PNNL-12057

Pacific Northwest
National Laboratory
Operated by Battelle for the
U.S. Department of Energy

# RCRA Assessment Plan for Single-Shell Tank Waste Management Area T at the Hanford Site

F. N. Hodges
C. J. Chou

February 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

A groundwater quality assessment plan was prepared to investigate the rate and extent of aquifer contamination beneath Waste Management Area T at the Hanford Site. The "first determination," concluded Waste Management Area T is contributing to groundwater contamination; therefore, a continued assessment is required. The plan described here implements this RCRA requirement, 40 CFR 265.93 (d)(7). This plan is an update of a draft plan issued in January 1999, which guided work performed in fiscal year 2000. Planned activities for fiscal year 2001 and beyond include additional groundwater sampling and analysis, hydraulic testing to further define flow rate and direction, and installation of additional wells to improve the detection monitoring network and to better define the areal and vertical extent of contamination. Four new downgradient wells to enhance spatial coverage will be completed during calendar year 2000. Five new wells (subject to funding) are planned for calendar year 2001 to further define areal and vertical extent and to help distinguish tank leak sources from upgradient crib sources.

The results of this groundwater quality assessment will be provided to the RCRA Facility Investigation Corrective Measures Study (RFI/CMS) conducted by the River Protection Program to investigate the vadose zone sources of observed groundwater contamination beneath Waste Management Area T. The groundwater quality assessment and the RFI/CMS work will be conducted under separate but coordinated plans. Results from the groundwater investigation together with the RFI/CMS will provide information to support decisions on interim measures, corrective measures, waste retrieval, and eventual closure of the tank farms.

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# 1.0 Introduction

Waste Management Area (WMA) T, containing the T Tank Farm, is located in the northern portion of the 200 West Area (Figure 1.1) and is used for the interim storage of radioactive waste from chemical processing of reactor fuel for plutonium production. The WMA, regulated under *Resource Conservation and Recovery Act of* 1976 (RCRA) interim status regulations was placed in assessment monitoring in 1993 in accordance with 40 CFR Part 265, Subpart F, and by reference of Washington Administrative Code (WAC) 173-303-400(3), because of elevated *specific conductance*, a RCRA indicator parameter, in one downgradient well. A draft plan was issued in January 1999, which guided work performed in fiscal year 2000. This document supersedes the draft plan for continued RCRA groundwater quality assessment of WMA T as required by 40 CFR 265.93 (d)(7). Pacific Northwest National Laboratory[(a)] conducted the assessment.

## 1.1 Background

A detection level RCRA groundwater monitoring program for WMA T was initiated in 1989 (Jensen et al. 1989; Caggiano and Goodwin 1991). The locations of groundwater monitoring wells in the RCRA monitoring network for WMA T are shown in Figure 1.2. The WMA was placed into assessment monitoring in 1993 because specific conductance values in downgradient well 299-W10-15 exceeded the upgradient background value (critical mean) of 1,175 μS/cm (Caggiano and Chou 1993). A water-table map, based on June 1997 measurements, showing the location of wells in the RCRA detection monitoring network is presented in Figure 1.3. Water-table elevations in the vicinity of WMA T and TX-TY have been strongly affected by reduction in wastewater discharge and more locally by the 200-ZP-1 pump-and-treat activity (DOE 2000), as indicated by the dramatic changes in the water-table elevation contours after 1997 south of WMA TX-TY (Figures 1.4 and 1.5).

Elevated specific conductance values in well 299-W10-15, principally a result of elevated sodium and nitrate from an upgradient source, dropped below the critical mean in 1994. However, before the WMA could be returned to a detection level monitoring program, specific conductance in well 299-W11-27 started a rapid increase in late 1995 and exceeded the critical mean in early 1996. In the case of well 299-W11-27, the increased specific conductance was accompanied by elevated technetium-99, tritium, nitrate, calcium, magnesium, sulfate, chromium, cobalt-60, and total organic carbon. In February 1997, technetium-99, the principal contaminant, reached a maximum concentration of 21,700 pCi/L, 24 times the drinking water standard of 900 pCi/L.

The first determination (Hodges 1998) did not identify an upgradient source for the contamination observed in monitoring well 299-W11-27, and indeed found evidence linking the contaminants in groundwater to the WMA. Accordingly, continuation of the groundwater assessment is required. The plan described here implements this RCRA requirement [40 CFR 265.93 (d)(7)].

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[(a)] Pacific Northwest National Laboratory is operated by Battelle for the U.S. Department of Energy under Contract DE-AC06-76RL01830.

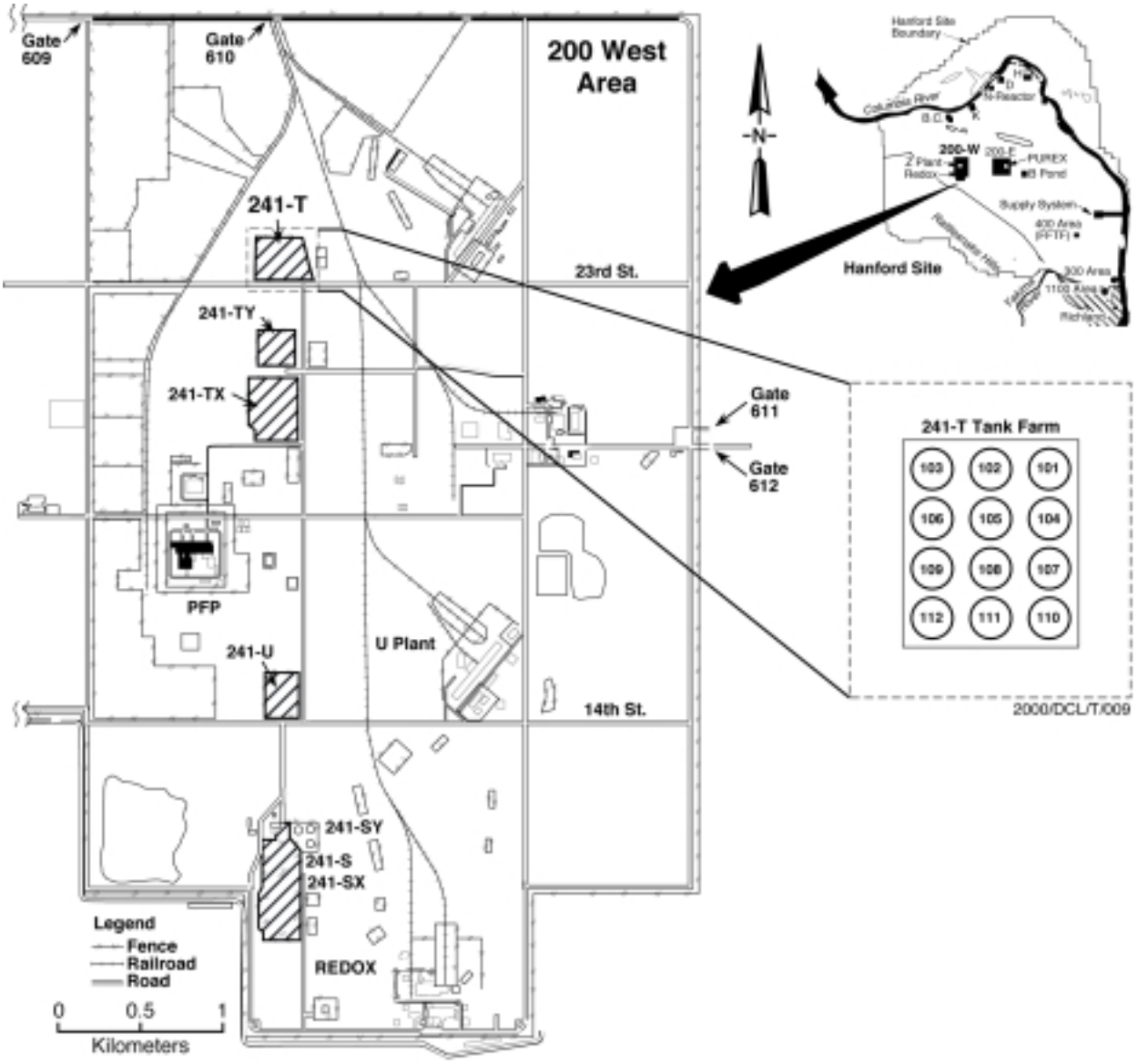


**Figure 1.1**. Location Map for WMA T

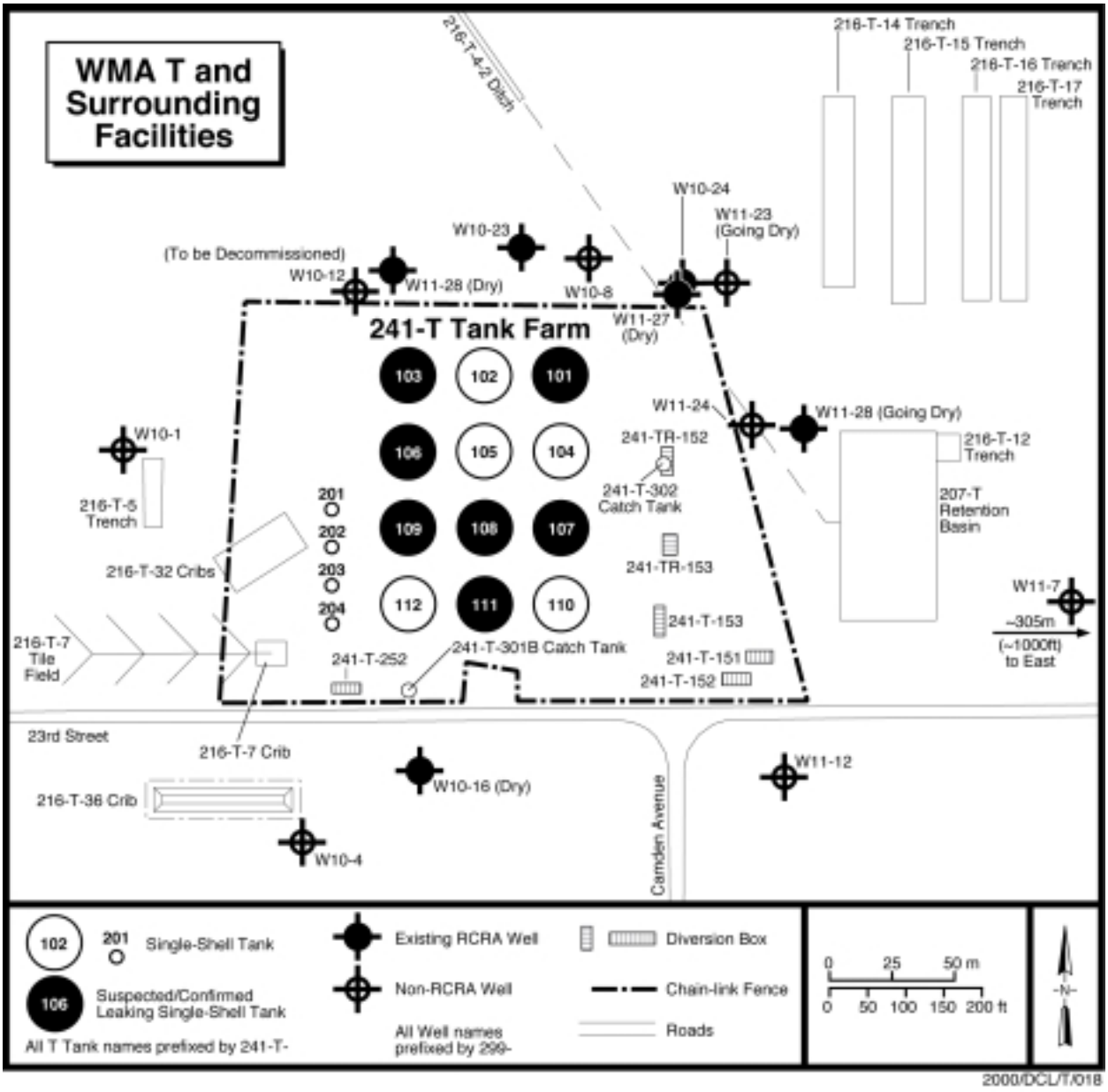


**Figure 1.2**. Monitoring Well Locations

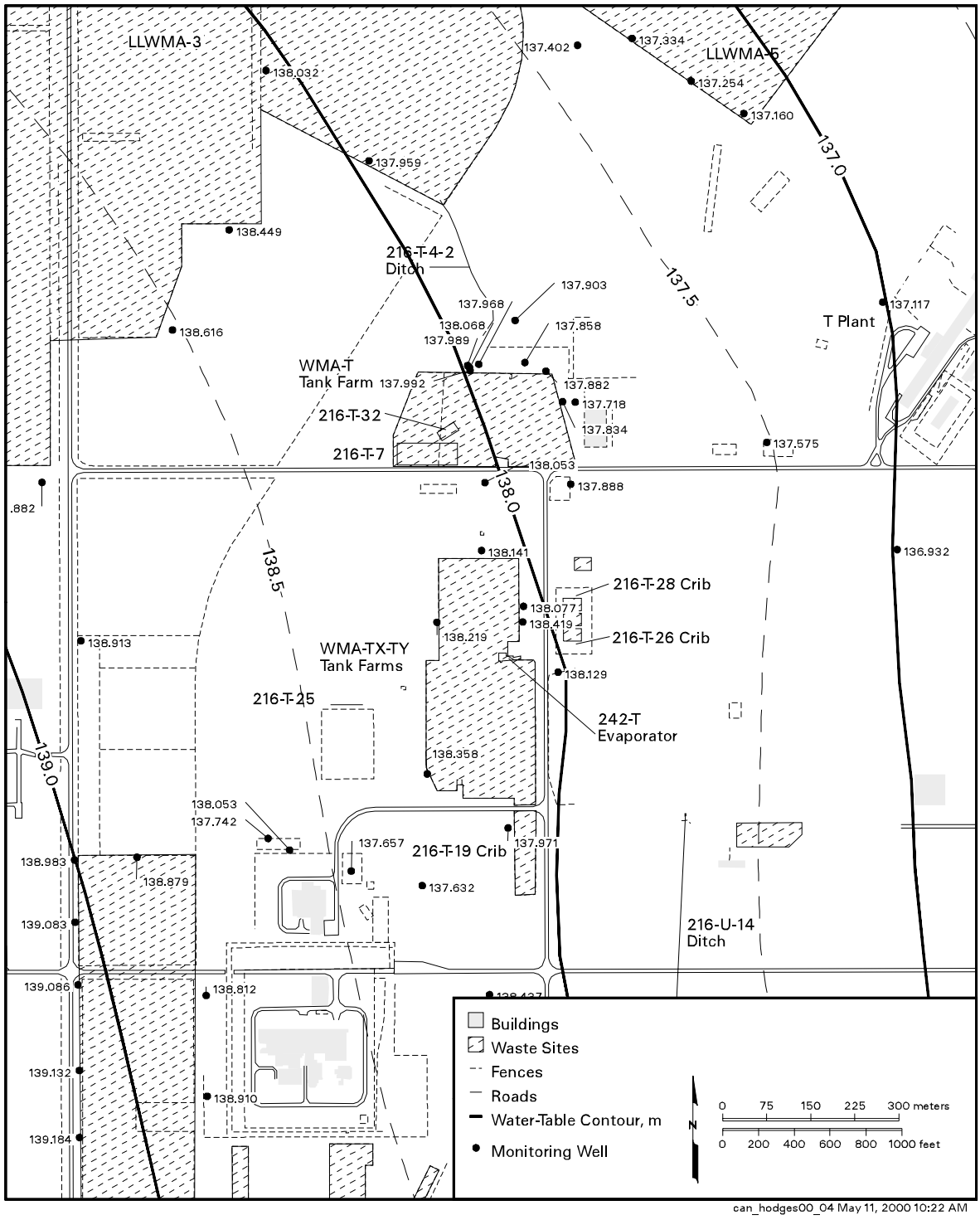


**Figure 1.3**. Water-Table Map, 1997

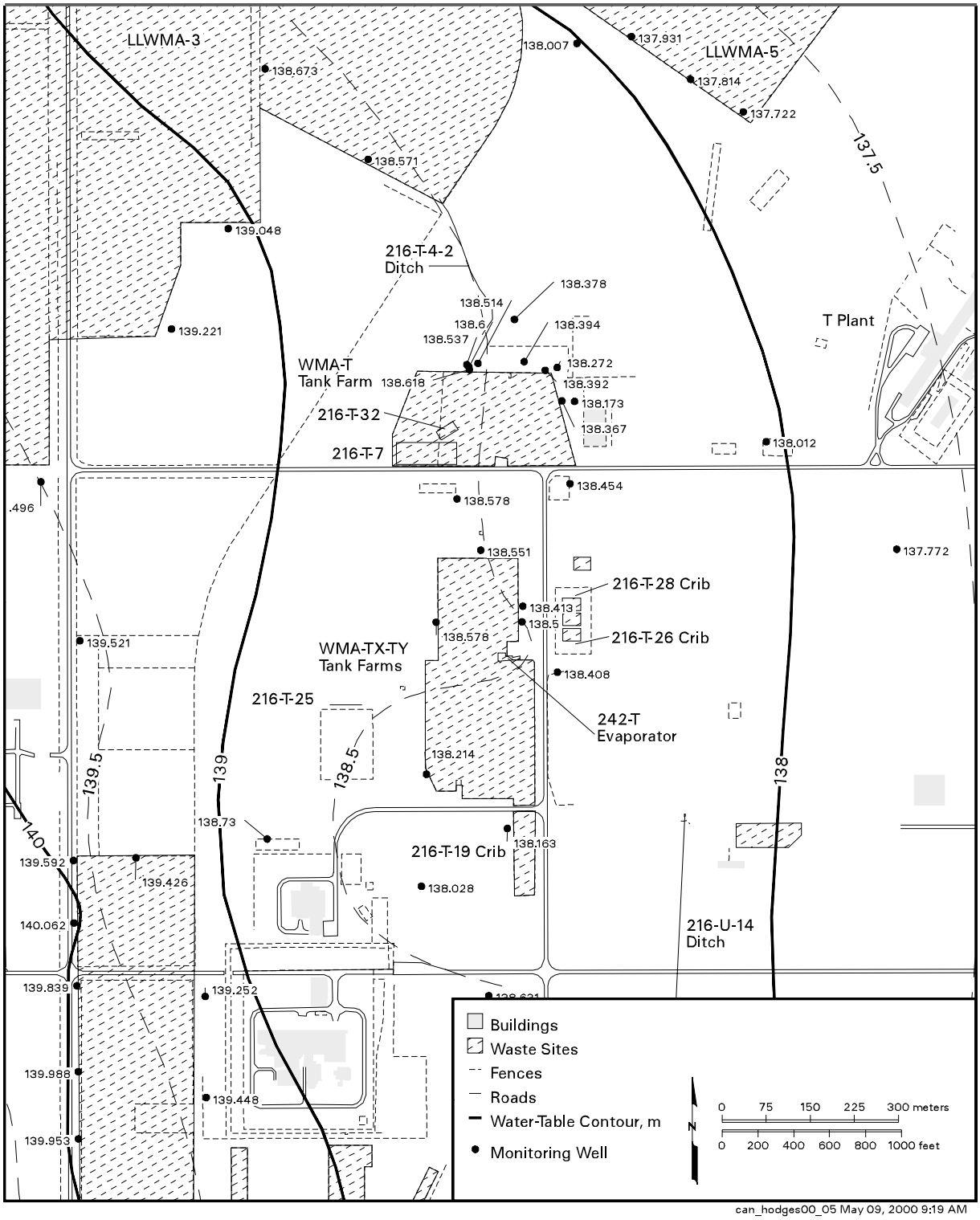


**Figure 1.4**. Water-Table Map, June 1998

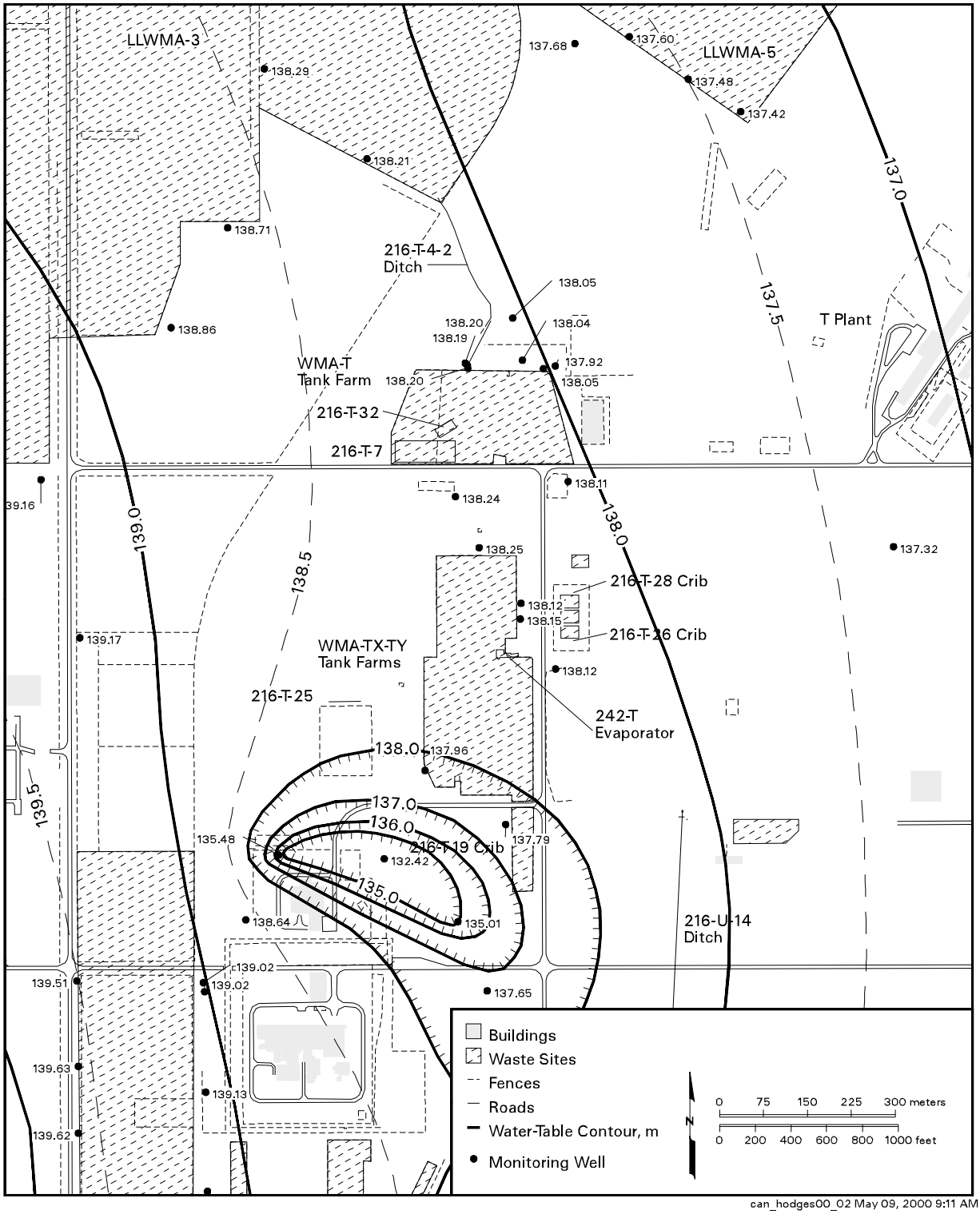


**Figure 1.5**. Water-Table Map, June 1999

As one outcome of the first determination (Hodges 1998), a RCRA Facility Investigation/Corrective Measures Study (RFI/CMS) will be initiated at WMA T. The primary focus is on characterization of the nature and extent of vadose zone contamination and assessment of data collected to date to identify initial activities to minimize intrusion and contaminant migration to groundwater. The schedule and activities for the RFI/CMS are described in the Hanford Federal Facility Agreement and Consent Order (Tri-Party Agreement, Ecology et al. 1998), Change Request M-45-98-03. In accordance with the agreement between the U.S. Department of Energy (DOE), and the Washington State Department of Ecology (Ecology) concerning this change request, the continuing RCRA groundwater quality assessment and the RFI/CMS work will be conducted under separate but coordinated plans. Integration of the groundwater quality assessment with the RFI/CMS will be accomplished through the Data Quality Objectives process for the Phase 1 RFI/CMS Work Plan addenda for WMA T and WMA TX-TY, due in December 2000 (milestone M-45-54). Data from the RCRA groundwater quality assessment will be used in RFI/CMS planning and will be included either by reference or directly with the vadose zone data from the RFI/CMS efforts in a field investigation report due June 2003 (milestone M-45-55-T03).

## 1.2 Objectives

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

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

*(ii) the concentration of hazardous waste or hazardous waste constituents in the groundwater.*

These objectives are related to the remedial investigation of the vadose zone for the RFI/CMS at WMA T. For example, results from both the groundwater and vadose zone are needed to assess the potential near-term risk (risk assessment) associated with hypothetical exposure pathways (DOE/RL-99-36). The RFI/CMS process will be used to determine the potential need for interim or corrective measures. The process will proceed incrementally. If there is a determination of substantial risk based on both the groundwater and vadose zone results, a decision to acquire additional data may be made or more immediate near-term mitigating actions may be taken (DOE/RL-99-36). Evaluation of risks associated with existing soil and groundwater contamination will serve the following purposes:

- establish the need for additional interim or corrective measures
- provide input to Hanford site-wide cumulative risk assessments
- serve as a basis to begin identifying cleanup standards (DOE/RL-99-36).

The endpoint for both the soil and groundwater investigations will be decided by Ecology using the risk assessment results.

Key questions related to the above objectives are as follows:

1. What is the vertical and horizontal concentration profile of all hazardous waste constituents in the plume(s) released from WMA T?

2. What is the rate and extent of contaminant migration in the groundwater?

3. What are the likely sources or source areas for observed groundwater contamination?

4. What are the likely driving forces for observed groundwater contamination?

5. What is the groundwater flow direction?

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

## 1.3 Scope

The scope of this plan is to acquire the necessary groundwater data to determine the vertical and areal extent of groundwater contamination, contaminant concentrations, and the rate of migration of contaminants originating from the WMA T. In addition, work conducted under the plan will provide information for the RFI/CMS to be conducted at this WMA. Accordingly, the areal study boundary for this plan is the same study boundary as described for the RFI/CMS at WMA T (Change Request M-45-98-03, Attachment One). This consists of the fenced area within the T Tank Farm as well as ancillary structures, such as cribs and transfer lines, etc. adjacent to the fenced area. The vertical extent is defined by the bottom of the aquifer (~56 m [184 ft] thick) contained within the semi-cemented sands and gravels of the Ringold Formation.

## 1.4 General Approach

The general approach to meet the specific or immediate objectives for the continued assessment (i.e., to determine the concentration, rate of movement, and extent of contamination) includes the following major components:

- Determine optimum locations for new monitoring wells to improve the probability of detecting contaminant plumes from the WMA. A combination of well network design modeling and observational inferences will be used for this purpose. A reliable detection network is also important to demonstrate the effectiveness of any interim corrective measures undertaken as a result of the RFI/CMS process.

- Determine depth distribution of contaminants within the aquifer by discrete depth sampling during drilling of new wells and multi-depth well completions.

- Conduct hydrologic testing on selected wells to obtain estimates of hydraulic conductivity, effective porosity, and preferential flow zones within the screened interval of monitoring wells. This information will be used in concert with new water-level data to determine groundwater flow velocities and to determine optimal locations of sampling intervals within the well screen intervals.

- Use spatial and temporal mapping of the contaminant plumes to delineate the extent and concentration of contaminants and their relationship to potential sources within the study boundary. In concert with hydrogeologic data, estimate the approximate rate and direction of contaminant migration.

- Use ratios between various chemical constituents and isotopes (fingerprinting) to aid the identification of contaminant sources (e.g., cribs versus tanks) affecting groundwater quality. This, in turn, can help narrow the areas of concern for the vadose zone studies to be conducted for the RFI/CMS. This activity will be closely coordinated with the Tank Farm Vadose Zone Project activities, which include reconstruction of tank waste inventories over time based on tank transfer and disposal history.

The above efforts will lead to

- improved knowledge of the direction and velocity of groundwater flow

- a better understanding of the location and areal and vertical extent of contaminant plume(s) in the vicinity of WMA T

- enhanced understanding about the sources and characteristics of the groundwater contamination

- recommendations for effective placement of new monitoring wells.

## 1.5 Plan Organization

In addition to this introduction, a review of existing data including stratigraphy, water-level data, groundwater chemistry, and conceptual model development is presented in Chapter 2.0. A description of the groundwater monitoring program including evaluation of the assessment network, constituent lists and sample frequency, hydraulic testing, groundwater flow direction, and plume extent are presented in Chapter 3.0. The references cited in the text are given in Chapter 4.0. The sampling and analysis plan is included as Appendix A. Geologic cross-sections and as-built drawings of the existing RCRA and non-RCRA monitoring wells that will be used in the investigative activities are included in Appendix B. Results from the spatial modeling effort (e.g., Monitoring Efficiency Model as documented in [Wilson et al. 1992]) are included in Appendix C. Preliminary results obtained from detailed hydrologic characterization tests within the WMA are presented in Appendix D.

# 2.0 Existing Data

This section summarizes existing stratigraphic, hydrologic, and groundwater chemistry data within and in the vicinity of WMA T. Most of this information is derived from RCRA and/or earlier non-RCRA groundwater monitoring wells. An extensive data set exists for the four RCRA-compliant wells (299 W10-16, 299-W10-15, 299-W11-27, and 299-W11-28) that were part of the original detection level monitoring network. Wells 299-W10-16 (upgradient), 299-W10-15, and 299-W11-27 went dry; well 299-W11-28 is going dry. In calendar year 1998, two wells, 299-W10-23 and 299-W10-24, were drilled to replace wells 299-W10-15 and 200-W11-27, respectively. Eight non-RCRA wells (299-W10-1, 299 W10-12, 299-W10-8, 299-W11-23, 299-W11-24, 299-W11-12, 299-W10-4 and 299-W11-7) were added to the extended assessment monitoring network. However, data for other wells in the area are sparse or non-existent. One of the goals of this assessment is to provide a viable database for water levels and groundwater chemistry in the larger area around the WMA. This information will aid the understanding of hydrogeologic conditions at the WMA and aid in tracking the movement of contaminant plumes.

## 2.1 Stratigraphy

WMA T is underlain by approximately 152 m (500 ft) of suprabasalt sediments, based on the stratigraphy in well 299-W11-26 (DH-6), reported by Lindsey (1995). The suprabasalt sediments consist of approximately 36 m (120 ft) of Hanford formation glacial flood deposits, 3 m (10 ft) of Plio-Pleistocene unit, and 117 m (385 ft) of Ringold Formation. The lower mud unit of the Ringold Formation occurs at a depth of 126 m (412 ft) and, where it is locally confining, the unconfined aquifer has a thickness of approximately 52 m (170 ft) and is contained entirely within unit E of the Ringold Formation. The water table beneath the WMA occurs at a depth of approximately 70 m (230 ft), thus, the unconfined aquifer beneath the WMA has a thickness of approximately 56 m (184 ft).

The Hanford formation consists of gravels, sands, and silts deposited by catastrophic glacial floods at the end of the Pleistocene. The Hanford formation sediments are clast supported, uncemented, and highly permeable to both liquid and gases. At WMA T, they are contained entirely within the vadose zone. The Plio-Pleistocene unit is a sandy, silty carbonate cemented (caliche) paleosol that occurs at the top of the Ringold Formation. It is present throughout the 200 West Area and forms an extensive, but imperfect, barrier to vertical migration within the vadose zone. The Ringold Formation, in the vicinity of WMA T, consists of fluvial sediments deposited by the ancestral Columbia River. It is dominated by two gravel packages, unit E above a fine gained unit, the lower mud unit, and unit A between the lower mud unit and the top of basalt. Gravels within unit E, which contains the unconfined aquifer beneath the WMA, are characterized by highly variable cementation. As a result of this irregular cementation, highly variable hydraulic conductivities and preferred flow zones likely occur within the aquifer. A generalized stratigraphic column for the Hanford Site is presented in Figure 2.1.

A north-south cross-section through WMA T and TX-TY, based on geologic and geophysical logs from existing RCRA monitoring wells, is presented in Figure 2.2.

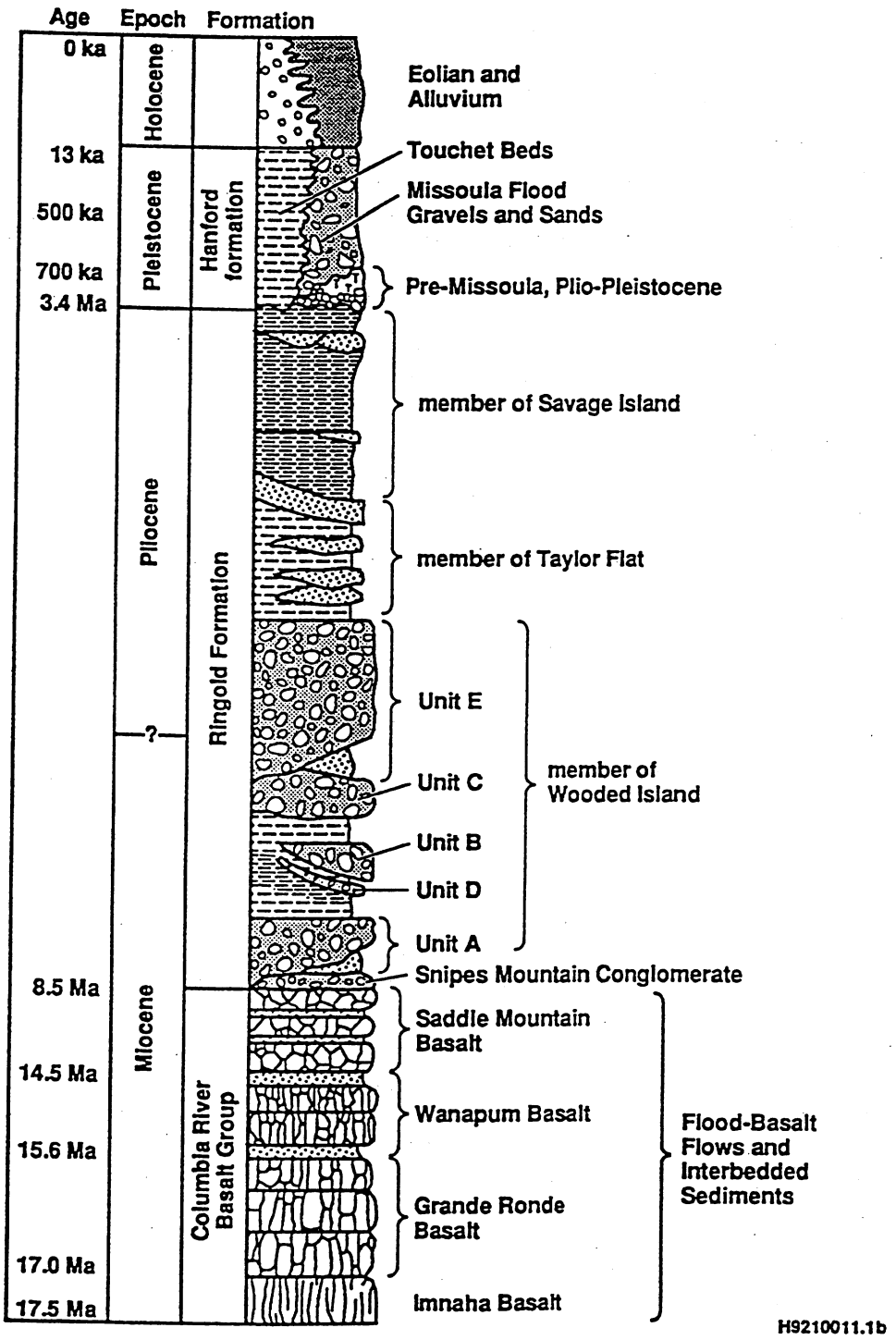


**Figure 2.1**. Generalized Stratigraphic Column for the Hanford Site (Lindsey 1995). Column emphasizes Ringold Formation and is not to scale.

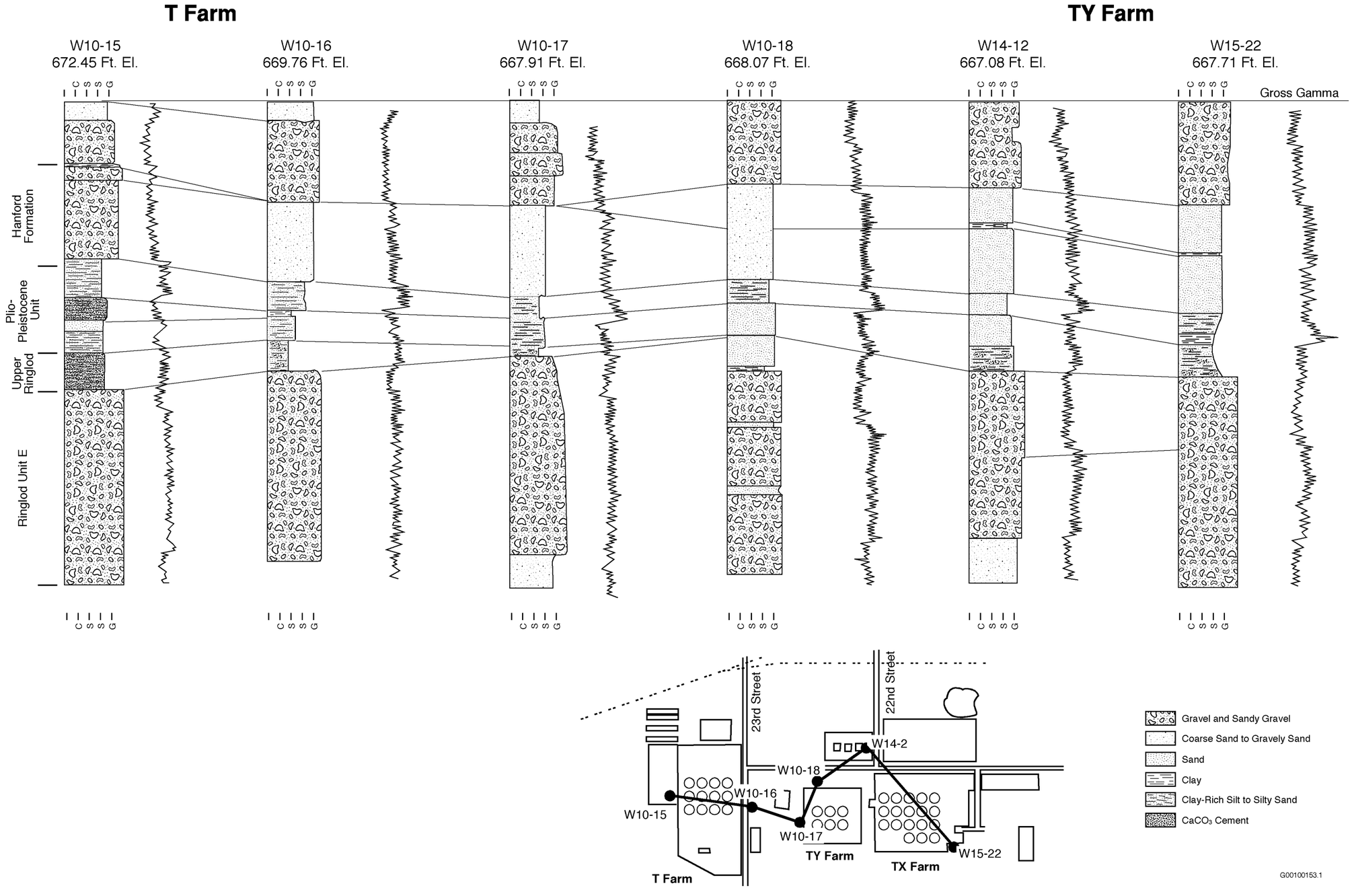


**Figure 2.2**. Cross-Section Through RCRA Monitoring Wells at WMAs and TX-TY Showing Geologic and Gross Gamma Logs

## 2.2 Water-Level Data

Water levels have declined beneath the WMA since the inception of RCRA monitoring in 1989 (Figure 2.3). This decline, resulting from decreasing effluent discharge in the 200 West Area, became much steeper in 1995 with the effective cessation of discharge to ground in this area. The rapid decrease in water levels after 1995 has resulted in monitoring wells going dry more quickly than previously predicted and has necessitated the drilling of new monitoring wells.

Groundwater flow directions in the vicinity of WMA T have been highly variable because of changing effluent discharge sites within the 200 West Area (Hodges 1998). At the time the RCRA detection network was established, the direction of groundwater flow was toward the northeast (Caggiano and Goodwin 1991). However, effluent discharges within the 200 West Area have declined in magnitude and stopped entirely in 1995. This caused the direction of groundwater flow to move to a more easterly direction, which is believed to be the direction of groundwater flow prior to the establishment of the Hanford Site. During 1998, this change in the direction of groundwater flow accelerated (see Figure 1.4). Whether the direction of groundwater flow will stabilize in an easterly direction, or will continue to rotate toward the southeast, is uncertain. Another variable is the high cementation within the Ringold Formation. Thus, locally, there may be preferred flow paths that differ from the general flow direction indicated by the water-table maps.

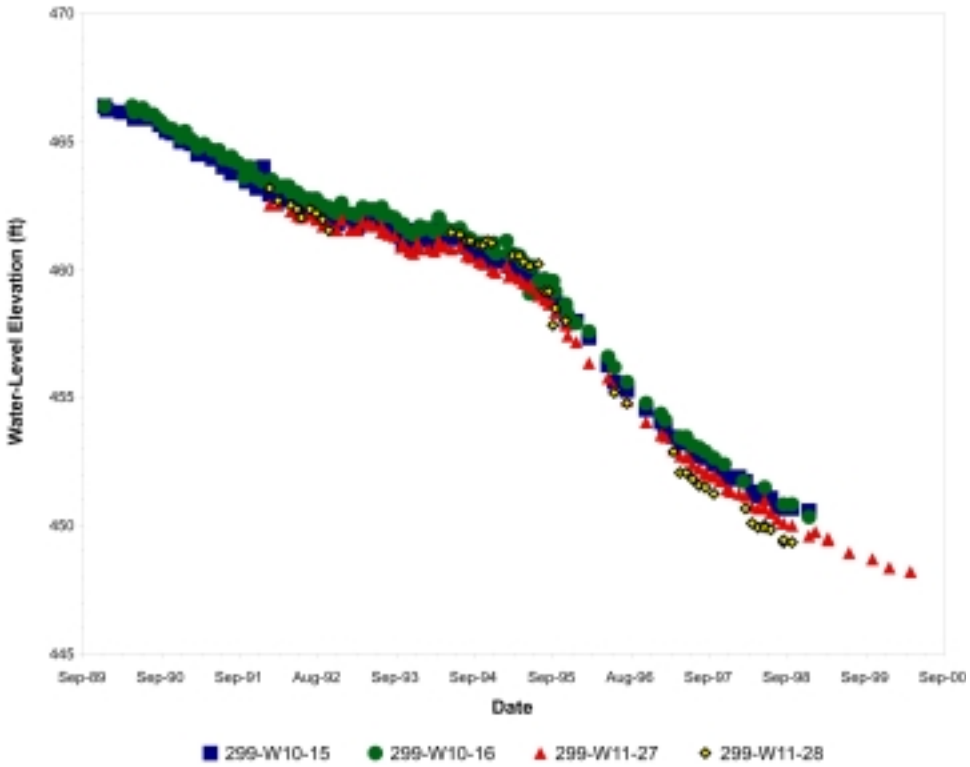


**Figure 2.3**. Hydrographs for RCRA Monitoring Wells at WMA T

## 2.3 Groundwater Chemistry

Groundwater chemistry in the vicinity of WMA T is dominated by high sodium, high nitrate groundwater containing varying concentrations of tritium, technetium-99, and other contaminants. These contaminants are a result of 50 years of waste management activities in the 200 West Area. In fact, the WMA was originally placed in assessment because of variations of specific conductance in background groundwater as it affected well 299-W10-15 (Caggiano and Chou 1993, Hodges 1998). In contrast, groundwater northeast of the WMA has very low ionic strength. This water is essentially contaminant free, possibly a result of leaks from a transfer line taking T Plant effluent (primarily cooling water) from the 207-T Retention Basin to the 216-T-4-2 Ditch as discussed below.

Prior to 1995, contour maps showed a localized area of very low specific conductance (<250 μS/cm) area near the northeast corner of T Tank Farm. However, a large area west of WMA T and extending east across WMA T showed high specific conductance (~1,000 μS/cm) (see Figure 3.6, Hodges 1998). Columbia River water, the source of Hanford Site makeup water, has a specific conductance of about 140 μS/cm. Thus, the very localized zone of low conductivity water was attributed to a leaking wastewater line in this area that was used to transfer cooling water to the 216 T-4-2 Ditch. In late 1995, following termination of surface discharges within the 200 West Area, downgradient well 299-W11-27, located at the northeast comer of WMA T, experienced a rapid increase in specific conductance, technetium-99, chromium and other contaminants. In February 1997, technetium-99 reached a maximum of 21,700 pCi/L (drinking water standard = 900 pCi/L). In late 1997, the contaminants affecting well 299-W11-27 reached downgradient well 299-W11-23 (Figure 2.4). Apparently the localized groundwater mound from the leaking wastewater transfer line diverted the contaminant plume away from the monitoring well(s) or pushed it down below the screened interval of well 299-W11-27. When the discharges to ground were terminated in 1995, the mound dissipated and the monitoring wells could then intercept the contaminant plume from T Tank Farm.

Sampling during drilling at well 299-W10-24 (WMA T) and 299-W14-14 (WMA TX-TY), drilled through the Ringold lower mud unit, indicate contamination with carbon tetrachloride, tritium, and technetium-99 throughout the thickness of the aquifer, and below the lower mud unit. Contaminant concentrations tend to peak at depths of 30 to 45 m (~100 to 150 ft) beneath the water table, however they are present in significant concentrations at all depths that were sampled.

The direction of groundwater flow at WMA T is complex, and there are multiple potential sources of groundwater contamination in the area. Therefore, a means is needed to distinguish one source type from another. One approach is to use elemental and isotopic ratios of mobile groundwater constituents as indicators to differentiate tank from crib sources. These ratios also may be used to define mixing lines for varying groundwater compositions (Hodges 1998). Contaminant concentrations can vary widely from the centerline of a plume to the outer edges. However, the ratio of two mobile constituents associated with the plume will not change (assuming the plume in question is the only source of the two constituents). Variation in the ratios (systematic deviation from a single or narrow range of values) of selected contaminant concentrations could be attributed to different source types. For example, the sodium/calcium ratio could provide useful information to discern between different sources. Other useful ratios include tritium/technetium-99, and nitrate/technetium-99.

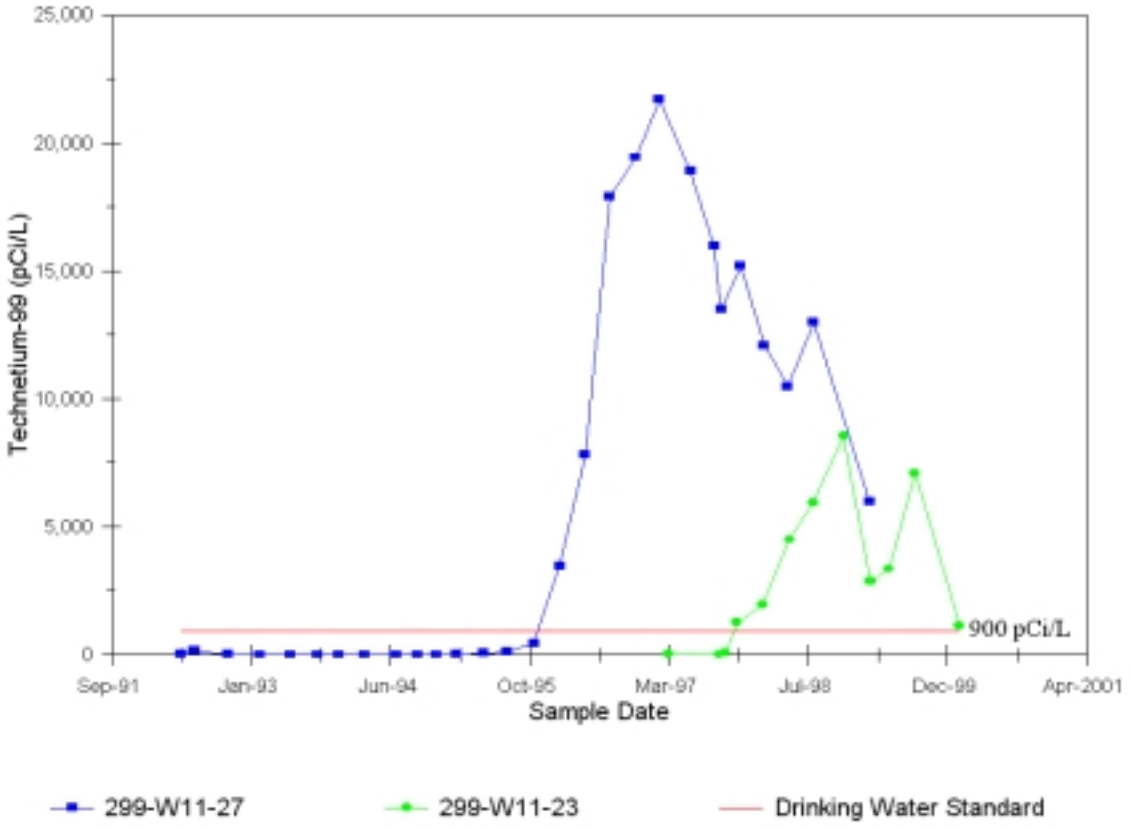


**Figure 2.4.** Technetium-99 Activities (pCi/L) in Monitoring Wells 299-W11-27 and 299-W11-23

## 2.4 Conceptual Model

Conceptual models are essentially collections of working hypotheses that provide a framework for ongoing work. This framework should be continually modified as new data become available and new understanding is developed.

Figure 2.5, taken from Johnson and Chou (1998), is a reasonable representation or first approximation of possible pathways to groundwater in the 200 West Area. Sources of contamination include tank leaks, tank overflows, junction box or transfer line leaks, and in the case of WMA T, cribs and part of a tile field included within the WMA boundaries. Although seven tanks within WMA T are known or suspected leakers, the major potential leak source is associated with tank T-106 that leaked an estimated 4.34 X $10^5$ L (115,000 gal) of tank supernate (Routson et al. 1979). In addition, a tank overflow event at tank T-101 prior to 1974 may have released a volume of waste comparable to the T-106 leak (Routson 1981).

Driving forces for moving waste through the vadose zone consist principally of gravel-enhanced infiltration of normal precipitation (Gee et al. 1992) and the effects of flooding during rapid snow melt events (Hodges 1998, Figure 3.23). Water lines within the T Tank Farm are generally lacking and do not represent the type of problem presented at WMA S-SX (Johnson and Chou 1998); however, it is possible

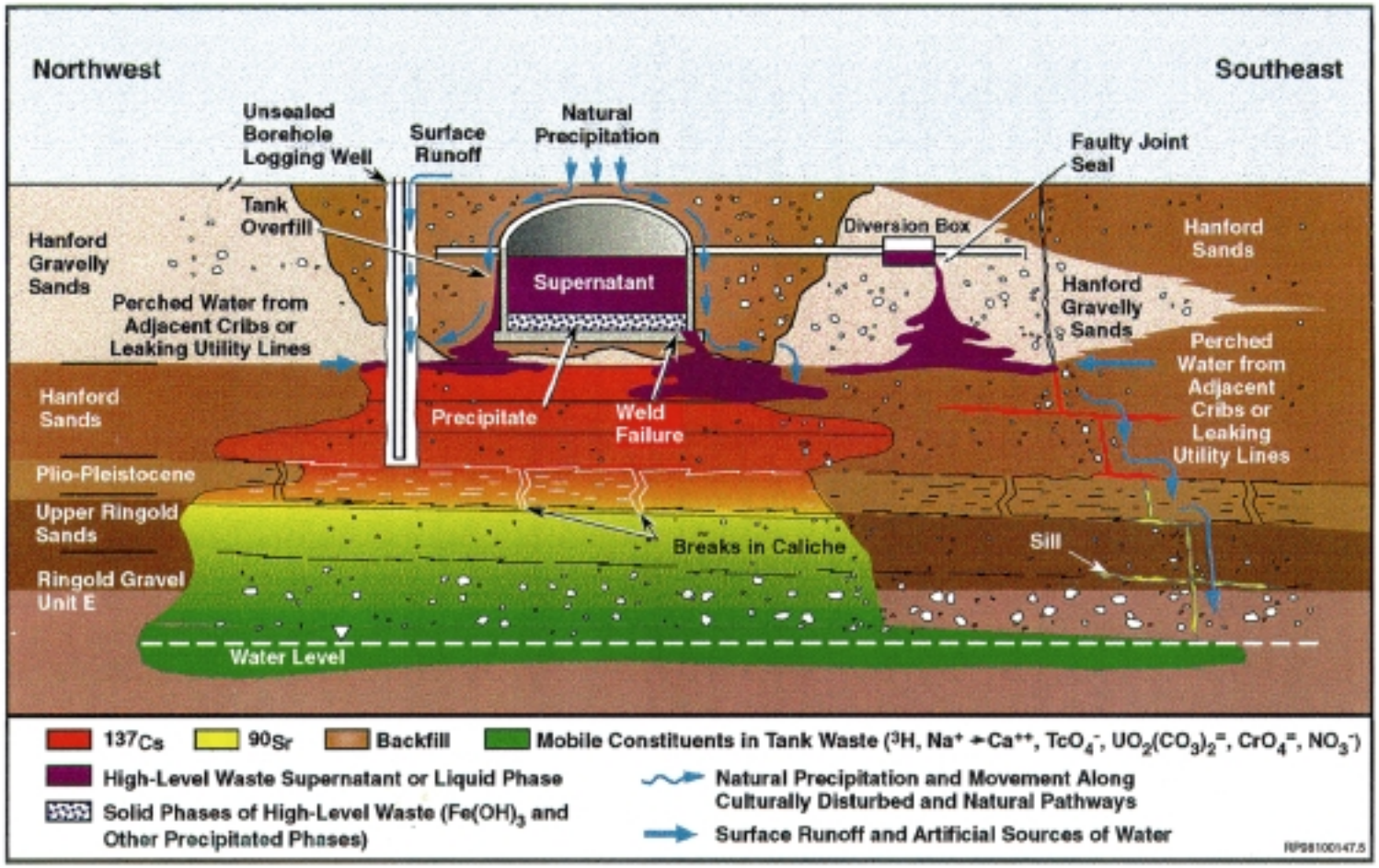


**Figure 2.5**. Soil Pathway Conceptual Model. Purple depicts tank waste and leakage during early operations in the 1960s. Subsequent hypothetical movement of contaminants through the vadose zone, shown in red, yellow, and green, covers a time period from early operations to the present. As a result of volume reduction measures, a much smaller volume of free liquid remains in the tanks today. Depth to groundwater is about 70 m (~230 ft) at WMA T. The tank base elevation is about 15 m (50 ft) below ground surface. The geologic strata shown are simplified for illustration purposes. (From Johnson and Chou [1998]).

that water from the pipeline along the northeastern corner of the WMA migrated down along the top of the calcite cemented Plio-Pleistocene unit (caliche layer) and mobilized waste in the vadose zone beneath the WMA.

Previous investigations of tank leaks at tanks SX-108 and T-106 (Serne et al. 1998, Freeman-Pollard et al. 1994), suggested that most of the contaminants remained high in the soil column. One hypothesis proposed to account for this observation involves both sorption and plugging of the pore spaces in the soil with silica and alumina gels or precipitates released through reaction of highly alkaline waste and silicate minerals in the soil column (Serne et al. 1998). Thus, on the basis of the two studies cited, there was not a general downward migration of contaminants, particularly cesium-137, strontium-90 or transuranics. However, these studies are not conclusive concerning the fate of more mobile constituents and ground-water evidence indicates that pathways do exist.

Regardless of the pathway through the vadose zone, when tank waste reaches the water table it may sink or form a layer at the top of the aquifer depending on the density of the waste and its arrival rate at the water table, relative to the rate of groundwater flow. Hanford tank waste is essentially a saturated sodium nitrate brine, and its density is sufficient to allow it to sink through the aquifer if flow rate is too low to facilitate mixing. Waste mobilized by influx of meteoric or other surface water will be diluted and the density will depend on the degree of mixing. An additional complication is relatively clean water that may infiltrate to the water table upgradient and/or downgradient of the point where the contaminants entered groundwater, an effect enhanced by wide gravel aprons around the tanks. Thus, there may be vertical layering in the aquifer resulting from multiple infiltration effects. Determination of the vertical variation of contaminants within the aquifer may aid in determining vadose zone transport mechanisms within the tank farms.

# 3.0 Groundwater Quality Assessment Program

The initial investigation of groundwater quality conditions at WMA T (Hodges 1998) addressed the basic question of whether or not the WMA was responsible for contributing to groundwater contamination. Because it was concluded that the WMA has affected groundwater (Hodges 1998), the general focus of the continued investigation is to determine the rate and extent of migration of the hazardous constituents or waste constituents in the groundwater and their concentrations [40 CFR 265(d)(4) and by reference WAC 173-303-400(3)]. The requirements under the continued assessment program are more intensive than what is required for RCRA indicator evaluation monitoring. This section presents the groundwater monitoring network (including proposed locations for new wells), sampling frequency, and analytical constituent lists to be used to meet the requirements of assessment monitoring.

## 3.1 Assessment Network

The current assessment network consists of point-of-compliance wells located near the tank farm fence line and one mid-field well (299-W11-7). As a result of the shift in groundwater flow direction to the east, and MEMO model predictions of well coverage efficiency (Appendix C), combined with both judgment and contaminant observations, three new wells as well as one replacement well are proposed to be drilled in calendar year 2000. These new wells will provide a more complete areal coverage to identify potential sources of contamination within the WMA and will help fulfill the requirement to assess the extent of groundwater contamination from this WMA. Existing monitoring wells and the proposed new wells for calendar year 2000 are listed in Table 3.1a. The approximate location of the wells are shown in Figure 3.1. In addition, five wells are planned for calendar year 2001 pending funding availability (Table 3.1b). The proposed well locations are shown in Figure 3.2. One well is an upgradient well, which will replace a non-RCRA well (299-W10-1). Another well is a near-field downgradient well, which will monitor at depth to evaluate contaminant depth distribution near the WMA. Also, two wells (a deep and an intermediate depth well) adjacent to well 1 (calendar year 2000 well, see Figure 3.2) will be drilled for a three well cluster. If contamination is detected at depth in downgradient wells, the results from monitoring wells installed at these locations will be evaluated to determine whether deep upgradient wells will be needed to differentiate possible upgradient sources of the deep contamination. As-built diagrams for the existing assessment network wells are presented in Appendix B.

There is a mid-field deep well to evaluate the horizontal and the vertical extent of contamination. The contaminant plume intercepted by well 299-W11-27 apparently came from within the WMA, and probably from the northern portion of the T tank farm. When the plume was intercepted at well 299-W11-27, the groundwater flow was generally toward the northeast. With the present groundwater flow toward the east, or slightly north of east, the existing plume should drift eastward across the downgradient wells. Any contaminants entering groundwater beneath the WMA will now form a plume moving toward the east from wherever it originates within the WMA. The contaminant chemistry of groundwater in the new downgradient wells, coupled with better estimates of flow velocities and of aquifer hydraulic properties resulting from tests in the new wells (see Section 3.4) will allow a determination of the best location for this well.

**Table 3.1a**. Assessment Monitoring Network, Constituent List and Sampling Frequency for WMA T

| Well | RCRA Standard | Sampling Frequency[a] | Constituent List[b] | Co-Sample | Comment |
|---|---|---|---|---|---|
| **Existing Monitoring Network** | | | | | |
| 299-W10-1 | N | Q | A | | |
| 299-W10-12 | N | Q | A | | To be decommissioned |
| 299-W10-23[c] | Y | Q | A | | 299-W10-15 replacement |
| 299-W10-8 | N | Q | A | | |
| 299-W10-24[d] | Y | Q | A,B,C | | 299-W11-27 replacement |
| 299-W11-23 | N | Q | A,B | | Going dry |
| 299-W11-24 | N | Q | A,B | | 299-W11-28 replacement |
| 299-W11-28 | Y | Q | A,B | | Going dry |
| 299-W11-12 | N | Q | A | | |
| 299-W10-4 | N | Q | A | | 299-W10-16 replacement |
| 299-W11-7 | NA | SA | A | AEA[e] | Mid-field |
| **New Wells to be Drilled in Calendar Year 2000** | | | | | |
| Well 1 | Y | Q | A,B,C | | |
| Well 2 | Y | Q | A,B | | 299-W11-24 replacement |
| Well 3 | Y | Q | A,B | | |
| Well 4 | Y | Q | A,B | | |

(a) SA = Semiannually; Q = Quarterly; NA = Not applicable.
(b) Letters refer to lists in Table 3.2.
(c) Completed October 1998.
(d) Completed September 1998.
(e) Integrated with Atomic Energy Act monitoring activity.

In addition, some wells may become unusable in the future because of the declining water table and/or changing direction of groundwater flow or being decommissioned. If this happens, the effect on the monitoring network must be re-evaluated and, on the basis of ongoing evaluations, it may be necessary to deepen existing wells, where feasible, and or to drill new wells.

Well 299-W10-24 (well 299-W11-27 replacement) was drilled through the lower mud unit of the Ringold Formation, with groundwater samples collected at discrete intervals within the aquifer, to determine the depth distribution of contaminants. Samples were taken at depths of approximately 15, 30, 46, 58, and 67 m (50, 100, 150, 190, and 220 ft) below the water table. The lower two depths provide samples immediately above and below the Ringold lower mud unit, based on the stratigraphy for nearby well 299-W11-26 presented by Lindsey (1995). After sampling, the well was backfilled and completed at the top of the water table with a 10-m (35-ft) screened interval. Results from the discrete depth sampling indicated deeply distributed nitrate, tritium, and carbon tetrachloride. Technetium-99, on the other hand,

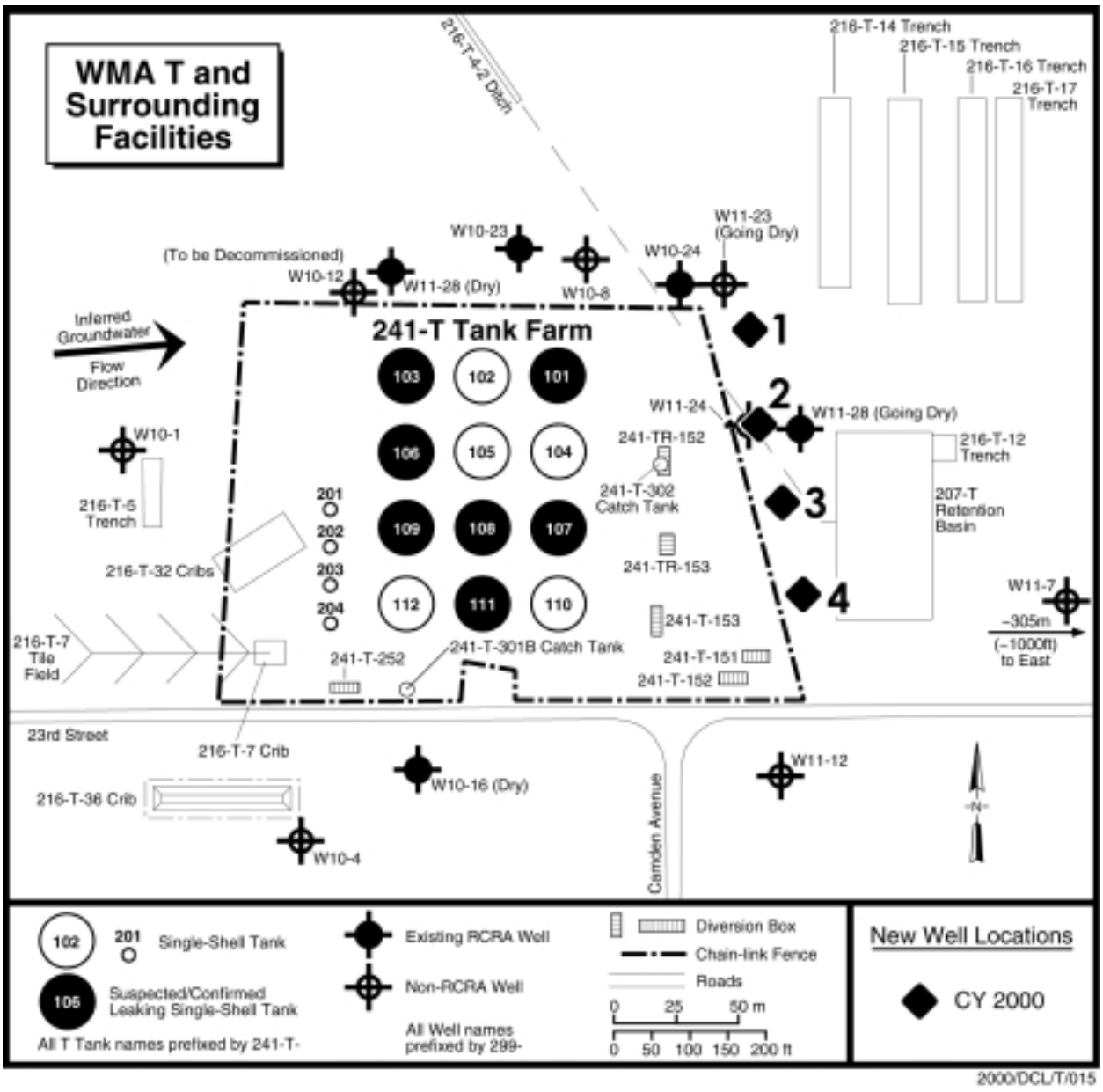


**Figure 3.1.** Locations of Wells in Assessment Network

declined rapidly with increasing depth. These observations suggest different sources that originated under different hydraulic conditions resulting in variable depth distribution of the contaminants.

Several older non-RCRA wells (see Table 3.1a) also are included in the assessment network. For example, a non-RCRA well (299-W11-24) is used to replace a RCRA well (299-W11-28) that is going dry. Well 299-W11-24 will be included in the assessment network until a new RCRA compliant well that replaces well 299-W11-24 is completed, developed, and ready for sampling. These wells, drilled prior to 1990, normally have carbon steel casings that are perforated to allow access to the aquifer. Because of

**Table 3.1b**. Additional Assessment Wells, Constituent List, and Sample Frequency Planned for WMA T in Calendar Year 2001 (not listed in order of priority)

| Well | RCRA Standard | Sampling Frequency[a] | Constituent List[b] | Co-Sample | Comment |
|---|---|---|---|---|---|
| **New Wells to be Drilled in Calendar Year 2001[c]** | | | | | |
| Well 5 | Y | Q | A,B | | Replace non-RCRA upgradient well 299-W10-1 |
| Well 6 | Y | Q | A,B | | Monitor at depth to evaluate down-gradient contaminant depth distribution |
| Well 7 | Y | Q | A,B | | A mid-field well to evaluate horizontal and vertical extent of downgradient contamination |
| Wells 8 and 9 | Y | Q | A,B,C | | Two wells adjacent to calendar year 2000 Well 1; these wells will evaluate contamination and monitor at selected depths |

(a) Q = Quarterly.
(b) Letters refer to lists in Table 3.2.
(c) Pending funding availability.

the materials used to construct these wells and the potential effects of corrosion on groundwater chemistry, special care must be taken to maintain these wells and to purge the wells before sampling. However, with proper precautions, they should yield water samples adequately representative of the aquifer.

The need for additional new RCRA wells beyond those discussed above will be evaluated at least on an annual basis to determine the effects of declining water tables, changing flow directions, and contaminant distribution patterns.

## 3.2 Constituents and Sampling Frequency

Sampling frequency (see Tables 3.1a and b) will depend on both proximity to the WMA and trends in contaminant concentrations in the well. Initially, wells immediately adjacent to the WMA will be sampled on a quarterly basis and more distant well (299-W11-7) on a semiannual basis. If there is a rapid increase in technetium-99 activity, or if technetium-99 exceeds the drinking water standard, sampling frequency in that well will be increased to quarterly. As the assessment study proceeds, the sampling frequencies may be increased or decreased on the basis of flow rates, flow directions, or contaminant patterns.

The analytical constituent lists (Table 3.2) are designed to meet monitoring needs of the assessment program. List A is the basic list for monitoring in near-field wells. Inductively coupled plasma (ICP) metals and anions, coupled with radionuclide analysis provide information on the major contaminants associated with the WMA and for calculating the ratios necessary for plume fingerprinting.

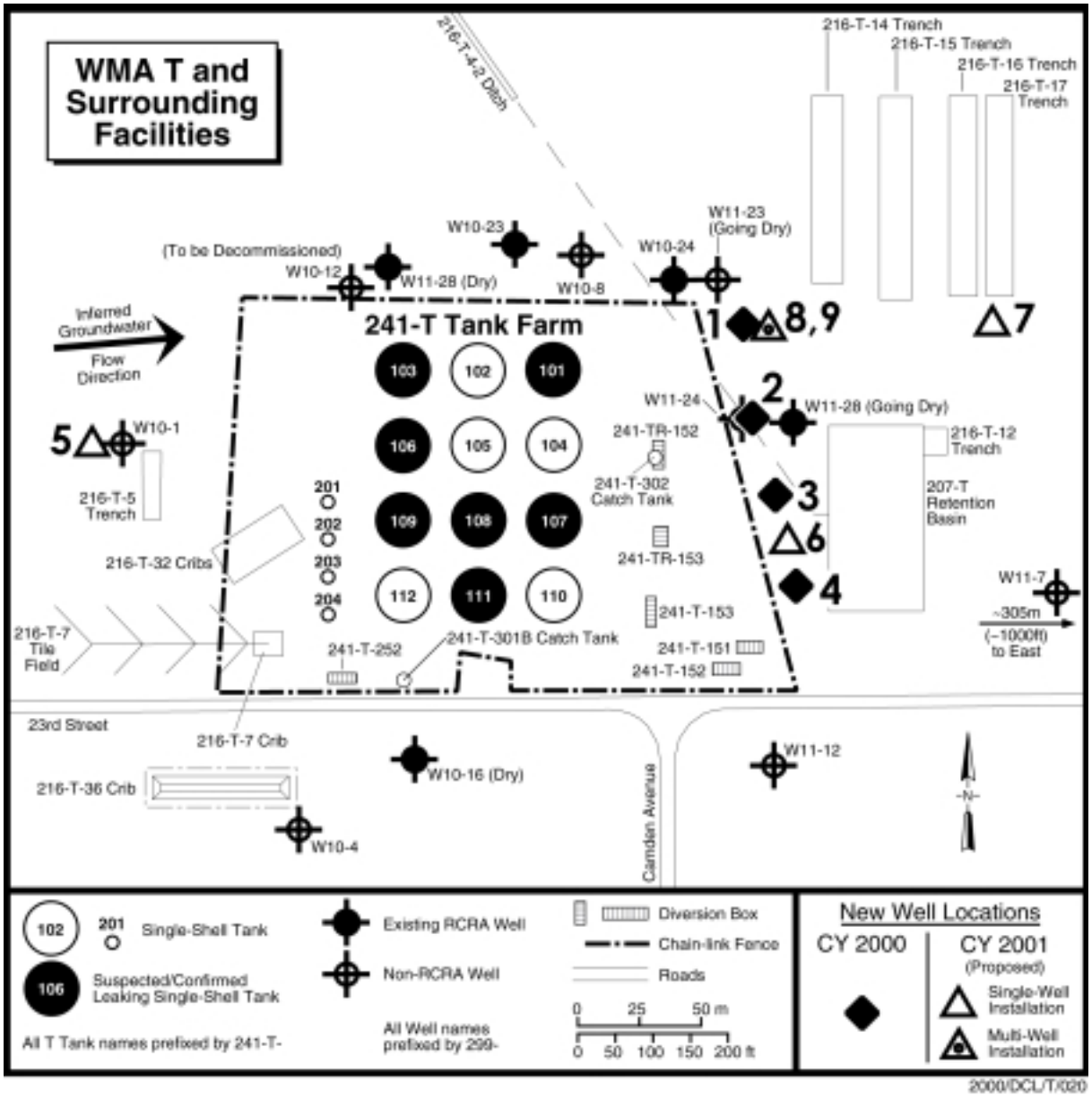


**Figure 3.2**. Proposed New Well Locations for WMA T

Total organic carbon (List B), a RCRA indicator parameter, will be analyzed in selected near-field downgradient well samples because many of the tanks contain organics (complexants) and because it is a co-contaminant in well 299-W11-27. Total organic halogen is not on the list because halogenated hydrocarbons are not believed to be significant tank waste components. Carbon tetrachloride and trichloroethene are present in groundwater throughout the area; however, they are principally a result of waste disposal activities at the Plutonium Finishing Plant and are tracked by monitoring activities required by the *Atomic Energy Act*. Because of its importance in delineating contaminant sources in the vicinity of the WMA, carbon tetrachloride may be added to the constituent list when needed.

**Table 3.2**. Analytical Constituents for WMA T

| List A | List B | List C |
|---|---|---|
| Temperature | Total organic carbon[a] | Strontium-90[b] |
| Specific Conductance | | Gamma scan |
| pH | | Special Analyses[c] |
| ICP Metals | | |
| Anions | | |
| Alkalinity | | |
| TDS | | |
| Gross Alpha | | |
| Gross Beta | | |
| Technetium-99 | | |
| Tritium | | |

(a) Individual analysis.
(b) Non-routine analysis. If analytical result of strontium is shown as nondetects, it will be dropped.
(c) Non-routine analyses and include ruthenium-101, selenium-79, americium-241, and neptunium-237.
ICP = Inductively coupled plasma.
TDS = Total dissolved solids.

Ruthenium-101 (stable), selenium-79 ($t_{½}$ = 6.5 x $10^4$ years), neptunium-237 ($t_{½}$ = 2.14 x $10^6$ years), and americium-241($t_{½}$ = 244 years), (List C) are tank waste constituents that are known to be present in tank waste and may be detectable in groundwater in low concentrations. Because of low expected concentrations, these constituents may be analyzed only in selected samples that have high concentrations of technetium-99, another mobile tank waste constituent. If results are positive for the high technetium-99 samples, the analysis may be extended to other samples.

## 3.3 Hydraulic Testing

Hydrologic data for the WMA T area are incomplete. Slug tests during completion of two RCRA wells yielded estimates of hydraulic conductivity. In addition, a tracer test carried out on the north side of WMA T in 1979, as part of the T-106 tank leak study (Routson et al. 1979), yielded a lower limit for groundwater-flow velocity of 0.41 m (1.3 ft) per day. Under present conditions (lower hydraulic gradient), that determination indicates a groundwater flow velocity lower limit of approximately 0.2 m (0.7 ft) per day. The tests described below are designed to provide hydrologic data that will allow evaluation of groundwater-flow rates and contaminant migration rates in the vicinity of WMA T and may be used in risk analysis.

Hydrologic testing is planned for the two monitoring wells (299-W10-24 and 299-W10-23) drilled during 1998 and selected new wells planned for calendar year 2000. The hydrologic test plan includes several individual test elements designed for specific characterization information. Identified individual test and parameters to be measured include

- Slug Testing – evaluating well-development conditions and providing preliminary hydraulic property information (e.g., hydraulic conductivity) for design of subsequent hydrologic tests

- Tracer-Dilution Test – determining the vertical distribution of hydraulic conductivity and/or groundwater flow velocity within the well screen section

- Tracer-Pumpback Test – tracer removal and characterizing effective porosity, an important hydraulic transport parameter

- Pumping Test/Recovery – conducted in concert with tracer-pumpback phase. Analysis of drawdown and recovery data provides quantitative hydraulic characterization property information (e.g., hydraulic conductivity, storativity, specific yield).

As noted above, slug testing is designed primarily to provide initial estimates of hydraulic properties to design more quantitative hydrologic tests. Several slug tests will be conducted at different stress levels during this characterization phase to provide information pertaining to well development and possible presence of near-well heterogeneities. After slug testing, a tracer-dilution test will be conducted on selected wells, and, in turn, a combined constant-rate pumping and tracer-pumpback test. Information obtained from the detailed hydraulic characterization will provide aquifer information pertaining to flow velocity, hydraulic properties, and effective porosity in the vicinity of the well site, as well as well performance/efficiency. This information will serve as input to numerical models used to simulate groundwater flow and to predict contaminant transport within the Hanford Site.

For the tracer-dilution test, a solution of potassium or lithium bromide (or other suitable tracer) of known concentration will be circulated/mixed within the well screen section. The decline (i.e., dilution) of tracer with time within the well screen will be monitored directly using bromide specific-ion electrodes located at known depth intervals. Based on the dilution characteristics observed, the vertical distribution (i.e., heterogeneity) of hydraulic properties and/or flow velocity can be estimated for the formation/well screen section.

After the tracer-dilution test is completed, and the tracer has sufficient time to clear the borehole, a pump will be placed in the well and water will be discharged at a constant rate to recover most of the tracer. The tracer-pumpback phase will be complete when the centroid of tracer concentration has been recovered. Analysis of the tracer recovery pattern will provide information on hydraulic conductivity and effective porosity. In order to quantitatively characterize the hydraulic properties of the surrounding formation, the constant-rate-pumping test might be extended for duration longer than required for "capturing" the centroid of tracer concentration. The time required to obtain representative hydrologic property results will be determined using diagnostic derivative analysis results of the drawdown data

obtained from the pumped and nearby observation well locations. A detailed description of the use of derivative analysis techniques is provided in Spane (1993) and Spane and Wurstner (1993).

After the constant-rate pumping test is complete, the recovery of water levels within the pumped and nearby observation wells will be monitored. The time required for recovery monitoring will be assessed through the use of diagnostic derivative analysis, similar to drawdown data during the pumping phase. For general planning purposes, however, recovery monitoring should be maintained for a period equal to the pumping period and preferably longer.

One important planning assumption for the hydrologic testing is that the water produced during pumping can be disposed of as ordinary purgewater. If the water must be handled as "F" listed waste, the cost may prohibit hydrologic testing that requires pumping large volumes of water.

As of September 30, 2000, all of the above identified hydrologic tests were completed for well 299-W10-24 and slug test was completed for well 299-W10-23. Preliminary results obtained from detailed hydrologic characterization tests within the WMA are presented in Appendix D. Final results will be documented in PNNL technical reports and in the groundwater annual report.

## 3.4 Groundwater Flow Direction

Determining both the direction and velocity of groundwater flow is important to assess and predict contaminant transport. The tests discussed in Section 3.4 provide estimates of groundwater flow velocities; however, they do not allow estimates of groundwater flow direction.

A number of techniques, including downhole flow measurements, and accurate determination of water-table elevations can be used to determine the direction of groundwater flow. It should be noted, however, that each of the identified techniques has strengths and weaknesses. For example, there is a high degree of uncertainty about the accuracy and reliability of downhole flow measurements, and the fact that they represent only a point in space.

For initial evaluation of groundwater flow directions at WMA T, trend-surface analysis will be applied to refined water-table elevation measurements. As of September 30, 2000, trend-surface analysis was completed for well 299-W10-24 (see Appendix D, Table 5). If, at a later date, the uncertainties about downhole flow meter measurements are positively resolved, flow meter measurements may be used to supplement or corroborate trend-surface analysis results.

## 3.5 Plume Extent

Regulations concerning RCRA assessment require both the horizontal and vertical extent of contaminant plumes be determined. Because the contaminant plume extends in both upgradient and downgradient directions from monitoring wells, it is important to determine the source as well as the downgradient extent of the plume. Groundwater monitoring wells, either existing or newly installed, are necessary to provide sampling data to establish the concentration of contaminants released from the WMA and the rate and extent of their migration. Four new wells are planned for calendar year 2000 to enhance the

downgradient coverage (see Figure 3.1). As of October 2000, three of the planned calendar year 2000 wells were drilled. Additionally, five wells are planned for calendar year 2001 to enhance the delineation of horizontal as well as vertical contaminant distribution (see Figure 3.2). If contamination is detected at depth in downgradient wells, the results from monitoring wells installed at these locations will be evaluated to determine whether deep upgradient wells will be needed to differentiate possible upgradient sources of the deep contamination. The determination of sources within the WMA can be done only through the integration of groundwater sampling data with vadose characterization results within the WMA. Information on the depth distribution of contamination within the aquifer can be obtained through drilling new wells into the deeper portions of the aquifer or by discrete level sampling of older wells with long perforated intervals within the aquifer. In this study, both approaches will be used. In all of these determinations, it is important to use the overall pattern ("fingerprint") of contaminant concentrations, not simply the presence or absence of a particular contaminant to determine the impact of the contaminant plume in a particular well.

### 3.5.1 Plume Fingerprinting

Given the complexity of groundwater contamination patterns and the multiple potential sources for most contaminants observed in groundwater, individual contaminants are not reliable indicators of source. However, Johnson (1997), Johnson and Chou (1998), and Hodges (1998) have shown that ratios of chemical constituents and isotopes, coupled with process knowledge, may allow distinction of different groundwater contaminant source chemistries (see Section 2.2). In this context, "fingerprint" is defined as a set of chemical and isotopic parameters that are considered unique to a particular contaminant source. Given different reactor fuel burnup parameters, different processes used to extract plutonium from the fuel, and the treatment and mixing of the waste after reaching the tank farms, it is highly unlikely that any two contaminant sources would share exactly the same fingerprint (see Agnew 1997). Ratios to be used include sodium/calcium, tritium/technetium-99, and nitrate/technetium-99. Contour plots of the ratios should allow discrimination of tank waste effects from contamination originating from either tank or crib sources and will facilitate determination of the extent of the contaminant plume.

In addition to nitrate/technetium-99 ratios, some trace mobile tank waste constituents (ruthenium-101, selenium-79, and neptunium-237 and possibly complexed americium-241) should be present in very low concentrations in groundwater contaminated by tank waste. The ratios of these isotopes to each other and to other mobile tank waste constituents could be specific to different waste sources within the tank farms. Thus, if concentrations for one or more of these isotopes can be determined for groundwater, and compared with ratios determined for the soluble fraction from solid samples within tank farm vadose contaminant plumes, it may be possible to identify specific source areas within the WMA. Because these tank waste constituents will most likely be present in detectable concentrations in groundwater containing high concentrations of mobile constituents such as technetium-99, initial analysis for them will be restricted to selected high technetium-99 samples from wells 299-W10-24 and new well $^{\#}$1 which is south of well 299-W11-23 (see Table 3.1a).

### 3.5.2 Horizontal Extent

The contaminants that resulted in continued assessment at WMA T were originally detected only in well 299-W11-27, located at the northeast comer of the tank farm (see Figure 3.1). A subsequent increase in technetium-99 in well 299-W11-23 (see Figure 2.4), starting in November 1997, may indicate this well intercepts the contaminant plume. The initial plume fingerprint is consistent with that determined for well 299-W11-27 (Hodges 1998).

The geometry of the plume is uncertain. Well 299-W11-23 is located approximately 20 m (66 ft) east of well 299-W11-27, not on a direct flow path from likely sources within the WMA. In addition, a flow rate as slow as 0.1 m (0.3 ft) per day would have carried the contaminants approximately 100 m (328 ft) past well 299-W11-27 in the two and a half years since their first detection, well past well 299-W11-23. Thus, the contaminants detected in well 299-W11-23 are either the result of lateral spreading of a north-easterly trending contaminant plume or a plume that was propagating in a northeasterly direction and is now being pushed in a more easterly direction as a result of changing groundwater flow directions.

Four additional wells will be drilled in calendar year 2000 to better define the extent of groundwater contamination from this WMA and to evaluate the validity of forecasts based on hydrologic parameters. This is particularly important given the aquifer heterogeneity found within the 200 West Area and changing flow conditions resulting from declining water-table mounds.

### 3.5.3 Vertical Extent

A preliminary attempt to detect vertical variation of contaminants within the aquifer was made by sampling the top of the aquifer in well 299-W11-27, using a Kabis Sampler. Results from this sampling were consistent with a decrease in contaminants near the top of the aquifer. An upward decrease in contaminant concentrations near the water table in that well may also be indicated by the decrease in contaminants sampled by the fixed pump as the water table has declined over the past several years.

The thickness of the aquifer above the basalt is about 56 m (~184 ft) beneath WMA T. Thus, determination of the vertical distribution of contaminants is an important task, complicated by three-dimensional variation in degree of cementation and hydraulic properties within the aquifer. The distribution of contaminants with depth, in addition to indicating the volume of contaminated groundwater, may provide important constraints on the transport mechanisms that resulted in the observed contamination. The depth of penetration of contaminants into the aquifer depends on both the densities of waste liquids reaching the water table and rate at which they arrive (relative to groundwater-flow rate). Denser liquids would be representative of relatively unmodified tank waste, while tank waste mobilized by surface water would tend to be more dilute and, therefore, of lower density. Denser liquids and rapid arrivals tend to penetrate deeper into the aquifer, while low arrival rates may result in thin layers of contaminants at the top of the aquifer.

New monitoring well 299-W10-24 (299-W11-27 replacement) was drilled through the entire thickness of the unconfined aquifer. Results from this effort indicated deeply distributed contaminants. High nitrate was detected throughout the entire unconfined aquifer, whereas technetium-99 was the highest at

the top and declined more rapidly with depth. Tritium and carbon tetrachloride both exhibited a subsurface maximum at a depth of 20 to 30 m (66 to 98 ft) below the water table. This observation suggests a tank waste "signature" occurs in the shallower portion of the aquifer while the deeply distributed (high nitrate) plume is of a different origin, possibly waste from the Plutonium Finishing Plant crib. This type of information is useful to support decisions regarding corrective or remedial action.

Vertical sampling within screened intervals to examine the depth variation in the upper aquifer will be carried out after a sufficient equilibration time has passed (2 to 3 months) to allow for recovery from any hydraulic disturbance due to sampling or other testing. The vertical sampling, to be conducted using either a KABIS[1] sampler or other suitable multi-level device, will include the collection of samples as near the top of the aquifer as possible as well as at selected depths.

[1] KABIS is a registered trademark of SIBAK Industries Limited, Peoria, Illinois.

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# Appendix A

# Sampling and Analysis Plan

# Appendix A

# Sampling and Analysis Plan

This appendix consists of a field sampling plan (FSP) and a quality assurance project plan (QAPP). The FSP specifies the data collection activities and schedule and the QAPP includes procedures and project controls for the activities that implement acquisition of the information needs described in Chapter 3. Planned activities include the following tasks.

- Task-1: Well drilling, hydraulic testing, and sampling
- Task-2: Transport /spatial modeling and directional mapping
- Task-3: Quarterly sampling and analysis
- Task-4: Data evaluation and reporting
- Task-5: Project planning and direction

The tasks, schedules and estimated cost to implement this continuing groundwater quality assessment are shown in Figure A.1. The data collection tasks shown in Figure A.1 are based on the rationale and discussion provided in Chapter 3. Additional background information can be found elsewhere in the main text. The dates shown in Figure A.1 are approximate times. Actual start and end dates may shift as detailed field work plans are prepared by the various subcontractors near the time the work is initiated. The need to coordinate with the Tank Farm Vadose Zone Project may also alter the schedule to accommodate co-sampling opportunities and/or to address other information needs that may be identified during the process to develop data quality objectives for the RCRA Facility Investigation/Corrective Measures Study (RFI/CMS) for Waste Management Area (WMA) T.

## A.1 Field Sampling Plan

Locations of existing wells and the approximate locations of the wells to be drilled in calendar year 2000 are shown in Figure A.2. Locations of planned wells to be drilled in calendar year 2001 are shown in Figure A.3. The vadose zone portion of Well #2 (see Figure A.2) will be cored for the Tank Farm Vadose Zone Project and will be drilled to 30.5 m (100 ft) below the water table, then back filled and completed with a 10.7 m (35 ft) screen. Samples will be collected using a submersible pump and packer assembly. Samples will be collected and processed in accordance with the standard groundwater sampling protocol (section A.2). Details for the well drilling and characterization are included in a description of work that was submitted to Bechtel Hanford, Inc. by Pacific Northwest National Laboratory.

All other groundwater sampling, analysis and data handling will be conducted in accordance with procedures described in the following section.

## A.2 Quality Assurance Project Plan

The Hanford Groundwater Monitoring Project Quality Assurance Project Plan,[(a)] hereafter referred to as the GW-QAPP, and associated subcontractor procedures/ manuals currently in place will cover the work activities required for conducting the WMA T groundwater quality investigation. Pacific Northwest National Laboratory administers the project for the Richland Operations Office of the U.S. Department of Energy, Environmental Restoration (ER) Branch.

### A.2.1 Groundwater Sampling and Analysis Procedures

**Sample Collection**. Groundwater sampling procedures, sample collection documentation, sample preservation and shipment, and chain-of-custody requirements are described in subcontractor operating procedures/manuals and in the GW-QAPP. Quality requirements for sampling activities, including requirements for procedures, containers, transport, storage, chain of custody, and records requirements, are specified in a statement of work to the performing subcontractor (Waste Management Technical Services, Inc.). To ensure that samples of known quality are obtained, the subcontractor is required to use contractor-controlled procedures based on standard methods for groundwater sampling whenever possible. Pacific Northwest National Laboratory will review these procedures for technical quality and consistency. In addition, periodic assessments will be performed by Pacific Northwest National Laboratory to further ensure that procedures are followed to maintain sample quality and integrity. A brief description of the sampling requirements is provided below.

Samples are generally collected after three casing volumes are withdrawn or after field parameters (pH, temperature, specific conductance, and turbidity) have stabilized. Field parameters are measured in a flow-through chamber. Generally, turbidities should be equal to or below 5 NTU (nephelometric turbidity units, 1 NTU = 1 mg/L of solids) prior to sample collection. The project scientist, depending on site-specific conditions and sampling objectives, however, could override this general requirement. For example, collection of water during drilling necessarily involves turbid, unfiltered water, which will be processed further in the laboratory. Thus, the 5 NTU requirement will be waived for these special water samples.

For routine groundwater samples, preservatives are added to the collection bottles in the laboratory prior to their use in the field. Duplicates, trip blanks, and field equipment blanks are collected as part of the general quality control program. The sampling and analysis methods and procedures and associated quality control results are described in more detail in Hartman et al. (2000).

**Analytical Procedures**. Procedures for field measurements (pH, specific conductance, temperature, and turbidity) are specified in the manufacturer's manual for each instrument used. The laboratory approved for the groundwater monitoring program will operate under the requirements of current

---

[(a)] The project quality assurance plan (ETD-012, Rev. 0) is available from Pacific Northwest National Laboratory, Richland, Washington.

| Hanford Groundwater Monitoring Project #28203 | | FY 2000 | | OUTYEAR | |
|---|---|---|---|---|---|
| TASK NO. | WMA T TASK TITLE | START | FINISH | START | FINISH |
| T-1 | **Well Drilling, Testing, and Sampling (see Figure A.2 for CY 2000 wells)** | 15-Jul-00 | → | | 31-Mar-01 |
| | Drill Downgradient Wells #2 and #4 | 15-Jul-00 | 30-Sep-00 | | |
| | Sampling During Drilling | | | | |
| | Hydraulic Tests (specific well(s) to be determined) | | | | |
| | Drill Downgradient Well #1 | 01-Sep-00 | → | | 31-Mar-01 |
| | Sampling During Drilling | | | | |
| | Hydraulic Tests (specific well(s) to be determined) | | | | |
| | Saturated Zone Depth Sampling | | | | |
| | Drill Downgradient Well #3 | | | 01-Oct-00 | 31-Mar-01 |
| | Sampling During Drilling | | | | |
| | Hydraulic Tests (specific well(s) to be determined) | | | | |
| | Drill Additional Outyear Wells (see Figure A.3 for CY 2001 wells) | | | 01-May-01 | 30-Sep-01 |
| | Near-Field New and/or Replacement Wells | | | | |
| | Mid-Field Plume Definition Wells | | | | |
| T-2 | **Transport/Spatial Modeling (e.g. MEMO) and Trend-Surface Analysis (FY00)** | 01-Jun-00 | 30-Sep-00 | | |
| | **Transport/Spatial Modeling (e.g. MEMO) and Trend-Surface Analysis (Outyear)** | | | 01-Oct-00 | 30-Sep-01 |
| T-3 | **Quarterly Groundwater Sampling and Analysis** | 01-Oct-99 | → | | 30-Sep-01 |
| | 1st Quarter Sampling and Analysis | 01-Oct-99 | 31-Dec-99 | | |
| | 2nd Quarter Sampling and Analysis | 01-Jan-00 | 31-Mar-00 | | |
| | 3rd Quarter Sampling and Analysis | 01-Apr-00 | 30-Jun-00 | | |
| | 4th Quarter Sampling and Analysis | 01-Jul-00 | 30-Sep-00 | | |
| | Outyear Quarterly Sampling and Analysis | | | 01-Oct-00 | 30-Sep-01 |
| T-4 | **Data Evaluation and Reporting** | 01-Oct-99 | → | | 30-Sep-01 |
| | Plume Fingerprinting | 01-Jun-00 | 30-Sep-00 | | |
| | Borehole Completion Data Package Report for Wells #1, #2, #3, #4 | | | 01-Jan-01 | 31-Mar-01 |
| | Quarterly Status Report to DOE/Ecology (FY00) | 01-Oct-99 | 30-Sep-00 | | |
| | Quarterly Status Report to DOE/Ecology (FY01) | | | 01-Oct-00 | 30-Sep-01 |
| | FY 1999 Annual Report | 01-Nov-99 | 29-Feb-00 | | |
| | FY 2000 Annual Report | | | 01-Nov-00 | 28-Feb-01 |
| | Assessment Results Documentation (FY00) | 01-Jun-00 | 30-Sep-00 | | |
| | Assessment Results Documentation (FY01) | | | 01-Oct-00 | 30-Sep-01 |
| T-5 | **Project Planning and Direction** | 01-Oct-99 | → | | 30-Sep-01 |
| | Assessment Plan | 15-Apr-00 | 30-Nov-00 | | |
| | Coordination of Groundwater/Vadose Zone Activities | 01-May-00 | → | | 30-Sep-01 |

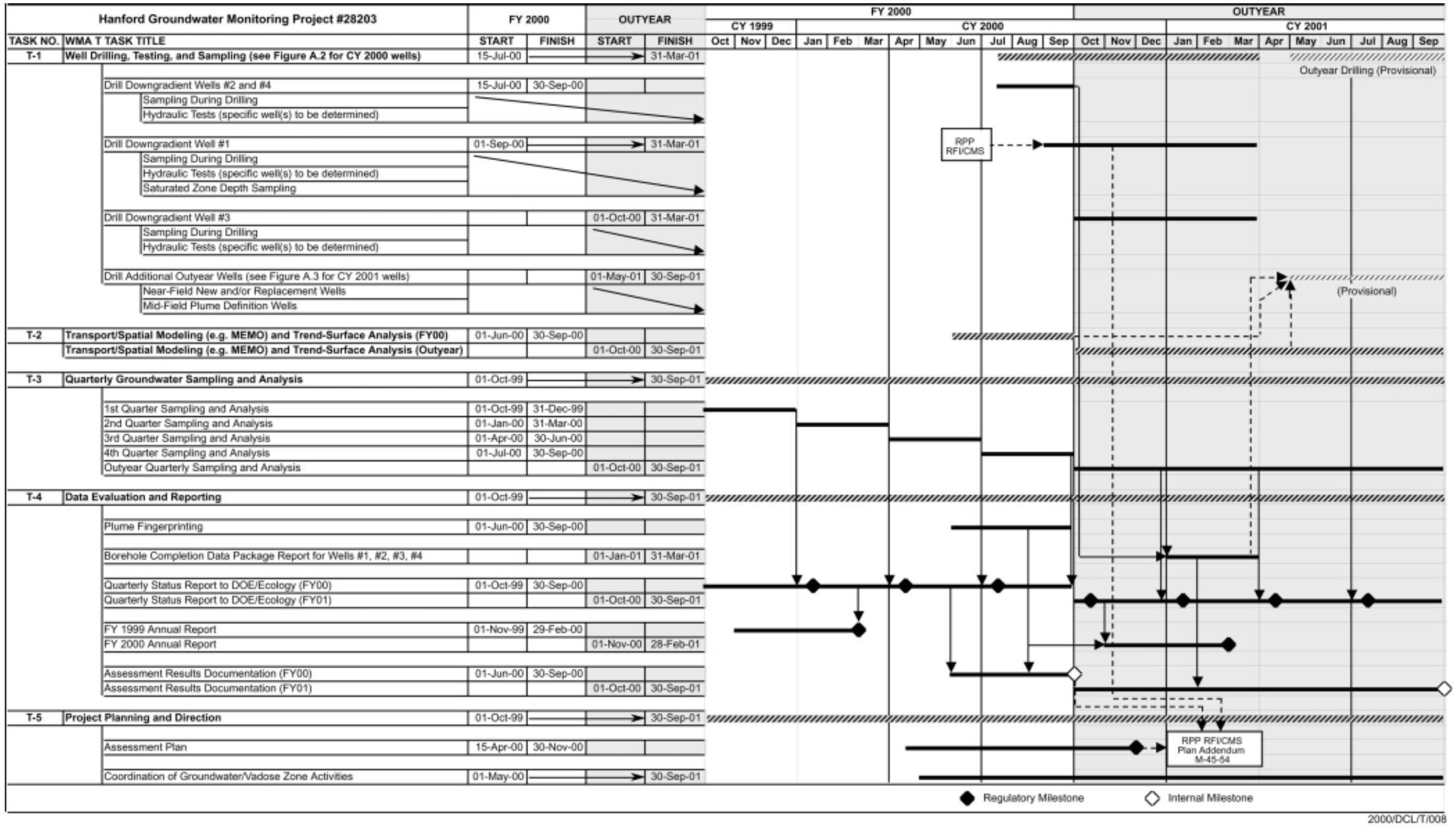



**Figure A.1**. Tasks and Schedule for Continuing Groundwater Assessment at Waste Management Area T

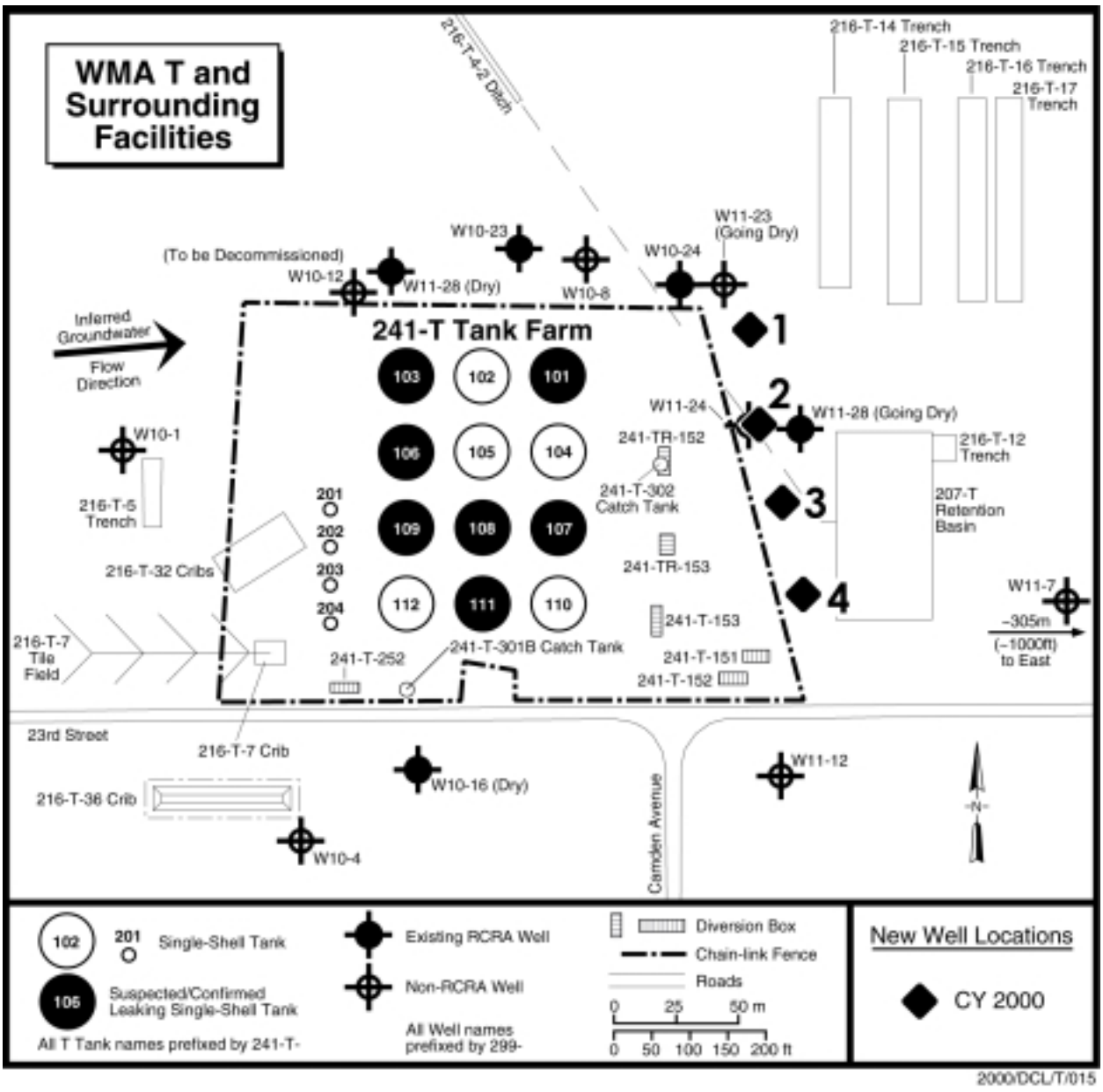



**Figure A.2**. Locations of Wells in Assessment Network for WMA T

laboratory contracts and will use standard laboratory procedures as listed in the SW-846 (EPA 1986) or an alternate equivalent. Alternative procedures, when used, will meet the guidelines of SW-846, Chapter 10. Analytical methods and quality control for the RCRA groundwater monitoring activities are described in the GW-QAPP.

**Data Storage and Retrieval**. All contract analytical laboratory results are submitted by the laboratory in electronic form and loaded in the Hanford Environmental Information Sys tem (HEIS) database. Parameters measured in the field either are entered into HEIS manually or through electronic transfer.

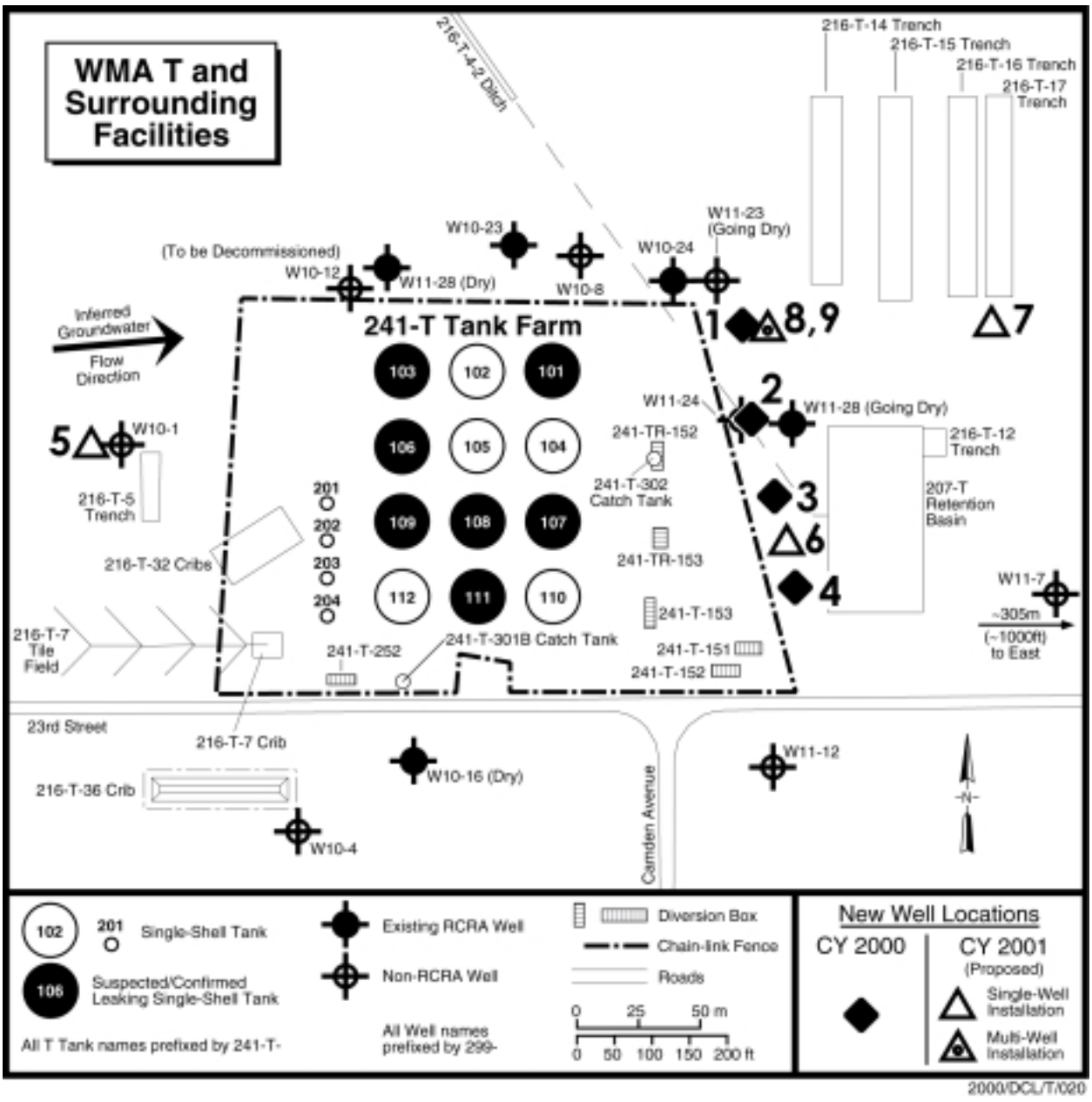



**Figure A.3**. Proposed New Well Locations for WMA T

Data from the HEIS database may be downloaded to smaller databases, for data validation, data reduction, and trend analysis. All field and laboratory hydrochemical results for this assessment will be entered in the publicly accessible HEIS database. Hard copy data reports and field records are considered to be the record copy of the data and are stored at Pacific Northwest National Laboratory.

### A.2.2 Hydrologic Testing

Hydraulic conductivity will be determined using slug test and tracer test procedures as specified in PNL-MA-567 ("Aquifer Testing," PNL 1999), or the most recent revision(s) or equivalent of this document. If procedures do not exist for particular tests, field instructions will be prepared prior to testing. Field data and other related information will be maintained in physical files at Pacific Northwest National Laboratory Groundwater Project Record files in Sigma V building. Hydraulic test results will be documented in a Pacific Northwest National Laboratory topical report and summarized in the assessment report for WMA T.

### A.2.3 Borehole Drilling and Testing

Bechtel Hanford, Inc, manages borehole drilling and well installation under their safety and related job control procedures. Data needs and objectives from this assessment plan are used as input to Bechtel Hanford, Inc. to write the detailed specifications for the drilling contracts. The drilling and sampling activities and requirements associated with installation of a new RCRA-compliant monitoring well to assess groundwater are specified in a Description of Work (DOW) submitted to BHI by PNNL. This document specifies the drilling and sampling requirements to meet the RCRA groundwater assessment project needs for WMA T, as identified in this plan. Additional requirements for special cosampling during drilling (e.g., coring) are submitted to BHI by the requesting sponsor or project.

### A.2.4 References

EPA. 1986. *Test Methods for Evaluating Solid Waste Physical/Chemical Methods, 3rd Ed*. EPA SW-846, U.S. Environmental Protection Agency, Washington, D.C.

PNL. 1999. *Procedures for Groundwater Investigations*. PNL-MA-567. Pacific Northwest National Laboratory, Richland, Washington.

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

Hartman M.J., L. F. Morasch, and W. D. Webber (eds.). 2000. *Hanford Site Groundwater Monitoring for Fiscal Year 1999*, PNNL-13116. Pacific Northwest National Laboratory, Richland, Washington.

# Appendix B

# Well Construction and Completion Summaries

0512638

# WELL CONSTRUCTION AND COMPLETION SUMMARY

| | | | |
|---|---|---|---|
| Drilling Method: | Air Rotary - TUBEX | Sample Method: | Grab/Split Spoon |
| Drilling Fluid Used: | Reverse Air | Additives Used: | None |
| Driller's Name: | Willie Franklin | WA State Lic Nr: | 1429 |
| Drilling Company: | Layne Christensen | Company Location: | Salt Lake City, Ut |
| Date Started: | 12Aug98 | Date Completed: | 19Aug98 |

WELL NUMBER: 299-W10-23 B8545 TEMPORARY WELL NO: Not Allowed

Coordinates: N Not documented

Coordinates: E Not documented

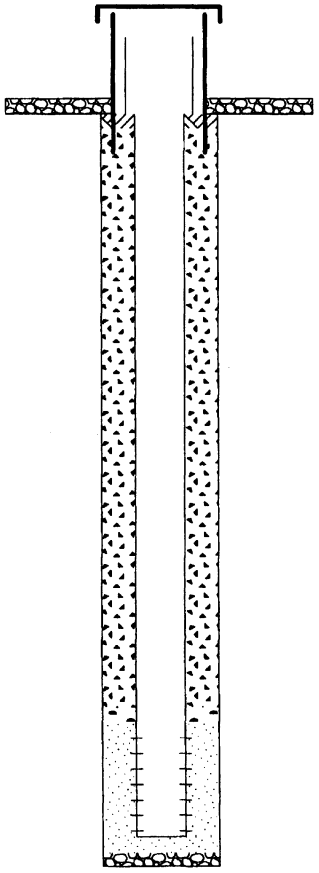
Start Card #: Not Available

Elevation Ground Surface: Brass Marker

Depth to Water: 223.61 ft 19Aug98
(Ground surface)

GENERALIZED STRATIGRAPHY Geologist's Log & Geophysical Logs

0 - 9 ft : Silty Sand
9 - 20 ft : Sandy gravel
20 - 34 ft : Sandy gravel
34 - 36 ft : Silty sand
36 - 43.5 ft : Sandy gravel
43.5 - 48 ft : Sand
48 - 52 ft : Gravelly sand
52 - 56 ft : Sand
56 - 75 ft : Gravelly sand
75 - 80 ft : Sand
80 - 106 ft : Silty sand - calcareous (98-99: Fine gravel; 101-106: Brittle caliche)
106 - 114 ft : Sand, calcareous
114 - 123 ft : Silty sand
123 - 131 ft : Thin beds cse sand & silty sand
131 - 149 ft : Silty sandy gravel
149 - 173 ft : Sandy gravel
173 - 198 ft : Silty sandy gravel
198 - 208 ft : Sandy gravel
208 - 256 ft : Silty sandy gravel
256 - 258 ft : Sand
258 - 272 ft : Silty sandy gravel



272 ft : Borehole drilled depth

0 - 272 ft : 9.125-in. 8-5/8" Temp. carbon steel csg.

Elevation of Reference Point: m

Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 5 ft.

Type of Surface Seal: 4x4 Concrete Pad

| *Fill* | *Casing* | *Screen* |
|---|---|---|
| 0 - 5 ft : 9.125-inch hole Cement Seal | 0 - 225.78 ft : 4 inch 4" SS Well Csg. | |
| 5 - 214.4 ft : 9.125-inch hole Medium Bentonite Chips | | |
| 214.4 - 220.3 ft : 9.125-inch hole 1/4" Bentonite Pellets | | 225.78 - 260.88 ft : 4 inch 4" .010 Slot Wire Wrap SS Screen |
| 220.3 - 260.88 ft : 9.125-inch hole 20-40 Mesh Silica Sand | 260.88 - 261.21 ft : 4 inch 4" SS End Cap | |
| 260.88 - 267 ft : 9.125-inch hole 20-40 Mesh Silica Sand | | |
| 267 - 272 ft : 9.125-inch hole | | |

| | |
|---|---|
| Drawing By: | TGB |
| Reference: | Hanford Wells |
| Revision: | 0 |
| Revision Date: | 21Sep98 |
| Print Date: | 03Nov99 |

Report Form: WELLS Project File: WELLS.GPJ

**SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS**
**RESOURCE PROTECTION WELL - 299-W10-23**

| | | |
|---|---|---|
| WELL DESIGNATION | : | **299-W10-23** |
| CERCLA UNIT | : | |
| RCRA FACILITY | : | **Groundwater Monitoring** |
| DEPTH DRILLED (GS) | : | **272.0 ft** |
| MEASURED DEPTH (GS) | : | **261.21 18Aug98** |
| AVAILABLE LOGS | : | **Geologist** |
| DATE EVALUATED | : | **Data not available** |
| EVAL RECOMMENDATION | : | **Data not available** |
| LISTED USE | : | **Groundwater Monitoring** |
| CURRENT USER | : | **Data not available** |
| PUMP TYPE | : | **Hydrostar** |
| MAINTENANCE | : | **Data not available** |
| COMMENTS | : | |
| TV SCAN COMMENTS | : | |

Report Form: WELLS Project File: WELLS.GPJ

| | |
|---|---|
| Drawing By: | TGB |
| Reference: | Hanford Wells |
| Revision: | 0 |
| Revision Date: | 21Sep98 |
| Print Date: | 03Nov99 |

0502369

# WELL CONSTRUCTION AND COMPLETION SUMMARY

| | | | |
|---|---|---|---|
| Drilling Method: | Air Rotary - TUBEX | Sample Method: | Grab/Split Spoon |
| Drilling Fluid Used: | Reverse Air | Additives Used: | None |
| Driller's Name: | Randy Wraspir | WA State Lic Nr: | Not Available |
| Drilling Company: | Layne Christensen | Company Location: | Salt Lake City, Ut |
| Date Started: | 07Oct98 | Date Completed: | 21Oct98 |

WELL NUMBER: 299-W10-24 B8546 TEMPORARY WELL NO: Not Allowed

Coordinates: N Not documented

Coordinates: E Not documented

Start Card #: Not Available

Elevation Ground Surface: Brass Marker

Depth to Water: 231.41 ft 21Oct98 (Ground surface)

Elevation of Reference Point: m

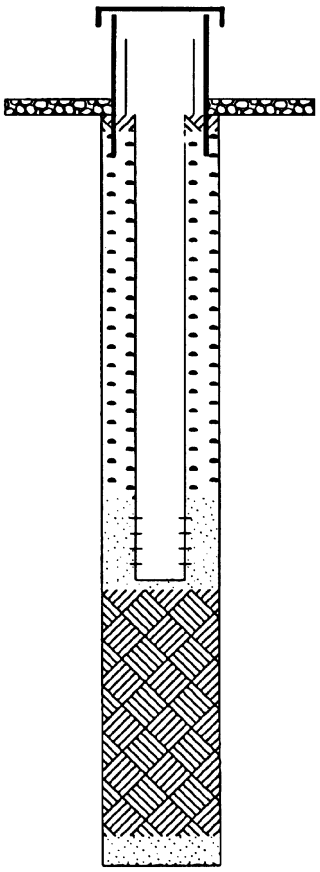
Height of Reference Point Above Ground Surface:

Depth of Surface Seal: 9.1 ft

Type of Surface Seal: 4x4 Concrete Pad

GENERALIZED STRATIGRAPHY — Geologist's Log & Geophysical Logs

0 - 2 ft : Backfill - cobbles, sand, & silt
2 - 5 ft : Silty Sandy Gravel (msG)
5 - 7 ft : Sasnd (s)
7 - 36 ft : Silty Sandy Gravel
36 - 39 ft : Gravelly Sand (gS)
39 - 42 ft : Sandy Gravel (aG)
42 - 59 ft : Sand
59 - 83.2 ft : Sandy Gravel
83.2 - 84 ft : Silty Sand (mS)
84 - 86 ft : Sand
86 - 98 ft : Silty Sand
98 - 108 ft : Caliche (calc. sand)
108 - 119 ft : Sand
119 - 128 ft : Sand
128 - 148 ft : Sandy Gravel
148 - 190 ft : Silty Sandy Gravel
190 - 228 ft : Silty Sandy Gravel
228 - 305 ft : Sandy Gravel
305 - 355 ft : Gravel (G)
355 - 409 ft : Sandy Gravel
409 - 413 ft : SiL. (M)
413 - 432.5 ft : Gravel (G)



| Fill | Casing | Screen |
|---|---|---|
| 0 - 9.1 ft : 9.125-inch hole Cement Surface Seal | 0 - 232.94 ft : 4 inch 4" Sch. 5 SS Csg. | |
| 9.1 - 218.5 ft : 9.125-inch hole Med. Bentonite Chunks | | |
| 218.5 - 221 ft : 9.125-inch hole 3/8" Bentonite Pellets (Pel Plug) | | 232.94 - 268.03 ft : 4 inch 4" SS Wire Wrap .010 Slot Screen |
| 221 - 260.2 ft : 9.125-inch hole 20/40 Silica Sand | 268.03 - 268.35 ft : 4 inch 4" SS End Cap | |
| 260.2 - 268.35 ft : 9.125-inch hole 10/20 and 8/16 Silica Sand | | |
| 268.35 - 274 ft : 9.125-inch hole 10/20 and 8/16 Silica Sand | | |
| 274 - 415.6 ft : 9.125-inch hole Cement Grout Seal | | |
| 415.6 - 431.5 ft : 9.125-inch hole 10/20 Silica Sand | | |
| 431.5 - 432.5 ft : 9.125-inch hole Slough | | |

432.5 ft : Borehole drilled depth

0 - 432.5 ft : 9.125-in. TUBEX w/8-5/8" Temp. carbon steel csg.

Drawing By: JEA
Reference: Hanford Wells
Revision: 0
Revision Date: 22Oct98
Print Date: 28Dec98

Report Form: WELLS Project File: WELLS.GPJ

**SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS**
**RESOURCE PROTECTION WELL - 299-W10-24**

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W10-24 |
| CERCLA UNIT | : | |
| RCRA FACILITY | : | |
| DEPTH DRILLED (GS) | : | 432.5 ft |
| MEASURED DEPTH (GS) | : | 268.35 21Oct98 |
| AVAILABLE LOGS | : | Geologist & Geophysical Logs |
| DATE EVALUATED | : | Data not available |
| EVAL RECOMMENDATION | : | Data not available |
| LISTED USE | : | RCRA Groundwater Monitoring |
| CURRENT USER | : | RCRA & Operations |
| PUMP TYPE | : | Hydrostar |
| MAINTENANCE | : | Data not available |
| COMMENTS | : | Air Rotary TUBEX w/Reverse Air drilled - 8-5/8" csg. to 432.5 ft. |
| TV SCAN COMMENTS | : | |

Report Form: WELL3 Project File: WELL3.GPJ

| | |
|---|---|
| Drawing By: | JEA |
| Reference: | Hanford Wells |
| Revision: | 0 |
| Revision Date: | 22Oct98 |
| Print Date: | 28Dec98 |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: Water
Driller's Name: Boner
Drilling Company: Not documented
Date Started: 18Jun47

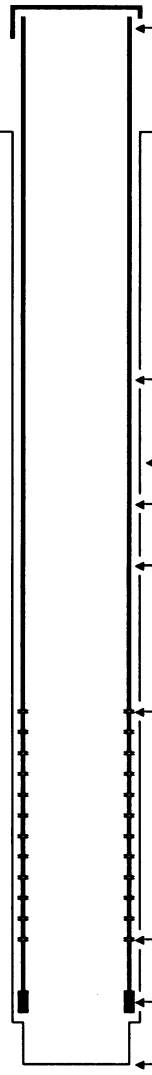
Sample Method: Hard tool nom
Additives Used: Not documented
WA State Lic Nr: Not documented
Company Location: Not documented
Date Complete: 07Aug47

WELL NUMBER: 299-W10-1 TEMPORARY WELL NO: 224-T-4
Hanford Coordinates: N/S N 43,550 E/W W 76,210
State Coordinates: N 448,656 E 2,219,003
Start Card #: Not documented T___ R___ S___
Elevation Ground surface (ft): 671.8 Estimated

Depth to water: Not documented
(Ground surface) 209.1-ft Apr92

GENERALIZED STRATIGRAPHY / Driller's Log

0↔5: All SAND
10: SAND & GRAVEL; 15,17,5: GRAVEL
20: Black SAND
25,30: GRAVEL
35,40: SAND & GRAVEL
45: GRAVEL, SAND & SILT
49: GRAVEL & SAND
50,52,55: Black SAND
57: SAND
60,62: SAND & GRAVEL
65: Coarse SAND and SILT
70,75: SAND & SILT
80↔105: SAND & CLAY
110: Coarse SAND & CLAY
112↔140: SAND, CLAY
142: GRAVEL & CLAY
145,150: GRAVEL
155: SAND & GRAVEL
160,163: GRAVEL
165,170: SAND and GRAVEL
180,185: SAND & GRAVEL
190: CLAY, SAND & GRAVEL
195: SAND & GRAVEL
200: SILT, SAND
205: SAND & GRAVEL
210: Coarse SAND, GRAVEL
215,220: SAND & GRAVEL
225↔255: CLAY, SAND, GRAVEL
260: SAND & GRAVEL
265↔270: CLAY, SAND, GRAVEL
275: SAND & GRAVEL
280: SAND
285: GRAVEL
290,293: SAND
295,297.5: SAND & GRAVEL
300: SILT, SAND & GRAVEL
303: SILT
305,306: SAND & GRAVEL



Elevation of reference point: [~677.00-ft] (top of casing)
Height of reference point above ground surface [5.2-ft]
Depth of surface seal [ND]
Type of surface seal: None documented
I.D. of surface casing [10-in nom] (None documented)
I.D. of riser pipe: [8-in]
Type of riser pipe: Carbon steel
Diameter of borehole: [9-in nom]
Type of filler: Not documented
Elevation/depth top of seal
Type of seal: Not documented
Depth top of perforations: [190-ft]
Description of perforations: Original not documented; 14↔15May48, not documented; 04Sep56, 190↔270-ft,3 holes/ft/rd
Depth bottom of perforations: [270-ft]
Depth bottom of casing [303-ft]
Depth bottom of borehole: [305-ft]

Drawing By: RKL/2W10-01.ASB Date: 16Apr93

Reference: HANFORD WELLS

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W10-1

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W10-1 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Not applicable |
| HANFORD COORDINATES | : | N 43,550.5 W 76,210.1 [200W-11Sep90] |
| LAMBERT COORDINATES | : | N 448,656 E 2,219,003 [HANCONV] |
| DATE DRILLED | : | Aug47 |
| DEPTH DRILLED (GS) | : | 305-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | Not documented;<br>209.1-ft, 01Apr92 |
| CASING DIAMETER | : | 8-in carbon steel, +5.2↔303-ft; |
| ELEV TOP CASING | : | 672.01-ft, [200W-11Sep90] (~677.0-ft by 5-ft extension) |
| ELEV GROUND SURFACE | : | 671.8-ft, Estimated |
| PERFORATED INTERVAL | : | 8-in casing, 190↔270-ft |
| SCREENED INTERVAL | : | Not applicable |
| COMMENTS | : | FIELD INSPECTION, 01Apr92<br>8-in carbon steel casing. Extended to 5.2-ft stickup.<br>No pad, No posts, capped, not locked.<br>No permanent identification.<br>OTHER: |
| AVAILABLE LOGS | : | Driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | Water Levels 30Dec48↔04Jan91<br>PNL Annual, WHC Quarterly water samples |
| PUMP TYPE | : | None documented |
| MAINTENANCE | : | 16Jan92 - Extended casing 5-ft, lock & hasp installed. |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: Water
Driller's Name: Gentz
Drilling Company: Not documented
Date Started: 14Oct52
Date Complete: 10Nov52

Sample Method: Hard tool nom
Additives Used: Not documented
WA State Lic Nr: Not documented
Company Location: Not documented

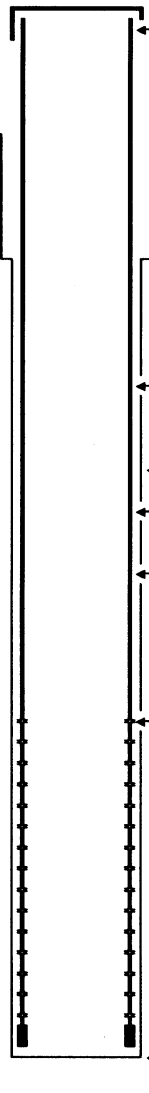
WELL NUMBER: 299-W10-4
TEMPORARY WELL NO: 241-T-16
Hanford Coordinates: N/S N 43,036.3 E/W W 75,976.7
State NAD83 N 136,578.25m E 556,734.98m
Coordinates: N 448,143 E 2,219,247
Start Card #: Not documented T___ R___ S___
Elevation Ground surface (ft): 669.78 Brass cap

Depth to water: 200-ft Sep56
(Ground surface) 206.6-ft Jan92

GENERALIZED STRATIGRAPHY / Driller's Log

0-10: SAND, SILT and GRAVEL
10-20: Pure GRAVEL, caves easy
20-29: Coarse GRAVEL
29-35 BOULDERS and GRAVEL
35-47: Coarse GRAVEL
47-54: GRAVEL
54-65: GRAVEL, SAND and SILT
65-70: SAND and SILT
70-88: SAND and a little SILT
88-90: Pure SAND, caved
90-100: SAND, SILT and CLAY
100-110: CALICHE, SAND and SILT
110-115: SAND and SILT
115-125: SAND, SILT and CLAY
125-131: SAND and SILT
131-132: Pure SAND, caves easy
132-135: Coarse GRAVEL
135-140: BOULDERS and GRAVEL
140-150: GRAVEL and SAND
150-159: SAND and GRAVEL
159-165: Coarse GRAVEL and SAND
165-175: GRAVEL and BOULDERS
175-180: GRAVEL and SAND
180-190: Coarse GRAVEL with a little SAND and SILT
190-205: GRAVEL, SAND and SILT
205-225: SAND, SILT, and GRAVEL
225-230: Coarse GRAVEL, SAND and SILT
230-235: Coarse SAND
235-240: Pea GRAVEL
240-245: GRAVEL

REMEDIATION; 04-05Sep56
Wall-Richards
Perforated 190-200-ft
Well was "hot." Required
RM coverage



Elevation of reference point: [670.67-ft] (top of casing)
Height of reference point above ground surface [0.89-ft]
Depth of surface seal [ND]
Type of surface seal: None documented
I.D. of surface casing [10-in nom] (21.5-ft starter pipe assumed pulled)
I.D. of riser pipe: [8-in]
Type of riser pipe: Carbon steel
Diameter of borehole: [9-in nom]
Type of filler: Not documented
Elevation/depth top of seal
Type of seal: Not documented
Depth top of perforations: [190-ft]
Description of perforations: 190-200-ft, 3 holes/ft/rd; 200-245-ft, not documented
Depth bottom of perforations:
Depth bottom of casing: [245-ft]
Depth bottom of borehole:

Drawing By: RKL/2W10-04.ASB Date: 16Apr93

Reference: HANFORD WELLS

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W10-4

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W10-4 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Not applicable |
| HANFORD COORDINATES | : | N 43,036.3 W 75,976.7 [200W-11Sep90] |
| LAMBERT COORDINATES | : | N 448,143 E 2,219,247 [HANCONV] |
| | | N 136,578.25m E 566,734.98m [NAD83-11Sep90] |
| DATE DRILLED | : | Nov52 |
| DEPTH DRILLED (GS) | : | 245-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 200-ft, Sep56; |
| | | 206.6-ft, Jan92 |
| CASING DIAMETER | : | 8-in carbon steel, +0.89-245-ft; |
| ELEV TOP CASING | : | 670.67-ft [200W-11Sep90] |
| ELEV GROUND SURFACE | : | 669.78-ft, Brass cap [200W-11Sep90] |
| PERFORATED INTERVAL | : | 8-in casing, 190-245-ft |
| SCREENED INTERVAL | : | Not applicable |
| COMMENTS | : | FIELD INSPECTION, 21Jan92, |
| | | 8-in carbon steel casing. |
| | | 2-ft pad, No posts, capped and locked. |
| | | Brass cap w/identification in pad. |
| | | Not in radiation zone. |
| | | OTHER: |
| AVAILABLE LOGS | : | Driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | Water Levels 17Dec52-02Jan91 |
| | | PNL Annual, Semiannual, WHC Semiannual water sample schedule |
| PUMP TYPE | : | Electric submersible |
| MAINTENANCE | : | |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: Water
Driller's Name: Evans/Bigham
Drilling Company: Hatch
Date Started: 14Jun73

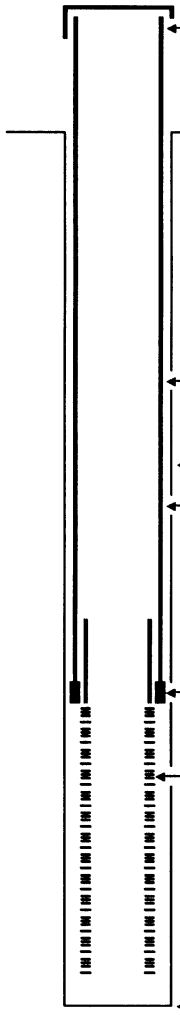
Sample Method: Hard tool (nom)
Additives Used: Not documented
WA State Lic Nr: Bigham-0036
Company Location: Pasco, WA
Date Complete: 27Jun73

WELL NUMBER: 299-W10-8
TEMPORARY WELL NO: 2997
Hanford Coordinates: N/S N 43,800.2 E/W W 75,600.1
State NAD83 N 136,811.3m 566,849.2m
Coordinates: N 448,908 E 2,219,613
Start Card #: Not documented T___ R___ S___
Elevation Ground surface (ft): 677.2 Estimated

Depth to water: 214 ft Jun73
(Ground surface) 215.5-ft 26Mar93

GENERALIZED STRATIGRAPHY / Geologist's Log

0↔5: Gravelly, silty SAND
5↔49: Gravelly, sandy SILT
49↔60: Silty, gravelly SAND
60↔65: Sandy GRAVEL
65↔80: Silty SAND
80↔83: Clayey, sandy SILT
83↔85: SAND
85↔95: Clayey, sandy SILT
95↔125: Sandy CALICHE
125↔138: Sandy SILT
138↔148: Sandy, silty GRAVEL
148↔168: Silty, sandy CLAY
168↔175: Sandy, gravelly SILT
168↔185: Silty, sandy GRAVEL
185↔235: Silty, gravelly SAND
235↔240: Silty SAND
240↔252: Very silty SAND



Elevation of reference point: [680.05-ft] (top of casing)
Height of reference point above ground surface [2.83-ft]
Depth of surface seal [ND]
Type of surface seal: None documented
I.D. of surface casing (If present) [ND]
I.D. of riser pipe: [6-in]
Type of riser pipe: Carbon steel
Diameter of borehole: [7-in nom]
Type of filler: Not documented
Depth bottom of casing: [210-ft] Casing pulled back from total depth
Screen 40-ft of #10 slot from 205↔251-ft, screened interval assumed 211↔251-ft
Depth bottom of borehole [252-ft]

Drawing By: RKL/2W10-08.ASB Date: 16Apr93

Reference: HANFORD WELLS

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W10-8

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W10-8 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Single Shell Tanks |
| HANFORD COORDINATES | : | N 43,800.2 W 75,600.1 [200W-11Sep90] |
| LAMBERT COORDINATES | : | N 448,908 E 2,219,613 [HANCONV] |
| | | N 136,811.3m E 566,849.2m [NAD83-11Sep90] |
| DATE DRILLED | : | Jun73 |
| DEPTH DRILLED (GS) | : | 252.0-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 214-ft, Jun73;<br>215.5-ft, 26Mar93 |
| CASING DIAMETER | : | 6-in carbon steel, +2.83↔210-ft,<br>(Pulled back from total depth) |
| ELEV TOP CASING | : | 680.05-ft, [200W-11Sep90] |
| ELEV GROUND SURFACE | : | 677.2-ft, Estimated |
| PERFORATED INTERVAL | : | Not applicable |
| SCREENED INTERVAL | : | 211↔251-ft telescoping |
| COMMENTS | : | FIELD INSPECTION, 09Feb90,<br>6-in carbon steel casing.<br>No pad, no posts, capped not locked.<br>No permanent identification.<br>In radiation zone.<br>OTHER: |
| AVAILABLE LOGS | : | Driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | SST Monthly water level measurement, 15Jul74↔26Mar93;<br>PNL Annual, Semiannual, WHC Semiannual water sample schedule |
| PUMP TYPE | : | Electric submersible |
| MAINTENANCE | : | |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

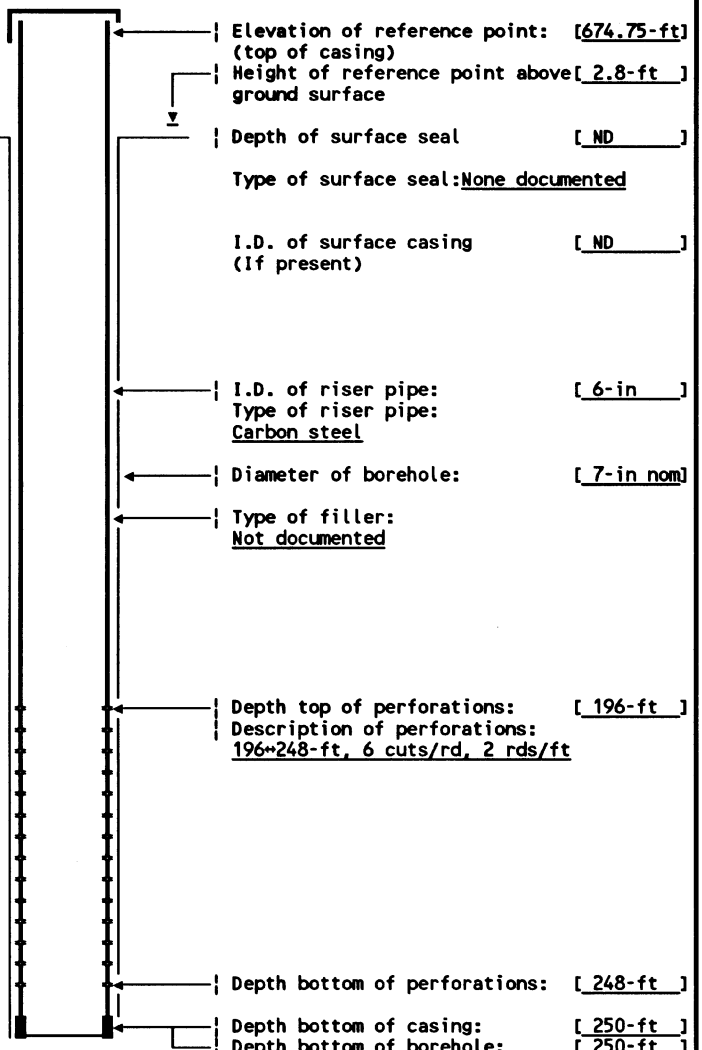
Drilling Method: Cable tool
Drilling Fluid Used: Water
Driller's Name: Evans
Drilling Company: Not documented
Date Started: 28Jan74
Sample Method: Hard tool (nom)
Additives Used: Not documented
WA State Lic Nr: Not documented
Company Location: Not documented
Date Complete: 14Jun74

WELL NUMBER: 299-W10-12
TEMPORARY WELL NO:
Hanford Coordinates: N/S N 43,756.2 E/W W 75,906.3
State NAD83 136,797.67m 566,755.90m
Coordinates: N 448,863 E 2,219,307
Start Card #: Not documented T___ R___ S___
Elevation Ground surface (ft): 672.0 Estimated

Depth to water: 206-ft Jun74
(Ground surface) 210.2-ft 26Mar93

GENERALIZED STRATIGRAPHY — Driller's Log

0↔18: SAND, PEBBLES and COBBLES
18↔82: SAND, COBBLES, PEBBLES, SILT
82↔90: SAND and SILT
90↔113: CALICHE
113↔135: SILT
135↔165: SAND, COBBLES, PEBBLES, SILT
165↔170: No record
170↔220: SAND, GRAVEL and SILT
220↔240: Ringold (SAND, GRAVEL and SILT)
240↔250: SAND, COBBLES, PEBBLES and SILT




Drawing By: RKL/2W10-12.ASB Date: 16Apr93

Reference: HANFORD WELLS

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W10-12

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W10-12 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Single Shell Tanks |
| HANFORD COORDINATES | : | N 43,756.2 W 75,906.3 [200W-11Sep90] |
| LAMBERT COORDINATES | : | N 448,863 E 2,219,307 [HANCONV] |
| | | N 136,797.67m E 566,755.90m [NAD83-11Sep90] |
| DATE DRILLED | : | Jun74 |
| DEPTH DRILLED (GS) | : | 250-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 206-ft, Jun74; |
| | | 210.0-ft, 26Mar93 |
| CASING DIAMETER | : | 6-in carbon steel, +2.8-250-ft; |
| ELEV TOP CASING | : | 675.00-ft, [200W-11Sep90] |
| ELEV GROUND SURFACE | : | 672.0-ft, Estimated |
| PERFORATED INTERVAL | : | 6-in casing, 196-248-ft |
| SCREENED INTERVAL | : | Not applicable |
| COMMENTS | : | FIELD INSPECTION, 01Feb90, |
| | | 6-in carbon steel casing. Capped, not locked |
| | | No pad, posts or permanent identification. |
| | | Not in radiation zone. |
| | | OTHER: |
| AVAILABLE LOGS | : | Driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | SST Monthly water level measurement, 11Apr90-26Mar93; |
| | | Not on water sample schedule |
| PUMP TYPE | : | None |
| MAINTENANCE | : | |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

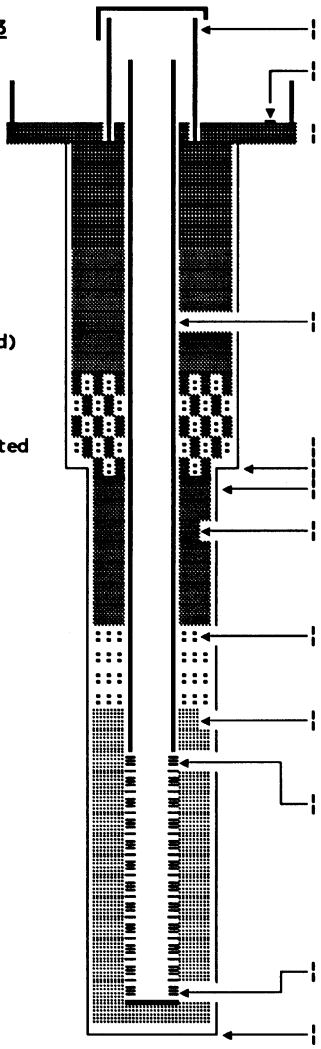
| | |
|---|---|
| Drilling Method: Cable tool | Sample Method: Hard tool |
| Drilling Fluid Used: 200 W Water Supply | Additives Used: Not documented |
| Driller's Name: C. Walmsley | WA State Lic Nr: Not documented |
| Drilling Company: Kaiser Engineers | Company Location: Hanford |
| Date Started: 20Sep89 | Date Complete: 07Nov89 |

| | |
|---|---|
| WELL NUMBER: 299-W10-15 | TEMPORARY WELL NO: None |
| Hanford Coordinates: N/S N 43,790.7 | E/W W 75,857.5 |
| State NAD83 N 136,808.33m | E 566,770.69m |
| Coordinates: N 448,898 | E 2,219,355 |
| Start Card #: Not documented | T___ R___ S___ |
| Elevation Ground surface (ft): 672.45 (Brass cap) | |

Depth to water: 206.2-ft Nov89
(Ground surface)210.6-ft 26Mar93

GENERALIZED Geologist's STRATIGRAPHY Log
Sl=slightly

0↔10: Muddy SAND
10↔15: Sl gravelly sl muddy SAND
15↔25: Sandy GRAVEL
25↔30: SAND with MUD layers
35↔40: Sandy GRAVEL
40↔45: GRAVEL
45↔50: Muddy sandy GRAVEL
50↔60: Sandy GRAVEL
60↔73: Gravelly SAND
73↔75: Muddy fine SAND (laminated)
75↔80: Gravelly SAND
80↔93: Muddy SAND (calcareous)
93↔94: CALICHE
94↔96: Muddy SAND
96↔132: CALICHE-calcareous cemented muddy SAND
132↔180: Muddy sandy GRAVEL
180↔185: Sandy GRAVEL
185↔190: Gravelly SAND
190↔222.3: Sandy GRAVEL



Elevation of reference point: [675.64-ft]
(top of casing)
Height of reference point above ground surface [ 3.19-ft ]
Depth of surface seal [2.0↔19.6-ft]

Type of surface seal:Pre-mix concrete
4x4-ft x 6-in surface pad to 2.4-ft
4 equidistant protective posts
Cement grout, 2.0↔19.6-ft

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

Diameter of borehole,
0↔140.0-ft, 11-in nominal
140.0↔222.3-ft, 9-in nominal

Type of filler, 19.6↔72.3 & 140.8↔193.3-ft
8↔20 mesh bentonite crumbles
72.3↔140.8-ft
Volclay Pure Gold slurry

Depth top of seal: [ 193.3-ft]
Type of seal:
5/8-in Volclay pellets

Depth top of sand pack: [ 197.1-ft]
20↔40-mesh silica sand

Depth top of screen: [ 201.0-ft]
4-in, #10-slot, stainless steel
with channel pack

Depth bottom of screen [ 222.0-ft]

Depth to bottom of borehole: [ 222.3-ft]

Drawing By: RKL/2W10-15.ASB Date: 16Apr93

Reference: WHC-MR-0209

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W10-15

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W10-15 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Single Shell Tanks |
| HANFORD COORDINATES | : | N 43,790.7 W 75,857.5 [200W-12Jan90] |
| LAMBERT COORDINATES | : | N 448,898 E 2,219,355 [HANCONV] |
| | | N 136,808.33m E 566,770.69m [NAD83-12Jan90] |
| DATE DRILLED | : | Nov89 |
| DEPTH DRILLED (GS) | : | 222.3-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 206.2-ft, Nov90; |
| | | 210.6-ft, 26Mar93 |
| CASING DIAMETER | : | 4-in stainless steel, ~+1.0↔201.0-ft; |
| | | 6-in stainless steel, +3.19↔~0.5-ft |
| ELEV TOP CASING | : | 675.64-ft, [200W-12Jan90] |
| ELEV GROUND SURFACE | : | 672.45-ft, Brass cap [200W-12Jan90] |
| PERFORATED INTERVAL | : | Not applicable |
| SCREENED INTERVAL | : | 201.0↔222.0-ft, 4-in #10-slot stainless steel, with channel pack |
| COMMENTS | : | FIELD INSPECTION, 02Feb90; |
| | | 6-in stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable capped and locked, brass cap in pad with well ID. |
| | | Not in radiation zone. |
| | | OTHER: |
| AVAILABLE LOGS | : | Geologist, driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | SST Monthly water level measurement, 01Dec89↔26Mar93; |
| | | Not on water sample schedule |
| PUMP TYPE | : | Hydrostar |
| MAINTENANCE | : | |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: 200 W Water Supply
Driller's Name: D. Garcia/G. Lydin
Drilling Company: Kaiser Engineers
Date Started: 07Sep89
Date Complete: 25Oct89

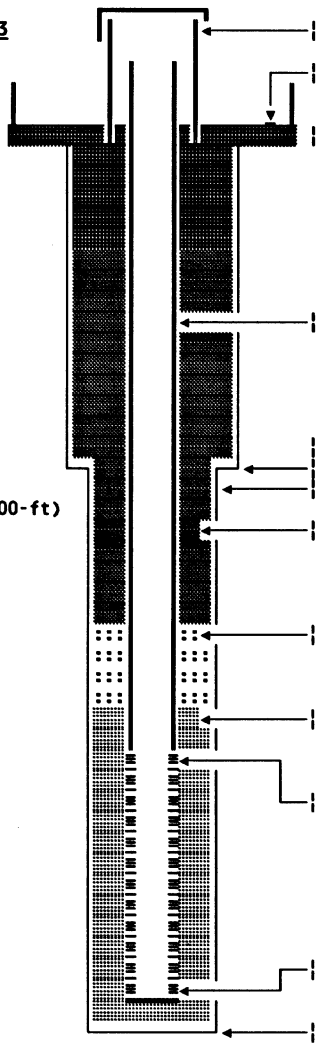
Sample Method: Drive barrel Hard tool
Additives Used: Not documented
WA State Lic Nr: Not documented
Company Location: Hanford

WELL NUMBER: 299-W10-16
TEMPORARY WELL NO: None
Hanford Coordinates: N/S N 43,129.6 E/W W 75,824.6
State NAD83 N 136,606.86m E 566,781.22m
Coordinates: N 448,237 E 2,219,390
Start Card #: Not documented T___ R___ S___
Elevation Ground surface (ft): 669.76 (Brass cap)

Depth to water: 202.9-ft Oct89
(Ground surface)207.5-ft 26Mar93

GENERALIZED Geologist's STRATIGRAPHY Log
Sl=slightly

0↔10: SAND
10↔15: Muddy SAND
15↔20: Muddy sandy GRAVEL
20↔25: GRAVEL
25↔30: Muddy sandy GRAVEL
30↔50: GRAVEL
50↔55: Muddy sandy GRAVEL
55↔60: Sl gravelly SAND
60↔65: Gravelly muddy SAND
65↔70: Sl gravelly SAND
70↔80: SAND
80↔85: Sl gravelly SAND
85↔90: Muddy SAND
90↔95: Sandy MUD (Buried soil?)
95↔100: Sl gravelly muddy SAND w/CALICHE
100↔110: Gravelly muddy SAND (15ppm VOC in spoils @ 100-ft)
110↔125: Sandy MUD
125↔130: Sl muddy SAND
130↔135: Sandy GRAVEL
135↔140: Muddy sandy GRAVEL
140↔145: Sandy GRAVEL
145↔160: Muddy sandy GRAVEL
160↔170: Sandy GRAVEL
170↔175: Muddy sandy GRAVEL
175↔190: Sandy GRAVEL
190↔200: Muddy sandy GRAVEL
200↔219.8: Sandy GRAVEL



Elevation of reference point: [672.76-ft] (top of casing)
Height of reference point above ground surface [3.0-ft]
Depth of surface seal [2.1↔18.1-ft]
Type of surface seal: Pre-mix concrete
4x4-ft x 6-in surface pad to 2.4-ft
4 equidistant protective posts
Cement grout, 2.1↔18.1-ft
I.D. of riser pipe: [4-in]
Type of riser pipe:
Stainless steel
Diameter of borehole,
0↔132.9-ft, 11-in nominal
132.9↔219.8-ft, 9-in nominal
Type of filler, 18.1↔191.4-ft
8↔20 mesh bentonite crumbles
Depth top of seal: [191.4-ft]
Type of seal:
3/8-in Volclay pellets
Depth top of sand pack: [195.4-ft]
20↔40-mesh silica sand
Depth top of screen: [198.3-ft]
4-in, #10-slot, stainless steel
with channel pack
Depth bottom of screen [219.3-ft]
Depth to bottom of borehole: [219.8-ft]

Drawing By: RKL/2W10-16.ASB Date: 16Apr93

Reference: WHC-MR-0209

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W10-16

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W10-16 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Single Shell Tanks |
| HANFORD COORDINATES | : | N 43,129.6 W 75,824.6 [200W-12Jan90 |
| LAMBERT COORDINATES | : | N 448,237 E 2,219,390 [HANCONV] |
| | | N 136,606.86m E 566,781.22m [NAD83-12Jan90] |
| DATE DRILLED | : | Oct89 |
| DEPTH DRILLED (GS) | : | 219.8-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 202.9-ft, Oct90; |
| | | 207.5-ft, 26Mar93 |
| CASING DIAMETER | : | 4-in stainless steel, ~+1.6↔201.0-ft; |
| | | 6-in stainless steel, +3.0↔~0.5-ft |
| ELEV TOP CASING | : | 672.76-ft, [200W-12Jan90] |
| ELEV GROUND SURFACE | : | 669.76-ft, Brass cap [200W-12Jan90] |
| PERFORATED INTERVAL | : | Not applicable |
| SCREENED INTERVAL | : | 198.3↔219.3-ft, 4-in #10-slot stainless steel, with channel pack |
| COMMENTS | : | FIELD INSPECTION, 02Feb90 |
| | | 6-in stainless steel casing. 4-ft by 4-ft concrete pad, 4 posts, 1 removable capped and locked, brass cap in pad with well ID. |
| | | Not in radiation zone. |
| | | OTHER: |
| AVAILABLE LOGS | : | Geologist, driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | SST Monthly water level measurement, 01Dec89↔26Mar93; |
| | | Not on water sample schedule |
| PUMP TYPE | : | Hydrostar |
| MAINTENANCE | : | |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: Water
Driller's Name: Row
Drilling Company: Not documented
Date Started: 23Jul51

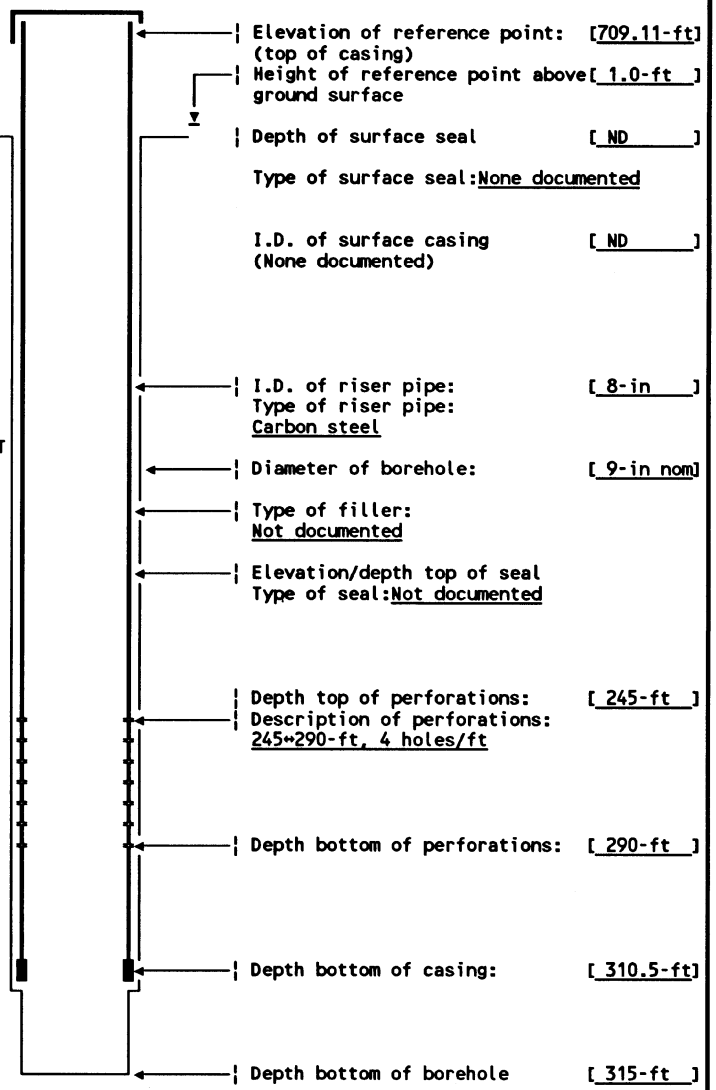
Sample Method: Hard tool nom
Additives Used: Not documented
WA State Lic Nr: Not documented
Company Location: Not documented
Date Complete: 17Sep51

WELL NUMBER: 299-W11-7
TEMPORARY WELL NO: 361-T-19
Hanford Coordinates: N/S N 43,350 E/W W 74,251
State Coordinates: N 448,461 E 2,220,963
Start Card #: Not documented T___ R___ S___
Elevation Ground surface (ft): 708.1 Estimated

Depth to water: 267-ft Sep51
(Ground surface) 247.4-ft 08Dec92

GENERALIZED STRATIGRAPHY / Driller's Log

0↔6: GRAVEL and TOPSOIL
6↔9: BOULDER (4-ft thick)
9↔15: GRAVEL, black SAND
15↔33: SAND and GRAVEL, no SILT
33↔58: GRAVEL and black and white SAND layers of SILT
58↔70: SAND
70↔75: SAND and a showing of SILT
75↔85: SAND and more SILT
85↔105: SAND and fine GRAVEL, very little SILT
105↔130: Heavy SILT bed
130↔139: Heavy CALICHE bed with fine GRAVEL and SAND
139↔145: GRAVEL, SAND & very little SILT
145↔153: SAND and very little SILT
153↔160: Sandy SILT
160↔165: GRAVEL and SILT
165↔178: Pure GRAVEL, no SILT
178↔182: Pure fine basalt SAND & GRAVEL
182↔187: SAND and GRAVEL, some binder
187↔195: GRAVEL, SAND and some binder
195↔197: GRAVEL and SAND, caves
197↔207: GRAVEL, SAND and some SILT
207↔218: GRAVEL, SAND and some binder
218↔254: GRAVEL, SAND and SILT
254↔259: GRAVEL and SAND, no SILT
259↔260: Coarse GRAVEL
260↔277: GRAVEL, SAND and SILT (Hit water at 260-ft, rose to 251-ft, possible perched)
277↔280: SAND, caves
280↔284: GRAVEL, SAND and SILT
284↔286: GRAVEL, caves
286↔295: GRAVEL, SAND and SILT
295↔297: White SAND
297↔310: White Sand, GRAVEL and SILT
310↔315: GRAVEL, SAND and SILT
315 : Good water GRAVEL



Elevation of reference point: [709.11-ft] (top of casing)
Height of reference point above ground surface [1.0-ft]
Depth of surface seal [ND]
Type of surface seal: None documented
I.D. of surface casing [ND] (None documented)
I.D. of riser pipe: [8-in]
Type of riser pipe: Carbon steel
Diameter of borehole: [9-in nom]
Type of filler: Not documented
Elevation/depth top of seal
Type of seal: Not documented
Depth top of perforations: [245-ft]
Description of perforations: 245↔290-ft, 4 holes/ft
Depth bottom of perforations: [290-ft]
Depth bottom of casing: [310.5-ft]
Depth bottom of borehole [315-ft]

Drawing By: RKL/2W11-07.ASB Date: 16Apr93

Reference: HANFORD WELLS

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W11-7

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W11-7 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Not applicable |
| HANFORD COORDINATES | : | N 43,350 W 74,251 |
| LAMBERT COORDINATES | : | N 448,461 E 2,220,963 |
| DATE DRILLED | : | Sep51 |
| DEPTH DRILLED (GS) | : | 315-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 267-ft, Sep51;<br>247.4-ft, 08Dec92 |
| CASING DIAMETER | : | 8-in carbon steel, +1.0↔310.5-ft; |
| ELEV TOP CASING | : | 709.11-ft |
| ELEV GROUND SURFACE | : | 708.1-ft, Estimated |
| PERFORATED INTERVAL | : | 8-in casing, 245↔290-ft |
| SCREENED INTERVAL | : | Not applicable |
| COMMENTS | : | FIELD INSPECTION, 13May91,<br>8-in carbon steel casing.<br>No pad, No posts, capped and locked.<br>No permanent identification.<br>In radiation zone.<br>OTHER: |
| AVAILABLE LOGS | : | Driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | Separations area Semiannual water level measurement, 14Sep51↔08Dec92<br>PNL Semiannual, WHC Quarterly water sample schedule |
| PUMP TYPE | : | None documented |
| MAINTENANCE | : | |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: Not documented
Driller's Name: Gentz
Drilling Company: Not documented
Date Started: 02Feb53

Sample Method: Hard tool (nom)
Drilling Additives Used: Not documented
WA State Lic Nr: Not documented
Company Location: Not documented
Date Complete: 21Dec53

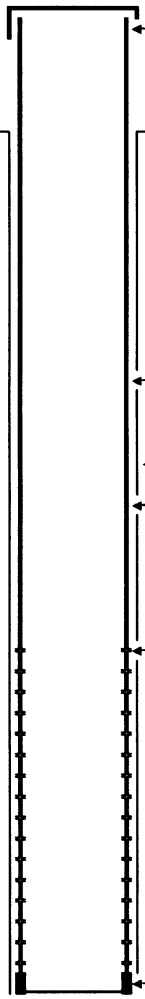
WELL NUMBER: 299-W11-12
TEMPORARY WELL NO: 241-T-18
Hanford Coordinates: N/S N 43,119.3 E/W W 75,345.9
State NAD83 N 136,604.01m E 566,927.14m
Coordinates: N 448,206 E 2,219,875
Start Card #: Not documented T___ R___ S___
Elevation Ground surface (ft): 678.5 Estimated

Depth to water: 210-ft Sep56
(Ground surface) 216.6-ft 04Dec92

GENERALIZED STRATIGRAPHY — Driller's Log

0↔8: Fine SAND
8↔30: Coarse GRAVEL and fine SAND
30↔45: Fine SAND
45↔55: Fine and coarse SAND
55↔70: Fine SAND
70↔80: Fine and coarse SAND
80↔95: Fine and coarse SAND, little SILT
95↔103: SAND and SILT
103↔127: SAND and SILT, CALICHE and GRAVEL
127↔135: GRAVEAL, COBBLES, SAND
135↔145: BOULDERS and GRAVEL, little SAND
145↔185: COBBLES and GRAVEL with some SAND
185↔195: GRAVEL and SAND
195↔200: GRAVEL, little SILT
200↔245: GRAVEL, SAND and SILT
245 : GRAVEL and SAND
245↔250: Not documented

REMEDIATION: Sep56, by Wall/Richards
Cleaned out and perforated 200↔210-ft.



Elevation of reference point: [679.26-ft] (top of casing)
Height of reference point above ground surface [0.8-ft]
Depth of surface seal [ND]
Type of surface seal: None documented
I.D. of surface casing (If present) [ND]
I.D. of riser pipe: [8-in]
Type of riser pipe: Carbon steel
Diameter of borehole: [9-in nom]
Type of filler: Not documented
Depth top of perforations: [200-ft]
Description of perforations:
200↔210-ft, not documented
210↔250-ft, not documented
Depth bottom of perforations: [250-ft]
Depth bottom of casing: [250-ft]
Depth bottom of borehole: [250-ft]

Drawing By: RKL/2W11-12.ASB Date: 16Apr93
Reference: HANFORD WELLS

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W11-12

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W11-12 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Not applicable |
| HANFORD COORDINATES | : | N 43,119.3 W 75,345.9 [200W-11Sep90] |
| LAMBERT COORDINATES | : | N 448,206 E 2,219,875 [HANCONV] |
| | | N 136,604.01m E 566,927.14m [NAD83-11Sep90] |
| DATE DRILLED | : | Dec53 |
| DEPTH DRILLED (GS) | : | 250-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 210-ft, Sep56; |
| | | 216.6-ft, 004Dec92 |
| CASING DIAMETER | : | 8-in carbon steel, +0.8↔250-ft; |
| ELEV TOP CASING | : | 679.26-ft, [200W-11Sep90] |
| ELEV GROUND SURFACE | : | 678.5-ft, Estimated |
| PERFORATED INTERVAL | : | 8-in casing, 200↔250-ft |
| SCREENED INTERVAL | : | Not applicable |
| COMMENTS | : | FIELD INSPECTION, 06Mar90, |
| | | 8-in carbon steel casing. Not capped or locked. |
| | | No pad, posts or permanent identification. |
| | | Not in radiation zone. |
| | | OTHER: |
| AVAILABLE LOGS | : | Driller |
| TV SCAN COMMENTS | : | 09Mar90; |
| | | DTW=213-ft. |
| | | DTB=246-ft. Post @ 242.7-ft, bottom silty. |
| | | Perforations @ 196.8-ft, 3 or 4/rd. |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | Separations area Semiannual water level measurement, 22Jan54↔04Dec92 |
| | | Not on water sample schedule |
| PUMP TYPE | : | None documented |
| MAINTENANCE | : | 26Apr90 - Installed cap and lock. |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

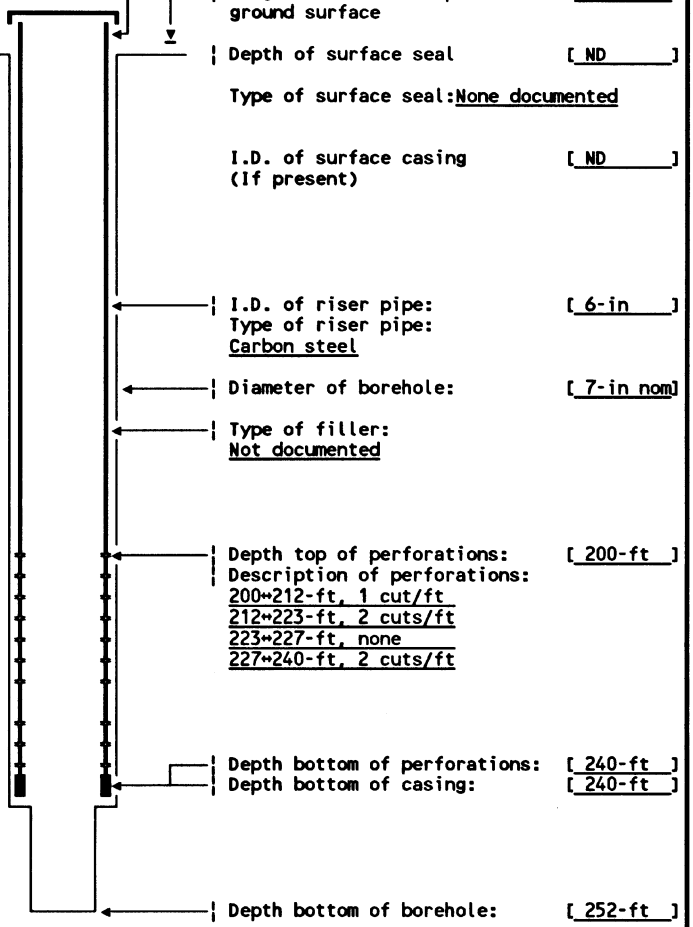
| | |
|---|---|
| Drilling Method: Cable tool | Sample Method: Hard tool (nom) |
| Drilling Fluid Used: Water | Additives Used: Not documented |
| Driller's Name: Evans/Bigham | WA State Lic Nr: Bigham-0036 |
| Drilling Company: Hatch | Company Location: Pasco, WA |
| Date Started: 28Jun73 | Date Complete: 14Jul73 |

| | |
|---|---|
| WELL NUMBER: 299-W11-23 | TEMPORARY WELL NO: |
| Hanford Coordinates: N/S N 43,766.8 | E/W W 75,415.9 |
| State NAD83 N 136,801.27m | 566,905.33m |
| Coordinates: N 448,874 | E 2,219,797 |
| Start Card #: Not documented | T R S |
| Elevation Ground surface (ft): 685.0 Estimated | |

Depth to water: 215.5-ft Jul73
(Ground surface) 223.7-ft 26Mar93

GENERALIZED STRATIGRAPHY — Driller's Log

0-6: COBBLES, GRAVEL & SAND
6-20: COBBLES, GRAVEL & SAND with SILT
20-25: COBBLES, GRAVEL & SAND
25-45: COBBLES, GRAVEL & SAND with SILT
45-50: GRAVEL & SAND
50-66: SAND
66: Layer of SILT (Thickness ND)
66-90: SAND
90-100: SILT
100-108: SAND & SILT
108-120: CALICHE
120-126: SILT
126-155: GRAVEL, SAND & SILT
155-160: SAND & GRAVEL
160-165: GRAVEL, SAND & SILT
165-226: Ringold
226-230: SAND & GRAVEL
230-238: Ringold
238-244: SAND & GRAVEL
244-252: SAND & SILT with some GRAVEL



Elevation of reference point: [685.42-ft] (top of casing)
Height of reference point above ground surface [0.4-ft]
Depth of surface seal [ND]
Type of surface seal: None documented
I.D. of surface casing (If present) [ND]
I.D. of riser pipe: [6-in]
Type of riser pipe: Carbon steel
Diameter of borehole: [7-in nom]
Type of filler: Not documented
Depth top of perforations: [200-ft]
Description of perforations:
200-212-ft, 1 cut/ft
212-223-ft, 2 cuts/ft
223-227-ft, none
227-240-ft, 2 cuts/ft
Depth bottom of perforations: [240-ft]
Depth bottom of casing: [240-ft]
Depth bottom of borehole: [252-ft]

Drawing By: RKL/2W11-23.ASB Date: 16Apr93

Reference: HANFORD WELLS

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W11-23

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W11-23 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Single Shell Tanks |
| HANFORD COORDINATES | : | N 43,766.8 W 75,415.9 [200W-11Sep90] |
| LAMBERT COORDINATES | : | N 448,874 E 2,219,797 [HANCONV] |
| | | N 136,801.27m E 566,905.33m [NAD83-11Sep90] |
| DATE DRILLED | : | Jul73 |
| DEPTH DRILLED (GS) | : | 252-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 215.5-ft, Jul73; |
| | | 223.7-ft, 26Mar93 |
| CASING DIAMETER | : | 6-in carbon steel, +0.4-240-ft; |
| ELEV TOP CASING | : | 685.42-ft, [200W-11Sep90] |
| ELEV GROUND SURFACE | : | 685.0-ft, Estimated |
| PERFORATED INTERVAL | : | 6-in casing, 200-240-ft |
| SCREENED INTERVAL | : | Not applicable |
| COMMENTS | : | FIELD INSPECTION, 29May92, |
| | | 6-in carbon steel casing. |
| | | No pad, no posts, capped and locked. |
| | | No permanent identification. |
| | | Not in radiation zone. |
| | | Casing needs extension. |
| | | OTHER: |
| AVAILABLE LOGS | : | Driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | SST Monthly water level measurement, 15Jul74-26Mar93; |
| | | WHC Semiannual water sample schedule |
| PUMP TYPE | : | Electric submersible |
| MAINTENANCE | : | |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: Water
Driller's Name: Bigham
Drilling Company: Hatch
Date Started: 05Jul73

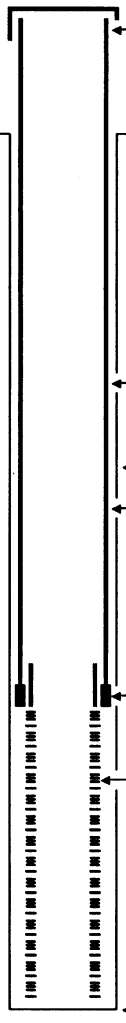
Sample Method: Hard tool (nom)
Additives Used: Not documented
WA State Lic Nr: Bigham-0036
Company Location: Pasco, WA
Date Complete: 24Aug73

WELL NUMBER: 299-W11-24
TEMPORARY WELL NO:
Hanford Coordinates: N/S N 43,581 E/W W 75,390
State NAD83 N 136,744.67m 566,913.30m
Coordinates: N 448,689 E 2,219,823
Start Card #: Not documented T R S
Elevation Ground surface (ft): 684.3 Estimated

Depth to water: 218-ft Mar90TV
(Ground surface) 222.6-ft 26Mar93

GENERALIZED STRATIGRAPHY
Driller's Log

0↔40: GRAVEL & SAND
40↔94: SAND & SILT
94↔104: SILT
104↔112: CALICHE
112↔140: CALICHE with SAND & SILT
140↔145: SAND & GRAVEL
145↔160: SAND, GRAVEL & COBBLES
160↔250: Ringold



Elevation of reference point: [687.17-ft]
(top of casing)
Height of reference point above ground surface [2.9-ft]
Depth of surface seal [ND]
Type of surface seal: None documented
I.D. of surface casing (If present) [ND]
I.D. of riser pipe: [6-in]
Type of riser pipe: Carbon steel
Diameter of borehole: [7-in nom]
Type of filler: Not documented
Depth bottom of casing: [210-ft]
Casing pulled back from total depth
Screen assembly;
Blank, 205↔210-ft
#20 Johnson, 210↔230-ft
#10 Johnson, 230↔250-ft
Depth bottom of borehole [250-ft]

Drawing By: RKL/2W11-24.ASB Date: 16Apr93

Reference: HANFORD WELLS

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W11-24

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W11-24 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Single Shell Tanks |
| HANFORD COORDINATES | : | N 43,581 W 75,390 [200W-11Sep90] |
| LAMBERT COORDINATES | : | N 448,689 E 2,219,823 [HANCONV] |
| | | N 136,744.67m E 566,913.30m [NAD83-11Sep90] |
| DATE DRILLED | : | Aug73 |
| DEPTH DRILLED (GS) | : | 250-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 218-ft, Mar90 TV;<br>222.6-ft, 26Mar93 |
| CASING DIAMETER | : | 6-in carbon steel, +2.9↔210-ft;<br>(Pulled back from total depth) |
| ELEV TOP CASING | : | 687.17-ft, [200W-11Sep90] |
| ELEV GROUND SURFACE | : | 684.3-ft, Estimated |
| PERFORATED INTERVAL | : | Not applicable |
| SCREENED INTERVAL | : | 6-in telescoping, #20 slot 210↔230-ft, #10-slot 230↔250-ft |
| COMMENTS | : | FIELD INSPECTION, 22Apr91,<br>6-in carbon steel casing.<br>No pad, no posts, capped not locked.<br>No permanent identification.<br>Not in radiation zone.<br>OTHER: |
| AVAILABLE LOGS | : | Driller |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | SST Monthly water level measurement, 05May89↔26Mar93;<br>WHC Semiannual water sample schedule |
| PUMP TYPE | : | Electric submersible |
| MAINTENANCE | : | |

WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: 200 W Water Supply
Driller's Name: D. Kruger/J. Carpenter
Drilling Company: Kaiser Engineers
Date Started: 08Oct91

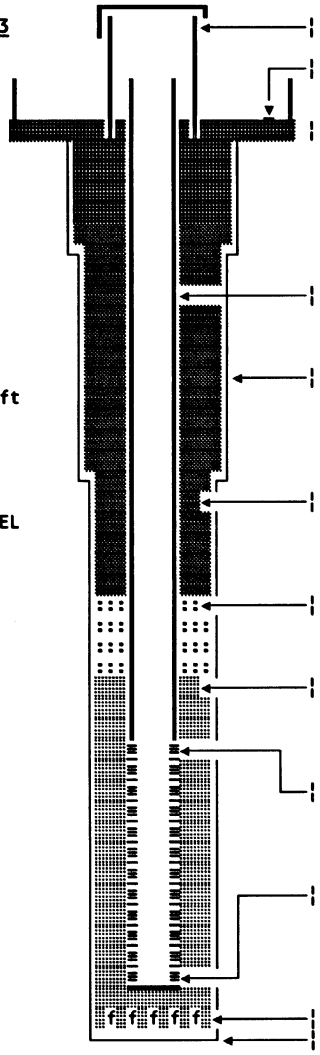
Sample Method: Drive barrel Hard tool
Additives Used: Not documented
WA State Lic Nr: Not documented
Company Location: Hanford
Date Complete: 21Nov91

WELL NUMBER: 299-W11-27 TEMPORARY WELL NO:
Hanford Coordinates: N/S N 43,751.5 E/W W 75,482.7
State NAD83 N 136,796.56m E 566,884.97m
Coordinates: N 448,860 E 2,219,730
Start Card #: Not documented T R S
Elevation Ground surface (ft): 681.81 (Brass cap)

Depth to water: 218.4-ft Nov91
(Ground surface) 220.0-ft 26Mar93

GENERALIZED STRATIGRAPHY Log
Sl=slightly

0↔3.5: Backfill and SAND
3.5↔10: Silty SAND
10↔15: Silty sandy GRAVEL
15↔20: Sandy GRAVEL
20↔25: Sl sandy GRAVEL
25↔35: Sl silty sandy GRAVEL
35↔40: Sandy GRAVEL
40↔80: SAND
80↔85: Sl gravelly SAND
85↔100: Sl sandy SILT
100↔108: SAND
108↔120: SAND w/trace CALICHE
CALICHE stringer @ 108-ft
120↔125: Sl gravelly SAND
125↔130: SAND w/trace SILT
130↔150: Sl sandy GRAVEL
150↔155: GRAVEL w/trace SAND
155↔175: Sl sandy GRAVEL
175↔190: Sl silty, sl sandy GRAVEL
190↔200: Silty sandy GRAVEL
200↔235: Sandy GRAVEL



Elevation of reference point (top of casing): [685.27-ft]
Height of reference point above ground surface: [3.46-ft]
Depth of surface seal: [0↔17.9-ft]
Type of surface seal: Pre-mix concrete
4x4-ft x 6-in surface pad
4 equidistant protective posts
Cement grout 1↔17.9-ft
I.D. of riser pipe: [4-in]
Type of riser pipe: Stainless steel
Diameter of borehole,
0↔19.7-ft, 13-in nominal
19.7↔106.8-ft, 11-in nominal
106.8↔235.0-ft, 9-in nominal
Type of filler, 17.9↔205.9-ft
8↔20-mesh bentonite crumbles
Depth top of seal: [205.9-ft]
Type of seal: 3/8-in bentonite pellets
Depth top of sand pack: [209.7-ft]
20↔40-mesh silica sand
Depth top of screen: [213.2-ft]
4-in, #10-slot, continous wrap T304 stainless steel with filter pack
Depth bottom of screen: [233.6-ft]
Fill, 234.0↔235.0-ft
Depth to bottom of borehole: [235.0-ft]

Drawing By: RKL/2W11-27.ASB Date: 16Apr93
Reference:

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W11-27

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W11-27 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Single Shell tanks |
| HANFORD COORDINATES | : | N 43,751.5 W 75,482.7 [200W-20May92] |
| LAMBERT COORDINATES | : | N 448,860 E 2,219,730 [HANCONV] |
| | | N 136,796.56m E 566,884.97m [NAD83-20May92] |
| DATE DRILLED | : | Nov91 |
| DEPTH DRILLED (GS) | : | 235.0-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 218.4-ft, Oct91; |
| | | 220.0-ft, 26Mar93 |
| CASING DIAMETER | : | 4-in stainless steel, +1.0↔213.2-ft; |
| | | 6-in stainless steel, +3.46↔~0.5-ft |
| ELEV TOP CASING | : | 685.27-ft, [NGVD'29-20May92] |
| ELEV GROUND SURFACE | : | 681.81-ft, Brass cap [NGVD'29-20May92] |
| PERFORATED INTERVAL | : | Not applicable |
| SCREENED INTERVAL | : | 213.2↔233.6-ft, 4-in #10-slot stainless steel; |
| COMMENTS | : | FIELD INSPECTION, |
| | | OTHER: |
| AVAILABLE LOGS | : | Geologist |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | SST Monthly water level measurement, 22Jan92↔26Mar93; |
| | | Not on water sample schedule |
| PUMP TYPE | : | Hydrostar, intake at 234.3-ft (TOC) |
| MAINTENANCE | : | |

## WELL CONSTRUCTION AND COMPLETION SUMMARY

Drilling Method: Cable tool
Drilling Fluid Used: 200 W Water Supply
Driller's Name: H. Baker
Drilling Company: Kaiser Engineers
Date Started: 03Oct91

Sample Method: Drive barrel Hard tool
Additives Used: Not documented
WA State Lic Nr: Not documented
Company Location: Hanford
Date Complete: 11Dec91

WELL NUMBER: 299-W11-28 A4908
TEMPORARY WELL NO:
Hanford Coordinates: N/S N 43,577.8 E/W W 75,319.3
State NAD83 N 136,743.74m 566,934.89m
Coordinates: N 448,686 E 2,219,894
Start Card #: Not documented T___ R___ S___
Elevation Ground surface: 689.94-ft (Brass cap)

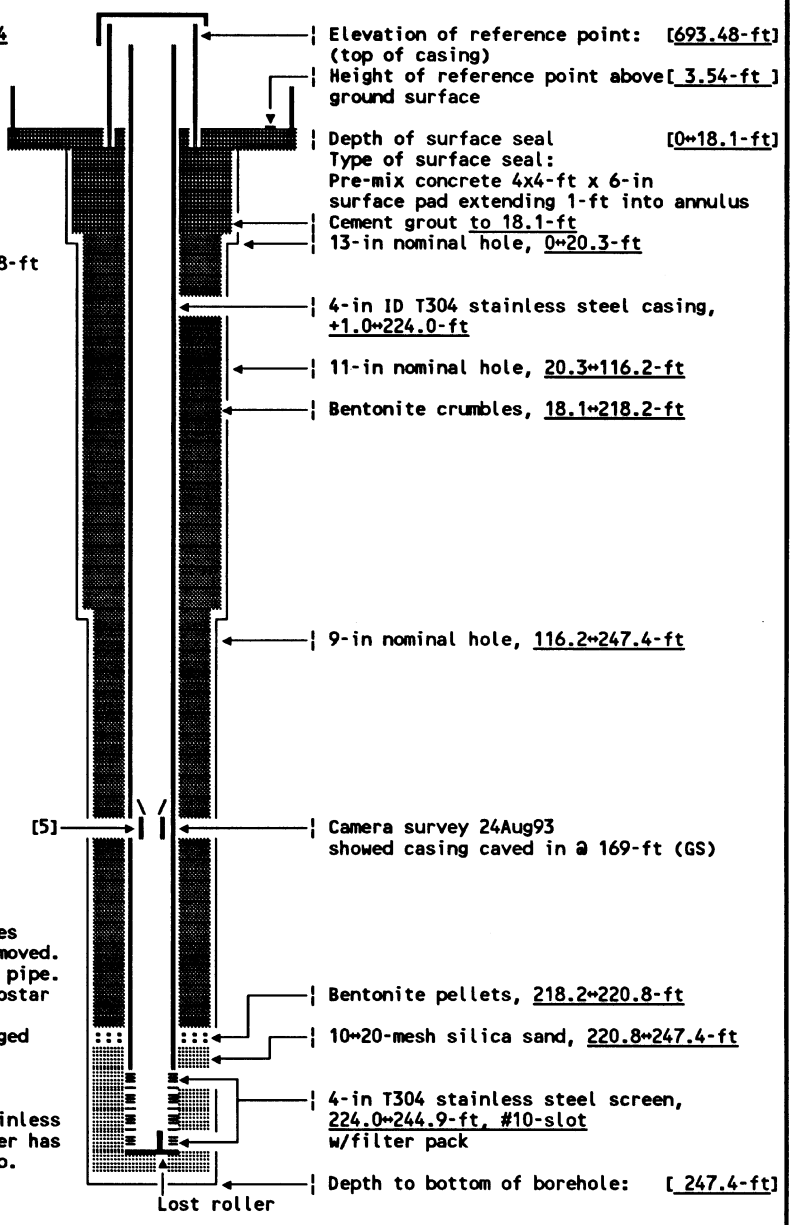
Depth to water: 226.5-ft Dec91
(Ground surface) 228.8-ft 16Aug94

GENERALIZED Geologist's STRATIGRAPHY Log
Sl=slightly

0↔5: Sandy GRAVEL
5↔10: SAND
10↔40: Sandy GRAVEL
40↔75: SAND
75↔80: Gravelly SAND
80↔97: SAND, 6-in SILT layer @ 88-ft
97↔99: SILT
99↔105: SAND
105↔110: SILT
110↔115: Sandy SILT
115↔120: SILT
120↔125: SILT w/CALICHE
125↔130: Sl silty, sandy GRAVEL
130↔140: Sl sandy SILT
140↔145: Sandy SILT
145↔150: Silty sandy GRAVEL
150↔155: Sandy GRAVEL
155↔160: Silty sandy GRAVEL
160↔165: Silty GRAVEL
165↔180: Sandy GRAVEL
180↔205: Silty sandy GRAVEL
205↔210: Sl gravelly silty SAND
210↔215: Sl sandy GRAVEL
215↔230: Silty sandy GRAVEL
230↔242: Sandy GRAVEL
242↔247: Sl gravelly SAND

COMPLETION NOTE:
Original drilled depth was 240-ft. Well was extended to 247.4-ft during second attempt at completion.
13Jul92 Problem reported Pump and tubing stuck in well due to caved casing @ 169-ft.

REMEDIATION:
30Aug↔08Oct93 by WHC Well Services
1] Cut ¾-in pipe @ 161.5-ft & removed.
2] Washed over & removed 1 joint pipe.
3] Swedged casing & removed hydrostar pump & pipe.
4] Ran concentric roller at damaged area, rolled to ~2 -in. Lost roller off tool string. Did not retrieve.
5] Installed 2-in ID by 3-ft stainless steel liner ~169↔172-ft. Liner has 3½-in ID funnel fitting at top.




Drawing By: RKL/2W11-28.ASB
Date : 10Oct94
Reference : WHC-SD-EN-DP-042

# SUMMARY OF CONSTRUCTION DATA AND FIELD OBSERVATIONS
# RESOURCE PROTECTION WELL - 299-W11-28

| | | |
|---|---|---|
| WELL DESIGNATION | : | 299-W11-28 |
| CERCLA UNIT | : | 200 Aggregate Area Management Study |
| RCRA FACILITY | : | Single Shell tanks |
| HANFORD COORDINATES | : | N 43,577.8 W 75,319.3 [200W-20May92] |
| LAMBERT COORDINATES | : | N 448,686 E 2,219,894 [HANCONV] |
| | | N 136,743.74m E 566,934.89m [NAD83-20May92] |
| DATE DRILLED | : | Dec91 |
| DEPTH DRILLED (GS) | : | 247.4-ft |
| MEASURED DEPTH (GS) | : | Not documented |
| DEPTH TO WATER (GS) | : | 226.5-ft, Dec91; |
| | | 228.8-ft, 16Aug94 |
| CASING DIAMETER | : | 4-in stainless steel, +1.0↔224.0-ft; |
| | | 6-in stainless steel, +3.54↔~0.5-ft |
| ELEV TOP CASING | : | 693.48-ft, [NGVD'29-20May92] |
| ELEV GROUND SURFACE | : | 689.94-ft, Brass cap [NGVD'29-20May92] |
| PERFORATED INTERVAL | : | Not applicable |
| SCREENED INTERVAL | : | 224.0↔244.9-ft, 4-in #10-slot stainless steel; |
| COMMENTS | : | FIELD INSPECTION, 24Aug93; |
| | | 4 and 6-in stainless steel casing. |
| | | 4-ft by 4-ft concrete pad, 4 posts, 1 removable. |
| | | Capped and locked, brass cap in pad with well ID. |
| | | Not in radiation zone. |
| | | OTHER: Well is obstructed by stuck pump. |
| AVAILABLE LOGS | : | Geologist |
| TV SCAN COMMENTS | : | Not applicable |
| DATE EVALUATED | : | Not applicable |
| EVAL RECOMMENDATION | : | Not applicable |
| LISTED USE | : | SST monthly w/l measurement, 22Jan92↔16Aug94; |
| | | Not on water sample schedule |
| PUMP TYPE | : | Not documented |
| MAINTENANCE | : | |

# Appendix C

# Monitoring Efficiency Model Output Regarding New Well Installation

# Appendix C

# Monitoring Efficiency Model Output Regarding New Well Installation

This appendix provides results of computer modeling used to guide locations for new monitoring wells to improve the probability of detecting contamination from Waste Management Area (WMA) T. The model is an analytical Monitoring Efficiency Model, referred to as MEMO, which was developed to assist in design of monitoring well networks (Wilson et al. 1992). The model uses a plume generation routine to compute the size and shape of a plume from hypothetical source locations uniformly distributed within the source area (i.e., waste management area). The model assumes the contaminant is released as a continuous line source to a uniform or homogeneous aquifer. If a contaminant occurrence is more of a short-term transient event, then there is likelihood that the computed monitoring efficiency may be over estimated because less lateral spreading will occur than with a continuous release source.

Major input parameters needed include groundwater flow direction; longitudinal and transverse dispersivities, velocity, buffer zone and well locations. The X-Y coordinates are entered to define well locations, the waste management area boundary and the buffer zone. The buffer zone is used to allow the hypothetical plume to expand to some point beyond the source area boundary. The further away the buffer boundary is set, the greater the lateral spreading that will occur in the vicinity of the line of compliance where the wells are located. Thus, there is a trade off between number of wells needed and the elapsed time when a contaminant plume would be detected. With a narrow buffer zone (boundary set close to the well locations), detection of hypothetical contaminant plumes would occur earlier but requires more wells.

Longitudinal and transverse dispersivities, the parameters that control the extent of spreading of the plume, were previously determined[(a)] using the observed distribution of the tritium plume in the 200 West Area. These same dispersivities are deemed appropriate for WMA T because the aquifer beneath both the northern and southern part of the 200 West Area is in the same hydrogeologic unit. Other input parameters and the values used for the WMA T computer iterations are defined below.

- X-Y coordinates: State Plane, meters.

- $C_D/C_0$: Dilution contour where $C_D$ is the detection standard selected as the limiting concentration to be detected by a monitoring well, and $C_0$ is the source concentration in groundwater at the location of origin within the waste management area. To provide adequate early warning of a release, the model should be based on a dilution contour for the more mobile potential contaminants at the site. For the

[(a)] Low-Level Waste Burial Grounds RCRA Part B Permit Application, Section 5: Groundwater Monitoring, 903-1201. Prepared for SAIC, Richland, Washington, by Golder Associates Inc., Redmond, Washington, 1990.

WMA T computer simulations, a detection limit of 10 pCi/L for Tc-99 is used as the detection standard ($C_D$) and 10,000 pCi/L is used as the source concentration ($C_0$), resulting a dilution contour of ($C_D/C_0$) = (10 pCi/L)/(10,000 pCi/L) = 0.001. This is a reasonable approximation of likely conditions at WMA T.

- ldisp. Longitudinal dispersivity, meters. A value of 8.5 m (28 ft) was used based on tritium plume dimensions in the 200 West Area (see Golder Associates 1990, page 102).

- tdisp. Transverse dispersivity, meters. A value of 2.5 m (8 ft) was used based on tritium plume dimensions in the 200 West Area (see Golder Associates 1990, page 102).

- diffc. Effective molecular diffusion coefficient (insignificant for this application so set to zero).

- source width, meters. The length in meters of the initial source dimension (modeled as a line source of the same length spaced evenly over the entire source area). A line source length of 6 m was used.

- lmb. First order radioactive decay constant. This term was set to zero because no decay was assumed.

- cvel. Average contaminant velocity, meters/day (m/d). A value of 0.1 m/d was used for computational purposes.

Output of the MEMO model using existing usable WMA T network (299-W10-4, 299-W10-1, 299-W10-23, 299-W10-8, 299-W10-24, 299-W11-24, and 299-W11-12) is shown in Figure C.1. Flow direction, as inferred from the most recent water table elevations, is almost due east. Input parameters and coordinates used for Figure C.1 are listed in Tables C.1. The shaded areas in Figure C.1 suggest there is a major area of inadequate well coverage at the southeast end of the waste management area and at the northeast corner. The possible sources not likely to be covered by the current network include tank T-111 and the diversion boxes (241-TR-153, 241-T-151, 241-T-152, and 241-T-153) in the southeastern area inside the tank farm fence line (Figure C.1). Three new well locations were added to eliminate the areas of predicted non-coverage (Figure C.2), one at the far northeast corner (well location #1, near tank T-101 when 299-W11-23 is dry), and two in the southeast corner of the waste management area (well locations #3 and #4). One new well is added to replace 299-W11-28 that is going dry (well location #2). The model results after inclusion of the four new well locations also suggests there may be a need to include an additional well at the far (outside) southeast corner of the T farm fence line. Printouts for the extended network (i.e., existing useable network plus four additional wells as indicated in Figure C.2), using input parameters values as provided above, are presented in Table C.2.

Based on the above analysis and professional judgment regarding actual site conditions (location of obstructions, contaminant observations, site-specific hydrogeology, etc.), the new well locations were chosen for enhancing near-field spatial coverage for this waste management area. Additional wells may be needed to define mid-field to far-field movement to assess areal extent beyond the waste management area study boundary and to eliminate the remaining non-covered area in the southeastern part of the waste management area.

## C.1 References

Wilson, C. R., C. M. Einberger, R. L. Jackson and R. B. Mercer. 1992. "Design of Ground-Water Monitoring Networks Using the Monitoring Efficiency Model (MEMO)." *Ground Water*, 30(6):965-970.

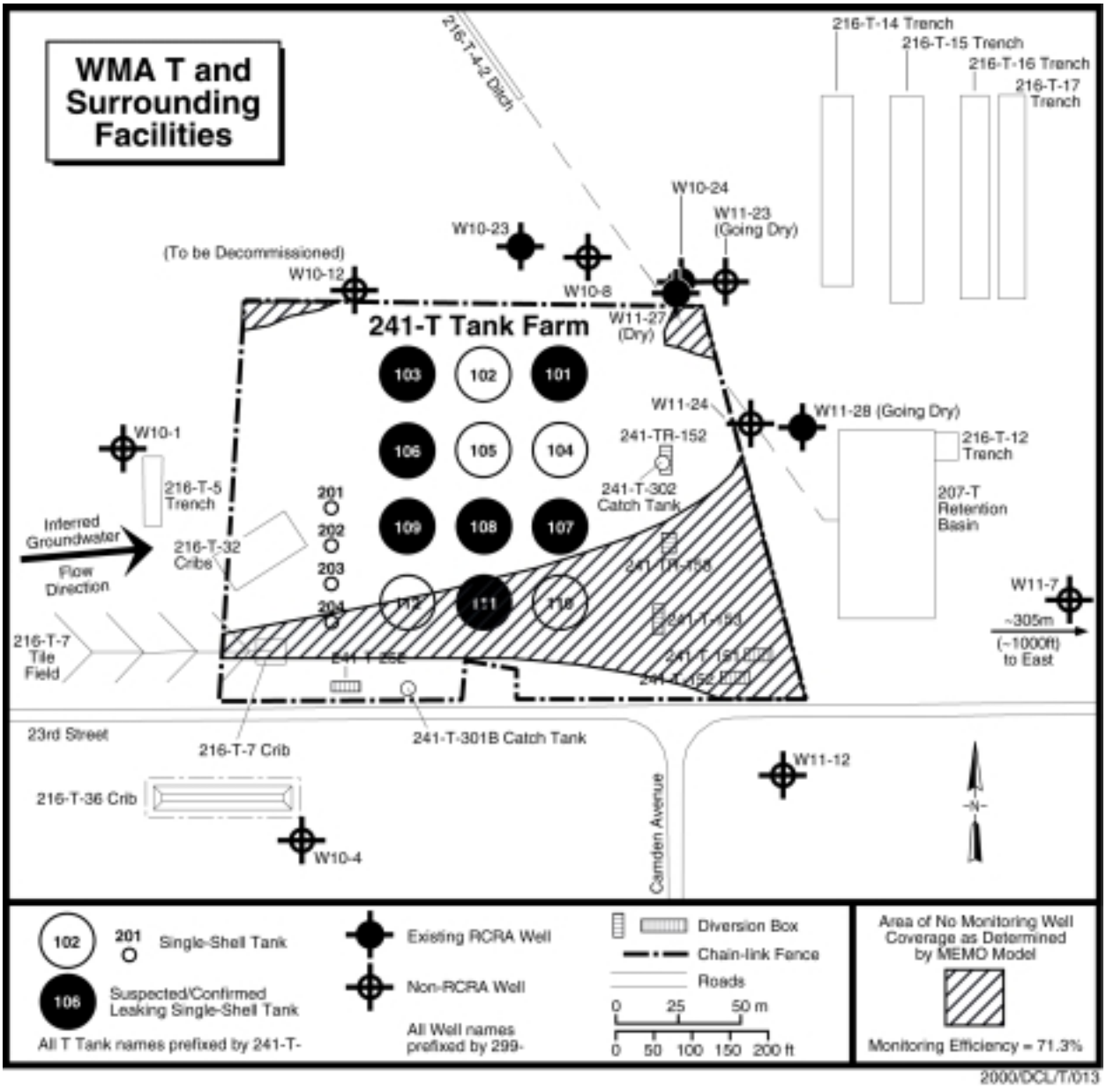



**Figure C.1**. Existing Monitoring Network Together with Non-covered Areas as Determined by MEMO Model

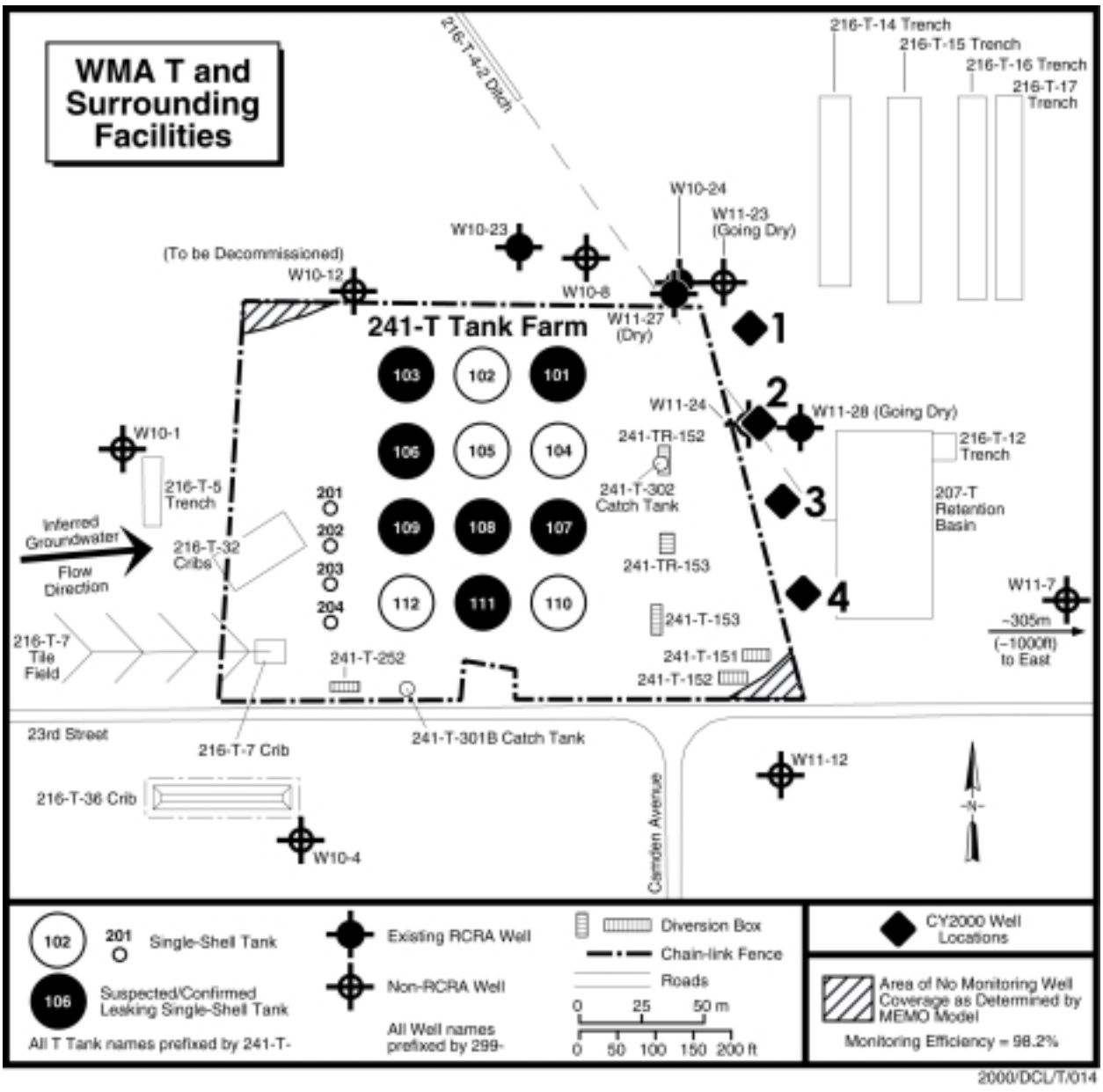



**Figure C.2**. Existing and New Monitoring Wells with Remaining Non-Covered Areas as Determined by MEMO Model

**Table C.1.** Input Parameters and Coordinates for Figure C.1

```
++++++++++++++++++++++++++++++++++++++++++++
++        MEMO Data File                  ++
++                                        ++
++     Monitoring Analysis Package        ++
++        MAP Version   1.1               ++
++                                        ++
++       GOLDER ASSOCIATES INC.           ++
++                                        ++
++    Run on 05/18/00 at 08:38:50         ++
++++++++++++++++++++++++++++++++++++++++++++


------------------------------------------
< T Tank Farm - RCRA Wells               >
------------------------------------------



  *   SCALE FACTOR
        1.000000
  *   SOURCE GRID PARAMETERS (x0,y0,grid spacing,max x incr,max y
incr)
   566703.000000   136633.700000        2.000000
         117           81
  *   POTENTIAL SOURCE AREA COORDINATES (#,x,y,unit#)
    1      566703.00      136633.70          1
    2      566711.90      136794.10          1
    3      566894.80      136794.10          1
    4      566936.40      136634.50          1
    5      566820.80      136634.50          1
    6      566820.80      136646.50          1
    7      566800.20      136650.10          1
    8      566798.90      136634.50          1
  *   LINE OF COMPLIANCE COORDINATES (#,x,y)
    1      566703.00      136633.70
    2      566711.90      136794.10
    3      566894.80      136794.10
    4      566936.40      136634.50
    5      566820.80      136634.50
    6      566820.80      136646.50
    7      566800.20      136650.10
    8      566798.90      136634.50
  *   ARRAY SPACING FOR BUFFER ZONE COORDINATES (max. spacing)
        4.000000
  *   INPUT BUFFER ZONE COORDINATES (#,x,y)
    1      566640.00      136565.00
    2      566655.00      136835.00
```

**Table C.1.** (contd)

```
    3       566925.00       136835.00
    4       567000.00       136565.00
  *   MONITORING WELL COORDINATES (#,x,y)
    1       566735.00       136578.00
    2       566663.00       136735.00
    3       566824.00       136815.00
    4       566849.00       136811.00
    5       566885.00       136799.00
    6       566927.00       136604.00
    7       566913.00       136745.00
  *   CONTAM. TRAN. PARAMETERS (CD/C0,ldisp,tdisp,diffc,source wid
th,lmb,cvel)
    1.000000E-03        8.500000        2.400000    0.000000E+00
       6.000000    0.000000E+00    1.000000E-01
  *   GRADIENT ZONE COORDINATES (#,x,y,unit#,angle)
    1       566550.00       136565.00          1           5.00
    2       566650.00       136860.00          1           5.00
    3       566925.00       136860.00          1           5.00
    4       567010.00       136565.00          1           5.00
  *   SOLUTION RESULTS
  Maximum advection time =    36500.000000
  Accuracy of solution =    1.000000E-04
  Solution basis = buffer zone/advection time
  Total # of source points =        8251
  # of undetected leaks =        2364
 Monitoring efficiency = 71.3 %.
  *   END OF MAP FILE
```

**Table C.2.** Input Parameters and Coordinates for Figure C.2

```
++++++++++++++++++++++++++++++++++++++++++++
++        MEMO Data File                  ++
++                                        ++
++     Monitoring Analysis Package        ++
++        MAP Version   1.1               ++
++                                        ++
++       GOLDER ASSOCIATES INC.           ++
++                                        ++
++    Run on 05/18/00 at 07:01:14         ++
++++++++++++++++++++++++++++++++++++++++++++


------------------------------------------
< T Tank Farm - RCRA Wells               >
------------------------------------------


*   SCALE FACTOR
      1.000000
*   SOURCE GRID PARAMETERS (x0,y0,grid spacing,max x incr,max y
incr)
   566703.000000   136633.700000        2.000000
        117           81
*   POTENTIAL SOURCE AREA COORDINATES (#,x,y,unit#)
    1       566703.00       136633.70          1
    2       566711.90       136794.10          1
    3       566894.80       136794.10          1
    4       566936.40       136634.50          1
    5       566820.80       136634.50          1
    6       566820.80       136646.50          1
    7       566800.20       136650.10          1
    8       566798.90       136634.50          1
*   LINE OF COMPLIANCE COORDINATES (#,x,y)
    1       566703.00       136633.70
    2       566711.90       136794.10
    3       566894.80       136794.10
    4       566936.40       136634.50
    5       566820.80       136634.50
    6       566820.80       136646.50
    7       566800.20       136650.10
    8       566798.90       136634.50
*   ARRAY SPACING FOR BUFFER ZONE COORDINATES (max. spacing)
      4.000000
*   INPUT BUFFER ZONE COORDINATES (#,x,y)
    1       566640.00       136565.00
    2       566655.00       136835.00
```

**Table C.2.** (contd)

```
    3      566925.00      136835.00
    4      567000.00      136565.00
  *   MONITORING WELL COORDINATES (#,x,y)
    1      566735.00      136578.00
    2      566663.00      136735.00
    3      566824.00      136815.00
    4      566849.00      136811.00
    5      566885.00      136799.00
    6      566927.00      136604.00
    7      566913.00      136745.00
    8      566915.00      136781.00
    9      566918.00      136745.00
   10      566928.00      136710.00
   11      566938.00      136675.00
  *   CONTAM. TRAN. PARAMETERS (CD/C0,ldisp,tdisp,diffc,source wid
th,lmb,cvel)
    1.000000E-03        8.500000        2.400000    0.000000E+00
       6.000000    0.000000E+00    1.000000E-01
  *   GRADIENT ZONE COORDINATES (#,x,y,unit#,angle)
    1      566550.00      136565.00         1           5.00
    2      566650.00      136860.00         1           5.00
    3      566925.00      136860.00         1           5.00
    4      567010.00      136565.00         1           5.00
  *   SOLUTION RESULTS
  Maximum advection time =    36500.000000
  Accuracy of solution =    1.000000E-04
  Solution basis = buffer zone/advection time
  Total # of source points =        8251
  # of undetected leaks =         149
 Monitoring efficiency = 98.2 %.
  *   END OF MAP FILE
```

# Appendix D

# Preliminary Results for FY-99 and FY-00 Detailed Hydrologic Characterization Tests Conducted in the WMA S-SX, TX-TY, and T

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Date September 26, 2000

To V.G. Johnson

From F.A. Spane F.A. Spane

Subject Preliminary Results for FY-99 and FY-00 Detailed Hydrologic Characterization Tests Conducted in the WMA S-SX, TX-TY, and T

This letter report presents preliminary results obtained from detailed hydrologic characterization tests conducted within the WMA S-SX, TX-TY, and T during FY-99 and FY-00. These results are in the process of being formally documented in several PNNL technical reports (e.g., Spane et al. 2000). This letter report is being issued as an interim measure to meet current hydrologic data needs of various WMA projects, prior to formal technical report issuance. The letter report only provides the preliminary results for the various detailed hydrologic characterization test elements, and does not present discussions pertaining to test descriptions, and analytical methods and result comparison. These discussions will be presented in detailed fashion in the subsequent technical reports.

## Detailed Hydrologic Characterization Program

As part of the Hanford Groundwater Monitoring Project, Pacific Northwest National Laboratory conducts detailed hydrologic characterization tests within wells at selected locations to provide information pertaining to the hydraulic properties and groundwater flow characteristics of the unconfined aquifer. The following identifies and briefly describes the various characterization components employed in FY-99 and FY-00, as part of the detailed hydrologic characterization program. Various individual test element activities include:

| | |
|---|---|
| **Groundwater Flow Characterization:** | for quantitative determination of groundwater flow direction and hydraulic gradient conditions |
| **Barometric Response Evaluation:** | for determining well response characteristics to barometric fluctuations; for estimating vadose zone transmission characteristics; and for removal of barometric pressure effects from hydrologic test responses |

E54-1900-001 (8/98)

| | |
|---|---|
| **Slug Testing:** | for evaluating well development conditions and to provide preliminary hydraulic property information (e.g., hydraulic conductivity) for design of subsequent hydrologic tests |
| **Tracer-Dilution Test:** | for determining the vertical distribution of hydraulic conductivity and/or groundwater flow velocity within the well-screen section, and for identifying vertical flow conditions within the well column |
| **Tracer-Pumpback Test:** | for tracer removal and characterizing effective porosity, an important hydraulic transport parameter |
| **Constant-Rate Pumping Test:** | conducted in concert with tracer-pumpback phase. Analysis of drawdown and recovery data provides quantitative, large-scale hydraulic characterization property information, e.g., hydraulic conductivity, storativity, specific yield |
| **Step-Drawdown Test:** | for determining well efficiency and well loss for the well-screen section; for removal of well loss effects from hydrologic test response |
| **In-Well Vertical Tracer/Test:** | for determining the existence of vertical flow within the well-screen section |

Accurate delineation of the prevailing groundwater-flow direction and hydraulic gradient, I, conditions is critical for proper evaluation of groundwater contaminant movement. Within study areas of small size and/or having low gradient conditions, detailed groundwater flow characterization can be difficult. A method that facilitates groundwater flow characterization in such areas is the use of trend-surface analysis of representative monitoring well total head measurements (not well water-level elevation). A description of the use of trend-surface analysis for detailed characterization of groundwater flow conditions is presented in Spane (1999).

Slug testing is designed primarily to provide initial estimates of hydraulic conductivity, K, for the design of subsequent, more quantitative hydrologic tests. At each well, slug tests are conducted using at least two different stress levels to provide information pertaining to well development and possible presence of near-well heterogeneities. A detailed description of the design, performance and analysis of slug test characterizations is presented in Butler et al. (1994) and Butler (1997).

Tracer dilution and tracer pumpack/constant-rate pumping and recovery tests are conducted at single-well sites. For the tracer-dilution test, a bromide solution of known concentration is circulated/mixed within the well-screen section. The decline of tracer concentration (i.e., "dilution") with time within the well screen is monitored directly using a vertical array of bromide specific-ion electrode probes located at known depth intervals. Based on the dilution

characteristics observed, the vertical distribution (i.e., heterogeneity) of hydraulic properties and/or flow velocity can be estimated for the formation within the well-screen section. The presence of vertical flow within the well screen can also be identified from the probe/depth dilution response pattern. A description of the performance and analysis of tracer-dilution test characterization investigations is provided in Halevy et al. (1966), Hall et al. (1991), and Hall (1993).

For the tracer pumpback, a constant-rate pumping test is initiated after the average tracer concentration has decreased (i.e., diluted) to a sufficient level within the well screen (usually a 1 to 2 order of magnitude reduction from the original tracer concentration). The objective of the pumpback test is to "capture" the tracer that has moved from the well into the surrounding aquifer. Tracer recovery is monitored by measuring the tracer concentration in water pumped from the well. The time required to recover the centroid of tracer mass/concentration provides information of the aquifer effective porosity, $n_e$. Effective porosity is a primary hydrologic parameter controlling contaminant transport. Once estimates for $n_e$, K, and I have been determined, the average aquifer groundwater flow velocity, $v_a$, can also be calculated.

The constant-rate pumping test may be extended for a time duration longer than required for capturing the tracer centroid. The extended pumping time enables quantitative large-scale characterization of the surrounding hydraulic properties. The time required to obtain representative hydrologic property results can be determined by using diagnostic derivative analysis results of the drawdown data obtained from the pumped and nearby observation well locations. A detailed description of the use of derivative analysis techniques is provided in Spane (1993) and Spane and Wurstner (1993).

Following termination of the constant-rate pumping test phase, the recovery of water levels within the pumped well and surrounding observation wells can also be monitored. The time required for recovery monitoring can be assessed in a manner similar to drawdown data collected during the pumping phase, through the use of diagnostic derivative analysis. For general planning purposes, however, recovery monitoring should be maintained for a period equal to the pumping period and preferably longer. Analysis of the associated pressure drawdown and recovery responses at the surrounding observation wells provides the basis for determining standard, large-scale hydraulic properties within the tested aquifer. These hydraulic properties include: horizontal conductivity ($K_h$), transmissivity (T), storativity (S), and specific yield ($S_y$). In addition, detailed hydrologic property characterization obtained from compositely analyzing drawdown and recovery data from multiple observation wells include: vertical anisotropy ($K_v/K_h$) and horizontal anisotropy ($K_{hx}/K_{hy}$). The vertical and horizontal anisotropy parameters are the principal hydraulic parameters controlling the directional contaminant transport within the local area.

A group of tables is presented in this letter report that summarize the results from various detailed hydraulic characterization activities. Table 1 provides a summary of the various detailed hydraulic characterization elements. Table 2 lists the preliminary analysis results for hydraulic conductivity and transmissivity determined from slug tests and constant-rate pumping tests. Table 3 presents pertinent information pertaining to tracer-dilution testing, and estimates for lateral groundwater flow velocity within the well screen, $v_w$. Table 4 presents results of tracer pumpback testing and associated estimates for effective porosity, $n_e$, and average aquifer groundwater flow velocity, $v_a$. Table 5 lists the results of groundwater flow characterization (hydraulic gradient, I, and groundwater flow direction), based on trend-surface analysis, for the various well sites selected for tracer testing.

**Data Discussion**

**Table 2**

Table 2 presents estimates obtained from slug testing and constant-rate pumping tests. The range for K listed for slug tests represent the average K value as determined using the Bouwer and Rice method and the type-curve matching procedure. Constant-rate pumping test results include the analysis of drawdown and/or recovery data using the methods identified previously. A close correspondence in estimates for K is evident between the two test methods. It should also be noted that the test analysis was completed independently by different analysts, i.e., F.A. Spane: slug tests and P.D. Thorne: constant-rate pumping tests.

**Table 3**

Table 3 lists pertinent information pertaining to the tracer-dilution tests performed. Several wells exhibited vertical flow conditions (denoted by VF in the table), which largely invalidate the results of the test. The vertical flow conditions detected during the tracer-dilution testing (i.e., well 299-W10-26: downward; well 299-W14-13: downward; and 299-W22-49: upward) were also corroborated independently directly using electromagnetic vertical flowmeter surveys conducted at these wells, as reported in Waldrop and Pearson (2000).

It should be noted that the $v_w$ estimates based on the tracer-dilution tests are strictly for in-well groundwater flow conditions. The relationship between $v_w$ and aquifer groundwater flow velocity, $v_a$, is shown in equation (1) below:

$$v_w = v_a n_e \propto \quad (1)$$

where, $\propto$ = groundwater flow distortion factor; dimensionless, common range 0.5 to 4

Average well flow velocities ranged between 0.007 to 0.311 m/d. It should be noted that the lowest average value of 0.007 m/d recorded at well 299-W22-48 (WMA S-SX), is a result of averaging depth/well velocity conditions that indicate very little flow within the lower part of the well screen. The value of 0.023 m/d indicated for the well screen maybe more reflective of actual aquifer conditions. The highest value of 0.311 m/d calculated for well 299-W15-41 (WMA T) is higher than expected, and may be the result of extraneous hydrologic effects imposed by the nearby 200-ZP-1 pump and treat facility. This well location is well within the potential radius of influence distances reported in Spane and Thorne (2000) and, therefore a possible cause for the observed elevated in-well flow velocities.

To assess the repeatability of the tracer-dilution test results, two separate tests were conducted at well 299-W22-50. A comparison of the tests indicates small, but discernable differences in the associated $v_w$ estimates, i.e., Test #1 = 0.066 m/d; Test #2 = 0.046 m/d. Results for Test #2 are considered to be more representative based on the lower initial tracer concentration used (i.e., possible tracer concentration bias), and the longer tracer-dilution period exhibited.

A comparison of the observed depth/well velocity profiles provided information about permeability distribution within the well-screen sections at four of the wells. At wells 299-W10-24 (WMA TX-TY)and -W15-41 (WMA T) the highest flow velocities (and inferred permeabilities) were exhibited near the middle of the screen, with lowest flow velocities indicated near the top. Conversely, for well 299-W22-48 (WMA S-SX), the highest flow velocity was denoted near the top, with essentially little to no flow indicated for the lower part of the well screen. For well 299-W22-50 (southern boundary of WMA S-SX), relatively uniform depth/well velocity profiles were exhibited, indicating homogeneous conditions throughout the well-screen section. This condition was indicated for both tests conducted at the well site.

**Table 4**

Table 4 lists pertinent information pertaining to the tracer pumpback tests performed. As noted previously, several wells exhibited vertical flow conditions during the tracer-dilution tests (denoted by VF in the table). The fact that tracer only was emplaced into the aquifer within a small portion of the well screen, seriously impacts the assumptions of the test ( which will be discussed in detail in the subsequent PNNL technical report). The tracer pumpback results for those wells affected by vertical flow conditions are highly questionable, and should not be used for quantitative assessment. The estimates calculated from the tests, however, are provided in the table (in parentheses) for only comparison/informational purposes.

Estimates for $n_e$ for the reportable tests ranged between 0.068 and 0.257 (note: Test #2 for well 299-W22-50 is believed more representative, due to the fact that longer tracer drift times are less affected by well effects). This range for $n_e$ falls within the common range usually reported for

semi-consolidated to unconsolidated alluvial aquifers of 0.05 to 0.30, and brackets the large-scale values for specific yield, $S_y$ ($S_y \approx n_e$) of 0.11 and 0.17, reported in Newcomb and Strand (1953) and Wurstner et al. (1995), respectively for the 200-West Area. These large-scale analysis values were based on analyzing the growth and decline of the groundwater mound beneath the 200-West Area, that were associated with water disposal practices in the area.

Estimates for $v_a$ for the reportable tests ranged between 0.013 and 0.374 m/d, and generally fall within a factor of 2 of the calculated in-well flow velocities, $v_w$. As noted previously for $v_w$ at well 299-W15-41, the observed estimate for $v_a$ of 0.374 m/d at this well site may be elevated due to affects imposed by operation of the adjacent 200-ZP-1 pump and treat system.

Table 5

Table 5 lists groundwater flow characterization results pertaining to determination of groundwater-flow direction and hydraulic gradient, I, conditions at the various test sites during the times of tracer testing. Groundwater-flow direction and hydraulic gradient were calculated using the commercially available WATER-VEL (In-Situ, Inc. 1991) software program. Water-level elevations from neighboring, representative wells were used as input with the WATER-VEL program to calculate groundwater-flow direction and hydraulic gradient conditions during the detailed characterization period. The program utilizes a linear, two-dimensional trend surface (least squares) to randomly located hydrologic head or water-level elevation input data. 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).

Calculations of I listed in Table 5 were used for estimates of $n_e$ and $v_a$ shown in Table 4. The indicated easterly groundwater flow directions for WMA S-SX and T sites and the southerly groundwater flow direction for the TX-TY directions is consistent with previous generalizations presented in Hartman et al. (1999) for these areas.

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**Table 1.** Detailed Hydrologic Characterization Elements

| Characterization Element | Activities | Results |
|---|---|---|
| **Groundwater Flow Characterization** | Trend-surface analysis of well water-level data | Quantitative determination of groundwater flow direction and hydraulic gradient |
| **Barometric Response Evaluation** | Well water-level response characteristics to barometric changes | Aquifer/well model identification, vadose zone property characterization, correction of hydrologic test responses for barometric pressure fluctuations |
| **Slug Testing** | Multi-stress level tests conducted at each well site | Local $K_h$, T of aquifer surrounding well site. |
| **Tracer-Dilution Testing** | Monitoring dilution of administered tracer at injection well site | Vertical distribution of $K_h$, groundwater flow velocity at injection well location |
| **In-Well Vertical Tracer Test** | Monitoring the vertical movement of tracer within the well screen | Determination of vertical flow within the monitoring well screen section |
| **Tracer Pumpback** | Pumping/monitoring of recovered tracer and associated pressure response in monitoring wells | Large-scale, interwell $n_e$, $K_h$, $K_v/K_h$, $K_{hx}/K_{hy}$, T, S, $S_y$ |
| **Step-Drawdown Test** | Determine well water-level response to selected pumping rates | Well loss characteristics |

Hydrologic parameters:

$K_h$ = horizontal hydraulic conductivity; (L/T)
$K_v/K_h$ = vertical anisotropy; (dimensionless)
$K_{hx}/K_{hy}$ = horizontal anisotropy; (dimensionless)
T = transmissivity; ($L^2/T$)
S = storativity; (dimensionless)
$n_e$ = effective porosity; (dimensionless)

**Table 2.** FY-99 and FY-00 Hydraulic Property Test Analysis Summary for WMA TX-TY, T, and S-SX

| WMA | Well | Hydrologic Characterization Tests | | |
|---|---|---|---|---|
| | | Slug Test | Constant-Rate Pumping Test | |
| | | Equivalent Hydraulic Conductivity $K_e$ m/d | Equivalent Hydraulic Conductivity $K_e$ m/d | Transmissivity T $m^2/d$ |
| TX-TY | 299-W10-26 | 1.40 – 1.95 | 1.5 | 82 |
| | 299-W14-13 | 1.66 – 2.43 | 2.4 | 135 |
| | 299-W14-14 | 2.44 – 2.87 | -- | -- |
| | 299-W15-40 | 0.88 – 1.22 | -- | -- |
| | 299-W15-41 | 15.1 – 19.5* | 19.6** | 1130** |
| T | 299-W10-23 | 1.65 – 2.35 | -- | -- |
| | 299-W10-24 | 1.04 – 1.68 | 1.2 | 66 |
| S-SX | 2-W22-48 | 1.55 - 1.98* | 1.81** | 127** |
| | 2-W22-49 | 6.92 – 8.20* | 7.17** | 520** |
| | 2-W22-50 | 5.18 – 5.46* | 5.24** | 385** |

Note: unless otherwise indicated, slug test analysis range represents the average analysis value for the Bouwer and Rice and type-curve methods

* slug test results do not include analysis results for Bouwer and Rice method; listed range will be updated when analysis results are complete in FY-01

** preliminary pumping test analysis values, subject to revision; to be documented in FY-01

$K_e$ assumes aquifer with uniform hydraulic conductivity value

-- constant-rate pumping test not conducted at the well site

**Table 3.** FY-99 and FY-00 Tracer-Dilution Test Analysis Summary for WMA TX-TY, T, and S-SX

| WMA | Well | Test Interval m, btoc[a] | Tracer-Dilution Test Results | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Date Test Initiated | Total Dilution Time $t_d$ min | Average Initial Tracer Concent. $C_o$ mg/L | Average Final Tracer Concent. $C_t$ mg/L | Average Well Flow Velocity $v_w$ m/d | Range Well Flow Velocity $v_{wz}$ m/d |
| TX-TY | 2-W10-26 | 67.4 - 77.8 | 4/23/99 | 7,259 | 219 | <1.0 | vf (0.086) | vf (downward) |
| | 2-W14-13 | 67.1 - 77.9 | 3/26/99 | 8,575 | VF | VF | VF | VF (downward) |
| | 2-W15-41 | 66.3 - 71.1 | 5/8/00 | 2,714 | 152 | < 1.5 | 0.311 | 0.232 – 0.401* |
| T | 2-W10-24 | 72.4 - 82.6 | 4/9/99 | 17,455 | 148 | 26 | 0.012 | 0.009 – 0.017* |
| S-SX | 2-W22-48 | 70.5 – 74.3 | 5/11/00 | 15,730 | 141 | 39 | 0.007 | 0.002 - 0.023** |
| | 2-W22-49 | 67.3 – 71.9 | 4/17/00 | 4,175 | 145 | 4.0 | vf (0.086) | vf (upward) |
| | 2-W22-50 | 67.5 – 71.9 | 5/1/00 (Test #1) | 5,765 | 190 | 5.2 | 0.066 | relatively uniform |
| | | | 5/26/00 (Test #2) | 7,240 | 148 | 6.5 | 0.046 | relatively uniform |

* permeability profile indicates highest permeability (highest flow velocity) near the middle of well screen; lowest permeability near top

** permeability profile indicates highest permeability (flow velocity) near top of well screen, becoming progressively lower with depth within well screen

$C_o$ estimated initial tracer concentration based linear back-projection of average well screen conditions

$C_t$ average observed well-screen tracer concentration at termination of test

$v_w$ average groundwater flow velocity within well

$v_{wz}$ groundwater flow velocity range within well determined from individual probe/depth-settings

vf slight vertical flow conditions detected adversely affect tracer test results; vertical flow direction indicated in parentheses

VF significant vertical flow conditions in well invalidating tracer-dilution test; vertical flow direction indicated in parentheses

**Table 4.** FY-99 and FY-00 Tracer-Pumpback Test Analysis Summary for WMA TX-TY, T, and S-SX

| WMA | Well | Aquifer Thickness b m | Hydrologic Characterization Tests | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Tracer Pumpback Test | | | |
| | | | Pumping Rate Q L/min | Hydraulic Gradient m/m | Trans-missivity T $m^2/d$ | Tracer Drift Time $t_d$ min | Tracer Recovery Time $t_p$ min | Effective Porosity, $n_e$ | Ground-Water Flow Velocity $V_a$ m/d |
| TX-TY | 2-W10-26 | 55.0 | 39.5 | 0.00073 | 82 | 7,259 | 16.0 | vf (0.010) | vf (0.124) |
| | 2-W14-13 | 55.0 | 48.9 | 0.00073 | 135 | 8,575 | 43.3 | VF (0.009) | VF (0.191) |
| | 2-W15-41 | 57.6 | 60.4 | 0.00129 | 1130* | 2,714 | 109.0 | 0.068* | 0.374* |
| T | 2-W10-24 | 54.0 | 41.2 | 0.00172 | 66 | 17,455 | 37.1 | 0.072 | 0.029 |
| S-SX | 2-W22-48 | 70.1 | 7.0 | 0.00180 | 127* | 15,730 | 159.1 | 0.257* | 0.013* |
| | 2-W22-49 | 72.5 | 42.2 | 0.00206 | 520* | 4,175 | 14.9 | VF (0.671*) | VF (0.022*) |
| | 2-W22-50 | 73.5 | 28.5 (Test #1) | 0.00206 | 385* | 5,765 | 43.4 | 0.354* | 0.030* |
| | | | 29.2 (Test #2) | 0.00206 | 385* | 7,240 | 108.8 | 0.221* | 0.049* |

* preliminary hydraulic property estimate values (T); tracer pumpback results subject to revision
$t_d$ time tracer allowed to drift from well into surrounding aquifer prior to pumpback
$t_p$ time required to recover 50% of the tracer mass during the pumpback
$v_a$ groundwater flow velocity within aquifer
(vf) slight vertical flow conditions in well detected; tracer test estimates for $n_e$ and $v_a$ are questionable
VF significant vertical flow conditions in well detected; tracer test estimates for $n_e$ and $v_a$ are highly questionable

**Table 5.** FY-99 and FY-00 Groundwater Flow Characterization Results Based on Trend-Surface Analysis for WMA TX-TY, T, and S-SX

| WMA | Well | Measurement Date | Trend-Surface Analysis Results | | |
|---|---|---|---|---|---|
| | | | Groundwater Flow Direction 0° = East; 90° = North | Hydraulic Gradient m/m | Wells Used in Analysis |
| TX-TY | 2-W10-26 | 5/3/99 | 288° | 0.00073 | 299-W10-17, -W10-18, -W14-12, -W15-12, -W15-22 |
| | 2-W14-13 | 5/3/99 | 288° | 0.00073 | 299-W10-17, -W10-18, -W14-12, -W15-12, -W15-22 |
| | 2-W15-41 | 5/8-11/00 | 286° | 0.00129 | 299-W14-5, -W14-6, -W14-14, -W15-40, -W15-41 |
| T | 2-W10-24 | 4/21/99 | 5° | 0.00172 | 299-W10-8, -W10-12, -W10-22, -W10-24, -W11-23, -W11-27 |
| S-SX | 2-W22-48 | 5/18/00 | 2° | 0.00180 | 299-W22-45, -W22-48, -W23-13 |
| | 2-W22-49 | 5/31/00 | 1° | 0.00206 | 299-W22-49, -W22-50, -W23-14, -W23-15 |
| | 2-W22-50 | 5/31/00 | 1° | 0.00206 | 299-W22-49, -W22-50, -W23-14, -W23-15 |

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