contamination that was recently found in well 299-W11-25B.

Remobilization of vadose zone waste also can occur as a result of heavy rainfall and sudden snow-melt. Johnson and Chou (1998) discuss the extent that rapid snowmelt from recent years has contributed to increased infiltration at WMA S-SX. A rapid snow melt in February 1979 caused extensive flooding in the T Tank Farm (Hodges 1998). The detrimental effects of natural recharge can be enhanced by gravel surfaces, lack of vegetation, and the presence of surface depressions that collect and pond runoff and snow melt. Recently, berms have been constructed around the T Tank Farm to eliminate run-on from adjacent areas so extensive flooding such as that of February 1979 should not occur in the future.

The surface of the tank farm is covered with gravel and kept free of vegetation. Recently, Gee and Ward (2002) used a water balance model based on surface sediment texture and the past 20-year climate record to predict the amount of annual drainage in selected tank farms. Drainage estimates from the model suggest an annual drainage of 28 to 56 millimeters/year for the U Tank Farm and the S Tank Farm in 200 West Area. No analysis was specifically made for the T Tank Farm but surface conditions are similar.

3.1.3.3 Migration Pathways

The water table at WMA T is approximately 69 to 81 meters below the surface. Because the vadose zone is so thick, much of the migration pathway from a near-surface source to a groundwater monitoring well will be in the unsaturated zone. Liquid migration through the unsaturated zone is highly dependent on heterogeneities and anisotropy in the sediment. The sediments making up the vadose zone beneath WMA T consist of moderate to high-energy Hanford formation flood deposits with a large variability in grain size and grain sorting; the Cold Creek unit with variable caliche development; and Ringold Formation member of Taylor Flats and member of Wooded Island unit E with variable grain size, grain sorting, cementation, and compaction. These variabilities occur at scales of centimeters to meters. Consequently, it is not realistic to define specific migration pathways through the vadose zone beneath WMA T.

The sediment layer with the most influence on moisture migration through the vadose zone is the Cold Creek unit. The relatively low permeability of the Cold Creek unit has two important effects on migration of moisture through the vadose zone. First, the fine-grained nature of the Cold Creek silt unit requires that it essentially become saturated before moisture breakthrough to underlying units. This tends to lengthen the time required for moisture to reach the water table and results in lateral spreading of moisture and contamination. Second, the cemented Cold Creek caliche unit tends to pond water locally in several places beneath the 200 West Area. This also lengthens the time required for moisture to reach the water table and results in lateral migration.

Clastic dikes are sub-vertical, sedimentary features that crosscut existing horizontal bedding. Recent work by Ward et al. (2004) shows that at low water fluxes the fine-textured region of clastic dikes dominate flow, at intermediate fluxes both the coarse sand host matrix and the fine-textured regions contribute to flow, and at high input fluxes the coarse-textured host sediments dominate flow.

Clastic dikes exist in the subsurface at several areas of the Hanford Site and have been documented at T Tank Farm (Price and Fecht 1976; Fecht et al. 1999). Clastic dikes also have been noted at the other tank farms in 200 West Area and in drill core from wells in the area (C3102 at the 216-T-26 crib, 299-W22-48 at the WMA S-SX, 299-W23-16 at the 216-U-14 ditch, and 299-W10-22 at the 216-T-4-2 ditch). Several clastic dikes are known to extend at least 20 meters into the subsurface and the maximum vertical extent known for a clastic dike is about 45 meters.

Another feature that can act as a preferential, vertical pathway is the outside of casings of wells and boreholes with no, or poorly constructed, annular seals. There is documentation that 45 of the 67 drywells in the T Tank Farm (Chamness and Merz 1993), used for secondary leak detection, have been modified since they were drilled to retrofit an annular seal in an effort to prohibit downward migration of fluids along the outside of the casing. There is no documentation in Chamness and Merz (1993), the Hanford Well Information System, or the PNNL well library that the remaining 22 drywells have an annular seal. Most drywells were drilled between 15.2 to 45.7 meters deep and the water table beneath WMA T is about 69 to 81 meters below ground surface. Thus, there is about 23 to 35 meters of vadose zone between the bottom of the deepest drywells and the water table.

All WAC 173-160 compliant monitoring wells at WMA T have annular seals. However, groundwater monitoring wells 299-W10-8 through 299-W10-12, located on the north side of the WMA, and (now dry) well 299-W11-23, located at the northeast corner of the tank farm, are older 14.9-centimeters

diameter carbon-steel-cased wells. The as-built diagrams for these wells have no documentation concerning annular seals. These wells are potential preferential pathways for any contaminants that encountered the wells in the past or may encounter the wells in the future.

Field studies at the Hanford Site suggest that relatively narrow, vertical zones of moisture can flow through unsaturated sediment. Gee and Ward (2001) describe infiltration tests with different ionic strength fluids and how the fluid properties influence formation of moisture “fingers.” Once such vertical pathways are established by an initial infiltration event, subsequent infiltration events will prefer the same channels.

Further evidence to support this type of flow behavior comes from direct observation of infiltration tests performed at the 105A mock tank site, 200 East Area (Narbutovskih et al. 1996). Electrical resistivity tomography was used at that site to track leaked saline water, as fingered flow, from the surface to a depth of about 21 meters. Furthermore, analysis of the infiltration rate, time to reach depth, and total volume of leaked fluid indicated that a low-volume, point leak might reach groundwater in that area within a few months (Hartman and Dresel 1997). This estimate, however, is for a part of 200 East Area where the vadose zone consists of only the Hanford formation. The travel time to groundwater beneath WMA T is expected to be somewhat larger because the less permeable Cold Creek Unit and Ringold Formation Unit E gravels make up the lower part of the vadose zone under much of north-central 200 West Area.

3.1.3.4 Changing Groundwater Flow Direction

Historical changes in groundwater flow direction were discussed in Section 2. Using the general flow directions from Figure 2.9 and the water-table gradients in Reidel et al. (2005) and assuming an average hydraulic conductivity of 2.5 meters/day (within the range given in Table 2.7) and an effective porosity of 0.2, groundwater could have traveled and carried contaminants from WMA T or other nearby sources approximately (1) 34 meters toward the south between 1954 and 1957, (2) 170 meters northeast between 1957 and 1982, (3) 110 meters north or northwest between 1983 and 1995, and (4) 32 meters toward the east between 1997 and 2004. (The earliest reported tank leak at WMA T is tank T-106 in 1973.) Although these distances are estimates, they show that changes in the groundwater flow direction could have contributed to relatively widespread contaminant distribution.

3.1.3.5 Contaminant Distribution

Section 2.6 discusses the vertical concentration gradients for certain contaminants in places at WMA T. Concentrations increase with depth in the aquifer in some places and decrease with depth in other places. Section 2.6 also provided information about the known lateral extent of contamination at WMA T. The lateral extent is not well known downgradient of the WMA. The eastern extent of the contamination found in the downgradient wells is not defined.

3.1.4 State the Problem

The problems addressed by this DQO are the uncertainties in the conceptual model which are summarized in Table 3.1.

Table 3.1. Summary of Problem Statement

	Problem Statement	Source of the Problem
1	The source or sources for contamination at WMA T are not well known.	Multiple potential sources include tank leaks, spills, transfer pipelines, adjacent cribs and trenches.
2	Groundwater flow rate and direction at WMA T have changed through time.	Groundwater flow rate and direction are required by 40 CFR 265.93(d)(4)(i) and WAC 173-303-400.
3	The mechanism(s) driving contamination to groundwater at WMA T are not well defined.	Potential driving forces include natural infiltration, past intentional disposal to ground, and water line leaks. Elimination of driving forces mitigates further contamination of groundwater from vadose zone sources.
4	The lateral and vertical distributions of contamination in groundwater at WMA T are not well known.	The extent of contamination is required by 40 CFR 265.93(d)(4)(i) and WAC 173-303-400.
5	The dangerous waste contaminants in groundwater at WMA T are well defined at monitoring well locations but the concentrations change with time.	The concentrations of dangerous waste constituents is required by 40 CFR 265.93(d)(4)(i) and WAC 173-303-400.
6	The pathway(s) for contaminant migration to groundwater at WMA T are not well defined.	The natural pathways to groundwater are through a heterogeneous and anisotropic unsaturated zone. Man-made pathways include poorly constructed wells and boreholes. Eliminating or inhibiting migrations pathways mitigates further contamination of groundwater from vadose zone sources.

3.2 Identify Decisions

The decision statements identified below are regulatory driven as stated in 40 CFR 265.93(d)(4)(i) and (ii) [and by reference WAC 173-303-400] and as indicated in the Technical Enforcement Guidance Document (EPA 1986). The primary information needed for the ongoing groundwater quality assessment at WMA T is the information to make the following decisions.

1. Determine if the compliance well network is consistent with the rate and direction of groundwater flow and, therefore, requires no action or if the compliance well network is inconsistent with the rate and direction of groundwater flow and, therefore, requires modification. (Addresses problem statements 2 and 4.)
2. Determine whether changes in concentrations of dangerous waste constituents in the groundwater originating from the regulated unit are well defined by the existing sampling frequency, in which case no change in the sampling schedule is required, or whether changes in concentrations are not well defined, requiring an increase in sampling frequency. (Addresses problem statement 5.)

Additional information is needed to support decisions concerning facility and groundwater remediation activities at WMA T. This information is the data needed to address the following decision statements.

3. Determine whether the source or sources of groundwater contamination beneath WMA T are adequately identified, requiring no change in the assessment well network, or if the source or

sources of groundwater contamination are not adequately identified, requiring modification of the well network. (Addresses problem statement 1.)

4. Determine whether identified driving forces account for migration of contamination through the vadose zone to groundwater, requiring no action, or whether driving forces for contaminant migration are not well understood, requiring modification to the assessment well network or additional studies. (Addresses problem statement 3.)
5. Determine whether the pathways that allowed contamination to traverse the vadose zone and enter groundwater at WMA T are adequately known, requiring no action, or whether the pathways for contaminant migration are not well identified, requiring modification to the assessment well network or additional studies. (Addresses problem statement 6.)

The information needed to make these decisions is discussed in Section 3.3.

3.3 Decision Inputs

This section describes the information needs for addressing the general decisions and site-specific questions identified above. A summary of the information needs is given in Table 3.2. More detailed discussion of the information needs is given in the sections following Table 3.2.

3.3.1 Groundwater Flow Rate and Direction

The rate and direction of groundwater flow is fundamental to assessing the rate of migration and extent of groundwater contamination from the assumed source. Placement of new wells to enhance the likelihood of detecting contaminant plumes and estimating the arrival times at some point of potential exposure (or point of compliance) depend on knowing the rate and direction of groundwater flow.

3.3.1.1 Data Needs and Approach

The flow rate and flow direction where tank waste constituents have been observed in groundwater need to be determined.

This fundamental information must be acquired by investigative techniques based on field measurements.

Flow Rate. Flow rate is a fundamental parameter for predicting plume movement and distribution. The configuration of wells in the monitoring network at WMA T is not conducive to measurement of flow rate using multi-well methods such as tracer tests.

Instead, the more classic method to estimate flow rate, using the Darcy equation, will be done. This approach is based on hydraulic conductivity of the aquifer in combination with the water-table gradient and effective porosity. The effective porosity and hydraulic conductivity have been estimated from the results of aquifer tests (slug tests, tracer tests, and pumping tests) in several wells at WMA T. The water-table gradient is determined from water-level measurements. Water-level measurements are collected quarterly at WMA T.

Table 3.2. Required Information and Sources

Decision Statement ^(a)	Variable	Required Information	Source
1	Groundwater flow rate	Calculated groundwater flow rate	Hydraulic conductivity, effective porosity, and water-table gradient
		Hydraulic conductivity, effective porosity, and water-table gradient	Hydraulic properties exist from aquifer testing; additional aquifer testing will be done at newly installed wells. Water-table gradient determined from water level measurements.
1	Groundwater flow direction	Water-table elevations	Quarterly and annual water level measurement.
1	Lateral extent of contamination	Groundwater flow rate and flow direction	See above.
		Groundwater chemical composition	Concentrations are determined from quarterly, semi-annual, and annual (depending on constituent) groundwater sampling and analysis
		New monitoring wells	One new monitoring well will be drilled about 80 m downgradient of WMA T. Additional wells require prioritization through the well drilling DQO.
		Contaminant distribution coefficients	Distribution coefficients exist for several contaminants (Cantrell et al. 2002).
1	Vertical extent of contamination	Groundwater chemical composition	Depth discrete groundwater samples will be collected from existing and new wells.
		New monitoring wells	Two new monitoring wells will be drilled to 36.57 m below the water table or to the Ringold Formation lower mud unit in calendar year 2005. Additional wells require prioritization through the well drilling DQO.
2	Contaminant concentrations	Concentrations of contaminants in groundwater.	Concentrations are determined from (1) quarterly, semi-annual, and annual (depending on constituent) groundwater sampling and analysis and (2) analysis of depth discrete groundwater samples.
3, 4, 5	Contaminant source(s), driving forces, and migration pathways	Lateral and vertical contaminant distribution	See above.
		Contaminant concentrations	See above.
		Isotopic signatures	Analyses of groundwater samples for Ru-101, -102, and -104; Sr-87/Sr-86; N-15 and O-18 in nitrate; uranium isotopes; and stable chromium isotopes.
		Possible new wells.	Any new wells needed to differentiate contaminant sources require prioritization through the well drilling DQO
(a) From Section 3.2. (b) DQO = Data quality objectives. (c) WMA = Waste management area.			

Additional hydrologic data will be collected from new boreholes by conducting several aquifer tests. These data will result in additional estimates of groundwater rate and flow direction. The aquifer tests to be performed and the resulting data include the following:

- Slug tests – preliminary hydraulic conductivity.
- Tracer-dilution tests – vertical distribution of hydraulic conductivity and/or groundwater flow velocity within the well screen section and vertical flow within the well screen section.
- Tracer-pumpback tests – effective porosity.
- Pumping Tests – hydraulic conductivity, storativity, and specific yield.

Multiple well pumping tests will be done where well configurations are appropriate.

Flow Direction. Groundwater flow direction will be inferred from water-table elevations in available wells. This approach depends on accurate depth-to-water measurements. Barometric corrections will be conducted if needed. Reliable casing elevations will be obtained or assessed based on available information.

The water-level measurements will be used to map the flow direction in the vicinity of WMA T after depth-to-water corrections are made. The current estimate of flow direction is shown in Figure 2.10.

A second method to estimate flow direction will be applied to the corrected depth-to-water measurements. A series of three point problems will be applied to several series of water-level measurements. The three point problem is a typical analysis used in earth science to determine the orientation of a plane in space.

3.3.1.2 Data Uses

The flow rate and flow direction are necessary input to the proper placement of monitoring wells for understanding the extent of contamination at WMA T. The uses of this input are described in Section 3.3.2.

3.3.2 Extent of Contamination

The spatial and vertical distribution of contaminants in the aquifer is required by 40 CFR 265.93(d)(4)(i) and provides indications of the nature of the vadose zone source, the driving forces and likely transport processes through the vadose zone and groundwater, input to risk assessments, and information supporting corrective measures and remediation.

3.3.2.1 Lateral Extent of Contamination

The lateral extent of contamination from WMA T will be estimated using plume maps and simple numeric models.

Data Needs and Approach

The lateral extent of contamination in the aquifer needs to be determined.

This fundamental information must be acquired by investigative techniques based on field measurements and analytical laboratory data obtained from monitoring wells. These data need to be integrated with historical groundwater compositions and historical groundwater flow characteristics.

Groundwater Flow Rate and Flow Direction. The groundwater flow rate and flow direction are input obtained from the decision inputs described in Section 3.3.1.

Groundwater Chemical Composition. Analyses of routinely collected groundwater samples are necessary to know the concentrations of contaminants and to estimate the lateral extent of contamination. The samples are collected from all wells in the monitoring network quarterly, semi-annually, or annually (depending on constituent). Samples are collected by pump after purging three well volumes and after stabilization of pH, specific conductance, temperature, and turbidity. Sample collection, storage, and transportation are done by subcontractors to the Hanford Groundwater Performance Assessment Project according to specifications in a statement of work to the subcontractor. Sample analyses are routinely done by subcontracted laboratories. Analytical procedures are based on EPA-approved methods or, in the case of radionuclides, on laboratory-specific procedures based on best laboratory practice. The analytical data are used to construct contaminant plume maps. The extent to which a plume map reflects the actual plume depends heavily on the distribution of monitoring wells.

Placement of Monitoring Wells. The current groundwater monitoring network at WMA T consists of 14 wells (Figure 2.23). Six new downgradient monitoring wells and one new upgradient well have been installed at the since 1998.

Monitoring wells must be strategically located to delineate contaminant plumes coming from the regulated unit.

In 2003, a DQO study was done with the Hanford Groundwater Performance Assessment Project DOE, and the regulatory agencies that determined the number and approximate locations of two wells at WMA T (Byrnes and Williams 2003). Those wells were intended to complete the groundwater detection and assessment network for the tank farm.

One of the wells, 299-W11-25B, was installed early in 2005. That well was initially to be drilled to 36.6 meters below the water table and sampled every 1.5 meters throughout the drilled part of the aquifer to assess the vertical distribution of contaminants at the northeast corner of the WMA. High levels of contamination encountered during drilling resulted in the well being deepened to the Ringold Formation lower mud unit. (Well 299-W11-25B was damaged during construction and replaced with well 299-W11-46.) The high levels of contamination and the depth distribution of the contamination resulted in relocation of the second well identified in the DQO study closer to the WMA and addition of a third well to be located adjacent to existing well 299-W11-41. Both new wells are to be drilled to the lower mud unit in calendar year 2005.

Based on the current understanding of the contaminant distribution at WMA T, the current groundwater monitoring network, including the two proposed wells, is probably not adequate to describe the lateral extent of contamination. The need for additional wells will be determined by the DOE and regulatory agencies after analytical results from the two proposed wells are available.

Contaminant Distribution Coefficients. The groundwater flow rate can approximate the migration of some highly mobile contaminant species. However, almost all contaminants are retarded somewhat with respect to water as they migrate through the aquifer. Adsorption is one of the primary mechanisms that control or retard the migration of many contaminants in the vadose zone and groundwater. The most common method used to describe contaminant adsorption on soil and sediment is the distribution coefficient. Distribution coefficients are experimentally derived. A catalog of available distribution coefficients recently has been published (Cantrell et al. 2002). Distribution coefficients are available for cobalt, cesium, strontium, chromium, iodine, nitrate, technetium, and other contaminants. The distribution coefficients are used to calculate retardation factors for contaminant flow and transport modeling purposes.

Data Uses

The analytical results from groundwater sample and analysis are used to construct contaminant plume maps illustrating contaminant distributions. These maps are produced quarterly and published annually for chromium, nitrate, uranium, carbon tetrachloride, trichloroethene, fluoride (annual only), sulfate (annual only), iodine-129, technetium-99, strontium-90, and tritium. The quarterly and annual maps typically show contaminant concentrations at the water table depth. Plume maps for additional analytes can be made if necessary.

Plume maps are also an aid in identification of source areas in cases where distinct plumes emanate from specific facilities.

The extent of contaminant plumes can be modeled using the simple, two-dimensional analytical transport model of Domenico and Robbins (1985). The model assumes that a solute is released along a continuous line source in a uniform aquifer, and predicts the concentrations that would be observed at points downstream of the source. Inputs to the model include the width of the source, the longitudinal and transverse dispersion coefficients, time, hydraulic conductivity, groundwater gradient, effective porosity, and retardation factors.

Retardation factors determined from experimental measured distribution coefficients are input to calculating retardation factors used in the plume generation model. The relationship is $R = 1 + (K_d \rho_b) / \theta$, where R is the retardation factor, K_d is the distribution coefficient, ρ_b is the bulk density, and θ is the volumetric water content.

3.3.2.2 Contaminant Depth Distribution

The vertical extent of contamination at WMA T will be determined from sample and analysis of groundwater in both the laboratory and field.

Data Needs and Approach

The vertical extent of contamination in the aquifer needs to be determined.

This fundamental information must be acquired by investigative techniques based on field measurements and analytical laboratory data described below.

Groundwater Chemical Composition. Samples to describe lateral contaminant distribution are collected by purging a well and then pumping the samples after the well has been completed. Samples collected for vertical contaminant distribution are collected at specific depth intervals in the aquifer typically during drilling. Wells drilled deep into the aquifer can be screened at depth during well completion. Sampling of wells screened at depth can help define the vertical extent of contamination.

Depth discrete groundwater samples will be collected from each new well drilled as part of the WMA T groundwater assessment. The number of samples to be collected and the method of sampling will depend on the drilling technique.

Depth discrete geochemical information also will be collected from selected existing boreholes. Specific candidate wells in or near WMA T are wells that have recently (or currently) exceeded the drinking water standard for chromium (100 µg/L) and nitrate (45 mg/L) (and technetium-99 [900 pCi/L] in support of tank farm corrective measures) are 299-W11-39, 299-W11-41, 299-W11-42, 299-W10-28, and 299-W10-4.

Initially, an electrical conductivity profile will be obtained to establish whether vertical concentration gradients exist in the screened intervals of the wells. If gradients exist, a discrete depth sampler will be used to collect additional data. The approach is to sample multiple depths throughout the screened interval with the shallowest sample collected as near the water table as possible (0 to 4 centimeters).

Data Uses

The analytical data will be used to make concentration versus depth profiles for each tested well. If sufficient profiles are made, cross-sections can be made of contaminant distribution in the aquifer.

The depth distribution of contaminants may help infer the size of the plume and distance of the contaminant source from the wells and provide inputs to remedial decisions. For example, a large utility line leak that mobilizes contaminants by localized saturated flow may result in a deeper contaminant distribution in the aquifer than mobilization by slowly migrating moisture from natural infiltration. Also, a deeper contaminant distribution is expected from vertical dispersion from distal sources whereas a shallow contaminant plume is expected from proximal sources.

The depth distribution of contaminants is basic information needed by the regulatory agencies and DOE to make decisions concerning remedial actions and risk assessments.

3.3.3 Contaminant Concentrations

The concentrations of contaminants in the uppermost aquifer need to be determined.

Data Needs and Approach

The results of groundwater sampling and analysis are the data needed to determine the concentrations of contaminants in the aquifer. These are the same data needs described above for determining the lateral and vertical extent of contamination.

Data Uses

Contaminant concentrations are evaluated and used to generate plume maps, trend plots, and cross-sections. Contaminant concentrations are reported in RCRA quarterly and annual reports.

3.3.4 Contaminant Sources, Driving Forces, and Migration Pathways

Data Needs and Approach

Lateral and Vertical Contaminant Distribution. This information is supplied from the decision inputs described above for determining the lateral and vertical contaminant distributions (Section 3.3.2).

Contaminant Concentrations. This information is supplied from the decision input described above for determining the contaminant concentrations (Section 3.3.3).

Isotopic Signatures. The isotopic signature work is planned in the scope of work funded by the Hanford Site Groundwater Remediation Project's Science and Technology Project and not the scope of this groundwater assessment. However, this assessment will use information provided by the Science and Technology Project to the fullest extent possible.

A proposal has been submitted to Science and Technology Project to use isotopic signatures of various waste streams in the vicinity of WMA T and isotopic measurements of groundwater from WMA T monitoring wells as tools to distinguish the source or sources of groundwater contamination at WMA T. The special isotopic work is a joint project between Lawrence Berkeley National Laboratory and PNNL. The isotopic systems proposed include

- Ruthenium-101, -102, and -104.
- $^{87}\text{Sr}/^{86}\text{Sr}$.
- $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ in nitrate.
- Uranium isotopes.
- Stable chromium isotopes.

All of these isotopic systems, except stable chromium, have been used previously at the Hanford Site. Although the chromium isotopic system may show little difference in the isotopic compositions of chromium from different Hanford Site sources, this proposition will be tested. It is speculative at the moment, but the chromium isotopes may reflect the fate of hexavalent chromium groundwater contamination.

New Monitoring Wells. Evaluation of information gathered during this assessment concerning source(s) of contamination, may lead to a conclusion that one or more new upgradient and/or

downgradient wells are needed. Any new proposed wells will be submitted to the DQO process for prioritizing drilling and construction of new wells.

Data Uses

Results from these special isotopic studies may help determine the source or sources for the ground-water contamination at WMA T. Examples of the uses of the isotopic systems are given below. It is these types of information that may be applicable to the groundwater assessment at WMA T.

A ruthenium fission isotope investigation in the WMA B-BX-BY area found that the technetium-99:ruthenium-101 ratio was higher than expected from the fission yield and that there were two geographically distinguishable technetium-99:ruthenium-101 populations suggesting possible separate technetium-99 sources in the area (Dresel et al. 2002). The ruthenium isotopic ratios also suggest that there are two sources for fission products in the area: material processed at B Plant and material processed at Plutonium-Uranium Reduction (PUREX) Plant. Strontium isotopic ratios have been found to vary in Hanford Site groundwater due to a combination of exchange with sediments and quantity of infiltration. Areas with very high $^{87}\text{Sr}/^{86}\text{Sr}$ are believed to reflect disposal of large volumes of process water (Maher et al. 2003). The stable nitrogen and oxygen isotopes in nitrate have been used at the Hanford Site to help distinguish high-level tank waste from low-level process waste and nitric acid (Singleton et al. 2005). Uranium isotopic ratios have been used at the Hanford Site to provide tight constraints on the source of uranium groundwater contamination in the WMA B-BX-BY area (Christenson et al. 2004).

3.4 Define the Boundaries of the Study

This section defines the boundaries for groundwater quality assessment monitoring at WMA T. Spatial and temporal boundaries are described as well as boundaries on the monitoring network and the analytes to be monitored. This step in the DQO process defines the set of circumstances covered by the questions being addressed.

3.4.1 Spatial Boundaries

The spatial boundaries for groundwater quality assessment monitoring at WMA T are boundaries defining the WMA, the area upgradient of the WMA between the WMA and upgradient monitoring wells, and the boundaries of downgradient contaminant plumes emanating from the WMA. The uppermost aquifer within this geographical area is the area of most concern. The uppermost aquifer extends down to the Ringold Formation lower mud unit. If the vertical extent of contamination extends down to the lower mud unit (or to 36.6 meters below the water table if the lower mud unit is not present) in the planned new wells, drilling will continue through the lower mud to the top of basalt. If contamination is found below the lower mud unit (or below 36.6 meters below the water table), the lower spatial boundary will be the top of basalt. The vadose zone within the above described area is also of concern because contaminants in the vadose zone are a source for groundwater contamination.

3.4.2 Temporal Boundaries

The first assessment report (Hodges 1998) found that the tank waste constituent technetium-99 had impacted groundwater. This implies that associated RCRA constituents chromium and nitrate have impacted groundwater in proportion to their concentrations relative to technetium-99 in tank waste. Under 40 CFR 265.93 (d)(7)(i), groundwater quality assessment monitoring must continue until final closure of WMA T. The expected closure date for all single-shell tanks is 2024.

3.4.3 The Monitoring Network

The current groundwater monitoring network at WMA T is based on the existing understanding of subsurface conditions. The initial groundwater monitoring network was designed based on a combination of professional judgment and modeling (Caggiano and Goodwin 1991; MEMO, Wilson et al. 1992). This provided an initial basis for the spacing and locations of wells. Subsequent wells were added to the network based on the same combination of judgment and modeling (Hodges and Chou 2001).

All four of the original WAC 173-160 compliant wells at WMA T (299-W10-15, 299-W10-16, 299-W11-27, and 299-W11-28) are dry as a result of the declining water table. In 2001, the last of the original wells, 299-W11-28, could no longer be sampled. Since publication of the previous assessment plan (Hodges and Chou 2001), four additional wells in the WMA assessment monitoring network have gone dry (299-W10-12, 299-W11-23, 299-W11-24, and 299-W11-28).

The current groundwater monitoring network at WMA T consists of 14 wells (Figure 2.23). As-built diagrams for the current WMA T assessment network wells are presented in Appendix C. Five of these wells are older wells constructed before WAC 173-160 was implemented. Well 299-W10-1 has been used as an upgradient well since flow directions shifted from a northward direction toward the east. It is an older well, with a 24-m perforated interval. A new upgradient well (299-W10-28) was drilled in 2001.

One older well, 299-W10-8, is currently used to fill a gap on the north side of WMA T between two newer WAC-compliant wells. Two older wells, 299-W10-4 and 299-W11-12, are south of WMA T. These wells were used as upgradient wells before groundwater flow direction changed from northward to eastward. These wells still are used to monitor regional contaminant plumes impinging on the WMA. Finally, one older non-WAC compliant well, 299-W11-7, is located about 350 meters east of the southern part of the WMA and is used as a distant, downgradient well. Data obtained from other distant, downgradient wells monitored for CERCLA and AEA will be used by the WMA T assessment as appropriate.

One existing WAC-compliant well, well 299-W10-22 located north of the WMA, was used as a downgradient, distant well until the flow direction change in 1997. The well is now situated more lateral than downgradient to the WMA with respect to groundwater flow direction. However, it will be included in the monitoring network for WMA T during the next phase of assessment. Data from the next assessment phase will be used to determine whether well 299-W10-22 will remain in the network.

Five new downgradient wells were drilled at WMA T and added to the monitoring network since the previous assessment plan was written (299-W11-39 through 299-W11-42 and 299-W11-46). With the exception of well 299-W11-46, the drilling and construction details for these wells are found in borehole

completion reports (Horton and Hodges 2001; Horton 2002). Well 299-W11-46 has just recently been completed and a borehole completion report will be made after all data become available. (Well 299-W11-46 was drilled to replace well 299-W11-25B which was damaged during construction.)

On the basis of observations at WMA T, Hodges (1998) and Hartman et al. (2000) postulated very narrow contaminant plumes and the need for a maximum spacing between wells of about 35 meters. The current well spacing on the downgradient side (east side) of WMA T ranges from 30 to 36 meters.

Two new wells are planned for fiscal year 2006.³ The locations for the wells are shown on Figure 2.23. The well labeled T-2 on the figure is located approximately 70 meters east of well 299-W11-46. This location is the estimated leading edge of the technetium-99 plume encountered in wells 299-W11-39 and 299-W11-46. Well T-2 will be drilled to the top of the Ringold Formation lower mud unit and sampled at pre-determined depth intervals during drilling. If contamination is encountered down to the lower mud, the well will be deepened to the top of basalt.

The second new well, well T-3 on Figure 2.23, will be drilled adjacent to well 299-W11-41. This is the location of the most recent, rapid increase in technetium-99 along the east side of WMA T. This well will also be drilled to the top of the Ringold Formation lower mud unit with the option to continue to top of basalt if deep contamination is encountered. Both new wells will be drilled such that they can be screened at depth in the aquifer and/or constructed as extraction wells for a pump-and-treat system if deemed necessary.

Additional new wells may be planned for calendar year 2006. However, the number and location of those wells will depend on the findings from the calendar year 2005 wells.

Some wells in the monitoring network may become unusable in the future because of the declining water table and/or changing direction of groundwater flow. If this happens, the effect on the monitoring network will be evaluated to determine whether it is necessary to either deepen the existing wells, where feasible, or to drill new wells. The need for additional new RCRA monitoring wells beyond those discussed above will be evaluated at least on an annual basis.

3.4.4 Constituents to be Monitored

The constituents to be monitored at WMA T include (1) RCRA-regulated, dangerous-waste constituents of concern, (2) non-RCRA non-dangerous-waste constituents of interest, and (3) supporting groundwater quality constituents. The constituents of concern are those constituents monitored for RCRA and discussed in Section 3.3.4.1 below. The constituents of interest are those constituents monitored under CERCLA and AEA to support tank farm retrieval and remediation and are discussed in Section 3.3.4.2. The supporting groundwater quality constituents are discussed in Section 3.3.4.3. All constituents to be monitored are listed in Table 3.3.

³ Both planned wells were under construction at the time this document was prepared.

Table 3.3. Constituents of Concern, Constituents of Interest, and Supporting Groundwater Quality Constituents to be Monitored at Waste Management Area T

Constituents of Concern	
Chromium	Nitrate
Constituents of Interest	
Fluoride	Technetium-99
Iodine-129	Tritium
Gross alpha	Gross beta
Gamma scan	
Supporting Groundwater Quality Constituents	
Major metals	Major anions
pH	Alkalinity
Specific conductance	Turbidity
Temperature	Dissolved oxygen
Oxidation-reduction potential	

3.4.4.1 Constituents of Concern

Chromium and **nitrate** are included as constituents of concern for RCRA monitoring at WMA T. The constituents of concern are those dangerous waste constituents regulated by RCRA that exist in the waste stored in WMA T and that are found in groundwater beneath WMA T. The specific constituents that have been documented in groundwater include chromium, nitrate, and carbon tetrachloride. Carbon tetrachloride is monitored under CERCLA and is not included as a WMA T groundwater assessment constituent of concern.

3.4.4.2 Constituents of Interest

The constituents of interest are non-RCRA regulated, non-dangerous waste constituents. The constituents of interest are compiled from known contaminants in groundwater beneath WMA T that are not covered in Section 3.3.4.1 and certain screening parameters for potential radionuclide contaminants.

The constituents of interest that are identified in the groundwater beneath WMA T are **technetium-99**, **tritium**, and **fluoride**. **Iodine-129** is also included for one well (well 299-W11-41) because the well is near the western edge of the regional iodine-129 plume.

The screening parameters gross alpha, gross beta, and gamma scan are also included in the constituents of interest. These analyses are used to indicate the possible presence of common radionuclide contaminants in the vadose zone and/or groundwater including strontium-90, cesium-137, and various isotopes of uranium and plutonium. If a screening parameter indicates an increase in alpha, beta, or gamma activity that cannot be explained by an increase in a specific radionuclide that is already included as a constituent of interest, then additional radionuclide-specific analyses will be initiated. The screening parameters are less expensive than most radionuclide-specific analyses and their use greatly decreases the cost of monitoring.

3.4.4.3 Supporting Groundwater Quality Constituents

Table 3.3 gives the supporting groundwater quality constituents. The supporting groundwater quality constituents are used to evaluate the chemical and physical quality of the sample. Basic hydrochemical information is obtained from the supporting groundwater quality constituents to allow quality control checks (e.g., cation/anion charge balance, specific conductance versus the sum of major constituents). Changes in pH and alkalinity also would be expected if tank waste or reaction products reached groundwater. Also, mixing of raw water (Columbia River water) with ambient groundwater may be discernable because the specific conductance and total dissolved solids are much lower for river water than for ambient groundwater. Some groundwater quality constituents can also help evaluate the size of liquid leaks and leak sources.

3.4.5 Practical Constraints

Although not strictly boundaries, practical constraints place limits on planned activities that get accomplished. The most obvious practical constraint is cost. Every effort is made to ensure the collection of the right types of data to support the decisions while keeping the cost of this assessment at a minimum. However, unforeseen changes in budgets may preclude some of the scope proposed for this groundwater assessment.

3.5 Decision Rules

Decision rules address the major or key questions and issues previously discussed. In accordance with the DQO process, “if-then” statements are formulated that lead to actions based on the data or information. However, not all issues or questions identified are amenable to this approach. Table 3.4 summarizes the decision rules and the following sections provide more detail.

3.5.1 Groundwater Flow Rate and Direction

The groundwater flow rate and flow direction are fundamental inputs to evaluating the lateral (and to some extent the vertical) distribution of contamination. The flow rate and flow direction are also valuable input to determine contamination sources. Therefore, the flow rate and flow direction where contaminants are encountered in the groundwater need to be known. However, a decision rule regarding flow rate and flow direction is not feasible because estimations of groundwater flow rate and flow direction are dependent on estimations of hydraulic conductivity and effective porosity, the accuracy of water-level measurements, and heterogeneities in the hydrogeologic system. The best possible recourse may be to continue collecting hydrologic data as they become available to refine existing estimates of groundwater conditions.

3.5.2 Extent of Contamination

The extent of groundwater contamination is required by 40 CFR 265.93(d)(4)(i). In addition, the extent of contamination is helpful to determine the source of contamination. Thus, it is important to

know the spatial and vertical distribution of contaminants in the unconfined aquifer at WMA T. A decision rule regarding the lateral extent of contamination could be the following:

If a given contaminant plume is enclosed laterally and downgradient by WMA T network wells or additional operable unit wells with concentrations of one-half or less of the drinking water standard for the given contaminant, then the lateral extent of the given contaminant plume is well understood.

Table 3.4. Summary of Decision Rules

Decision Statement ^(a)	Decision Rule
What is the rate and extent of migration of dangerous waste or dangerous waste constituents in the groundwater?	A decision rule for flow rate is not appropriate because flow rate and direction are dependent on estimates of hydrologic properties from a heterogeneous and anisotropic system.
	<i>If a given contaminant plume is enclosed laterally and downgradient by WMA T network wells or additional operable unit wells with concentrations of one-half or less of the drinking water standard for the given contaminant, then the lateral extent of the given contaminant plume is well understood.</i>
	<i>If sampling within a single well shows that, at some depth, the concentration for a given contaminant is at the local background level, and that concentrations above that depth passed through a maximum value, then the vertical extent of contamination for the given contaminant in the area is well known.</i>
What are the concentrations of dangerous waste constituents in the groundwater originating from the regulated unit?	<i>If contaminant concentrations are stable or on an established trend line, then no frequency change will be made to the sampling schedule.</i>
	<i>If a screening constituent shows an increase that can not be accounted for by other monitored constituents, then additional groundwater evaluation will be done.</i>
	<i>If results of the additional evaluation indicate that additional constituents of concern or constituents of interest have adversely impacted groundwater quality and are attributed to WMA T, then that (those) constituent(s) will be added to the list of constituents of concern or to the list of constituents of interest as appropriate.</i>
What is the location or source of groundwater contamination at WMA T?	<i>If more data are needed in a specific area to distinguish among two or more potential sources of contamination, then the location for appropriately placed new wells will be submitted for consideration in the next update of the well drilling DQO.</i>
What are the driving forces that account for the temporal and spatial occurrences of contaminants in the groundwater at WMA T?	A decision rule for this decision statement is not appropriate because determination of migration pathways results from a synthesis of historical data, data gathered during this assessment, and data gathered as part of other Hanford Site projects.
What are the pathways that allowed contamination to traverse the vadose zone and enter groundwater at WMA T?	A decision rule for this decision statement is not appropriate because determination of driving mechanisms results from a synthesis of historical data, data gathered during this assessment, and data gathered as part of other Hanford Site projects.
(a) From Section 3.2. (b) DQO = Data quality objective. (c) WMA = Waste management area.	

For cases where the lateral extent of a given contaminant plume is not known, additional wells may be necessary to define the extent of the plume. The installation of new wells is prioritized by the DQO process at the Hanford Site. Therefore, the addition of new wells to the WMA T monitoring network will be decided based on all of the Hanford Site's needs.

An additional decision rule regarding the vertical extent of contamination could be as follows:

If sampling within a single well shows that, at some depth, the concentration for a given contaminant is at the local background level, and that concentrations above that depth passed through a maximum value, then the vertical extent of contamination for the given contaminant in the area is well known.

For cases where the concentration for the given contaminant remains high at the total depth of the well, the vertical extent of contamination in the area is not well known. If the well is in the process of being drilled, the decision can be made by DOE, Ecology, and EPA to extend the depth of the well until contaminant concentrations approach local background. If the subject well is not a new well, decisions can be made to prioritize a new, deeper well at that location.

3.5.3 Sampling and Analysis Considerations

3.5.3.1 Sampling Frequency

A quarterly sampling frequency is required by 40 CFR 265.93(d)(7)(i) and by reference WAC 173-303-400(3) for RCRA-regulated constituents at WMA T. There are no requirements for sampling frequency associated with non-dangerous waste constituents at a WMA under groundwater quality assessment. The sampling frequency for each constituent sampled under this groundwater quality assessment plan is given in the Sampling and Analysis Plan (Appendix A).

A decision rule covering sampling frequency is as follows:

If contaminant concentrations are stable or on an established trend line, then no frequency change will be made to the sampling schedule.

All groundwater data are reviewed quarterly and the sampling schedule is reviewed annually. The sampling schedule will be changed if it is thought necessary by the project scientist.

3.5.3.2 Analyzed Constituents

The constituents of concern were defined in Section 3.4.4.1 as those dangerous waste constituents regulated by RCRA, and that exist in the wastes stored in WMA T, and that are found in groundwater beneath WMA T; specifically chromium and nitrate. The definition of constituents of concern allows for the list of those constituents to be changed (if additional dangerous wastes are found in the groundwater in the future). Decision rules addressing a change in the list of constituents of concern are as follows:

If a screening constituent shows an increase that can not be accounted for by other monitored constituents, then additional groundwater evaluation will be done.

This additional evaluation may include more frequent sampling, or the analysis of specific constituents previously covered by a screening constituent (e.g., strontium-90 as indicated by gross beta), or analysis of other heretofore unconsidered constituent.

If results of the additional evaluation indicate that additional constituents of concern or constituents of interest have adversely impacted groundwater quality and are attributed to WMA T, then that (those) constituent(s) will be added to the list of constituents of concern or to the list of constituents of interest as appropriate.

3.5.4 Contaminant Source(s), Migration Pathways, and Driving Mechanisms

Determinations of contaminant source(s), migration pathways, and driving mechanisms results from syntheses of historical data, data gathered during this assessment, and data gathered as part of other programs such as the River Protection Project (RPP) Tank Farm Vadose Zone Project and the 200-ZP-1 Operable Unit. One likely outcome from these determinations is that more information is needed from a specific area to differentiate between two or more contaminant sources. The major access way for gathering additional information is through additional boreholes or wells. A decision rule addressing this is as follows:

If more data are needed in a specific area to distinguish among two or more potential sources of contamination, then the location for appropriately placed new wells will be submitted consideration in the next update of the well drilling DQO.

The well drilling DQO process will prioritize the needed wells with wells required by other Hanford Site projects.

3.6 Optimize the Sampling Design

The groundwater quality assessment program for WMA T outlined in this DQO section is judged to be the current most resource-effective data collection design for generating data that are expected to satisfy the DQOs. The resulting data collection design is given in the Sampling and Analysis Plan in Appendix A. However, priority and on-going activities frequently change at the Hanford Site and these changes could lead to further design optimization. Also, additional groundwater quality assessment information may lead to further design optimization. This assessment plan will be reviewed annually to determine whether the activities for the groundwater assessment remain the most resource-effective data generating activities.

An additional cost savings is realized by coordination of sampling activities among RCRA, CERCLA, and AEA monitoring. The sampling schedules for the three monitoring programs are integrated to minimize well trips and duplicate analyses.

Finally, a high resolution resistivity survey was begun at WMA T in 2005 by CH2M HILL Hanford Group, Inc. The method is being tested to see whether subsurface zones of high conductivity can be mapped. If the method proves successful, it can provide information useful for citing new wells. High resolution resistivity data will be used, if available, when citing new wells at WMA T.

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Appendix A

Sampling and Analysis Plan

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Sampling and Analysis Plan

This appendix consists of a field sampling plan (FSP) and a quality assurance project plan (QAPP). The FSP specifies the data collection design and the QAPP includes the procedures and project management controls intended to ensure the data collected and associated measurement errors are appropriate to meet the quantitative and qualitative data quality objectives (DQO). Together these two plans form the Sampling and Analysis Plan. The Sampling and Analysis Plan is used as the principal controlling document for conducting the work identified in Section 3.

A.1 Field Sampling Plan

This section contains the data collection design and activities for the continued groundwater quality assessment of Waste Management Area (WMA) T. A description of each task is provided as follows. Additional discussion and background information associated with the tasks are provided in the main body of the plan.

A.1.1 Task Description

The tasks described are a subpart of the Groundwater Performance Assessment Project (groundwater project) managed for the U.S. Department of Energy (DOE) by Pacific Northwest National Laboratory (PNNL). Project management and organizational interfaces and procedures are described in Section A.2.

A.1.1.1 Well Testing and Special Sampling

This task combines those activities that require removal of the sample pumps for free access to the well. Cost savings are achieved by combining the activities and minimizing disruption of the ongoing monitoring program. This task includes the following specific tests:

- Gyroscope surveys
- Special sampling

Gyroscopic Surveys. Past surveys have shown that monitoring wells are not necessarily vertical and straight. Knowing the exact configuration of a well is particularly necessary when multi-well aquifer testing is done. For this reason, gyroscopic surveys will be done in wells to be used for multi-well aquifer tests.

Special Sampling. Previous reports have shown that there are vertical concentration gradients for some constituents of concern and constituents of interest at WMA T (Hodges 1998; Horton et al. 2002; Serne et al. 2004). Several special sampling activities are planned at WMA T to better understand the vertical distribution of contaminants and are described below.

Specific Conductance Profiles

Specific conductance profiles will be measured in wells 299-W11-39, 299-W11-40, 299-W11-41, 299-W11-42, 299-W10-4, and 299-W10-28. The first five of these wells are chosen because they are downgradient and monitor contaminated groundwater. The latter two wells are chosen for comparison purposes because they are not downgradient. The conductivity measurements will be taken with a calibrated meter fastened to an electrical tape. Measurements will be taken at 0.3-meter intervals throughout the screened interval. Measurements will be repeated until two consecutive results are within 10%.

Discrete Depth Sampling

Based on the results of the specific conductance profiles, passive multi-level sampling of groundwater using a dialysis cell equilibration method may be done in wells 299-W11-39, 299-W11-41, 299-W11-42, 299-W10-4, and 299-W10-28. The first three of these wells are chosen because they are downgradient and currently show increases in contaminant concentrations. The latter two wells are chosen for comparison because they are not downgradient but sample highly contaminated groundwater. The sampler consists of a support rod, 30-milliliter sample cells, and baffles separating the cells. The baffles rest against a well screen and prevent cross contamination from vertical in-well flow. The cells will be filled with water and placed in the well screen for a period of time sufficient to allow replacement of the water in the cells by formation water flowing into the well screen (nominally one to two weeks).

The multi-level pore water sampling device will be deployed in and retrieved from the wells using the pump setting rig used to remove and replace the dedicated sample pump from the well. The sampling device will be suspended in the well by a non-stretching cable and secured at the surface to a metal rod extended across the well head. Because the well cap may not fit on the well with the sampling device in place, the well head will be wrapped in plastic and taped tight while sampling is in progress.

At a minimum, depth discrete groundwater samples will be collected every meter throughout the screened intervals and analyzed for chromium, technetium-99, and nitrate. Analyses will be done at the PNNL's 325 Laboratory.

A.1.1.2 Determine Groundwater Flow Direction

Water Level Measurements. The depth to water will be measured quarterly in all wells at the time of sampling. These measurements are an indicator of conditions in the well at the time of sampling. However, because these measurements are generally taken over a time period of a few days, they are subject to differential barometric effects due to diurnal and storm-related changes in atmospheric pressure. Therefore, depth-to-water measurements taken at the time of sampling and used to construct water table maps will be corrected for changes in atmospheric pressure (Spane 1999).

Additionally, depth to water is measured annually in March to construct the annual Hanford Site water-table map. At WMA T, these March measurements are generally taken in all wells within a few hours time. Thus, the March measurements are not as susceptible to barometric effects as are the quarterly measurements.

A.1.1.3 Well Drilling and Testing

Determining the vertical and lateral extent of groundwater contamination is required for this groundwater quality assessment (Section 3.3.2). For this purpose, two new wells were identified for WMA T in the DQO for prioritization of new groundwater monitoring wells (Byrnes and Williams 2003). One of those wells (299-W11-25B which was later replaced by 299-W11-46 after being damaged) was installed in calendar year 2005. The other new well (well T-2 on Figure 2.23) is scheduled for later in calendar year 2005. The second new well will be a mid-field well located about 70 meters downgradient of existing well 299-W11-25B to test the lateral and vertical extent of contamination coming from the area of well 299-W11-25B.¹

The location of well T-2 was determined by using the best available hydrologic information (flow rate and flow direction) and the breakthrough of technetium-99 at wells 299-W11-27, 299-W11-23, and 299-W11-39. Using this information, well T-2 was located just outside of where the leading edge of the technetium-99 plume is expected.

As a result of groundwater analyses obtained during drilling of well 299-W11-25B, the DOE, U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (Ecology) agreed to drill a third new well in calendar year 2005. The third well (well T-3 on Figure 2.23) tentatively is located adjacent to existing well 299-W11-41 near the southeast corner of WMA T. This is the location of the greatest rate of increase in technetium-99 downgradient of WMA T. However, the location of well T-3 may be changed pending the results of surface geophysical surveys being conducted by CH2M HILL Hanford Group, Inc.

Both new wells will be drilled to the top of the Ringold Formation lower mud unit or to 36.6 meters below the water table if the lower mud unit is not present. If significant contamination exists at the top of the lower mud unit, drilling and sampling will continue to the top of basalt. Both new wells will be drilled so that casing can be downsized in the lower mud unit and can be constructed as extraction wells for a pump-and-treat system is deemed necessary.

Well construction will comply with the requirements for monitoring well design and construction as specified in 40 CFR 265.91(c) by reference of WAC 173-303-400(3). Specifications for well designs and procedures for performing the well installations are contained in Washington Administrative Code (WAC 173-160) and contractor/sub-contractor procedure manuals. A separate statement of work describing well specifications will be issued prior to well drilling. Only special conditions related to the WMA T groundwater assessment are described in this plan.

Data Collection Activities. Data collection activities associated with drilling the new wells include the following:

- Geologic description of sediments encountered during drilling.
- Collection of sediment samples returned to the surface during drilling.
- Collection and analysis of groundwater samples during drilling.
- Water level measurements.

¹ Well T-2 had been drilled and constructed at the time this document was published.

- Geophysical logging.
- Well development parameters (drawdown during pumping and recovery).
- Aquifer testing.
- Deviation survey to determine borehole deviations caused by drilling.

Geologic Description

Continuous geologic description of drill cuttings is required. The purpose of the descriptions is to record the physical appearance and conditions of the vadose zone and saturated zone sediments to be used in conceptual models of subsurface hydrogeologic conditions. The geologic log will include descriptions of the following:

- Drilling conditions and changes in drilling conditions (e.g., drilling method, drill rate, addition of water, heaving sand).
- Depths of all collected samples.
- Lithologic descriptions of sediments.
- Water levels.

Collection of Sediment Samples

The purposes of the sediment samples are to (1) provide physical samples to aid geologist's description of lithologies, (2) provide a sample for future testing of physical or chemical properties as needed, and (3) provide an archive record of hydrogeologic conditions encountered during drilling.

Representative sediment samples will be collected at 1.5-m intervals throughout the entire borehole. Additional samples will be collected at significant changes in lithology or at depths where unusual conditions or sediments are encountered. Samples will be collected in pint or quart, glass jars capable of sealing existing moisture in the sample for a reasonable time period. If representative samples can not be collected (for example, if large particles do not fit in the container), notes describing the condition of the sample will be put in the geologist's log. The samples will be archived in the Geotechnical Sample Library after collection. All sediment samples will be labeled with the borehole number, sample depth, and date of sample and documented on the geologist log.

In addition to the archived samples, small volume samples for chip trays will be collected. These samples will be made available to the project scientist to corroborate the field geologist descriptions and aid in the hydrogeologic interpretation for use in constructing maps and cross-sections for conceptual models.

No sediment samples will be collected from zones of subsurface contamination that would prohibit the uncontrolled transport and storage of the samples to the Geotechnical Sample Library in the 300 Area. The presence or absence of contamination will be determined by surveys using hand held instruments in the field conducted by radiological control technicians. Surveys will be on a schedule determined by the contractor responsible for well drilling.

Collection of Groundwater Samples

This section briefly discusses groundwater sampling during drilling of two new wells in calendar year 2005. A more detailed description of sampling activities during drilling will be made in a sampling and analysis plan specific to the two wells. If sampling requirements change between the time this plan is written and the well-specific sampling and analysis plan is written, the well-specific plan takes precedence. Sampling for analytes not included in this Sample and Analysis Plan (e.g., volatile organics) will be coordinated through the Hanford Groundwater Remediation Project.

Two types of groundwater samples will be collected during drilling: grab samples and pumped samples. Samples will be collected as near to the water table as possible and at every 1.5-m depth. The samples are to be representative, to the extent practicable, of the aquifer at the depth of the samples; therefore, the following collection method will be used. The grab samples will be air lifted if drilling is by air rotary or by dual-wall percussion; the grab samples will be bailed if drilling is by cable tool.

The geologist at the borehole will collect the samples in clean and new containers with screw top lids labeled with the borehole number, sample depth, and date and time of collection. Groundwater samples will be turned over to the groundwater project after collection. The groundwater project will decant the groundwater into the appropriate containers with preservatives if necessary. The specific conductance and pH will be measured at the time of decanting. Because the samples will be a mixture of groundwater and sediment slurry, all samples will be filtered. Sample bottles, preservatives, and associated sample paperwork will be supplied by the groundwater project.

Slurry sampling during drilling at well 299-W11-25B showed that soluble Cr^{6+} in the groundwater was reduced to insoluble Cr^{3+} during the time that particulates were allowed to settle and the groundwater was in contact with the drill cuttings. Therefore, during drilling of well 299-W14-11, special precautions were taken when sampling for Cr^{6+} (hexavalent chromium). An aliquot of the groundwater-slurry sample was pumped and filtered into a sample bottle preserved and labeled for hexavalent chromium analysis as soon as possible after the slurry sample was collected. Analyses of the samples for Cr^{6+} suggested that the chromium was reduced to the insoluble ion. For this reason, chromium will be analyzed only from pumped samples.

Pumped samples will be collected after purging the wells for at least one hour. Pumped samples will be collected from predetermined and pre-agreed upon depth by DOE, Ecology, and EPA. The specific depths for both pumped and grab samples will be specified in detailed sample and analysis plans.

All air lifted samples will be analyzed for anions (nitrate) and technetium-99 at the PNNL Applied Geology and Geochemistry Laboratory (325 Laboratory). Pumped samples will be analyzed for anions, chromium (total, filtered), and technetium-99 at the 325 Laboratory. In addition, pumped samples from well T-2 will be analyzed for tritium, gross alpha, gross beta, and gamma scan and pumped samples from well T-3 will be analyzed for tritium and iodine-129 at the groundwater project's contract laboratory.

Sample volumes are to be 50 milliliters for technetium-99 and nitrate in the air lifted samples. For pumped samples, volumes will be 1,000 milliliters for tritium, 50 milliliters for chromium, 50 milliliters for anions, 50 milliliters for technetium-99, 4,000 milliliters for gamma scan, 1,000 milliliters for gross

alpha and gross beta, and 8,000 milliliters for iodine-129. The contract laboratory requires 20 milliliters for total activity scan. If insufficient water exists in an air lifted sample, the project scientist will prioritize the analytes.

The analysis of chromium, nitrate, and technetium-99 will require rapid turnaround from the laboratory so as to minimize standby time at the drill site.

Groundwater samples will be collected according to this sampling plan and documented procedures. Chain of custody is required for all samples transported to the laboratories. Instrumentation used during the collection of groundwater samples will be calibrated according to the manufacturer's procedures.

Water-Level Measurements

Water-level measurements are required at several times during well drilling, construction, and development. The purpose of the measurements is to aid understanding of the hydraulic properties of the aquifer through which the borehole is drilled. These properties are used to (1) decide well construction details such as screen slot size, screen length and depth, and pump depth; (2) interpret aquifer flow direction; and (3) interpret subsurface contaminant movement.

The depth to water should be measured (1) as soon as possible after encountering the water table; (2) periodically throughout the day after drilling activities have stopped for some time (at a minimum, once in the morning prior to drilling and once in the evening before leaving the borehole for the day); (3) during well development to monitor drawdown; and (4) after well development to monitor recovery.

Water-level measurements will be monitored during drilling and construction activities and well development.

Borehole Deviation Surveys

A borehole deviation survey will be conducted in the new boreholes to evaluate the amount of deviation from vertical. The amount of deviation is used to make corrections to depth-to-water measurements and determine water-table elevations.

The deviation surveys will be done with a downhole gyroscope in the wells prior to sample pump installation. The surveys will be scheduled by Fluor Hanford, Inc. and conducted by Duratek Technical Services according to Fluor Hanford, Inc. requirements.

Geophysical Logging

Spectral gamma geophysical logging is required in the new boreholes. The purposes of the logs are to determine the depth distribution of any gamma emitting contaminants around the borehole and to interpret subsurface lithology. The boreholes are to be logged throughout the entire drilled depth.

The results of geophysical logging will include a header sheet describing the test conditions (logging rate, logging dates, correction factors, calibration information, etc.) used during the logging and subsequent analysis and a log summary sheet describing the results of the geophysical logging.

Geophysical logging will be done according to documented procedures by other DOE contractors (currently Stoller Corp.).

Aquifer Testing

Aquifer testing is to be done in each new borehole during drilling and after well construction. The test results will provide aquifer properties used to calculate groundwater flow velocity and help interpret the results of sampling and analysis. The tests to be done after well construction are independent of activities associated with drilling and construction of the new wells. Details of the aquifer tests will be described in a separate test plan.

Five slug tests will be done in each of new wells T-2 and T-3 during drilling. The depths will be specified in the well specifications provided to Fluor Hanford, Inc.

A more detailed suite of tests may be conducted in the new wells after well construction. (The detailed hydraulic tests are contingent on the budget level in fiscal year 2006.) The test suite may include slug tests, tracer-dilutions tests, tracer pumpback tests, constant-rate pumping tests, and vertical flow, in-well tracer tests. Vertical flow has been measured in existing wells screened at the water table and it is important to know whether such vertical flow extends deeper in the aquifer. Also, well T-3 will be adjacent to existing well 299-W11-41. Therefore, aquifer testing done in new well T-3 may use the existing well as an observation well.

In addition to aquifer tests scheduled for new wells, slug testing will be done in recently completed well 299-W11-46. Well 299-W11-46 is located adjacent to well 299-W11-39. The results of the slug tests in well 299-W11-46 will be used to evaluate whether additional and detailed aquifer tests will be useful in the well using the adjacent well as an observation well.

The types of data that will be obtained from aquifer testing and the data uses are as follows:

Slug Testing:	for evaluating well development conditions and to provide preliminary hydraulic property information (e.g., hydraulic conductivity) for design of subsequent hydrologic tests
Tracer-Dilution Test:	for determining the vertical distribution of hydraulic conductivity and/or groundwater flow velocity within the well screen section, and for identifying vertical flow within the well screen section.
Tracer-Pumpback Test:	for tracer removal and characterizing effective porosity, an important hydraulic transport parameter
Pumping Test/Recovery:	conducted in concert with tracer-pumpback test. Analysis of drawdown and recovery data provides quantitative hydraulic characterization property information, e.g., hydraulic conductivity, storativity, specific yield

Criteria for Selection of Screened Interval

There are three criteria for selecting the screened interval in the new WMA T well located down-gradient of well 299-W11-25B. The basis for the criteria for selection of the screened interval is to sample that part of the aquifer with the highest levels of contaminants unless an adjacent well already

samples the high contamination zone. If an adjacent well already samples the high contamination zone, the well will be screened below the screened interval of the existing well to allow for declines in the water table.

1. If there is a maximum in the concentration of *Resource Conservation and Recovery Act* (RCRA) regulated constituent chromium greater than 10 times site background (site background is 3.17 µg/L at the 95th percentile) in the upper 36.6 meters of the aquifer at a depth greater than 10.7 meters, a 3-meter screen will be centered on the concentration maximum. If a maximum concentration of chromium greater than 10 times site background exists in the upper 10.7 meters, then the top of a 10.7-meter screen will be placed at the water table.
2. If there is no maximum in chromium concentration greater than 10 times site background and if there is a maximum in the concentration of tank farm constituent technetium-99 greater than 10 times site background (site background is 0.988 pCi/L at the 95th percentile) in the upper 36.6 meters of the aquifer at a depth greater than 10.7 meters, a 3-m length of screen will be centered on the concentration maximum. If a maximum concentration of technetium-99 greater than 10 times site background exists in the upper 10.7 meters, then the top of a 10.7-meter screen will be placed at the water table.
3. If there are no maxima in the concentrations of chromium or technetium-99 greater than 10 times site background, then a 10.7-meter screen will be placed at the water table.

There also are three criteria for the selection of the screened interval in the new WMA T well located adjacent to existing well 299-W11-41.

1. If there is a maximum in the concentration of RCRA-regulated constituent chromium greater than 10 times site background (site background is 3.17 µg/L at the 95th percentile) below the 10.7-meter depth in the aquifer (the bottom of the screen in adjacent well 299-W11-41), then a 3-meter length of screen will be centered on the concentration maximum.
2. If there is no maximum in chromium concentration greater than 10 times site background and if there is a maximum in the concentration of tank farm constituent technetium-99 greater than 10 times site background (site background is 0.988 pCi/L at the 95th percentile) at a depth below the 10.7-meter depth in the aquifer, then a 3-meter length of screen will be centered on the concentration maximum.
3. If there are no maxima in the concentrations of chromium or technetium-99 greater than 10 times site background below the 10.7-meter depth in the aquifer, then the top of a 3-meter screen will be placed 3 meters below the bottom of the screen in the adjacent well 299-W11-41.

A.1.1.4 Quarterly Groundwater Sampling and Analysis

Sampling in the WMA T well network identified for this assessment is an ongoing activity. A quarterly frequency is required by 40 CFR 265.93(d)(7)(i) by reference of WAC 173-303-400(3) for RCRA-regulated constituents. This frequency also is adopted for some constituents of interest and groundwater quality indicators. Other constituents of interest are sampled semi-annually or annually. These frequencies is judged to be adequate for assessing the rate and extent of contaminant migration in the groundwater, and contaminant concentrations for the WMA T based on the time response of previous

contaminant occurrences in monitoring wells and a relatively slow groundwater flow rate (4 to 73 meters/year based on flow rates in Table 2.9 of the main report).

The selection of the constituents to be monitored was discussed in Section 3.4 of the main body of this assessment plan. The wells to be monitored and the monitoring schedule are shown in Table A.1.

A.1.1.5 Special Isotopic Studies

Special isotopic investigations are planned under the scope of the Science and Technology Project and in conjunction with Lawrence Berkeley National Laboratory to try and distinguish the source or sources for contamination downgradient of WMA T. The WMA T groundwater assessment will take full advantage of any results from the special isotope studies as is appropriate for the assessment. The isotopic systems to be investigated include

- Ruthenium-101, -102, and -104.
- $^{87}\text{Sr}/^{86}\text{Sr}$.
- $\delta^{15}\text{N}$ and $\delta^{18}\text{O}$ in nitrate.
- Uranium isotopes.
- Stable chromium isotopes.

Several sample sets will be used for these studies. Nine depth-discrete samples of pumped groundwater from the new well 299-W11-25B will be available for isotopic analyses. Supplementing these samples are aliquots of the anion and inductively coupled plasma (ICP) metal samples collected in February 2005 from eight wells in the WMA T monitoring network (299-W10-1, 299-W10-4, 299-W10-24, 299-W10-28, 299-W11-39, 299-W11-40, 299-W11-41, and 299-W11-42). In addition, 23 vadose zone pore water samples are available from two boreholes drilled through the T-106 leak in 2003. These sample sets can be augmented with additional groundwater samples from the May 2005 quarterly sampling if needed.

A.1.1.7 Project Planning and Direction

This task involves ensuring that tasks are on schedule, that resources and personnel will be available when they are needed, and developing workarounds when schedule conflicts occur. Preparation of the assessment plan (this document), preparation of further assessment work plans that may be necessary to implement individual tasks, and any subsequent revisions of the assessment plan are also included in this task. Attending meetings with stakeholders and the integration project team leads to ensure coordination with other related projects is part of this task.

A.2 Quality Assurance Plan

The groundwater quality assessment investigation at WMA T is an integral part of the RCRA groundwater-monitoring program of the consolidated groundwater project. The scope of the consolidated project includes groundwater monitoring and the hydrogeologic services necessary to install, design, and monitor groundwater quality and contaminant movement on the Hanford Site. The project is administered by PNNL for the Richland Operations Office of DOE, Environmental Restoration (ER) Branch.

Table A.1. Sampling Schedule for Groundwater Monitoring at WMA T

Constituents of Concern					Constituents of Interest and Supporting Groundwater Quality Constituents														
Well Name	Purpose ^(a)	WAC Compliant	Chromium (total, filtered)	Nitrate (anions)	Technetium-99	Tritium	Gamma Scan ^(b)	Gross Beta ^(c)	Gross Alpha ^(d)	Metals, filtered ^(e)	Anions ^(f)	Alkalinity ^(g)	pH ^(g)	Specific Conductance ^(g)	Turbidity ^(g)	Temperature ^(g)	Dissolved Oxygen ^(g)	Redox ^(g)	Iodine-1129
299-W10-1	Upgradient	N	Q	Q	Q	Q	- ^(g)	A	A	Q	Q	Q	Q	Q	Q	Q	Q	Q	
299-W10-4	Assessment	N	Q	Q	Q	Q	A	A	A	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W10-8	Downgradient	N	Q	Q	Q	Q	-	A	A	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W10-22	Assessment	Y	SA	SA	SA	SA	-	-	-	SA	SA	SA	SA	SA	SA	SA	SA	SA	-
299-W10-23	Assessment	Y	Q	Q	Q	Q	-	A	A	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W10-24	Downgradient	Y	Q	Q	Q	Q	SA	SA	SA	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W10-28	Upgradient	Y	Q	Q	Q	Q	-	A	A	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W11-7	Far Field	N	SA	SA	SA	SA	-	-	-	SA	SA	SA	SA	SA	SA	SA	SA	SA	-
299-W11-12	Downgradient	N	Q	Q	Q	Q	-	A	A	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W11-46	Downgradient	Y	Q	Q	Q	Q	SA	SA	SA	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W11-39	Downgradient	Y	Q	Q	Q	Q	SA	SA	SA	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W11-40	Downgradient	Y	Q	Q	Q	Q	-	A	A	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
299-W11-41	Downgradient	Y	Q	Q	Q	Q	SA	SA	SA	Q	Q	Q	Q	Q	Q	Q	Q	Q	A
299-W11-42	Downgradient	Y	Q	Q	Q	Q	SA	SA	SA	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
New Well T-2	Far Field	Y	Q	Q	Q	Q	A	A	A	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
New Well T-3	Downgradient	Y	Q	Q	Q	Q	SA	SA	SA	Q	Q	Q	Q	Q	Q	Q	Q	Q	-
<p>(a) Assessment wells are not necessarily directly up or downgradient. Some assessment wells are used to help distinguish plumes impinging on the WMA T. Far field wells are wells located far downgradient to determine lateral extent of contamination.</p> <p>(b) Gamma Scan - Analytes include but are not limited to cobalt-60, cesium-137, europium-152, -154.</p> <p>(c) Gross Beta - Indicator parameter for strontium-90 and other beta emitters.</p> <p>(d) Gross Alpha - Indicator parameter for uranium isotopes and other alpha emitters.</p> <p>(e) Metals - Analytes include but are not limited to aluminum, bismuth, chromium, manganese, sodium, magnesium, potassium, and calcium.</p> <p>(f) Anions - Analytes include but are not limited to nitrite, nitrate, chloride, sulfate, and fluoride.</p> <p>(g) Field Measurement.</p> <p>(h) Dash indicates analysis is not performed for the indicated well.</p>																			

The consolidated groundwater project was established in 1996 when scope and personnel for the RCRA groundwater and related operational monitoring activities were transferred from Westinghouse Hanford Company to PNNL. The groundwater project quality assurance plan and current subcontractor procedures/manuals cover much of the work activities required for conducting the WMA T groundwater quality assessment.

Project description, project organization and designated responsibilities, and project management interfaces between DOE and subcontractor organizations are described in the groundwater project quality assurance plan.

A.2.1 Groundwater Sampling and Analysis Protocol

Samples will be collected for this assessment both during routine quarterly sampling and during drilling of new wells. The sampling and analysis methods and procedures and associated quality control for routine quarterly groundwater sampling and analysis are described in detail in Hartman 2000. Sampling during drilling is a non-routine type of sampling. The requirements for these latter samples are documented in sampling and analysis plans that specifically address each individual well and its requirements and are not covered in this QAPP.

A.2.1.1 Water-Level Monitoring

Field personnel measure depth to water before sampling or at other times as specified by the groundwater project (e.g., annual water-level measurements). The tapes used to make depth measurements are periodically calibrated. Field personnel obtain two consecutive measurements that agree within 6 millimeters and record them along with date, time, measuring tape number, and other pertinent information. Depth to water is subtracted from the elevation of a reference point (usually top of casing) to obtain water-level elevation. Water-level elevations are used to construct water-table maps.

Groundwater flow direction beneath WMA T is inferred from the water-table map(s) and plume maps. Rate of flow is estimated from hydraulic gradient, hydraulic conductivity and porosity or from rates of contaminant movement.

A.2.1.2 Routine, Quarterly Sampling and Analysis Protocol

Groundwater monitoring for WMA T is part of groundwater project and follows project quality assurance protocols. Groundwater monitoring for WMA T will follow the requirements of the most recent revision of the project quality assurance protocols; this monitoring plan need not be revised to cite future revisions of those protocols.

Project staff schedule sampling and initiate paperwork and oversee sample collection, shipping, and analysis. Quality requirements for any work subcontracted are specified in statements of work or contracts.

The statement of work for sampling activities specifies that those activities will be conducted in accordance with a quality assurance project plan that meets the requirements defined in *Requirements for*

Quality Assurance Project Plans, EPA/240/B-01/003 (EPA QA/R-5) (EPA 2001, as revised). Additional requirements are specified in the statement of work.

Groundwater project staff conduct laboratory audits and field surveillances to assess the quality of subcontracted work and initiate corrective action if needed.

Scheduling Groundwater Sampling

The groundwater project schedules well sampling. Many Hanford Site wells are sampled for multiple objectives and requirements; e.g., RCRA, *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), and *Atomic Energy Act* (AEA). Scheduling activities help manage the overlap, eliminate redundant sampling, and meet the needs of each sampling objective. Scheduling activities include the following:

- Each fiscal year, project scientists provide well lists, constituent lists, and sampling frequency. Each month, project scientists review the sampling schedule for the following month. Changes are requested via change request forms and approved by the sampling and analysis task lead and monitoring project manager.
- Project staff track sampling and analysis through an electronic schedule database stored on a server at PNNL. Quality control samples also are managed through this database. A scheduling program generates unique sample numbers, and a special user interface generates sample authorization forms, field services reports, groundwater sample reports, chain-of-custody forms, and sample container labels.
- Sampling and analysis staff verify that well name, sample numbers, bottle sizes, preservatives, etc. are indicated properly on the paperwork, which is transmitted to the sample collector. Staff verify that the paperwork was generated correctly.
- At each month's end, project staff use the schedule database to determine if any wells were not sampled as scheduled. If the wells or sampling pumps require maintenance, sampling is rescheduled following repair. If a well can no longer be sampled it is cancelled, and the reason is recorded in the database.

Chain of Custody

The sample collector uses chain-of-custody forms to document the integrity of groundwater samples from the time of collection through data reporting. The forms are generated during scheduling and managed by the sample collector. Samplers enter required information on the forms, including the following:

- Sampler's name(s).
- Method of shipment and destination.
- Collection date and time.
- Sample identification numbers.
- Analysis methods.
- Preservation methods.

When samples are transferred from one custodian to another (e.g., from sampler to shipper or shipper to analytical laboratory), the receiving custodian inspects the form and samples and notes any deficiencies. Each transfer of custody is documented by the printed names and signatures of the custodian relinquishing the samples and the custodian receiving the samples, and the time and date of transfer.

Sample Collection

All of the wells in the WMA T network are equipped with dedicated sampling pumps. Field personnel measure water levels in each well prior to sampling, then purge stagnant water from the well. Groundwater samples generally are collected after three casing volumes of water have been purged from the well or after field parameters (pH, temperature, specific conductance, and turbidity) have stabilized.

For routine groundwater samples, preservatives are added to the collection bottles, if necessary, before their use in the field. Samples for metals analyses are filtered in the field with 0.45 micrometer, in-line, disposable filters. After sampling, pH, temperature and specific conductance are measured again. Sample bottles are sealed with evidence tape and placed in a cooler with ice for shipping.

Analytical Protocols

Instruments for field measurements (e.g., pH, specific conductance, temperature, and turbidity) are calibrated using standard solutions prior to use and are operated according to manufacturer's instructions. Each instrument is assigned a unique number that is tracked on field documentation and calibrated and controlled.

Laboratory analytical methods are specified in contracts with the laboratories, and are standard methods from *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* (EPA/SW-846; EPA 1986, as revised) or *Methods for Chemical Analysis of Water and Wastes* (EPA-600/4-79-020, EPA 1983, as revised).

A.2.2 Borehole Drilling and Testing and Well Completion

Fluor Hanford, Inc. manages borehole drilling and well installation under their safety and related job control procedures. Data needs and objectives from this assessment plan are transmitted by letter report to Fluor Hanford, Inc. to include in the detailed specifications for the drilling contracts.

Several types of samples will be taken during drilling as described in Section A.1. The types of samples include (1) geologic drill cuttings for archive, (2) chip tray samples, and (3) groundwater samples for chemical analysis.

A.2.2.1 Geologic Drill Cutting Samples

Drill cutting samples will be taken at 1.5-m depth intervals for archival purposes. Sampling activities will be administered in accordance with applicable procedures in subcontractor's manuals. The archived drill cuttings are archived in the Hanford Geotechnical Sample Library in the 300 Area. Chain of custody is not required for the archived samples.

The well site geologist will describe the samples in the field and record the descriptions on borehole logs per approved Hanford Site contractor procedures. The field descriptions will be based on drill cuttings. Each sample collected will be recorded on a borehole log at the drill site. Detailed field lithologic descriptions of available material will include, if possible, color, texture, sorting, bulk mineralogy, roundness, relative calcium carbonate reactivity, consolidation, and cementation. All drilling and well construction data, sample depths, radiological and chemical survey points, will be documented on the borehole logs.

A.2.2.2 Groundwater Sampling

Slurries of groundwater and drill cuttings will be sampled during drilling as described in Section A.1. Sampling during drilling is a non-routine sampling event. The requirements of sampling during drilling are documented in separate sampling and analysis plans that are specific to each new well. Chain of custody is required for groundwater samples collected during drilling.

A.2.2.3 Analysis of Groundwater Sampled Collected during Drilling

Groundwater samples to be transferred to the groundwater project's contract laboratories will be analyzed according to approved laboratory standard operating procedures.

Groundwater samples to be transferred to the PNNL 325 Laboratory in the 300 Area will be analyzed according to the laboratory's established and approved procedures.

A.2.2.4 Borehole Geophysics

Borehole geophysical logging (spectral gamma ray) will be done in each new well. If the well is drilled using other than dual-wall casing, a neutron moisture log will also be done. The logging will be done by a subcontractor using the subcontractor's approved logging procedures. Optimal conditions for logging require that no more than one thickness of casing be present. This will require logging to be done in stages before each additional casing is telescoped into place.

A.2.2.5 Well Completion

The well will be completed as a standard RCRA monitoring well according to WAC 173-160 specifications. The length of the well screen and the screen depth will be based on analysis of samples collected during drilling. The procedure for selecting the well screen depths for the new calendar year 2005 wells at WMA T is in Section A.1.

A.2.2.6 Gyroscope

Gyroscope surveys will be conducted by Duratek Federal Services, Inc. using established and approved procedures.

A.2.2.7 Hydrologic Testing

The requirements and procedures for hydrologic testing will be documented in a separate sampling and testing plan.

A.2.3 Quality Assurance

The groundwater project's quality assurance protocols meet *EPA Requirements for Quality Assurance Project Plans*, EPA/240/B-01/003 (EPA QA/R-5), (EPA 2001 as revised). A quality control protocol is included in the groundwater project quality documentation, and quality control sampling requirements for subcontracted work are discussed in the statement of work with the subcontractor.

The groundwater project's quality control program is designed to assess and enhance the reliability and validity of groundwater data. This is accomplished through evaluating the results of quality control samples, conducting audits, and validating groundwater data. This section describes the quality control program for the entire groundwater project, which includes WMA T. The quality control practices of the groundwater project are based on EPA guidance cited in the Tri-Party Agreement Action Plan, Section 6.5 (Ecology et al. 1989). Accuracy, precision, and detection are the primary parameters used to assess data quality (Mitchell et al. 1985). Data for these parameters are obtained from two categories of quality control samples: those that provide checks on field and laboratory activities (field quality control) and those that monitor laboratory performance (laboratory quality control). Table A.2 summarizes the types of samples in each category and the sample frequencies and characteristics evaluated.

Table A.2. Quality Control Samples

Sample Type	Primary Characteristics Evaluated	Frequency
Field Quality Control		
Full Trip Blank	Contamination from containers or transportation	1 per 20 well trips
Field Transfer Blank	Airborne contamination from the sampling site	1 each day volatile organic compound samples are collected
Equipment Blank	Contamination from non-dedicated sampling equipment	1 per 10 well trips or as needed ^(a)
Duplicate Samples	Reproducibility	1 per 20 well trips
Laboratory Quality Control		
Method Blank	Laboratory contamination	1 per batch
Lab Duplicates	Laboratory reproducibility	Method/contract specific ^(b)
Matrix Spike	Matrix effects and laboratory accuracy	Method/contract specific ^(b)
Matrix Spike Duplicate	Laboratory reproducibility and accuracy	Method/contract specific ^(b)
Surrogates	Recovery/yield	Method/contract specific ^(b)
Laboratory Control Sample	Accuracy	1 per batch
Double Blind Standards	Accuracy and precision	Varies by constituent ^(c)
<p>(a) When a new type of non-dedicated sampling equipment is used, an equipment blank should be collected every time sampling occurs until it can be shown that less frequent collection of equipment blanks is adequate to monitor the equipment's decontamination procedure.</p> <p>(b) If called for by the analytical method, duplicates, matrix spikes, and matrix spike duplicates are typically analyzed at a frequency of 1 per 20 samples. Surrogates are routinely included in every sample for most gas chromatographic methods.</p> <p>(c) Double blind standards containing known concentrations of selected analytes are typically submitted in triplicate or quadruplicate on a quarterly, semi-annual, or annual basis.</p>		

A.2.3.1 Quality Control Criteria

Quality control data are evaluated based on established acceptance criteria for each quality control sample type. For field and method blanks, the acceptance limit is generally two times the instrument detection limit (for metals), or method detection limit (for other chemical parameters). However, for common laboratory contaminants such as acetone, methylene chloride, 2-butanone, and phthalate esters, the limit is five times the method detection limit. Groundwater samples that are associated (i.e., collected on the same date and analyzed by the same method) with out-of-limit field blanks are flagged with a “Q” in the database to indicate a potential contamination problem.

Field duplicates must agree within 20%, as measured by the relative percent difference (RPD), to be acceptable. Only those field duplicates with at least one result greater than five times the appropriate detection limit are evaluated. Unacceptable field duplicate results are also flagged with a “Q” in the database.

The acceptance criteria for laboratory duplicates, matrix spikes, matrix spike duplicates, surrogates, and laboratory control samples are generally derived from historical data at the laboratories in accordance with *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* (EPA 1986 as revised). Typical acceptance limits are within 25% of the expected values, although the limits may vary considerably with the method and analyte. Current values for laboratory duplicates, matrix spikes, and laboratory control samples are 20% RPD, 60% to 140%, and 70% to 130%, respectively. These values are subject to change if the contract is modified or replaced.

Table A.3 lists the acceptable recovery limits for the double blind standards. These samples are prepared by spiking background well water (currently wells 699-19-88 and 699-49-100C) with known concentrations of constituents of interest. Spiking concentrations range from the detection limit to the upper limit of concentration determined in groundwater on the Hanford Site. Double blind standard results that are outside the acceptance limits are investigated, and appropriate actions are taken if necessary.

Holding time is the elapsed time period between sample collection and analysis. Exceeding recommended holding times could result in changes in constituent concentrations due to volatilization, decomposition, or other chemical alterations. Recommended holding times depend on the analytical method, as specified in *Test Methods for Evaluating Solid Wastes, Physical/Chemical Methods* (EPA 1986, as revised) or *Methods for Chemical Analysis of Water and Wastes* (EPA 1983, as revised). These holding times are specified in laboratory contracts. Data associated with exceeded holding times are flagged with an “H” in the Hanford Environmental Information System (HEIS) database. Flagged data generally are suitable for use in plume maps and trend plots, but may not be suitable for decision-making.

Additional quality control measures include laboratory audits and participation in nationally based performance evaluation studies. The contract laboratories participate in national studies such as the EPA-sanctioned water pollution and water supply performance evaluation studies. The groundwater project periodically audits the analytical laboratories to identify and solve quality problems, or to prevent such problems. Audit results are used to improve performance. Summaries of audit results and performance evaluation studies are presented in the annual groundwater monitoring report.

Table A.3. Recovery Limits for Double Blind Standards

Constituent	Frequency	Recovery Limits (%)	Precision Limits (RSD) (%)
Specific conductance	Quarterly	75–125	25
Fluoride	Quarterly	75–125	25
Nitrate	Quarterly	75–125	25
Chromium	Annually	80–120	20
Gross alpha ^(a)	Quarterly	70–130	20
Gross beta ^(b)	Quarterly	70–130	20
Tritium	Annually	70–130	20
Cobalt-60	Annually	70–130	20
Strontium-90	Semiannually	70–130	20
Technetium-99	Quarterly	70–130	20
Iodine-120	Semiannually	70–130	20
Uranium	Quarterly	70–130	20
(a) Gross alpha standards will be spiked with plutonium-239. (b) Gross beta standards will be spiked with strontium-90. RSD = Relative standard deviation.			

A.2.3.2 Groundwater Data Validation Process

The groundwater project's data validation process provides requirements and guidance for validation of groundwater data that are routinely collected as part of the groundwater project. Validation is a systematic process of reviewing data against a set of criteria to determine whether the data are acceptable for their intended use. This process applies to groundwater data that have been verified (see Section A.2.4.1) and loaded into HEIS. The outcome of the activities described below is an electronic data set with suspect or erroneous data corrected or flagged. Groundwater project staff document the validation process quarterly. Documentation is stored in the project file.

Responsibilities for data validation are divided among project staff. Each monitored facility or geographic region is assigned to a project scientist, who is familiar with the hydrogeologic conditions of that site. The data validation process includes the following elements.

- **Generation of data reports** – Twice each month, data management staff provide tables of newly loaded data to project scientists for evaluation (biweekly reports). Also, after laboratory results from a reporting quarter have been loaded into HEIS, staff produce tables of water-level data and analytical data for wells sampled within that quarter (quarterly reports). The quarterly data reports include any data flags added during the quality control evaluation or as a result of prior data review.
- **Project scientist evaluation** – As soon as practical after receiving biweekly reports, project scientists review the data to identify changes in groundwater quality or potential data errors. Evaluation techniques include comparing key constituents to historical trends or spatial patterns. Other data checks may include comparison of general parameters to their specific counterparts (e.g.,

conductivity to ions) and calculation of charge balances. Project scientists request data reviews if appropriate (see Section A.2.4.2). If necessary, the laboratory may be asked to check calculations or reanalyze the sample, or the well may be resampled. After receiving quarterly reports, project scientists review sampling summary tables to determine whether network wells were sampled and analyzed as scheduled. If not, they work with other project staff to resolve the problem. Project scientists also review quarterly reports of analytical and water-level data using the same techniques as for biweekly reports. Unlike the biweekly reports, the quarterly reports usually include a full data set (i.e., all the data from the wells sampled during the previous quarter have been received and loaded into HEIS).

- Staff report results of quality control evaluations informally to project staff, DOE, and Ecology each quarter. Results for each fiscal year are described in the annual groundwater monitoring report.

A.2.4 Data Management and Reporting

This section describes how groundwater data are stored, retrieved, and interpreted.

A.2.4.1 Loading and Verifying Data

The contract laboratories report analytical results electronically and in hard copy. The electronic results are loaded into HEIS. Hard copy data reports and field records are maintained as part of the Hanford Facility operating record, unit specific file for the monitored facility. Project staff perform an array of computer checks on the electronic file for formatting, allowed values, data flagging (qualifiers), and completeness. Verification of the hard copy results includes checks for (1) completeness, (2) notes on condition of samples upon receipt by the laboratory, (3) notes on problems that arose during the analysis of the samples, and (4) correct reporting of results. If data are incomplete or deficient, staff work with the laboratory to get the problems corrected. Notes on condition of samples or problems during analysis may be used to support data reviews (see Section A.2.4.2).

Field data such as specific conductance, pH, temperature, turbidity, and depth-to-water are recorded on field records. Data management staff enter these into HEIS manually through data-entry screens, verify each value against the hard copy, and initial each value on the hard copy.

A.2.4.2 Data Review

The groundwater project conducts special reviews of groundwater analytical data or field measurements when results are in question. Groundwater project staff document the process on a review form, and results are used to flag the data appropriately in HEIS. Various staff may initiate a review form: e.g., project scientists, data management staff, and quality control staff. The data review process includes the following steps:

- The initiator fills out required information on the review form, such as sample number, constituent, and reason for the request (e.g., “result is two orders of magnitude greater than historical results and disagrees with duplicate”). The initiator recommends an action, such as a data re-check, sample re-analysis, well re-sampling, or simply flagging the data as suspect in HEIS.

- The data review coordinator determines that the review form does not duplicate a previously submitted review form, then assigns a unique review form number and records it on the form. A temporary flag is assigned to the data in HEIS indicating the data are undergoing review (“F” flag).
- If laboratory action is required, the data review coordinator records the laboratory’s response on the review form. Other documentation also may be relevant, such as chain-of-custody forms, field records, calibration logs, or chemist’s sheets.
- A project scientist assigned to examine a review form determines and records the appropriate response and action on the review form including changes to be made to the data flags in HEIS. Actions may include updating HEIS with corrected data or result of re-analysis, flagging existing data (e.g., “R” for reject, “Y” for suspect, “G” for good), and/or adding comments. Data management staff updates the temporary “F” flag to the final flag in HEIS.
- The data review coordinator signs the review form to indicate its closure.
- If a review form is filed on data that are not “owned” by the groundwater project, the data review coordinator forwards a copy of the partially filled review form to the appropriate contact for their action. The review is then closed.

A.2.4.3 Interpretation

After data are validated and verified, the acceptable data are used to interpret groundwater conditions at the site. Interpretive techniques include the following.

Hydrographs

Hydrographs will be made using historical (and current) water level information. Hydrographs show water levels versus time for specified wells. Hydrographs are used to determine decreases, increases, seasonal, or manmade fluctuations in groundwater levels.

Water-Table Maps

Water-table maps will be made using both current and historic water-level measurements. The current water-table maps will be made with water-level measurements obtained as described above. The historic water-table maps will be made with data in the groundwater project’s water-level database.

Care must be exercised in using water table maps (and hydrographs) for interpretation purposes because there are several potential problems with using historic water level data. In addition to unknown barometric effects, other potential sources of error in resulting water table maps and calculated water-table gradients include (1) the straightness of the wells; (2) for some time periods, a relatively flat water table coupled with measurement errors; (3) the communication between the aquifer and the screened or perforated part of the well; (4) changes in lithology; and (5) periodic and local influence from nearby liquid disposal facilities.

Trend Plots

Trend plots will be made using current and historic groundwater compositions. Trend plots graph concentrations of constituents versus time to determine increases, decreases, and fluctuations; they may be used in tandem with hydrographs and/or water-table maps to determine if concentrations relate to changes in water level or in groundwater flow directions.

Plume Maps

Plume maps will be prepared for chromium and nitrate and for selected constituents of interest such as technetium-99. These maps will be made using results of current groundwater sampling and analysis. The maps will describe the current understanding of contaminant distribution. Changes in plume distribution over time aid in determining movement of plumes and direction of flow. Plume maps are prepared by the groundwater project quarterly and published annually. Plume maps generally reflect the geographic distribution of contamination in the uppermost part of the aquifer where most wells are screened.

Contaminant Ratios

Ratios of contaminant concentrations will be calculated and used to distinguish between different sources for the contamination is possible. Contaminant ratios are only useful where chemically different waste streams were disposed to two or more different potential source facilities.

Three Point Analyses

Corrected water-table elevations will be used to calculate groundwater flow direction using the three-point analysis (three point problem) method. The method is commonly used by geologists to determine the strike and dip of a plane from the elevations of three points. For this application, the groundwater flow direction is equivalent to the dip of the water table determined by measured water-table elevations in three wells. Several triplets of wells will be used.

Transport Modeling

A simple transport models will be used to (1) predict the distribution of hypothetical contaminants released within the WMA and (2) help locate any future wells to be drilled in calendar year 2006.

The monitoring analysis package (Golder 1991) includes the Plume Generation Model (PLUME), the Monitoring Efficiency Model (MEMO), and the Contamination Probability Model (COPRO). This task will use the PLUME model in conjunction with professional judgment estimates to assess the extent of contamination at WMA T.

PLUME uses an analytical contaminant transport function to generate dilution contour plots of a contaminant plume emanating from a line source of specified length. The model has been used since 1992 to generate the plumes used by the MEMO model. PLUME is based on the two-dimensional analytical transport model presented in Domenico and Robbins (1985) and modified in Domenico (1987).

This model assumes that solute is released along a continuous line source in a uniform aquifer, and predicts the concentrations that would be observed at points downstream of the source. The important user input parameters include the following:

- Advection time.
- Source history.
- Width of line source.
- Longitudinal and transverse dispersivities.
- Diffusion coefficient.
- First order decay constant.
- Average contaminant velocity.

Because some of these parameters are not well known, the model will be run to simulate a variety of conditions.

One of the primary uses of the model results is to aid professional judgment in locating any new monitoring wells planned for calendar year 2006. The model results will estimate potential migration distances downgradient from WMA T.

The model can also be run “backwards.” That is, the contaminant configuration today can be used with estimated historical conditions as input to the model and the model can be run for different periods of time representing the time periods when groundwater flow was to the south, north, and east. These results may help verify potential source area for contamination.

A.2.4.4 Reporting

Regular annual progress reports are required for RCRA sites that are in assessment. As required by 40 CFR 265.94(b)(2) [by reference of WAC 173-303-400(3)], the results of the groundwater quality assessment program must be submitted to the regulator (Ecology) no later than March 1 following each calendar year. Also, as part of the groundwater project, it is anticipated that quarterly status reports will be submitted to DOE and Ecology. Borehole completion packages must also be prepared for each new monitoring well installed to document compliance with WAC 173-160.

A.4 References

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Appendix B

Supporting Information

Appendix B

Supporting Information

This section contains supporting geologic and groundwater monitoring information. This appendix includes the following information:

- Data about wells used to interpret the geology and hydrology.
- Geologic data used to interpret the geology and hydrology.
- As-built diagrams for wells in the WMA T monitoring network.

Table B.1. Wells and Data Sources Used in This Report

Well Name	Sample Method ^(a)	Northing (m)	Easting (m)	Surface Elevation (m)	Survey Reference	Total Depth (m)	Drill Date	Data Sources
299-W10-1^(b)		136734.6	566663.1	207.459	NAVD88	93.0	1947	Driller's Log, CaCO₃, Gamma Log, Sieve
299-W10-2	CT	136798	566672	206.601	NAVD88	70.1	1953	Driller's Log, CaCO ₃ , Gamma Log, Sieve
299-W10-3	CT	136673.4	566731.9	205.763	NAVD88	72.8	1951	Driller's Log, Gamma Log
299-W10-4	CT	136578.1	566734.6	205.524	NAVD88	74.7	1952	Driller's Log, Gamma Log, CaCO₃, Sieve
299-W10-8	CT	136811.2	566848.8	208.382	NAVD88	76.8	1973	Driller's Log, CaCO₃, Sieve
299-W10-9	CT	136798.8	566748.2	206.746	NAVD88	68.6	1973	Driller's Log, Sieve
299-W10-10	CT	136805.9	566751.3	206.873	NAVD88	76.2	1973	Driller's Log, Sieve
299-W10-11	CT	136802.2	566755	206.845	NAVD88	76.2	1974	Driller's Log
299-W10-12	DB 0-36 HT 36-76	136797.5	566755.6	206.768	NAVD88	76.2	1974	Driller's Log
299-W10-15	DB 0-29 HT 29-68	136808	566770.4	207.039	NAVD88	67.8	1989	Geologist's Log, Gamma Log
299-W10-16	DB 0-13, 17-36 HT 13-12, 36-67	136606.6	566780.9	206.162	NAVD88	67.0	1989	Geologist's Log, Gamma Log
299-W10-22	DB 0-32, HT 32-91	136883.1	566832.6	208.954	NAVD88	91.4	1994	Geologist's Log, Gamma Log
299-W10-23	Air Rotary	136815.3	566823.7	207.4707	NAVD88	82.9	1998	Geologist's Log, Gamma Log
299-W10-24	Air Rotary	136798.8	566885.4	209.7253	NAVD88	129.1	1998	Geologist's Log, Gamma Log
299-W10-28	DB 0-175 HT 175-280	136709.9	566701.6	206.826	NAVD88	85.3	2001	Geologist's Log, Gamma Log
299-W10-196	CT - SS	136724.8	566787.8	205.286	NGVD29	53.9	1992	Geologist's Log, Gamma Log, Moisture
299-W11-7	HT	136675.3	567260.9	217.108	NAVD88	96.0	1951	Driller's Log
299-W11-12	HT	136598.3	566928.6	208.201	NAVD88	76.2	1953	Driller's Log
299-W11-23	DB 0-25 HT 25 – 77	136801.1	566905	210.778	NAVE88	76.8	1973	Driller's Log, Sieve
299-W11-24	HT 0-9 DB 12-36 HT 36 – 76	136744.5	566913	210.553	NAVE88	76.2	1973	Driller's Log
299-W11-25B	DWP	NA	NA	NA	NA	124.8	2005	Geologist's Log, Gamma Log
299-W11-26	Core 27 to TD	2220255	448095	211.4	NA	157.0	1976	Driller's Log

Table B.1. (contd)[illegible]

Table B.2. Geologic Data for WMA T^(a)

Well Name	Elevation at Bottom ^(b) (m)	Water-Level Elevation (m)	Date of Water Level	Top of Hanford Formation Sand Sequence	Top of Cold Creek Fluvial Sequence	Top of Cold Creek Caliche	Top of Taylor Flats	Top of Unit E	Top of Lower Mud	Top of Unit A	Top of Basalt
299-W10-1	113.7	137.117	5/02	188	184	178	173	165			
299-W10-2	135.9	141.298	6/95	187	180	176	172	167			
299-W10-3	133.0	141.88	7/93	198	180	177	172	167			
299-W10-4	130.5	137.023	5/02	189	178	175	170	165			
299-W10-8	130.7	136.829	6/02	194	182	179	172	169			
299-W10-9	137.2	139.873	6/96	191	181	178	168	165			
299-W10-10	129.7	136.957	6/02	197	184	179	172	165			
299-W10-11	129.8	137.685	6/00	197	181	177	168	165			
299-W10-12	129.7	137.679	6/00	189	181	178	171	165			
299-W10-15	138.7	138.401	9/99	188	184	178	175	165			
299-W10-16	138.2	138.323	9/99	188	180	177	173	166			
299-W10-22	117.0	136.809	6/02	198	183	180	175	165			
299-W10-23	123.7	136.877	6/02	192	181	179	172	166			
299-W10-24	127.1	136.8	6/02	199	184	179	176	170	84		
299-W10-28	120.6	137.219	11/01	189	181	177	172	167			
299-W10-196	150.9	NA	NA	193	180	177	173	168			
299-W11-7	120.8	136.315	5/02	199	183	177	174	167			
299-W11-12	131.8	136.827	6/02	199	182	178	Not Present	169			
299-W11-23	133.7	NA	NA	195	183	178	173	172			
299-W11-24	133.5	136.761	6/02	199	181	179	176	169			
299-W11-25 B ^(c)	85.7	136.7	3/04	198	183	180	174	170	86		
299-W11-26	88.0	NA	NA	196	179	178	174	169	86	80	58
299-W11-27	137.3	NA	NA	198	183	180	173	170			
299-W11-28	136.0	141.621	2/99	199	182	179	175	168			
299-W11-30	128.4	136.354	5/02	203	182	215	171	163			
299-W11-39	123.8	136.788	5/02	200	183	179	174	170			
299-W11-40	124.4	136.807	5/02	200	183	178	174	169			
299-W11-41	124.3	136.78	6/02	198	182	179	174	170			
299-W11-42	124.8	136.85	5/02	198	182	180	173	169			

(a) Tops are elevation above sea level in meters.

(b) Elevation at completion depth.

(c) Not surveyed at the time of report preparation. Assumes elevation equal to 299-W11-39, located ~6 m away. Elevation = 210.55.

Bold text indicates wells are in the groundwater monitoring network.

WELL CONSTRUCTION AND COMPLETION SUMMARY						
Drilling Method: Cable tool Drilling Fluid Used: Water Driller's Name: Boner Drilling Company: Not documented Date Started: 18Jun47	Sample Method: Hard tool non Additives Used: Not documented WA State Lic Nr: Not documented Company Location: Not documented Date Complete: 07Aug47	WELL NUMBER: 299-W10-1 Hanford Coordinates: N/S N 43,550 E/W W 76,210 State Coordinates: N 448,656 E 2,219,003 Start Card #: Not documented T R S Elevation Ground surface (ft): 671.8 Estimated				
Depth to water: Not documented (Ground surface) 209.1-ft Apr92						
GENERALIZED STRATIGRAPHY Driller's Log	<table border="0" style="width: 100%;"> <tr> <td style="width: 40%; vertical-align: top;"> 0-5: All SAND 10: SAND & GRAVEL; 15,17,5: GRAVEL 20: Black SAND 25,30: GRAVEL 35,40: SAND & GRAVEL 45: GRAVEL, SAND & SILT 49: GRAVEL & SAND 50,52,55: Black SAND 57: SAND 60,62: SAND & GRAVEL 65: Coarse SAND and SILT 70,75: SAND & SILT 80-105: SAND & CLAY 110: Coarse SAND & CLAY 112-140: SAND, CLAY 142: GRAVEL & CLAY 145,150: GRAVEL 155: SAND & GRAVEL 160,163: GRAVEL 165,170: SAND and GRAVEL 180,185: SAND & GRAVEL 190: CLAY, SAND & GRAVEL 195: SAND & GRAVEL 200: SILT, SAND 205: SAND & GRAVEL 210: Coarse SAND, GRAVEL 215,220: SAND & GRAVEL 225-255: CLAY, SAND, GRAVEL 260: SAND & GRAVEL 265-270: CLAY, SAND, GRAVEL 275: SAND & GRAVEL 280: SAND 285: GRAVEL 290,293: SAND 295,297.5: SAND & GRAVEL 300: SILT, SAND & GRAVEL 303: SILT 305,306: SAND & GRAVEL </td> <td style="width: 10%; text-align: center; vertical-align: middle;"> </td> <td style="width: 50%; vertical-align: top; padding-left: 10px;"> Elevation of reference point: [~677.00-ft] (top of casing) Height of reference point above [5.2-ft] ground surface Depth of surface seal [ND] Type of surface seal: <u>None documented</u> I.D. of surface casing [10-in nom] (None documented) I.D. of riser pipe: [8-in] Type of riser pipe: <u>Carbon steel</u> Diameter of borehole: [9-in nom] Type of filler: <u>Not documented</u> Elevation/depth top of seal Type of seal: <u>Not documented</u> Depth top of perforations: [190-ft] Description of perforations: <u>Original not documented</u> <u>14-15 May 48, not documented</u> <u>04 Sep 56, 190-270-ft, 3 holes/ft/rd</u> Depth bottom of perforations: [270-ft] Depth bottom of casing [303-ft] Depth bottom of borehole: [305-ft] </td> </tr> </table>			0-5: All SAND 10: SAND & GRAVEL; 15,17,5: GRAVEL 20: Black SAND 25,30: GRAVEL 35,40: SAND & GRAVEL 45: GRAVEL, SAND & SILT 49: GRAVEL & SAND 50,52,55: Black SAND 57: SAND 60,62: SAND & GRAVEL 65: Coarse SAND and SILT 70,75: SAND & SILT 80-105: SAND & CLAY 110: Coarse SAND & CLAY 112-140: SAND, CLAY 142: GRAVEL & CLAY 145,150: GRAVEL 155: SAND & GRAVEL 160,163: GRAVEL 165,170: SAND and GRAVEL 180,185: SAND & GRAVEL 190: CLAY, SAND & GRAVEL 195: SAND & GRAVEL 200: SILT, SAND 205: SAND & GRAVEL 210: Coarse SAND, GRAVEL 215,220: SAND & GRAVEL 225-255: CLAY, SAND, GRAVEL 260: SAND & GRAVEL 265-270: CLAY, SAND, GRAVEL 275: SAND & GRAVEL 280: SAND 285: GRAVEL 290,293: SAND 295,297.5: SAND & GRAVEL 300: SILT, SAND & GRAVEL 303: SILT 305,306: SAND & GRAVEL		Elevation of reference point: [~677.00-ft] (top of casing) Height of reference point above [5.2-ft] ground surface Depth of surface seal [ND] Type of surface seal: <u>None documented</u> I.D. of surface casing [10-in nom] (None documented) I.D. of riser pipe: [8-in] Type of riser pipe: <u>Carbon steel</u> Diameter of borehole: [9-in nom] Type of filler: <u>Not documented</u> Elevation/depth top of seal Type of seal: <u>Not documented</u> Depth top of perforations: [190-ft] Description of perforations: <u>Original not documented</u> <u>14-15 May 48, not documented</u> <u>04 Sep 56, 190-270-ft, 3 holes/ft/rd</u> Depth bottom of perforations: [270-ft] Depth bottom of casing [303-ft] Depth bottom of borehole: [305-ft]
0-5: All SAND 10: SAND & GRAVEL; 15,17,5: GRAVEL 20: Black SAND 25,30: GRAVEL 35,40: SAND & GRAVEL 45: GRAVEL, SAND & SILT 49: GRAVEL & SAND 50,52,55: Black SAND 57: SAND 60,62: SAND & GRAVEL 65: Coarse SAND and SILT 70,75: SAND & SILT 80-105: SAND & CLAY 110: Coarse SAND & CLAY 112-140: SAND, CLAY 142: GRAVEL & CLAY 145,150: GRAVEL 155: SAND & GRAVEL 160,163: GRAVEL 165,170: SAND and GRAVEL 180,185: SAND & GRAVEL 190: CLAY, SAND & GRAVEL 195: SAND & GRAVEL 200: SILT, SAND 205: SAND & GRAVEL 210: Coarse SAND, GRAVEL 215,220: SAND & GRAVEL 225-255: CLAY, SAND, GRAVEL 260: SAND & GRAVEL 265-270: CLAY, SAND, GRAVEL 275: SAND & GRAVEL 280: SAND 285: GRAVEL 290,293: SAND 295,297.5: SAND & GRAVEL 300: SILT, SAND & GRAVEL 303: SILT 305,306: SAND & GRAVEL		Elevation of reference point: [~677.00-ft] (top of casing) Height of reference point above [5.2-ft] ground surface Depth of surface seal [ND] Type of surface seal: <u>None documented</u> I.D. of surface casing [10-in nom] (None documented) I.D. of riser pipe: [8-in] Type of riser pipe: <u>Carbon steel</u> Diameter of borehole: [9-in nom] Type of filler: <u>Not documented</u> Elevation/depth top of seal Type of seal: <u>Not documented</u> Depth top of perforations: [190-ft] Description of perforations: <u>Original not documented</u> <u>14-15 May 48, not documented</u> <u>04 Sep 56, 190-270-ft, 3 holes/ft/rd</u> Depth bottom of perforations: [270-ft] Depth bottom of casing [303-ft] Depth bottom of borehole: [305-ft]				
Drawing By: RKL/2W10-01.ASB Date: 16Apr93 Reference: HANFORD WELLS						

WELL CONSTRUCTION AND COMPLETION SUMMARY			
Drilling Method: Cable tool Drilling Fluid Used: Water Driller's Name: Gantz Drilling Company: Not documented Date Started: 14Oct52	Sample Method: Hard tool non Additives Used: Not documented WA State Lic Nr: Not documented Company Location: Not documented Date Complete: 10Nov52	WELL NUMBER: 299-W10-4 Hanford Coordinates: N/S N 43,036.3 E/W W 75,976.7 State NAD83 N 136,578.25m E 556,734.98m Coordinates: N 448,143 E 2,219,247 Start Card #: Not documented T R S Elevation Ground surface (ft): 669.78 Brass cap	
Depth to water: 200-ft Sep56 (Ground surface) 206.6-ft Jan92			
GENERALIZED STRATIGRAPHY Driller's Log	<div style="display: flex; align-items: center;"> <div style="flex: 1; border-left: 1px solid black; border-right: 1px solid black; position: relative; height: 300px; margin: 0 10px;"> <!-- Well diagram representation --> </div> <div style="flex: 2;"> <p>Elevation of reference point: [670.67-ft] (top of casing)</p> <p>Height of reference point above [0.89-ft] ground surface</p> <p>Depth of surface seal [ND]</p> <p>Type of surface seal: <u>None documented</u></p> <p>I.D. of surface casing [10-in nom] (21.5-ft starter pipe assumed pulled)</p> <p>I.D. of riser pipe: [8-in] Type of riser pipe: <u>Carbon steel</u></p> <p>Diameter of borehole: [9-in nom]</p> <p>Type of filler: <u>Not documented</u></p> <p>Elevation/depth top of seal Type of seal: <u>Not documented</u></p> <p>Depth top of perforations: [190-ft] Description of perforations: <u>190-200-ft, 3 holes/ft/rd</u> <u>200-245-ft, not documented</u></p> <p>Depth bottom of perforations: Depth bottom of casing: [245-ft] Depth bottom of borehole:</p> </div> </div>		
0-10: SAND, SILT and GRAVEL 10-20: Pure GRAVEL, caves easy 20-29: Coarse GRAVEL 29-35 BOULDERS and GRAVEL 35-47: Coarse GRAVEL 47-54: GRAVEL 54-65: GRAVEL, SAND and SILT 65-70: SAND and SILT 70-88: SAND and a little SILT 88-90: Pure SAND, caved 90-100: SAND, SILT and CLAY 100-110: CALICHE, SAND and SILT 110-115: SAND and SILT 115-125: SAND, SILT and CLAY 125-131: SAND and SILT 131-132: Pure SAND, caves easy 132-135: Coarse GRAVEL 135-140: BOULDERS and GRAVEL 140-150: GRAVEL and SAND 150-159: SAND and GRAVEL 159-165: Coarse GRAVEL and SAND 165-175: GRAVEL and BOULDERS 175-180: GRAVEL and SAND 180-190: Coarse GRAVEL with a little SAND and SILT 190-205: GRAVEL, SAND and SILT 205-225: SAND, SILT, and GRAVEL 225-230: Coarse GRAVEL, SAND and SILT 230-235: Coarse SAND 235-240: Pea GRAVEL 240-245: GRAVEL			
REMEDIATION: 04-05Sep56 Wall-Richards Perforated 190-200-ft Well was "hot." Required RM coverage			
Drawing By: RKL/2W10-04.ASB Date: 16Apr93 Reference: HANFORD WELLS			

WELL CONSTRUCTION AND COMPLETION SUMMARY			
Drilling Method: Cable tool Drilling Fluid Used: Water Driller's Name: Evans/Bigham Drilling Company: Hatch Date Started: 14Jun73	Sample Method: Hard tool (nom) Additives Used: Not documented WA State Lic Nr: Bigham-0036 Company Location: Pasco, WA Date Complete: 27Jun73	WELL NUMBER: 299-W10-8 Hanford Coordinates: N/S N 43,800.2 E/W W 75,600.1 State NAD83 N 136,811.3m 566,849.2m Coordinates: N 448,908 E 2,219,613 Start Card #: Not documented T R S Elevation Ground surface (ft): 677.2 Estimated	TEMPORARY WELL NO: 2997
Depth to water: 214 ft Jun73 (Ground surface) 215.5-ft 26Mar93		Elevation of reference point: [680.05-ft] (top of casing) Height of reference point above [2.83-ft] ground surface	
GENERALIZED STRATIGRAPHY Geologist's Log		Depth of surface seal [ND] Type of surface seal: None documented	
0-5: Gravelly, silty SAND 5-49: Gravelly, sandy SILT 49-60: Silty, gravelly SAND 60-65: Sandy GRAVEL 65-80: Silty SAND 80-83: Clayey, sandy SILT 83-85: SAND 85-95: Clayey, sandy SILT 95-125: Sandy CALICHE 125-138: Sandy SILT 138-148: Sandy, silty GRAVEL 148-168: Silty, sandy CLAY 168-175: Sandy, gravelly SILT 168-185: Silty, sandy GRAVEL 185-235: Silty, gravelly SAND 235-240: Silty SAND 240-252: Very silty SAND		I.D. of surface casing [ND] (if present)	
		I.D. of riser pipe: [6-in] Type of riser pipe: <u>Carbon steel</u>	
		Diameter of borehole: [7-in nom]	
		Type of filler: <u>Not documented</u>	
		Depth bottom of casing: [210-ft] Casing pulled back from total depth	
		Screen 40-ft of #10 slot from 205-251-ft, screened interval assumed 211-251-ft	
		Depth bottom of borehole [252-ft]	
Drawing By: RKL/2W10-08.ASB Date: 16Apr93			
Reference: HANFORD WELLS			

0500652

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable Tool	Sample Method: Grab/Split Spoon	WELL NUMBER: 299-W10-22	TEMPORARY WELL NO: None
Drilling Fluid Used: NA	Additives Used: None	Coordinates: N	Not documented
Driller's Name: D. Ludke	WA State Lic Nr: Not Available	Coordinates: E	Not documented
Drilling Company: KEH Constr. Forces	Company Location: Hanford	Start Card #: Not Available	
Date Started: 09Aug94	Date Completed: 02Oct94	Elevation Ground Surface:	

Depth to Water: 218.43 ft 01Sep94 (Ground surface) 219.2 ft 10Sep94	Elevation of Reference Point: m
GENERALIZED STRATIGRAPHY	Geologist's Log

Fill	Casing	Screen
0 - 9.9 ft : 13-inch hole	0 - 9.9 ft : 12-3/4" CS Temp.	
9.9 - 10.4 ft : Cement	10.4 - 76 ft : 4" Perm. Casing	
10.4 - 76 ft : 11-inch hole	76 - 80 ft : 10-3/4" CS Temp.	
76 - 80 ft : Cement	80 - 95.95 ft : 9 inch	
80 - 95.95 ft : 11-inch hole	95.95 - 97.3 ft : 9-inch hole	
95.95 - 97.3 ft : Cement	97.3 - 209.1 ft : 9-inch hole	
97.3 - 209.1 ft : Bentonite Hole	209.1 - 212 ft : 9-inch hole	
209.1 - 212 ft : Bentonite Pellets	212 - 245.8 ft : 9-inch hole	
212 - 245.8 ft : 20-40 Silica Sand	245.8 - 247.6 ft : 9-inch hole	
245.8 - 247.6 ft : 8-12 Silica Sand	247.6 - 295.5 ft : 9-inch hole	
247.6 - 295.5 ft : Bentonite Hole	295.5 - 300 ft : 9-inch hole	
295.5 - 300 ft : Plug		
300 ft : Slough		

300 ft : Borehole drilled depth

0 - 9.9 ft : 13-in. 12-3/4" CS Temp. Casing

9.9 - 95.95 ft : 11-in. 10-3/4" CS Temp. Casing

95.95 - 300 ft : 9-in. 8-5/8" CS Temp. Casing

Drawing By: DLF
Reference: Hanford Wells
Revision: 0
Revision Date: 29Dec97
Print Date: 29Dec97

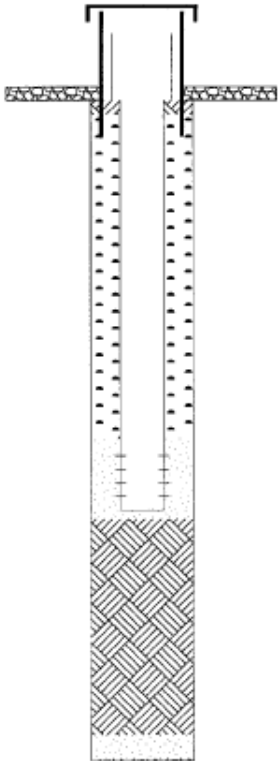

Report Form: WELLS Project File: WELLS.GPJ

0512638

WELL CONSTRUCTION AND COMPLETION SUMMARY																											
Drilling Method: Air Rotary - TUBEX Drilling Fluid Used: Reverse Air Driller's Name: Willie Franklin Drilling Company: Layne Christensen Date Started: 12Aug98	Sample Method: Grab/Spill Spoon Additives Used: None WA State Lic No.: 1429 Company Location: Salt Lake City, Ut Date Completed: 19Aug98	WELL NUMBER: 299-W10-23 TEMPORARY WELL NO: Not Allowed Coordinates: N Not documented Coordinates: E Not documented Start Card #: Not Available Elevation Ground Surface: Brass Marker																									
Depth to Water: 223.61 ft 19Aug98 GENERALIZED STRATIGRAPHY Geologist's Log & Geophysical Logs		Elevation of Reference Point: m Height of Reference Point Above Ground Surface: Depth of Surface Seal: 5 ft. Type of Surface Seal: 4x4 Concrete Pad																									
<div style="display: flex;"> <div style="flex: 1;"> <p>0 - 9 ft : Silty Sand</p> <p>9 - 20 ft : Sandy gravel</p> <p>20 - 34 ft : Sandy gravel</p> <p>34 - 36 ft : Silty sand</p> <p>36 - 43.5 ft : Sandy gravel</p> <p>43.5 - 48 ft : Sand</p> <p>48 - 52 ft : Gravelly sand</p> <p>52 - 56 ft : Sand</p> <p>56 - 75 ft : Gravelly sand</p> <p>75 - 80 ft : Sand</p> <p>80 - 106 ft : Silty sand - calcareous (98-99: Fine gravel; 101-106: Brittle caliche)</p> <p>106 - 114 ft : Sand, calcareous</p> <p>114 - 123 ft : Silty sand</p> <p>123 - 131 ft : Thin beds cse sand & silty sand</p> <p>131 - 149 ft : Silty sandy gravel</p> <p>149 - 173 ft : Sandy gravel</p> <p>173 - 198 ft : Silty sandy gravel</p> <p>198 - 208 ft : Sandy gravel</p> <p>208 - 256 ft : Silty sandy gravel</p> <p>256 - 258 ft : Sand</p> <p>258 - 272 ft : Silty sandy gravel</p> </div> <div style="flex: 1; text-align: center;"> </div> </div>		<table border="0" style="width: 100%;"> <thead> <tr> <th style="text-align: left;">Fill</th> <th style="text-align: left;">Casing</th> <th style="text-align: left;">Screen</th> </tr> </thead> <tbody> <tr> <td>0 - 5 ft : 9.125-inch hole Cement Seal</td> <td>0 - 225.78 ft : 4 inch 4" SS Well Csg.</td> <td></td> </tr> <tr> <td>5 - 214.4 ft : 9.125-inch hole Medium Bentonite Chips</td> <td></td> <td></td> </tr> <tr> <td>214.4 - 220.3 ft : 9.125-inch hole 1/4" Bentonite Pellets</td> <td></td> <td>225.78 - 260.88 ft : 4 inch 4" .010 Slot Wire Wrap SS Screen</td> </tr> <tr> <td>220.3 - 260.88 ft : 9.125-inch hole 20-40 Mesh Silica Sand</td> <td></td> <td></td> </tr> <tr> <td>260.88 - 261.21 ft : 9.125-inch hole 20-40 Mesh Silica Sand</td> <td></td> <td></td> </tr> <tr> <td>261.21 - 267 ft : 9.125-inch hole 4 inch 4" SS End Cap</td> <td></td> <td></td> </tr> <tr> <td>267 - 272 ft : 9.125-inch hole</td> <td></td> <td></td> </tr> </tbody> </table>		Fill	Casing	Screen	0 - 5 ft : 9.125-inch hole Cement Seal	0 - 225.78 ft : 4 inch 4" SS Well Csg.		5 - 214.4 ft : 9.125-inch hole Medium Bentonite Chips			214.4 - 220.3 ft : 9.125-inch hole 1/4" Bentonite Pellets		225.78 - 260.88 ft : 4 inch 4" .010 Slot Wire Wrap SS Screen	220.3 - 260.88 ft : 9.125-inch hole 20-40 Mesh Silica Sand			260.88 - 261.21 ft : 9.125-inch hole 20-40 Mesh Silica Sand			261.21 - 267 ft : 9.125-inch hole 4 inch 4" SS End Cap			267 - 272 ft : 9.125-inch hole		
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<p>272 ft : Borehole drilled depth</p> <p>0 - 272 ft : 9.125-in. 8-5/8" Temp. carbon steel csg.</p>		<div style="border: 1px solid black; padding: 5px;"> <p>Drawing By: TGB</p> <p>Reference: Hanford Wells</p> <p>Revision: 0</p> <p>Revision Date: 21Sep98</p> <p>Print Date: 03Nov99</p> </div> <div style="text-align: right; margin-top: 10px;"> </div>																									

Report Form: WELLS Project File: WELLS.GPJ

0502369

WELL CONSTRUCTION AND COMPLETION SUMMARY																																			
Drilling Method: Air Rotary - TUBEX Drilling Fluid Used: Reverse Air Driller's Name: Randy Wraspir Drilling Company: Layne Christensen Date Started: 07Oct98	Sample Method: Grab/Spill Spoon Additives Used: None WA State Lic Nr: Not Available Company Location: Salt Lake City, UT Date Completed: 21Oct98	WELL NUMBER: 299-W10-24 TEMPORARY WELL NO: B8546 Coordinates: N: Not documented Coordinates: E: Not documented Start Card #: Not Available Elevation Ground Surface: Brass Marker																																	
Depth to Water: 231.41 ft 21Oct98 (Ground surface) GENERALIZED STRATIGRAPHY		Elevation of Reference Point: m Height of Reference Point Above Ground Surface: Depth of Surface Seal: 9.1 ft Type of Surface Seal: 4x4 Concrete Pad																																	
Geologist's Log & Geophysical Logs 0 - 2 ft : Backfill - cobbles, sand, & silt 2 - 5 ft : Silty Sandy Gravel (msG) 5 - 7 ft : Sased (s) 7 - 36 ft : Silty Sandy Gravel 36 - 39 ft : Gravelly Sand (gs) 39 - 42 ft : Sandy Gravel (sG) 42 - 59 ft : Sand 59 - 83.2 ft : Sandy Gravel 83.2 - 94 ft : Silty Sand (mS) 94 - 98 ft : Sand 98 - 108 ft : Calciche (calc. sand) 108 - 119 ft : Sand 119 - 128 ft : Sand 128 - 148 ft : Sandy Gravel 148 - 190 ft : Silty Sandy Gravel 190 - 228 ft : Silty Sandy Gravel 228 - 305 ft : Sandy Gravel 305 - 355 ft : Gravel (G) 355 - 409 ft : Sandy Gravel 409 - 413 ft : SIL (M) 413 - 432.5 ft : Gravel (G)																																			
		<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="text-align: left;">Fill</th> <th style="text-align: left;">Casing</th> <th style="text-align: left;">Screen</th> </tr> </thead> <tbody> <tr> <td>0 - 9.1 ft : 9.125-inch hole Cement Surface Seal</td> <td>0 - 232.94 ft : 4 inch Sch. 5 SS Csg.</td> <td></td> </tr> <tr> <td>9.1 - 218.5 ft : 9.125-inch hole Med. Bentonite Chunks</td> <td></td> <td></td> </tr> <tr> <td>218.5 - 221 ft : 9.125-inch hole 3/8" Bentonite Pellets (Pel Plug)</td> <td></td> <td>232.94 - 268.03 ft</td> </tr> <tr> <td>221 - 260.2 ft : 9.125-inch hole 20/40 Silica Sand</td> <td></td> <td>4 inch 4" SS Wire Wrap 010 Slot Screen</td> </tr> <tr> <td>260.2 - 268.35 ft : 9.125-inch hole 10/20 and 8/16 Silica Sand</td> <td>268.03 - 268.35 ft : 4 inch 4" SS End Cap</td> <td></td> </tr> <tr> <td>268.35 - 274 ft : 9.125-inch hole 10/20 and 8/16 Silica Sand</td> <td></td> <td></td> </tr> <tr> <td>274 - 415.6 ft : 9.125-inch hole Cement Grout Seal</td> <td></td> <td></td> </tr> <tr> <td>415.6 - 431.5 ft : 9.125-inch hole 10/20 Silica Sand</td> <td></td> <td></td> </tr> <tr> <td>431.5 - 432.5 ft : 9.125-inch hole Slough</td> <td></td> <td></td> </tr> </tbody> </table>				Fill	Casing	Screen	0 - 9.1 ft : 9.125-inch hole Cement Surface Seal	0 - 232.94 ft : 4 inch Sch. 5 SS Csg.		9.1 - 218.5 ft : 9.125-inch hole Med. Bentonite Chunks			218.5 - 221 ft : 9.125-inch hole 3/8" Bentonite Pellets (Pel Plug)		232.94 - 268.03 ft	221 - 260.2 ft : 9.125-inch hole 20/40 Silica Sand		4 inch 4" SS Wire Wrap 010 Slot Screen	260.2 - 268.35 ft : 9.125-inch hole 10/20 and 8/16 Silica Sand	268.03 - 268.35 ft : 4 inch 4" SS End Cap		268.35 - 274 ft : 9.125-inch hole 10/20 and 8/16 Silica Sand			274 - 415.6 ft : 9.125-inch hole Cement Grout Seal			415.6 - 431.5 ft : 9.125-inch hole 10/20 Silica Sand			431.5 - 432.5 ft : 9.125-inch hole Slough		
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Drawing By: JEA Reference: Hanford Wells Revision: 0 Revision Date: 22Oct98 Print Date: 28Dec98																																			

Report Form: WELLS - Project File: WELLS.GPJ

0540437

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable Tool	Sample Method: Grab/Split Spoon	WELL NUMBER: 299-W10-28	TEMPORARY WELL NO: C3400	Not Allowed
Drilling Fluid Used: none	Additives Used: none reported	Coordinates: N Not documented		
Driller's Name: G. Howell	WA State Lic. Nr: 1930	Coordinates: E Not documented		
Drilling Company: RSI	Company Location: Woodland, Ca.	Start Card #: R037816		
Date Started: 10Sep01	Date Completed: 17Oct01	Elevation Ground Surface:		

Depth to Water: 225.51 ft	17Oct01	Elevation of Reference Point: m
(Ground surface)		
GENERALIZED STRATIGRAPHY	Geologist's Log	


Fill	Casing	Screen
0 - 10.3 ft : 11-inch hole Cement Surface Seal	0 - 225.19 ft : 4 inch 304L SS sch 5 csg	
10.3 - 111 ft : 11-inch hole Granular Bentonite		
111 - 209.4 ft : 9-inch hole Granular Bentonite		
209.4 - 215.3 ft : 9-inch hole 3/8" Bentonite pELLETS		225.19 - 260.19 ft : 4 inch 304L SS Wire Wrap .020 slot scrm
215.3 - 262.19 ft : 9-inch hole 10/20 Silica Sand		
262.19 - 271.6 ft : 9-inch hole 10/20 Silica Sand	260.19 - 262.19 ft : 4 inch 304L SS Sump	
271.6 - 273.9 ft : 9-inch hole 3/8" Bentonite Hole Plug		
273.9 - 278.3 ft : 9-inch hole 10/20 Silica Sand		
278.3 - 280 ft : 9-inch hole Slough		

280 ft : Borehole drilled depth

0 - 111 ft : 11-in. Cable Tool 10-5/8" CS Temp csg

111 - 280 ft : 9-in. Cable Tool 8-5/8" CS Temp csg

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 08Nov01
Print Date: 08Nov01



WELL CONSTRUCTION AND COMPLETION SUMMARY			
Drilling Method: Cable tool	Sample Method: Hard tool non	WELL NUMBER: 299-W11-7	TEMPORARY WELL NO: 361-T-19
Drilling Fluid Used: Water	Additives Used: Not documented	Hanford Coordinates: N/S N 43,350 E/W W 74,251	State
Driller's Name: Row	WA State Lic Nr: Not documented	Coordinates: N 448,461 E 2,220,963	Start
Drilling Company: Not documented	Location: Not documented	Card #: Not documented	T R S
Date Started: 23Jul51	Date Complete: 17Sep51	Elevation Ground surface (ft): 708.1	Estimated
Depth to water: 267-ft Sep51 (Ground surface) 247.4-ft 08Dec92		Elevation of reference point: [709.11-ft] (top of casing) Height of reference point above [1.0-ft] ground surface	
GENERALIZED STRATIGRAPHY	Driller's Log	Depth of surface seal [ND] Type of surface seal: None documented I.D. of surface casing [ND] (None documented)	
0-6: GRAVEL and TOPSOIL		I.D. of riser pipe: [8-in] Type of riser pipe: Carbon steel	
6-9: BOULDER (4-ft thick)		Diameter of borehole: [9-in nom]	
9-15: GRAVEL, black SAND		Type of filler: Not documented	
15-33: SAND and GRAVEL, no SILT		Elevation/depth top of seal Type of seal: Not documented	
33-58: GRAVEL and black and white SAND layers of SILT		Depth top of perforations: [245-ft] Description of perforations: 245-290-ft, 4 holes/ft	
58-70: SAND		Depth bottom of perforations: [290-ft]	
70-75: SAND and a showing of SILT		Depth bottom of casing: [310.5-ft]	
75-85: SAND and more SILT		Depth bottom of borehole [315-ft]	
85-105: SAND and fine GRAVEL, very little SILT			
105-130: Heavy SILT bed			
130-139: Heavy CALICHE bed with fine GRAVEL and SAND			
139-145: GRAVEL, SAND & very little SILT			
145-153: SAND and very little SILT			
153-160: Sandy SILT			
160-165: GRAVEL and SILT			
165-178: Pure GRAVEL, no SILT			
178-182: Pure fine basalt SAND & GRAVEL			
182-187: SAND and GRAVEL, some binder			
187-195: GRAVEL, SAND and some binder			
195-197: GRAVEL and SAND, caves			
197-207: GRAVEL, SAND and some SILT			
207-218: GRAVEL, SAND and some binder			
218-254: GRAVEL, SAND and SILT			
254-259: GRAVEL and SAND, no SILT			
259-260: Coarse GRAVEL			
260-277: GRAVEL, SAND and SILT (Hit water at 260-ft, rose to 251-ft, possible perched)			
277-280: SAND, caves			
280-284: GRAVEL, SAND and SILT			
284-286: GRAVEL, caves			
286-295: GRAVEL, SAND and SILT			
295-297: White SAND			
297-310: White Sand, GRAVEL and SILT			
310-315: GRAVEL, SAND and SILT			
315 : Good water GRAVEL			
Drawing By: RKL/2W11-07.ASB Date: 16Apr93		Reference: HANFORD WELLS	

WELL CONSTRUCTION AND COMPLETION SUMMARY			
Drilling Method: Cable tool Drilling Fluid Used: Not documented Driller's Name: Gentz Drilling Company: Not documented Date Started: 02Feb53	Sample Method: Hard tool (nom) Additives Used: Not documented WA State Lic Nr: Not documented Company Location: Not documented Date Complete: 21Dec53	WELL NUMBER: 299-W11-12 Hanford Coordinates: N/S N 43,119.3 E/W W 75,345.9 State NAD83 N 136,604.01m E 566,927.14m Coordinates: N 448,206 E 2,219,875 Start Card #: Not documented T R S Elevation Ground surface (ft): 678.5 Estimated	
Depth to water: 210-ft Sep56 (Ground surface) 216.6-ft 04Dec92 GENERALIZED Driller's STRATIGRAPHY Log		Elevation of reference point: [679.26-ft] (top of casing) Height of reference point above [0.8-ft] ground surface I Depth of surface seal [ND] Type of surface seal: None documented I.D. of surface casing [ND] (if present) I.D. of riser pipe: [8-in] Type of riser pipe: Carbon steel Diameter of borehole: [9-in nom] Type of filler: Not documented Depth top of perforations: [200-ft] Description of perforations: 200-210-ft, not documented 210-250-ft, not documented Depth bottom of perforations: [250-ft] Depth bottom of casing: [250-ft] Depth bottom of borehole: [250-ft]	
0-8: Fine SAND 8-30: Coarse GRAVEL and fine SAND 30-45: Fine SAND 45-55: Fine and coarse SAND 55-70: Fine SAND 70-80: Fine and coarse SAND 80-95: Fine and coarse SAND, little SILT 95-103: SAND and SILT 103-127: SAND and SILT, CALICHE and GRAVEL 127-135: GRAVEL, COBBLES, SAND 135-145: BOULDERS and GRAVEL, little SAND 145-185: COBBLES and GRAVEL with some SAND 185-195: GRAVEL and SAND 195-200: GRAVEL, little SILT 200-245: GRAVEL, SAND and SILT 245 : GRAVEL and SAND 245-250: Not documented REMEDIATION: Sep56, by Wall/Richards Cleaned out and perforated 200-210-ft.			
Drawing By: RKL/2W11-12.ASB Date: 16Apr93 Reference: HANFORD WELLS			

0532876

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable Tool	Sample Method: Grab/Spit Spoon	WELL NUMBER: 299-W11-39	TEMPORARY WELL NO: C3117	Not Allowed
Drilling Fluid Used: none	Additives Used: None	Coordinates: N	Not documented	
Driller's Name: M. Waspir	WA State Lic No: 1909	Coordinates: E	Not documented	
Drilling Company: RSI	Company Location: Woodland, Ca.	Start Card #: Not Available		
Date Started: 09Nov00	Date Completed: 18Dec00	Elevation Ground Surface:		

Depth to Water: 237.31 ft 18Dec00 (Ground surface)	Elevation of Reference Point: m
GENERALIZED STRATIGRAPHY	Geologist's Log

Fill	Casing	Screen
0 - 5.5 ft : Backfill	0 - 10.9 ft : 12-inch hole	0 - 238.6 ft : 4 inch
5.5 - 33.5 ft : Sandy GRAVEL	Cement Surface Seal	4" 304 SS sch 5 csg.
33.5 - 57 ft : Gravelly SAND	10.9 - 50.94 ft : 12-inch hole	
57 - 63 ft : SAND	Bentonite Chips	
63 - 82.5 ft : Gravelly SAND		
82.5 - 90 ft : SAND	50.94 - 96.5 ft : 9-inch hole	
90 - 112 ft : Silty SAND	Bentonite Chips	
112 - 127 ft : Slightly Silty SAND		
127 - 131 ft : Slightly Silty Gravelly SAND		
131 - 145 ft : Silty Sandy GRAVEL		
145 - 150 ft : Sandy GRAVEL		
150 - 265 ft : Silty Sandy GRAVEL (Sandy GRAVEL at 265)	96.5 - 222.47 ft : 9-inch hole	
	Granular Bentonite	
	222.47 - 227.15 ft : 9-inch hole	
	1/4" & 1/2" Bentonite pellets	
	227.15 - 275.66 ft : 4" SS Wire Wrap .020 Slot screen.	
265 - 282.31 ft : Silty Sandy GRAVEL	9-inch hole	238.6 - 273.66 ft : 4 inch
	10/20 Silica Sand	
	275.66 - 282.31 ft : 4 inch	
	9-inch hole	
	10/20 Silica Sand	4" SS Sump

282.31 ft : Borehole drilled depth

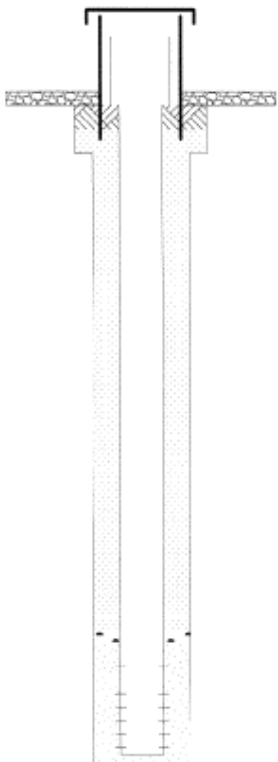

0 - 50.94 ft : 12-in. Cable Tool 11-3/4 CS Temp. csg.

50.94 - 282.31 ft : 9-in. Cable Tool 8-5/8 CS Temp. csg.

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 20Mar01
Print Date: 20Mar01

Report Form: WELLS - Project File: WELLS.GPJ

0532874

WELL CONSTRUCTION AND COMPLETION SUMMARY																																													
Drilling Method:	Cable Tool & A. R. Dri & Drive	Sample Method:	Grab/Spill Spoon																																										
Drilling Fluid Used:	Air	Additives Used:	None																																										
Driller's Name:	K. Cowden	WA State Lic No:	Not Available																																										
Drilling Company:	R&I	Company Location:	Woodland, Ca.																																										
Date Started:	28Sep00	Date Completed:	09Oct00																																										
WELL NUMBER: 299-W11-40		TEMPORARY WELL NO: C3118 Not Allowed																																											
Coordinates: N		Not documented																																											
Coordinates: E		Not documented																																											
Start Card #:		Not Available																																											
Elevation Ground Surface:																																													
Depth to Water: 237.05 ft 06Oct00		Elevation of Reference Point: m																																											
GENERALIZED STRATIGRAPHY		Geologist's Log																																											
<p>0 - 2 ft : Silty Sandy GRAVEL</p> <p>2 - 6.5 ft : Slightly Silty SAND</p> <p>6.5 - 32 ft : Sandy GRAVEL</p> <p>32 - 43 ft : SAND</p> <p>43 - 46 ft : Gravelly SAND</p> <p>46 - 64 ft : SAND</p> <p>64 - 70 ft : Gravelly SAND</p> <p>70 - 88 ft : SAND</p> <p>88 - 92 ft : Slightly Silty SAND</p> <p>92 - 103 ft : Sandy SILT</p> <p>103 - 117 ft : Gravelly Silty SAND</p> <p>117 - 122 ft : Gravelly SAND</p> <p>122 - 133 ft : Silty SAND</p> <p>133 - 142 ft : Silty Sandy GRAVEL</p> <p>142 - 163 ft : Sandy GRAVEL</p> <p>163 - 170 ft : Silty Sandy GRAVEL</p> <p>170 - 198 ft : Sandy GRAVEL</p> <p>198 - 222 ft : Silty Sandy GRAVEL</p> <p>222 - 280 ft : Sandy GRAVEL</p>																																													
		<p>Height of Reference Point Above Ground Surface:</p> <p>Depth of Surface Seal: 10.2 ft</p> <p>Type of Surface Seal: 4x4 Concrete Pad</p>																																											
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Report Form: WELLS Project File: WELLS.GPJ

0526560

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method:	Cable Tool/Air Rotary	Sample Method:	Grab/Spill Spoon	WELL NUMBER:	299-W11-41	TEMPORARY	C3119	WELL NO:	Not Allowed
Drilling Fluid Used:	NA/Air	Additives Used:	None	Coordinates N	Not documented				
Driller's Name:	M. Wraspir	WA State Lic Nr:	1909	Coordinates E	Not documented				
Drilling Company:	RBI	Company Location:	Woodland, Ca.	Start Card #:	R037802				
Date Started:	04Aug00	Date Completed:	22Aug00	Elevation Ground Surface:					

Depth to Water: 236.6 ft. ft 22Aug00
(Ground surface)

Elevation of Reference Point: m

GENERALIZED STRATIGRAPHY Geologist's Log

0 - 4 ft: Silty Sandy GRAVEL
 4 - 7 ft: Silty Sandy SAND
 7 - 33 ft: Silty Sandy GRAVEL

33 - 37 ft: Gravelly SAND
 37 - 39 ft: Sandy GRAVEL
 39 - 44 ft: SAND
 44 - 94 ft: Sand

94 - 98 ft: Silty SAND (calcareous)
 98 - 118 ft: Silty Sandy SAND - trace of caliche
 103-106 ft

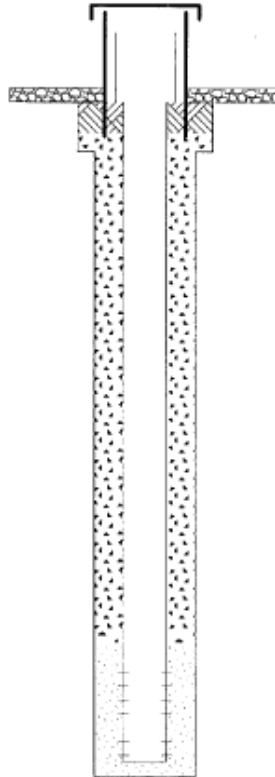
118 - 122 ft: SAND
 123 - 133 ft: Sandy SILT
 133 - 144 ft: Gravelly Silty SAND
 144 - 158 ft: Silty Sandy GRAVEL

158 - 169 ft: Sandy GRAVEL
 169 - 173 ft: Gravelly SAND
 173 - 188 ft: Sandy GRAVEL

188 - 208 ft: Silty Sandy GRAVEL
 208 - 213 ft: Sandy GRAVEL
 213 - 218 ft: Gravelly SAND
 218 - 246 ft: Sandy GRAVEL

246 - 270 ft: Silty Sandy GRAVEL

270 - 280 ft: Sandy GRAVEL



FW	Casing	Screen
0 - 12.9 ft: 12-inch hole Cement Surface Seal	0 - 236.7 ft: 4 inch 4" 304L SS Sch 5 csg	
12.9 - 20.6 ft: 12-inch hole Bentonite Crumbles		
20.6 - 218.6 ft: 9-inch hole Bentonite Crumbles		
218.6 - 226 ft: 9-inch hole Bentonite Pellets		
226 - 273.7 ft: 9-inch hole 10/20 Silica Sand		
273.7 - 280 ft: 9-inch hole 10/20 Silica Sand	271.7 - 273.7 ft: 4 inch 4" SS Sump	
		236.7 - 271.7 ft: 4 inch 4" 304L SS Wire Wrap .020 slot scrm.

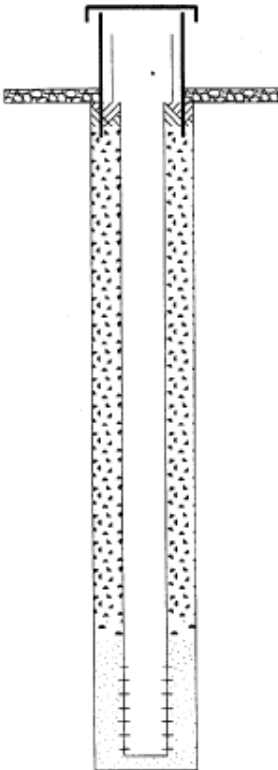

280 ft: Borehole drilled depth

0 - 20.6 ft: 12-in. 11-3/4" CS Temp. csg
 set w/Cable Tool
 20.6 - 280 ft: 9-in. 8-5/8" CS Temp. csg
 set w/Air Rotary csg hammer

Drawing By: JEA
 Reference: Hanford Wells
 Revision: 0
 Revision Date: 22Sep00
 Print Date: 22Sep00



Report Form: WELLS Project File: WELLS.GPJ

WELL CONSTRUCTION AND COMPLETION SUMMARY																								
Drilling Method: Air Rotary Csg. Hammer Drilling Fluid Used: Air Driller's Name: M. Wraspir Drilling Company: RSI Date Started: 16Sep00	Sample Method: Grab/Spill Spoon Additives Used: None WA State Lic Nr: 1909 Company Location: Woodland, Ca. Date Completed: 13Sep00	WELL NUMBER: 299-W11-42 TEMPORARY C3242 WELL NO: Not Allowed Coordinates: N Not documented Coordinates: E Not documented Start Card #: Not Available Elevation Ground Surface:																						
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<div style="border: 1px solid black; padding: 5px;"> 0 - 8 ft : Slightly Silty Gravel Sand (m)gS 8 - 39 ft : Sandy Gravel 39 - 62 ft : Slightly Silty Sand (m)S 62 - 69 ft : Sand S 69 - 74 ft : Gravelly Sand gS 74 - 91 ft : Slightly Silty Sand (m)S 91 - 100 ft : Silty Sand mS 100 - 117 ft : Slightly Silty Sand (m)S w/calcite 117 - 121 ft : Gravelly Sand gS 121 - 128 ft : Sandy Silty sM 128 - 134 ft : Slightly Silty Sand (m)S 134 - 140 ft : Silty Sandy Gravel msG 140 - 179 ft : Sandy Gravel sG 179 - 188 ft : Silty Sandy Gravel msG 188 - 200 ft : Sandy Gravel sG 200 - 223 ft : Silty Sandy Gravel msG 223 - 280 ft : Sandy Gravel sG </div>		<div style="border: 1px solid black; padding: 5px;"> <table style="width: 100%; border-collapse: collapse;"> <tr> <th style="text-align: left; padding: 2px;">Fill</th> <th style="text-align: left; padding: 2px;">Casing</th> <th style="text-align: left; padding: 2px;">Screen</th> </tr> <tr> <td style="padding: 2px;">0 - 10.2 ft : 9-inch hole</td> <td style="padding: 2px;">0 - 236.76 ft : 4 inch</td> <td></td> </tr> <tr> <td style="padding: 2px;">Cement Surface Seal</td> <td style="padding: 2px;">4" 304L SS Sch 5 Csg</td> <td></td> </tr> <tr> <td colspan="3" style="padding: 10px 0 0 0;"> 10.2 - 217.8 ft : 9-inch hole Bentonite Crumbles </td> </tr> <tr> <td colspan="3" style="padding: 10px 0 0 0;"> 217.8 - 225.5 ft : 9-inch hole Bentonite Pellets </td> </tr> <tr> <td colspan="3" style="padding: 10px 0 0 0;"> 225.5 - 273.77 ft : 9-inch hole 10/20 Silica Sand </td> </tr> <tr> <td colspan="3" style="padding: 10px 0 0 0;"> 273.77 - 280 ft : 9-inch hole 10/20 Silica Sand </td> </tr> </table> </div>		Fill	Casing	Screen	0 - 10.2 ft : 9-inch hole	0 - 236.76 ft : 4 inch		Cement Surface Seal	4" 304L SS Sch 5 Csg		10.2 - 217.8 ft : 9-inch hole Bentonite Crumbles			217.8 - 225.5 ft : 9-inch hole Bentonite Pellets			225.5 - 273.77 ft : 9-inch hole 10/20 Silica Sand			273.77 - 280 ft : 9-inch hole 10/20 Silica Sand		
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