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**Pacific Northwest  
National Laboratory**

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# Groundwater Quality Assessment Plan for Single-Shell Tank Waste Management Area U

R. M. Smith  
F. N. Hodges  
B. A. Williams

August 2001



Prepared for the U.S. Department of Energy  
under Contract DE-AC06-76RL01830

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Pacific Northwest National Laboratory  
Richland, Washington 99352

## Summary

Single-shell tank Waste Management Area U (WMA U) is in the 200 West Area on the Hanford Site. The area includes the U tank farm that contains 16 underground, single-shell tanks and their ancillary equipment and waste systems. WMA U is regulated under the *Resource Conservation and Recovery Act of 1976* (RCRA) as codified in 40 CFR Part 265, Subpart F and Washington's Hazardous Waste Management Act (HWMA, RCW 70.105) and its implementing requirements in the Washington State dangerous waste regulations (WAC 173-303-400).

Releases of hazardous wastes from WMA U have contaminated groundwater beneath the area. Therefore, WMA U is being assessed to determine the rate of movement and extent of the contamination released and to determine the concentrations in groundwater. The original finding of groundwater impact was determined from elevated specific conductance in downgradient well 299-W19-41. The elevated specific conductance was attributed to the nonhazardous constituents calcium, magnesium, sulfate, and chloride. Tank waste constituents nitrate and technetium-99 are also present as co-contaminants and have increased over the past several years; however, at concentrations well below the respective drinking water standards. Chromium concentrations in downgradient wells have generally exceeded background levels, but similar levels were also observed in upgradient well 299-W18-25 in early 2000 before it went dry.

The objective of this report is to present the current conceptual model for how and where contaminant releases have reached the water table and how that contamination has dispersed in the groundwater system. These efforts will achieve the requirements of a groundwater quality assessment under RCRA [40 CFR 265.93 (d)(4)]. On that basis, a monitoring schedule with appropriate analytes and proposals for new wells and tests are presented in this document.



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## 1.0 Introduction

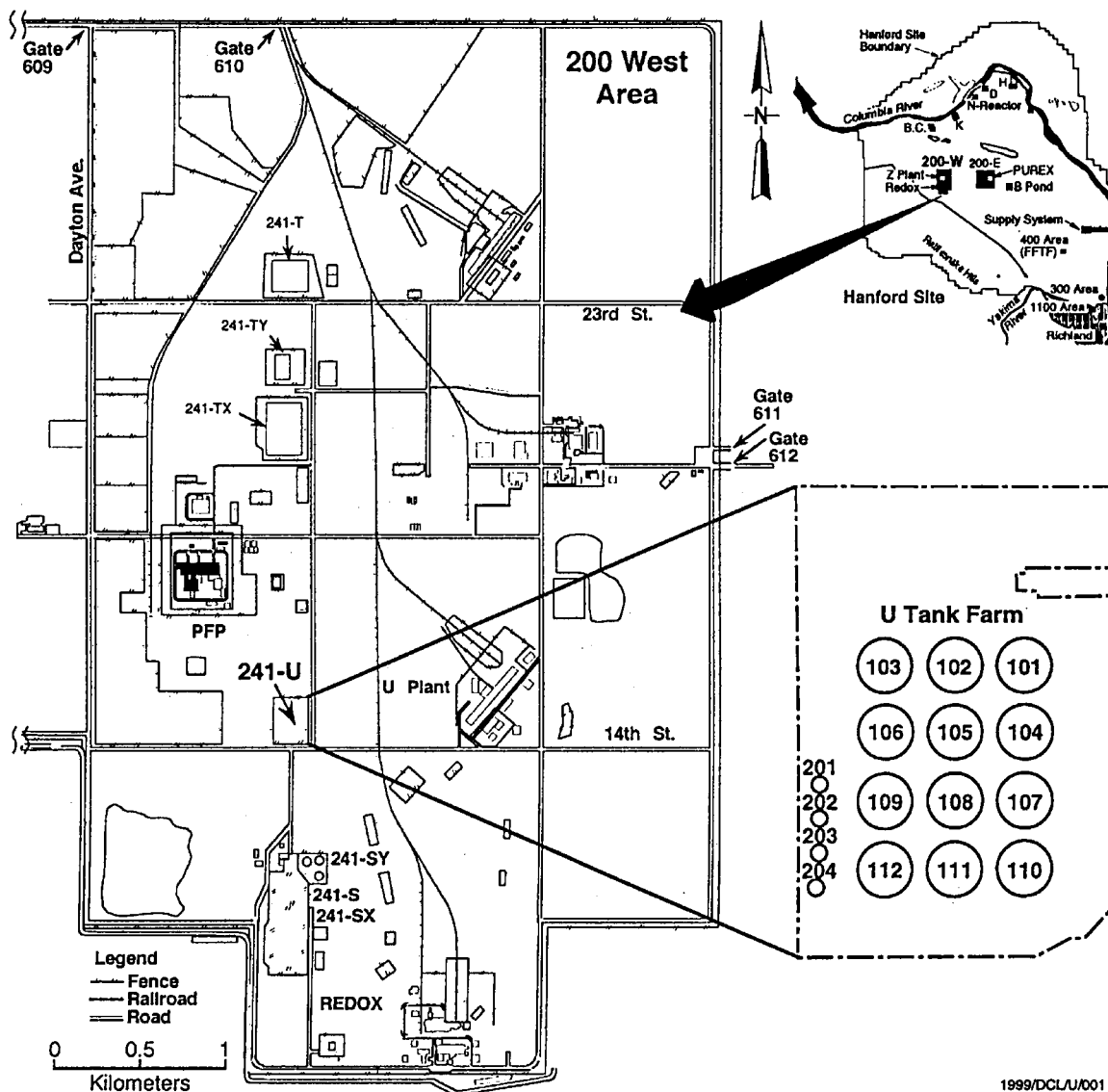
Single-shell tank Waste Management Area U (WMA U) consists of 16 single-shell underground tanks, 8 diversion boxes, and associated pipelines and valve boxes. In the normal operation of these structures, leaks and spills released hazardous and radioactive constituents into the surrounding soils. In 2000, the WMA U was determined to have affected groundwater quality (Hodges and Chou 2000); therefore, a plan must be prepared to determine the rate of contaminant migration and the extent of that impact. Specifically, the plan must describe the steps to delineate the concentrations of groundwater contamination and the rate and extent of contaminant migration. The ultimate goal of this work is to provide information necessary for decisions regarding control and remediation of WMA U impacts.

### 1.1 Regulatory Authority

WMA U, located on the Hanford Site (Figure 1.1), was used to store high-level radioactive liquid and entrained solid wastes. The Hanford Federal Facility Agreement and Consent Order (commonly known as the Tri-Party Agreement; Washington State Department of Ecology et al. 1989 as amended) placed WMA U under the authority of the *Resource Conservation and Recovery Act of 1976* (RCRA) interim status regulation. The Tri-Party Agreement also placed the interim status sites under the supervision of the Washington State Department of Ecology. In accordance with these decisions, WMA U is now regulated under RCRA interim status regulations as codified in 40 CFR Part 265, Subpart F and Washington State dangerous waste regulations (WAC 173-303-400).

The U.S. Department of Energy (DOE) submitted a RCRA Part A (interim status) permit application and closure/work plan in 1989 to include all RCRA facilities at Hanford. Since that time, some RCRA sites have been included in the RCRA Part B (final status) permit. As prescribed under Tri-Party Agreement Major Milestone M-45-00, single-shell tank farm WMAs will be closed in accordance with WAC 173-303-610, but the tanks will remain and be closed under interim status regulations. The time and method of closure are uncertain, but the current version of the milestone requires closure of all single-shell tank farms by the end of FY 2024. In the meantime, groundwater beneath the WMA U must continue to be monitored.

Starting in 1991, groundwater beneath WMA U was monitored by an interim status indicator evaluation system that compared concentrations of contamination indicator parameters in downgradient wells to background concentrations of the same constituents established from upgradient wells. Groundwater flow directions changed approximately 180° twice since 1991 and background concentrations were reestablished to accommodate those changes. The most recent recalculation was done in August 1999. At that time, one of the indicator parameters, specific conductance, exceeded its background value in one downgradient well, 299-W19-41, triggering a change from detection monitoring to a groundwater quality assessment (Hodges and Chou 2000).



**Figure 1.1.** Location of Waste Management Area U in the 200 West Area of the Hanford Site

Major contributors to the higher downgradient-specific conductance are nonhazardous constituents, including calcium, magnesium, sulfate, and chloride. Nitrate and technetium-99 are also present as co-contaminants and have increased over the past several years, however, at concentrations well below their respective drinking water standards. Chromium and nitrate concentrations in downgradient wells have generally exceeded background levels, but similar levels were also observed in upgradient well 299-W18-25 in early 2000 before it went dry. The higher upgradient chromium concentrations were accompanied by elevated nickel, iron, manganese, chloride, and turbidity, of which only chloride was elevated in downgradient wells.

## **1.2 Objective of the Plan**

The objective of this plan is to delineate specific actions necessary to determine the rate and extent of migration of hazardous wastes constituents and the concentrations of those constituents in the groundwater. Specific actions include well drilling, hydrologic characterization to determine groundwater flow direction and velocity, and groundwater quality characterization to delineate the extent and concentrations of specific hazardous and radioactive contaminants.

## **1.3 Organization of the Plan**

The plan is organized as follows:

- Chapter 1.0 – Introduction
- Chapter 2.0 – Background including a brief description of facilities in the WMA U, associated operations, waste characteristics, site geology, and hydrology as they impact contaminant migration, and a summary of known vadose zone contamination from spectral gamma logging
- Chapter 3.0 – Groundwater Quality including our current understanding of groundwater quality beneath the WMA and a description of conceptual models by which contaminants from the WMA have and may in the future impact groundwater quality
- Chapter 4.0 – Data Needs required to characterize the rate of movement and extent of contamination and contaminant concentrations
- Chapter 5.0 – Groundwater Assessment Plan presenting specific actions to collect those data identified in Chapter 4.0
- Chapter 6.0 – Quality Assurance
- Chapter 7.0 – References
- Appendix A contains a supporting hydrology letter report
- Appendix B provides as-built drawings for the existing monitoring wells.

## 2.0 Background

### 2.1 Facility Description

WMA U occupies an area of  $\sim 30,000 \text{ m}^2$  and contains 16 underground single-shell tanks constructed between 1943 and 1944 (Figure 2.1). Twelve tanks (U-101 through U-112) have capacities of 2,017,000 L and four tanks (U-201 through U-204) have capacities of 208,000 L. In addition to the tanks, eight diversion boxes, four valve boxes, and associated underground piping are included in the WMA.

The tanks consist of a reinforced concrete tank with a carbon steel liner that extends across the bottom of the tanks and approximately 6 m up the walls of the tanks. The concrete dome top is unlined. The larger tanks are 22.9 m in diameter and are  $\sim 9$  m in height. The bottom of the tanks are  $\sim 11$  m below grade with  $\sim 2$  m of fill over the top. Various ports in the tank tops are available for waste transfer and monitoring. In addition, vadose zone monitoring wells (dry wells) are located in the fill material around the tanks to allow monitoring of radionuclide migration around the tanks using geophysical (gamma logging) methods. The smaller tanks are 6.1 m in diameter and 7.8 m in height. The bottom of the smaller tanks are at  $\sim 11.3$  m below grade with  $\sim 3.6$  m of fill over the top. Buried waste transfer lines run into the farm to diversion boxes where wastes were routed to various tanks through valve boxes.

### 2.2 Operational History

The tanks began receiving waste in 1946 (Anderson 1990) and were in more-or-less continual use from that time until 1980. A more detailed history of operations is presented in Hodges and Chou (2000).

Four of the tanks in the WMA have been declared leakers based on liquid losses and, in the case of tank U-104, a known tank rupture (Anderson 1990; DOE 1992; Hanlon 1996). Information about these leaks is presented in Table 2.1. There is considerable uncertainty in the reported leak volumes, but it is believed that this waste liquid constitutes part of the source of contaminants that have affected groundwater quality. All four tanks have been stabilized and contain little or no pumpable liquid.

In addition to the leaks, three unplanned releases have been documented (DOE 1992). The releases were at ground surface or near surface and waste volumes associated with these unplanned releases are unknown. The releases may have resulted in significant spread of contamination. One release consisted of beta contamination of up to 20 mR/hr at the surface in the vicinity of the 241-U-151 and 241-U-152 diversion boxes east of the south end of the WMA (UN-200-W-6) in 1950. The second release consisted of a “violent chemical reaction” in a blending tank in the 244-UR vault located on the north end of the WMA that spread first-cycle metal waste contamination over an unspecified area (UPR-200-W-24) in 1953. This release continued to spread to the north beyond the fence where it is roped off and identified as a radiation area. The third release involved a ruptured buried waste line at tank U-103 (UPR-200-W-128) in 1971. DOE (1997) reported significant surface contamination within the tank farm and evidence for several additional unreported releases.



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**Table 2.1.** Summary of Tank Leaks at Waste Management Area U

Tank	Location in WMA	Date Leak Declared	Estimated Leak Volume (L)
U-101	NE Corner	1959	114,000
U-104	E Central	1954	208,000
U-110	SE Corner	1975	31,000
U-112	SW Corner	1969	32,000

The 216-U-13 trench, located immediately west of the tank farm fence (see Figure 2.1), was used for steam cleaning and decontaminating vehicles and never received tank waste. Contaminated soil was removed from the trench and backfilled with clean fill (DOE 1992).

## 2.3 Waste Characteristics

A description of wastes sent to the U tank farm is presented in Hodges and Chou (2000), but Table 2.2 is repeated here to document the chemicals and radionuclides present in the WMA. Table 2.2 presents average concentrations for selected components in the waste at WMA U and ratios of their concentrations to drinking water standards or maximum contaminant levels. These unweighted averages represent bulk tank concentrations and do not distinguish between liquid and solid phases within the tanks and, therefore should be used only as a gross indication of tank concentrations. Considerable effort has been expended over the past 5 years to develop best-basis inventory estimates for the contents of all 177 Hanford waste tanks. Table 2.2 presents the constituents that could appear in the groundwater from an impact attributable to the WMA. Major chemical species include sodium, chromium, nitrate, sulfate, chloride, and fluoride. Nitrite and ammonium are present in the tanks in significant quantities, but they are rarely detected in Hanford Site groundwater because they are probably converted to nitrate by bacterial action. Nitrite has only rarely been detected in samples collected in WMA U.

Some of the tanks also contain significant quantities of organic complexants used during plutonium separations operations. These compounds are mobile and may be co-contaminants in wastes originating from the tanks.

In addition to the chemical constituents, the tank waste contains a wide variety of radioactive constituents, including cesium-137, strontium-90, cobalt-60, tritium, technetium-99, iodine-129, selenium-79, and neptunium-237, along with several isotopes of uranium and plutonium. From the perspective of transport, the most important radioactive indicators of groundwater contamination for the WMA are tritium, technetium-99, and iodine-129.

**Table 2.2.** Selected Waste Constituents in Tanks at Waste Management Area U  
(Hodges and Chou 2000)

Waste Component	Average Concentration in the Tanks	Concentration Divided by DWS or MCL
Sodium	$1.5 \times 10^8 \mu\text{g/L}$	(a)
Calcium	$1.6 \times 10^6 \mu\text{g/L}$	(a)
Chromium	$2.6 \times 10^6 \mu\text{g/L}$	26,000
Nitrate	$1.4 \times 10^8 \mu\text{g/L}$	3,111
Nitrite	$4.46 \times 10^7 \mu\text{g/L}$	13,500
Ammonium	$6.68 \times 10^5 \mu\text{g/L}$	(a)
Sulfate	$1.7 \times 10^7 \mu\text{g/L}$	34
Chloride	$3.0 \times 10^6 \mu\text{g/L}$	(a)
Fluoride	$6.2 \times 10^5 \mu\text{g/L}$	155
Phosphate	$1.3 \times 10^7 \mu\text{g/L}$	(a)
Carbon-14	$2.02 \times 10^7 \text{ pCi/L}$	10,100
Cesium-137	$1.59 \times 10^{11} \text{ pCi/L}$	795,000,000
Strontium-90	$7.83 \times 10^{10} \text{ pCi/L}$	9,790,000,000
Tritium	$1.4 \times 10^8 \text{ pCi/L}$	7,000
Cobalt-60	$2.2 \times 10^7 \text{ pCi/L}$	220,000
Technetium-99	$1.4 \times 10^8 \text{ pCi/L}$	155,555
Selenium-79	$2.01 \times 10^6 \text{ pCi/L}$	(a)
Iodine-129	$2.7 \times 10^5 \text{ pCi/L}$	270,000
Uranium-232	$4.15 \times 10^5 \text{ pCi/L}$	(a)
Uranium-233	$1.59 \times 10^6 \text{ pCi/L}$	(a)
Uranium-234	$2.05 \times 10^7 \text{ pCi/L}$	(a)
Uranium-235	$9.1 \times 10^5 \text{ pCi/L}$	(a)
Uranium-236	$2.02 \times 10^5 \text{ pCi/L}$	(a)
Uranium-238	$2.06 \times 10^7 \text{ pCi/L}$	(a)
Uranium	$2.52 \times 10^5 \mu\text{g/L}$	12,600
Neptunium-237	$5.19 \times 10^5 \text{ pCi/L}$	34,600
Plutonium-238	$6.71 \times 10^6 \text{ pCi/L}$	44,700
Plutonium-239	$3.85 \times 10^8 \text{ pCi/L}$	25,700,000
Plutonium-240	$5.52 \times 10^7 \text{ pCi/L}$	3,680,000
Plutonium-241	$3.72 \times 10^8 \text{ pCi/L}$	24,800,000
Plutonium-242	$1.6 \times 10^3 \text{ pCi/L}$	107
Americium-241	$3.4 \times 10^6 \text{ pCi/L}$	227,000
Americium-243	$3.92 \times 10^3 \text{ pCi/L}$	261
Curium-242	$3.14 \times 10^5 \text{ pCi/L}$	20,900
Curium-243	$1.33 \times 10^4 \text{ pCi/L}$	887
Curium-244	$1.78 \times 10^5 \text{ pCi/L}$	11,900
(a) No applicable drinking water standard (DWS) or maximum contaminant level (MCL).		

## 2.4 Geology

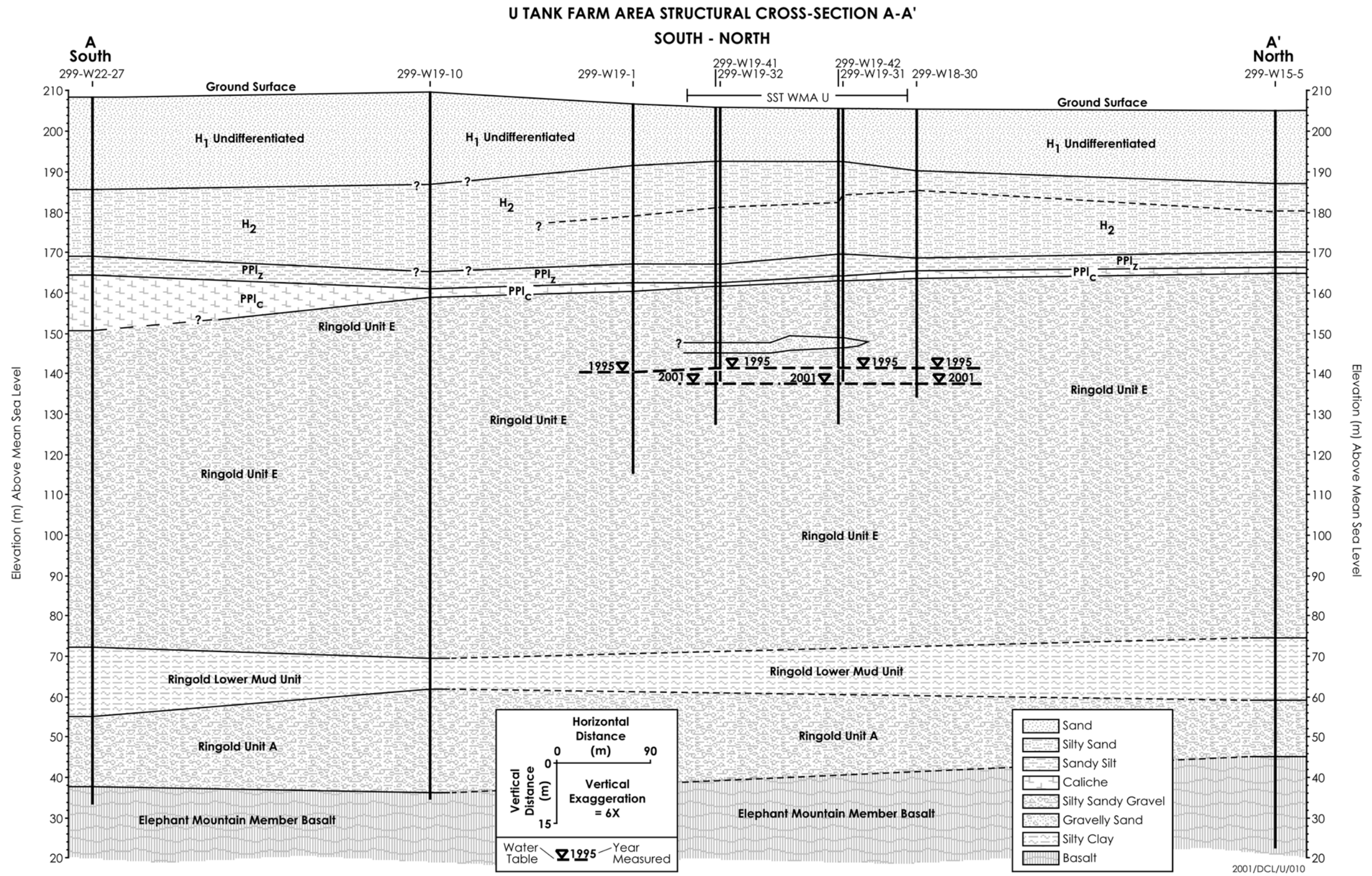
The geologic materials beneath the WMA play an important role in this plan by serving as a secondary source from contamination leaked to ground as well as influencing where and how contaminants move through the vadose and saturated groundwater zones. In general in 200 West Area, the Elephant Mountain Member of the Saddle Mountains Basalt, Columbia River Basalt Group serves as the base of the unconfined aquifer (Reidel and Fecht 1981). The unconfined aquifer is located in the Ringold Formation. The Hanford formation (informal name) sedimentary sequence overlies the Ringold Formation and extends to ground surface. For a detailed geographic and geologic description of the stratigraphic units present in the 200 West Area, see Lindsey et al. (1992). Additional discussions of the geology beneath WMA U specifically are found in Price and Fecht (1976).

WMA U is situated in the south central portion of the 200 West Area where specific sedimentary strata influence contaminant migration pathways in significant ways. Two geologic cross sections are shown in Figures 2.2 and 2.3. Figure 2.4 is a location map showing where the cross-sections are located. Plate 1 in the back of the report provides a more complete description of the geology summarized in Figures 2.2 and 2.3. The suprabasalt sediments that compose the uppermost aquifer system are approximately 170 m thick and lie on the surface of the Elephant Mountain Basalt bedrock, which dips to the south-southwest beneath WMA U. Ringold Unit 9 lies directly on top of the basalt and is up to 30 m thick. This unit is composed of sand and gravel and dips to the south-southwest. The Ringold Unit 8 (Lower mud unit) confining interval lies on top of Ringold Unit 9 approximately 140 m below ground surface and averages over 15 m thick. The hydraulic conductivity of this unit is low, estimated at less than  $10^{-6}$  m/d (Bergeron and Wurstner 2000); therefore, it effectively serves as the base of the upper aquifer. Ringold Unit 8 also dips to the south-southwest beneath the tank farm. The uppermost aquifer, approximately 65 m thick beneath WMA U, is entirely within the Ringold Unit 5 (Ringold Unit E) gravel, which lies on top of Ringold Unit 8.

Ringold Unit 5 gravel is best described as fluvial sandy gravel ranging from sand to silty sandy gravel and cobble gravel. Gravels are generally clast supported. Drill cuttings, drill rate, and geophysical logs easily identify the Ringold Unit 5 gravel. The top of Unit 5 is above the water table and drops approximately 3 m to the south-southwest beneath the tank farm. The Upper Ringold Unit (Unit 4) is not present beneath the tank farm based on a review of drilling, geologic, and geophysical logs. The fine-grained Plio-Pleistocene interval overlies Ringold Unit 5.

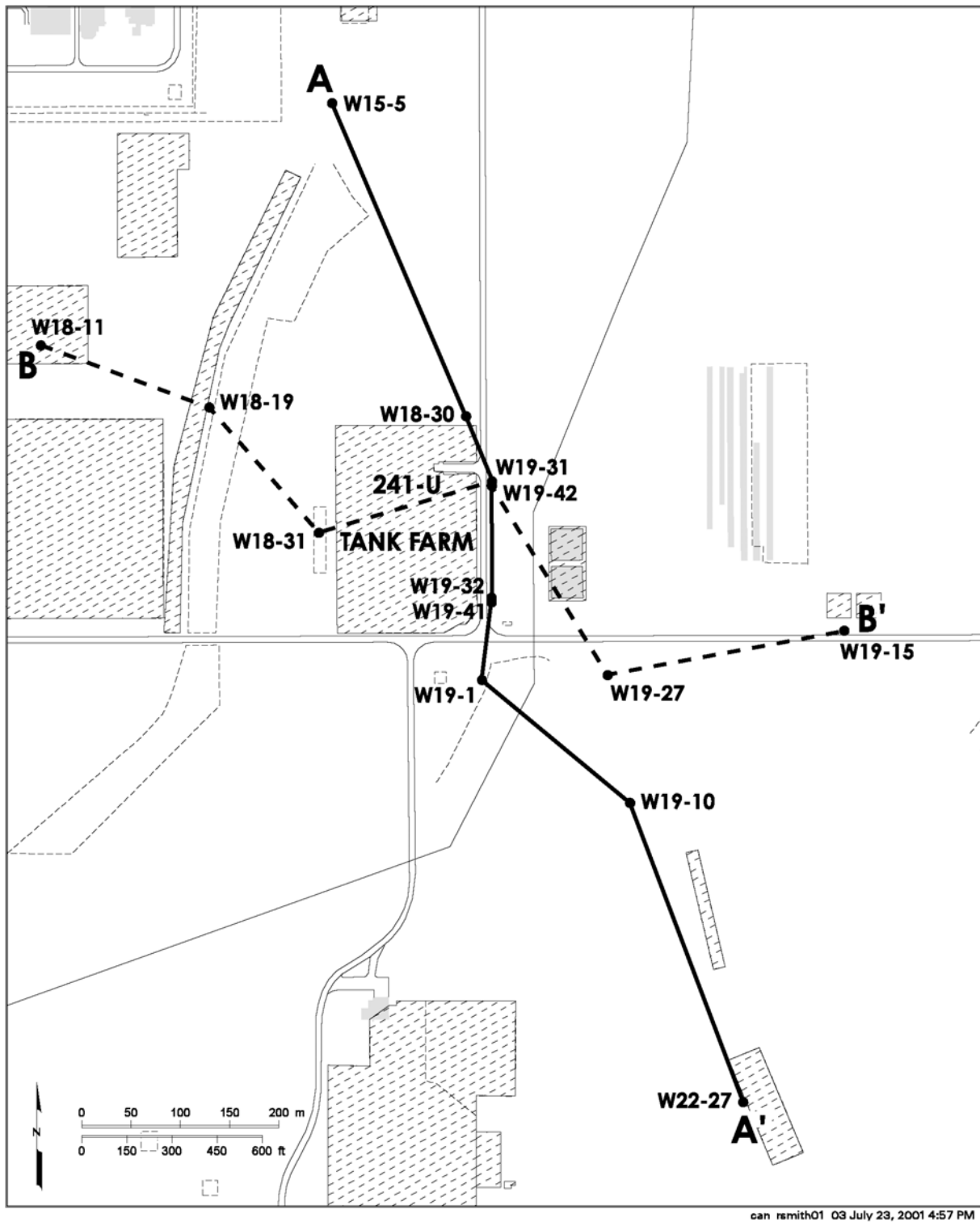
Above the water table, the vadose zone is composed in ascending order of the upper Ringold Unit 5 silty sandy gravel, which is unconformably overlain by the Plio-Pleistocene interval composed of sandy silt to clay and includes a basal carbonate cemented soil horizon (caliche zone), and finally the Hanford silt, sand, and gravel. The vadose zone is approximately 67 m thick.

The Plio-Pleistocene interval is composed of two distinct intervals that may affect infiltration of tank leaks and other liquids: 1) a basal soil horizon (caliche zone) that developed on the exposed paleo-surface of the Ringold Formation, and 2) a thicker fine sand/silt unit above. The caliche zone is composed of calcium carbonate cemented sand, silt, and/or Ringold gravel. Cementation varies from finely disseminated carbonate particles in the silt to calcium carbonate nodules in the fine sands. Within the gravel the



**Figure 2.2.** North-South Geologic Cross-Section





**Figure 2.4.** Water Table in the Vicinity of Waste Management Area U, March 2001



caliche exhibits variable matrix cementation that can form hard solid white to pale white stringers or layers. Root casts and weathered sediments have also been identified (elsewhere) within this interval. The top of the caliche zone dips approximately 3 m to the south-southwest beneath the tank farm similar to the Ringold Formation Unit 5. The caliche grades downward into unaltered, un-weathered Ringold Unit 5 gravel, which can be distinguished from the weathered gravel by the lack of carbonate reaction to dilute hydrochloric acid. The caliche zone averages approximately 1 m thick.

Above the caliche zone, the Plio-Pleistocene is composed of mostly very fine sandy silt to silt/clay that exhibits very little depositional structure (i.e., massive) in core samples and, therefore, has been interpreted to be eolian in origin. This interval dips 2.5 to 3 m to the southwest similar to the Ringold Unit 5 and ranges from 3 to 6 m thick beneath WMA U. The Plio-Pleistocene interval is an areally extensive zone beneath most of the 200 West Area where conditions of perched water have been noted. Locally, liquid effluent discharged at the Z ditches to the west and the U-14 Ditch and U1/2 Cribs to the east, has perched above this interval. These observations indicate that water percolating through the vadose zone beneath the WMA may move to the south-southwest along the top of the Plio-Pleistocene interval.

The Hanford formation (Unit 1) overlies the Plio-Pleistocene interval and can be separated into two depositional intervals: 1) the lower H2 unit composed of mostly sand and silt, and 2) the H1 unit, which is composed of higher-energy deposits consisting of coarse-grained sand to gravel. The contact between the H1 and H2 units is gradational and irregular and slopes to the east-northeast, unlike the older formations beneath the Hanford formation that all dip to the southwest. The H1-H2 contact drops approximately 3 m to the northeast across WMA U. The H2 unit averages 24 m thick, thinning to the northeast and east. The slope of this unit most likely was shaped and controlled by higher-energy flood deposits as a facies transition as indicated by the accumulation of coarser-grained sediments above it. The H2 unit is composed of stacked, repeating, flat lying sequences of silt and fine sand lamina. These thin-bedded intervals can be differentiated only by intact sediment core evaluation. The H2 typically is a fining downward sequence based on core analysis and geophysical log interpretations. The only notable change in the H2 unit is a gravelly sand lens that develops in wells just west of the tank farm near the Z ditches. The gravel does not exist beneath the tank farm but records indicate that infiltrating water from the Z ditches at one time saturated the upper H2 unit and this gravel interval. The eastern extent of this gravelly interval has not been determined because it does not exist in wells beneath or surrounding the tank farm.

The base of the tanks is within the H1 unit, near the H1-H2 boundary, therefore, the migration of water and waste liquids from within the tank farm is controlled within the vadose zone by this contact, the Plio-Pleistocene unit, and Ringold Unit 5. With the exception of the H1-H2 contact, these units slope to the south-southwest; therefore, it is probable that leaking tank liquids could migrate laterally to the southwest along the older, lower sedimentary interfaces.

The upper H1 unit is differentiated from the H2 unit primarily by grain size; a significant change in overall grain size occurs at the H1-H2 boundary, from a uniformly coarser sand and gravel above to finer-grained sand and silt of the H2 unit below. Within the H1, sediments may be composed of coarse sand to silty sandy gravel, and clean clast-supported (open framework) gravel. The H1 interval is considered the most permeable unit in the suprabasalt sequence because of the lack of cementation and its well-sorted

and clast-supported nature. The H1 unit is approximately 12 to 15 m thick. Most cribs and ditches in the area surrounding the tank farm that have released liquids to the ground are constructed within this very permeable interval. Overlying the Hanford H1 unit is a thin veneer (1 to 3 m) of recently deposited eolian silt and sand.

## **2.5 Hydrology**

Water beneath the WMA is found in the unsaturated vadose zone above the water table and in the saturated zone below the water table. Properties of groundwater in both regions are important in understanding how the WMA may impact groundwater quality. Generally, groundwater refers to water below the water table and this convention will be used in this plan.

### **2.5.1 Vadose Zone Hydrology**

The unsaturated sediments above the water table affect how waste solutions move through the soil, how much is retained in the sediment column, and how much waste eventually reaches the water table. The source of contamination for the WMA is liquid waste released to near surface or subsurface sediments. These liquids move through the sediment under unsaturated conditions and as a result, tend to spread laterally at changes in stratigraphy. Small volume leaks would tend to be retained in the vadose zone near the leak point. Larger leaks would be expected to move deeper in the soil, spreading laterally as the wetting front moves downward.

A major stratigraphic change is the top of the Plio-Pleistocene unit. This unit, located about 30 m below ground surface would slow the downward movement of water and divert it to the southwest, the direction the top of the unit is dipping beneath the WMA. Water from a waste release may reach the water table at a time, location, and concentration depending on its volume, depth of release, and diversion from downward movement at a stratigraphic change. Over time, wastewater released to the sediment column near ground surface will evaporate or be driven downward to the water table by new inputs of water to the sediment column from above. It is this downward movement of water in the vadose zone that carries waste contaminants to the water table. Water movement in the unsaturated zone is relatively slow compared to groundwater flow below the water table, delaying the observed impact of a near surface waste release on groundwater quality.

### **2.5.2 Saturated Zone Hydrology**

Properties of the groundwater system determine where contaminants are transported, how widely they spread and their resultant concentrations, and how fast they move away from the WMA. Groundwater characteristics important for this plan are the direction of groundwater flow in three dimensions and the flow rate. These properties may be determined several ways, but the standard method for this WMA has been to measure water levels in surrounding monitoring wells. A depiction of the water table surface in March 2001 is presented as a water table map in Figure 2.5.



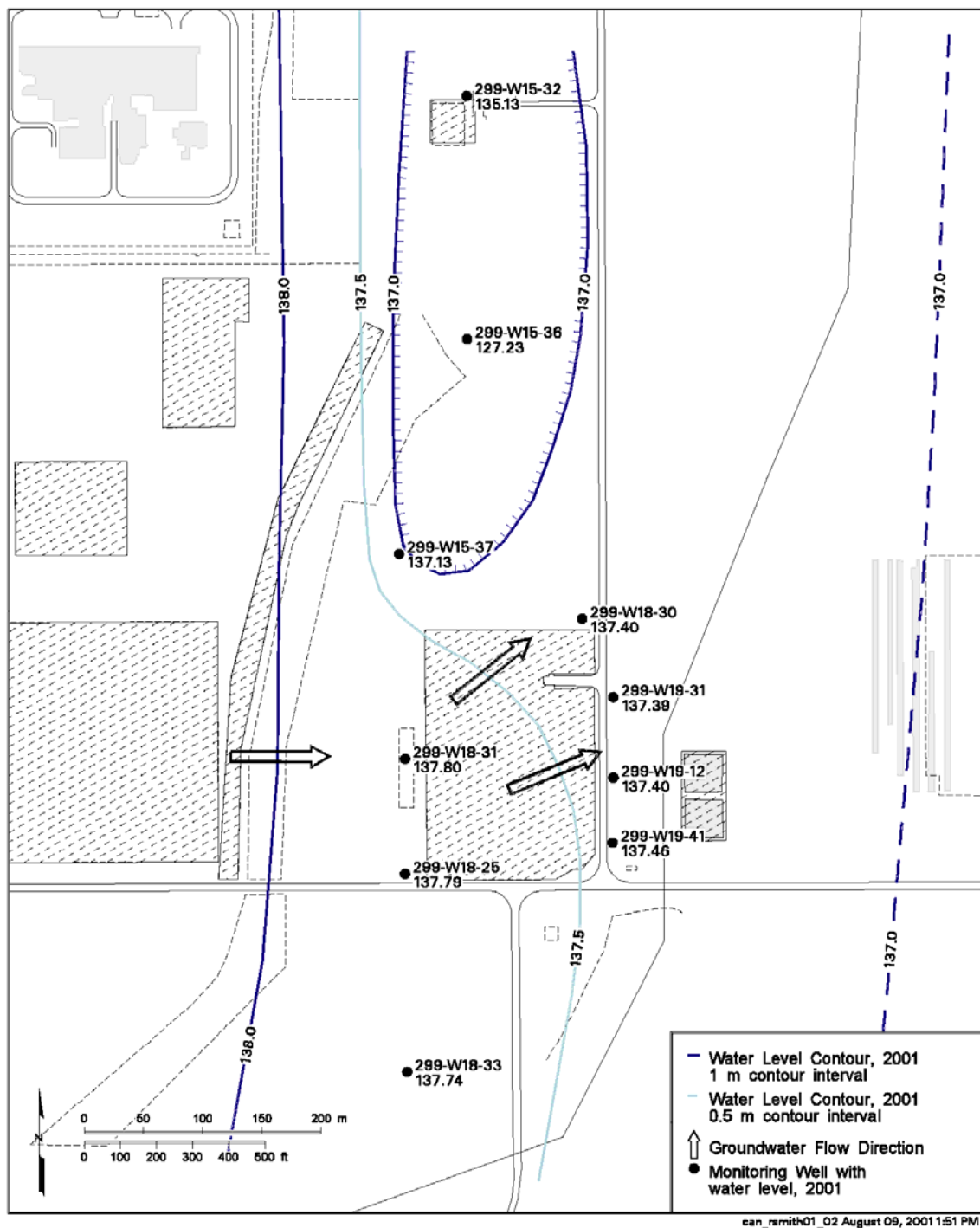


Figure 2.5. Water Table in the Vicinity of Waste Management Area U, March 2001

Groundwater flow direction and hydraulic gradient across WMA U were also determined by performing a trend surface analysis of water level measurements in surrounding monitoring wells. An analysis of these data is presented in the letter report provided in Appendix A<sup>(a)</sup>. Three combinations were evaluated: 1) the WMA as a whole, 2) the northern WMA, and 3) the southern WMA. In summary, the hydraulic gradient has remained constant at approximately 0.0021 and consistently easterly groundwater flow direction is indicated (Tables 2, 3, and 4, Appendix A).

Groundwater flow velocity,  $v$ , has been estimated using the Darcy equation:

$$v = -K i / n_e$$

where  $K$  = hydraulic conductivity  
 $i$  = hydraulic gradient  
 $n_e$  = effective porosity.

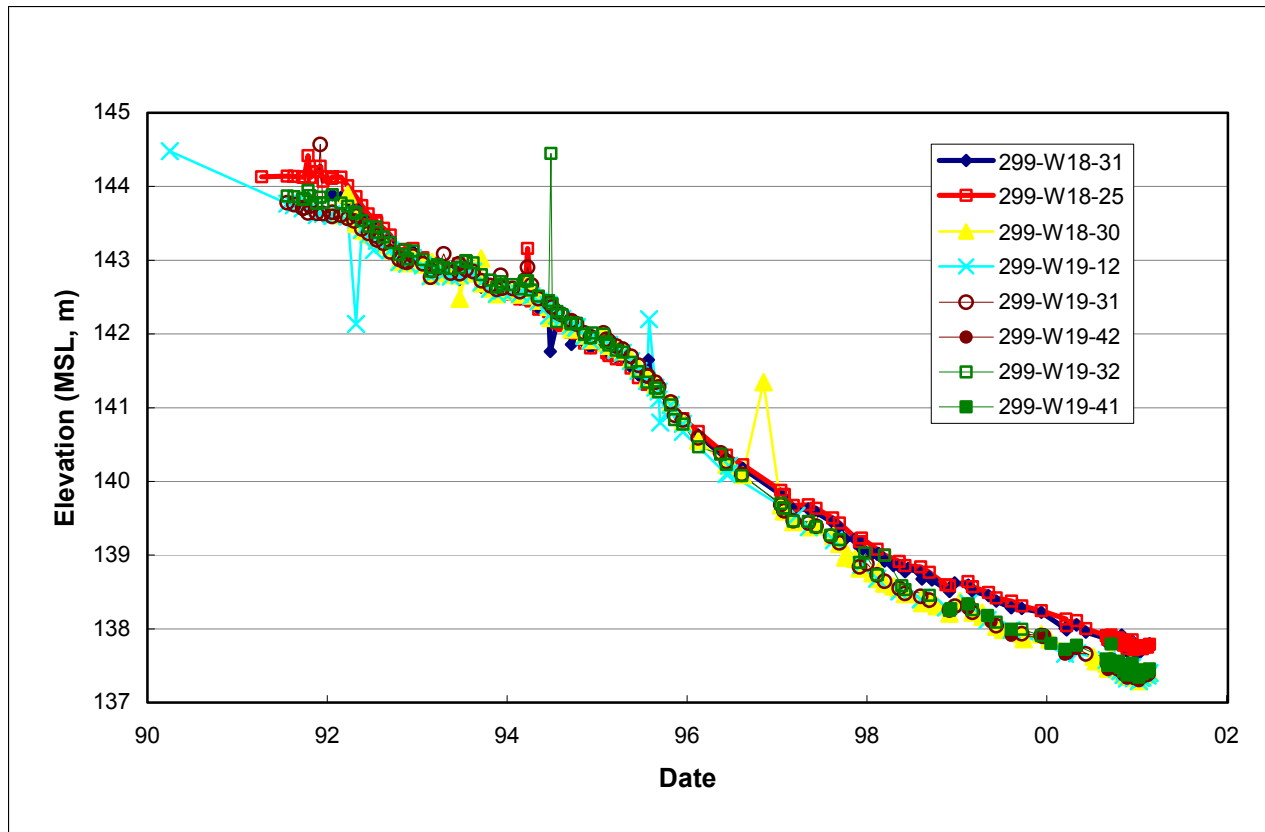
Values for hydraulic conductivity and effective porosity have been determined from various aquifer tests including slug tests, constant-rate pumping tests, and tracer-dilution tests. A description of these tests and their results are presented in Spane et al. (2001). These tests indicated that the hydraulic conductivity and effective porosity (specific yield) for the area around well 299-W19-42 are 6.12 m/d and 0.17. Hydraulic conductivity determined from slug tests at well 299-W19-41 ranged from 1.1 m/d to 1.9 m/d, but, according to Spane et al. (2001), the test responses indicated that the well was probably not fully developed, which may explain why the hydraulic conductivity was lower than in well 299-W19-42. Using the data from well 299-W19-42, the groundwater flow velocity is calculated to be about 30 m/yr.

Over time, groundwater flow direction and velocity may change in response to dewatering of the unconfined aquifer beneath the WMA. The aquifer, which was artificially recharged by Hanford operations resulting in a rise in the water table, is no longer receiving large volumes of water and the excess water is draining from the aquifer. The resultant falling water table may change the groundwater flow direction and cause the hydraulic gradient to decrease. Hydrographs for WMA U groundwater monitoring wells are shown in Figure 2.6. The water table has been dropping at a linear rate of about 0.4 m/yr since 1998. Since 1997, water levels in upgradient and downgradient wells have separated into two populations indicating a distinct gradient across the WMA.

Previous interpretations of water levels in an area north of WMA U indicated that groundwater withdrawals from a nearby pumping well 299-W15-37, part of the ZP-1 Operable Unit pump-and-treat remedial action, caused groundwater in the northern half of WMA U to be diverted to the north-northeast direction from the generally easterly flow direction. Because the well is about 100 m from the northern boundary of the WMA, the well was thought to have diverted groundwater flow even though there were no wells between the pumping well and the north end of the WMA to support this assumption. Pumping of the well was permanently discontinued on January 17, 2001. Before the pumping well was to be shut down, pressure transducers and data loggers were placed on two WMA U monitoring wells to record any impact on water levels. In addition, weekly water level measurements in wells surrounding the WMA

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(a) F. A. Spane, letter report to R. M. Smith, March 14, 2001.

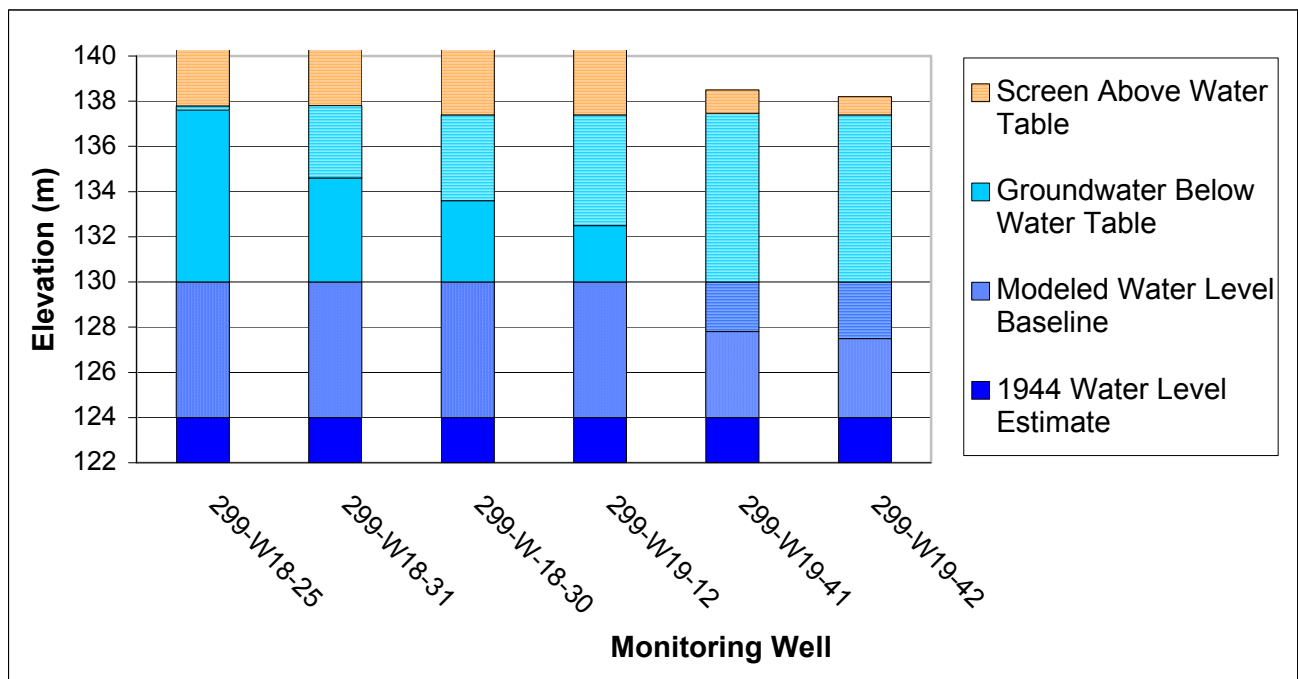


**Figure 2.6.** Hydrographs for Groundwater Monitoring Wells at Waste Management Area U

were started. The letter report presented in Appendix A provides a detailed analysis of water levels and groundwater flow before and after well 299-W15-37 was removed from the remedial action. Figure 2 in Appendix A shows the manually measured water levels for six monitoring wells around WMA U. This figure shows that water levels in all of the wells responded similarly; therefore, pumping at well 299-W15-37 has affected all of the wells equally. Spane (Appendix A) evaluated the effects of shutting down pumping well 299-W15-37 and concluded that water levels were affected in the two wells monitored, 299-W18-31 and 299-W19-42, but only by up to 0.1 m. Because atmospheric changes affected water levels by up to 0.25 m over a several day period, the effect of the pumping well could be determined only by removing barometric effects. Continued monitoring indicated that the rising water levels (recovery period) lasted only 1 month, at which time, water levels began to drop at the rate of the regional water table in 200 West Area of about 0.4 m/yr. Therefore, contrary to previous interpretations, while pumping well 299-W15-37 did have an impact on groundwater in the vicinity of WMA U, that effect was apparently equal across the entire area and negligible in its effect on groundwater flow direction and velocity.

The falling water table affects the regional hydraulic gradient and groundwater flow rate and also shortens the useful lifetime of monitoring wells. The water table will reach steady-state levels when it reaches pre-Hanford levels or some other level based on current and future aquifer recharge scenarios.

Kipp and Mudd (1974) presented a water table map for the Hanford Site in 1944, prior to Hanford operations, which was based on water levels estimated from data collected between 1948 and 1952. The estimated water table elevation in the vicinity of WMA U was about 124 m above sea level and is the assumed base level to which the water table could fall. The 1944 estimated water table elevation for 200 West Area may be low, indicated by later maps showing the water table 3 m to 6 m higher in areas unaffected by Hanford operations. Bergeron and Wurstner (2000) predicted post-Hanford steady-state water levels using a three-dimensional groundwater flow model of the Hanford Site. The predicted steady-state water level elevation for the WMA U area is about 130 m. These water levels, the current water table position, and the screened intervals for the current monitoring wells are presented on Figure 2.7. The figure shows how much screened interval is currently available for groundwater monitoring and where the bottom of the screened interval is located relative to possible future baseline water levels.



**Figure 2.7.** Screened Interval Relative to Current and Future Water Levels

Upgradient well 299-W18-25 had about 0.2 m of water above the screen bottom; too little to sample and it will be completely dry within 6 months. With the water table falling at a rate of 0.4 m/yr, the next well that will become unsampleable is well 299-W18-31 in about 6 years. Well 299-W18-30 has an estimated lifetime of about 8 years. The other wells and the new wells will likely have a lifetime that is independent of water levels unless the baseline water level drops to the 1944 predicted level. Conservatively, those wells have a minimum lifetime, based on water levels, of about 25 years.

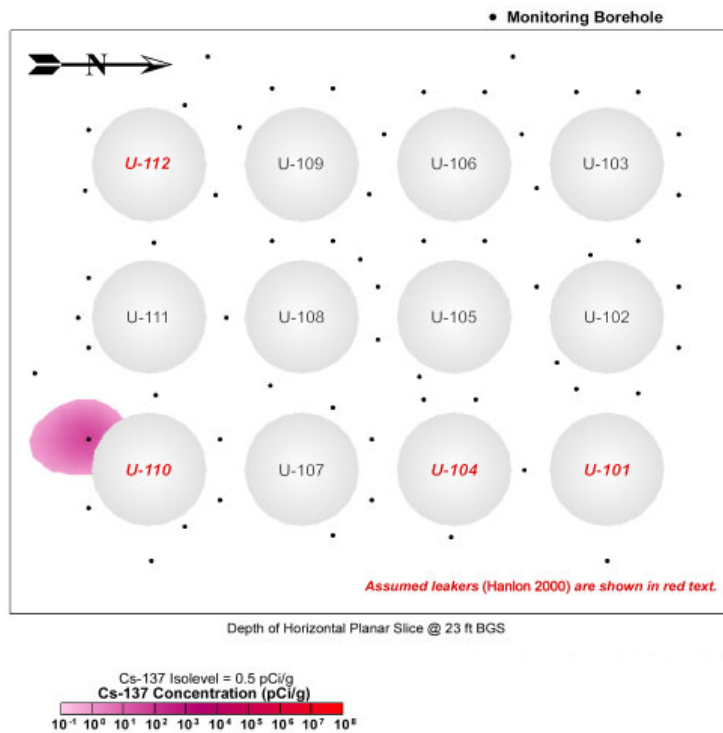
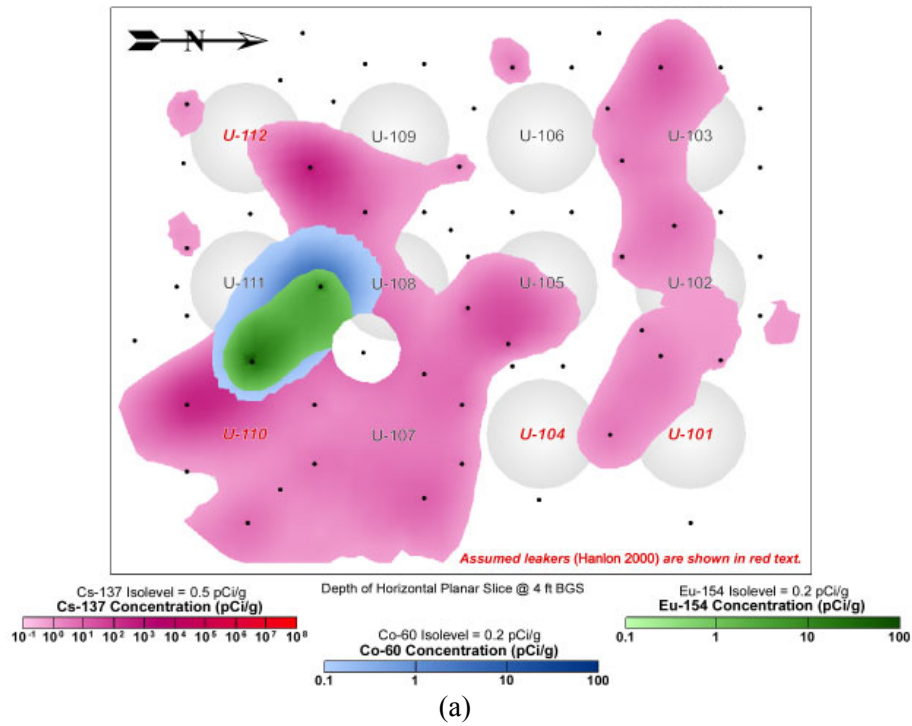
## 2.6 Vadose Zone Contamination

Contaminants that reach the water table must pass through the vadose zone where plumes from past leaks and spills have been retained or their movement slowed by either chemical (sorption) or physical (water retention under unsaturated conditions) processes. Knowing the location of current vadose zone contamination provides a basis for focusing groundwater monitoring on a specific area of the WMA or providing an explanation for groundwater contamination if it is detected. Spectral gamma logging in boreholes drilled around tanks in the WMA has been conducted to delineate where gamma emitting radionuclides are located in the vadose zone (DOE 2000). While the radioactive contaminants detectable by gamma logging are considered fairly immobile in Hanford sediments, the vadose zone plumes identified indicate where more mobile tank constituents have been released to the soil and provide a minimum indication of how deep the plumes may have migrated.

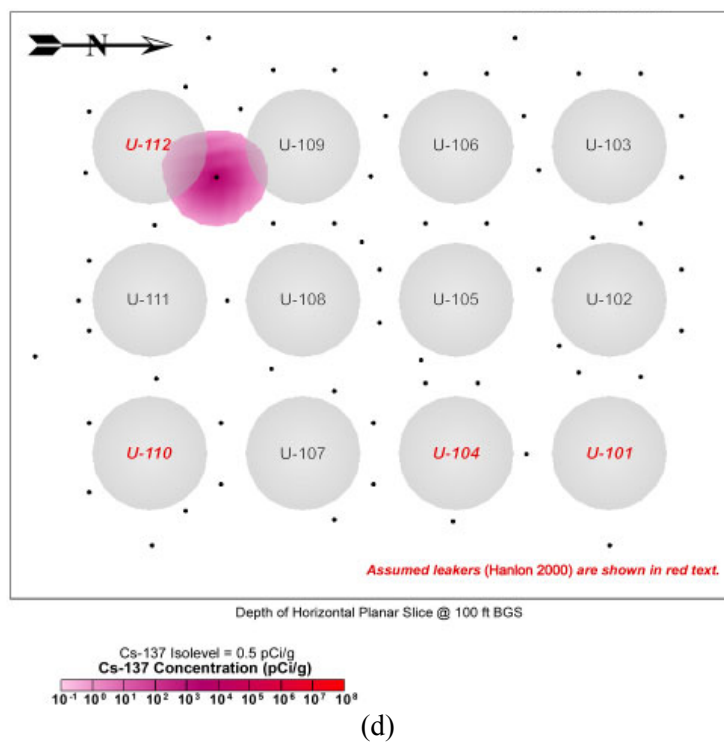
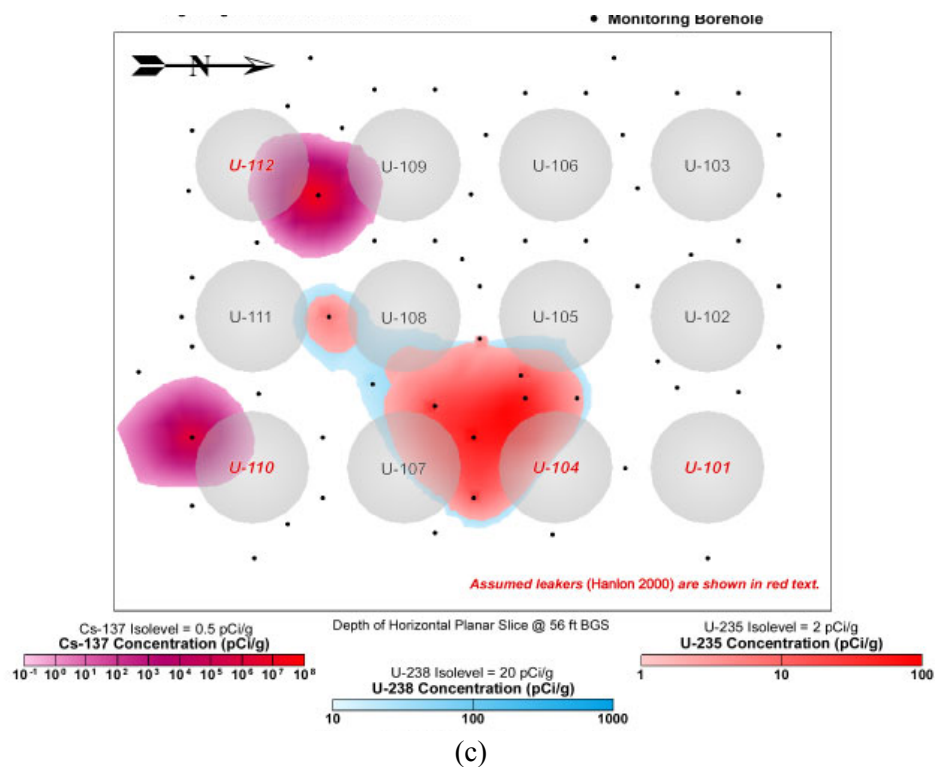
Figures 2.8 and 2.9 contain selected figures from the addendum to the U tank farm spectral gamma logging report (DOE 2000). These figures present the authors' spatial representation of the spectral gamma logs collected for each drywell and are used in this report to indicate the general locations of gamma contamination around the tanks. The gamma logs, which present the actual data, are included in the logging report (DOE 2000). The addendum and the original report can be viewed at <http://www.doegipo.com/programs/hanf/HTFVZ.html>.

Figure 2.8 presents a general representation of detected contamination at progressively deeper positions beneath ground surface ranging from 1.2 m to 30.5 m deep. This figure generally indicates that contaminated sediments are located mainly near ground surface and at and just below the bottom of the tanks. Approximately 50% of the near surface sediments (1.2 m below ground) appear to be contaminated as shown in Figure 2.8a. At 7 m deep, just above the bottom of the tanks, Figure 2.8b indicates that only one borehole adjacent to tank U-110 contained significant gamma contamination. Figure 2.8c shows that at 17 m, approximately 6 m below the bottom of the tanks, uranium and cesium spread from each of the reported leaking tanks except for tank U-101. Subsurface contamination appears to be the most widespread at this depth indicating that most of the deep contamination was from tank leaks and that it was retained close to the bottoms of the tanks. The uranium distribution suggests that liquids leaked from tank U-104 may have spread to the southwest. At 30.5 m, only one borehole contained measurable amounts of cesium contamination. Figure 2.9 shows four, three-dimensional views of vadose zone contamination. These figures indicate that liquid wastes leaked to the sediments tended to spread at a depth that is near the contact between the H1 and H2 units in the Hanford formation. This effect can be observed most easily in Figure 2.9b where the shape of the cesium plume beneath tank U-110 and the uranium plume beside tank U-111 appear flattened. The maximum depth of cesium detection beneath tank U-112 appears to coincide with the top of the Plio-Pleistocene interval. These relationships warrant additional attention when the WMA is investigated for closure purposes.

These spectral gamma data indicate that near surface sediments are extensively contaminated, but this contamination has remained near the surface. The source of this contamination is likely spills and unplanned releases and not the tanks. Deeper contamination appears to be associated with tank leaks that spread laterally at the bottom of the tanks. It appears that some of the contamination also spread laterally

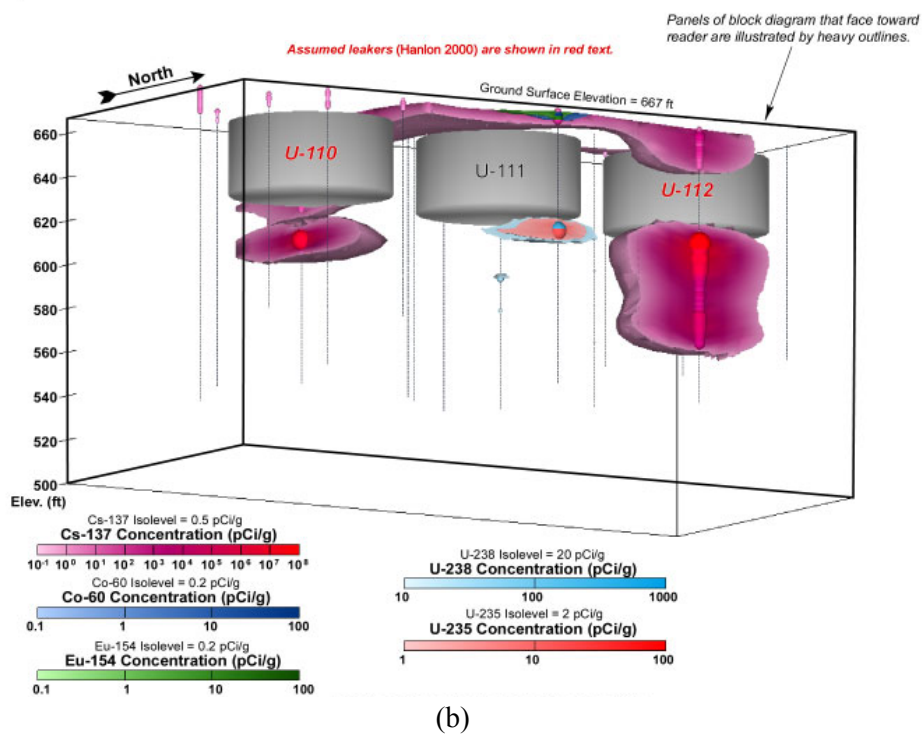
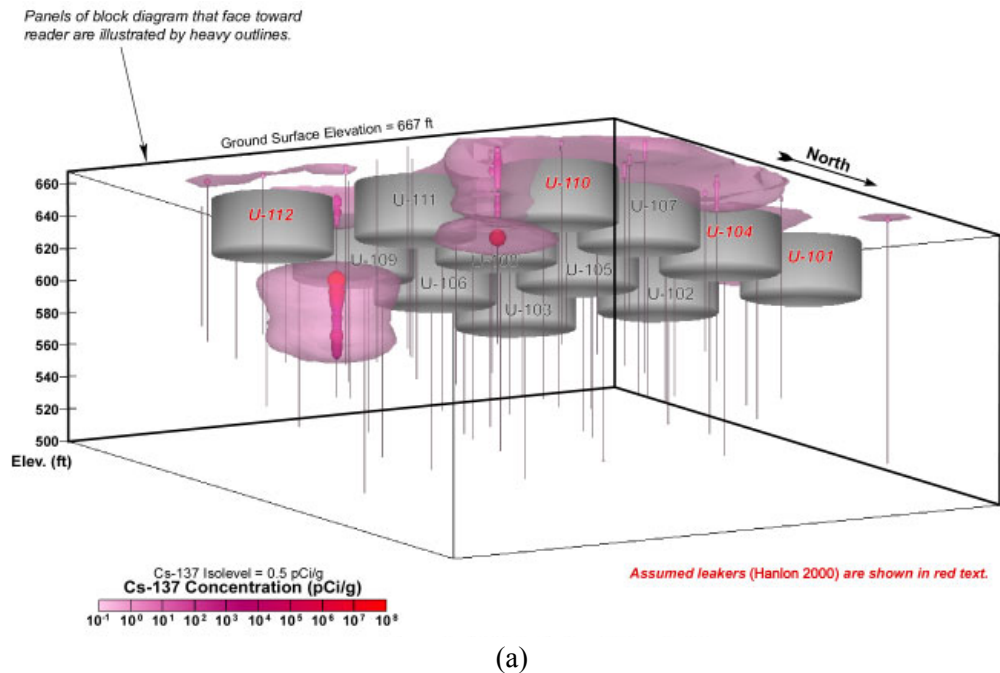


**Figure 2.8.** Distribution of Gamma Emitting Radionuclides at Various Depths in Waste Management Area U (from DOE 2000)



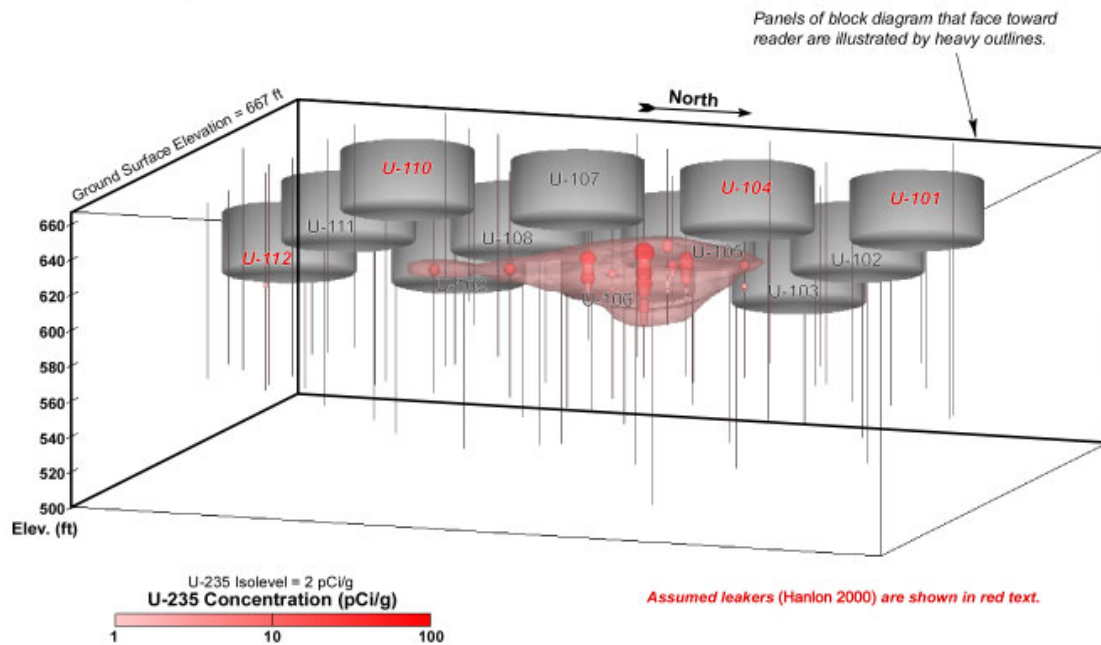
**Figure 2.8.** Distribution of Gamma Emitting Radionuclides at Various Depths in Waste Management Area (from DOE 2000) (continued)



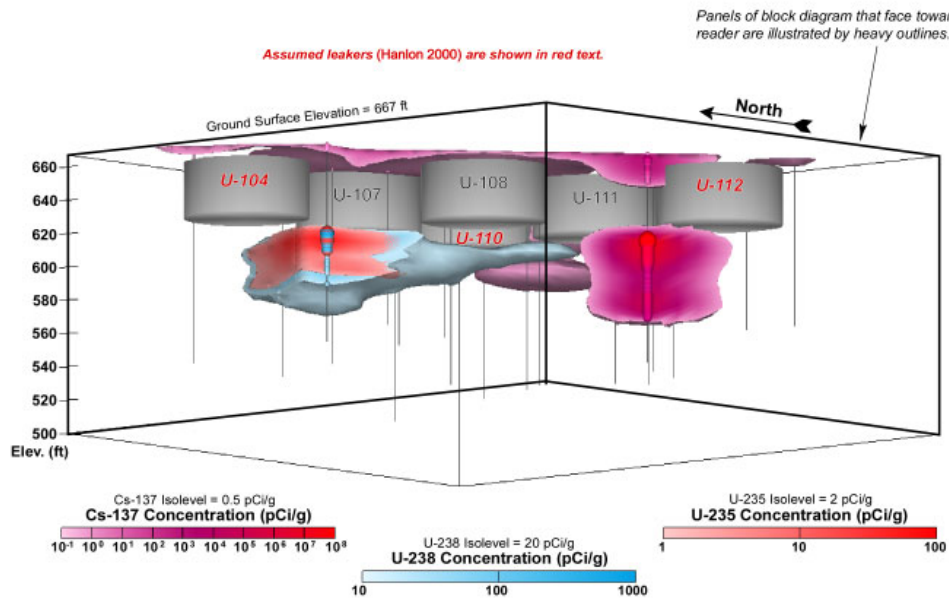


**Figure 2.9.** Three-Dimensional Distribution of Gamma Radionuclides Beneath Waste Management Area U (from DOE 2000)





(c)



(d)

**Figure 2.9.** Three-Dimensional Distribution of Gamma Radionuclides Beneath Waste Management Area U (from DOE 2000) (continued)

at the contact between two sediment units within the Hanford formation. The deepest extent of contamination detected is cesium-137 at slightly deeper than 30 m adjacent to tank U-112. Subsurface gamma emitting contaminants were found at various depths in the southern half of the WMA; therefore, mobile contaminants in the leaked waste would be expected to reach groundwater beneath the middle to southern half of the WMA. A surprising observation was that no subsurface contamination was found in the four drywells around tank U-101 that reportedly leaked 114,000 L of tank waste into the surrounding sediments. This could be because there are no monitoring drywells on the northern half of the tank and only one drywell on the east side of the tank.

## **3.0 Groundwater Quality**

### **3.1 Existing Data**

Hodges and Chou (2000) discussed groundwater quality data for WMA U. Concentrations of calcium, magnesium, sulfate, chloride, nitrate, technetium, and chromium were higher in downgradient wells than upgradient wells. None of the constituents that affected groundwater quality exceeded drinking water standards. Increases in calcium, magnesium, sulfate, chloride, and nitrate are responsible for elevated levels of specific conductance. The impacts were observed mainly in the downgradient wells on the southern half of the WMA. The pH in well 299-W19-12 is statistically higher than all other wells in the monitoring network. The cause of the elevated pH may be due to well construction techniques in which cement was used to seal the annulus of the well. The elevated pH is not currently thought to be an effect of the WMA.

### **3.2 Conceptual Model**

The sources of contaminants in groundwater beneath the WMA are vadose zone plumes generated from tank leaks, pipe leaks, and various releases as described in Section 2.2. None of the releases were likely to be of sufficient volume to reach the water table independent of additional water sources. It is likely that infiltrating precipitation was focused to the sides of the tanks by the “umbrella effect” where the tops of the tanks shed percolating water to the sediments surrounding the tanks. In addition, the tank farm has received “run-on” water from snow melt and high intensity, short duration precipitation events, and pipeline leaks of clean water used in the tank farm. In addition to these sources of water, the gravel cover and the practice of removing and preventing the growth of vegetation on the surface of the WMA, encourage the infiltration of any water that reaches the area. These sources of water likely mobilized contaminants in the vadose zone where they were eventually leached to the water table where they affected groundwater quality.

Groundwater chemistry downgradient of the WMA indicates the source of contamination is close and of small volume so far. The major changes in groundwater chemistry are increases in calcium, magnesium, sulfate, and nitrate. While nitrate and sulfate are major constituents in the waste, the other ionic

species are major components of the natural vadose zone sediments. As water moves through the vadose zone, it may encounter a contaminant plume, mix with waste solutions, incorporating sodium, nitrate, sulfate, and other soluble species from the plume and continue migrating through the vadose zone. The migrating solution encounters natural deposits of calcium carbonate and gypsum (calcium sulfate) and dissolves them in accordance with their solubility. As the solution migrates through the sediment column, soluble cations calcium, magnesium, and sodium compete for ion exchange sites on the sediment particles. Because of the limited supply of sodium, it exchanges for cations on exchange sites, leaving the solution enriched in calcium and magnesium, rather than sodium. Therefore, with a small volume or percolating liquid, the first arrival of the waste will contain elevated calcium and magnesium. Sulfate will be present because gypsum would be dissolved by the percolating solution and sulfate will be leached from any waste plumes encountered. Soluble nitrate in the waste plume would dissolve into the percolating solution and be carried downward. Technetium-99 behaves similarly to nitrate, so the percolating solution that encountered a technetium-99 bearing waste plume would also contain elevated technetium concentrations. If the percolating solution were a large volume plume of tank waste, the solution arriving at the water table would be characterized by high concentrations of sodium, nitrate, sulfate, and technetium. These conditions were not found in groundwater downgradient from the WMA. The chemical composition and low concentrations of waste constituents in groundwater downgradient of WMA U indicate that the impact has more likely been from small volumes of water leaching through existing vadose contaminant plumes.

## **4.0 Data Needs**

Waste sources within WMA U caused increases in nonhazardous major ion species and co-contaminants technetium-99, nitrate, and possibly chromium in groundwater downgradient of the area. These contaminant concentrations are currently low and their presumed spatial extent is small, however, knowledge about where waste releases have occurred suggests that there are some gaps in groundwater monitoring coverage. In addition, the current conceptual model for the Site indicates that most of the released contamination is in the vadose zone; so continued groundwater monitoring is warranted to determine if contaminants are transported into the groundwater system in the future. The site conceptual model could change as additional data are collected.

### **4.1 Spatial Coverage**

Five wells are currently used to monitor the WMA U. These wells, shown on Figure 2.1, are insufficient to monitor the WMA for three reasons. First, the north end of the WMA is contaminated from releases from the 244-UR-Vault and there are no wells monitoring the downgradient, eastern side of the WMA at this point. Second, well 299-W19-12 is an older well with elevated pH indicating that cement used in its construction may be affecting the quality of groundwater samples. Third, upgradient well 299-W18-25 went dry in 2000 and has not been replaced. Most of the contamination has and is

currently detected downgradient of the southern end of the WMA in monitoring well 299-W19-41. An upgradient well is needed for the WMA. These wells are discussed in Section 5.2.

No monitoring wells have extended more than 10 m below the water table. Therefore, the vertical extent of contamination from the WMA is unknown. There are no indications that drivers currently exist to cause contamination to migrate below the current depth of the monitoring wells. Wastes released from the WMA are concentrated brines which might suggest that if a dense fluid waste reached the water table, it could migrate deeper in the groundwater system before it is transported laterally from the area. Because the wastes reaching the water table to date have been of relatively low concentration, these conditions probably have not existed. A planned well completed deeper in the groundwater system near well 299-W19-41, where the highest downgradient contamination is found, will be used to evaluate the depth of contamination below the water table.

## **4.2 Groundwater Flow**

As described in Section 2.4, groundwater flow in the vicinity of WMA U has been characterized well enough to know the current flow direction and velocity. Aquifer properties such as hydraulic conductivity and specific yield have been determined from aquifer tests. As additional monitoring wells are drilled, aquifer tests will be conducted to collect additional point measurements of hydraulic conductivity. These tests are necessary because as the water table falls, the wells are completed in deeper, uncharacterized portions of the aquifer.

The major data need for groundwater flow is to continue monitoring water levels so that groundwater flow directions and gradients can be updated on a periodic basis.

## **4.3 Groundwater Quality**

The major groundwater quality data needs are to monitor known tank waste constituents and indicators that could reach the water table. Trends in these constituents are needed to judge the nature of the continued impact of the WMA on groundwater quality. Samples from deeper in the aquifer will provide information about the vertical extent of contamination from the WMA.

# **5.0 Groundwater Assessment Plan**

Plans presented in this section are based on data needs presented in Section 4.0. The observed impacts of the WMA on groundwater quality are minor to date, but some gaps in coverage need to be filled and the area needs to be monitored to ensure that possible future impacts are characterized. Therefore, the plans include constructing additional groundwater monitoring wells and monitoring groundwater for those Site-specific constituents contained in the wastes at frequencies appropriate for the rate of groundwater flow beneath the area, quarterly at a minimum.

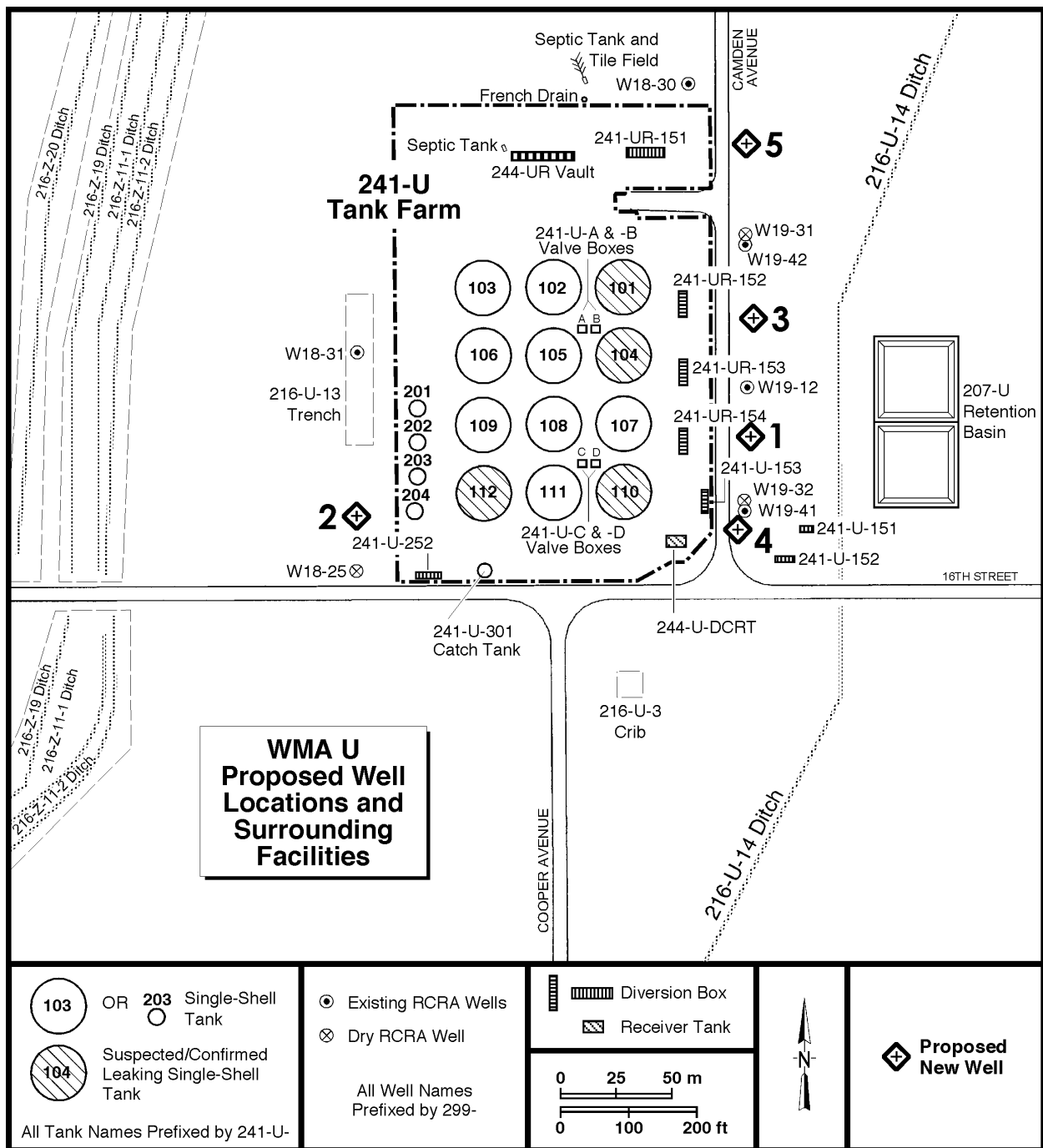
## 5.1 Approach

The original assessment, the first determination (Hodges and Chou 2000), showed that WMA U had affected groundwater quality with nonhazardous major ion species and co-contaminants technetium-99, nitrate, and chromium. Since that report was published, levels for specific conductance, nitrate, and technetium-99 have continued to rise, indicating that wastes are continuing to drain through the vadose zone. Continued groundwater monitoring will be performed to follow those trends. In addition, on a periodic basis, samples will be analyzed for other tank waste constituents to see if they have reached groundwater. Five additional wells are planned to fill some gaps along the downgradient margin of the WMA, to replace a dry upgradient well, and to explore the vertical extent of the detected contamination.

## 5.2 New Wells

Five new monitoring wells are planned for WMA U. The new well locations are shown on Figure 5.1. These wells and their locations have been agreed to between DOE and the Washington State Department of Ecology. Wells 1 through 3 will be drilled in CY 2001; wells 4 and 5 have been proposed but their construction schedule has yet to be determined. Wells 1 and 3 will be drilled on the down-gradient margin of the WMA and completed in the top 10.7 m of the aquifer. These two wells will be evenly spaced between wells 299-W19-41 and 299-W19-42. The two new wells will replace well 299-W19-12 because groundwater samples collected from the well have elevated pH levels, indicating that the samples may be compromised by the cement used in construction of the well. Well 2 will be drilled on the upgradient side of the WMA, about 30 m north of existing well 299-W18-25 that is dry. Well 2 will be drilled far enough north to avoid a U tank farm runoff control system that will be constructed through the area in the summer of 2001. Well 4 will be drilled directly downgradient of the 244-UR Vault. Well 4 will be drilled adjacent to well 299-W19-41 and will be drilled to the Ringold Lower Mud unit. Water samples will be collected as the well is drilled. Rapid groundwater analyses will provide information about the distribution of contaminants and ultimately where the well should be completed in the deeper part of the aquifer. The purpose of this well is to define the vertical extent of contamination at the location where the largest groundwater quality impact has been detected. Well 5 will be drilled downgradient of the north end of the WMA where releases from the 244-UR Vault occurred. These new wells will be placed on the same sampling and analysis schedule as the existing wells.

As the wells are drilled, sediment samples will be collected every 5 ft and at changes in stratigraphy. Continuous core will be collected from ground surface to the top of the Ringold Formation or refusal in well 1. Moisture samples will be collected from the splitspoon shoe. As well 4 is drilled through the unconfined aquifer, water samples will be collected at the water table; at 10 m, 20 m, and 30 m below the water table; and just above the Lower Mud Unit. These samples will be analyzed for nitrate, sulfate, and technetium-99, the major waste constituents whose elevated concentrations would indicate a WMA impact on groundwater quality. The wells will be logged by spectral gamma techniques to provide gross gamma logs and specific logs for potassium-40, uranium, thorium-234, and anthropogenic gamma emitting radionuclides before a smaller string of casing is used in the well. These data will be used



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**Figure 5.1.** Proposed New Wells for Waste Management Area U

to refine the geologic model of the area. The geologist's logs, geophysical logs, construction specifications, and any other information collected during drilling will be documented in borehole completion reports.

### 5.3 Sampling and Analysis

The current groundwater monitoring network consists of five wells. The wells and some of their important characteristics are presented in Table 5.1. Well 299-W18-31 is upgradient of the WMA and the other four wells are downgradient. Wells 299-W18-25, 299-W19-31, and 299-W19-32 are included for reference only because they have gone dry and can no longer be sampled. They are included because water quality data from those wells are important in understanding past groundwater conditions.

**Table 5.1.** Wells in Monitoring Network

Well	Depth to Bottom of Screen (m)	Depth to Water on 3/1/01 (m)	Length of Water Column in Screen on 3/1/01 (m)	Screen Length (m)	Construction Casing/Screen	Monitoring Interval
299-W18-30 <sup>91</sup>	71.4	68.7	2.7	10.7	SS/SS <sup>(a)</sup>	Top of unconfined
299-W18-31 <sup>91</sup>	67.8	65.7	2.1	10.7	SS/SS	Top of unconfined
299-W19-12 <sup>83 (b)</sup>	73.2	68.6	4.6	12.2	CS <sup>(c)</sup> /SS	Top of unconfined
299-W19-41 <sup>98</sup>	77.8	69.1	8.7	10.7	SS/SS	Top of unconfined
299-W19-42 <sup>98</sup>	77.8	68.9	8.9	10.7	SS/SS	Top of unconfined
299-W18-25 <sup>90 (d)</sup>	65.5	65.9 <sup>(e)</sup>	-0.4	4.6	SS/SS	Dry
299-W19-31 <sup>90 (d)</sup>	67.8	68.1 <sup>(e)</sup>	-0.3	4.6	SS/SS	Dry
299-W19-32 <sup>91 (d)</sup>	67.8	68.3 <sup>(e)</sup>	-0.5	4.6	SS/SS	Dry
Note: Superscript following well number denotes year of installation. (a) Stainless steel. (b) Pre-RCRA; the bottom 3 m of the well have been filled. (c) Carbon steel. (d) Unsampleable. (e) The water table has dropped below the screen; depth to water has been approximated from nearby wells.						

Table 5.2 presents the sampling frequency for each well and the analyses that will be performed. Additional constituents present in tank wastes may be added to the list presented in Table 5.2 and the monitoring frequency may be modified at the discretion of the project scientist based on data needs. After the new wells are sampled the first time, their sampling and analysis schedule will be adjusted so that they are sampled at the same time as the currently existing wells.

**Table 5.2.** Sampling Frequency and Constituent List

Well	Specific Conductance	pH	Temperature	Alkalinity	Anions (chloride, fluoride, nitrate, nitrite, and sulfate)	Metals <sup>(a)</sup>	Technetium-99	Gross Alpha	Iodine-129	Tritium	Low-Level Gamma Scan	VOAs <sup>(b)</sup>	Water Level
299-W18-30	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
299-W18-31	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
299-W19-12	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
299-W19-41	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
299-W19-42	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
New Well 1 <sup>(c)</sup>	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
New Well 2 <sup>(c)</sup>	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
New Well 3 <sup>(c)</sup>	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
New Well 4 <sup>(c)</sup>	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
New Well 5 <sup>(c)</sup>	Q	Q	Q	Q	Q	Q	Q	A	A	A	A	A	Q
Note: Sampling and analysis frequency is Q for quarterly (February, May, August, and November) and A for annual (February). (a) Metals include Al, Sb, Ba, Be, Cd, Ca, Cr, Co, Cu, Fe, Mg, Mn, Ni, K, Ag, Na, Sr, V, Zn. (b) Volatile organic compound's of specific interest are carbon tetrachloride and chloroform. (c) All listed analyses will be performed on first time samples from new wells.													

## 5.4 Groundwater Flow

Groundwater flow direction and rate must be determined regularly. These properties are determined several ways, but the standard method for this WMA has been to measure water levels in surrounding monitoring wells. Water levels will continue to be measured on a quarterly basis in all WMA U monitoring wells. These data will be converted to elevations and evaluated using trend surface analysis and shown as a water table map. Groundwater flow velocity,  $v$ , will be estimated using the Darcy equation.

Slug tests will be conducted at all new wells to determine hydraulic conductivity. Additional aquifer testing such as vertical flow tracer tests may be conducted in the future if detected contamination increases rapidly or to levels well above the drinking water standard.



## 5.5 Data Evaluation

Water level data will be used to calculate a least squares linear surface (plane) from which groundwater flow direction and gradient are determined. Calculated water level gradients between upgradient and downgradient wells will be used to calculate the groundwater flow rate. These data will be presented as water table maps.

Groundwater chemistry data will be collected in accordance with the schedule presented in Table 5.2. These data will be evaluated using time series plots to identify any changes in trends and differences between upgradient and downgradient locations. Trends will be evaluated in light of groundwater flow; surface events such as leaks, spills, and releases of water or wastes on the WMA; and any other actions that could affect groundwater quality. The assessment strategy is to continue monitoring the WMA to determine how the existing impact on groundwater quality changes over time. Currently, groundwater contamination is at low concentrations and contaminant distribution maps are not warranted. Plume maps will be developed to depict the areal distribution of any additionally identified groundwater contamination. Constituent ratios may be used as done in Hodges and Chou (2000) to help evaluate sources of detected contamination.

## 6.0 Quality Assurance

Groundwater samples will be collected and analyzed in accordance with written contractor procedures, and data will be managed in accordance with written Pacific Northwest National Laboratory procedures, all controlled by a quality assurance project plan (QAPjP). Tasks performed in this plan will be conducted in accordance with QA plan ETD-012, Rev.2 (or latest revision). Specific items in this assessment plan controlled by the QA plan and their controlling procedures are

- Groundwater Sampling controlled by Duratek subcontract for groundwater sample collection and shipping to the lab and field measurements
- Water Level Monitoring will be controlled by Duratek subcontract and PNL-MA-567
- Analytical Analyses will be controlled by Severn Trent Laboratories, Inc., subcontract
- Data Management will be controlled by PNL-MA-567.

Quality assurance and quality control are discussed in detail for the entire PNNL Groundwater Monitoring Project in Appendix B of the annual groundwater monitoring report (Hartman et al. 2001). Specific analytical procedures are presented in Hartman (2000).

## 7.0 References

40 CFR 265. “Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities.” *Code of Federal Regulations*.

Anderson, J. D. 1990. *A History of the 200 Area Tank Farms*. WHC-MR-0132, Westinghouse Hanford Company, Richland, Washington.

Bergeron, M. P., and S. K. Wurstner. 2000. *Groundwater Flow and Transport Calculations Supporting the Immobilized Low-Activity Waste Disposal Facility Performance Assessment*. PNNL-13400, Pacific Northwest National Laboratory, Richland, Washington.

DOE – see U.S. Department of Energy

Hanlon, B. M. 1996. *Waste Tank Summary Report for Month Ending September 30, 1996*. WHC-EP-0182-102, Westinghouse Hanford Company, Richland, Washington.

Hartman, M. J., ed. 2000. *Hanford Site Groundwater Monitoring: Setting, Sources, and Methods*. PNNL-13080, Pacific Northwest National Laboratory, Richland, Washington.

Hartman, M. J., L. F. Morasch, and W. D. Webber, eds. 2001. *Hanford Site Groundwater Monitoring for Fiscal Year 2000*. PNNL-13404, Pacific Northwest National Laboratory, Richland, Washington.

Hodges, F. N., and C. J. Chou. 2000. *Groundwater Quality Assessment for Waste Management Area U: First Determination*. PNNL-13282, Pacific Northwest National Laboratory, Richland, Washington.

Kipp, K. L., and R. D. Mudd. 1974. *Selected Water Table Contour Maps and Well Hydrographs for the Hanford Reservation, 1944-1973*. BNWL-B-360, Pacific Northwest Laboratory, Richland, Washington.

Lindsey, K. A., B. N. Bjornstad, J. W. Lindberg, and K. M. Hoffman. 1992. *Geologic Setting of the 200-East Area: An Update*. WHC-SD-EN-TI-012, Rev. 0, Westinghouse Hanford Company, Richland, Washington.

Price, W. H., and K. R. Fecht. 1976. *Geology of the 241-U Tank Farm*. ARH-LD-138, Atlantic Richfield Hanford, Richland, Washington.

Reidel, S. P., and K. R. Fecht. 1981. *Wanapum and Saddle Mountains Basalt in the Cold Creek Syncline Area*, In *Subsurface Geology of the Cold Creek Syncline*. RHO-BWI-ST-14, Rockwell Hanford Operations, Richland, Washington.

*Resource Conservation and Recovery Act of 1976*, as amended, Public Law 94-580, 90 Stat. 2795, 42 USC 6901 et seq.

Spane, F. A., Jr., P. D. Thorne, and D. R. Newcomer. 2001. *Results of Detailed Hydrologic Characterization Tests – Fiscal Year 1999*. PNNL-13378, Pacific Northwest National Laboratory, Richland, Washington.

U.S. Department of Energy. 1992. *U-Plant Source Aggregate Area Management Area Study Report*. DOE/RL-91-52, Richland Operations Office, Richland, Washington.

U.S. Department of Energy. 1997. *Vadose Zone Characterization Project at the Hanford Tank Farms - U Tank Farm Report*. GJO-97-1-TAR, GJO-HAN-8, Albuquerque Operations Office and Grand Junction Office, Grand Junction, Colorado.

U.S. Department of Energy. 2000. *Addendum to the U Tank Farm Report*. GJO-97-1-TARA, GJO-HAN-8, Albuquerque Operations Office and Grand Junction Office, Grand Junction, Colorado.

Washington Administrative Code, 173-303-400. *Interim Status Facility Standards*. Olympia, Washington.

Washington Administrative Code, 173-303-610. *Closure and Postclosure*. Olympia, Washington.

Washington State Department of Ecology, U.S. Environmental Protection Agency, and U.S. Department of Energy. 1998. *Hanford Federal Facility Agreement and Consent Order*. Document No. 89-10, Rev. 5 (The Tri-Party Agreement) Olympia, Washington.

## **Appendix A**

### **Preliminary Assessment of the Hydrologic Impact of the Shutdown of ZP-1 Extraction Well 299-W15-37 within Waste Management Area U**

F. A. Spane  
March 14, 2001

Date March 14, 2001

To R.M. Smith

From F.A. Spane

C. J. Chou  
F.N. Hodges  
V.G. Johnson  
S.P. Luttrell  
D.R. Newcomer  
File/LBSubject Preliminary Assessment of the Hydrologic Impact of  
the Shutdown of ZP-1 Extraction Well 299-W15-37  
Within the WMA U

This letter report presents the results of a preliminary assessment of the hydrologic impact of the recent shutdown of pumping activities at a ZP-1 extraction well (299-W15-37) on groundwater conditions within the Waste Management Area (WMA) U, in the Hanford Site 200 West Area. The assessment included two analytical methods: trend-surface analysis of discrete well water-level elevation measurements for investigating changes in groundwater flow characteristics (i.e., groundwater flow direction and hydraulic gradient) within the WMA U, and dynamic well response analysis, which can be used to examine water-level trends after removal of extraneous stress effects (e.g., barometric fluctuations). Most of discussion on analytical methods used in this letter report are presented in Spane (1999) and Spane and Thorne (2000) and will not be repeated here. These analytical methods were applied to representative well measurements available within the WMA U. Previous groundwater-flow characterization investigations for other Hanford Site locations are reported in Spane (1999), for WMA 216-B-63; Spane (2000a), for WMA SST S-SX; and Spane (2000b), for LLWMA-1. Examples of dynamic well response analysis, where the effects of barometric fluctuations are removed to reveal background aquifer water-level trends are presented in Spane (1999) and Spane and Thorne (2000).

## Introduction

Groundwater flow characterization is important as it pertains to predicting and monitoring groundwater contaminant migration within the Hanford Site. Accurate delineation of local groundwater-flow direction and hydraulic gradient conditions within study areas of small size and/or having low gradient conditions, however, can be difficult. A method that facilitates groundwater flow characterization in such areas is the use of trend-surface analysis of representative monitoring well water-level measurements (see Spane 1999).

Various factors can affect the accuracy of well water-level measurements and how they are used to determine hydraulic head and to infer groundwater-flow conditions within an aquifer. These factors include measurement error, well fluid-column density conditions, and external stress effects. Measurement error includes the cumulative effect of instrument and measuring point elevation errors, borehole deviation, and random measurement factors, such as operator error.

Systematic components of measurement error can be evaluated qualitatively by assessing the relative influence of individual well water-level measurements on the calculated groundwater flow characteristics. This was done using sensitivity analysis (i.e., “jack-knife” analysis), wherein each well’s measurement was removed individually from the selected well data set, and then subjected to trend-surface analysis. Results from this sensitivity analysis suggest that systematic measurement errors were not significant for studying groundwater flow characteristics in the WMA U.

Well fluid-column density conditions relate to factors that affect the height of a fluid column in a well above a known elevation datum. Factors that can affect fluid-column density include fluid temperature, salinity, pressure, dissolved gas content, multiphase conditions, and gravitational acceleration effects. Generally, these factors are only significant for deep or thick aquifers having long fluid-column lengths, which was not the case for this investigation.

Natural external stresses that can influence well water-level measurements include barometric effects, tidal or river-stage fluctuations, and earth tides. Earlier papers have addressed these effects on well water-level measurements within confined and unconfined aquifer systems (e.g., Jacob 1940; Ferris 1963; Bredehoeft 1967; Weeks 1979; Hsieh et al. 1988; Erskine 1991). Only recently, however, has the importance of accounting for external stress factor effects in groundwater-flow characterization investigations of unconfined aquifer systems been recognized (see Rasmussen and Crawford 1997, and Spaine 1999). However, since well water-level measurements used in the WMA U study were generally obtained within a period of 1 to 2 hr, no significant impact of external stresses was anticipated or accounted for prior to trend-surface analysis.

This letter report focuses specifically on assessing any subtle changes in groundwater flow characteristics within the WMA U between November 3, 2000 and March 1, 2001, as well as examining for observable hydrologic response associated with the shutdown of the southern most extraction well (well 299-W15-37) of the 200-ZP-1 pump and treat system (which occurred on January 17, 2001). Any impact of the shutdown of extraction well 299-W15-37 is anticipated to be small, due to the relatively low pumping rates at the extraction well (~60 L/min), and the distance to the RCRA WMA U monitoring wells (distance = 165 – 305 m) analyzed in this preliminary study. In a previous study by Spaine and Thorne (2000) predicted responses for the northeastern part of the ZP-1 pump and treat system potentially exceeding a radial distance of 500 m for prolonged extraction periods. These predictions, however, were based on the combined pumping rates of the three extraction wells in this area, which for the predictions used a composite pumping rate of 379 L/min. This is over six times the extraction rate recorded at well 299-W15-37 prior to shutdown on January 17, 2001. For these reasons, the anticipated hydrologic impact of terminating pumping at extraction well 299-W15-37 would be proportionately smaller.

## Data Discussion

To evaluate any potential hydrologic impact at WMA U caused by terminating pumping at extraction well 299-W15-37, other factors affecting the groundwater-flow conditions in the area should also be known. Of note are the significant changes in the water table in the 200-West Area, due to past and present wastewater disposal activities in the area. Of particular importance to the study area were wastewater disposals to U Pond complex (located approximately 1000 m southwest of the WMA U, which received approximately 60% of the total wastewater released in the 200-West Area (Newcomer 1990). These wastewater disposal activities caused discernable changes in the prevailing groundwater flow pattern and formation of a large groundwater mound with elevated water-table conditions approximately 20 m over pre-disposal conditions (Hartman and Dresel 1998).

With the decommissioning of U Pond in 1984, a significant decrease in wastewater disposal and associated decline in water-table elevation were exhibited across the 200-West Area. For example, Hartman and Dresel (1998) report a 6 m decline between 1984 and 1997. The decline in the water table and changes in groundwater flow characteristics are expected to continue with future decreases in wastewater releases to 200-West Area disposal facilities.

To evaluate existing and temporal groundwater flow characteristics within the WMA U area prior to and immediately following the termination of pumping at extraction well 299-W15-37, well water-level measurements were evaluated from RCRA monitoring wells within the WMA. Figure 1 shows the locations of monitoring wells having data for groundwater-flow characterization. Table 1 lists pertinent information concerning well completion, current monitoring conditions for the RCRA wells, and distance to ZP-1 extraction well 299-W15-37.

## Groundwater Flow Characterization

In previous detailed groundwater-flow characterization studies at selected Hanford Site WMA locations reported in Spane (1999) and Spane (2000a, 2000b), water-level measurements were used in the trend-surface analysis for wells that met the following criteria:

- are along the same hydrologic flow plane (i.e., planar potential surface)
- are measured close in time (e.g., 1 to 4 h for low-gradient areas)
- monitor similar depth intervals within the respective hydrogeologic unit
- display similar dynamic well-response characteristics (e.g., to barometric fluctuations)
- are not significantly affected by well-skin effects.

This site was identified in Hartman et al.(2000) as being an intermediate-hydraulic gradient area ( $\sim 0.002$ ), and having a predominant, easterly, groundwater-flow direction. The criteria for wells being on the same hydrologic flow plane would appear to be met.

As noted previously, well measurements used in the trend-surface analysis were obtained close in time (e.g. 1 to 2 h) for all dates analyzed, and all wells monitor the upper-section of the unconfined aquifer within the WMA U. The overall similar well water-level patterns displayed in Figure 2 suggests that the wells exhibit similar dynamic well-response characteristics and that well-skin effects are not likely to impose significant impacts on water-level measurements between wells. A comparison of a detailed barometric response analysis for monitor wells 299-W18-31 and -W19-42 (described later in the letter report) also exhibited nearly identical barometric behavior, with demonstrated time-lag effects up to 50 h for these sites.

Because of the similar dynamic well-response characteristics, intermediate hydraulic gradient conditions (i.e.,  $\sim 0.002$ ), and closeness of well measurements in time, no significant impact of barometric effects was anticipated for measurements used in the trend-surface analysis. Therefore, no accounting of barometric effects was utilized for well water-level measurements for this phase of the study.

### **Trend-Surface Analysis Results**

Available RCRA WMA U monitoring well data were quantitatively evaluated for groundwater-flow characterization using the screening criteria listed previously. Figure 2 shows the similarity in dynamic well-response characteristics exhibited for the six monitoring wells over the time period selected for detailed groundwater-flow characterization. The overall declining water-level elevation trend pattern is consistent with the general decrease in total wastewater disposal within the 200-West Area during the mid-1980's as previously discussed.

To facilitate quantitative determination of groundwater-flow direction and hydraulic gradient conditions, the commercially available WATER-VEL (In-Situ, Inc. 1991) software program was utilized. Water-level elevation and calculated total head values were used with the WATER-VEL program to calculate groundwater-flow direction and hydraulic gradient conditions over the measurement period. The program utilizes a linear, two-dimensional trend surface (least squares) to randomly located hydrologic head or water-level elevation input data. This technique is accurate as long as the two-dimensional linear approximation is applicable (i.e., no significant vertical groundwater-flow gradients exist within the aquifer). This method is similar also to the linear approximation technique described by Abriola and Pinder (1982) and Kelly and Bogardi (1989). A report that demonstrates the use of the WATER-VEL program for calculation of groundwater-flow velocity and direction is presented in Gilmore et al. (1992) and Spane (1999).

To quantitatively assess the groundwater-flow characteristics within the WMA U over the November 3, 2000 to March 1, 2001 time period, observed well water-level elevation measurements (not adjusted for barometric effects) were analyzed. Table 2 lists the results of quantitative trend-surface analysis for nine selected measurement periods for the six existing RCRA monitoring wells during the period of investigation. As shown, a consistent easterly flow direction (ranging between  $6^\circ$  and  $12^\circ$ ; average =  $10^\circ$ . Note: 0 degrees = East; 90 degrees = North) and hydraulic gradient (ranging between 0.00199 and 0.00215; average = 0.00208) are indicated for all nine measurements. No appreciable change in groundwater flow characteristics (i.e., flow direction or gradient) are evident within the WMA U, due to the shutdown of extraction well 299-W15-37, based on the trend-surface analysis results for all RCRA wells within this area.



To examine for the presence of any apparent groundwater flow pattern differences across the WMA facility, an evaluation for the northern WMA U area was also initiated. Four RCRA monitoring wells in this immediate area (wells 299-W18-30, 299-W18-31, 299-W19-12, and 299-W19-42) were selected for this areal analysis. Table 3 lists the results of the trend-surface analysis for the same measurement periods. As shown, nearly identical temporal groundwater flow characteristics were exhibited for the northern U area as were exhibited for the entire WMA U (Table 2). Results from the trend-surface analysis for the four northern monitor wells provide a consistent easterly flow direction (ranging between 4° and 11°; average = 9°) and hydraulic gradient (ranging between 0.00208 and 0.00231; average = 0.00219) for all nine measurements.

To examine for any possible groundwater flow pattern differences within the southern half of the WMA facility, four RCRA monitoring wells in this immediate area (wells 299-W18-25, 299-W18-31, 299-W19-12, and 299-W19-41) were selected. Note: wells 299-W18-31 and 299-W19-12 are shared wells for the north and south WMA U analysis areas. Table 4 lists the results of the trend-surface analysis for the same measurement periods. As shown, nearly identical temporal groundwater flow characteristics were exhibited for the southern U area as were exhibited for the entire (Table 2) and northern WMA U (Table 3), respectively. Results from the trend-surface analysis for the four southern monitor wells provide a consistent easterly flow direction (ranging between 4° and 14°; average = 8°) and hydraulic gradient (ranging between 0.00199 and 0.00215; average = 0.00207) for all nine measurements. It should be noted that a small (~5°) change in flow direction for the southern monitor wells is evident for the last four measurement periods. It is not readily apparent, however, whether this slight change in flow direction can be directly attributable to the termination of pumping activities from extraction well 299-W15-37; particularly since no similar pattern was exhibited for the northern wells, which one would expect to be more affected by well 299-W15-37 effects.

In summary, no significant impact on groundwater flow characteristics (i.e., flow direction and hydraulic gradient) within the WMA U were discernable over the relatively short, six-week period following termination of pumping activities at nearby extraction well 299-W15-37. While trend-surface analysis methods are very useful in detecting changes in flow direction or hydraulic gradient over time, they are rather insensitive for direct detection of hydrologic response or influence at individual monitor well locations. Detection of possible hydrologic effects from well 299-W15-37 within the WMA U, requires quantitative analysis (i.e., dynamic well response analysis) of closely-spaced (in time) well water-level measurements. This quantitative analysis procedure is described in the following section.

## Hydrologic Response

As noted previously, the potential hydrologic impact of terminating pumping activities at extraction well 299-W15-37 is anticipated to be extremely small. For example, if the areal hydrologic properties determined by Spane and Thorne (2000) for the northeast section of the ZP-1 are representative of conditions within the WMA U, then termination of pumping at extraction well 299-W15-37 is anticipated to produce only a recovery response of ~ 0.1 m after 30 days in the northern half of WMA U. This response magnitude is difficult to discern visually from

well water-level records, given the presence of daily barometric fluctuations and the long-term water-table trend (decline) that is occurring within this area. Methods have recently been developed, however, that facilitate removal of masking barometric pressure fluctuations; enabling recognition of potential hydrologic responses associated with pumping activities.

To assess whether the shutdown of extraction well 299-W15-37 had a hydrologic impact within the WMA U, two RCRA monitor wells (299-W18-31 and 299-W19-42) were selected for high-frequency well water-level response data collection. The monitor wells are located on the west and east side of the WMA, respectively (see Figure 1), and are between 173 and 220 m from extraction well 299-W15-37 (see Table 1). Well water-level data were measured every 10 min with pressure transducers suspended a short distance below the water-level surface. Data were stored in surface data loggers and retrieved on a weekly or bi-weekly basis. Well water-level measurements were also collected manually on those days that data were retrieved from the data loggers.

Figure 3 shows the baseline response of water-levels with monitor wells 299-W18-31 and 299-W19-42 for a ~28-d period prior to and following shutdown of extraction well 299-W15-37 on January 17, 2001 (calendar day 383). As shown, the well water-level responses are nearly identical and display a typical inverse relationship to barometric pressure fluctuations. To ascertain any background hydrologic response within the aquifer, the effects of barometric pressure on the well water-level measurements were removed using the multiple-regression deconvolution technique, which is discussed in detail in Rasmussen and Crawford (1997) and Spane (1999).

The removal process requires that the well barometric response characteristics be determined first using multiple-regression convolution techniques. Monitor well water-levels and barometric pressures were analyzed for the ~28-d period immediately prior to shutdown of well 299-W15-37. Linear trends in the pre-shutdown water-level and barometric pressure were determined using linear regression analysis and removed from the data. Use of detrended data allows for a more quantitative analysis of barometric response characteristics, and facilitates detection of background trends within the water-level record when barometric effects are removed. Figure 4 presents the barometric response function characteristics for both monitor wells, showing persistent barometric time-lag effects up to 50-hr at both sites. As indicated, the barometric response characteristics are nearly identical and are typical of an unconfined aquifer pattern with minor wellbore storage/skin effects, as discussed in Spane (1999).

Figure 5 shows the predicted (based on the observed barometric pressure record) and the barometric-corrected well water-level response for monitor well 299-W18-31. The deviation between the observed and predicted response for the 7 - 10 d period prior to well 299-W15-37 shutdown is indicative of the presence of a background water-level trend (decline) within the aquifer. Additionally, the later match between the observed and predicted response is indicative of a reversal in the background water-level trend during the post-shutdown period. This is more clearly shown in the barometric-corrected response, where the obscuring effects of barometric pressure fluctuation have been removed. As shown, a declining water-level trend of -0.0027 m/d is indicated for the ~28-d pre-shutdown period, while a +0.0015 m/d was calculated for the ~28-d

post-shutdown period using linear-regression of the corrected water-level response. Interestingly, the projected recovery response ( $+0.0042$  m/d) after 1 month amounts to  $\sim 0.1$  m, which is consistent to what was previously predicted within the northern WMA U for the extraction well shutdown.

Figure 6 shows the predicted and the barometric-corrected well water-level response for monitor well 299-W19-42. As shown, a similar overall pattern and identical pre-shutdown trend with monitor well 299-W18-31 are indicated. A higher post-shutdown trend ( $+0.0029$  m/d), however, was calculated for well 299-W19-42. It should be noted, that the pressure transducer system was removed temporarily from this well during the first week following the extraction well shutdown to support scheduled water-sampling activities at this site. It is not known, whether this apparent change in post-shutdown trend for this well site is real or an artifact of changes to the pressure transducer measuring system.

In summary, dynamic well response analysis reveals the presence of a reversal in aquifer water-level trends within the WMA U for the  $\sim 28$ -d period immediately prior to and following shutdown of pumping activities at ZP-1 extraction well 299-W15-37. While the magnitudes in calculated water-level trends are small, the timing of the trend reversal suggests that the termination of pumping at extraction well 299-W15-37 is the causative factor. It is likely that the impact of the shutdown is temporary, and with time the influence of the more dominant area-wide decline in aquifer water levels occurring within the 200-West Area (e.g., due to U-Pond decommissioning) will be reestablished within the WMA U.

## References

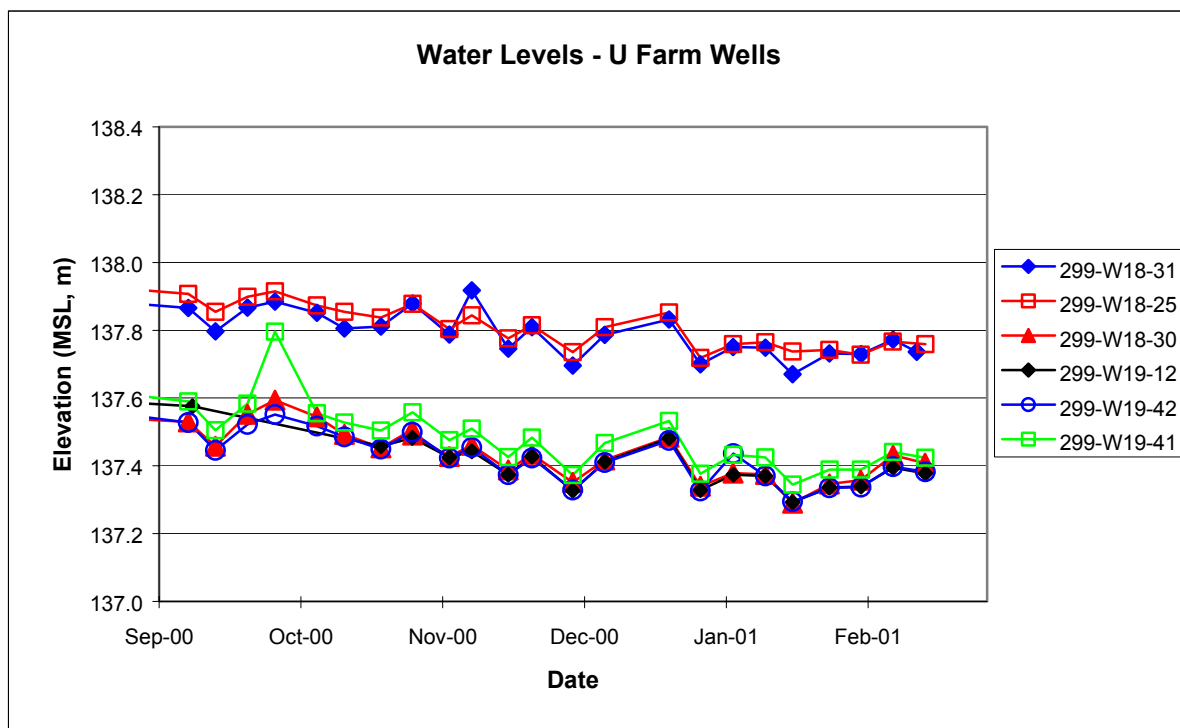
- Abriola LM and GF Pinder. 1982. "Calculation of velocity in three space dimensions from hydraulic head measurements." *Ground Water* 20(2):205-213.
- Bredehoeft JD. 1967. "Response of well-aquifer systems to earth tides." *Journal of Geophysical Research* 72(12):3075-3087.
- Erskine AD. 1991. "The effect of tidal fluctuation on a coastal aquifer in the UK." *Ground Water* 29(4):556-562.
- Gilmore TJ, DR Newcomer, SK Wurster, and FA Spane, Jr. 1992. *Calculation of groundwater discharge to the Columbia River in the 100-N area*. PNL-8057, Pacific Northwest Laboratory, Richland, Washington.
- Hartman MJ and PE Dresel (eds.). 1998. *Hanford Site groundwater monitoring for fiscal year 1997*. PNNL-11793, Pacific Northwest National Laboratory, Richland, Washington.
- Hartman MJ, LF Morasch, and WD Webber, (eds). 2000. *Hanford Site groundwater monitoring for fiscal year 1999*. PNNL-13116, Pacific Northwest National Laboratory, Richland, Washington
- Hsieh PA, JD Bredehoeft, and SA Rojstaczer. 1988. "Response of well aquifer systems to earth tides: Problem revisited." *Water Resources Research* 24(3):468-472.
- In-Situ, Inc. 1991. *WATER-VEL<sup>TM</sup> groundwater velocity*. ISI-GWV-2.21-1, Laramie, Wyoming.
- Jacob CE. 1940. "On the flow of water in an elastic artesian aquifer." *American Geophysical Union, Transactions* 14:446-460.
- Kelly WE and I Bogardi. 1989. "Flow directions with a spreadsheet." *Ground Water - Computer Notes* 27(2):245-247.
- Newcomer DR. 1990. *Evaluation of Hanford Site Water-Table Changes – 1980 – 1990*. PNL-7498, Pacific Northwest Laboratory, Richland, Washington.
- Rasmussen TC and LA Crawford. 1997. "Identifying and removing barometric pressure effects in confined and unconfined aquifers." *Ground Water* 35(3):502-511.
- Spane FA, Jr. 1999. *Effects of barometric fluctuations on well water-level measurements and aquifer test data*. PNNL-13078, Pacific Northwest National Laboratory, Richland, Washington.
- Spane, FA, Jr. 2000a. *Groundwater flow characterization within the S-SX tank farm vicinity*; Hanford Groundwater Monitoring Project letter report to V.G. Johnson, March 23, 2000, 17 p.
- Spane FA, Jr. 2000b. *Detailed groundwater-flow characterization within low-gradient areas: initial results for LLWMA-1*; letter report to R.B. Mercer (Site-Wide Project), December 12, 2000.

Spane FA, Jr., and PD Thorne. 2000. *Analysis of the hydrologic response associated with shutdown and restart of the 200-ZP-1 pump-and-treat system*. PNNL-13342, Pacific Northwest National Laboratory, Richland, Washington.

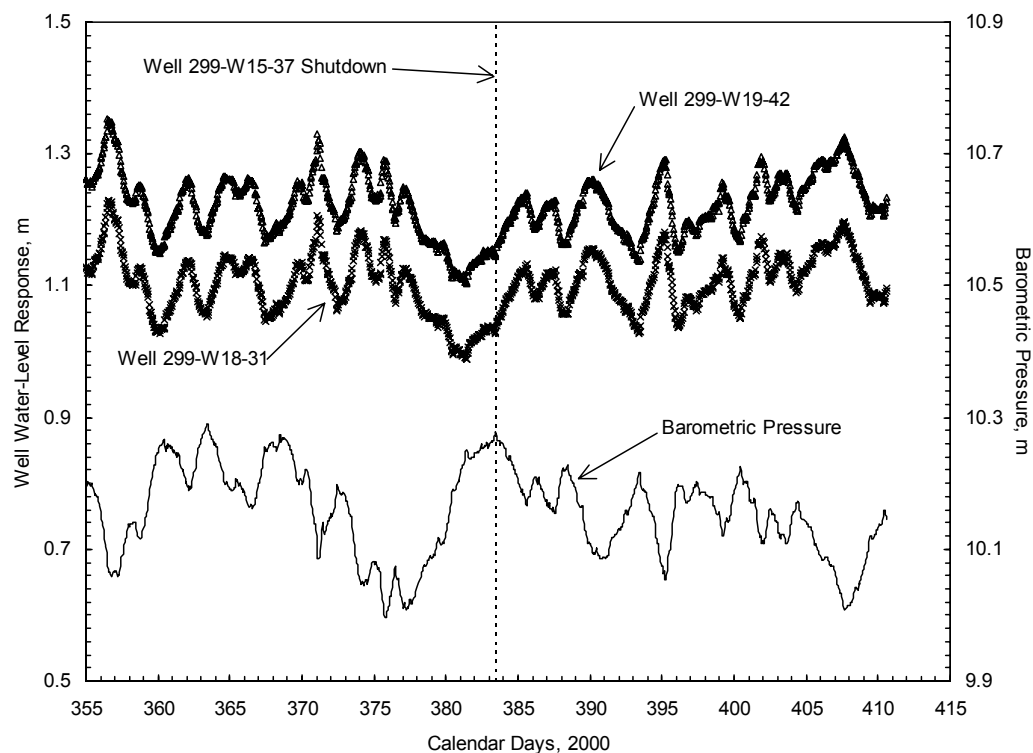
Weeks EP. 1979. "Barometric fluctuations in wells tapping deep unconfined aquifers." *Water Resources Research* 15(5):1167-1176.



**Figure 1.** Location Map of Wells Monitoring the WMA U, 200-West Area.

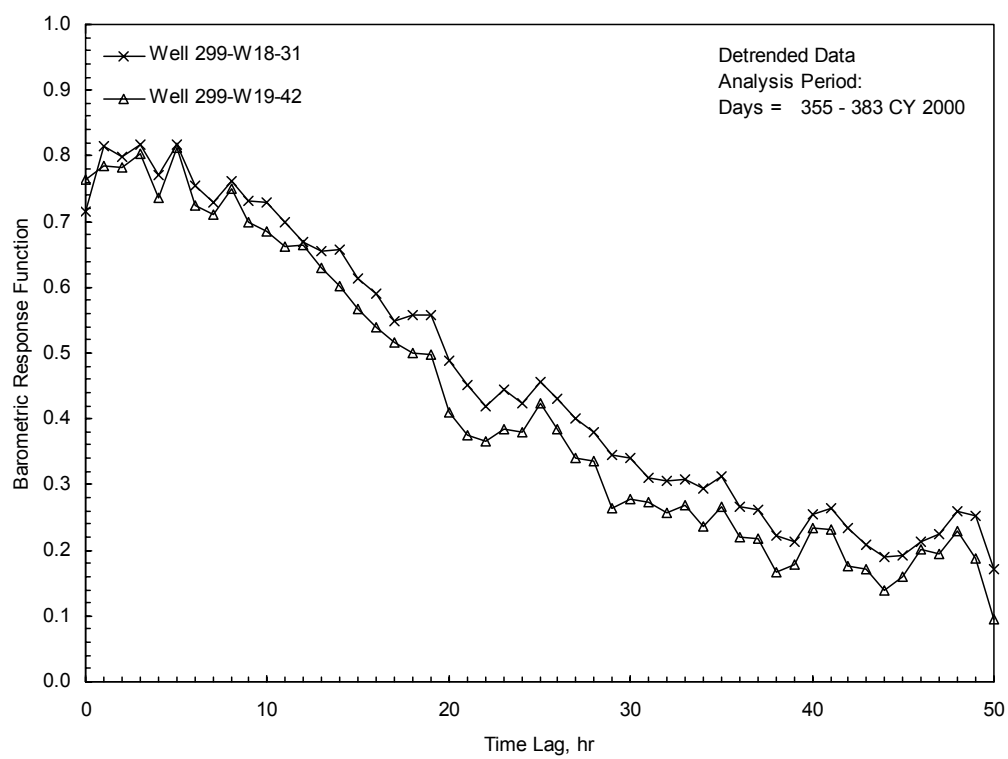


**Figure 2.** Comparison of Well Water-Level Elevation Response for RCRA Wells Monitoring the WMA U

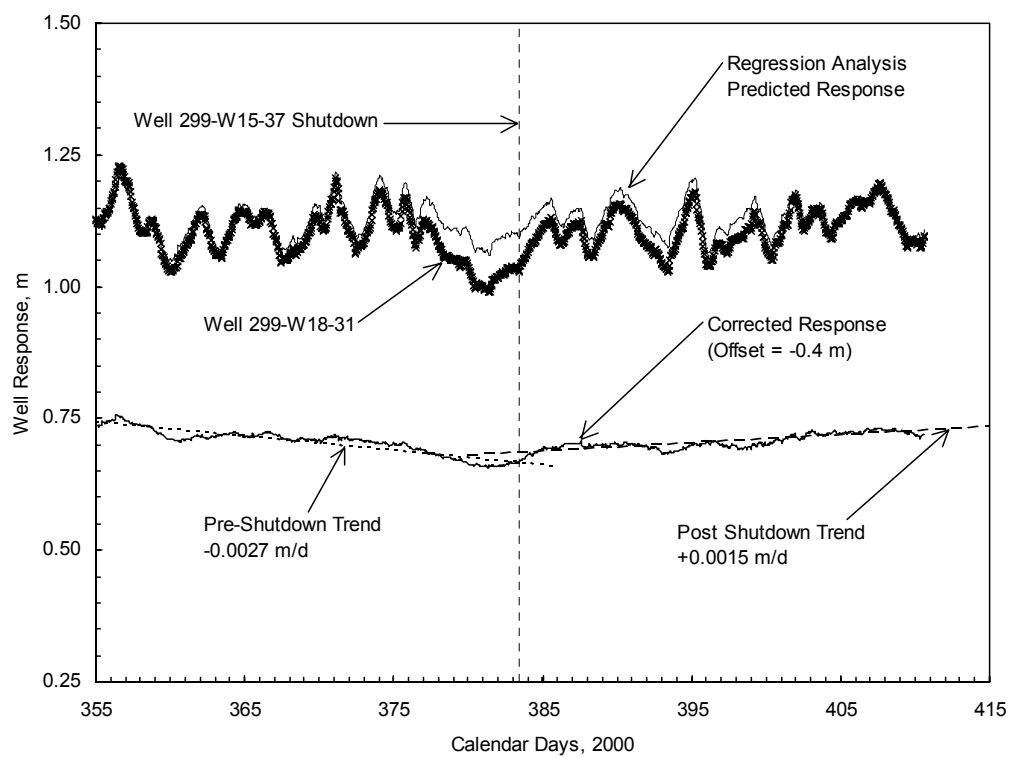


**Figure 3.** Baseline Monitor Well Water-Levels (Wells 299-W18-31 and –W19-42) and Barometric Pressure Response for the ~28-d Period Prior to and Following Shutdown of ZP-1 Extraction Well 299-W15-37.

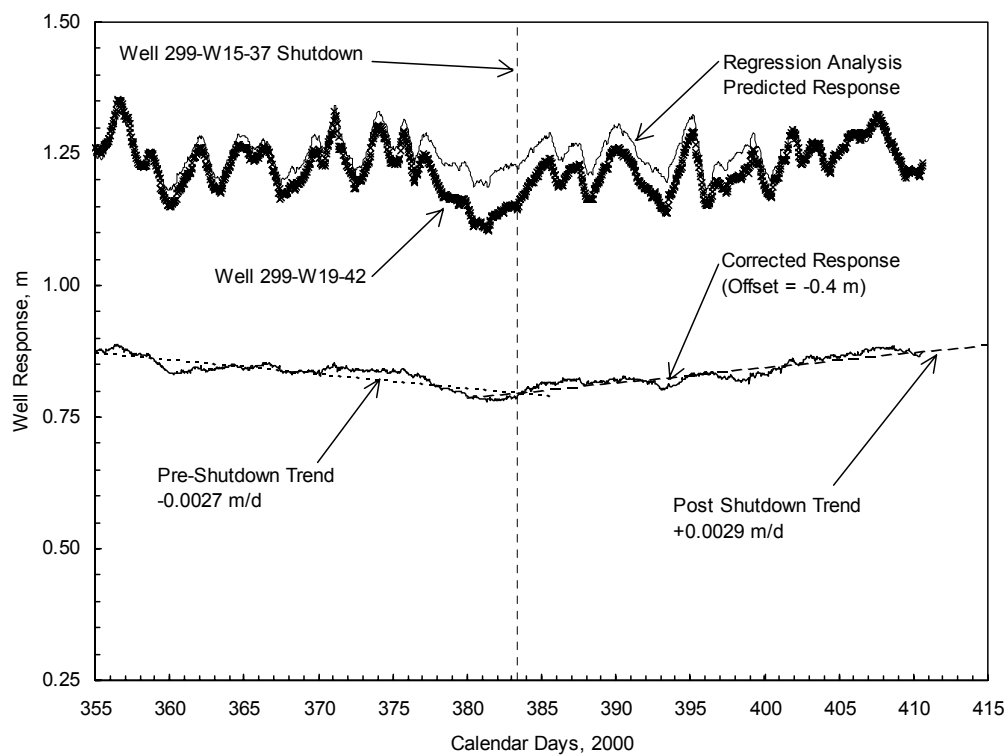




**Figure 4.** Barometric Response Analysis for Monitor Wells 299-W18-31 and 299-W19-42



**Figure 5.** Multiple-Regression Match and Barometric Corrected Water Levels for Monitor Well 299-W18-31



**Figure 6.** Multiple-Regression Match and Barometric Corrected Water Levels for Monitor Well 299-W19-42

**Table 1.** Pertinent Well Completion Information for RCRA Wells Monitoring the WMA U Facilities

Well	Completion Date M/Yr	Well Screen Length m, bgs	Water-Level Depth, m, bgs	Water-Column Length Above Well Screen Bottom, m	Distance to ZP-1 Extraction Well 299-W15-37, m
299-W18-25	12/90	58.98 - 65.47	65.24 (9/00)	0.23 (9/00)	270.1
299-W18-30	11/91	60.20 - 71.41	67.48 (9/00)	3.93 (9/00)	163.7
299-W18-31	12/91	57.09 - 67.76	64.15 (9/00)	3.61 (9/00)	173.2
299-W19-12	1/83	64.01 - 76.20	68.11 (9/00)	8.09 (9/00)	261.4
299-W19-41	9/98	67.07 - 77.77	67.99 (9/00)	9.78 (9/00)	303.1
299-W19-42	9/98	67.14 - 77.84	67.96 (9/00)	9.88 (9/00)	219.7

**Table 2.** Groundwater-Flow Characterization Results Based on Trend-Surface Analysis: All RCRA U WMA Monitor Wells

Measurement Date	Groundwater-Flow Direction <sup>(a)</sup>	Hydraulic Gradient, m/m
11/3/00	12.0°	0.00199
11/30/00	9.9°	0.00208
12/28/00	10.7°	0.00205
1/11/01	11.9°	0.00207
1/25/01	10.7°	0.00215
2/1/01	8.9°	0.00210
2/8/01	6.3°	0.00202
2/22/01	9.9°	0.00209
3/1/01	11.4°	0.00213
Average	10.2° (± 1.8°)	0.00208 (± 0.00006)
(a) 0 degrees East; 90 degrees North. RCRA monitor wells used in analysis: 299-W18-25, -W18-30, -W18-31, -W19-12, -W19-41, and -W19-42		

**Table 3.** Groundwater-Flow Characterization Results Based on Trend-Surface Analysis:  
 North RCRA U WMA Monitor Wells

Measurement Date	Groundwater-Flow Direction <sup>(a)</sup>	Hydraulic Gradient, m/m
11/3/00	10.8°	0.00208
11/30/00	6.6°	0.00210
12/28/00	9.2°	0.00213
1/11/01	10.5°	0.00217
1/25/01	9.6°	0.00227
2/1/01	7.8°	0.00224
2/8/01	4.2°	0.00214
2/22/01	9.5°	0.00223
3/1/01	11.3°	0.00231
Average	8.8° ( ± 2.3°)	0.00219 ( ± 0.00008)
(a) 0 degrees East; 90 degrees North. RCRA monitor wells used in analysis: 299-W18-30, -W18-31, -W19-12, and -W19-42		

**Table 4.** Groundwater-Flow Characterization Results Based on Trend-Surface Analysis: South RCRA U WMA Monitor Wells

Measurement Date	Groundwater-Flow Direction <sup>(a)</sup>	Hydraulic Gradient, m/m
11/3/00	10.0°	0.00199
11/30/00	13.6°	0.00213
12/28/00	9.7°	0.00205
1/11/01	10.1°	0.00207
1/25/01	8.2°	0.00215
2/1/01	5.5°	0.00209
2/8/01	4.5°	0.00201
2/22/01	5.4°	0.00207
3/1/01	4.7°	0.00209
Average	8.0° (± 3.1°)	0.00207 (± 0.00005)
(a) 0 degrees East; 90 degrees North. RCRA monitor wells used in analysis: 299-W18-25, -W18-31, -W19-12, and -W19-41		

## **Appendix B**

### **Well Construction and Completion Summaries**



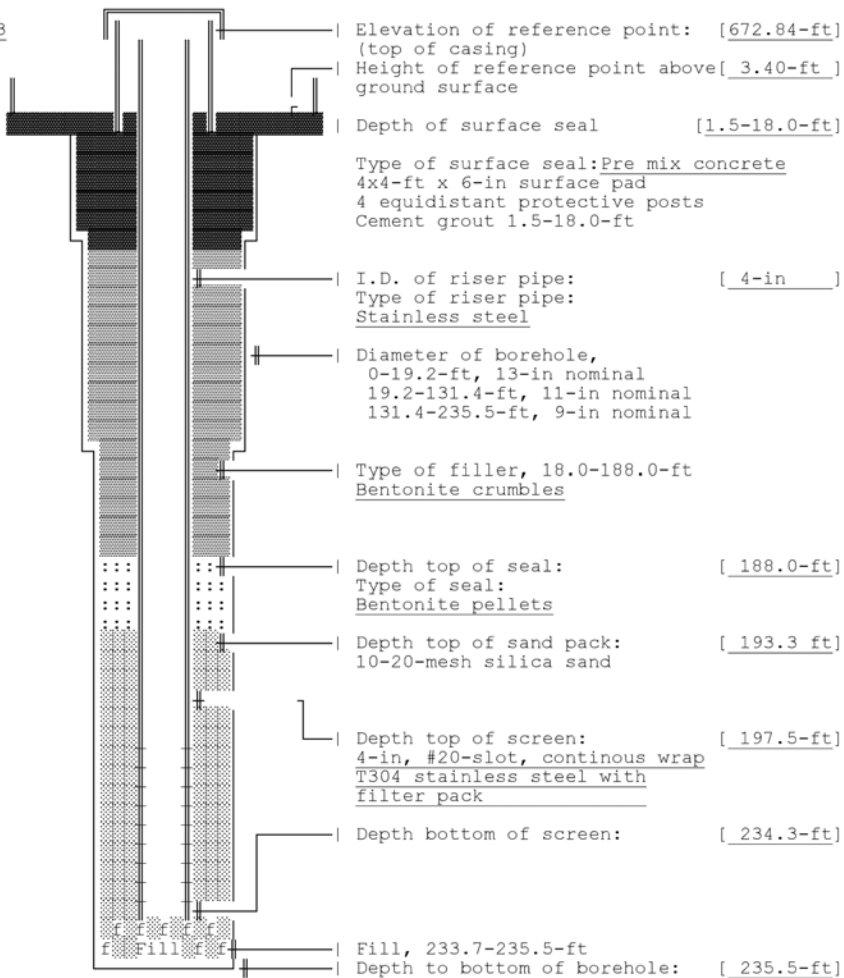
# WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Drive barrel Method: Hard tool	WELL NUMBER: 299-W18-30	TEMPORARY WELL NO: _____
Drilling 200 W Water	Additives	Hanford	
Fluid Used: Supply	Used: Not documented	Coordinates: N/S N 38,492.8 E/W W 75,541.4	
Driller's	WA State	State NAD83 N 135,193.95m E 566,871.07m	
Name: D. Kruger	Lic Nr: Not documented	Coordinates: N 443,601 E 2,219,685	
Drilling Company: Kaiser Engineers	Company Location: Hanford	Start Card #: Not documented T _____ R _____ S _____	
Date	Date	Elevation	
Started: 11Sep91	Complete: 14Nov91	Ground surface (ft): 669.44 (Brass cap)	

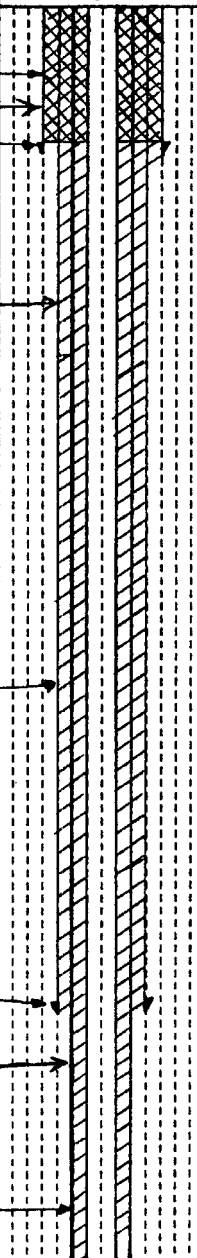
Depth to water: 201.2-ft Nov91  
(Ground surface) 204.1-ft 26Mar93

GENERALIZED Geologist's  
STRATIGRAPHY Log  
Sl=slightly

0-2: GRAVEL  
2 10: GRAVEL  
10-12: Sl sandy GRAVEL  
12-15: GRAVEL  
15-25: GRAVEL, tr. SAND  
25-35: Sl sandy GRAVEL  
35-40: Sandy GRAVEL  
40-50: Sl sandy GRAVEL  
50-55: Sl gravelly SAND  
55-60: Gravelly SAND  
60-65: SAND w/trace GRAVEL  
65-70: Sl silty SAND  
70-75: SAND, w/trace SILT  
75-79.4: SAND  
79.4-80.7: Silty SAND  
80.7-89.2: SAND, w/trace SILT  
89.2-100: Silty SAND  
100-110: Sl silty SAND  
110-119.4: SAND  
119.4-120.7: Silty SAND  
120.7-123.7: SAND  
123.7-129.6: SILT, w/trace SAND  
129.6-131: CALICHE  
131-140: Sandy GRAVEL  
140-150: Sl silty sandy GRAVEL  
150-170: Silty sandy GRAVEL  
170 175: Sandy GRAVEL  
175-205: Sl sandy GRAVEL  
205-210: Sl silty sandy GRAVEL  
210-225: Sandy GRAVEL  
225-230: Sl sandy GRAVEL  
230-233.3: Sandy GRAVEL  
233.3-235.5: Silty sandy GRAVEL



Drawing By: RKL/2W18-30.ASB Date: 19Apr93  
Reference:

WELL SUMMARY SHEET				0503023		Boring or Well No. <u>299-W18-30</u>	
						Sheet <u>1</u> of <u>      </u>	
Location <u>200 WEST - 241 N Farm</u>			Project <u>RCRA W017 / SST</u>				
Elevation <u>                    </u>			Drilling Contractor <u>KEH</u>				
Driller <u>Don Kruger</u>			Drilling Method and Equipment <u>CABLE TOOL - Bucyrus Erie</u>				
Prepared By <u>Dennis Anderson</u> (Sign/Print Name)			Date <u>7/1/91</u>		Reviewed By <u>                    </u> (Sign/Print Name)		
CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA				
Description	Diagram		Graphic Log	Lithologic Description			
12" temporary carbon steel casing to 19.16' b/s		5		SAND			
CEMENT GROUT ~15'-19.0'		10		SILTY SANDY GRAVEL			
12" shoe w/ 1.1' Ø		15		GRAVEL			
		20		GRAVEL w/ trace sand			
		25		SILTY SANDY GRAVEL			
		30		SILTY SANDY GRAVEL			
		35		SANDY GRAVEL			
BENTONITE CRUMBLES 180'-190.0'		40		SLIGHTLY SANDY GRAVEL			
		45		" " "			
		50		SLIGHTLY GRAVELLY SAND			
		55		GRAVELLY SAND			
		60		SAND w/ trace gravel			
		65		SLIGHTLY SILTY SAND			
		70		SILTY SAND			
		75		SAND			
10" temporary carbon steel casing to 131.37' b/s		80		SILTY SAND			
	85		SLIGHTLY SILTY SAND				
	90		SILTY SAND				
	95		" " "				
	100		SLIGHTLY SILTY SAND				
	105		" " "				
	110		SAND				
	115		SAND				
	120		SILTY SAND				
	125		SILT w/ trace sand				
10" shoe w/ .94' Ø	130		" " w/ caliche @ 129.				
	135		SANDY GRAVELS				
BENTONITE CRUMBLES 130'-135.0'	140		SLIGHTLY SILTY SANDY GRAVELS				
	145		SILTY SANDY GRAVEL				
	150		" " "				
8" temporary carbon steel casing to 235.5' b/s	155		" " "				
	160		" " "				

A-6000-384 (04/90)

WELL CONSTRUCTION REPORT				0503022		Page <u>1</u> of <u>2</u>	
Specification No. <u>WMC-5-014</u> <span style="float: right;">(SEE COMMENT)</span> ECNs <u>144240, 144241, 127437, 150204</u> Project <u>W017 / 5ST</u> Location <u>200 W / 241 U Farm</u> Drilling Company <u>KEH</u> Driller <u>Don Kruger</u> Other (Companies) <u>WMC, SALEM</u> Geologist(s) <u>Dennis Anderson - SALEM</u> <u>William C. Brennan - EPMCO</u> <u>Karl Linn - HAT (COWSEN) (CONNECTION)</u>				Well No. <u>299-W18-30</u> Temp. Well No. <u>N/A</u> Coordinates _____ Casing Elev. _____ Ground Elev. _____ Drilling Method _____ Verification Method <u>VISUAL OBSERVATION</u> Criteria <u>WMC-5-014 5.2, 5.3, 7.5, EII 6.7 SEC 6.2</u> Rotary Air <u>N/A</u> Mud <u>N/A</u> Initials <u>N/A</u> Date <u>N/A</u> Cable Tool <u>DJ-225'</u> H <u>225'-235.3'</u> <u>DJA</u> <u>10/7/91</u> Drilling Fluid <u>RAW H2O</u> <u>DJA</u> <u>9/11/91</u> Other _____			
Geophysical Logging Sondes Interval Date <u>Gross Gamma 130.7' - 1.0' 9/23/91</u> <u>Gross Gamma 232.7 - 100.0' 10/7/91</u> <u>- NEED</u> <u>- Aquifer TESTING</u> <u>- Pump INSTALLATION</u>		Completion Data Drilled Depth <u>235.3'</u> Completed Depth <u>234.3</u> Date Started <u>9/11/91</u> Date Completed <u>11-14-91</u> Static Water Level/Date <u>201.2' bgs 11-14-91</u>		Aquifer Testing Type <u>SLUG TEST</u> Flow Meter I.D. No. <u>N/A</u> Cal. Due Date <u>N/A</u> Length of Test <u>1 HR</u> Volume Pumped <u>N/A</u> Drawdown <u>N/A</u> Date of Test <u>12/10/91</u>			
Verification Method <u>VISUAL INSP &amp; DIRECT OBS OF LOG</u> Criteria <u>WMC-5-014 4.2.2, 7.6, 7.7, NAL-CM-7-7, SEC 5.4</u> Drilling Tools/Rig Initials <u>DJA</u> Date <u>9/11/91</u> Temporary Materials <u>DJA</u> <u>10/7/91</u> Permanent Materials <u>K.L.</u> <u>11-12-91</u>				Completion Results Material Storage/Packing Verification Method <u>VISUAL OBSERVATION</u> Criteria <u>WMC-5-014 4.2.2, 7.3</u> Mtl. Handling/Storage Initials <u>K.L.</u> Date <u>11-14-91</u> Material Packing <u>K.L.</u> <u>11-14-91</u> Lubricants/Additives Verification Method <u>VISUAL OBSERVATION</u> Criteria <u>WMC-5-014 7.2</u> Additives <u>RAW H2O</u> Initials <u>DJA</u> Date <u>9/11/91</u> Lubricants <u>JET LUBE</u> <u>DJA</u> <u>9/11/91</u> Straightness Test Verification Method <u>VISUAL OBSERVATION</u> Criteria <u>WMC-5-014 8.2</u> Initials <u>DJA</u> <u>WES</u> Date <u>10/7/91</u>			
Screen Type Length Slot Size <u>T-304 36.7' WITH END CAP 20 SLOT</u> <u>15' 1 X 5' SECTION 3 X 10' SECTIONS</u> Depth(s) <u>197.5'</u> - <u>234.3' END CAP</u> Verification Method <u>STEEL TAPE MEASUREMENT</u> Criteria <u>WMC-5-014 4.2.3, 4.2.5, 12.2, 9.2.1</u> Initials <u>K.L.</u> Date <u>11-14-91</u>							

A-6000-436 (09/90)

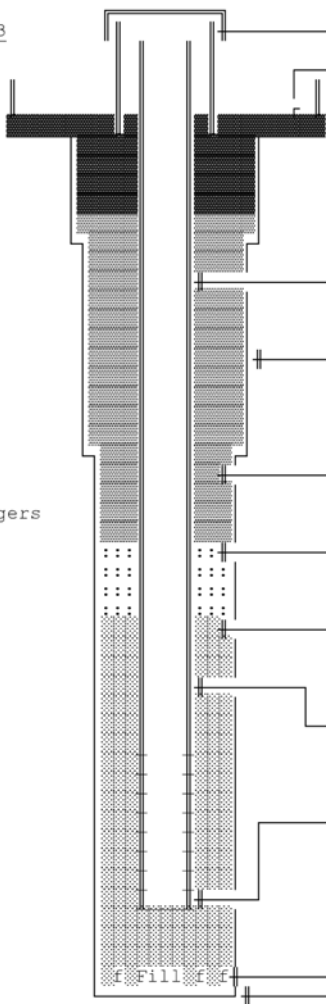
# WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool	Sample Method: Drive barrel	WELL NUMBER: 299-W18-31	TEMPORARY WELL NO: _____
Drilling Fluid Used: 200 W Water	Additives Used: Not documented	Hanford	
Driller's Name: H. Baker	WA State Lic Nr: Not documented	Coordinates: N/S N 38,105.3 E/W W 76,032.1	
Drilling Company: Kaiser Engineers	Company Location: Hanford	State NAD83 N 135,075.47m E 566,721.83m	
Date Started: 06Sep91	Date Complete: 11Dec91	Coordinates: N 443,212 E 2,219,195	
		Start Card #: Not documented T _____ R _____ S _____	
		Elevation Ground surface (ft): 660.73 (Brass cap)	

Depth to water: 191.2-ft Dec91  
(Ground surface) 195.4-ft 26Mar93

GENERALIZED Geologist's  
STRATIGRAPHY Log  
Sl=slightly

0-5: Gravelly silty SAND  
5-10: Sl silty SAND  
10-20: Gravelly silty SAND  
20-25: Silty sandy GRAVEL  
25-30: Sl silty SAND  
30-35: Silty SAND  
35-45: Sl silty SAND  
45-50: SAND  
50-55: Silty SAND  
55-60: Sl silty gravelly SAND  
60-65: SAND  
65-70: Sl silty SAND  
70-75: Silty SAND  
75-80: SAND  
80-85: Silty SAND  
85-95: Sl silty SAND  
95-110: Silty SAND  
110-118: Sl silty SAND  
118-119: CLAY, calcareous  
119-130: Silty SAND w/CLAY stringers  
130-131: CALICHE  
131-132: Silty GRAVEL  
132-140: Silty gravelly SAND  
140-155: Silty sandy GRAVEL  
155-160: GRAVEL  
160-180: Sandy GRAVEL  
180-200: Silty sandy GRAVEL  
200-210: GRAVEL  
210-220: Silty sandy GRAVEL  
220-227.6: Sandy GRAVEL



Elevation of reference point: [664.16-ft]  
(top of casing)  
Height of reference point above [3.43-ft]  
ground surface  
Depth of surface seal [2.0-18.0-ft]  
Type of surface seal: Pre mix concrete  
4x4-ft x 6-in surface pad  
4 equidistant protective posts  
Cement grout 2.0-18.0-ft  
I.D. of riser pipe: [4-in]  
Type of riser pipe: Stainless steel  
Diameter of borehole,  
0-19.0-ft, 13-in nominal  
19.0-127.4-ft, 11-in nominal  
127.4-227.6-ft, 9-in nominal  
Type of filler, 18.0-178.8-ft  
8-20-mesh bentonite crumbles  
Depth top of seal: [178.8-ft]  
Type of seal:  
3/8-in bentonite pellets  
Depth top of sand pack: [181.5-ft]  
20 40 mesh silica sand  
Depth top of screen: [187.3-ft]  
4-in, #10-slot, continous wrap  
T304 stainless steel with  
filter pack  
Depth bottom of screen: [222.3-ft]  
Fill, 226.0-227.6-ft  
Depth to bottom of borehole: [227.6-ft]

Drawing By: RKL/2W18-31.ASB Date: 19Apr93  
Reference:

WELL SUMMARY SHEET				0503604		Boring or Well No. 299-W18-31	
						Sheet 1 of 2	
Location <u>200 W D Tank Farm</u>		Project <u>W017-55T</u>					
Elevation _____		Drilling Contractor <u>KEH</u>					
Driller <u>H. Baker</u>		Drilling Method and Equipment <u>BE 60 L Cable Tool</u>					
Prepared By <u>R. Wempe</u> (Sign/Print Name)		Date <u>1-2-92</u>		Reviewed By _____ (Sign/Print Name)		Date _____	

CONSTRUCTION DATA		Depth in Feet	GEOLOGIC/HYDROLOGIC DATA	
Description	Diagram		Graphic Log	Lithologic Description
Current GWT 18.0 - 2.0'		10		slightly silty SAND
		11		gravelly silty SAND
12" C.S. Casing 19.02'		20		silty sandy GRAVEL
4" ID T304SS.				silty silty SAND
Casing 187.3' - 2.4'		30		silty SAND
		40		silty silty SAND
8-20 mesh Bent. Cables.		50		SAND
178.8' - 18.0'		60		silty SAND
		70		silty silty gravelly SAND
		80		SAND
		90		slightly silty SAND
		100		silty SAND
		110		SAND
		120		slightly silty SAND
10" C.S. Casing 127.43		130		Caliche
		140		silty gravelly SAND
	150		silty sandy GRAVEL	
	160		GRAVEL	
			sandy GRAVEL	

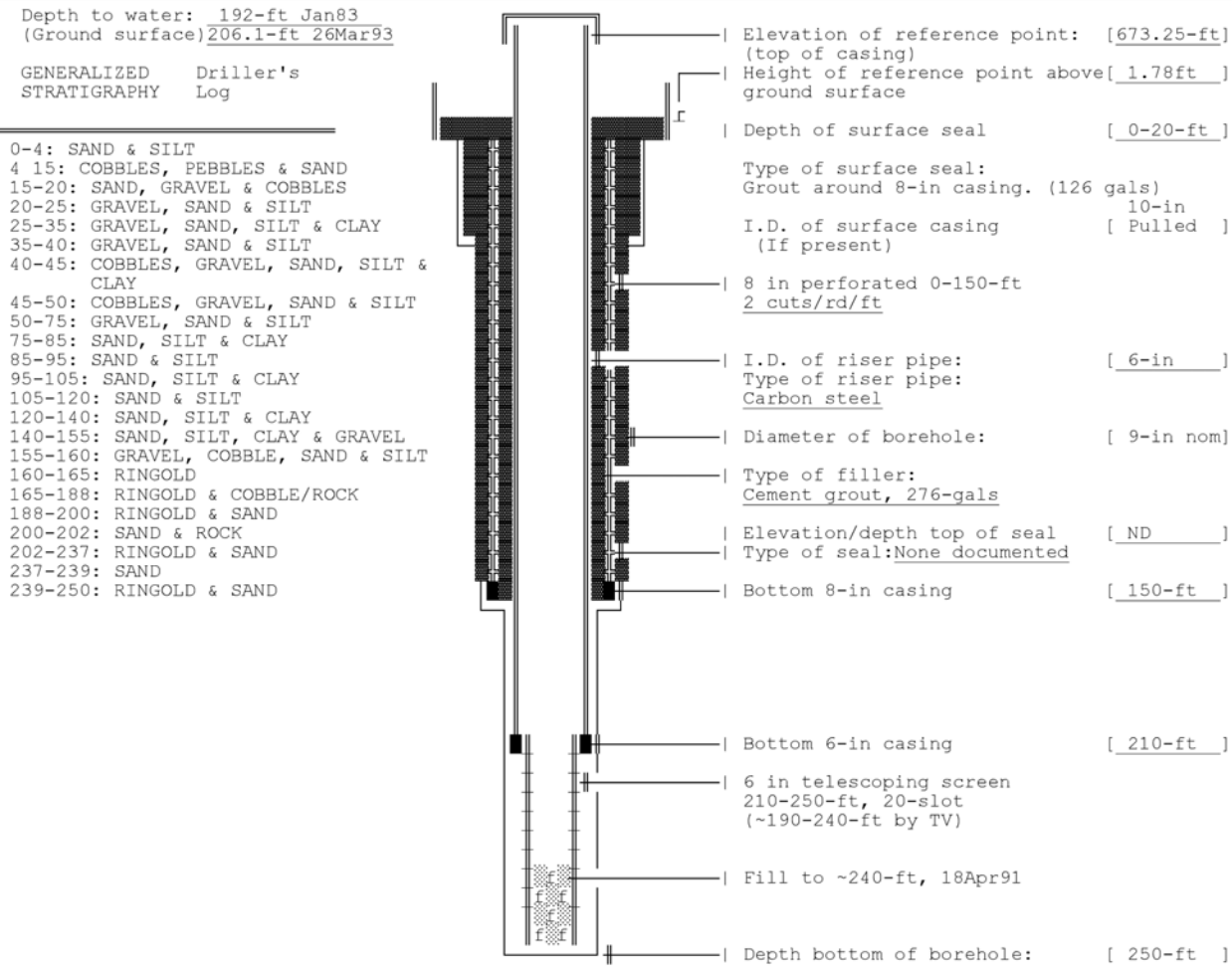
A-6000-384 (04/90)

WELL CONSTRUCTION REPORT				0503603		Page 1 of 2																																					
Specification No. <u>WHC-S-014</u> (SEE COMMENTS) <u>EW11-5-91</u> Rev No. <u>5.6</u> ECNs <u>144240, 144241, 127437, 150204</u> (SEE COMMENTS) Project <u>RCRA W017 / SST 200 WEST</u> Location <u>WASTE MANAGEMENT AREA U</u> Drilling Company <u>KAISER ENGINEERING HANFORD</u> Driller <u>HARRY BAKER, J. C. CROWDER</u> Other (Companies) <u>WHC, EBASCO, HART GROWER</u> Geologist(s) <u>MYRA VAAG - EBASCO, R. W. WONG - ES1</u> <u>SUE HAVENS - EBASCO</u> <u>WILLIAM C. BRENNAN - EBASCO</u> <u>CARL WOLFE - HART GROWER</u>				Well No. <u>299</u> <u>W18-31</u> Temp. Well No. <u>N/A</u> Coordinates _____ Casing Elev. _____ Ground Elev. _____ Drilling Method _____ Verification Method <u>VISUAL OBSERVATION</u> Criteria <u>WHC-S-014 5.2, 5.3, 7.5 EII 6.7 SEC 6.2</u> <table border="0" style="width: 100%;"> <tr> <td>Rotary</td> <td>Air</td> <td><u>N/A</u></td> <td>Mud</td> <td><u>N/A</u></td> <td>Initials</td> <td><u>N/A</u></td> <td>Date</td> <td><u>N/A</u></td> </tr> <tr> <td>Cable Tool</td> <td>D</td> <td><u>227.57</u></td> <td>H</td> <td><u>N/A</u></td> <td><u>WCB</u></td> <td><u>092691</u></td> <td></td> <td></td> </tr> <tr> <td>Drilling Fluid</td> <td colspan="2"><u>Raw Water</u></td> <td colspan="2"><u>KDR</u></td> <td><u>12/13/91</u></td> <td></td> <td></td> <td></td> </tr> <tr> <td>Other</td> <td colspan="7"></td> <td></td> </tr> </table>				Rotary	Air	<u>N/A</u>	Mud	<u>N/A</u>	Initials	<u>N/A</u>	Date	<u>N/A</u>	Cable Tool	D	<u>227.57</u>	H	<u>N/A</u>	<u>WCB</u>	<u>092691</u>			Drilling Fluid	<u>Raw Water</u>		<u>KDR</u>		<u>12/13/91</u>				Other								
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Geophysical Logging <table border="0" style="width: 100%;"> <tr> <td>Sondes</td> <td>Interval</td> <td>Date</td> </tr> <tr> <td><u>BROSS GAMMA</u></td> <td><u>0.4' - 128.3'</u></td> <td><u>9-12-91</u></td> </tr> <tr> <td><u>GROSS GAMMA</u></td> <td><u>100.0 - 227.2</u></td> <td><u>10-3-91</u></td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> <tr> <td> </td> <td> </td> <td> </td> </tr> </table>				Sondes	Interval	Date	<u>BROSS GAMMA</u>	<u>0.4' - 128.3'</u>	<u>9-12-91</u>	<u>GROSS GAMMA</u>	<u>100.0 - 227.2</u>	<u>10-3-91</u>										Completion Data Drilled Depth <u>227.57' SLG</u> Completed Depth <u>222.3'</u> Date Started <u>090691</u> Date Completed <u>12/11/91</u> Static Water Level/Date <u>192.26' ALS - 092791</u> <u>190.4' NIS 11-6-91, 191.2' 12/1/91</u>																					
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				Aquifer Testing Type <u>INSTANTANEOUS SUG</u> Flow Meter I.D. No. <u>- NA -</u> Cal. Due Date <u>- NA -</u> Length of Test <u>1HR</u> Volume Pumped <u>- NA -</u> Drawdown <u>- NA -</u> Date of Test <u>12-14-91</u>																																							
Completion Results																																											
Cleaning Verification Method <u>VISUAL INSP + DIRECT OBS OF DOC</u> Criteria <u>WHC-S-014 4.2.2, 7.6, 7.7 WAC-LM-7-7</u> <table border="0" style="width: 100%;"> <tr> <td></td> <td>Initials</td> <td>Date</td> </tr> <tr> <td>Drilling Tools/Rig</td> <td><u>MKV</u></td> <td><u>9-5-91</u> ①</td> </tr> <tr> <td>Temporary Materials</td> <td><u>MKV</u></td> <td><u>9-5-91</u> ②</td> </tr> <tr> <td>Permanent Materials</td> <td><u>MMJ</u></td> <td><u>11-6-91</u></td> </tr> </table>					Initials	Date	Drilling Tools/Rig	<u>MKV</u>	<u>9-5-91</u> ①	Temporary Materials	<u>MKV</u>	<u>9-5-91</u> ②	Permanent Materials	<u>MMJ</u>	<u>11-6-91</u>	Material Storage/Packing Verification Method <u>VISUAL OBSERVATION</u> Criteria <u>WHC-S-014 4.2.2, 7.3</u> <table border="0" style="width: 100%;"> <tr> <td></td> <td>Initials</td> <td>Date</td> </tr> <tr> <td>Mtl. Handling/Storage</td> <td><u>KDR</u></td> <td><u>12/13/91</u></td> </tr> <tr> <td>Material Packing</td> <td><u>KDR</u></td> <td><u>12/13/91</u></td> </tr> </table>					Initials	Date	Mtl. Handling/Storage	<u>KDR</u>	<u>12/13/91</u>	Material Packing	<u>KDR</u>	<u>12/13/91</u>															
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Screen <table border="0" style="width: 100%;"> <tr> <td>Type</td> <td>Length</td> <td>Slot Size</td> </tr> <tr> <td><u>Stainless steel communs</u></td> <td><u>35.15'</u></td> <td><u>10 slot</u></td> </tr> <tr> <td><u>wire wrap 10 slot T-304</u></td> <td></td> <td></td> </tr> <tr> <td>Depth(s)</td> <td><u>197.3' - 224.4'</u> <u>KR 12/13/91</u></td> <td></td> </tr> <tr> <td></td> <td><u>187.3' - 222.3'</u></td> <td></td> </tr> </table>				Type	Length	Slot Size	<u>Stainless steel communs</u>	<u>35.15'</u>	<u>10 slot</u>	<u>wire wrap 10 slot T-304</u>			Depth(s)	<u>197.3' - 224.4'</u> <u>KR 12/13/91</u>			<u>187.3' - 222.3'</u>		Lubricants/Additives Verification Method <u>VISUAL OBSERVATION</u> Criteria <u>WHC-S-014 7.2</u> <table border="0" style="width: 100%;"> <tr> <td></td> <td>Identify</td> <td>Initials</td> <td>Date</td> </tr> <tr> <td>Additives</td> <td><u>RAW H2O</u> ③</td> <td></td> <td></td> </tr> <tr> <td>Lubricants</td> <td><u>WELL GUARD</u> ④</td> <td></td> <td></td> </tr> </table>					Identify	Initials	Date	Additives	<u>RAW H2O</u> ③			Lubricants	<u>WELL GUARD</u> ④											
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Straightness Test Verification Method <u>VISUAL OBSERVATION</u> Criteria <u>WHC-S-014 8.2</u> Initials <u>WCB, WGS</u> Date <u>092791</u>																																											

A-6000-436 (09/90)

# WELL CONSTRUCTION AND COMPLETION SUMMARY

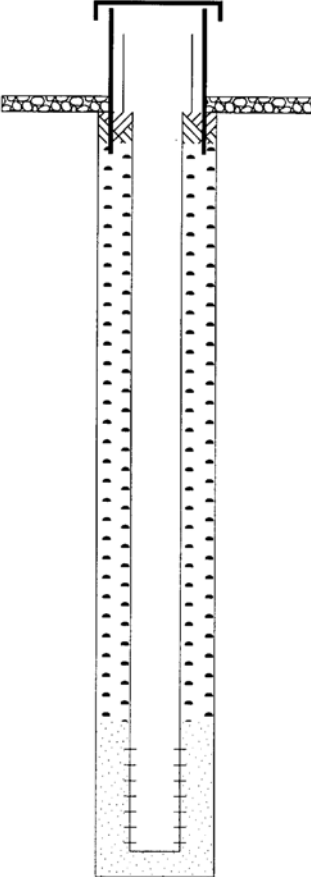

Drilling Method: <u>Cable tool</u>	Sample Method: <u>Hard tool (nom)</u>	WELL NUMBER: <u>299-W19-12</u>	TEMPORARY WELL NO: _____
Drilling Fluid Used: <u>Water</u>	Additives Used: <u>Not documented</u>	Hanford	
Driller's Name: <u>Garcia/Bultena</u>	WA State Lic Nr: <u>1143/ND</u>	Coordinates: N/S <u>N 38,052</u> E/W <u>W 75,456</u>	
Drilling Company: <u>Not documented</u>	Company Location: <u>Not documented</u>	State NAD83 N <u>135,059.75m</u> E <u>566,897.42m</u>	
Date Started: <u>01Dec82</u>	Date Complete: <u>24Jan83</u>	Coordinates: N <u>443,160</u> E <u>2,219,771</u>	
		Start Card #: <u>Not documented</u> T _____ R _____ S _____	
		Elevation _____	
		Ground surface (ft): <u>671.47 Brass cap</u>	



Drawing By: RKL/2W19-12.ASB Date: 19Apr93

Reference:

0502374

<b>WELL CONSTRUCTION AND COMPLETION SUMMARY</b>																				
<b>Drilling Method:</b> Air Rotary - TUBEX <b>Drilling Fluid Used:</b> Reverse Air <b>Driller's Name:</b> Willie Franklin <b>Drilling Company:</b> Layne Christensen <b>Date Started:</b> 17Sep98	<b>Sample Method:</b> Grab/Split Spoon <b>Additives Used:</b> None <b>WA State Lic Nr:</b> Not Available <b>Company Location:</b> Salt Lake City, Ut <b>Date Completed:</b> 23Sep98	<b>WELL NUMBER:</b> 299-W19-41 <b>Coordinates: N:</b> Not documented <b>Coordinates: E:</b> Not documented <b>Start Card #:</b> Not Available <b>Elevation Ground Surface:</b> Brass Marker	<b>TEMPORARY WELL NO:</b> B8551 <b>Not Allowed</b>																	
<b>Depth to Water:</b> 220.35 ft 23Sep98 <b>GENERALIZED STRATIGRAPHY</b>		<b>Geologist's Log &amp; Geophysical Logs</b>		<b>Elevation of Reference Point:</b> m <b>Height of Reference Point Above Ground Surface:</b> <b>Depth of Surface Seal:</b> 10.5 ft <b>Type of Surface Seal:</b> 4x4 Concrete Pad																
0 - 0.1 ft : Asphalt 0.1 - 14 ft : Silty sandy gravel 14 - 22 ft : Sand 22 - 39 ft : Sandy gravel  39 - 43 ft : Gravelly sand 43 - 47 ft : Sandy gravel 47 - 54 ft : Gravelly sand 54 - 81 ft : Sand  81 - 84 ft : Sand (Fn) 84 - 88 ft : Sand (Cse) 88 - 91 ft : Sand (Fu) 91 - 127 ft : Sand  127 - 136 ft : Silty sand 136 - 144 ft : Sandy silt - calcareous 144 - 168 ft : Silty sandy gravel  168 - 188 ft : Sandy gravel  188 - 249 ft : Silty sandy gravel (Water Level = 220.35')  249 - 253 ft : Silty sandy gravel - Fe staining 253 - 264.5 ft : Silty sandy gravel				<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 - 10.5 ft : 9.125-inch hole Cement Seal</td> <td>0 - 220.05 ft : 4 inch 4" Sch.5 SS Csg.</td> <td></td> </tr> <tr> <td>10.5 - 210.4 ft : 9.125-inch hole Bentonite Chips</td> <td></td> <td></td> </tr> <tr> <td>210.4 - 255.47 ft : 9.125-inch hole 20/40 Silica Sand</td> <td></td> <td>220.05 - 255.14 ft : 4 inch 4" Wire Wrap SS Screen .010 Slot</td> </tr> <tr> <td>255.47 - 264.5 ft : 9.125-inch hole 20/40 Silica Sand</td> <td>255.14 - 255.47 ft : 4 inch 4" SS End Cap</td> <td></td> </tr> </tbody> </table>		Fill	Casing	Screen	0 - 10.5 ft : 9.125-inch hole Cement Seal	0 - 220.05 ft : 4 inch 4" Sch.5 SS Csg.		10.5 - 210.4 ft : 9.125-inch hole Bentonite Chips			210.4 - 255.47 ft : 9.125-inch hole 20/40 Silica Sand		220.05 - 255.14 ft : 4 inch 4" Wire Wrap SS Screen .010 Slot	255.47 - 264.5 ft : 9.125-inch hole 20/40 Silica Sand	255.14 - 255.47 ft : 4 inch 4" SS End Cap	
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264.5 ft : Borehole drilled depth 0 - 264.5 ft : 9.125-in. 8-5/8" CS Temp. Csg. set with TUBEX reverse air rotary																				
<b>Drawing By:</b> TGB <b>Reference:</b> Hanford Wells <b>Revision:</b> 0 <b>Revision Date:</b> 25Sep98 <b>Print Date:</b> 28Dec98																				

Report Form: WELLS Project File: WELLS GPJ



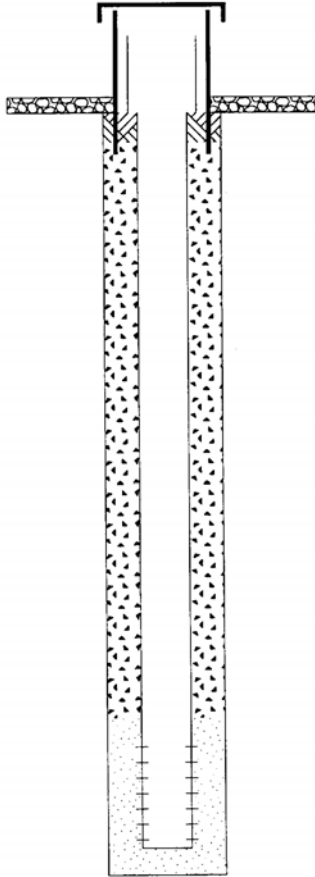

0502441

WELL SUMMARY SHEET				Page <u>1</u> of <u>2</u>	
				Date: <u>9-23-98</u>	
Well ID: <u>B8551</u>		Well Name: <u>299-W19-41</u>			
Location: <u>200W; intersect of Camden Ave &amp; 16<sup>th</sup> St.</u>		Project: <u>RCRA Drilling 1998</u>			
Prepared By: <u>L.D. Walker</u>	Date: <u>9-23-98</u>	Reviewed By: <u>F.C. Ruffe</u>	Date: <u>09/29/98</u>		
Signature: <u>[Signature]</u>		Signature: <u>[Signature]</u>			
CONSTRUCTION DATA		GEOLOGIC/HYDROLOGIC DATA			
Description	Diagram	Depth in Feet	Graphic Log	Lithologic Description	
		0		0'-0.1': Asphalt	
				0.1'-14': Silty Sandy GRAVEL	
Portland Cement: 0'-10.5'					
				14'-22': SAND	
		25		22'-39': Sandy GRAVEL	
				39'-43': Gravelly SAND	
		50		43'-47': Sandy GRAVEL	
Bentonite Chips:				47'-54': Gravelly SAND	
10.5'-210.4'					
				54'-81': SAND	
		75			
				81'-84': SAND (F <sub>n</sub> )	
				84'-88': SAND (cse)	
4 1/2" OD (4" ID) type 304				88'-91': SAND (F <sub>n</sub> )	
stainless steel casing:		100		91'-127': SAND	
+2.0'-220.05'					
		125		127'-136': Silty SAND	
				136'-144': Sandy SILT	
				-calcareous	

<div style="float: right; font-weight: bold; font-size: 1.2em;">0502400</div> WELL CONSTRUCTION SUMMARY REPORT				Start Date: 9-17-98			
				Finish Date: 9-23-98			
				Page 1 of 1			
Specification No.: 0200X-SP- V0001		Rev. No.: 1		Well Name: 299-W19-41			
ECNs: NA		Approximate Location: intersect of Candia Ave & 16 <sup>th</sup> St.					
Project: RCRA Drilling 1998		Other Companies: CH2M Hill 200W					
Drilling Company: Layne Christensen		Geologist(s): L.D. Walker					
Driller: W. Franklin							
TEMPORARY CASING AND DRILL DEPTH			DRILLING METHOD/HOLE DIAMETER				
*Size/Grade/Lbs. Per Ft.	Interval	Shoe O.D./I.D.	Auger:	Diameter From _____ to _____			
8 5/8" OD CS (FJ)	0' - 264.5	8 5/8" / 8"	Cable Tool:	Diameter From _____ to _____			
	_____ - _____		Air Rotary: Odex, 9 1/2"	Diameter From 0' to 264.5'			
	_____ - _____		A.R. w/Sonic:	Diameter From _____ to _____			
	_____ - _____			Diameter From _____ to _____			
	_____ - _____			Diameter From _____ to _____			
*Indicate Welded (W) - Flush Joint (FJ) Coupled (C) & Thread Design			Diameter From _____ to _____				
			*Note on water added: all at total depth (264.5') to keep fine sediment out of borehole				
			Drilling Fluid: Air				
Total Drilled Depth: 264.5		Hole Dia @ TD: 9 1/2" 9 1/8"		Total Amt. Of Water Added During Drilling: ~300 gal. *			
Well Straightness Test Results:			Static Water Level: 220.35'		Date: 9-23-98		
GEOPHYSICAL LOGGING							
Sondes (type)	Interval	Date	Sondes (type)	Interval	Date		
	_____ - _____			_____ - _____			
	_____ - _____			_____ - _____			
	_____ - _____			_____ - _____			
COMPLETED WELL							
Size/Wt./Material	Depth	Thread	Slot Size	Type	Interval Annual Seal/Filter Pack	Volume (Ft <sup>3</sup> )	Mesh Size
4" ID SS	+2.0 - 220.05'	FJ	NA	Portland Cement	0' - 10.5'	5.14 ft <sup>3</sup>	NA
4" ID SS wire wrap	220.05' - 255.14'	FJ	0.010-in	Bentonite Chips	10.5' - 210.4'	66.24	medium
4" ID SS	255.14' - 255.47'	FJ	NA	Silica Sand	210.4' - 264.5'	29.68	20-40
	_____ - _____				_____ - _____		
	_____ - _____				_____ - _____		
OTHER ACTIVITIES							
Aquifer Test:		Date:		Well Abandoned:		Yes:	No:
Description:				Description:			
WELL SURVEY DATA							
Date:				Protective Casing Elevation:			
Washington State Plane Coordinates:				Brass Cap Elevation:			
COMMENTS/REMARKS							
CS = carbon steel, SS = stainless steel. Volume calc: cement = 1.285 x 4 = 5.14 ft <sup>3</sup> , bentonite chips = 0.69 x 96 = 66.24 ft <sup>3</sup> , 20-40 Silica Sand = 1.12 x 26.5 = 29.68 ft <sup>3</sup>							
Reported By: L.D. Walker				Reported By: E.C. Rafuse			
Title: Geologist		Date: 9-23-98		Title: FIELD ENGINEER (BNI)		Date: 09/29/98	
Signature: L.D. Walker				Signature: E.C. Rafuse			

BHI-EE-181 (12/97)


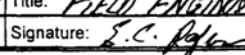
0502376

WELL CONSTRUCTION AND COMPLETION SUMMARY																		
<b>Drilling Method:</b> Air Rotary - TUBEX <b>Drilling Fluid Used:</b> Reverse Air <b>Driller's Name:</b> Willie Franklin <b>Drilling Company:</b> Layne Christensen <b>Date Started:</b> 31Aug98	<b>Sample Method:</b> Grab/Split Spoon <b>Additives Used:</b> None <b>WA State Lic Nr:</b> Not Available <b>Company Location:</b> Salt Lake City, Ut <b>Date Completed:</b> 16Sep98	<b>WELL NUMBER:</b> 299-W19-42 <b>TEMPORARY WELL NO:</b> B8553 Not Allowed <b>Coordinates: N</b> Not documented <b>Coordinates: E</b> Not documented <b>Start Card #:</b> Not Available <b>Elevation Ground Surface:</b> Brass Marker																
<b>Depth to Water:</b> 219.56 ft 16Sep98 <b>GENERALIZED STRATIGRAPHY</b> <b>Geologist's Log &amp; Geophysical Logs</b>		<b>Elevation of Reference Point:</b> m <b>Height of Reference Point Above Ground Surface:</b> <b>Depth of Surface Seal:</b> 10.2 ft <b>Type of Surface Seal:</b> 4x4 Concrete Pad																
<div style="display: flex; align-items: center;">  <table border="1" style="margin-left: 10px; border-collapse: collapse; font-size: 0.8em;"> <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 - 10.2 ft : 9.125-inch hole Cement Seal</td> <td>0 - 220.28 ft : 4 inch 4" Sch 5 SS Csg.</td> <td></td> </tr> <tr> <td>10.2 - 210.2 ft : 9.125-inch hole Bentonite Chips</td> <td></td> <td></td> </tr> <tr> <td>210.2 - 255.7 ft : 9.125-inch hole 20-40 Silica Sand</td> <td></td> <td>220.28 - 255.37 ft : 4 inch 4" Wire Wrap SS Screen .010 Slot</td> </tr> <tr> <td>255.7 - 265.2 ft : 9.125-inch hole 20-40 Silica Sand</td> <td>255.37 - 255.7 ft : 4 inch 4" SS End Cap</td> <td></td> </tr> </tbody> </table> </div>		Fill	Casing	Screen	0 - 10.2 ft : 9.125-inch hole Cement Seal	0 - 220.28 ft : 4 inch 4" Sch 5 SS Csg.		10.2 - 210.2 ft : 9.125-inch hole Bentonite Chips			210.2 - 255.7 ft : 9.125-inch hole 20-40 Silica Sand		220.28 - 255.37 ft : 4 inch 4" Wire Wrap SS Screen .010 Slot	255.7 - 265.2 ft : 9.125-inch hole 20-40 Silica Sand	255.37 - 255.7 ft : 4 inch 4" SS End Cap		<p>0 - 0.7 ft : Backfill (gm 5)</p> <p>0.7 - 7 ft : Sand</p> <p>7 - 15 ft : Sandy gravel</p> <p>15 - 119.5 ft : Silty sand</p> <p>15 - 16 ft : Sand</p> <p>16 - 32.5 ft : Sandy gravel</p> <p>32.5 - 39 ft : Sandy gravel</p> <p>39 - 43.5 ft : Sandy gravel</p> <p>43.5 - 52 ft : Slightly silty gravelly sand</p> <p>52 - 53 ft : Sandy gravel</p> <p>53 - 71 ft : Sand</p> <p>71 - 79 ft : Sand</p> <p>79 - 84 ft : Slightly silty sand</p> <p>84 - 89 ft : Sand</p> <p>89 - 105 ft : Slightly silty sand</p> <p>119.5 - 138.5 ft : Silt</p> <p>138.5 - 141 ft : Caliche</p> <p>141 - 170 ft : Silty sandy gravel</p> <p>170 - 189 ft : Silty sandy gravel</p> <p>189 - 196 ft : Gravelly sand</p> <p>196 - 222 ft : Sandy gravel</p> <p>222 - 265.2 ft : Silty sandy gravel</p>	
Fill	Casing	Screen																
0 - 10.2 ft : 9.125-inch hole Cement Seal	0 - 220.28 ft : 4 inch 4" Sch 5 SS Csg.																	
10.2 - 210.2 ft : 9.125-inch hole Bentonite Chips																		
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<p>265.2 ft : Borehole drilled depth</p> <p>0 - 265.2 ft : 9.125-in. 8-5/8" CS Temp. Csg.</p>																		
<b>Drawing By:</b> TGB <b>Reference:</b> Hanford Wells <b>Revision:</b> 0 <b>Revision Date:</b> 21Sep98 <b>Print Date:</b> 28Dec98																		

Report Form: WELLS Project File: WELLS.GPJ

0502439

WELL SUMMARY SHEET				Page <u>1</u> of <u>2</u>
				Date: 9-17-98
Well ID: 88553		Well Name: 299-W19-42		
Location: 55' East of 241-U Tank Farm, 200W		Project: RCRA Drilling 1998		
Prepared By: L.D. Walker	Date: 9-12-98	Reviewed By: EDWARD C. RAFAEL	Date: 09/23/98	
Signature: <i>L.D. Walker</i>		Signature: <i>Edward C. Rafael</i>		
CONSTRUCTION DATA		GEOLOGIC/HYDROLOGIC DATA		
Description	Diagram	Depth in Feet	Graphic Log	Lithologic Description
		0		0'-0.7' : Backfill (gm S)
				0.7'-7' : Sand
Portland Cement : 0'-10.2'				7'-15' : Sandy Gravel
				15'-16' : Sand
		25		16'-32.5' : Sandy Gravel
				32.5'-39' : Sandy Gravel
				39'-43.5' : Sandy Gravel
Bentonite Chips:		50		43.5'-52' : Slightly Silty Gravelly Sand
10.2' - 210.2'				52'-53' : Sandy Gravel
				53'-71' : Sand
		75		71'-79' : Sand
4 1/2" OD (4" ID) type 304 stainless steel casing:				79'-84' : Slightly Silty Sand
+ 2.0' - 220.28'				84'-89' : Sand
				89'-105' : Slightly Silty Sand
		100		105'-119.5' : Silty Sand
				119.5'-138.5' : Silt
		125		138.5'-141' : Caliche (Sandy Gravel)

<div style="display: flex; justify-content: space-between;"> <span>0502398</span> <span>Start Date: 8/31/98</span> </div> <div style="display: flex; justify-content: space-between;"> <span>WELL CONSTRUCTION SUMMARY REPORT</span> <span>Finish Date: 9-16-98</span> </div> <div style="display: flex; justify-content: space-between;"> <span></span> <span>Page 1 of 1</span> </div>							
Specification No.: 0200X-SP-V0001		Rev. No.: 1	Well Name: 299-W19-42	Temp. Well No.: B8553			
ECNs: NA		Approximate Location: 55' East of 24-U Tank Farm, 300W					
Project: RCRA Drilling 1998		Other Companies: CH2M Hill					
Drilling Company: Layne Christensen		Geologist(s): DC Weekes					
Driller: M. Wraspin / W. Franklin		LD Walker					
TEMPORARY CASING AND DRILL DEPTH		DRILLING METHOD/HOLE DIAMETER					
*Size/Grade/Lbs. Per Ft.	Interval	Shoe O.D./I.D.	Auger:	Diameter From _____ to _____			
9" OD carbon steel (FJ)	0' - 135.7'	0.8' / 0.7'	Cable Tool: Drive barrel	Diameter From 0' to 140'			
8 5/8" OD CS (FJ)	0' - 265.2'	8 5/8" / 8"	Air Rotary: Colex; 9 1/2"	Diameter From 0' to 265.2'			
			A.R. w/Sonic:	Diameter From _____ to _____			
				Diameter From _____ to _____			
				Diameter From _____ to _____			
*Indicate Welded (W) - Flush Joint (FJ) Coupled (C) & Thread Design				Diameter From _____ to _____			
Note on water added: all at total depth to keep fine sediment out of casing							
Drilling Fluid: Air							
Total Drilled Depth: 265.2'		Hole Dia @ TD: 9 1/2"		Total Amt. Of Water Added During Drilling: ~ 300 gal.			
Well Straightness Test Results: NA		Static Water Level: 219.56' bgs		Date: 9-16-98			
GEOPHYSICAL LOGGING							
Sondes (type)	Interval	Date	Sondes (type)	Interval	Date		
Spectral Gamma (KUT + CS-100)	0' - 139'	9-9-98	Spectral Gamma KUT	118' - 262'	9-13-98		
Neutron	0' - 136'	9-9-98	Neutron	120' - 219'	9-13-98		
COMPLETED WELL							
Size/Wt./Material	Depth	Thread	Slot Size	Type	Interval Annual Seal/Filter Pack	Volume (Ft³)	Mesh Size
4" ID SS	220.28' - 220.28'	FJ	NA	Portland Cement	0' - 10.2'	30.84	NA
4" ID SS wire wrap	220.28' - 255.37'	FJ	0.010-in	Bentonite chips	10.2' - 210.2'	75.21	medium
4" ID SS	255.37' - 265.70'	FJ	NA	Silica Sand	210.2' - 265.1'	29.68	20-40
OTHER ACTIVITIES							
Aquifer Test:		Date:	Well Abandoned:		Yes:	No:	Date:
Description:				Description:			
WELL SURVEY DATA							
Date:				Protective Casing Elevation:			
Washington State Plane Coordinates:				Brass Cap Elevation:			
COMMENTS/REMARKS							
CS = carbon steel; SS = stainless steel; Volume calc: cement = 1.285 x 24 = 30.84 Ft³, Bentonite chips = 0.69 x 109 = 75.21 Ft³, 20-40 silica sand = 1.12 x 26.5 = 29.68 Ft³							
Reported By: L.D. Walker				Reported By: E.C. Rafuse			
Title: Geologist		Date: 9-17-98		Title: FIELD ENGINEER (BNI)		Date: 09/23/98	
Signature: 				Signature: 			

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