PNNL-13801

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

Groundwater Quality Assessment Report for Waste Management Area S-SX (April 2000 through December 2001)

V. G. Johnson
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Prepared for the U.S. Department of Energy
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Preface

This report was written to comply with the requirements stipulated in the Resources Conservation and Recovery Act (40 CFR 265, Subpart F) and in the State of Washington dangerous waste regulations (WAC 173-303). These regulations require groundwater monitoring at facilities that treat, store, transfer, and/or dispose of dangerous waste.

The regulated unit addressed in this report is one of seven single-shell tank waste management areas at the Hanford Site located in south central Washington State. The single-shell tanks contain radioactive high-salt defense waste generated during the chemical separation of weapons grade plutonium. Nearly half of the 149 individual single-shell tanks are known or suspected to have leaked. Spills associated with waste transfers within the waste management areas have also occurred. Retrieval, processing, and final disposal and/or stabilization in place of these wastes will take place over the next 30 to 40 years.

Mobile tank waste constituents (e.g., technetium-99, hexavalent chromium, and nitrate) have appeared in some downgradient wells at five of the seven single-shell tank waste management areas. Groundwater and vadose zone characterization activities are underway to evaluate the nature and extent of the subsurface contamination. The groundwater studies at the single-shell tank waste management areas are part of the Hanford Groundwater Monitoring Project conducted by Pacific Northwest National Laboratory for the U.S. Department of Energy. Additional background information and related subsurface conditions at Hanford Site can be found at http://hanford-site.pnl.gov/groundwater.

Summary

This report presents the results of a continued groundwater quality assessment to determine the rate of movement and extent of contamination in the uppermost aquifer beneath Waste Management Area S-SX in the 200 West Area of the Hanford Site. The primary focus is on interpretation of data acquired between April 2000 and December 2001 from new and existing wells since the last assessment report (PNNL-13441). In addition to routine quarterly groundwater sampling from the new and existing network wells, additional hydrologic testing was also conducted, adding to the understanding of site-specific hydrologic conditions.

Two upgradient replacement wells and six new downgradient wells were installed. No significant new contamination was discovered in the new wells during the report period. However, rapidly increasing concentrations of technetium-99 and associated mobile tank waste contaminants were observed in two existing S tank farm wells (299-W22-44 and 299-W22-48).

Technetium-99 continues to be the constituent with the highest concentration relative to a drinking water standard. Well 299-W23-19 at tank SX-115 continues to exhibit elevated concentrations with a maximum of 81,500 pCi/L relative to the drinking water standard of 900 pCi/L. Interim corrective measures (conducted by CH2M HILL Hanford Group, Inc.) included (1) permanently cutting and capping old pressurized water lines in close proximity to the soil column source of contamination near tank SX-115 and (2) surface run-on control. The water line work was completed on April 25, 2001. If suspected water line leakage transported tank waste through the vadose zone to groundwater at this location, contaminant concentrations should begin to decline from the maximum of 81,500 pCi/L that occurred in March 2001. A clear downward trend has not yet been established in this well. However, technetium-99 concentrations have not continued to increase as observed prior to the corrective measures.

Evaluation of the extent of the apparent contaminant plume at the southern end of the SX tank farm suggests the rate of movement is slow (<20 meters per year) and the contaminant plume is limited in extent. Predicted areal distribution is consistent with contaminant concentrations in the observations wells within the boundaries of the theoretical concentration contours, lending confidence in the predictive modeling approach used.

Based on the predicted technetium-99 concentration contours, the areal extent of groundwater contamination that exceeds the cleanup target level of 9,000 pCi/L is estimated to be equivalent to the area of two single-shell tanks (about 800 m^2). The very low hydraulic conductivities in the southwestern area of the SX tank farm indicate that movement of contaminants that reach the water table in this area may be severely restricted in lateral movement.

The groundwater quality assessment at Waste Management Area S-SX has evolved from a detection phase to assessment and characterization followed by interim corrective measures. The groundwater sampling and analysis conducted at this site in the future should help determine the efficacy of the corrective measures that were undertaken to reduce or eliminate sources of groundwater contamination within Waste Management Area S-SX.

Acknowledgments

The authors wish to thank Dave Myers (CH2M HILL Hanford Group, Inc.) and Frank Spane, Stuart Luttrell, and Ron Smith (Pacific Northwest National Laboratory) for critical review and constructive comments on the manuscript. We are also indebted to Evan Dresel, Bruce Williams, Chris Newbill, and Dave Lanigan (Pacific Northwest National Laboratory) for interpretive graphics. Special thanks are due to Darrell Newcomer and Vince Vermeul (Pacific Northwest National Laboratory) for the hydrologic field testing conducted for this project.

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1.0 Introduction

This report presents the results of a continued groundwater quality assessment to determine the rate and extent of contamination in the uppermost aquifer beneath Waste Management Area S-SX in the 200 West Area of the Hanford Site (Figure 1.1). The primary focus is on interpretation of data acquired between April 2000 and December 2001 from new and existing wells since the last assessment report (Johnson and Chou 2001).

Eight new wells were installed between April 2000 and December 2001:

- Two upgradient replacement wells (299-W23-20 and 299-W23-21) to address past-practice discharge sources (ponds, ditches, and cribs)

- Four downgradient wells (299-W22-80, 299-W22-81, 299-W22-84, 299-W22-85) to enhance spatial coverage, and two downgradient wells (299-W22-82 and 299-W22-83) to further delineate the areal extent of groundwater contamination in the vicinity of the south end of the SX tank farm.

In addition to the routine quarterly groundwater sampling from the new and existing network wells, additional hydrologic testing was conducted, adding to the understanding of site-specific hydrologic conditions. The hydrologic testing is summarized in this report and will be released as a separate document that will include a detailed description of hydrologic test procedures and results.

1.1 Background

Waste Management Area S-SX was placed into groundwater quality assessment monitoring status in June 1996. An initial assessment report, based on the results of a first determination, was issued in February 1998 and concluded the waste management area was contributing to groundwater contamination (Johnson and Chou 1998). Thus, a continued assessment of the rate, extent, and concentration profiles of the contamination is required [see 40 CFR 265.93(d)(7)]. Accordingly, an assessment plan (Johnson and Chou 1999a) was prepared to obtain the data needed to determine the rate and extent of contaminant migration and concentrations in groundwater.

The groundwater assessment for Waste Management Area S-SX is being conducted concurrently and in coordination with the vadose zone investigations for the Resource Conservation and Recovery Act (RCRA) Facility Investigation/Corrective Measures Study (RFI/CMS), as described in Tri-Party Agreement Milestone M-45 (Ecology et al. 1998). The RFI/CMS work is being conducted by CH2M HILL Hanford Group, Inc. (Tank Farm Vadose Zone Project) for the Office of River Protection, U.S. Department of Energy, in response to Tri-Party Agreement Milestone M-45. Summary information on assessment results is also included in quarterly reports to the Washington State Department of Ecology (Ecology) and annually in the groundwater monitoring annual reports (http://hanford-site.pnl.gov/groundwater/reports/gwrep00/start.htm).

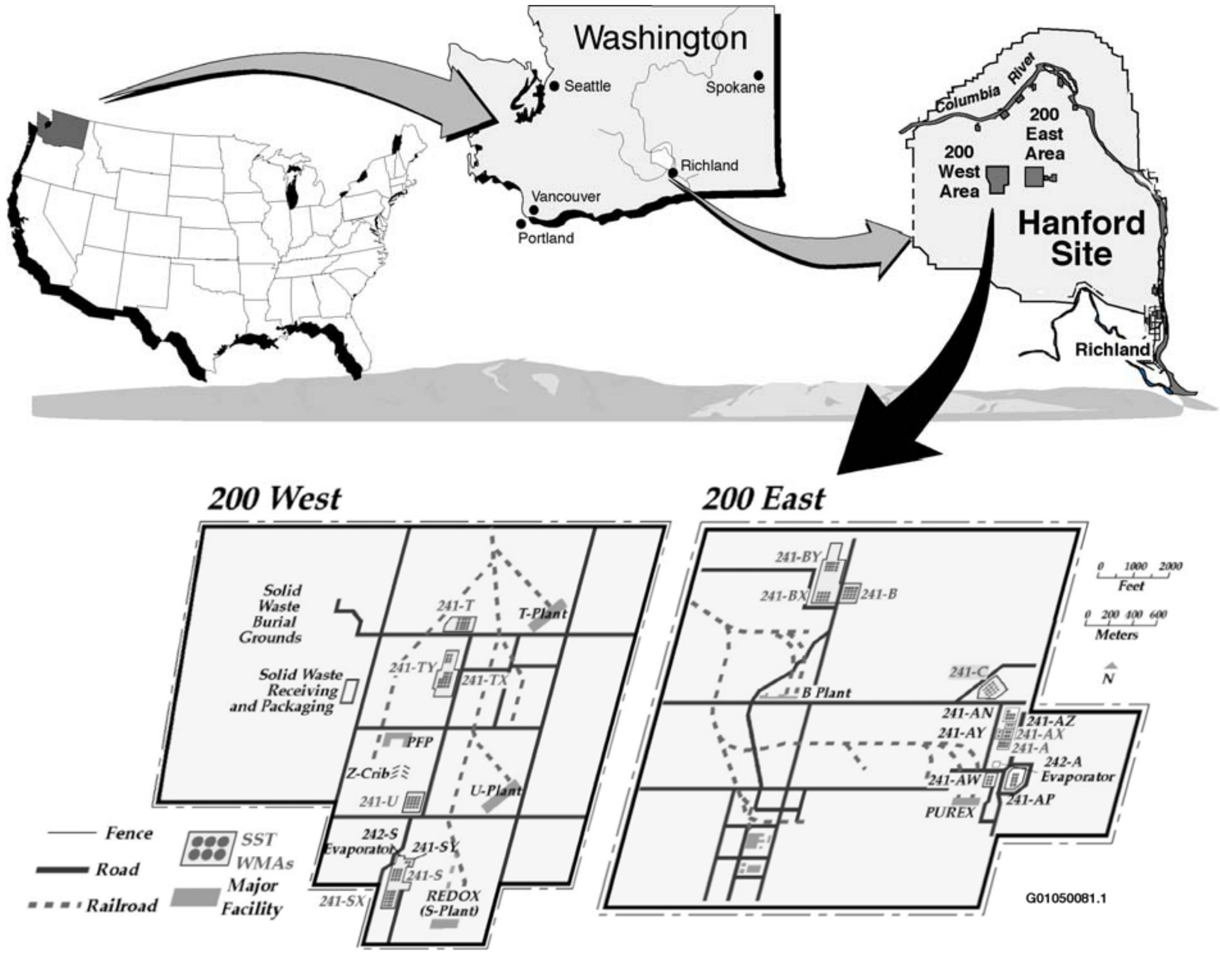

Figure 1.1. Map of the Hanford Site. The single-shell tank storage area addressed in this paper is designated as the 241-S and 241-SX tank farms, located at the southern end of the 200 West Area. SST = Single-shell tanks. WMA = Waste management areas. Rectangles with solid circles show the locations of the nuclear waste storage areas (subsurface tanks and ancillary equipment).

1.2 Scope and Objectives

The primary objective of a RCRA groundwater quality assessment is to determine the rate, extent, and concentrations of contaminants attributable to the regulated waste management unit. The scope of this report is limited to new water quality data and hydrologic testing results obtained subsequent to the cutoff (April 2000) for the previous assessment report. Hydrogeology of the site, stratigraphy, waste site descriptions, and contaminant hydrology were described in the first assessment report (Johnson and Chou 1998) and addendum (Johnson and Chou 1999b), and in the updated assessment plan (Johnson and Chou 1999a).

Supporting information (e.g., drillers log, geologist logs, geophysical logging results) are available in the project files of the Hanford Groundwater Monitoring Project at Pacific Northwest National Laboratory (PNNL) and in the borehole data packages for the new wells that were drilled during the report period (e.g., Horton and Johnson 2001).

1.3 Report Organization

Organization of this report is based on the objectives for the continuing assessment, which are to determine the rate and extent of migration and concentration of groundwater contamination. The primary focus is on interpretation of data acquired between April 2000 and December 2001 from new and existing wells since the last assessment report (Johnson and Chou 2001). Accordingly, Chapter 2 provides information on the eight new wells drilled during the report period. Chapter 3 addresses the rate of groundwater movement and direction of flow based on hydrologic data acquired from the existing and new wells tested. Chapter 4 provides the maximum concentrations of the primary mobile constituents of concern at Waste Management Area S-SX that were detected during the report period. Non-RCRA wells are included in addition to the RCRA-compliant wells in the network. Chapter 5 addresses areal and vertical extent of contamination based on existing well data and on new observations from new RCRA-compliant monitoring wells installed for this assessment. Chapter 6 presents conclusions regarding the rate and extent of contaminant migration.

Preliminary analysis results of hydrologic characterization at new wells installed during the report period at Waste Management Area S-SX are included in Appendix A. Results of continuous monitoring of specific conductance during step drawdown and constant discharge testing at well 299-W23-19 inside the SX tank farm are presented in Appendix B. The hydrologic testing in well 299-W23-19 was conducted by CH2M HILL Hanford Group, Inc. to assess the feasibility of a pump and treat at this location.

English units are used in some places in this report (e.g., Tables 2.1, 5.1) to maintain the integrity of the data and because they are used by drillers to measure and report depths and well construction and development details. The conversion to metric may be made by multiplying feet by 0.3048 to obtain meters or multiplying inches by 2.54 to obtain centimeters, and gallons by 3.785 to obtain liters.

2.0 Description of New Wells

The eight new wells drilled during the report period are listed in Table 2.1. Drilling method used, completion depth, drawdown during development, and sediment texture characteristics for the screened interval in the saturated zone are also summarized in Table 2.1. Locations are shown in Figure 2.1.

The two new upgradient wells (299-W23-20 and 299-W23-21) were installed to replace the old upgradient wells (299-W23-13 and 299-W23-14), which were going dry. Four of the new downgradient wells were added to address gaps in spatial coverage as identified in PNNL-13441 (Johnson and Chou 2001). Two mid-field wells (299-W22-82 and 299-W22-83), located near the southeastern corner of SX tank farm, were added to assess the lateral extent of the contaminants believed to be emanating from the southern end of the SX tank farm (see Figure 2.1 for locations).

All of the wells were completed with nominally 11 meters of submerged screen. Two of the wells (one upgradient and one downgradient) were drilled by air rotary methods. The others were all drilled by cable tool methods. Split spoon core sections in 2-ft (0.61 meter) lengths were collected at the top, mid and bottom of the screened intervals. The latter were used to determine particle size distribution and for lithologic examination.

Indications of relative aquifer permeability are evident from the drawdown that occurred during development pumping (see Table 2.1). The maximum observed drawdown in each well ranged from 2 to 29 ft (0.61 to 8.8 meters). The wide range in drawdown is indicative of the heterogeneity of the uppermost aquifer in this area.

Sediment texture (see Table 2.1) is suggestive of vertical variability in permeability over the screened interval in several of the wells. For example, sediments in the upper portions of wells 299-W22-20, -81, -82, -83, and -84 are described as silty sandy gravel changing to sandy gravel in the bottom sections (approximately the lower quarter of the screened intervals). The most significant textural change is in the bottom of well 299-W22-80 at the southern end of the SX tank farm. The driller's log notes that "heaving sand" was encountered in the bottom portion of this well (Horton and Johnson 2001). Particle-size data from the three core sections collected during drilling of this well also indicate a dramatic change in lithology near the bottom of the well. For example, the sediments are well sorted (uniform sand size) in the core section for the bottom of the well. In contrast, the upper sections indicate a mixture of sand, silt, and gravel. The well-sorted sand from the bottom section was unconsolidated and difficult to maintain in the core barrel (poor recovery). In contrast, the sediments from the upper sections were tightly packed (consolidated or semi-cemented) and good recovery was obtained. The well-sorted, unconsolidated sands in the bottom section are more permeable than the upper zones.

In addition to the above, discrete depth water samples were collected from the air lifted drill cuttings slurry produced from well 299-W22-80 (Horton and Johnson 2001). Field nitrate measurements indicated that nitrate concentrations were fairly uniform at about 8 mg/L in the upper three-quarters of the screened interval and declined to about 4 mg/L in the heaving sand zone near the bottom. The nitrate concentration

Table 2.1. New Wells Installed at Waste Management Area S-SX in 2000-2001

Well[a]	Date Drilled	Drilling Method	Submerged Screen Length (ft)	Development Rate/Max. Drawdown (gpm/ft)	Pump Intake (ft)	Total Drill Depth (ft)	Depth to Water (ft)[b]	Comments
W23-20[c]	08/2000	Air Rotary	34.9	29/2	220.8	260	215.6	Silty sandy gravel in upper sections of screened interval and sandy gravel in bottom (250 ft)
W23-21[c]	10/2000	Cable Tool	37.0	6/25	223	259	212.7	Silty sandy gravel – no change in texture for screened interval
W22-80[d]	09/2000	Air Rotary	34.8	30/3	214.5	251	205.3	Major texture break in bottom ¼ of screened interval; "heaving" sand at bottom (241 ft) Silty-sandy gravel down to heaving sand zone
W22-81[d]	01/2001	Cable Tool	35.8	8.5/22	237	269	225.9	Silty-sandy-gravel in screened interval – sandy gravel in bottom section (260.5 ft)
W22-82[e]	02/2001	Cable Tool	34.9	10/18.8	237.4	261	226.3	Silty sandy gravel in top section – sandy gravel in bottom section (260 ft)
W22-83[e]	03/2001	Cable Tool	33.5	10/29	237	261.3	227.8	Silty sandy gravel in upper sections and sandy gravel in bottom section (262 ft)
W22-84[d]	10/2001	Cable Tool	31.4	10/17.5	245.4	273	235.6	Silty sandy gravel in upper sections – sandy gravel in bottom section (265 ft)
W22-85[d]	10/2001	Cable Tool	33.6	30/11.5	226.6	260	218.4	Sandy gravel over entire screened interval

(a) All well name prefixed by 299-.
(b) At time of drilling.
(c) Replacement for upgradient well going dry.
(d) Enhance spatial coverage.
(e) Help delineate contaminant plume.

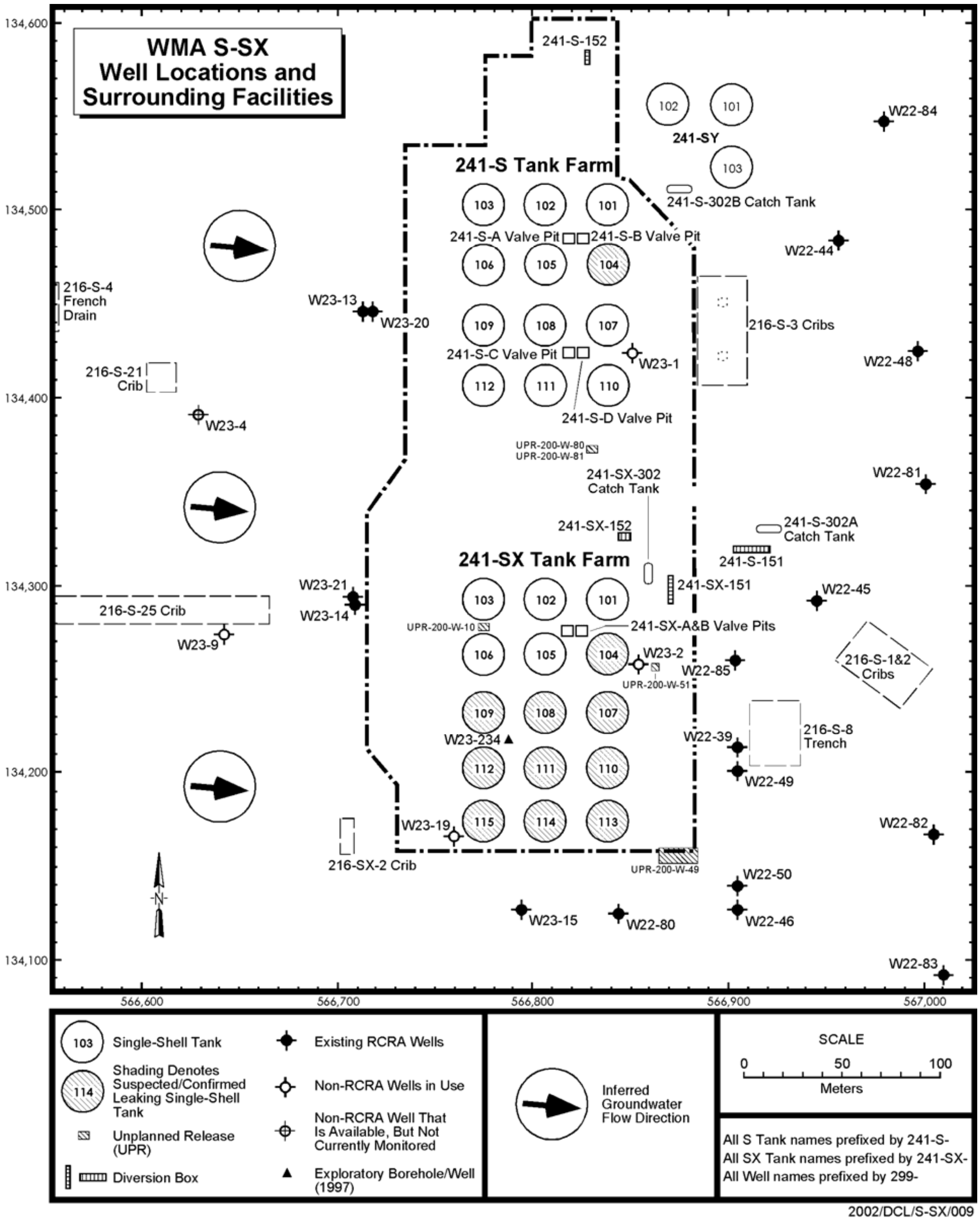

Figure 2.1. Location Map of Waste Management Area S-SX Monitoring Wells

observed after a pump was installed was 6 mg/L, suggesting that about half of the water produced from the well came from the lower quarter of the screened interval. The heaving sand zone observed at the bottom of this well was apparently not evident in the other wells in the S-SX network, although it has been noted in other wells in the 200 West Area. At S-SX, the heaving sand zone could be present but at depths below the maximum drill depths at the other network well locations (i.e., in wells other than well 299-W22-80).

The above observation suggests a deeper, relatively thin producing zone with low contaminant concentrations can dilute the concentrations from a lower yielding zone with higher contaminant concentrations at the top of the aquifer. The opposite could occur if the deeper, higher yielding zone has high contaminant concentrations relative to the top of the aquifer. The latter effect was observed in a well at the northeast corner of T farm.

In summary, vertical variability in aquifer properties must be kept in mind when interpreting contaminant concentrations and hydraulic data from wells completed across zones with variable permeability (i.e., in heterogeneous aquifers).

3.0 Rate and Direction of Groundwater Flow

The rate of groundwater movement beneath and in the vicinity of Waste Management Area S-SX is estimated from classical methods (Darcy equation), borehole tracer dilution tests, and observation of contaminant plume movement and tracer drift test arrival times.

3.1 Darcy Velocity

The Darcy equation for estimating velocity (v) requires measurement of hydraulic conductivity (K), effective porosity (n_e) and hydraulic gradient (i). The velocity is calculated from the following relationship:

$$v = Ki/n_e$$

For the Waste Management Area S-SX assessment, new hydraulic conductivity data were obtained from slug tests and drawdown tests conducted in the new wells installed for this site and in selected existing wells. Effective porosity was determined using tracer drift and pumpback test methods as described in PNNL Procedures for Groundwater Investigations[1] (PNL-MA-567, AT-7) and in Spane et al. (2001).

Variation in hydraulic conductivities among the existing and new wells tested (see Figure 3.1 and Appendix A) is consistent with the known aquifer heterogeneity and low permeability in the study area. The results also suggest the average groundwater velocity should be very low (5 to 20 meters per year) in the study area based on Darcy velocity estimates previously reported (Connelly et al. 1992) and based on more recent hydrologic test results (Spane et al. 2001).

3.2 Tritium Arrival Time

High concentrations of tritium occurred in groundwater at the 216-S-25 Crib in the past due to discharges of condensate from the S and SX tank farms. The most recent discharge occurred in 1985 and continued semi-erratically for about 5 years (Figure 3.2). Monitoring well 299-W23-9, located next to the eastern end of the crib (see Figure 2.1 for the 216-S-25 Crib and well locations), showed a sharp upward increase in 1986 in response to the crib discharges. This same sharp upward inflection occurs in three of the downgradient wells (299-W23-2, 299-W22-39, and 299–W22-46) located near the southeastern corner of the SX tank farm (see Figure 3.2). The sharp upward inflection in all of these downgradient wells

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[1] "Recommendations for Conducting Bromide Tracer-Dilution and Drift Pump-Back Tests." Procedure AT-7, found in *Procedures for Ground-Water Investigations*, PNL-MA-567, Pacific Northwest National Laboratory, Richland, Washington.

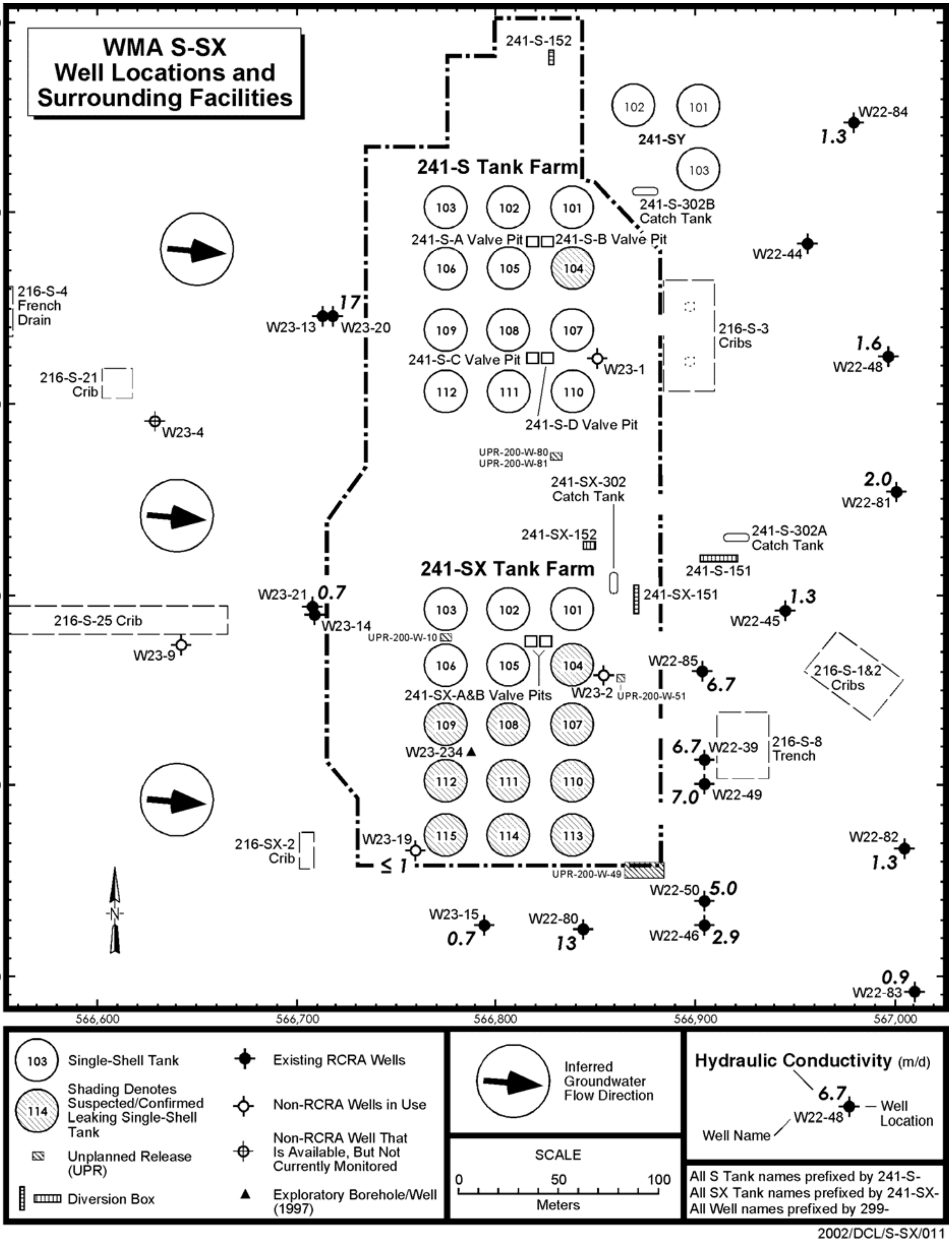

Figure 3.1. Hydraulic Conductivities in New and Existing Wells (1999-2001)

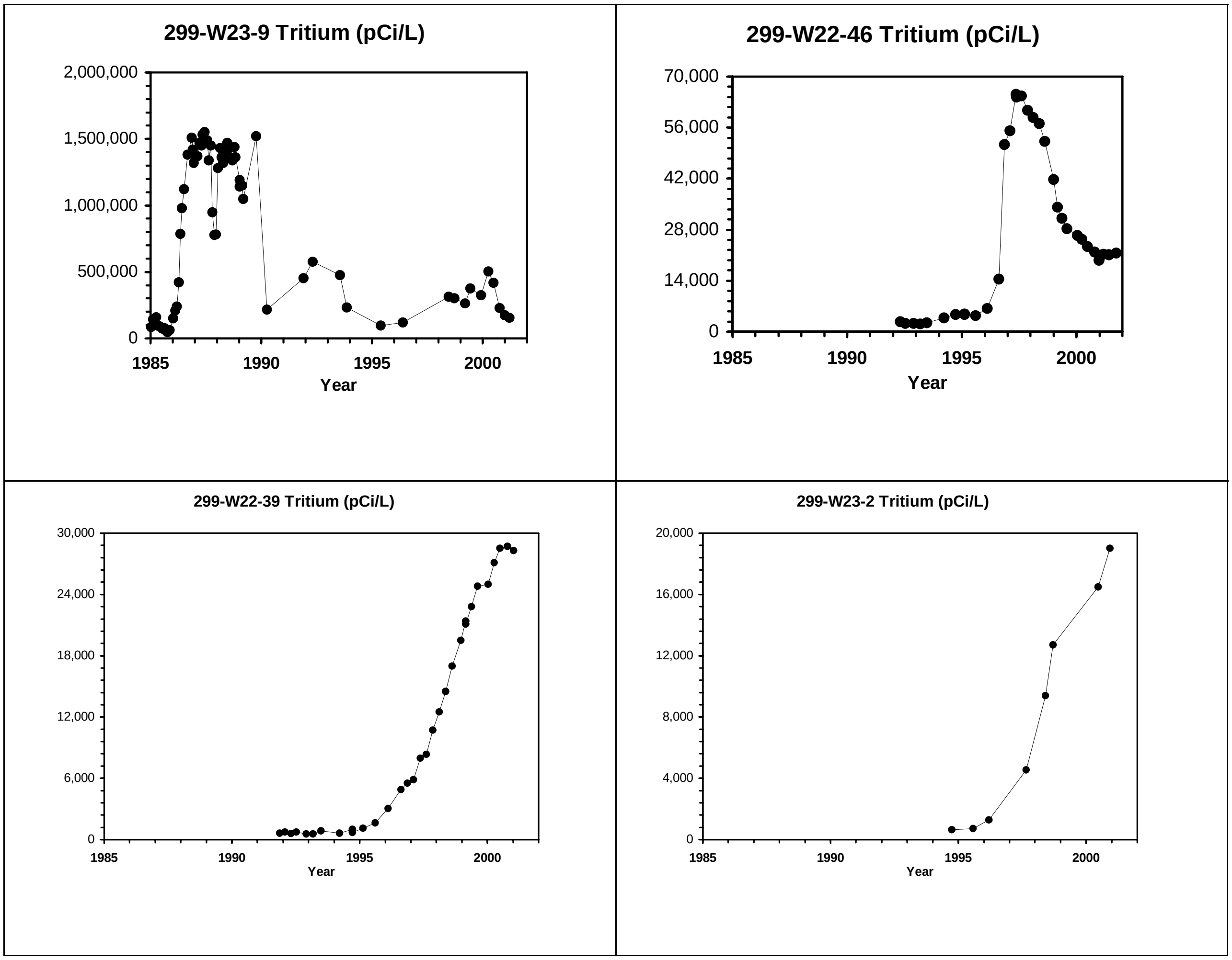

Figure 3.2. Correlation of Tritium Breakthrough in Upgradient Well 299-W23-9 and Downgradient Wells 299-W22-46, 299-W22-39, and 299-W23-2

occurs in about 1996 (plus or minus a year). Assuming the tritium source was the 216-S-25 crib and that well 299-W23-9 reflects the time-concentration pattern for this source in groundwater, the apparent travel time to the downgradient wells noted above is ~10 years (1986 to 1996). The average distance between well 299-W23-9 and these wells is about 250 meters. The apparent flow velocity along the centerline of the plume (Figure 3.3), is then 250 meters per 10 years = 25 meters per year.

3.3 Large Scale Bromide Tracer Drift Test

A volume of 16,000 liters of a 60,000 µg/L bromide solution (in Columbia River water) was injected into the top of the aquifer beneath the SX tank farm in March 1999, just prior to abandonment of borehole 41-09-39 (now named well 299-W23-234). The tracer was injected into a shallow (1.5 meter) screened interval in an attempt to simulate a large area source that had just entered the aquifer. The total dissolved solids content of the bromide solution matched the ambient groundwater. An initial tracer patch of

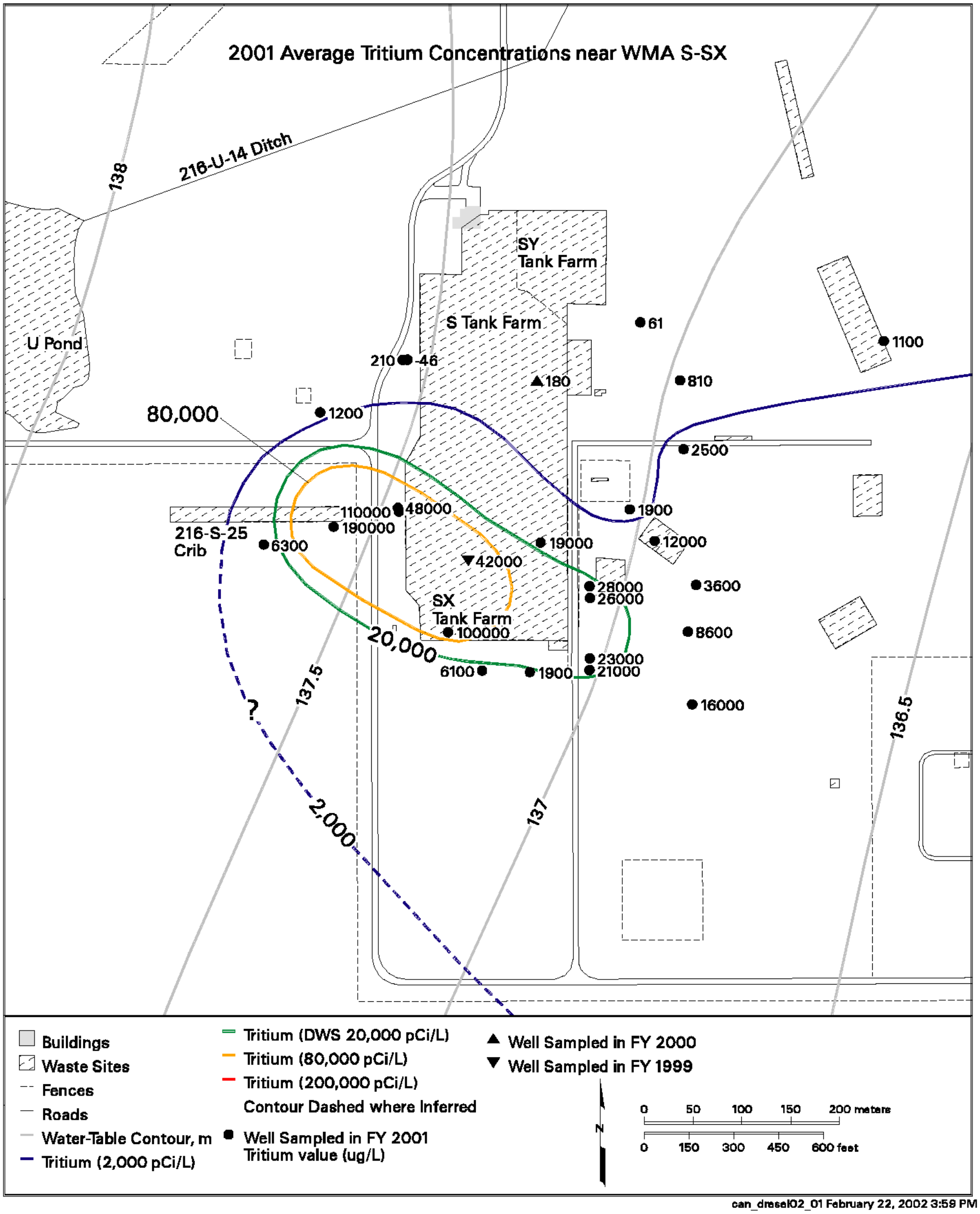

Figure 3.3. 2001 Average Tritium Plume and Water-Table Elevation Map (March 2001) for Waste Management Area S-SX and Vicinity

20 meters in diameter, or about the diameter of a single-shell tank, was intended. The primary objective was to test the efficiency of the downgradient monitoring wells to detect a simulated leak from a tank source. The elapsed time between when the tracer was injected and when it first appears in downgradient monitoring wells should also indicate flow rate in that area of the waste management area. Bromide measurements in downgradient wells are made by special request on samples collected during the routine RCRA quarterly sampling of the monitoring network wells. Nearly 3 years have passed since injection of the tracer. There is no evidence that the tracer has arrived yet in any of the wells located downgradient from the point of injection (i.e., wells 299-W23-19, 299-W23-15, 299-W22-50, 299-W22-49, 299-W22-46, 299-W22-39, and 299-W22-45). Bromide concentrations in these wells are currently being reported as non-detects with a detection limit of 10 μg/L. Since the initial bromide concentration of the tracer patch was 60,000 μg/L, bromide should be detectable in downgradient wells even at a dilution of 100 to 1,000 fold. Also, with such a slow apparent flow rate, it should take a year or more for the tracer patch (estimated to be 20 meters in diameter at the source) to pass by. Based on trend surface analysis of flow direction, well 299-W22-49 should be close to the center line of the trajectory (15 degrees south of due east) from the point of injection at well 299-W23-234. Of course in a heterogeneous aquifer, the actual pathway could deviate significantly from a straight line. Nevertheless, some idea of lateral spreading of the tracer patch can be obtained from the continuous release plume case (see Section 5.2.3).

The absence of bromide from the tracer drift test in any downgradient well is consistent with the low computed Darcy velocities (Spane et al. 2001) and the contaminant plume arrival times. For example, the nearest distance to a downgradient well from the point of injection is ~100 meters, and assuming an average velocity 25 meters per year (see Section 3.2), it would take 4 years to arrive at this well. The absence of the tracer in downgradient wells is consistent with the slow travel times indicated above based on tritium arrival times and Darcy velocities.

3.4 Flow Direction

The direction of groundwater flow was estimated based on the gradient in the water-table elevations in the S-SX network monitoring wells. This approach assumes the aquifer is homogeneous. Because there is evidence that the aquifer is non-homogeneous, this limitation must be kept in mind when applying the gradient analysis approach to estimate flow direction. A general flow direction may be estimated over the study area, but at any specific location, perturbations may occur in the local flow direction due to localized low permeability zones. Such variability is evident in the distribution of hydraulic conductivities for this waste management area (see Figure 3.1). For example, the southwestern area of the waste management area appears to be in a zone of very low hydraulic conductivity.

Trend surface analysis was applied to the water-table elevation gradient for various combinations of wells in the waste management area network (Spane et al. 2001). Annual water-table elevation measurements from 1992 to the present were selected for the same month of the year (August) to minimize atmospheric disturbance effects (barometric pressure changes can cause fluctuations in the static water level in a well and these effects are at a minimum during the late summer). Three combinations were evaluated: (1) the S tank farm and vicinity; (2) SX tank farm; and (3) the waste management area as a whole. A change in the direction of groundwater flow from southeast to a more easterly direction over time was evident in all three cases evaluated. Most of the shift in flow direction occurred in the northern part of the waste management area. This is because until June 1995, wastewater was discharged to the 216-U-14 ditch along the northwestern edge of the waste management area. The ditch caused a localized groundwater mound at that location, causing a southeasterly flow direction beneath the waste management area. Thus, prior to 1995 the prevailing direction of groundwater flow was more southeasterly. At the present time, the trend surface results for all the network wells combined suggests groundwater is flowing in nearly a due east direction.

The larger scale water-table map of Waste Management Area S-SX (see Figure 3.3) and the surrounding area suggests a flow direction that is a little more east-southeast than indicated by the localized trend surface analysis for Waste Management Area S-SX. The apparent tritium plume superimposed on the water-table map also seems consistent with the flow direction suggested by the larger scale water-table map. The difference in the trend surface results based on a relatively close grouping of network wells (Waste Management Area S-SX network) versus the larger area water-table map may be one manifestation of the effect of a non-homogeneous aquifer.

4.0 Maximum Contaminant Concentrations

Table 4.1 shows the maximum concentrations of the primary mobile constituents of concern at Waste Management Area S-SX detected during the report period. Non-RCRA wells are included as well as the RCRA-compliant wells in the network. Only filtered (0.4 µm) metal results were included in the summary. Results for anions and radionuclides are all based on unfiltered samples. The last column shows the highest maximum contaminant concentration (values in bold type) for each constituent divided by the applicable maximum contaminant level or drinking water standard, referred to as the relative hazard index for purposes of this report. The maximum uranium concentration is less than the maximum contaminant level of 30 µg/L and concentrations are higher in the upgradient wells than in down gradient wells (see Table 4.1).

Tritium is widespread in the network wells (see Table 4.1 and Figure 3.2) with the maximum concentration (417,000 pCi/L) occurring in well 299-W23-9 at the 216-S-25 crib. A persistent tritium plume has been associated with this crib for some time. The slow rate of movement is consistent with the low permeability of the aquifer sediments in this area as indicated in Chapter 3. While tritium also is associated with tank waste, the past-practice crib sources obscure additional contributions from tank farm sources, at least in the southern half of the waste management area. In contrast, tritium is virtually absent (see Table 4.1) in the northern half of the waste management area. Thus, any tank farm contribution should be evident in the S tank farm downgradient monitoring wells. Detectable tritium (maximum of 1,460 pCi/L, Table 4.1) was detected in just one well (299-W22-48) in the S tank farm area. This well is also currently showing an increasing trend in technetium-99, chromium, and nitrate (Figure 4.1).

The technetium-99 to nitrate ratios (Johnson and Chou 2001) are about the same (~0.05 pCi/1g-NO3) in 299-W22-48 as observed in the older well (299-W23-1) located 110 meters directly upgradient and inside the S tank farm. A transient in technetium-99 concentration that lasted for about one year occurred in well 299-W23-1 in 1986. The maximum concentration observed was 8,250 pCi/L (June 1986). Assuming this transient is just now arriving at well 299-W22-48 (see Figure 4.1), the implied travel time between the two wells is 14 years or 110 m/14 years = 8 m/year. An aquifer flow velocity of about 5 meters per year was determined based on tracer-pump back tests conducted in well 299-W22-48 (Spane et al. 2001). If the above assumptions are correct, the technetium-99 concentrations in well 299-W22-48 should reach a maximum and decline rapidly in 2002. If so, the apparent flow velocity in the S tank farm area, at least in the vicinity of wells 299-W23-1 and 299-W22-48, must be even slower than previously thought. The above considerations also rule out the 216-S-3 crib as a source of the increasing technetium-99 in 299-W22-48 since adequate technetium-99 concentrations occurred in groundwater upgradient of both the crib and well 299-W22-48.

The highest concentrations for all mobile tank waste related constituents of concern (technetium-99, nitrate, chromium, and tritium) occur in well 299-W23-19 located immediately adjacent to tank SX-115. The well with the second highest concentrations of technetium-99, nitrate, and chromium (well 299W-22-46) occurs directly downgradient from tank SX-115. Well 299-W22-48 (downgradient from S tank farm) is a close third. Contaminant concentrations in the latter well have been rising rapidly over

Table 4.1. Maximum Contaminant Concentrations for Groundwater Samples Collected from Waste Management Area S-SX Network Wells (April 2000 to December 2001)

Analyte	MCL	W22-39	W22-44	W22-45	W22-46	W22-48	W22-49	W22-50	W22-80	W22-81
Chromium(a) (µg/L)	100	16.3	5.1	27.8	39	37.3	9.3	20	4.4	10.4
^{99}Tc (pCi/L)	900	115	141	1,470(b)	4,550(b)	4,050(b)	381	3,530(b)	6.4U	529
Nitrate (as NO_3) (µg/L)	45,000	21,200	35,900	46,000(b)	48,300(b)	72,200(b)	18,100	30,500	7,530	22,600
Uranium (µg/L)	30	4.64	6.32	8.43	5.82	4.56	5.65	4.82	3.54	4.95
Gross alpha (pCi/L)	15	3.26	4.08	5.77	6.26	3.88	2.68	4.21	---	---
Gross beta (pCi/L)	50	38.1	39.4	689(b)	1,780(b)	954(b)	33.2	1,340(b)	---	---
Tritium (pCi/L)	20,000	28,700(b)	74.4 U	2,800	23,400(b)	1,460	27,400(b)	24,800(b)	1,970	3,110
^{90}Sr (pCi/L)	8	0.42 U	0.06 U	0.64 U	0.73 U	0.09 U	0.05 U	**1.49**	---	---
^{129}I (pCi/L)	1	---	---	---	0.22 U	0 U	---	0.312 U	---	---
^{137}Cs (pCi/L)	200	1.73 U	0 U	1.38 U	0 U	0.669 U	0.641 U	0 U	---	---
Iron(a) (µg/L)	300	118	30.5	30.4	37.2	34.2	347(b)	56.6 U	35.3	31.5 U
Manganese(a) (µg/L)	50	7.7	0.85	0.7	0.76	120(b)	13.8	24.6	2.8	24.1
Fluoride (µg/L)	4,000	470	360	470	500	440	520	520	530	440
Aluminum(a) (µg/L)	50	Not detected	Not detected	12.5	Not detected	28.3	Not detected	Not detected	29.7	25.1
pH	[6.5, 8.5]	[**6.99**, 8.29	[7.39, **8.98**]	[8.08, 8.43	[7.80, 7.89]	[8.22, 8.81]	[8.46, 8.92]	[7.90, 8.14]	[7.86, 7.9]	[7.7, 7.87]

Analyte	W22-82	W22-83	W22-84	W22-85	W23-1	W23-2	W23-4(c)	W23-9(c)	W23-13(c)
Chromium(a) (µg/L)	4.1	3.5	10	30 U	4.6 U	5.7 U	7.5 U	8	30.6
^{99}Tc (pCi/L)	62.7	483	85 U	70 U	371	131	13.6	71.4	0 U
Nitrate (as NO_3) (µg/L)	9,300	11,500	6,200	7,085	20,400	23,900	6,640	95,200(b)	10,600
Uranium (µg/L)	1.17	1.31	1.3	0.3	5.77	6.35	25.3	19.5	16.9
Gross alpha (pCi/L)	---	---	---	---	1.74 U	4.97	**17.9**(b)	12	11.3
Gross beta (pCi/L)	---	---	---	---	110(b)	56.6(b)	16.2	27.5	11.8
Tritium (pCi/L)	10,800	16,900			176 U	19,000	1,480	**417,000**(b)	152 U
^{90}Sr (pCi/L)	---	---	---	---	0.54 U	0.18 U	0.16 U	---	0.13 U
^{129}I (pCi/L)	---	---	---	---	0 U	0.073 U	---	0.148 U	---
^{137}Cs (pCi/L)	---	---	---	---	4.96 U	1.39 U	0.253 U	0 U	0.341 U
Iron(a) (µg/L)	40.1	27.7	320(b)	30 U	23	94.7	56.6 U	34.9 U	176
Manganese(a) (µg/L)	113(b)	72.6(b)	51(b)	53(b)	109(b)	9.1	2.9 U	12.3	14.4
Fluoride (µg/L)	570	530	1,300	**1,500**	440	420	380	390	410
Aluminum(a) (µg/L)	43.8	20.8	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected	Not detected
pH	[7.71, 7.85]	[7.81, 7.91]	7.8	7.7	7.22	8.2	[7.93, 8.09]	[7.73, 8.29]	[8.09, 8.31]

Note: All well numbers prefixed by 299-. U denotes analytical result is not detected. --- indicates not analyzed. **Bold** indicates well with maximum.
(a) Filtered sample results.
(b) Exceeds MCL.
(c) Upgradient wells.
(d) Maximum across all network wells.

Table 4.1. (contd)

Analyte	MCL	W23-14[c]	W23-15	W23-19	W23-20[c]	W23-21[c]	Max[d]	Max/MCL
Chromium[a] (µg/L)	100	8.1	8.7	**138**[b]	3.1	3.8	138	1.4
^{99}Tc (pCi/L)	900	36.9	21.4	**81,500**[b]	13.2	39.7	81,500	90.6
Nitrate (as NO_3) (µg/L)	45,000	68,600[b]	12,800	**677,000**[b]	4,870	54,400[b]	677,000	15.0
Uranium (µg/L)	30	18	13.8	**25.8**	5.83	14.2	25.8	0.9
Gross alpha (pCi/L)	15	10.3	9.16	16.1[b]	---	---	17.9	NA
Gross beta (pCi/L)	50	22	13.8	**28,700**[b]	---	---	28,700	NA
Tritium (pCi/L)	20,000	113,000[b]	8,530	115,000[b]	134 U	49,000[b]	417,000	20.8
^{90}Sr (pCi/L)	8	0.10 U	0.15 U	15.1 U	---	---	1.49	0.19
^{129}I (pCi/L)	1	---	---	**5.64**[b]	---	---	5.64	5.6
^{137}Cs (pCi/L)	200	0 U	2.06 U	2.56 U	---	---	Not detected	NA
Iron[a] (µg/L)	300	**2,530**[b]	248	102	16	40.5	2,530	8.4
Manganese[a] (µg/L)	50	202[b]	2.2	**329**[b]	2.2	16.9	329	6.6
Fluoride (µg/L)	4,000	320	500	330	480	460	1,500	0.4
Aluminum[a] (µg/L)	50	**1,160**[b]	21.2	24.7	25.6	44.3	1,160	23.2
pH	[6.5, 8.5]	[8.16, 8.28]	[7.89, 8.11]	[7.5, 7.84]	[7.96, 8.05]	[7.71, 7.91]	[6.99, 8.98]	NA

Note: All well numbers prefixed by 299-. U denotes analytical result is not detected. --- indicates not analyzed. **Bold** indicates well with maximum.
(a) Filtered sample results.
(b) Exceeds MCL.
(c) Upgradient wells.
(d) Maximum across all network wells.

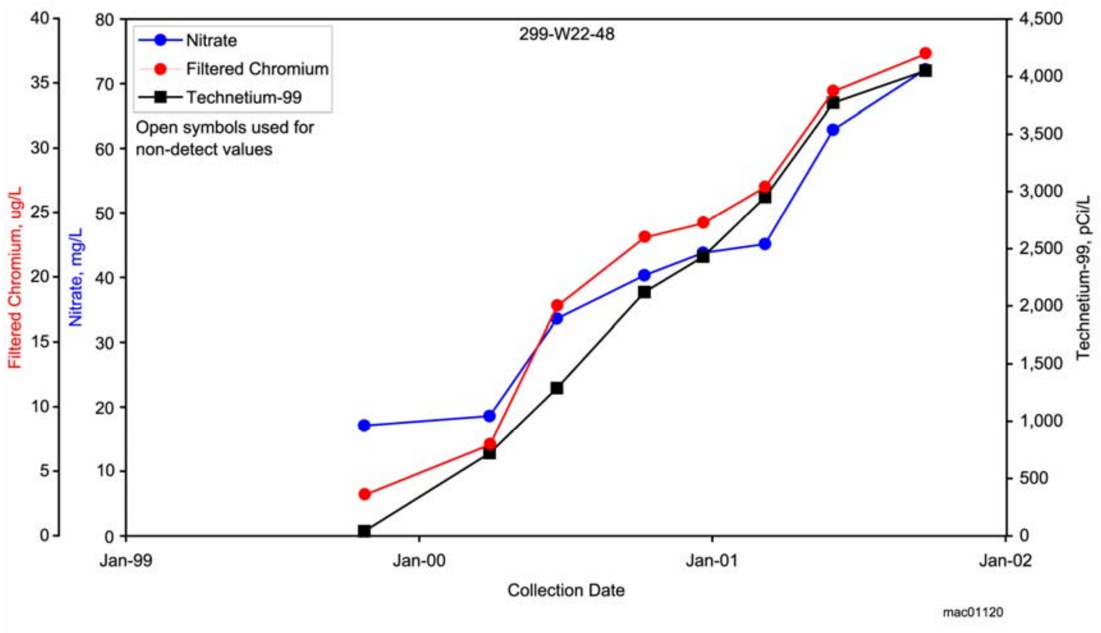

Figure 4.1. Technetium-99, Nitrate, and Chromium in Well 299-W22-48

the last year or so. Trends for the major mobile constituents related to tank waste are similar in both this well (see Figure 4.1) and well 299-W23-19 (Figure 4.2), indicative of a tank waste source in the S and SX tank farm areas, respectively.

The abrupt decline from the maximum that occurred in March 2001 for well 299-W23-19 may be related to pumping rate during purging prior to sampling (see Appendix B). For example, during a 3-hour development/step drawdown test at this well, continuous electrical conductivity monitoring of the discharge water was conducted. The electrical conductivity was observed to increase from a low of 800 µS/cm to a high of nearly 1,600 µS/cm as the pumping rate was decreased from 5 gallons per minute to about 1 gallon per minute. Nitrate and technetium-99 are approximately proportional to electrical conductivity in this well. Thus, contaminant concentrations ranged approximately a factor of two as a result of the altered pumping rate. When the pumping rate was held constant for a 72-hour period at a rate of 3 gallons per minute, the conductivity remained within a narrow range of 1,250 to 1,300 µS/cm (see Appendix B). Routine sampling of this well typically is conducted with a nominal purge rate of 1 gallon per minute. However, for the sampling event that resulted in the sharp drop in contaminant concentrations (August 2001; see Figure 4.2), the purge rate was initially set at 3 gallons per minute. The lower contaminant concentrations may have been due to the higher than normal purge rate rather than due to an actual change in contaminant concentrations in the aquifer.

Other apparent exceedances (see Table 4.1) are for aluminum, iron, and manganese. The elevated concentrations of these constituents are often associated with high turbidity. Apparently breakthrough of fine particulates (colloidal) through the membrane filter must occur when particle loading is high.

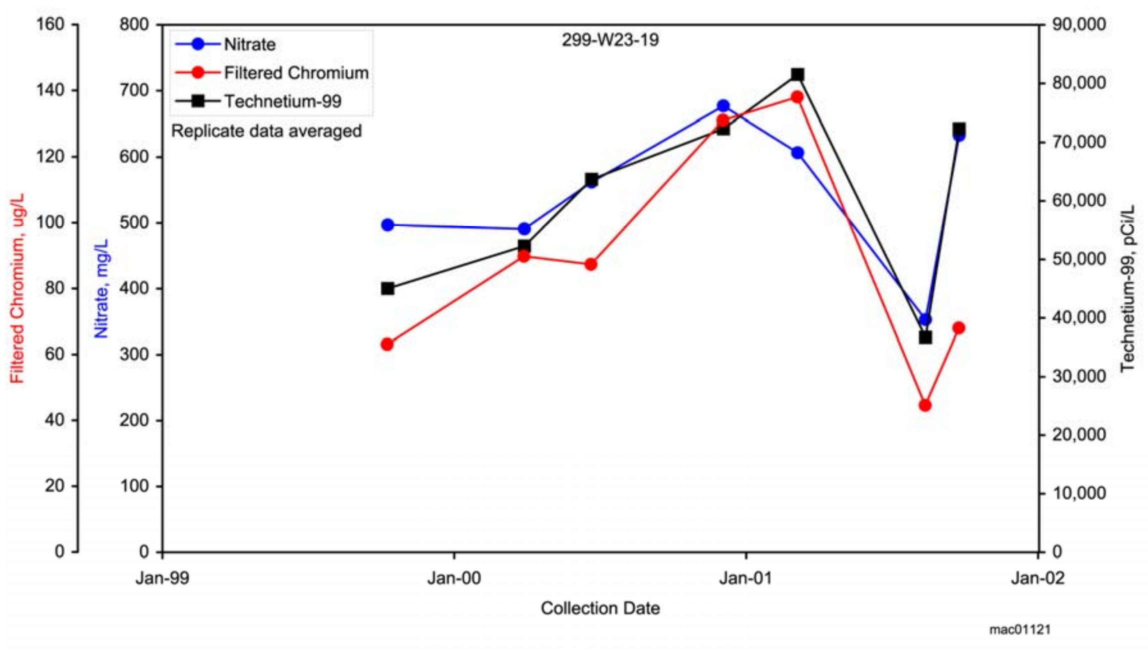

Figure 4.2. Technetium-99, Nitrate, and Chromium in Well 299-W23-19

Aluminum is abundant in contained tank waste but is not expected to be very soluble at the natural pH of groundwater. For example, based on pH-aluminum solubility calculations (Figure 4.3), the theoretical dissolved aluminum concentration (zones below the line separating the solid phase, gibbsite, from dissolved species) is about 27 µg/L at a typical groundwater pH of 8. Thus it is unlikely that dissolved aluminum could exist at concentrations approaching the MCL (50 µg/L) even if elevated concentrations in pore fluid reached groundwater

Figure 4.3 also shows that aluminum is soluble at a pH that is either very high or very low. Therefore, tank waste that leaked into the soil column at very high pH (~12 or greater) would contain mobile species of aluminum. Some concern has been expressed that soluble aluminum in tank waste could reach groundwater. However, once the excess hydroxide is neutralized by reaction with aluminosilicate mineral phases, the pH will drop to ~9 and the dissolved aluminum should precipitate as a solid phase. By the time additional dilution of pore fluid occurs in transit to the water table, and after reaching the saturated zone at the water table, the natural groundwater pH of around 8 should dominate the pH of any waste liquid mixtures in groundwater. Except for two wells (299-W22-48 and 299-W22-49) that have somewhat elevated pH (attributed to residual cement that seeped into the sand pack around the screen), all network wells have a pH of around 8 (see Table 4.1).

The high maximum concentrations (filtered) of iron (up to 2,500 µg/L), manganese (202 µg/L), and aluminum (1,160 µg/L) occurred in well 299-W23-14 during a sampling event (December 29, 2000)

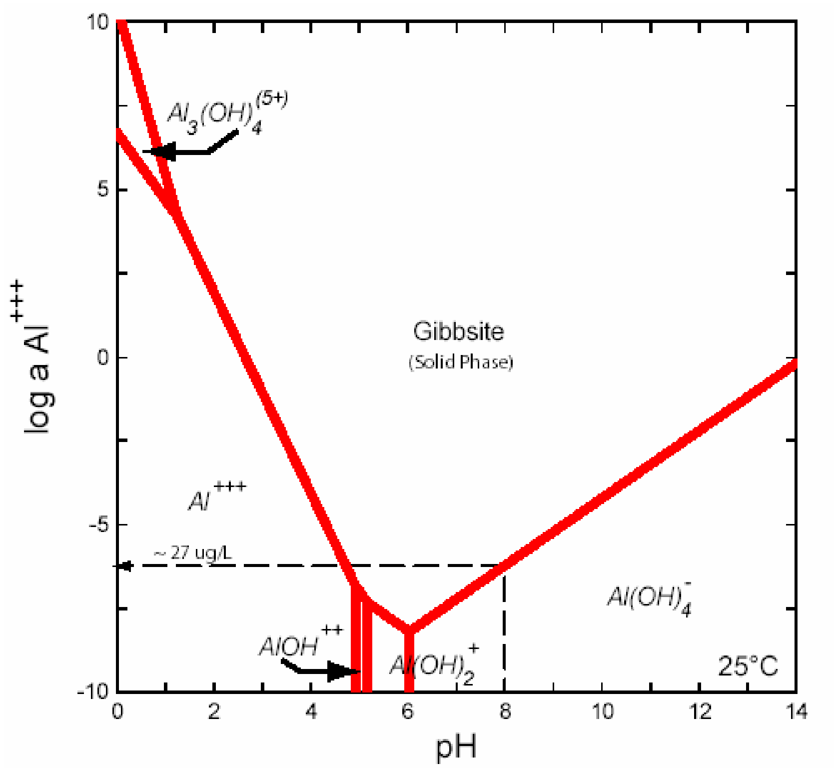

Figure 4.3. Dissolved Aluminum Concentrations as a Function of pH (Evan Dresel, personal communication, December 2001)

when the turbidity was very high (916 NTU). The high concentrations of iron, manganese, and aluminum are deemed to be sampling related and not representative of the aquifer. The high turbidity was due to re-suspension of sediment in the bottom of a well that was going dry (this well was replaced by new well 299-W23-21). Apparently, the high particulate loading of the filter resulted in failure of the membrane, allowing particulates to pass through.

Other constituents of concern not listed in the table were previously analyzed in selected wells with the highest likelihood of occurrence (Johnson and Chou 2001). For example, groundwater samples from well 299-W23-234 near tank SX 108 and well 299-W23-19 near tank SX-115 were analyzed for iodine-129, neptunium-237, plutonium-238, -239, and -240, and americium-241 (all unfiltered samples). The vendor reported non-detect results for all these constituents.

5.0 Extent of Contamination

Evaluation of the extent of contamination involves consideration of both vertical and areal distribution of contaminant concentrations. Vertical distribution at Waste Management Area S-SX was reported in the previous assessment report (Johnson and Chou 2001). Some new information related to vertical extent also was acquired for this report but the primary emphasis is on areal extent based on:

- data from existing wells and new wells installed to fill gaps along the S and SX tank farm fence lines

- data from new wells that allow better delineation of the lateral extent of the technetium-99 plume originating from the south end of the SX tank farm.

A review of previous and new vertical information is discussed first, followed by a discussion of areal distribution based on both observed and predicted results.

5.1 Vertical Distribution

Discrete depth sampling during drilling in 1999 suggested that most of the tank waste contaminants were within the upper 5 to 10 meters of the aquifer at the south end of this waste management area (Johnson and Chou 2001). Most of these data were acquired during air rotary drilling that allowed collection of multiple discrete-depth samples. A field screening method for technetium-99 (Beals et al. 2001) also was demonstrated in the field during the above air rotary drilling, providing discrete depth data in the field as the well was advanced. Only very limited discrete depth sampling was possible during the current report period since the cable tool method was used for most of the well drilling. However, some opportunity was provided to compare the very top of the aquifer (upper ~0.5 meter) with results for samples pumped from a 5- or 10-meter screened interval, discussed in the following paragraph.

Some reviewers (tank farm expert panel) postulated that tank farm contaminants at the SX tank farm may be wide spread but were missed because of either the long well screens (dilution of the signal) or deeper pump intakes that missed the major zone of contamination. To investigate this hypothesis, three well pairs (a well going dry and its replacement) were sampled at the same time, thus allowing comparison of contaminant concentrations at the very top of the aquifer with concentrations pumped from a relatively long screened interval. Results are shown in Table 5.1. Technetium-99 concentrations in the downgradient pair at the SX tank farm are very low and about the same concentration. This suggests that at this location, a major contaminant plume was not missed due to the use of sample pump intakes that are set too far below a thin contaminant layer at the top of the aquifer.

Contaminants in the upgradient well pairs indicate concentrations are a factor of 2 or 3 higher in the shallow well as compared to concentrations in the deeper wells. There appears to be dilution due to mixing from sampling across the long well screen at these upgradient locations (Martin-Hayden and Robbins 1997). But even in this case, the contaminants were not missed. Some dilution of the signal can be expected, especially in a heterogeneous aquifer (see discussion in Chapter 2).

Table 5.1. Comparison of Concentrations in Shallow and Deep Wells at Waste Management Area S-SX

Constituent (Unit)	Upgradient Pair (S Farm)		Upgradient Pair (SX Farm)		Downgradient Pair (SX Farm)	
	W23-13[(a)] (Shallow)	W23-20[(b)] (Deep)	W23-14[(a)] (Shallow)	W23-21[(b)] (Deep)	W22-39[(a)] (Shallow)	W22-49[(c)] (Deep)
Uranium (μg/L)	15	5.4	14.8	11	4.6	3.6
Tritium (pCi/L)	152 U	40 U	100,000	48,600	28,300	24,500
Technetium-99 (pCi/L)	0 U	0 U	36.9	29.2	115	86.4
Nitrate (μg/L)	8,411	3,537	62,860	46,039	21,249	11,952
Chromium (μg/L)	5.7	5.7	8.1	3.9	9.8	5.7
Sodium (μg/L)	20,600	21,700	28,800	26,100	23,700	23,000
Calcium (μg/L)	21,200	17,600	33,600	32,800	19,500	18,200
Alkalinity (μg/L)	94,000	86,000	82,000	66,000	86,000	92,000

Note: All well numbers prefixed by 299. U denotes analytical result is not detected. Results in the table for shallow wells W23-13, W23-14, and W22-39 were collected from the last sampling events on 01/8/01, 12/29/00, and 01/8/01, respectively (all three wells went dry). Results in the table for deep wells W23-20, W23-21, and W22-49 were collected on 03/8/01, 03/19/01, and 01/8/01, respectively.
(a) 1-2 ft screen.
(b) 35-ft screen length.
(c) 15-ft screen length.

5.2 Areal Distribution

The most recent concentrations of technetium-99, the primary indicator of mobile tank waste, in the completed well network are shown in Figure 5.1. Data for the two most recently installed wells (299-W22-84 and 299-W22-85) are based on samples collected during drilling and development. Results for these two wells are provisional. Observed areal distribution is discussed separately for the S and SX tank farm areas followed by a comparison of observed and predicted technetium-99 plume concentrations at the south end of the SX tank farm.

5.2.1 S Tank Farm Area

Technetium-99 in a sample collected during drilling at well 299-W22-85 (located along the northern, downgradient fence line) was at or near the detection limit. This is the first time groundwater in this area has been available. There was some concern that groundwater contamination may exist in this area due to a past spill from a transfer line in the SY farm and the diversion box (241-S-152) at the north end of the S tank farm. With this new well in place, this area of the waste management area is now covered.

Elevated technetium-99 concentrations occur in the relatively new well 299-W22-48. In contrast, concentrations are relatively low in the wells immediately north (well 299-W22-44) and south (well

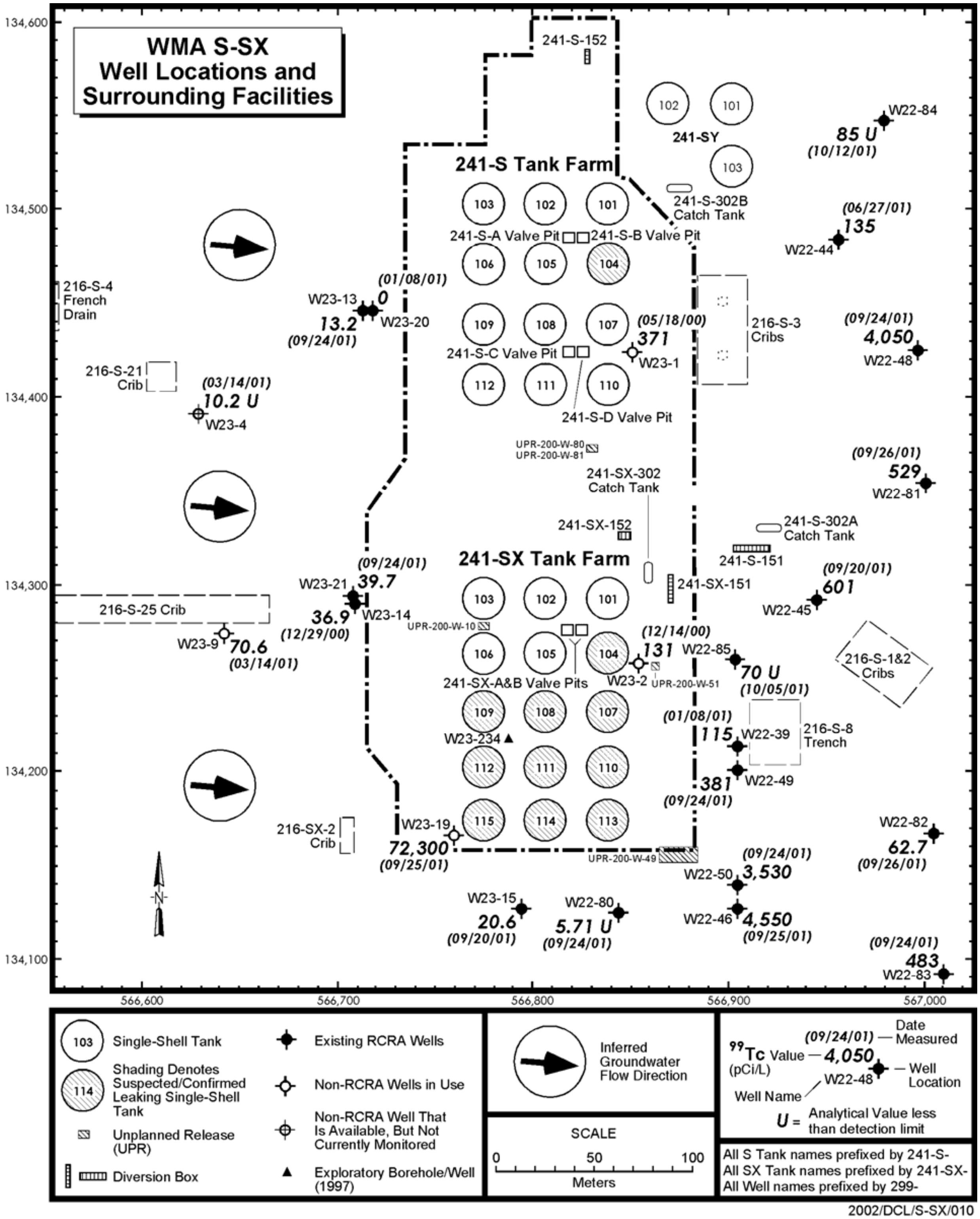

Figure 5.1. Areal Distribution of Technetium-99 at Waste Management Area S-SX

299-W22-81) of well 299-W22-48. The distance between wells at this location is ~60 meters. Thus, the contaminant plume must be somewhat narrow. The sharp upward trend in technetium-99 concentrations at well 299-W22-48 (see Figure 4.1) also suggests relatively little dispersion has occurred between the source and the well (see Section 5.3 discussion of the significance of sharp breakthrough curves).

While technetium-99 concentrations are low in well 299-W22-44, the sharp upward trend suggests the recent arrival of a groundwater plume in this area of the tank farm (Figure 5.2). Valve pits and tank S-104, the only tank designated as leaking in S tank farm, are upgradient from wells 299-W22-44 and 299-W22-48.

In addition to technetium-99 distribution, tritium provides some important information concerning areal distribution and groundwater movement in the S tank farm area. For example, in contrast to the SX tank farm area, tritium is virtually absent (see Table 4.1) in the S tank farm and vicinity. More importantly, there is no upgradient source (based on upgradient wells 299-W23-13 and W23-20). Any tank farm contribution of tritium should be evident in the S tank farm downgradient monitoring wells. Detectable tritium (maximum of 1,460 pCi/L, see Table 4.1) was observed in just one well (299-W22-48) in the S tank farm area. This well is also currently showing increasing trends in technetium-99, chromium, and nitrate (see Figure 4.1).

The areal distribution of uranium also reflects the past-practice, upgradient sources. However, unlike tritium, residual upgradient sources of uranium occur in the S tank farm area. For example, the 216-U-14 ditch, which passed along the northwestern side of the S tank farm, carried wastewater from the U Plant

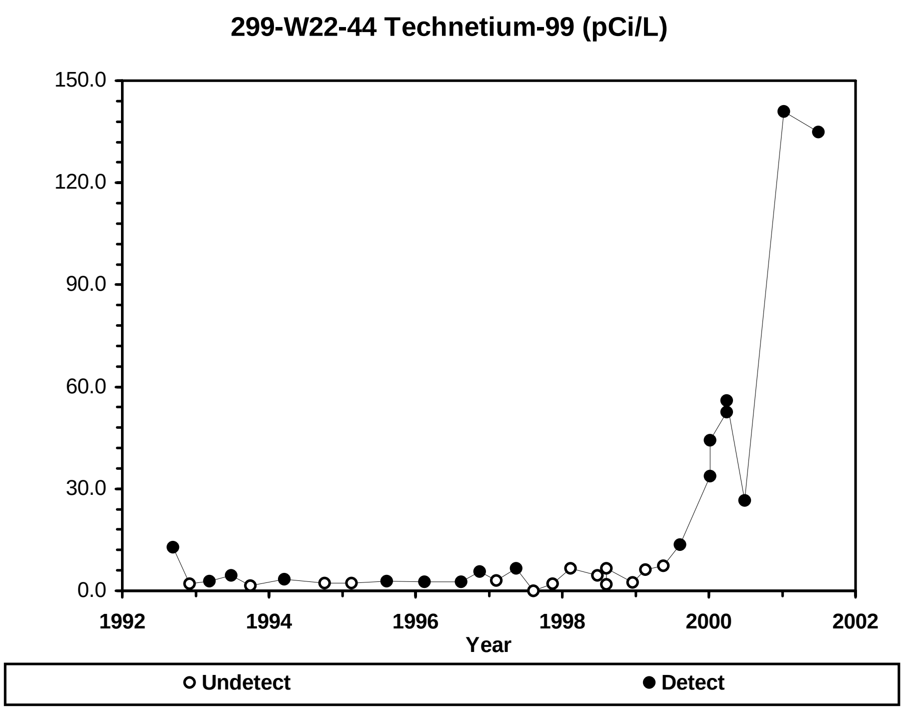

Figure 5.2. Technetium-99 Concentration in Well 299-W22-44 at S Tank Farm

to U Pond. Spills of uranium-bearing waste released to the ditch during the operational period may account for the apparent upgradient source in this area. The areal distribution of both tritium and uranium are consistent with the inferred flow direction (i.e., west to east or east-southeast).

5.2.2 SX Tank Farm Area

Contrary to expectations, no significant new contamination was found in new well 299-W22-85 located midway along the eastern fence line of the SX tank farm. This well is located downgradient from spill sites as well as tanks that have leaked in the past. Either groundwater contamination existed in this area but passed by, or it has not yet arrived (or it has not broken through the vadose zone to groundwater). Whichever the case, the gap in spatial coverage at this important location has been eliminated.

The distribution of technetium-99 in the SX tank farm area continues to be dominated by the source in the southwest corner near or at tank SX-115 (i.e., at well 299-W23-19). The new downgradient wells (299-W22-80, 299-W22-82, and 299-W22-83) help to define the transverse and longitudinal distribution of the assumed plume emanating from the vicinity of tank SX-115. The low concentrations observed thus far in the two new mid-field downgradient wells (299-W22-82 and 299-W22-83) suggest the assumed contaminant plume must be fairly restricted in areal extent. However, given the limited number of monitoring wells, predicted plume distribution patterns would be very useful. An initial attempt to provide such information is described in the following section.

5.2.3 Predicted Areal Extent

As already noted, one of the major objectives of the RCRA assessment is to evaluate the areal extent of contamination. However, the cost of an adequate density of wells to fully delineate plume dimensions is prohibitive. Predictive modeling provides one means of extending the limited well point data available. If there is concordance between predicted and observed data at a few well locations, more reliance on predicted plumes to aid in evaluation of the extent of contamination can be made.

Spatial domain. The highest and most persistent groundwater contaminant concentrations occur at the southern end of Waste Management Area S-SX, where tank leaks have occurred in the past. This is also the area where old pressurized water-supply lines that are suspected of leaking pass near some of the waste tanks with soil column contamination. Thus, this portion of the waste management area is of particular interest for interim corrective measures and remediation (such as eliminating sources of infiltrating water and conducting groundwater pump and treat). The scale of interest chosen for predicting plume dimensions is 75 meters wide by 200 meters long beginning at tank SX-115.

Approach. Plume modeling requires dispersivity values at the scale of interest as input parameters to the model. Since such information does not exist for the study site, a curve matching approach was first used to estimate dispersivities at the appropriate scale. Efforts were first directed at matching model predicted concentrations with an observed downgradient time-concentration pattern from which apparent dispersivity can be extracted. Technetium-99 in well 299-W22-46 (Figure 5.3) was assumed to represent the arrival and continued passing of a plume from the SX-115 tank area. The variable but persistent elevated concentrations over time indicate there is a quasi-continuous upgradient release. The well is located ~125 meters directly downgradient from tank SX-115, the assumed source. Travel time from the tank location to well 299-W22-46 is estimated to be over 6 years at a nominal flow rate of 0.06 meter per day. The lower initial concentrations (from 1992 and 1996) may be due to another upgradient crib source.

A three-dimensional, analytical dispersion model (PLUME –3D, Van der Heijde and Beljin 1998) was used (1) to simulate the contaminant arrival time of technetium-99 at well 299-W22-46, (2) to approximate the plume shape, and (3) to help estimate the lateral extent of contamination from the source area. As noted in Van der Kamp et al. (1994), simulation of contaminant arrival times and breakthrough patterns at known well distances from the contaminant source is particularly valuable for determining groundwater flow velocity and longitudinal dispersion.

The analysis procedure included an initial simulation of the technetium-99 contaminant arrival time profile at well 299-W22-46 (see Figure 5.3) to obtain preliminary estimates for hydrologic and transport parameters (e.g., groundwater-flow velocity, longitudinal and transverse dispersivities) within the contaminant plume area. Well 299-W22-46 is located near the plume center and ~125 meters from the contaminant source.

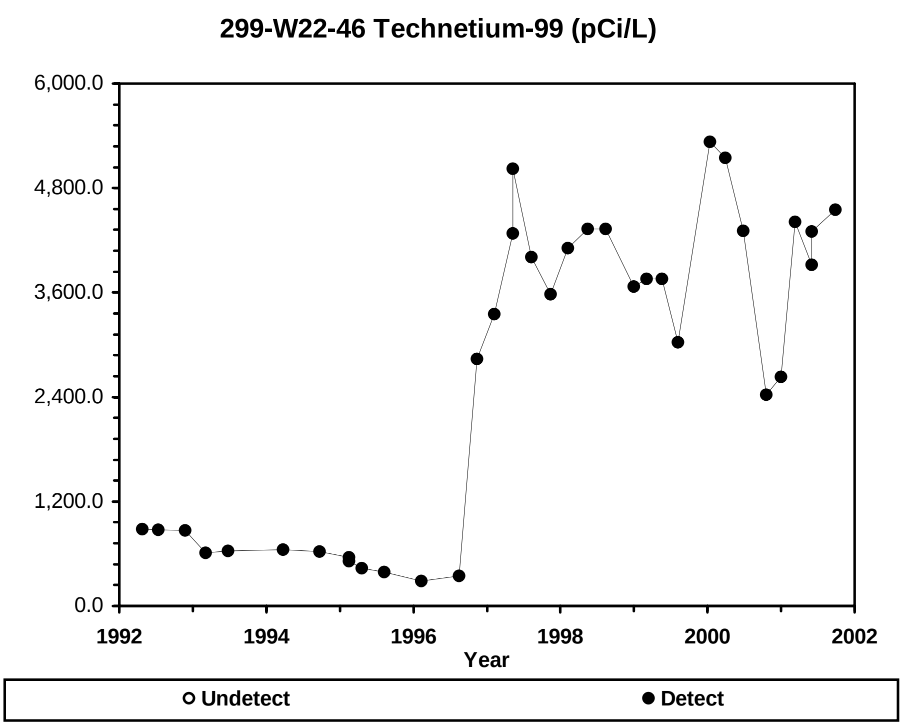

Figure 5.3. Technetium-99 Concentration in Well 299-W22-46 at SX Tank Farm

For initial input parameters for the simulation, the following values were used:

- A contaminant source input rate ranging between 6.6E-6 and 6.6E-7 kilograms per day (based on vadose zone core sample data from the tank leak site, a source area of 400 m^2, base area of a single-shell tank, and an infiltration rate of 10 centimeters per year)

- Ambient groundwater flow velocities ranging between 0.03 and 0.10 meter per day and an aquifer effective porosity of 0.25 (based on single-tracer test results: Spane et al. 2001)

- Transverse and longitudinal dispersivities of 1.2 and 8.5 meters, respectively (empirically derived from existing contaminant plumes in the vicinity, Wilson et al. 1992)

- An initial contaminant input date of circa 1990 (from Johnson and Chou 2001)

- A constant flow direction of 15 degrees south of due east (based on water level data for the nearest wells; Spane et al. 2001)

- Homogenous aquifer properties are assumed and concentrations were computed for the top of the aquifer where the highest technetium-99 concentrations have been observed (Johnson and Chou 2001).

The driving force for transporting contaminant from the tank to groundwater is assumed to be either enhanced natural infiltration or a leaking water line as depicted in Figure 5.4a. The single-shell tank (SX-115) is in a direct line of predicted flow to downgradient well 299-W22-46 (and adjacent well 299-W22-50).

Soil column characterization at borehole 48B revealed very high levels of cesium-137 (up to 1E+08 pCi/g; Raymond and Shdo 1966) just beneath the bottom elevation of tank SX-115 (illustrated as the red patch in Figure 5.4a). Mobile tank waste (technetium-99, nitrate, and chromium), however, were distributed downward to a much greater extent and assumed to eventually reach the water table. The blue area in Figure 5.4a indicates hypothetical distribution of infiltrating water and water-soluble tank waste. The water table is at about 65 meters below ground surface at this location.

The water line piping diagram (Figure 5.4b) shows the proximity of a 6- and 8-inch water line to the single-shell tanks along the southern fence line of the SX tank farm. These old water distribution lines were pressurized over an unknown time period but were capped and sealed permanently on April 25, 2001.

If seepage of water from these old lines acted as the primary driving force for transporting tank waste to groundwater at this location, technetium-99 concentrations should start to decline in well 299-W23-19 in the near future.

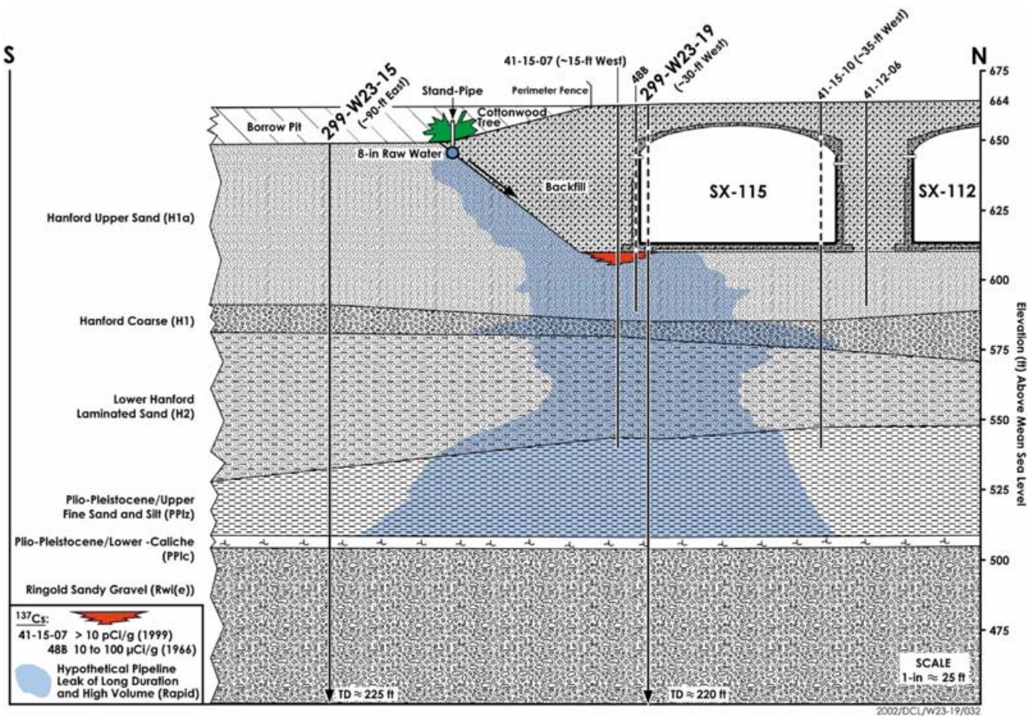

Figure 5.4a. Conceptual Model of Tank Waste Transport through Vadose Zone to Groundwater at Tank SX-115

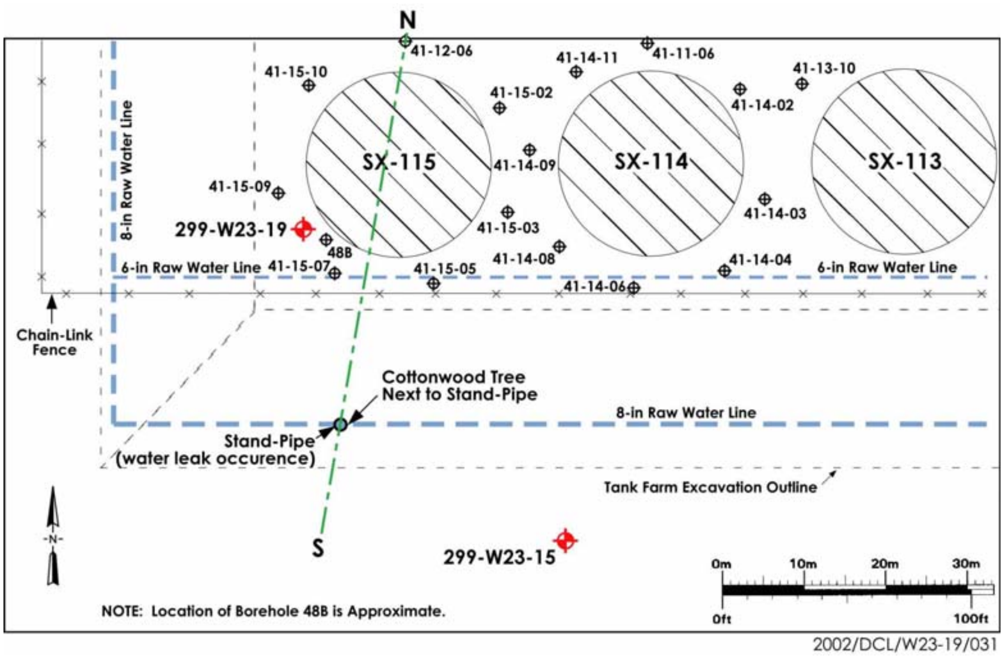

Figure 5.4b. Location of Water Lines at Southern End of SX Tank Farm (Pipeline locations are based on engineering drawings. Incomplete geophysical surveys suggest the 8-inch and 6-inch lines may have passed closer to tank SX-115 than shown.)

The abrupt contaminant arrival-time profile exhibited in Figure 5.5 for well 299-W22-46 suggests that very little dispersion (spreading or mixing) is occurring along the contaminant plume flow front. Simulation efforts in using the initial input values for dispersivity were not successful in matching the observed arrival-time profile. Consequently, dispersivities had to be lowered significantly to match the observed pattern. The effects of channelization (i.e., boundaries) that commonly occur in alluvial-type aquifers and uniformity of groundwater flow conditions has been noted by others (e.g., Van der Kamp et al. 1994) as a possible cause for low calculated dispersion values, particularly transverse dispersivity. In addition, the relatively small area investigated may be contributing to the low calculated dispersivity values and may not be representative of larger scale transport behavior. The scale dependency of dispersivity has been previously noted by others (Palmer and Johnson 1989). Figure 5.6 shows the best simulation match for the observed technetium-99 arrival-time profile. The observed data were corrected for a small background technetium-99 value attributed to other surrounding sources, which was shown to occur previously in Figure 5.3 prior to contaminant breakthrough. The input parameters used in the simulation match include: groundwater-flow velocity of 0.05 meter per day, effective porosity of 0.25, longitudinal and transverse dispersivities of 0.5 meter, and a contaminant source term of 2.0×10^{-6} kilograms per day (34 µCi/day).

To examine whether the dispersion parameters are reasonable for the area examined, a comparison with the observed technetium-99 concentrations in monitoring wells within the predicted path of the contaminant plume was undertaken. Technetium-99 concentrations observed for March-June 2001 are shown together with the predicted areal distribution (see Figure 5.6). As indicated, there is reasonable agreement between the predicted and observed well data. The slight deviation in observed data from the

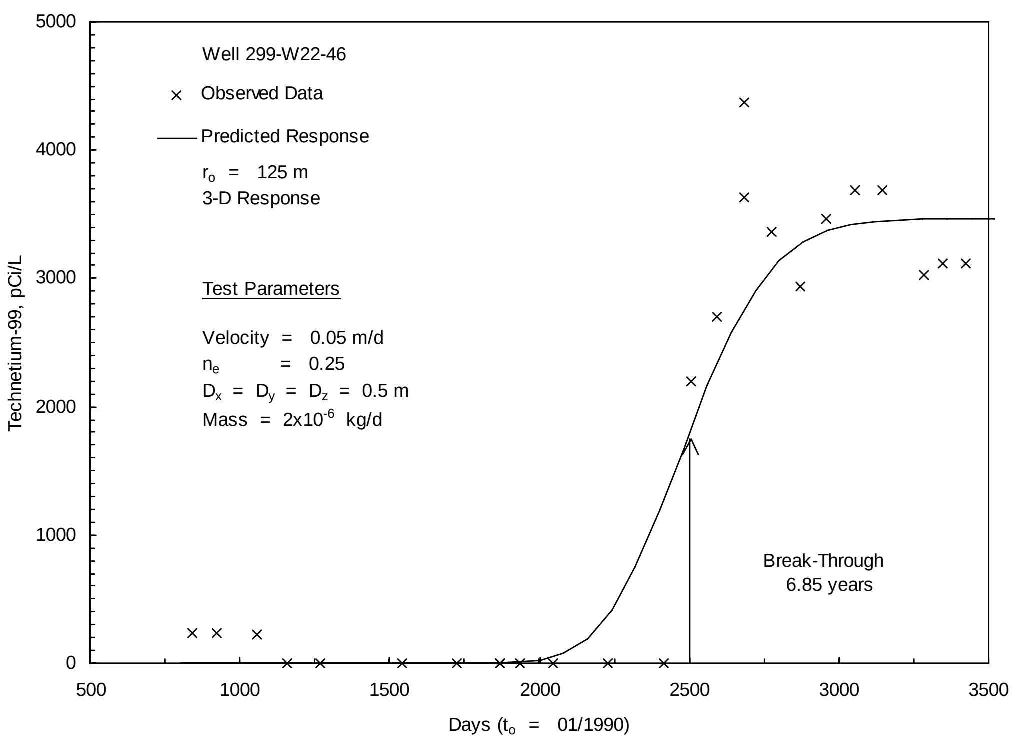

Figure 5.5. Predicted versus Observed Contaminant Arrival Time Response

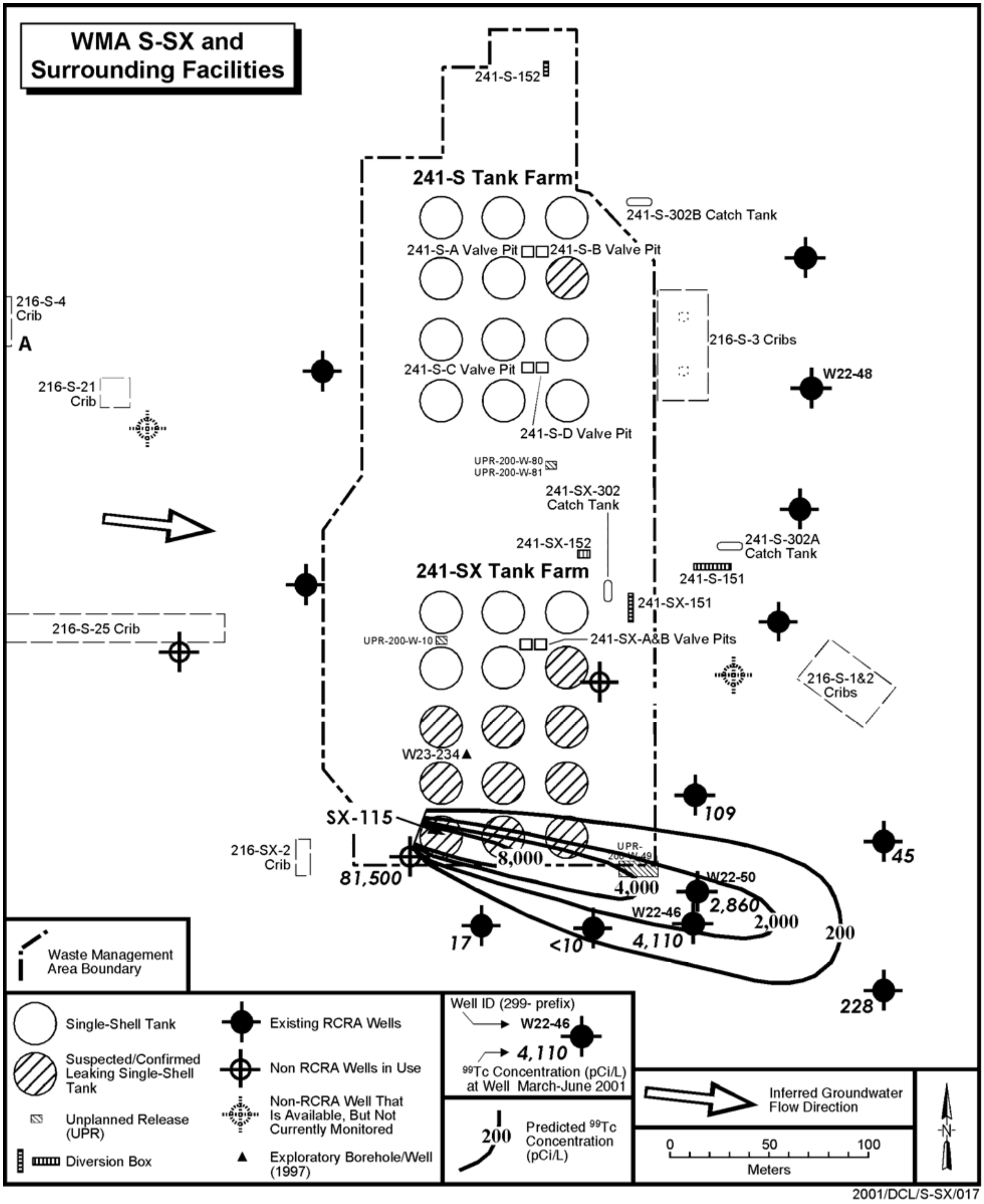

Figure 5.6. Predicted Technetium-99 Plume Downgradient from the Source Area Near Tank SX-115

predicted symmetrical plume shape (along southern edge of the plume) may be attributed to local heterogeneities within the aquifer, or to a progressive change in groundwater flow direction (i.e., more easterly), which has been observed for this site over the past 10-year period. Nevertheless, the analytical model does approximate the general shape suggested by the observed distribution.

The predicted and observed technetium-99 suggest that dispersal of contamination in groundwater from the southwestern corner of the waste management area is very limited in both its longitudinal and transverse directions and migrates at a very slow rate. The slow rate of movement is consistent with the low hydraulic conductivities (see Chapter 3) especially those close to or within the southern end of the SX tank farm.

6.0 Summary and Conclusions

Installation of eight new monitoring wells at Waste Management Area S-SX completes the well spacing needs previously identified (Johnson and Chou 2001). No significant new contamination was discovered at the new well sites. However, rapidly increasing concentrations of technetium-99 and associated mobile tank waste contaminants were detected in two wells at S tank farm.

Technetium-99 remains as the constituent with the highest concentration relative to a drinking water standard. Well 299-W23-19 at tank SX-115 continues to exhibit elevated concentrations with a maximum of 81,500 pCi/L relative to the drinking water standard of 900 pCi/L. Interim corrective measures (conducted by CH2M HILL Hanford Group, Inc.) included

- permanently cutting and capping old pressurized water lines in close proximity to the source of contamination near tank SX-115

- surface run-on controls (berming and diversion ditches).

The water line work was completed on April 25, 2001. A downward trend in contaminant concentrations in groundwater in well 299-W23-19, located next to tank SX-115, has not been observed as of September 2001. However, there is no longer an upward trend in technetium-99, chromium, and nitrate as observed prior to the corrective measures work.

As noted above, technetium 99 concentrations in downgradient wells at S tank farm indicate rapidly increasing concentrations in two wells (299-W22-44, and 299-W22-48). The technetium-99 concentration in the latter well is over 4,000 pCi/L. The steeply rising concentrations suggest a nearby source and or that very little dispersion is occurring between the source and the well.

Evaluation of the extent of the apparent contaminant plume at the southern end of the SX tank farm suggests the rate of movement is very slow and the contaminant plume concentrations of concern are limited in extent. Predicted areal distribution is consistent with contaminant concentrations in the observation wells within the boundaries of the theoretical concentration contours, lending confidence in the predictive modeling approach used.

Based on the predicted technetium-99 concentration contours, the areal extent of groundwater contamination that exceeds the cleanup target level of 9,000 pCi/L is estimated to be equivalent to the area of two single-shell tanks (about 800 m^2). The very low hydraulic conductivities in the southwestern area of the SX tank farm suggest that movement of contaminants that reach the water table in this area may be hydraulically contained or at least severely restricted in lateral movement.

The groundwater quality assessment at Waste Management Area S-SX has matured from a detection phase to assessment and characterization followed by interim corrective measures. Groundwater monitoring at this site in the future should help to assess the efficacy of the corrective measures that were undertaken to reduce or eliminate sources of groundwater contamination within Waste Management Area S-SX.

7.0 References

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Appendix A

Hydraulic Conductivity Estimates in Waste Management Area S-SX

...Putting Technology To Work

Project No. F29504

Internal Distribution

C.J. Chou
S.P. Luttrell
D.R. Newcomer
R.M. Smith
P.D. Thorne
PFile/LB

Date April 14, 2005

To V.G. Johnson

From F.A. Spane

Subject Summary of Hydraulic Conductivity Estimates Obtained From Recent Hydrologic Characterization Tests Conducted in the WMA S-SX

This letter report presents a summary of hydraulic conductivity estimates obtained from recent hydrologic characterization tests conducted within the WMA S-SX over the past three years as part of PNNL's detailed characterization program. These estimates include those results reported previously in Spane et al. (2000), as well as test results that are in the process of being formally documented in subsequent PNNL technical reports. This letter report is being issued as an interim measure to meet current hydrologic data needs of the WMA S-SX project, prior to formal technical report issuance. The letter report only provides the hydraulic conductivity estimates 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 PNNL technical reports.

Detailed Hydrologic Characterization Program

As part of the Hanford Groundwater Monitoring Project, Pacific Northwest National Laboratory conducts detailed hydrologic characterization tests in 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 through FY-01, 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

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 TracerTest:	for determining the existence of vertical flow within the well-screen section

Of the various individual test element activities, only slug testing and constant-rate pumping tests are relevant for the estimates of hydraulic conductivity that are provided in this letter report. Slug testing is designed primarily to provide initial estimates of hydraulic conductivity, K, for the design of subsequent, more quantitative hydrologic tests, and for well development assessment. 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).

As noted above, constant-rate pumping tests are conducted as part of the single-well tracer-dilution and pumpback tests. Pumping is commonly extended for a duration longer than required for capturing the tracer centroid emplaced within the aquifer. The extended pumping time enables quantitative large-scale characterization of the surrounding hydraulic properties (i.e., hydraulic conductivity). 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.

Hydraulic Conductivity Results

The S-SX monitor wells are all constructed of 10.16-cm-diameter stainless-steel casing with wire-wrapped stainless-steel screens and sand pack. All wells are screened across the water table and penetrate approximately the top 3 to 10 m of the unconfined aquifer. The unconfined aquifer lies almost entirely within unit 5 of the Ringold Formation (geologic unit E) and is composed of fluvial, gravel-dominated sediments with a fine-sand matrix (Spane et al., 2000). Sediments within unit 5 exhibit variable degrees of cementation, ranging from partially to well developed. Thin, laterally discontinuous, sand and silt beds also are intercalated in the gravelly deposits.

Table 1 lists the analysis results for hydraulic conductivity (and transmissivity) determined from slug tests 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 (Bouwer and Rice, 1976; Bouwer 1989) and the type-curve matching procedure, respectively. As discussed in Spane et al. (2000), the Bouwer and Rice method consistently provides lower K estimates, in comparison to the type-curve method. 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 (i.e., slug and pumping tests), particularly when type-curve analysis estimates are used for the slug test results. It should also be noted that the test methods were analyzed completely independently from each other using different analysts, i.e., F.A. Spane: slug tests and P.D. Thorne: constant-rate pumping tests.

As shown, the average K values for slug testing ranged from a low of 0.7 m/d (well 299-W23-21) to a high of 17.1 m/d (well 299-W23-20). Approximately 65% of the wells (i.e., 9 out of 14 wells) characterized by slug testing exhibit K values within the range of 1.0 to 10.0 m/d (Figure 2). The geometric mean for K for the fourteen SX wells tested equals 2.54 m/d, with a standard deviation of 5.09 m/d.

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Figure 1. S-SX Monitor Well Location Map

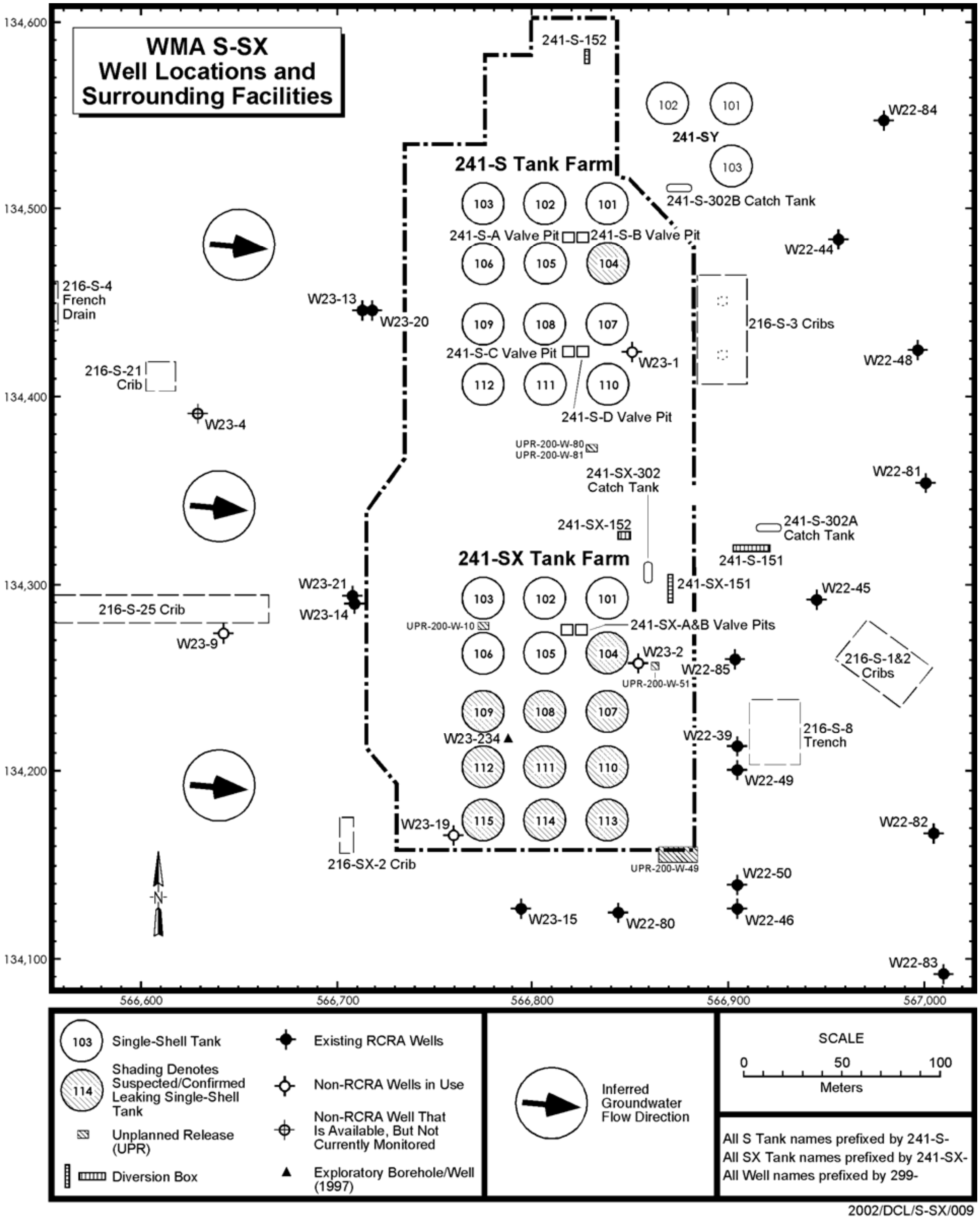

Figure 2. Hydraulic Conductivity Distribution for S-SX Monitor Wells Based on Slug Test Results

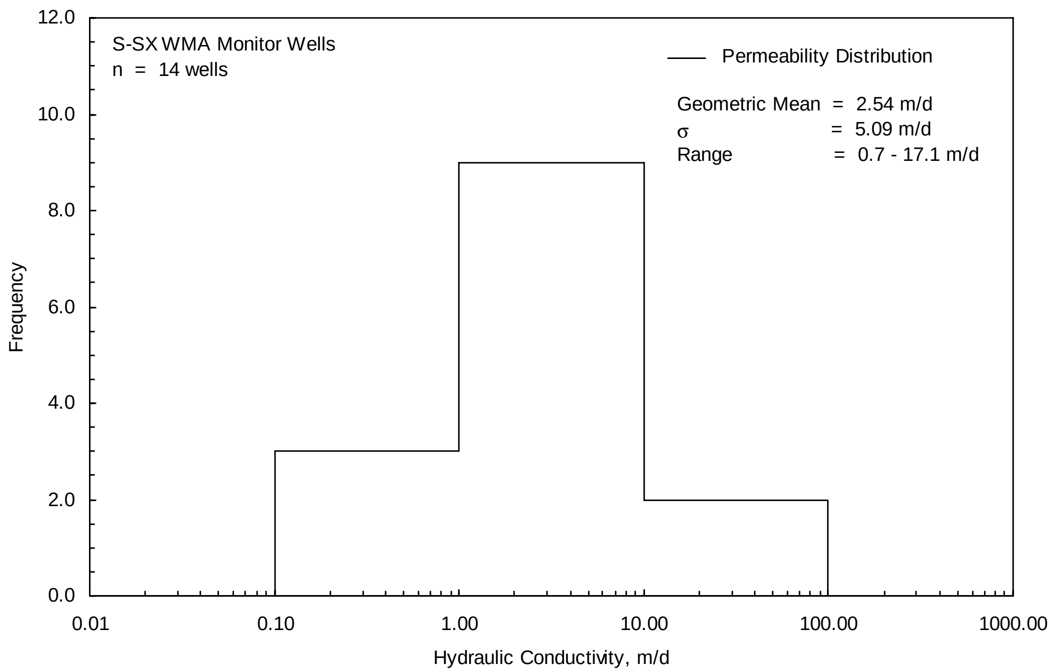

Table 1. Hydraulic Property Summary for Slug- and Constant-Rate Pumping Tests Conducted During 1999 - 2001.

Waste Management Area	Well	Slug Test[(a)]	Constant-Rate Pumping Test		
		Hydraulic Conductivity, K_h, m/d	Hydraulic Conductivity, K_h, m/d	Transmissivity, T, m^2/d	Specific Yield, S_y
S-SX	299-W22-45* heterogeneous	1.10 - 1.45 outer zone	-[(b)]	-	-
	299-W22-46	2.43 - 3.37	-	-	-
	299-W22-48	1.42 - 1.86	1.78	125	0.09
	299-W22-49	6.04 - 7.97	7.59	550	0.09
	299-W22-50	4.24 - 5.70	5.24	385	0.11
	299-W22-80	(11.3 - 15.4)	(14.4)	(1035)	(0.12)
	299-W22-81 heterogeneous	(1.77 - 2.27) outer zone	(1.63)	(112)	(0.12)
	299-W22-82 heterogeneous	(1.16 - 1.45) outer zone	-	-	-
	299-W22-83 heterogeneous	(0.78 - 1.00) outer zone	-	-	-
	299-W22-84 heterogeneous	(1.15 - 1.51) outer zone	-	-	-
	299-W22-85 heterogeneous	(5.69 - 7.73) outer zone	-	-	-
	299-W23-15* heterogeneous	0.56 - 0.78 outer zone	-	-	-
	299-W23-20	(16.9 - 17.2)	-	-	-
	299-W23-21 heterogeneous	(0.59 - 0.75) outer zone	-	-	-

Note: K_h = assumes aquifer with uniform hydraulic conductivity value.
heterogeneous = slug tests exhibiting a composite permeability response, with a higher K inner zone and an outer zone of lower hydraulic conductivity
* = reanalyzed slug test results; slightly higher K values for outer zone from previously reported values (Spane et al., 2000) for these well sites
(a) Listed range represents the average K_h value obtained from the Bouwer and Rice and type-curve analysis methods. Except for well 299-W23-20, type-curve analysis provides the higher listed value.
(b) Dashed symbol indicates that a constant-rate pumping test was not conducted at the well site.
(c) Parentheses indicate values are preliminary and may be subject to change upon final test analysis/documentation.

Appendix B

Hydrologic Testing at Well 299-W23-19: Specific Conductance Results

Appendix B

Hydrologic Testing at Well 299-W23-19: Specific Conductance Results

Specific conductance was monitored continuously with a flow through cell and a data logger during a step drawdown and constant discharge test conducted at well 299 W23-19 during the period of December 13 to 20, 2001. The test step drawdown was conducted first and covered a 250-minute period during which the well was pumped at 5 gallons per minute and then adjusted downward to about 1 gallon per minute. In general the specific conductance increased as the pumping rate decreased (Figure B.1).

The 72-hour constant discharge test was initiated three days following the step drawdown test. Specific conductance was recorded every minute for the first few hours and then at 10-minute intervals. Results are provided in the Table B.1. Initially the specific conductance was in the 1,500 μS/cm range. This was during an initial flow rate adjustment period when the rate was at about 1 gallon per minute. Then as the target flow rate of 3 gallons per minute was achieved, and thereafter, the specific conductance dropped to the 1,250 to 1,300 μS/cm range and remained at this level for the duration of the test.

Both of the above tests suggest that pumping rate has a significant impact on contaminant concentrations from this well. Also, the invariant specific conductance values over the 72-hour period, during which a volume of nearly 13,000 gallons was removed from the well, suggests contaminant concentrations are fairly uniform in the immediate vicinity of the well (radius of influence is estimated to be about 12 ft (3.7 meters) assuming an effective porosity of 0.2).

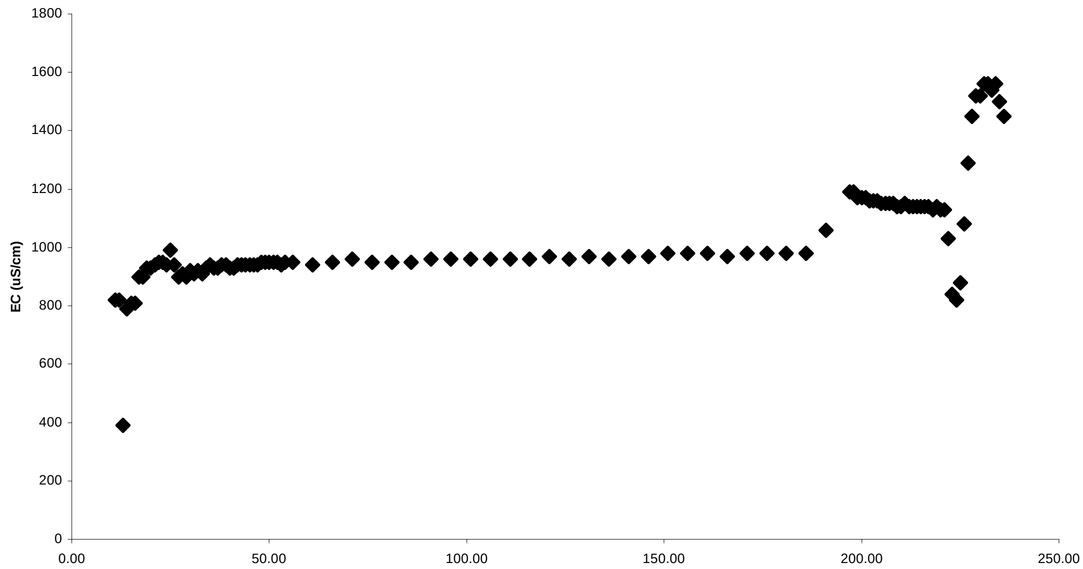

Figure B.1. Specific Conductance versus Time (minutes) at Well 299-W23-19 during a Step Drawdown Test (flow rate ranged from 1 to 5 gpm)

Table B.1. Specific Conductance at Well 299-W23-19 during a 72-Hour Constant Discharge Test

Sample Number	Date	Time	Conductivity (μS/cm)	Temperature (°C)	Notes
1	12/17/2001	08:52:00AM	0.04	15.8	
2	12/17/2001	08:53:00AM	0.03	16.4	
3	12/17/2001	08:54:00AM	0.03	16.8	
4	12/17/2001	08:55:00AM	1,258	10	Pump started
5	12/17/2001	08:56:00AM	1,518	7.3	
6	12/17/2001	08:57:00AM	1,538	7.1	Flow was set too low (~1gpm)
7	12/17/2001	08:58:00AM	1,552	7	
8	12/17/2001	08:59:00AM	1,556	7.1	
9	12/17/2001	09:00:00AM	1,557	7.1	
10	12/17/2001	09:01:00AM	1,562	7.2	
11	12/17/2001	09:02:00AM	1,568	7.3	
12	12/17/2001	09:03:00AM	1,570	7.6	
13	12/17/2001	09:04:00AM	1,572	8.1	
14	12/17/2001	09:05:00AM	1,570	8.8	
15	12/17/2001	09:06:00AM	1,566	9.5	
16	12/17/2001	09:07:00AM	1,564	10.3	
17	12/17/2001	09:08:00AM	1,557	11.2	
18	12/17/2001	09:09:00AM	1,554	11.9	
19	12/17/2001	09:10:00AM	1,549	12.6	
20	12/17/2001	09:11:00AM	1,541	13.2	
21	12/17/2001	09:12:00AM	1,533	13.7	
22	12/17/2001	09:13:00AM	1,529	14.1	
23	12/17/2001	09:14:00AM	1,521	14.4	
24	12/17/2001	09:15:00AM	1,514	14.5	
25	12/17/2001	09:16:00AM	1,505	14.6	
26	12/17/2001	09:17:00AM	1,501	14.6	
27	12/17/2001	09:18:00AM	1,497	14.5	
28	12/17/2001	09:19:00AM	1,487	14.4	
29	12/17/2001	09:20:00AM	1,475	14.2	
30	12/17/2001	09:21:00AM	1,465	14.2	
31	12/17/2001	09:22:00AM	1,438	14.1	
32	12/17/2001	09:23:00AM	1,414	14	
33	12/17/2001	09:24:00AM	1,374	13.8	
34	12/17/2001	09:25:00AM	1,329	13.6	
35	12/17/2001	09:26:00AM	1,293	13.5	
36	12/17/2001	09:27:00AM	1,257	13.4	
37	12/17/2001	09:28:00AM	1,144	13.4	
38	12/17/2001	09:29:00AM	999	13.4	
39	12/17/2001	09:30:00AM	908	13.4	Flow set back to 3 gpm (took awhile for DynCorp crew to get system adjusted

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
40	12/17/2001	09:31:00AM	904	13.5	
41	12/17/2001	09:32:00AM	1,019	14.3	
42	12/17/2001	09:33:00AM	1,075	15.5	
43	12/17/2001	09:34:00AM	1,337	16.8	
44	12/17/2001	09:35:00AM	1,471	17.8	
45	12/17/2001	09:36:00AM	1,245	18.9	
46	12/17/2001	09:37:00AM	1,231	18.9	
47	12/17/2001	09:38:00AM	1,267	18.6	
48	12/17/2001	09:39:00AM	1,319	18.4	
49	12/17/2001	09:40:00AM	1,293	19	
50	12/17/2001	09:41:00AM	1,338	19	
51	12/17/2001	09:42:00AM	1,347	18.9	
52	12/17/2001	09:43:00AM	1,313	18.9	
53	12/17/2001	09:44:00AM	1,312	18.9	
54	12/17/2001	09:45:00AM	1,327	18.9	
55	12/17/2001	09:46:00AM	1,337	18.8	
56	12/17/2001	09:47:00AM	1,314	18.8	
57	12/17/2001	09:48:00AM	1,319	18.7	
58	12/17/2001	09:49:00AM	1,320	18.7	
59	12/17/2001	09:50:00AM	1,300	18.7	
60	12/17/2001	09:51:00AM	1,309	18.6	
61	12/17/2001	09:52:00AM	1,322	18.5	
62	12/17/2001	09:53:00AM	1,355	18.5	
63	12/17/2001	09:54:00AM	1,335	18.5	
64	12/17/2001	09:55:00AM	1,315	18.5	
65	12/17/2001	09:56:00AM	1,314	18.5	
66	12/17/2001	09:57:00AM	1,301	18.5	
67	12/17/2001	09:58:00AM	1,286	18.5	
68	12/17/2001	09:59:00AM	1,273	18.5	
69	12/17/2001	10:00:00AM	1,261	18.4	
70	12/17/2001	10:01:00AM	1,260	18.3	
71	12/17/2001	10:02:00AM	1,253	18.3	
72	12/17/2001	10:03:00AM	1,248	18.1	
73	12/17/2001	10:04:00AM	1,245	18	
74	12/17/2001	10:05:00AM	1,239	18	
75	12/17/2001	10:06:00AM	1,237	18	
76	12/17/2001	10:07:00AM	1,235	17.9	
77	12/17/2001	10:08:00AM	1,239	17.9	
78	12/17/2001	10:09:00AM	1,230	17.9	
79	12/17/2001	10:10:00AM	1,235	17.9	
80	12/17/2001	10:15:00AM	1,248	17.9	
81	12/17/2001	10:20:00AM	1,241	18.2	
82	12/17/2001	10:25:00AM	1,246	18.3	

Sample Number	Date	Time	Conductivity (μS/cm)	Temperature (°C)	Notes
83	12/17/2001	10:30:00AM	1,245	18.1	
84	12/17/2001	10:35:00AM	1,257	18.2	
85	12/17/2001	10:40:00AM	1,248	18.3	
86	12/17/2001	10:45:00AM	1,241	18.2	
87	12/17/2001	10:50:00AM	1,245	17.9	
88	12/17/2001	10:55:00AM	1,244	18	
89	12/17/2001	11:00:00AM	1,249	18	
90	12/17/2001	11:05:00AM	1,248	17.4	
91	12/17/2001	11:10:00AM	1,245	16.7	
92	12/17/2001	11:15:00AM	1,242	16.5	
93	12/17/2001	11:20:00AM	1,246	16.7	
94	12/17/2001	11:25:00AM	1,239	16.7	
95	12/17/2001	11:30:00AM	1,244	16.7	
96	12/17/2001	11:35:00AM	1,239	16.6	
97	12/17/2001	11:40:00AM	1,247	17	
98	12/17/2001	11:45:00AM	1,236	17.1	
99	12/17/2001	11:50:00AM	1,242	16.9	
100	12/17/2001	11:55:00AM	1,247	16.6	
101	12/17/2001	12:00:00PM	1,242	16.6	
102	12/17/2001	12:05:00PM	1,230	16.9	
103	12/17/2001	12:10:00PM	1,234	17	
104	12/17/2001	12:15:00PM	1,233	17.1	
105	12/17/2001	12:20:00PM	1,231	17	
106	12/17/2001	12:25:00PM	1,239	17.1	
107	12/17/2001	12:30:00PM	1,226	17.3	
108	12/17/2001	12:35:00PM	1,228	17	
109	12/17/2001	12:40:00PM	1,226	16.9	
110	12/17/2001	12:45:00PM	1,228	17.2	
111	12/17/2001	12:50:00PM	1,233	17.3	
112	12/17/2001	12:55:00PM	1,232	17.2	
113	12/17/2001	01:00:00PM	1,238	17.2	
114	12/17/2001	01:05:00PM	1,236	17.1	
115	12/17/2001	01:10:00PM	1,232	17.1	
116	12/17/2001	01:15:00PM	1,230	17.1	
117	12/17/2001	01:20:00PM	1,228	17.1	
118	12/17/2001	01:25:00PM	1,238	17.1	
119	12/17/2001	01:30:00PM	1,242	17.2	
120	12/17/2001	01:35:00PM	1,225	17.2	
121	12/17/2001	01:40:00PM	1,234	17.3	
122	12/17/2001	01:45:00PM	1,230	17.4	
123	12/17/2001	01:50:00PM	1,235	17.3	
124	12/17/2001	01:55:00PM	1,224	17.4	
125	12/17/2001	02:00:00PM	1,228	17.5	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
126	12/17/2001	02:05:00PM	1,233	17.5	
127	12/17/2001	02:10:00PM	1,226	17.5	
128	12/17/2001	02:15:00PM	1,231	17.4	
129	12/17/2001	02:20:00PM	1,234	17.3	
130	12/17/2001	02:25:00PM	1,231	17.2	
131	12/17/2001	02:30:00PM	1,235	17.4	
132	12/17/2001	02:35:00PM	1,226	17.6	
133	12/17/2001	02:40:00PM	1,232	17.6	
134	12/17/2001	02:45:00PM	1,236	17.7	
135	12/17/2001	02:50:00PM	1,227	17.7	
136	12/17/2001	02:55:00PM	1,225	17.7	
137	12/17/2001	03:00:00PM	1,227	17.5	
138	12/17/2001	03:05:00PM	1,235	17.7	
139	12/17/2001	03:10:00PM	1,228	17.6	
140	12/17/2001	03:15:00PM	1,231	17.6	
141	12/17/2001	03:20:00PM	1,237	17.5	
142	12/17/2001	03:25:00PM	1,222	17.3	
143	12/17/2001	03:30:00PM	1,233	17.3	
144	12/17/2001	03:35:00PM	1,233	17.2	
145	12/17/2001	03:40:00PM	1,234	17.2	
146	12/17/2001	03:45:00PM	1,224	17.1	
147	12/17/2001	03:50:00PM	1,231	17	
148	12/17/2001	03:55:00PM	1,234	17	
149	12/17/2001	04:00:00PM	1,229	17.1	
150	12/17/2001	04:05:00PM	1,233	17	
151	12/17/2001	04:10:00PM	1,235	16.8	
152	12/17/2001	04:15:00PM	1,224	16.9	
153	12/17/2001	04:20:00PM	1,230	16.8	
154	12/17/2001	04:25:00PM	1,231	16.8	
155	12/17/2001	04:30:00PM	1,227	17	
156	12/17/2001	04:35:00PM	1,232	16.8	
157	12/17/2001	04:40:00PM	1,243	16.8	
158	12/17/2001	04:45:00PM	1,233	16.8	
159	12/17/2001	04:50:00PM	1,238	16.7	
160	12/17/2001	04:55:00PM	1,234	16.8	
161	12/17/2001	05:00:00PM	1,241	16.7	
162	12/17/2001	05:05:00PM	1,226	16.9	
163	12/17/2001	05:10:00PM	1,244	16.6	
164	12/17/2001	05:15:00PM	1,233	16.6	
165	12/17/2001	05:20:00PM	1,243	16.7	
166	12/17/2001	05:25:00PM	1,230	16.4	
167	12/17/2001	05:30:00PM	1,236	16.3	
168	12/17/2001	05:35:00PM	1,241	16.3	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
169	12/17/2001	05:40:00PM	1,233	16.4	
170	12/17/2001	05:45:00PM	1,242	16.5	
171	12/17/2001	05:50:00PM	1,232	16.4	
172	12/17/2001	05:55:00PM	1,239	16.6	
173	12/17/2001	06:00:00PM	1,231	16.7	
174	12/17/2001	06:05:00PM	1,236	16.2	
175	12/17/2001	06:10:00PM	1,236	16.1	
176	12/17/2001	06:15:00PM	1,232	15.7	
177	12/17/2001	06:20:00PM	1,241	15.4	
178	12/17/2001	06:25:00PM	1,238	15.7	
179	12/17/2001	06:30:00PM	1,241	16.2	
180	12/17/2001	06:35:00PM	1,238	16.4	
181	12/17/2001	06:40:00PM	1,234	16.2	
182	12/17/2001	06:45:00PM	1,231	16.1	
183	12/17/2001	06:50:00PM	1,240	16.2	
184	12/17/2001	06:55:00PM	1,233	16.2	
185	12/17/2001	07:00:00PM	1,243	16.1	
186	12/17/2001	07:05:00PM	1,236	16	
187	12/17/2001	07:10:00PM	1,239	16	
188	12/17/2001	07:15:00PM	1,237	15.9	
189	12/17/2001	07:20:00PM	1,241	15.9	
190	12/17/2001	07:25:00PM	1,232	16	
191	12/17/2001	07:30:00PM	1,234	15.9	
192	12/17/2001	07:35:00PM	1,241	15.5	
193	12/17/2001	07:40:00PM	1,242	15.5	
194	12/17/2001	07:45:00PM	1,239	15.5	
195	12/17/2001	07:50:00PM	1,238	15.8	
196	12/17/2001	07:55:00PM	1,242	15.9	
197	12/17/2001	08:00:00PM	1,242	16	
198	12/17/2001	08:05:00PM	1,235	16	
199	12/17/2001	08:10:00PM	1,236	15.9	
200	12/17/2001	08:15:00PM	1,239	15.8	
201	12/17/2001	08:20:00PM	1,243	15.9	
202	12/17/2001	08:25:00PM	1,233	16.2	
203	12/17/2001	08:30:00PM	1,244	16.3	
204	12/17/2001	08:35:00PM	1,234	16	
205	12/17/2001	08:40:00PM	1,248	15.8	
206	12/17/2001	08:45:00PM	1,246	16.1	
207	12/17/2001	08:50:00PM	1,240	16	
208	12/17/2001	08:55:00PM	1,233	16.1	
209	12/17/2001	09:00:00PM	1,233	16.1	
210	12/17/2001	09:05:00PM	1,242	16.3	
211	12/17/2001	09:10:00PM	1,236	16.2	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
212	12/17/2001	09:15:00PM	1,241	16.2	
213	12/17/2001	09:20:00PM	1,241	15.9	
214	12/17/2001	09:25:00PM	1,240	15.7	
215	12/17/2001	09:30:00PM	1,247	15.8	
216	12/17/2001	09:35:00PM	1,242	16.1	
217	12/17/2001	09:40:00PM	1,246	16.1	
218	12/17/2001	09:45:00PM	1,234	15.9	
219	12/17/2001	09:50:00PM	1,246	15.8	
220	12/17/2001	09:55:00PM	1,237	15.8	
221	12/17/2001	10:00:00PM	1,242	15.7	
222	12/17/2001	10:05:00PM	1,238	15.6	
223	12/17/2001	10:10:00PM	1,241	15.9	
224	12/17/2001	10:15:00PM	1,237	15.8	
225	12/17/2001	10:20:00PM	1,240	15.8	
226	12/17/2001	10:25:00PM	1,244	15.5	
227	12/17/2001	10:30:00PM	1,246	15.4	
228	12/17/2001	10:35:00PM	1,242	15.6	
229	12/17/2001	10:40:00PM	1,244	15.6	
230	12/17/2001	10:45:00PM	1,235	15.7	
231	12/17/2001	10:50:00PM	1,249	15.7	
232	12/17/2001	10:55:00PM	1,240	15.8	
233	12/17/2001	11:00:00PM	1,245	15.8	
234	12/17/2001	11:05:00PM	1,234	15.7	
235	12/17/2001	11:10:00PM	1,238	15.3	
236	12/17/2001	11:15:00PM	1,245	15.4	
237	12/17/2001	11:20:00PM	1,245	15.4	
238	12/17/2001	11:25:00PM	1,247	15.4	
239	12/17/2001	11:30:00PM	1,242	15.4	
240	12/17/2001	11:35:00PM	1,242	15.4	
241	12/17/2001	11:40:00PM	1,241	15.4	
242	12/17/2001	11:45:00PM	1,245	15.5	
243	12/17/2001	11:50:00PM	1,245	15.5	
244	12/17/2001	11:55:00PM	1,244	15.6	
245	12/17/2001	12:00:00AM	1,236	15.7	
246	12/18/2001	12:05:00AM	1,242	15.7	
247	12/18/2001	12:10:00AM	1,244	15.6	
248	12/18/2001	12:15:00AM	1,241	15.5	
249	12/18/2001	12:20:00AM	1,240	16	
250	12/18/2001	12:25:00AM	1,244	16.1	
251	12/18/2001	12:30:00AM	1,242	16.1	
252	12/18/2001	12:35:00AM	1,245	16.4	
253	12/18/2001	12:40:00AM	1,241	16.5	
254	12/18/2001	12:45:00AM	1,239	16.2	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
255	12/18/2001	12:50:00AM	1,233	16	
256	12/18/2001	12:55:00AM	1,241	16	
257	12/18/2001	01:00:00AM	1,239	16.1	
258	12/18/2001	01:05:00AM	1,237	16.3	
259	12/18/2001	01:10:00AM	1,233	16.4	
260	12/18/2001	01:15:00AM	1,246	16.4	
261	12/18/2001	01:20:00AM	1,244	16.3	
262	12/18/2001	01:25:00AM	1,239	16.3	
263	12/18/2001	01:30:00AM	1,240	16.5	
264	12/18/2001	01:35:00AM	1,238	16.6	
265	12/18/2001	01:40:00AM	1,236	16.5	
266	12/18/2001	01:45:00AM	1,240	16.1	
267	12/18/2001	01:50:00AM	1,236	16.2	
268	12/18/2001	01:55:00AM	1,234	16.5	
269	12/18/2001	02:00:00AM	1,228	14.5	
270	12/18/2001	02:05:00AM	1,239	16.1	
271	12/18/2001	02:10:00AM	1,237	16.1	
272	12/18/2001	02:15:00AM	1,206	15.9	
273	12/18/2001	02:20:00AM	1,256	16.1	
274	12/18/2001	02:25:00AM	1,269	15.8	
275	12/18/2001	02:30:00AM	1,249	15.8	
276	12/18/2001	02:35:00AM	1,245	15.8	
277	12/18/2001	02:40:00AM	1,246	16.1	
278	12/18/2001	02:45:00AM	1,330	15.9	
279	12/18/2001	02:50:00AM	1,249	15.8	
280	12/18/2001	02:55:00AM	1,196	15.7	
281	12/18/2001	03:00:00AM	1,194	15.9	
282	12/18/2001	03:05:00AM	1,240	16.1	
283	12/18/2001	03:10:00AM	1,349	16	
284	12/18/2001	03:15:00AM	1,244	15.8	
285	12/18/2001	03:20:00AM	1,243	15.9	
286	12/18/2001	03:25:00AM	1,240	15.9	
287	12/18/2001	03:30:00AM	1,250	15.5	
288	12/18/2001	03:35:00AM	1,255	15.6	
289	12/18/2001	03:40:00AM	1,254	15.7	
290	12/18/2001	03:45:00AM	1,255	15.8	
291	12/18/2001	03:50:00AM	1,256	15.9	
292	12/18/2001	03:55:00AM	1,255	15.8	
293	12/18/2001	04:00:00AM	1,253	15.9	
294	12/18/2001	04:05:00AM	1,259	15.8	
295	12/18/2001	04:10:00AM	1,254	15.7	
296	12/18/2001	04:15:00AM	1,254	15.6	
297	12/18/2001	04:20:00AM	1,259	15.3	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
298	12/18/2001	04:25:00AM	1,257	14.9	
299	12/18/2001	04:30:00AM	1,259	14.6	
300	12/18/2001	04:35:00AM	1,258	14.6	
301	12/18/2001	04:40:00AM	1,258	14.8	
302	12/18/2001	04:45:00AM	1,268	14.9	
303	12/18/2001	04:50:00AM	1,255	15.2	
304	12/18/2001	04:55:00AM	1,265	15.4	
305	12/18/2001	05:00:00AM	1,267	15.7	
306	12/18/2001	05:05:00AM	1,263	15.6	
307	12/18/2001	05:10:00AM	1,260	15.5	
308	12/18/2001	05:15:00AM	1,261	15.5	
309	12/18/2001	05:20:00AM	1,259	15.4	
310	12/18/2001	05:25:00AM	1,260	15.1	
311	12/18/2001	05:30:00AM	1,256	15	
312	12/18/2001	05:35:00AM	1,257	14.6	
313	12/18/2001	05:40:00AM	1,264	14.5	
314	12/18/2001	05:45:00AM	1,265	14.3	
315	12/18/2001	05:50:00AM	1,264	14.4	
316	12/18/2001	05:55:00AM	1,268	14.3	
317	12/18/2001	06:00:00AM	1,265	14.5	
318	12/18/2001	06:05:00AM	1,255	14.6	
319	12/18/2001	06:10:00AM	1,260	14.5	
320	12/18/2001	06:15:00AM	1,266	14.5	
321	12/18/2001	06:20:00AM	1,259	14.6	
322	12/18/2001	06:25:00AM	1,257	14.7	
323	12/18/2001	06:30:00AM	1,261	14.8	
324	12/18/2001	06:35:00AM	1,261	14.9	
325	12/18/2001	06:40:00AM	1,256	14.6	
326	12/18/2001	06:45:00AM	1,263	14.5	
327	12/18/2001	06:50:00AM	1,263	15	
328	12/18/2001	06:55:00AM	1,260	15	
329	12/18/2001	07:00:00AM	1,258	15.2	
330	12/18/2001	07:05:00AM	1,256	14.8	
331	12/18/2001	07:10:00AM	1,271	14.6	
332	12/18/2001	07:15:00AM	1,270	14.5	
333	12/18/2001	07:20:00AM	1,261	14.8	
334	12/18/2001	07:25:00AM	1,267	15	
335	12/18/2001	07:30:00AM	1,263	15.2	
336	12/18/2001	07:35:00AM	1,260	15.4	
337	12/18/2001	07:40:00AM	1,269	15.1	
338	12/18/2001	07:45:00AM	1,265	15.4	
339	12/18/2001	07:50:00AM	1,260	15.6	
340	12/18/2001	07:55:00AM	1,264	15.5	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
341	12/18/2001	08:00:00AM	1,259	15.5	
342	12/18/2001	08:05:00AM	1,261	15.5	
343	12/18/2001	08:10:00AM	1,264	15.5	
344	12/18/2001	08:15:00AM	1,265	15.3	
345	12/18/2001	08:20:00AM	1,260	14.9	
346	12/18/2001	08:25:00AM	1,261	14.9	
347	12/18/2001	08:30:00AM	1,261	15.1	
348	12/18/2001	08:35:00AM	1,267	15.1	
349	12/18/2001	08:40:00AM	1,260	15.1	
350	12/18/2001	08:45:00AM	1,259	14.9	
351	12/18/2001	08:50:00AM	1,266	15	
352	12/18/2001	08:55:00AM	1,265	15.1	
353	12/18/2001	09:00:00AM	1,265	15.1	
354	12/18/2001	09:05:00AM	1,261	15.8	
355	12/18/2001	09:10:00AM	1,262	15.7	
356	12/18/2001	09:15:00AM	1,361	15.5	
357	12/18/2001	09:20:00AM	1,245	15.4	
358	12/18/2001	09:25:00AM	1,242	15.6	
359	12/18/2001	09:30:00AM	1,249	15.8	
360	12/18/2001	09:35:00AM	1,251	15.8	
361	12/18/2001	09:40:00AM	1,254	16	
362	12/18/2001	09:45:00AM	1,246	15.7	
363	12/18/2001	09:50:00AM	1,252	15.8	
364	12/18/2001	09:55:00AM	1,246	15.8	
365	12/18/2001	10:00:00AM	1,253	15.8	
366	12/18/2001	10:05:00AM	1,252	16	
367	12/18/2001	10:10:00AM	1,251	16.3	
368	12/18/2001	10:15:00AM	1,254	16	
369	12/18/2001	10:20:00AM	1,249	15.7	
370	12/18/2001	10:25:00AM	1,254	16.1	
371	12/18/2001	10:30:00AM	1,255	16.2	
372	12/18/2001	10:35:00AM	1,250	16.2	
373	12/18/2001	10:40:00AM	1,252	16	
374	12/18/2001	10:45:00AM	1,256	16	
375	12/18/2001	10:50:00AM	1,252	16.3	
376	12/18/2001	10:55:00AM	1,256	16.3	
377	12/18/2001	11:00:00AM	1,252	16.3	
378	12/18/2001	11:05:00AM	1,252	16.3	
379	12/18/2001	11:10:00AM	1,257	16.2	
380	12/18/2001	11:15:00AM	1,256	16.3	
381	12/18/2001	11:26:56AM	2,710	19.9	2,764 µS calibration standard
382	12/18/2001	11:28:51AM	447	19.8	447 µS calibration standard
383	12/18/2001	11:40:00AM	1,303	15.9	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
384	12/18/2001	11:50:00AM	1,318	15.7	
385	12/18/2001	12:00:00PM	1,277	15	
386	12/18/2001	12:10:00PM	1,280	14.5	
387	12/18/2001	12:20:00PM	1,270	14.7	
388	12/18/2001	12:30:00PM	1,276	14.9	
389	12/18/2001	12:40:00PM	1,281	15	
390	12/18/2001	12:50:00PM	1,275	15.4	
391	12/18/2001	01:00:00PM	1,281	15.8	
392	12/18/2001	01:10:00PM	1,277	16.4	
393	12/18/2001	01:20:00PM	1,278	16.1	
394	12/18/2001	01:30:00PM	1,274	15.8	
395	12/18/2001	01:40:00PM	1,277	15.7	
396	12/18/2001	01:50:00PM	1,275	16.4	
397	12/18/2001	02:00:00PM	1,279	16	
398	12/18/2001	02:10:00PM	1,282	16.2	
399	12/18/2001	02:20:00PM	1,279	16.1	
400	12/18/2001	02:30:00PM	1,282	16	
401	12/18/2001	02:40:00PM	1,286	15.9	
402	12/18/2001	02:50:00PM	1,283	16	
403	12/18/2001	03:00:00PM	1,282	16	
404	12/18/2001	03:10:00PM	1,277	16.1	
405	12/18/2001	03:20:00PM	1,279	16.2	
406	12/18/2001	03:30:00PM	1,280	16.2	
407	12/18/2001	03:40:00PM	1,279	16.8	
408	12/18/2001	03:50:00PM	1,278	16.8	
409	12/18/2001	04:00:00PM	1,281	16.5	
410	12/18/2001	04:10:00PM	1,285	16.1	
411	12/18/2001	04:20:00PM	1,287	16.1	
412	12/18/2001	04:30:00PM	1,286	15.8	
413	12/18/2001	04:40:00PM	1,278	15.8	
414	12/18/2001	04:50:00PM	1,288	15.9	
415	12/18/2001	05:00:00PM	1,288	15.8	
416	12/18/2001	05:10:00PM	1,276	16.3	
417	12/18/2001	05:20:00PM	1,275	16.1	
418	12/18/2001	05:30:00PM	1,280	15.9	
419	12/18/2001	05:40:00PM	1,276	15.5	
420	12/18/2001	05:50:00PM	1,283	15.5	
421	12/18/2001	06:00:00PM	1,277	16.1	
422	12/18/2001	06:10:00PM	1,291	15.5	
423	12/18/2001	06:20:00PM	1,281	15.6	
424	12/18/2001	06:30:00PM	1,280	15.7	
425	12/18/2001	06:40:00PM	1,275	15.5	
426	12/18/2001	06:50:00PM	1,281	15.7	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
427	12/18/2001	07:00:00PM	1,276	15.7	
428	12/18/2001	07:10:00PM	1,283	15.7	
429	12/18/2001	07:20:00PM	1,279	15.8	
430	12/18/2001	07:30:00PM	1,277	15.9	
431	12/18/2001	07:40:00PM	1,277	15.6	
432	12/18/2001	07:50:00PM	1,275	15.6	
433	12/18/2001	08:00:00PM	1,277	16	
434	12/18/2001	08:10:00PM	1,281	15.7	
435	12/18/2001	08:20:00PM	1,274	16.4	
436	12/18/2001	08:30:00PM	1,275	16.2	
437	12/18/2001	08:40:00PM	1,269	16.2	
438	12/18/2001	08:50:00PM	1,271	15.4	
439	12/18/2001	09:00:00PM	1,275	15.8	
440	12/18/2001	09:10:00PM	1,277	15.9	
441	12/18/2001	09:20:00PM	1,277	15.4	
442	12/18/2001	09:30:00PM	1,276	15.7	
443	12/18/2001	09:40:00PM	1,280	15.1	
444	12/18/2001	09:50:00PM	1,280	15.4	
445	12/18/2001	10:00:00PM	1,280	15.4	
446	12/18/2001	10:10:00PM	1,274	15.2	
447	12/18/2001	10:20:00PM	1,281	15.2	
448	12/18/2001	10:30:00PM	1,277	14.8	
449	12/18/2001	10:40:00PM	1,281	14.7	
450	12/18/2001	10:50:00PM	1,286	14.6	
451	12/18/2001	11:00:00PM	1,284	14.9	
452	12/18/2001	11:10:00PM	1,283	14.3	
453	12/18/2001	11:20:00PM	1,280	15.1	
454	12/18/2001	11:30:00PM	1,279	14.8	
455	12/18/2001	11:40:00PM	1,286	14.9	
456	12/18/2001	11:50:00PM	1,281	14.9	
457	12/19/2001	12:00:00AM	1,281	15.1	
458	12/19/2001	12:10:00AM	1,279	15.2	
459	12/19/2001	12:20:00AM	1,288	14.9	
460	12/19/2001	12:30:00AM	1,284	14.5	
461	12/19/2001	12:40:00AM	1,283	14.5	
462	12/19/2001	12:50:00AM	1,289	15.5	
463	12/19/2001	01:00:00AM	1,367	15	
464	12/19/2001	01:10:00AM	1,251	15.3	
465	12/19/2001	01:20:00AM	1,313	15.5	
466	12/19/2001	01:30:00AM	1,300	15.2	
467	12/19/2001	01:40:00AM	1,293	14.7	
468	12/19/2001	01:50:00AM	1,326	15.3	
469	12/19/2001	02:00:00AM	1,205	15.1	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
470	12/19/2001	02:10:00AM	1,240	15.5	
471	12/19/2001	02:20:00AM	1,248	15.1	
472	12/19/2001	02:30:00AM	1,255	15.1	
473	12/19/2001	02:40:00AM	1,250	14.8	
474	12/19/2001	02:50:00AM	1,285	14.8	
475	12/19/2001	03:00:00AM	1,279	14.2	
476	12/19/2001	03:10:00AM	1,288	14.3	
477	12/19/2001	03:20:00AM	1,283	14.3	
478	12/19/2001	03:30:00AM	1,280	14.7	
479	12/19/2001	03:40:00AM	1,281	13.9	
480	12/19/2001	03:50:00AM	1,282	13.4	
481	12/19/2001	04:00:00AM	1,284	13.9	
482	12/19/2001	04:10:00AM	1,278	13.7	
483	12/19/2001	04:20:00AM	1,283	13.9	
484	12/19/2001	04:30:00AM	1,282	13.6	
485	12/19/2001	04:40:00AM	1,279	14.2	
486	12/19/2001	04:50:00AM	1,289	14.4	
487	12/19/2001	05:00:00AM	1,281	14.4	
488	12/19/2001	05:10:00AM	1,281	14.9	
489	12/19/2001	05:20:00AM	1,282	14.9	
490	12/19/2001	05:30:00AM	1,282	14.3	
491	12/19/2001	05:40:00AM	1,292	14.4	
492	12/19/2001	05:50:00AM	1,282	14.2	
493	12/19/2001	06:00:00AM	1,277	14.2	
494	12/19/2001	06:10:00AM	1,287	14.6	
495	12/19/2001	06:20:00AM	1,286	14.6	
496	12/19/2001	06:30:00AM	1,282	13.5	
497	12/19/2001	06:40:00AM	1,283	13.1	
498	12/19/2001	06:50:00AM	1,286	13.3	
499	12/19/2001	07:00:00AM	1,287	13	
500	12/19/2001	07:10:00AM	1,281	12.8	
501	12/19/2001	07:20:00AM	1,282	13.3	
502	12/19/2001	07:30:00AM	1,283	13.4	
503	12/19/2001	07:40:00AM	1,285	14.7	
504	12/19/2001	07:50:00AM	1,279	14.7	
505	12/19/2001	08:00:00AM	1,282	15	
506	12/19/2001	08:10:00AM	1,284	15.6	
507	12/19/2001	08:20:00AM	1,281	15.7	
508	12/19/2001	08:30:00AM	1,281	15.2	
509	12/19/2001	08:40:00AM	1,277	15.9	
510	12/19/2001	08:50:00AM	1,278	15.9	
511	12/19/2001	09:00:00AM	1,277	15.9	
512	12/19/2001	09:10:00AM	1,275	16.3	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
513	12/19/2001	09:20:00AM	1,275	16.5	
514	12/19/2001	09:30:00AM	1,275	16.6	
515	12/19/2001	09:40:00AM	1,273	16.6	
516	12/19/2001	09:50:00AM	1,270	16.6	
517	12/19/2001	10:00:00AM	1,269	16.7	
518	12/19/2001	10:10:00AM	1,264	16.6	
519	12/19/2001	10:20:00AM	1,272	16.6	
520	12/19/2001	10:30:00AM	1,271	16.3	
521	12/19/2001	10:40:00AM	1,267	16.5	
522	12/19/2001	10:50:00AM	1,266	16.6	
523	12/19/2001	11:00:00AM	1,270	16.4	
524	12/19/2001	11:10:00AM	1,276	16.6	
525	12/19/2001	11:20:00AM	1,269	17	
526	12/19/2001	11:30:00AM	1,268	15.9	
527	12/19/2001	11:40:00AM	1,267	16.5	
528	12/19/2001	11:50:00AM	1,274	16.5	
529	12/19/2001	12:00:00PM	1,268	16.8	
530	12/19/2001	12:10:00PM	1,273	16.3	
531	12/19/2001	12:20:00PM	1,270	16.6	
532	12/19/2001	12:30:00PM	1,272	15.9	
533	12/19/2001	12:40:00PM	1,222	16.3	
534	12/19/2001	12:50:00PM	1,416	16.8	
535	12/19/2001	01:00:00PM	1,284	16.3	
536	12/19/2001	01:10:00PM	1,267	16.5	
537	12/19/2001	01:20:00PM	1,274	16.4	
538	12/19/2001	01:30:00PM	1,273	16.3	
539	12/19/2001	01:40:00PM	1,272	16.5	
540	12/19/2001	01:50:00PM	1,268	16.3	
541	12/19/2001	02:00:00PM	1,274	16.1	
542	12/19/2001	02:10:00PM	1,268	16.1	
543	12/19/2001	02:20:00PM	1,270	15.8	
544	12/19/2001	02:30:00PM	1,267	15.8	
545	12/19/2001	02:40:00PM	1,275	15.6	
546	12/19/2001	02:50:00PM	1,268	15.5	
547	12/19/2001	03:00:00PM	1,274	15.2	
548	12/19/2001	03:10:00PM	1,273	15.1	
549	12/19/2001	03:20:00PM	1,270	15.4	
550	12/19/2001	03:30:00PM	1,271	15.7	
551	12/19/2001	03:40:00PM	1,280	15.5	
552	12/19/2001	03:50:00PM	1,262	15.7	
553	12/19/2001	04:00:00PM	1,277	15.6	
554	12/19/2001	04:10:00PM	1,272	15.5	
555	12/19/2001	04:20:00PM	1,279	15.5	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
556	12/19/2001	04:30:00PM	1,280	15.2	
557	12/19/2001	04:40:00PM	1,278	15.2	
558	12/19/2001	04:50:00PM	1,281	14.8	
559	12/19/2001	05:00:00PM	1,281	14.5	
560	12/19/2001	05:10:00PM	1,282	14.5	
561	12/19/2001	05:20:00PM	1,282	14.4	
562	12/19/2001	05:30:00PM	1,278	14.4	
563	12/19/2001	05:40:00PM	1,276	14.3	
564	12/19/2001	05:50:00PM	1,280	14.4	
565	12/19/2001	06:00:00PM	1,278	14.4	
566	12/19/2001	06:10:00PM	1,274	14.3	
567	12/19/2001	06:20:00PM	1,280	14.3	
568	12/19/2001	06:30:00PM	1,284	14.5	
569	12/19/2001	06:40:00PM	1,281	14.7	
570	12/19/2001	06:50:00PM	1,277	14.5	
571	12/19/2001	07:00:00PM	1,282	14.6	
572	12/19/2001	07:10:00PM	1,279	14.5	
573	12/19/2001	07:20:00PM	1,280	14.4	
574	12/19/2001	07:30:00PM	1,288	14	
575	12/19/2001	07:40:00PM	1,284	14.4	
576	12/19/2001	07:50:00PM	1,279	14.1	
577	12/19/2001	08:00:00PM	1,283	13.7	
578	12/19/2001	08:10:00PM	1,283	13.8	
579	12/19/2001	08:20:00PM	1,277	13.8	
580	12/19/2001	08:30:00PM	1,284	14	
581	12/19/2001	08:40:00PM	1,282	13.9	
582	12/19/2001	08:50:00PM	1,286	14	
583	12/19/2001	09:00:00PM	1,285	14.4	
584	12/19/2001	09:10:00PM	1,282	14	
585	12/19/2001	09:20:00PM	1,286	14.1	
586	12/19/2001	09:30:00PM	1,288	14.3	
587	12/19/2001	09:40:00PM	1,287	14.4	
588	12/19/2001	09:50:00PM	1,284	14.2	
589	12/19/2001	10:00:00PM	1,286	13.9	
590	12/19/2001	10:10:00PM	1,288	13.8	
591	12/19/2001	10:20:00PM	1,290	13.9	
592	12/19/2001	10:30:00PM	1,290	13.8	
593	12/19/2001	10:40:00PM	1,293	13.9	
594	12/19/2001	10:50:00PM	1,286	14	
595	12/19/2001	11:00:00PM	1,290	14.2	
596	12/19/2001	11:10:00PM	1,294	14.6	
597	12/19/2001	11:20:00PM	1,287	14.7	
598	12/19/2001	11:30:00PM	1,282	14.8	

Sample Number	Date	Time	Conductivity (μS/cm)	Temperature (°C)	Notes
599	12/19/2001	11:40:00PM	1,286	14.9	
600	12/19/2001	11:50:00PM	1,304	15.4	
601	12/19/2001	12:00:00AM	1,269	15.7	
602	12/20/2001	12:10:00AM	1,219	15.3	
603	12/20/2001	12:20:00AM	1,292	15.7	
604	12/20/2001	12:30:00AM	1,273	15.8	
605	12/20/2001	12:40:00AM	1,271	15.5	
606	12/20/2001	12:50:00AM	1,272	15.5	
607	12/20/2001	01:00:00AM	1,269	15.2	
608	12/20/2001	01:10:00AM	1,269	15.1	
609	12/20/2001	01:20:00AM	1,271	14.8	
610	12/20/2001	01:30:00AM	1,274	14.9	
611	12/20/2001	01:40:00AM	1,280	14.9	
612	12/20/2001	01:50:00AM	1,270	15.2	
613	12/20/2001	02:00:00AM	1,279	15.3	
614	12/20/2001	02:10:00AM	1,273	15.3	
615	12/20/2001	02:20:00AM	1,271	15.4	
616	12/20/2001	02:30:00AM	1,268	15.4	
617	12/20/2001	02:40:00AM	1,274	15	
618	12/20/2001	02:50:00AM	1,269	14.4	
619	12/20/2001	03:00:00AM	1,268	14.2	
620	12/20/2001	03:10:00AM	1,275	14.4	
621	12/20/2001	03:20:00AM	1,276	14.4	
622	12/20/2001	03:30:00AM	1,280	14.5	
623	12/20/2001	03:40:00AM	1,271	14.7	
624	12/20/2001	03:50:00AM	1,275	14.8	
625	12/20/2001	04:00:00AM	1,271	15.1	
626	12/20/2001	04:10:00AM	1,277	15.3	
627	12/20/2001	04:20:00AM	1,276	15.1	
628	12/20/2001	04:30:00AM	1,272	15.2	
629	12/20/2001	04:40:00AM	1,276	15.2	
630	12/20/2001	04:50:00AM	1,276	15.2	
631	12/20/2001	05:00:00AM	1,269	15.3	
632	12/20/2001	05:10:00AM	1,273	15.2	
633	12/20/2001	05:20:00AM	1,273	15.4	
634	12/20/2001	05:30:00AM	1,279	15.2	
635	12/20/2001	05:40:00AM	1,281	15	
636	12/20/2001	05:50:00AM	1,274	15	
637	12/20/2001	06:00:00AM	1,275	15.1	
638	12/20/2001	06:10:00AM	1,277	15.2	
639	12/20/2001	06:20:00AM	1,274	15.3	
640	12/20/2001	06:30:00AM	1,275	15.1	
641	12/20/2001	06:40:00AM	1,272	15.2	

Sample Number	Date	Time	Conductivity (µS/cm)	Temperature (°C)	Notes
642	12/20/2001	06:50:00AM	1,278	15.3	
643	12/20/2001	07:00:00AM	1,281	15.1	
644	12/20/2001	07:10:00AM	1,270	15.5	
645	12/20/2001	07:20:00AM	1,277	15.4	
646	12/20/2001	07:30:00AM	1,273	15.1	
647	12/20/2001	07:40:00AM	1,272	15	
648	12/20/2001	07:50:00AM	1,270	15.2	
649	12/20/2001	08:00:00AM	1,276	15.1	
650	12/20/2001	08:10:00AM	1,279	15.1	
651	12/20/2001	08:20:00AM	1,275	15.2	
652	12/20/2001	08:30:00AM	1,278	15.4	
653	12/20/2001	08:40:00AM	1,243	16	
654	12/20/2001	08:50:00AM	1,262	13.9	Pump off at 0854
655	12/20/2001	09:00:00AM	0.03	17.5	
656	12/20/2001	09:10:00AM	0.1	20	
657	12/20/2001	09:20:00AM	0.11	21.1	
658	12/20/2001	09:30:00AM	0.32	21.4	
659	12/20/2001	09:40:00AM	0.29	21.2	
660	12/20/2001	09:50:00AM	0.29	21	
661	12/20/2001	10:00:00AM	0.28	21.1	
662	12/20/2001	10:10:00AM	0.26	21.2	

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