# U.S. Department of Energy

**Oakland Operations Office, Oakland, California 94612**

## Lawrence Livermore National Laboratory

**University of California    Livermore, California 94551**

**UCRL-AR-126020**


# LLNL
# Ground Water Project

## 1996 Annual Report


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## Environmental Protection Department

**Environmental Restoration Program and Division**

Work performed under the auspices of the U. S. Department of Energy by Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

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# Acknowledgments

The Lawrence Livermore National Laboratory (LLNL) Ground Water Project is supported by a number of people who contribute significantly to the project. The editors and authors are pleased to recognize their efforts.

W. McConachie, LLNL Environmental Restoration Program/Division Leader, provided overall direction and technical guidance.

A. Copeland, LLNL Environmental Restoration Deputy Program/Division Leader, provided quality assurance and technical guidance.

A. Lamarre, LLNL Livermore Site Project Leader, provided overall guidance and directed the Livermore Site activities.

D. Bishop of LLNL directed program development.

G. Aarons, K. Barber, T. Carson, E. Nielsen, and L. Rodriguez of Weiss Associates supervised drilling, monitor well installation, well development, and borehole logging.

P. Anderson and S. Kawaguchi of LLNL maintained Treatment Facility A and B, and provided technical support.

California Laboratory Services, GTEL Environmental Laboratories, FGL Environmental, and Lockheed Analytical Services provided analytical chemistry services to the project.

T. Canales, C. Grant, and D. Lager of LLNL provided computer programming support.

M. Chiarappa of LLNL worked on ground water and sediment chemistry investigations.

J. Chiu of Weiss Associates oversaw and performed well development, initial sampling, hydraulic tests; measured ground water levels; and provided preliminary interpretation of hydraulic data.

D. Coufal of LLNL maintained Treatment Facility E East and provided technical support.

R. Depue of LLNL performed report composition, editing, proofreading, compilation.

G. Duarte, J. Greci, L. Kita, and P. Lyra of LLNL coordinated field activities.

A. Elsholz of LLNL provided technical support for Accelerated Cleanup Initiative field activities.

K. Fitzgerald and R. Quakenbush of LLNL coordinated computer resources.

S. Fleming and P. Ries of PC Exploration operated the mud-rotary drill rigs.

B. Heffner, LLNL provided community relations support.

K. Heyward and J. Orloff of LLNL prepared the graphics.

B. Johnson of LLNL assisted with activities at Treatment Facility 406 (TF406), and at the Vapor Extraction Facility 518.

C. Justin and B. Staley of LLNL provided publication services.

B. Kidd of LLNL maintained Treatment Facility G and provided technical support.

C. Kuks of LLNL provided administrative support.

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# Summary

The major Livermore Site Ground Water Project (GWP) restoration activities conducted in 1996 are:

1. The Lawrence Livermore National Laboratory (LLNL) Livermore Site GWP produced two major Comprehensive Environmental Response, Compensation, and Liability Act documents in 1996: The Compliance Monitoring Plan, issued January 25, 1996; and the Contingency Plan (CP), issued November 15, 1996. Eleven additional documents or letter reports were submitted to the regulatory agencies in 1996, consisting of 10 Remedial Project Managers Meeting Summaries and the GWP 1995 Annual Report. All seven Department of Energy (DOE)/LLNL milestones in 1996 were met ahead of schedule.
2. The Community Work Group met twice in 1996 to discuss topics including: cleanup progress; DOE budget updates; evaluation of new technologies; the Priority List/Consensus Statement; and the CP.
3. Eighteen source investigation boreholes were drilled during 1996 in the following areas: Treatment Facility A (TFA); Treatment Facility B (TFB); Treatment Facility D (TFD); Treatment Facility E (TFE); Treatment Facility 406 (TF406); Treatment Facility G (TFG); Building 419; and Trailer 5475 (T-5475). Nine were completed as piezometers, four were completed as monitor wells, two were completed as soil vapor extraction/injection wells, and two were completed as soil vapor instrumented boreholes.
4. A technical report describing computer simulations to determine 1) the potential impacts of the volatile organic compound (VOC) source in the vadose zone and 2) the potential effectiveness of various soil vapor extraction design alternatives at Building 518 was completed in 1996.
5. An investigation using numerical modeling and geostatistical techniques to study the migration of tritium in unsaturated heterogeneous sediments beneath the Building 292 area was completed in 1996. Modeling results indicate that the subsurface tritium poses no serious long-term threat to ground water quality.
6. A three-dimensional (3-D) ground water flow and contaminant transport model was developed, and a description of the 3-D model calibration and a summary of the preliminary results for the TFA area was completed in 1996.
7. The 1996 extraction wells, extraction rates, and estimated VOC mass removed at TFA, TFB, Treatment Facility C (TFC), TFD, TFE, TF406, TFG, and Vapor Treatment Facility 518 (VTF518) are summarized in Table Summ-1. Vapor Treatment Facility 518 is designated VTF518 to distinguish it from future ground water treatment (TF518) in the Building 518 area.
8. 1996 construction activities included:
    - Construction of the TFC North Pipeline connecting wells W-1015, W-1102, W-1103, W-1104, and W-1116;

- Construction of PTU stations at TFE East, TF406, and TFG-1;
- Modifying TFA to increase facility flow capacity to 350 gpm and at TFB to add hexavalent chromium treatment capability; and

9. Thirty wells installed in 1996 are shown in Table Summ-2.
10. In 1996, hydraulic tests were conducted as presented in Table Summ-3.
11. During 1996, TFA, TFB, TFC, TFD, TFE East, TF406, TFG-1, and VTF518 were operational. To date, about 338 million gal of ground water and almost 2 million cubic ft of vapor have been processed, removing more than 186 kg of VOCs.
12. During 1996, a passive bioremediation approach was initiated in the TFF area and treatment of residual dissolved-fuel hydrocarbons in ground water extracted from hydrostratigraphic units 3A and 3B was discontinued with regulatory approval.

**Table Summ-1. 1996 extraction wells, extraction rates, and estimated VOC mass removed.**

| Treatment facility area | Extraction wells | Extraction rate | Estimated total VOC mass removed (kg) |
|---|---|---|---|
| **TFA** | **W-109, W-262, W-408, W-415, W-457, W-518, W-520, W-522, W-601, W-602, W-603, W-609, W-614, W-712, W-903, W-904, W-1004, W-1009** | **175-310 gpm** | **16.8** |
| **TFB** | **W-357, W-610, W-620, W-621, W-655, W-704** | **50 gpm** | **7.7** |
| **TFC** | **W-701, W-1015, W-1102, W-1103, W-1104, W-1116** | **15-50 gpm** | **2.4** |
| **TFD** | **W-351, W-906, W-907** | **8.5-40 gpm** | **12.1** |
| **TFE** | **W-566, W-1109** | **20 gpm** | **0.8** |
| **TF406** | **W-1114** | **10-16 gpm** | **0.2** |
| **TFG** | **W-1111** | **8 gpm** | **0.2** |
| **VTF518** | **SIP-518-201** | **18 scfm** | **42.0** |
| **1996 Total** | | | **82.2** |

**Notes:**

**kg = Kilograms.**

**gpm = Gallons per minute.**

**scfm = Standard cubic feet per minute.**

**Table Summ-2. 1996 well installations.**

| Treatment facility area | Well(s) |
|---|---|
| TFA | W-1214, W-1217 |
| TFB | W-1226 |
| TFC | W-1212, W-1213, W-1224 |
| TFD | W-1208, W-1215, W-1216, W-1218, W-1220, W-1221, W-1223, W-1250, W-1251, W-1252, W-1253, W-1254, W-1255, W-1301 |
| TFE | W-1210, W-1211, W-1219, W-1225 |
| TF406 | W-1209 |
| T-5475 | W-1222, SVI-ETS-504, SVI-ETS-505, SEA-ETS-506, SEA-ETS-507 |

**Table Summ-3. Hydraulic tests.**

| Treatment facility area | Well(s) |
|---|---|
| TFA | W-254 |
| TFC | W-1014, W-1102, W-1106, W-1110, W-1116, W-1212, W-1213 |
| TFD | W-1205, W-1207, W-1215, W-1216, W-1218, W-1220, W-1221, W-1254 |
| TFE | W-911, W-1109, W-1203, W-1204, W-1210, W-1211, W-1202 |
| TFF/TF406 | W-1112, W-1113, W-1209 |
| TFG | W-1111 |
| TF518 | W-112 |
| T-5475 | W-356, W-1108, W-1117, W-1118, W-1201, W-1222 |

**Notes:**

TF518 = Ground Water Treatment Facility 518.

TFF = Treatment Facility F.

# 1. Introduction

This report summarizes the 1996 Lawrence Livermore National Laboratory (LLNL) Livermore Site Ground Water Project (GWP) activities in five sections: Regulatory Compliance; Field Investigations; Flow and Transport Modeling; Annual Summary of Remedial Action Program, including discussions of treatment facility activities; and Trends in Ground Water Analytical Results. The 1996 GWP quarterly self-monitoring reports (McConachie and Brown, 1996a; Ko and Lamarre, 1996; Littlejohn and Lamarre, 1996; 1997) were issued separately.

Figure 1 shows the locations of monitor wells, piezometers, extraction wells, and treatment facilities at the Livermore Site and vicinity as well as other areas referenced in this report. Wells and boreholes drilled in 1996 are shown in bold typeface.

Appendices A through D show Well Construction and Closure Data, Hydraulic Test Results, the 1997 Ground Water Sampling Schedule, and the 1996 Drainage Retention Basin Annual Monitoring Program Summary. The data on ground water volatile organic compound (VOC) analyses, water level elevations, and the Treatment Facility F/Treatment Facility 406 (TFF/TF406) area ground water VOC and fuel hydrocarbon (FHC) analyses are available on request.

# 2. Regulatory Compliance

In 1996, the U.S. Department of Energy (DOE)/LLNL submitted documents required by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Livermore Site Federal Facility Agreement (FFA). In addition, DOE/LLNL continued the environmental restoration and community activities discussed below.

## 2.1. CERCLA Documents

During 1996, DOE/LLNL issued two final CERCLA documents for the Livermore Site according to the amended schedule in the Remedial Action Implementation Plan (RAIP) (Dresen et al., 1993). The Compliance Monitoring Plan (CMP) (Nichols et al., 1996) was issued on January 25, 1996, and the Contingency Plan (CP) (McKereghan et al., 1996) was issued on November 15, 1996.

As required by the FFA, DOE/LLNL issued the 1995 GWP Annual Report (Hoffman et al., 1996). DOE/LLNL also submitted 10 Remedial Project Managers' Meeting Summaries; the March (McConachie and Brown, 1996), July (Ko and Lamarre, 1996), September and December (Littlejohn and Lamarre, 1996; 1997, respectively) summaries included quarterly self-monitoring data.

## 2.2. Milestones and Activities

Table 1 presents the amended 1996 RAIP DOE/LLNL milestones (Dresen et al., 1993) for the Livermore Site. All seven of the milestones were completed ahead of schedule.

In addition to RAIP milestones, DOE/LLNL completed the following tasks on the revised LLNL Livermore Site priority list (Dresen et al., 1993):

- Conducted source investigations at Treatment Facility G (TFG).
- Completed and activated the Treatment Facility C (TFC) North Pipeline on September 26, 1996.

Environmental Restoration activities in 1996 also included the following:

- Negotiated the Bay Area Air Quality Management District permit conditions for Portable Treatment Units (PTUs).
- Revised LLNL's GWP Standard Operating Procedures (Dibley and Depue, 1996).
- Received regulatory approval to modify treatment facility effluent discharge limits for metals and sampling frequencies (Bessette Rochette, 1996). See Sections 5.2, 5.3.1, and 5.4 for further discussion.
- Received regulatory approval on an outline for the Five-Year Review, due August 5, 1997 (Littlejohn and Lamarre, 1996).
- Submitted *Application for Containment Zone for the Livermore Site Hydrocarbon Impacted Zone at Treatment Facility F* (Happel et al., 1996) on July 17, 1996, and received regulatory approval for "no further action" for the fuel hydrocarbons on October 30, 1996 (CRWQCB-SF, 1996). See Section 5.6.1 for further discussion.
- Issued the report *Simulation of Soil Vapor Extraction at Building 518* (Vogele et al., 1996a) to the regulatory agencies. See Section 4.1.1 for additional information.
- Agreed to a revised Livermore Site Consensus Statement/Priority List and the RAIP schedule on September 19, 1996 (Ko et al., 1996).

In addition, DOE/LLNL have started to prepare two Explanation of Significant Differences reports for changes to the remedial action plan described in the Record of Decision (U.S. DOE, 1992). One is for a change to air stripping only at Treatment Facilities A and B (TFA and TFB), and the other is for changes in the metals discharge limits. A revised Site Safety Plan is also in preparation.

## 2.3. Community Relations

The Community Work Group (CWG) met twice in 1996 to discuss cleanup progress, DOE budget issues, evaluation of new technologies, the Priority List/Consensus Statement, and the CP. There was ongoing correspondence and communication with CWG members throughout the year.

Other Livermore Site community relations activities in 1996 included communications and meetings with a local interest group and other community organizations; public presentations including those to local realtors and international student and business groups; producing and distributing the *Environmental Community Letter*; maintaining the Information Repositories and the Administrative Record; conducting tours of the site environmental activities; organizing a Treatment Facility G-1 (TFG-1) ribbon cutting ceremony; and responding to public and news media inquiries. DOE/LLNL also began meeting with members of Tri-Valley Citizens Against a

Radioactive Environment and their technical advisor prior to the renewal of their U.S. Environmental Protection Agency Technical Assistance Grant.

# 3. Field Investigations

## 3.1. Ground Water Sampling

In 1996, the GWP submitted 1,582 samples for analyses. These samples were collected during 990 individual sampling events from 385 sampling locations. These locations consisted of 303 monitor wells, 59 source investigation piezometers, 15 TFF area wells and eight Alameda County Flood Control and Conservation District (Zone 7) or domestic wells. The samples were analyzed for VOCs, FHCs, metals, tritium and gamma-emitting radionuclides, or a combination of analyses depending on the compounds of concern.

Livermore Site ground water sampling frequency recommendations are updated quarterly by a cost-effective sampling algorithm that evaluates trends in contaminant levels in each well over an 18-month period. The algorithm aids in evaluating chemical trends. The sampling frequency is determined by the treatment facility Task Leaders based on algorithm results and other data. The main features of the algorithm that help to determine the sampling frequencies are based on the following criteria:

- Wells exhibiting little change [< 10 parts per billion (ppb) per year] are sampled annually or biennially.
- Wells exhibiting moderate change (≥ 10 ppb but < 30 ppb per year) are sampled semiannually.
- Wells showing large change (≥ 30 ppb) are sampled quarterly.
- Wells with less than 18 months of analytical history are sampled quarterly for the first 18 months, then the algorithm logic, and input from the Task Leaders for each treatment facility area, determines the sampling frequency.

Wells located at the leading edge of VOC plumes are sampled quarterly. The sampling schedule for 1997 is presented in Appendix C.

## 3.2. Source Investigations

Drilling activities for source investigations conducted in 1996 are summarized in Table 2 and drilling locations are shown in Figure 1.

The 1996 source investigation activities are briefly summarized below by area.

- **Building 419**. Two boreholes were drilled west of Building 419, downgradient of piezometer SIP-419-101. These boreholes were drilled to evaluate elevated levels of tritium detected in the unsaturated zone in SIP-419-101. Both of these boreholes were completed as piezometers (SIP-419-201 and SIP-419-202) and screened in hydrostratigraphic unit (HSU) 3A and HSU 3A/3B (Blake et al., 1995), respectively from 97 to 107 ft below ground surface (bgs).

- **Trailer 5475 (T-5475)**. Five boreholes were drilled in the T-5475 area. Four boreholes were drilled in the vicinity of the T-5475 source area for a soil vapor treatability test for Remedial Design Report No. 4 (RD4). Two of the boreholes were completed as soil vapor installations SVI-ETS-504 and SVI-ETS-505 screened in the unsaturated portion of HSU 2. SVI-ETS-504 was completed as a vapor extraction well, and SVI-ETS-505 was completed as a vapor extraction/injection well. The other two boreholes, SEA-ETS-506 and SEA-ETS-507 were each completed with Flexible Liner Underground Technologies, Ltd. (FLUTe; formerly called SEAMIST) liners. The FLUTe liners were equipped with vapor ports, temperature sensors and soil-moisture sensors distributed at eight different depths within HSU 1B and HSU 2, between 7 and 61 ft bgs.
- **Treatment Facility 406 (TF406)**. Two boreholes were drilled upgradient of TF406 to investigate potential sources of the TF406 VOC plume. Both boreholes were drilled near Building 511 and completed as piezometers SIP-511-101 and SIP-511-102.
- **Treatment Facility A (TFA)**. Two boreholes (W-1214 and W-1217) were drilled in the TFA area to further characterize the unsaturated zone VOC distribution and to provide better source area ground water monitoring locations. Both wells are screened in HSU 1B, between 78 and 100 ft bgs.
- **Treatment Facility B (TFB)**. Three boreholes were drilled in the TFB area to follow up on drilling conducted in 1989 and 1990 in the vicinity of Building 141. All three boreholes were completed as piezometers (SIP-141-201, SIP-141-202, and SIP-141-203) and were screened in HSU 1B, between 57 to 83 ft bgs.
- **Treatment Facility D (TFD)**. One borehole was drilled in the southern portion of the TFD area to investigate increasing VOC concentrations south of the Drainage Retention Basin. This borehole was completed as piezometer SIP-ETC-201and was screened in HSU 2 from 80 to 100 ft bgs.
- **Treatment Facility D (TFD)/Accelerated Cleanup Initiative (ACI)**. One borehole was drilled in the TFD area as part of the ACI characterization. This borehole was completed as piezometer SIP-HPA-201 and was screened in HSU 2 from 71 to 76 ft bgs.
- **Treatment Facility E (TFE)**. Two boreholes were drilled to further characterize the extent of VOCs in the unsaturated zone in the TFE area. One borehole was drilled and completed as well W-1219 and was screened in HSU 3A from 138 to 142 ft bgs. The other borehole was completed as well W-1225 and was screened in HSU 3A from 113 to 121 ft bgs.
- **Treatment Facility G (TFG)**. One borehole was drilled south of Building 212 to investigate a release of tritiated water. This borehole was completed as piezometer SIP-212-101 and was screened in HSU 2 from 87 to 90 ft bgs.

Significant highlights of 1996 source investigation studies include:

- **Building 419**. Trichloroethylene (TCE), in concentrations generally below 100 ppb, was detected in most unsaturated sediment samples collected from the boreholes for both piezometers SIP-419-201 and SIP-419-202. Bailed ground water samples collected following development of both piezometers detected total VOCs around 1 part per million (ppm). The chemical constituents detected in the ground water samples were similar to those detected in the sediment samples, indicating this area was a probable old source area. Elevated tritium detected in the unsaturated zone of SIP-419-101 diminishes laterally and is confined to the upper 30 ft.

- **T-5475**. Analytical results from sediment samples collected from the five boreholes drilled in the T-5475 area indicate that the highest unsaturated zone VOC and tritium concentrations were detected in sediment samples collected from the boreholes for wells SVI-ETS-504 and SEA-ETS-507. Both of these boreholes are adjacent to the largest of the former T-5475 area disposal pits. A full discussion of T-5475 area source investigation results will be presented in RD4.
- **TF406**. Sediment samples collected from the borehole for piezometer SIP-511-101 contained total VOCs up to 21 ppb from the lower part of the unsaturated zone. A ground water sample collected from this piezometer in November 1996 contained just under 400 ppb total VOCs.
- **TFA**. Unsaturated sediment samples collected from the borehole for well W-1214 contained PCE throughout the unsaturated zone in concentrations up to 32 ppb, indicating this location is near the source area of the TFA plume. Unsaturated sediment samples collected from the borehole for well W-1217 detected PCE sporadically through the unsaturated zone at concentrations less than 2 ppb, indicating this location is near the northern extent of the TFA source area.
- **TFB**. Total VOCs between about 4 and 420 ppb were detected throughout the unsaturated zone just north of Building 141 in the borehole for piezometer SIP-141-202, indicating that this location is near a probable old source.
- **TFD**. Unsaturated sediment samples collected from the borehole for piezometer SIP-ETC-201 contained up to 100 ppb total VOCs, primarily tetrachloroethylene (PCE) at most depths. This area is a probable past contributing source of the ground water VOC plume in the southern portion of the TFD area.
- **TFE**. Low concentrations of tritium, up to 2,040 picocuries per liter of soil moisture ($pCi/L_{sm}$) were detected in most unsaturated sediment samples collected from the borehole for well W-1225. Tritium concentrations in saturated HSU 2 sediment samples were generally less than 1,000 $pCi/L_{sm}$. Tritium was detected at a concentration of 3,390 pCi/L in a ground water sample bailed from the well following development. The source of the tritium in the T-5475 area will be more fully discussed in RD4.
- **TFG**. Sediment samples collected from the borehole for piezometer SIP-212-101 contained tritium in concentrations that increased with depth. The maximum concentration of 9,900 $pCi/L_{sm}$, was detected in the first saturated sample collected from a depth of 90 ft bgs. Three ground water samples collected from the piezometer during 1996 contained tritium in concentrations ranging from 1,180 to 1,900 pCi/L.

Source investigation drilling is ongoing, as needed to collect additional data to aid in remediation optimization, to respond to new information on past releases, and to investigate new releases.

# 4. Flow and Transport Modeling

Unsaturated and saturated zone contaminant transport modeling were conducted in 1996 to support the design and evaluate the performance of Livermore Site remediation systems. Modeling results were also used to support ongoing subsurface characterization.

## 4.1. Unsaturated Zone Modeling

The numerical, multiphase, multicomponent computer code, NUFT (Nonisothermal Unsaturated-Saturated Flow and Transport; Nitao, 1996) was used to simulate contaminant transport in the unsaturated zone beneath both Building 518 (B-518) and Building 292 (B-292) (Fig. 1).

### 4.1.1. Building 518

In September 1996, a report was issued describing computer simulations to determine: 1) the potential impacts on ground water of VOCs in the vadose zone, and 2) the potential effectiveness of various soil vapor extraction design alternatives at B-518 (Vogele et al., 1996a). These simulations were conducted to evaluate the need for vadose zone source removal and to support the remedial design of Vapor Treatment Facility 518 (VTF518). The modeling results were used to develop site-specific cleanup goals for the B-518 area (Fig. 1).

### 4.1.2. Building 292

Source investigation results indicate that tritiated water was released from leaking underground storage tank (R1U1) beneath the B-292 area (Fig. 1). An investigation using numerical modeling and geostatistical techniques to study the migration of tritium in unsaturated heterogeneous sediments beneath the B-292 area was completed in December 1996. The primary objective of the study was to use available site characterization and monitoring data to predict the impact of the release on future ground water quality. Major findings of the study are:

- Modeling results indicate that the release poses no serious long-term threat to ground water quality.
- Elevated concentrations of tritium in sediment, over $1.0 \times 10^7$ pCi/L$_{sm}$, are expected to persist in the vadose zone for about 50 years. Because fluid velocities are very low in the vadose zone, tritium activity is more strongly controlled by radioactive decay than by transport.
- Based on a concentration field generated by ordinary kriging of analytical data, the total tritium activity in the subsurface was estimated to be about five curies in 1990. Approximately 91% of this activity existed north of Tank R1U1.
- The impact of the tritium release on ground water quality is substantially reduced by an asphalt cap that partially covers the underground storage tank, thereby limiting surface water infiltration.
- Vapor diffusion has a negligible effect on ground water tritium concentrations and a very small effect on vadose zone concentrations.

- Numerical simulations based on soil permeability fields derived by kriging yield substantially lower ground water tritium concentrations compared to simulations based on fields derived by conditional simulation. Conditional simulations provide better results because they are more representative of real heterogeneities present in the subsurface away from the actual data points.

Although modeling results indicate that the tritium release poses no long-term threat to ground water quality beneath the Livermore Site, the ground water and vadose zone tritium concentration will continue to be monitored.

If the tritium concentration rises above the Maximum Contaminant Level (MCL) of 20,000 pCi/L for two consecutive quarters, a re-evaluation of the sampling frequency will be warranted.

## 4.2. Saturated Zone Modeling

As part of the effort to forecast, monitor, and interpret the progress of remediation at the Livermore Site, a three-dimensional (3-D) ground water flow and contaminant transport model was developed using the CFEST (Coupled Flow, Energy and Solute Transport) computer code (Gupta, 1987). The 3-D model builds vertical resolution into the two-dimensional model previously developed for the Livermore Site (Tompson et al., 1995) and focuses on the transport of the dissolved PCE plume in HSUs 1B and 2 in the TFA area. A technical note containing a description of the 3-D model calibration and a summary of the preliminary results was completed in August 1996 (Vogele et al., 1996b).

As described in Vogele et al. (1996b), the 3-D flow model was calibrated to measured ground water elevation data collected from the Livermore Site monitoring wells. The contaminant transport portion of the model was calibrated to PCE ground water concentrations observed in the TFA area from 1988 through 1995. These simulations were comprised of a series of remedial-pumping time steps that were constructed to reflect changes in extraction well flow rates.

Results from these preliminary simulations were within the uncertainty limits of the model and will be further improved after lower HSUs (e.g., 3A, 3B, 4, etc.) are incorporated into the 3-D model (Figs. 2 and 3). In addition, the simulated mass removal rate was consistent with actual measurements at TFA. Results also indicate that the current and planned TFA wellfield should hydraulically control and clean up the PCE plumes.

In late 1996, the model was further improved by including the pumping history and flow rate data for other Livermore Site treatment facility extraction wells. The pumping schedules in the model were refined to reflect these additional data. Surface recharge from rainfall was also converted to a time-dependent boundary condition to account for the general increase in ground water elevations observed since the end of the drought period. In addition, the computer code CFEST was optimized by the model’s author in 1996, and modified to more accurately simulate potential dewatering of Livermore Site sediments. The current model will be used to evaluate and improve the effectiveness of individual treatment facilities cleanup of specific contaminant plumes.

Preliminary simulations of the TCE plume beneath the TFB area should be completed in early 1997. Time-history isoconcentration contour maps of other VOC plumes beneath the Livermore Site are currently being constructed. The 3-D model will be compared and normalized to these plume maps. Transport of the individual plumes will be simulated with the aid of the MapIt interface tool, which was improved in 1996 to streamline CFEST input and output, and reduce the effort needed to prepare, execute, and interpret simulations (Canales and Grant, 1996).

# 5. Annual Summary of Remedial Action Program

This section summarizes activities performed during 1996 to support the Remedial Action Program at the Livermore Site, and includes treatment facility performance, well installations, hydraulic and treatability tests, and treatment facility design, construction and modifications performed during 1996. The volume of ground water and soil vapor treated at the facilities and the estimated VOC mass removed from the subsurface during 1996 and historically are presented in Tables 3 and 4, respectively. The VOC mass removed from beneath the site is also shown graphically in Figure 4. Figures 5, 6, and 7 show the capture areas, based on November ground water elevation data, in the vicinity of the pumping wells for HSUs 1B, 2, and 3A, respectively. Figures 8, 9, and 10 show fourth quarter isoconcentrations in the same three HSUs. Figures 11 through 17 show treatment facility extraction wells, pipelines, discharge locations, and self-monitoring program sampling stations.

## 5.1. Treatment Facility A

TFA is located in the southwestern quadrant of the Livermore Site near Vasco Road (Fig. 1). TFA processes ground water using a combination of ultraviolet light/hydrogen peroxide (UV/$H_2O_2$) treatment and air stripping. Beginning in December 1995, LLNL modified TFA to increase the maximum flow rate from 200 gallons per minute (gpm) to the regulatory limit of 350 gpm. Operation of TFA resumed in February 1996; due to higher ground water extraction rates, VOC plumes in HSUs 1B, 2, and 3A were fully captured (Figs. 5, 6, 8, 9, and 10).

As shown in Figure 11, 18 extraction wells now contribute ground water to TFA via four pipelines, for a total flow rate of about 310 gpm. The wells are: W-415 (TFA East Pipeline); W-262, W-518, W-520, W-522, W-601, W-602, W-603, and W-609 (TFA South Pipeline); W-614, W-712, W-1004, and W-1009 (TFA North Pipeline); and W-109, W-408, W-457, W-903, and W-904 (TFA Arroyo Pipeline). Six HSU 1B extraction wells contribute a flow of approximately 105 gpm, 11 HSU 2 extraction wells contribute an average flow of 195 gpm, and one HSU 3A extraction well contributes about 10 gpm. Water levels were measured in this area at startup to evaluate the capture area of the TFA remedial wellfield, and to more accurately define hydraulic communication both within and between HSUs 1B, 2, and 3A.

### 5.1.1. Performance Summary

During 1996, TFA treated more than 92 million gal of ground water containing an estimated 16.8 kg of VOCs (Table 3). This treated ground water was discharged to the Recharge Basin, located about 2,000 ft southeast of TFA on Sandia National Laboratory property (Figs. 1 and 11).

Since system startup in 1989, TFA has treated nearly 262 million gal of ground water and removed about 75 kg of VOC mass from the subsurface (Table 4).

### 5.1.2. Field Activities

Two wells, W-1214 and W-1217 (Fig. 1), were installed during 1996 to further define the extent of the suspected HSU 1B PCE source in the southeast portion of the TFA area. These wells were discussed in Section 3.2, and construction details are presented in Appendix A.

### 5.1.3. Hydraulic Tests

Results of one-hour drawdown tests conducted on wells W-913, W-1001, W-1007, and W-1105 (Fig. 1) in 1995 are presented in Appendix B. A two-week long-term hydraulic test of proposed HSU 1B PCE source area extraction well W-254 was conducted in late December 1996. Analysis of this test is in progress and the results will be included in the next annual report.

## 5.2. Treatment Facility B

TFB is located east of Vasco Road and north of Mesquite Way (Fig. 1). Similar to TFA, ground water is processed at TFB using a combination of UV/$H_2O_2$ treatment and air stripping.

From 1991 through 1995, TFB treated ground water extracted primarily from wells W-357 and W-704 (Figs. 1 and 12). The TFB North Pipeline was activated in September 1995, which connected four additional extraction wells (W-610, W-620, W-621, and W-655) to TFB. During 1996, the average combined flow rate of these six TFB extraction wells was about 50 gpm. Wells W-704, W-610, and W-620 extract a total of about 18 gpm of ground water from HSU 1B. Wells W-357, W-621, and W-655 extract a total of about 32 gpm of ground water from HSU 2. These wells hydraulically capture offsite VOC plumes in both HSUs 1B and 2 in the west-central portion of the Livermore Site (Figs. 5, 6, 8, and 9).

TFB was modified during 1996 to more effectively treat ground water containing hexavalent chromium. Results from treatability tests confirmed that hexavalent chromium in low pH water can be reduced to trivalent chromium by adding hydrogen peroxide. To lower the pH of the influent at TFB, carbon dioxide is added to ground water after it has passed through the UV/$H_2O_2$ system. A 5,000-gal tank was added to TFB immediately prior to the air stripper to allow sufficient time for the injected hydrogen peroxide to reduce the hexavalent chromium. Subsequent air stripping removes excess carbon dioxide, thereby raising the pH. As a result of these modifications, the average TFB hexavalent chromium influent concentration of 25 ppb has been reduced to less than 15 ppb.

Subsequent to these modifications, the Livermore Site metals discharge limits were revised (Bessette Rochette, 1996). Under the new discharge limit, the wet-season (December 1 through March 31) hexavalent chromium limit is 22 ppb. During the dry season (April 1 through November 30), there is no specific hexavalent chromium limit, and the total chromium limit is 50 ppb. The treatment method described above is only used during the wet season when it is necessary to reduce hexavalent chromium concentrations below the 22 ppb discharge limit.

### 5.2.1. Performance Summary

During 1996, TFB processed almost 15 million gal of ground water containing an estimated 7.7 kg of VOCs (Table 3). Since system startup in 1990, TFB has processed more than 48 million gal of ground water and removed an estimated 20.1 kg of VOC mass from the subsurface (Table 4). Treated water is discharged to a drainage ditch that flows north along Vasco Road and ultimately flows into Arroyo Las Positas near the northwest corner of the Livermore Site (Figs. 1 and 12).

### 5.2.2. Field Activities

One well, W-1226, was installed in the TFB area during 1996 (Fig. 1). This well was screened in HSU 2 to better define the southern portion of the TFB VOC plume, and to monitor the impact of TFA ground water extraction, if any, on the TFB plume. Construction details for well W-1226 are presented in Appendix A.

To gain additional information from the TFB source areas and to provide additional monitoring points for evaluating the effectiveness of TFB source area remediation, three source investigation piezometers (SIP-141-201, SIP-141-202, and SIP-141-203) were installed in HSU 1B in the vicinity of Building 141 (Fig. 1).

### 5.2.3. Hydraulic Tests

Results of one-hour drawdown tests conducted on wells W-1010, W-1011, W-1012, and W-1013 (Fig. 1) in 1995 are presented in Appendix B. No hydraulic tests were performed in the TFB area during 1996.

## 5.3. Treatment Facility C

TFC is located in the northwest quadrant of the Livermore Site (Fig. 1) and utilizes air stripping and ion exchange to treat ground water.

TFC began operation in 1993 and currently treats ground water extracted from HSU 1B wells W-701, W-1015, W-1102, W-1103, W-1104, and W-1116 (Fig. 13). The TFC North Pipeline was constructed during 1996 and connects wells W-1015, W-1102, W-1103, W-1104, and W-1116 to TFC. The TFC North Pipeline was activated on September 26, 1996.

From January through September 1996, the average flow from TFC extraction well W-701 was about 15 gpm. In September, LLNL began extracting ground water from the five TFC North pipeline wells at a rate of about 45 gpm for a 6-hour period each working day (Monday through Friday). TFC began 24-hour operation in early 1997. The average combined flow for the six TFC extraction wells is about 50 gpm. These wells hydraulically capture plumes located beneath the northwestern portion of the Livermore Site (Fig. 8). Hydraulic capture in the TFC area is not shown on Figure 5 because the treatment facility was not operating when the November water levels were measured.

### 5.3.1. Performance Summary

During 1996, TFC processed about 4.4 million gal of ground water containing an estimated 2.4 kg of VOCs (Table 3). Since system startup in 1993, TFC has processed nearly 13 million gal of ground water and removed over 6 kg of VOC mass from the subsurface (Table 4). Treated water at TFC is discharged into Arroyo Las Positas near the northwest corner of the Livermore Site (Fig. 13).

As described in Section 5.2, the discharge limits for chromium were changed during 1996 to vary seasonally. Because influent total chromium concentrations are consistently less than 50 ppb, ion-exchange treatment is now only required during the wet season.

### 5.3.2. Field Activities

Wells W-1212, W-1213, and W-1224 were installed in HSU 1B in the TFC area during 1996 (Fig. 1; Appendix A). Well W-1213 will be used as an HSU 1B extraction well for the TFC Southeast PTU to meet the RAIP milestone startup date of January 31, 1997. Well W-1212 will be used to monitor ground water VOC concentrations near the TFC Southeast source area. Well W-1224 will be used to more accurately define the hydraulic capture in this area.

### 5.3.3. Hydraulic Tests

One-hour drawdown tests were performed on TFC area wells W-1014, W-1102, W-1106, W-1110, W-1116, W-1212, and W-1213 during 1996 (Fig. 1). In addition, 72-hour pumping tests were performed on wells W-1212 and W-1213. These long-term tests were performed to evaluate the effectiveness of these HSU 1B wells as TFC Southeast extraction wells. Well W-1212 was unable to sustain a flow rate greater than 1 gpm and is therefore unsuitable as an extraction well despite its location within the source area. Well W-1213 sustained a flow rate of about 7 gpm during testing. Results of these tests and of 1995 one-hour drawdown tests on wells W-1101 and W-1103 are provided in Appendix B.

## 5.4. Treatment Facility D

TFD is located in the northeast quadrant of the Livermore Site (Fig. 1) and uses air stripping and ion exchange to treat ground water. TFD remediation performance is summarized in Section 5.4.1.

TFD began operation in September 1994 and treats ground water extracted from wells W-351, W-906, and W-907. Prior to 1996, the NPDES discharge limit of 7.1 ppb nickel constrained LLNL from using well W-907 as an extraction well. Subsequently, the discharge limit for nickel was increased to 100 ppb during the dry season (April 1 to November 30) and to 320 ppb during the wet season (December 1–March 31) (Bessette Rochette, 1996). As a result, LLNL resumed using W-907 as a full-time extraction well in August 1996.

From January through July 1996, the average combined flow rate of the two TFD extraction wells, W-351 and W-906, was about 8.5 gpm. With the addition of well W-907 in August, the average combined flow rate of these three wells increased to about 40 gpm. Well W-906 produces about 7 gpm of ground water from HSUs 2 and 3A. Wells W-351 and W-907 extract ground water at a combined rate of about 33 gpm from HSU 4. These wells hydraulically capture VOCs associated with the northern portion of the East Traffic Circle and Helipad source areas (Figs. 6, 7, 9, and 10).

### 5.4.1. Performance Summary

During 1996, TFD processed about 10.7 million gal of ground water containing an estimated 12.1 kg of VOCs (Table 3). Since system startup in 1994, TFD has processed nearly 13 million gal of ground water and removed about 18 kg of VOC mass from the subsurface (Table 4). Treated water at TFD flows through an underground pipe which discharges into Arroyo Las Positas (Fig. 14).

### 5.4.2. Field Activities

Fourteen wells and two piezometers were installed in the TFD area during 1996. Extraction well W-1208 was installed near TFD (Fig. 1) and is screened in HSUs 3A and 3B. Wells W-1215 and W-1216 were installed in the western portion of the TFD area (Fig. 1) and are planned HSU 2 extraction wells for the TFD West PTU. Monitor wells W-1218, W-1220, and W-1221 were installed south of the Drainage Retention Basin in HSU 3A, HSU 2, and HSU 4, respectively (Fig. 1). Monitor wells W-1223 and W-1301 were installed east of the Drainage Retention Basin (Fig. 1) in HSU 2 and HSU 3A, respectively. These five monitor wells improve our definition of plumes related to the East Traffic Circle source areas and are potential extraction locations.

Six wells (W-1250, W-1251, W-1252, W-1253, W-1254, and W-1255) were installed east of TFD, near the Helipad, to provide detailed characterization data for the proposed ACI test site (Fig. 1). These wells were all completed within HSU 4. Construction details of these TFD wells are presented in Appendix A, and their locations are shown in Figure 1.

As discussed in Section 3.2, source investigation piezometer SIP-ETC-201 was installed south of the East Traffic Circle to further characterize the VOC plume. Source investigation piezometer SIP-HPA-201 was installed near the Helipad as part of the ACI characterization.

### 5.4.3. Hydraulic Tests

One-hour drawdown tests were performed on TFD area wells W-1215, W-1216, W-1218, W-1220, and W-1221 during 1996. Slug tests were also performed on wells W-1205 and W-1207. In addition, 72-hour pumping tests were performed on HSU 2 wells W-1215, W-1216 individually, and wells W-1215 and W-1216 simultaneously. These tests were performed to evaluate the effectiveness of these wells to extract ground water for the TFD West PTU. Both wells were able to sustain flow rates of about 14 gpm, and good hydraulic communication was observed in nearby HSU 2 monitor wells W-369 and W-411.

A 72-hour hydraulic test was performed on HSU 4 well W-1254 to evaluate the hydraulic conditions in the area of the proposed ACI project. Well W-1254 sustained a flow rate of about 20 gpm and good hydraulic communication was observed in HSU 4 monitor wells over a wide area up to 1,000 ft from the pumping well. In addition, an area of vertical leakage between HSUs 4 and 5 was identified when two HSU 5 wells in the vicinity also showed hydraulic communication. The limited number of HSU 5 wells in the area precludes delineating the full extent of leakage. Results of these tests are provided in Appendix B, and the well locations are shown on Figure 1.

## 5.5. Treatment Facility E

The TFE area is located in the southeast quadrant of the Livermore Site and will consist of multiple PTUs that utilize air stripping to treat ground water (Fig. 1). The TFE East PTU was activated on November 25, 1996, ahead of the RAIP milestone date of November 27, 1996 (Dresen et al., 1993). Wells W-566 and W-1109 supplied 20 gpm of ground water to the treatment facility, which operated for six hours each working day (Monday through Friday) during the first two weeks. From that point on, TFE East began operating 24 hours a day. Wells W-1109 and W-566 produce about 5 and 15 gpm ground water from HSUs 2 and 5, respectively.

### 5.5.1. Performance Summary

TFE East PTU processed about 0.5 million gal of ground water through the end of the year, and removed an estimated 0.8 kg of VOC mass from the subsurface (Tables 3 and 4). Water treated at TFE East is discharged to a north-flowing drainage ditch that empties into the Drainage Retention Basin (Fig. 15).

### 5.5.2. Field Activities

Four wells, W-1210, W-1211, W-1219, and W-1225 were installed in the TFE area during 1996. As shown in Figure 1, well W-1210 is located west of TFE East and provides a downgradient HSU 5 monitoring location. Well W-1211 provides an HSU 4 monitoring location in the central part of the Livermore Site. Well W-1219 is located in the south-central part of the Livermore Site and well W-1225 is located north of TFE East. Both of these wells provide HSU 3A monitor locations. Source investigation data were also collected during the drilling of W-1219 and W-1225 as described in Section 3.2. Construction details for these wells are presented in Appendix A.

### 5.5.3. Hydraulic Tests

One-hour drawdown tests were performed on TFE area wells W-911, W-1203, W-1204, W-1210, and W-1211 during 1996. A slug test was also performed on well W-1202, but because of poor data quality, hydraulic parameters could not be calculated. In addition, a 72-hour pumping test was performed on HSU 2 well W-1109 to evaluate its effectiveness as a potential extraction well for TFE East. During the test, well W-1109 sustained a flow rate of about 7 gpm. Good hydraulic communication was observed in surrounding HSU 2 monitor wells W-257, W-909, W-911, and SIP-543-101. A secondary objective of the test was to determine if pumping W-1109 would impact the HSU 3A tritium plume beneath T-5475. No response was observed in any of the HSU 3A wells monitored. Results of these tests, and a 1995 one-hour drawdown test on well W-1109, are provided in Appendix B.

## 5.6. Treatment Facility F

TFF was located in the southeastern part of the Livermore Site in the TF406 area, where HSUs 2, 3A, and 3B had been impacted by a FHC spill (Dresen et al., 1986) (Fig. 1). Prior to remediation, significant FHC concentrations existed in both the unsaturated and saturated zones. Currently, low concentrations of VOCs exist in the FHC ground water plume beneath the TF406 area. This VOC plume is discussed further in Section 5.7.

### 5.6.1. Performance Summary

During 1996, passive bioremediation was implemented in the TFF area, which permanently discontinued ground water extraction and treatment for residual dissolved FHCs from HSUs 3A and 3B. Prior to its permanent shutdown, TFF operation was interrupted for 194 days as a result of storm damage that occurred on December 8, 1995. During June 1996, ground water was extracted and treated at TFF for a total of six hours to evaluate FHC concentrations in ground water extracted from HSU 3B well GEW-816. No rebound of FHC concentrations was observed in ground water from GEW-816. Following submittal of *Application for Containment Zone for the Livermore Site Hydrocarbon Impacted Zone at Treatment Facility F* (Happel et al., 1996), "No Further Action" status was granted by the regulatory agencies on October 30, 1996 (CRWQCB-SF, 1996). As part of the terms of this agreement, HSU 3 wells in this area will be sampled and analyzed for FHCs on a semiannual basis.

### 5.6.2. Hydraulic Tests

During June 1996, a six-hour pumping test was conducted on HSU 3A/3B wells GEW-808 and GEW-816 using a PTU (Fig. 1). The test demonstrated that the integrity of the annular seal in well GSW-445, a proposed HSU 4 extraction well for TF406, was not compromised during electrical-resistance heating and steaming associated with the Dynamic Underground Stripping Project (Newmark, 1994). The test also showed that HSU 3B is well connected with higher permeability sediments to the northwest, near the proposed PTU extraction well GSW-215. Well GSW-215 will be used to extract ground water containing VOCs from HSUs 3A and 3B. No hydraulic tests were performed on individual TFF wells during 1996.

## 5.7. Treatment Facility 406

TF406 is located in the southeastern part of the Livermore Site and consists of a PTU that utilizes air stripping to treat ground water (Fig. 1). TF406 is designed to treat VOCs extracted from HSUs 4 and 5 beneath the former TFF area.

TF406 began operating on August 27, 1996 ahead of the August 30, 1996 milestone date. As shown in Figure 16, TF406 processes ground water extracted from well W-1114, which is positioned to clean up and hydraulically control a TCE plume in HSU 5. In the spring of 1997, we plan to start treating ground water from HSU 4 extraction well GSW-445.

### 5.7.1. Performance Summary

During 1996, TF406 processed about 0.4 million gal of ground water from well W-1114 (Table 3) at flow rates between 10 and 16 gpm. The total VOC mass removed during 1996 was about 0.2 kg. All treated ground water was discharged to a storm drain that leads to Arroyo Las Positas (Fig. 16).

### 5.7.2. Field Activities

Well W-1209 was installed in the western portion of the TF406 area during 1996 (Fig. 1). Well W-1209 will be used to monitor hydraulic capture and ground water cleanup in HSU 4 while ground water is extracted from well GSW-445. Construction details for well W-1209 are presented in Appendix A.

### 5.7.3. Hydraulic Tests

No long-term hydraulic tests were conducted at TF406 during 1996. The results of one 1995 long-term test (W-1114) and three 1996 one-hour drawdown tests (W-1112, W-1113, and W-1209) are presented in Appendix B.

## 5.8. Treatment Facility G

Treatment Facility G-1 (TFG-1) is located about 300 ft north of East Avenue in the south-central part of the Livermore Site (Fig. 1). TFG-1 consists of a PTU that utilizes air stripping and ion exchange to treat ground water from HSU 2 extraction well W-1111.

### 5.8.1. Performance Summary

During 1996, TFG-1 processed about 0.9 million gal of ground water at an average flow rate of 8 gpm. TFG-1 has removed an estimated 0.2 kg of VOCs since operation began on April 11, 1996 (Table 3). All treated ground water has been discharged to a storm drain located about 50 ft north of TFG-1 (Fig. 17), which empties into Arroyo Seco.

### 5.8.2. Field Activities

One source investigation piezometer (SIP-212-101) was installed south of Building 212 (Fig. 1).

### 5.8.3. Hydraulic Tests

During December 1996, a week-long hydraulic test was conducted on extraction well W-1111 to evaluate the hydraulic influence of this HSU 2 well. The test results suggest that some hydraulic communication may exist between HSU 1B and HSU 2 in the vicinity of well W-1111. A one-hour drawdown test was also conducted on well W-1111 during 1996. The results of these tests are presented in Appendix B.

## 5.9. Vapor Treatment Facility 518

VTF518 is located in the southeast quadrant of the Livermore Site near East Avenue (Fig. 1). Soil vapor is extracted from vadose zone well SIP-518-201 using a vapor extraction system (VES). VOCs are removed from the vapor at VTF518 using granular activated carbon canisters.

### 5.9.1. Performance Summary

The VES operated at an average vacuum of 18 standard cubic feet per minute (scfm). From January 1 through December 27, 1996, VTF518 processed approximately 1,550,000 cubic feet ($ft^3$) of soil vapor removing an estimated 42 kg of VOCs (Table 3). Since VTF518 began operating on September 25, 1995, about 66 kg of VOC mass has been removed from approximately 1,870,000 $ft^3$ of soil vapor (Table 4).

### 5.9.2. Field Activities

Two SEAMIST instrumented/sampling wells, SIB-518-301 and SIB-518-304, are used to monitor vadose zone remediation in the VTF518 area. The SEAMIST system is an impermeable, everted membrane that carries soil vapor sampling instrumentation down an unlined borehole (Keller and Lowry, 1991). The SEAMIST system is used to collect vapor pressure, soil temperature, soil moisture, and soil vapor VOC concentration data from various discrete depths. VOC vapor concentrations at SIB-518-301, the SEAMIST system borehole nearest the VTF518 vapor extraction well, have declined from an average of 111 parts per million by volume (ppmv) in September 1995 to an average of 59 ppmv in November 1996.

### 5.9.3. Hydraulic Tests

During November 1996, a 72-hour long-term hydraulic test was conducted on HSU 5 well W-112, which is the planned ground water extraction well for Treatment Facility 518 when the facility becomes operational in October 1997. The hydraulic test results indicate that ground water extraction at well W-112 will hydraulically control ground water flow in the vicinity of B-518 (Fig. 1). Results of this test are presented in Appendix B.

## 5.10. Treatment Facility 5475

Treatment Facility 5475 (TF5475) is located in the southeast quadrant of the Livermore Site (Fig. 1). As agreed to by the regulatory agencies, the operation of TF5475 has been postponed until September 1998. However, field activities supporting HSU analysis of this area will continue in 1997 and is described in RD4.

### 5.10.1. Field Activities

Well W-1222 was installed in the T-5475 area during 1996. This well was screened in HSU 3A (as was downgradient TFE well W-1225, discussed in Section 5.5.2) to define the extent of VOCs and tritium downgradient from the T-5475 source area. Construction details for this well are presented in Appendix A, and its location is shown on Figure 1.

As discussed in Section 3.2 and shown in Figure 1, five source investigation boreholes were drilled in 1996. SIB-ETS-503 was drilled downgradient (west) of the T-5475 source area to obtain unsaturated sediment lithologic and chemistry data. Two soil vapor installations, SVI-ETS-504 and SVI-ETS-505, were drilled near the T-5475 source area. Boreholes SEA-ETS-506 and SEA-ETS-507 were drilled in the vicinity of vapor extraction well SVI-ETS-504. FLUTe instrumented sampling systems were installed in these boreholes to monitor the effectiveness of vapor extraction.

### 5.10.2. Hydraulic Tests

During 1996, one-hour drawdown tests were performed in the T-5475 area on wells W-1117, W-1118, W-1201, and W-1222. Results of these tests are presented in Appendix B, and the well locations are shown on Figure 1. In addition, slug tests were performed on piezometers SIP-ETS-201, SIP-ETS-204, and SIP-ETS-207.

Seventy-two-hour hydraulic tests were performed on HSU 3B well W-356, and HSU 5 well W-1108 to determine the hydraulic characteristics of saturated sediments in the T-5475 area. The primary objective of these tests was to determine the effect of pumping these wells on the T-5475 tritium plume in HSU 3A. Well W-356 is located southwest of T-5475 and was used to test the influence of pumping from HSU 3B on the distal portion of the plume. Well W-1108 is located near T-5475 and is screened in HSU 5, which underlies the portion of HSU 3A containing the tritium plume.

Well W-1108 extracted about 12 gpm of ground water from HSU 5 during the first 24 hours. The flow rate was then reduced to eight gpm due to an observed hydraulic boundary effect. Similarly, well W-356 extracted about five gpm from HSU 3B during the first 24 hours, but the flow rate was reduced to three gpm in response to a hydraulic boundary effect. These test results are presented in Appendix B, and will be discussed in RD4.

### 5.10.3. Soil Vapor Extraction Treatability Test

A treatability test was conducted at T-5475 to evaluate the feasibility of soil vapor extraction. The test consisted of extracting vapor from well SVI-ETS-504 and then reinjecting the treated vapor into well SVI-ETS-505. Flow rates were varied from 12 to 30 scfm. The effects of vapor extraction were monitored in FLUTe wells SEA-ETS-506 and SEA-ETS-507. The results of these tests will be discussed in RD4.

### 5.10.4. Ground Water Treatability Test

A down-hole in-situ treatment technology is being developed at LLNL to clean up VOCs in ground water in the T-5475 area, thus eliminating the need to extract ground water contaminated with VOCs and tritium for aboveground treatment. This technology is based upon a catalytic reductive dehalogenation process, where hydrogen, in the presence of a suitable catalyst, is used as a reducing agent to dechlorinate and transform VOCs into environmentally-benign hydrocarbons. The rapid reaction rates characterizing this process, with removal rates greater than 95% for most VOCs, allow it to be used in a flow-through vessel. Bench-scale experiments are being conducted to optimize the vessel design.

The down-hole treatment unit will consist of a two-stage vessel. The first stage consists of an electrolyzer, which produces hydrogen from the influent water under an applied voltage. The second stage consists of a catalyst bed of palladium metal supported by beads of alumina, and is where the dechlorination reactions take place. Contaminated water extracted from a saturated permeable zone is passed through the vessel and then reinjected into an adjacent saturated permeable zone. This treatment technology is scheduled for a pilot test in a well west of T-5475 in 1997.

# 6. Trends in Ground Water Analytical Results

Notable results of VOC analyses of ground water received from January 1996 through December 1996 are discussed below. Figures 8, 9, and 10 show isoconcentration contours for total VOCs underlying the Livermore Site and vicinity within HSU 1, HSU 2 and HSU 3A, respectively. VOC analytical data are available upon request or can be viewed through the Environmental Restoration Division Web pages.

1. The chloroform concentration in well W-114 has increased. Well W-114 is located directly south of the West Traffic Circle (Fig. 1), and is screened from 51 to 63 ft bgs in HSU 1B. In July 1985, 3 ppb of chloroform was reported in the initial analysis. Chloroform was not detected again in well W-114 until January 1995 at 4.4 ppb. Since that time, the chloroform has increased to 22 ppb as of January 1996.

2. The PCE concentration in well W-143 has gradually decreased. Well W-143 is located about 450 ft east of TFA (Fig. 1), and is screened from 121 to 126 ft bgs in HSU 2. In May 1985, 260 ppb PCE was reported in the initial analysis. Since that time, the PCE increased up to 340 ppb in March 1986, but has since decreased to 11 ppb as of October 1996.

3. The TCE concentration in well W-217 has increased. Well W-217 is located about 450 ft directly north of VTF518 (Fig. 1), and is screened from 98 to 112 ft bgs in HSU 5. In June 1986, 44 ppb TCE was reported in the initial analysis. From that time through August 1991, the TCE concentration has fluctuated from the tens of ppb, up to 140 ppb. Since August 1991, TCE concentrations remained between 14 and 75 ppb until 1996. In May 1996, TCE increased from 28 to 570 ppb and was reported at 550 and 680 ppb in October 1996.

4. Trichlorotrifluoroethane (Freon 113) and 1,1-dichloroethylene (1,1-DCE) have been consistently reported in well W-503 for several sampling events. Well W-503 is located about 1,000 ft south of TFC (Fig. 1), and is screened from 74 to 80 ft bgs in HSU 1B. Freon 113 and 1,1-DCE were not detected in well W-503 from November 1988 until April 1993. 1,1-DCE was detected at 1.1 ppb in April 1993 and has increased to 3 ppb as of May 1996. Freon 113 was detected at 4.9 ppb in April 1995 and has increased to 11 ppb as of May 1996.

5. The Freon 113 concentration in well W-565 has increased. Well W-565 is located about 850 ft southeast of TFC (Fig. 1), and is screened from 75 to 82 ft bgs in HSU 1B. Freon 113 was not detected in well W-565 from April 1989 until February 1995. Freon 113 was detected at 0.99 ppb in February 1995 and has increased to 20 ppb as of October 1996.

6. Freon 113 has been reported in well W-607 for the last two sampling events. Well W-607 is located about 900 ft east of TFC (Fig. 1), and is screened from 49 to 55 ft bgs in HSU 1B. Freon 113 was not detected in well W-607 from February 1990 until January 1995. Freon 113 was detected at 3 ppb in January 1995 and has increased to 11 ppb as of January 1996.

# References

# References

Bessette Rochette, M. (1996), Letter from the Michael Bessette Rochette, RWQCB Project Manager, to Paul Ko, DOE Project Manager, stating approval of changes to metals discharge limits and sampling frequencies, dated August 15, 1996.

Blake, R. G., C. M. Noyes, M. P. Maley (1995), "Hydrostratigraphic Analysis-The Key to Cost-Effective Ground Water Cleanup at Lawrence Livermore National Laboratory," in *Environmental Remediation '95*, Denver, Colorado, August 13–18, 1995 (UCRL-JC-120614).

California Regional Water Quality Control Board - San Francisco Bay Region (CRWQCB-SF), 1996, October 30, *Case Closure Letter from Loretta Barasmian, Executive Officer, to Mr. Paul Ko of DOE regarding Petroleum Hydrocarbon Impacted Zone at Treatment Facility F*; 4 p.

Canales, T. W. and C. W. Grant (1996), "MapIt: A New Tool to Assist in the Transition from Conceptual Model to Numeric Simulation Models" in *Spectrum '96*, Seattle, Washington, August 1996 (UCRL-JC-122298 Abs).

Dibley, V. and R. Depue (Eds.) (1996), *Environmental Restoration Division Standard Operating Procedures (SOPs)*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-MA-109115 Rev. 2).

Dresen, M. D., F. Hoffman, and S. Lovejoy, Jr. (1986*), Subsurface Distribution of Hydrocarbons in the Building 403 Area at LLNL*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCID-20787).

Dresen, M. D., J. P. Ziagos, A. J. Boegel, and E. M. Nichols (Eds.) (1993), *Remedial Action Implementation Plan for the LLNL Livermore Site*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-110532)(Page 43 revised September 2, 1993; Table 5 revised July 2, 1996).

Gupta, S. K., C. R. Cole, C. T. Kincaid, and A. M. Monti (1987), *Coupled Fluid, Energy, and Solute Transport (CFEST) Model: Formulation and User's Manual,* Office of Nuclear Waste, Battelle Memorial Institute, Columbus, Ohio (Report BMI/ONWI-660).

Happel, A. M., R. W. Bainer, L. L. Berg, M. D. Dresen, and A. L. Lamarre (Eds.) (1996), *Application for Containment Zone for the Livermore Site Hydrocarbon Impacted Zone at Treatment Facility F,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-123385).

Hoffman, J., P. McKereghan, B. Qualheim, R. Bainer, E. Folsom, and M. Dresen (Eds.) (1996), *LLNL Ground Water Project 1995 Annual Report*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-122596).

Keller C., and B. Lowry (1991), "A New Vadose Zone Fluid Sampling System for Uncased Holes," in *Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration*, *Ground Water Monitoring and Geophysical Methods*, pp. 3–10, May 4–17, 1991, Las Vegas, Nev., presented by the Association of Ground Water Scientists and Engineers (division of the National Ground Water Association).

Ko, P. and A. L. Lamarre (1996), Letter Report: LLNL Livermore Site July 2, 1996 Remedial Program Manager's Meeting Summary and Second Quarter Self-Monitoring Report, dated August 29, 1996.

Ko, P., M D. Gill, B. R. Feather, and M. Bessette Rochette (1996), Consensus Statement for Environmental Restoration of Lawrence Livermore National Laboratory (LLNL) Livermore Site, dated September 19, 1996.

Littlejohn, J. and A. L. Lamarre (1996), Letter Report: LLNL Livermore Site September 18, 1996 Remedial Program Manager's Meeting Summary and Third Quarter Self-Monitoring Report, dated November 27, 1996.

Littlejohn, J. and A. L. Lamarre (1997), Letter Report: LLNL Livermore Site December 10, 1996 Remedial Program Manager's Meeting Summary and Fourth Quarter Self-Monitoring Report, dated February 27, 1997.

Macdonald, J. K., M. D. Dresen, and J. P. Ziagos (Eds.) (1991), *LLNL Ground Water Project Monthly Progress Report*, *June 1991*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCAR-10160-91-6).

McConachie W. A. and M. G. Brown (1996), Letter Report: LLNL Livermore Site March 21, 1996 Remedial Program Manager's Meeting Summary and First Quarter Self-Monitoring Report, dated May 29, 1996.

McKereghan, P. F., L. L. Berg, M. D. Dresen, R. W. Bainer, E. N. Folsom, and A. L. Lamarre (1996), *Contingency Plan for the Lawrence Livermore National Laboratory Livermore Site*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-123370).

Newmark, R. (Ed.) (1994), *Dynamic Underground Stripping Project: LLNL Gasoline Spill Demonstration Report,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-ID-116964 vols 1-4).

Nichols, E. M., L. L. Berg, M. D. Dresen, R. J. Gelinas, R. W. Bainer, E. N. Folsom, and A. L Lamarre (Eds.) (1996), *Compliance Monitoring Plan for the Lawrence Livermore National Laboratory Livermore Site*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-120936).

Nitao, J. (1996), *Reference Manual for the NUFT Flow and Transport Code,* Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-104040).

Tompson, A. F. B., P. F. McKereghan, and E. M. Nichols (Eds.) (1995), *Preliminary Simulation of Contaminant Migration in Ground Water at the Lawrence Livermore National Laboratory*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-ID-115991).

U.S. Department of Energy (DOE) (1992), *Record of Decision for the Lawrence Livermore National Laboratory, Livermore Site*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-109105).

Vogele, T. J., A. Kulresthra, J. J. Nitao, and K. Lee (1996a), *Simulation of Soil Vapor Extraction at Building 518, Lawrence Livermore National Laboratory Livermore Site*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-124995).

Vogele, T. J., P. F. McKereghan, R. Gelinas, and A. F. B. Tompson (1996b), *Technical Note: Preliminary 3D Simulations of Contaminant Migration in and Removal from Ground Water at the LLNL's Livermore Site, Summary of First Interim Results, TFA Area*, Lawrence Livermore National Laboratory, Livermore, Calif. (MI-ERD/LS/3DIR:1).

# Figures

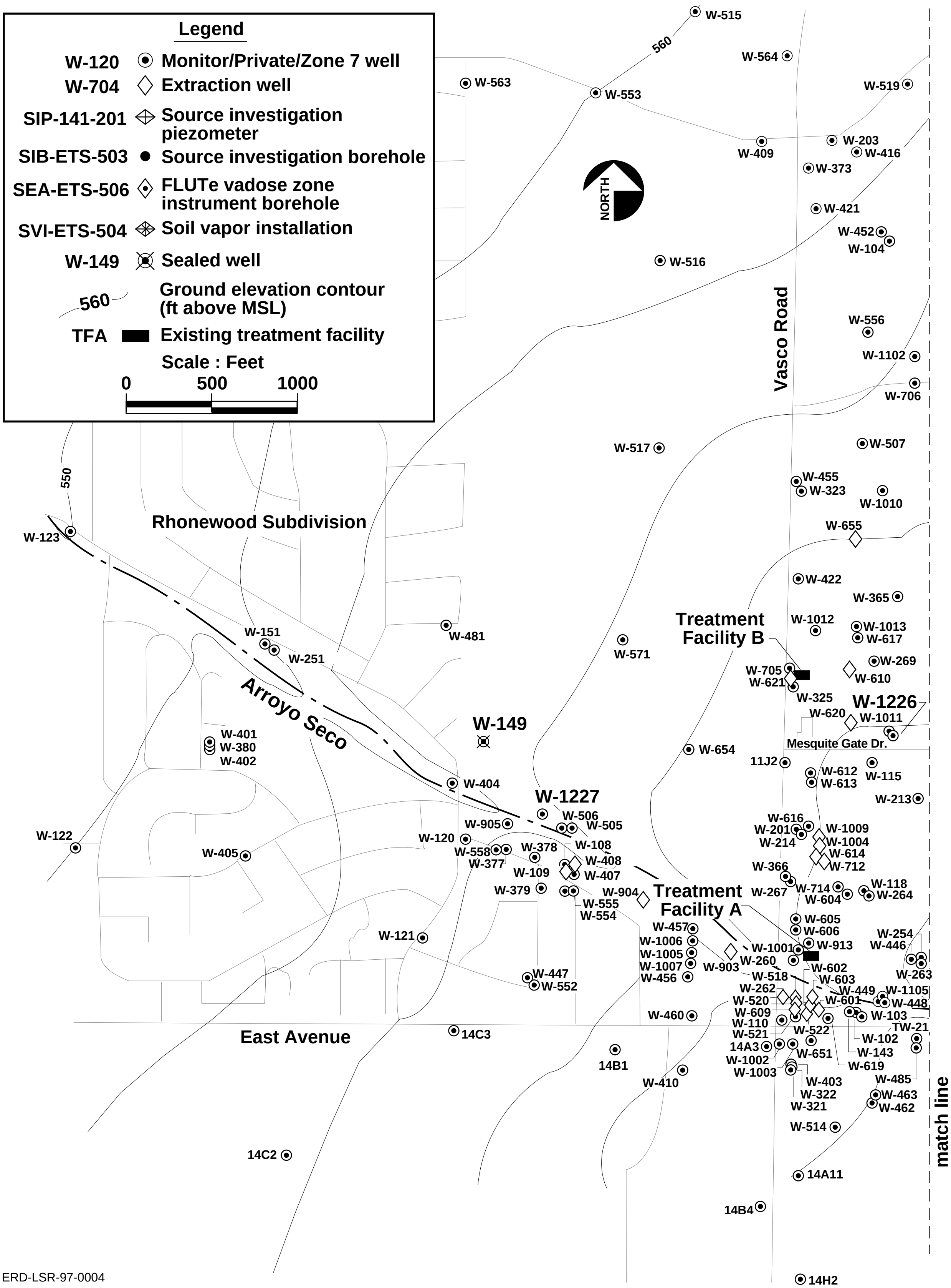



**Figure 1. Locations of Livermore Site monitor wells, piezometers, extraction wells, and treatment facilities, December 1996.**

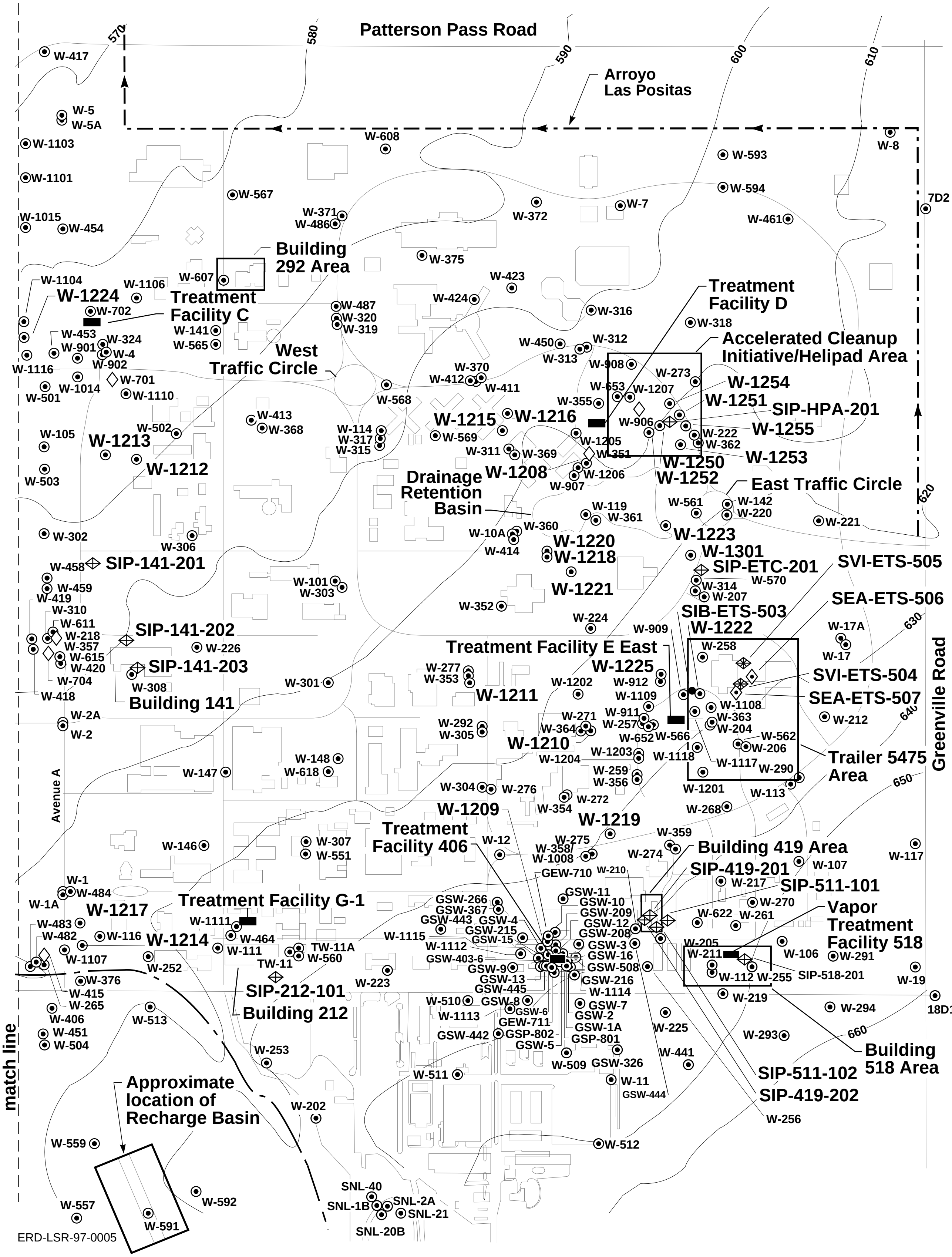
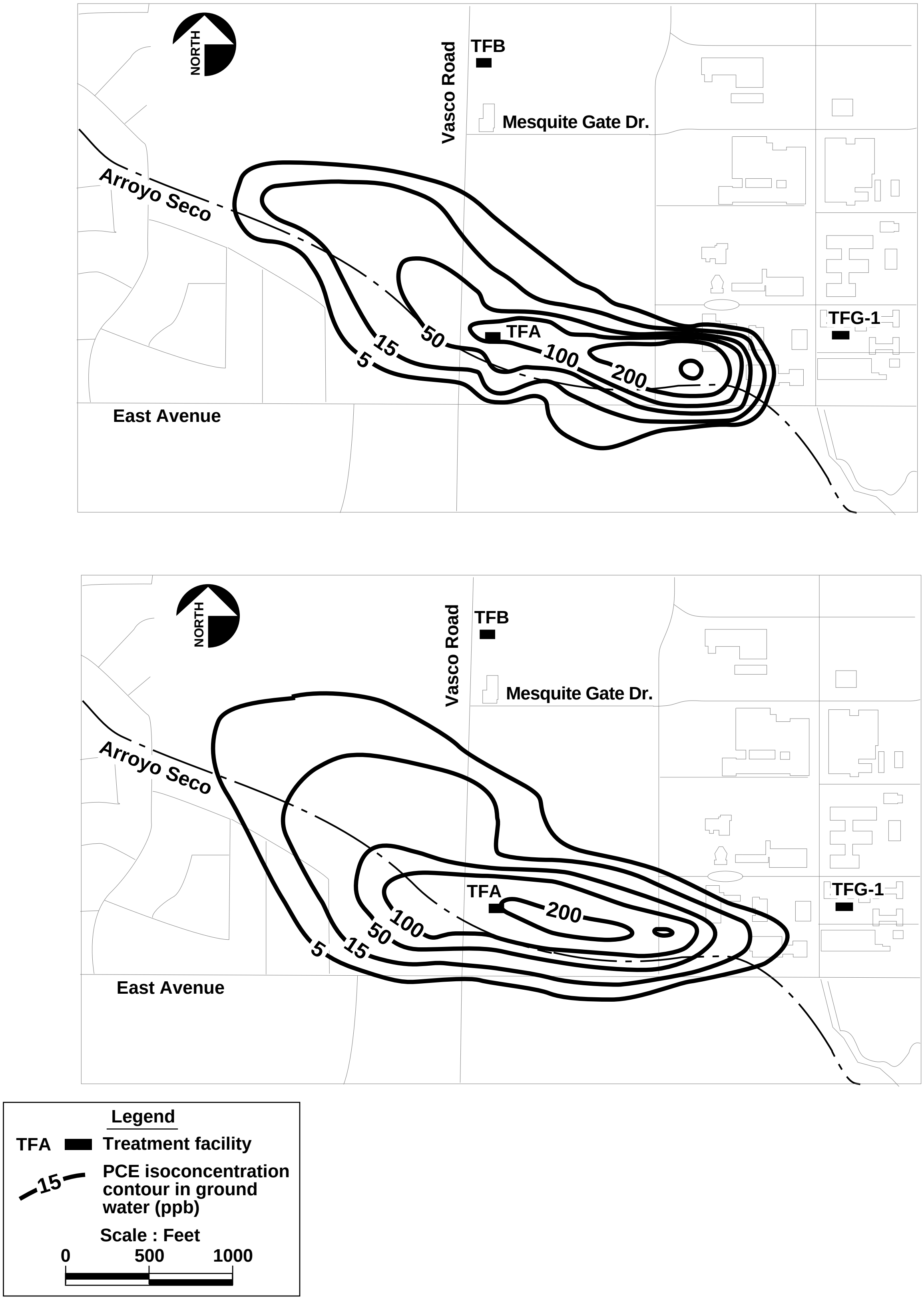
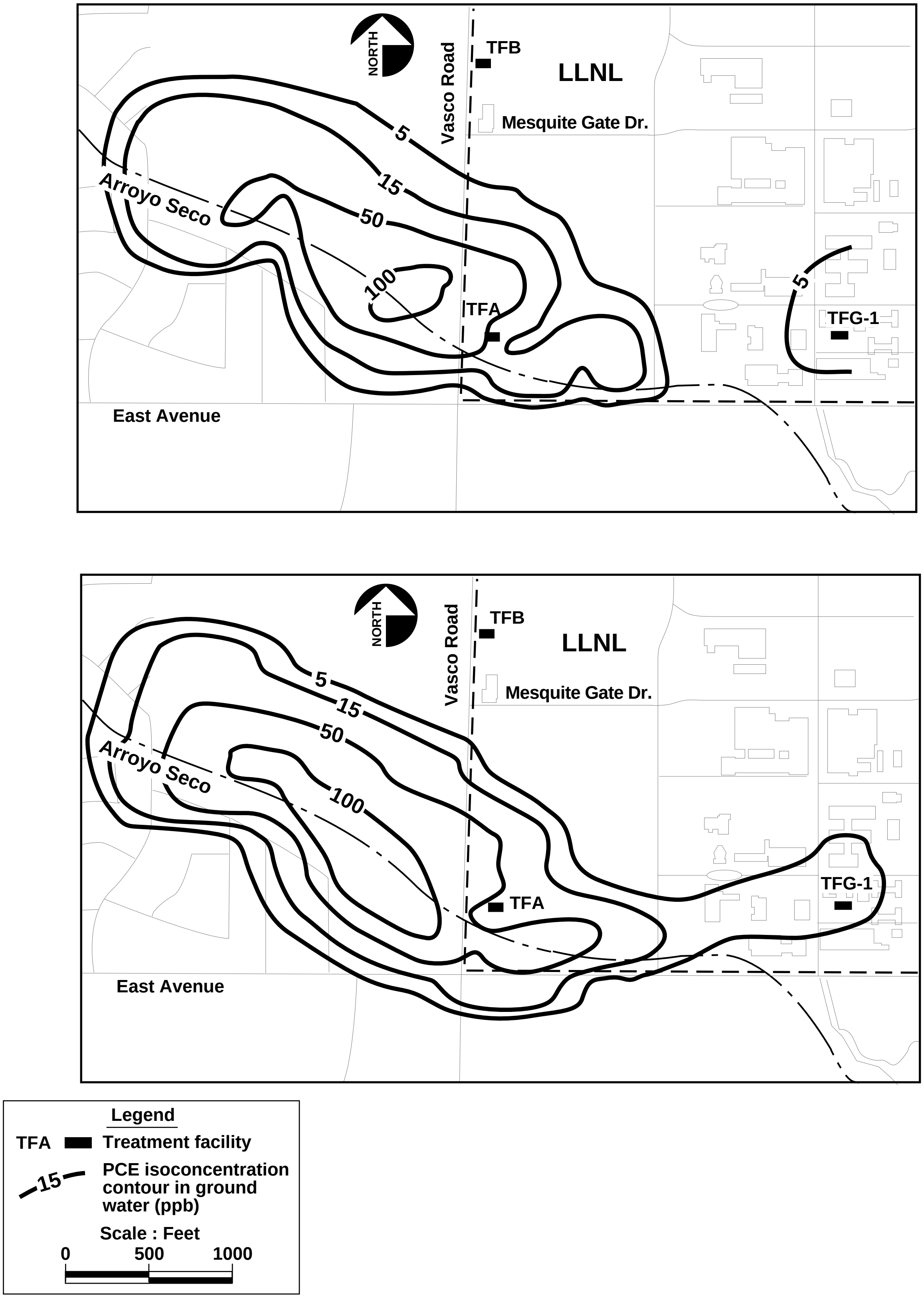



**Figure 1 (continued).**



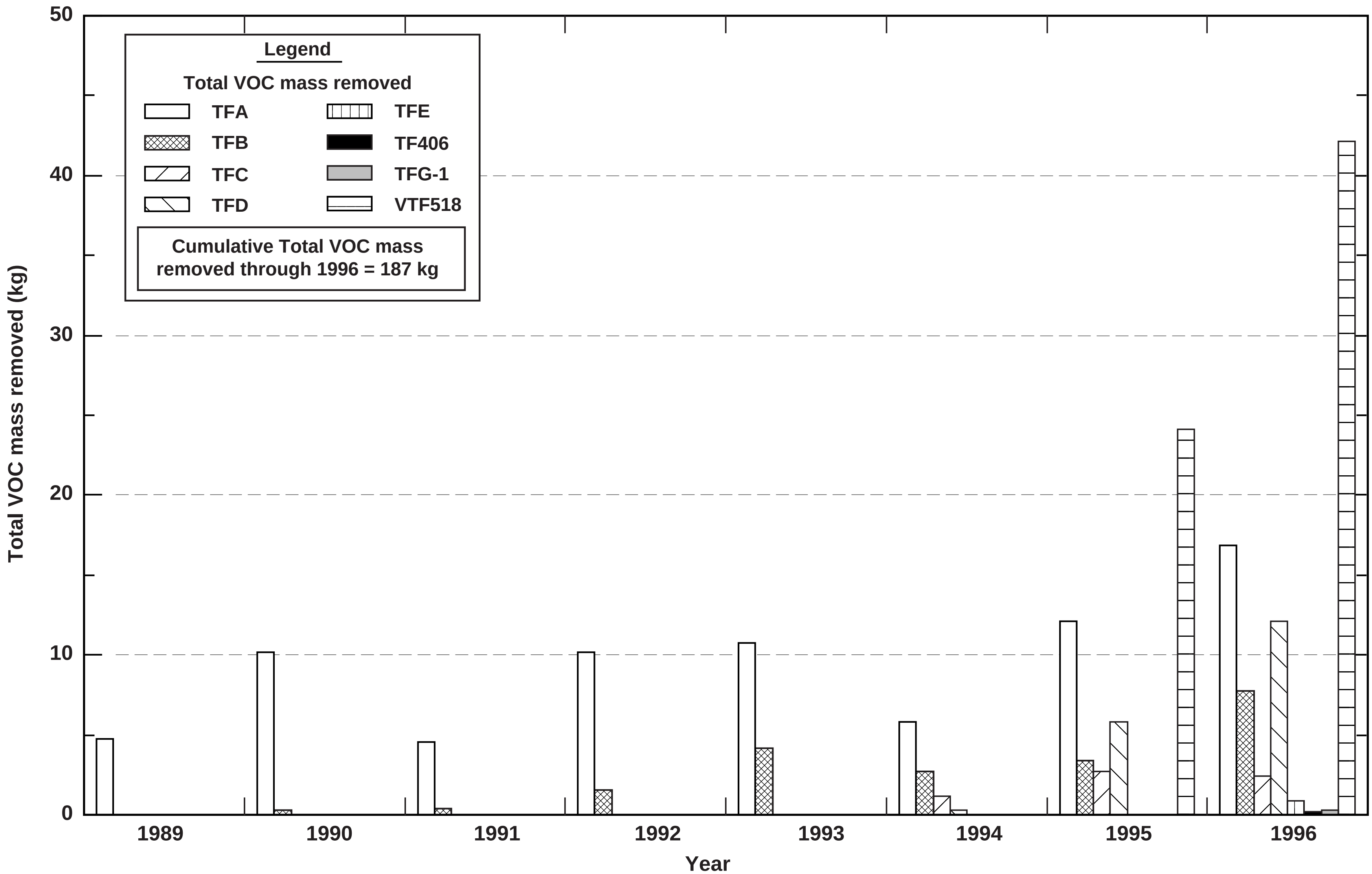

ERD-LSR-97-0014

**Figure 2. Comparison of measured (top) and simulated (bottom) aqueous PCE concentrations in HSU 1B for October 1995.**




ERD-LSR-97-0015

**Figure 3. Comparison of measured (top) and simulated (bottom) aqueous PCE concentrations in HSU 2 for October 1995.**




ERD-LSR-97-0003

**Figure 4. Total VOCs removed from the Livermore Site subsuface at treatment facilities.**

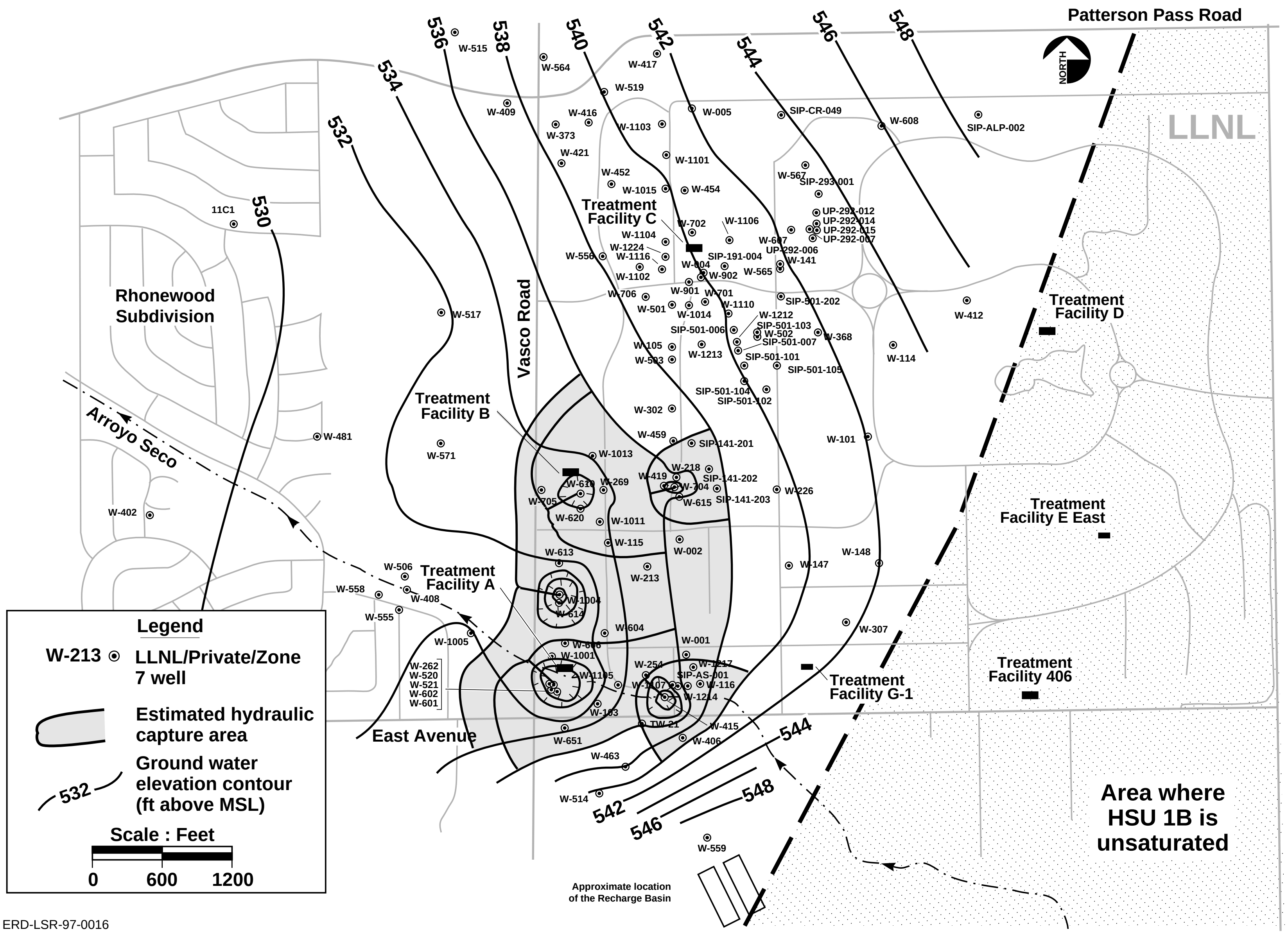



**Figure 5. Ground water elevation contour map based on water levels collected from 121 of the wells completed within HSU 1B showing estimated HSU 1B hydraulic capture areas, LLNL and vicinity, fourth quarter of 1996.**

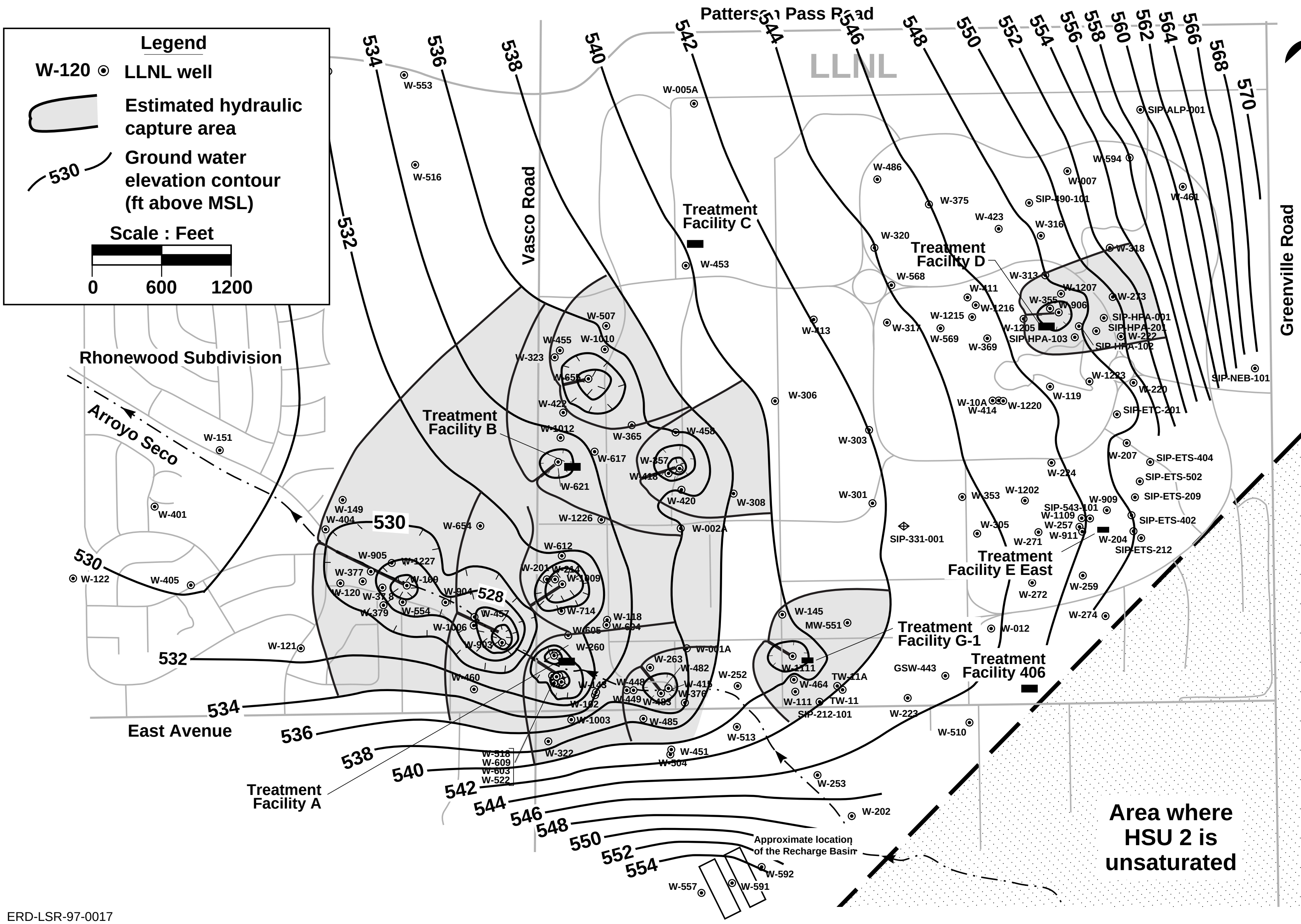



**Figure 6. Ground water elevation contour map based on water levels collected from 145 of the wells completed within HSU 2 showing estimated HSU 2 hydraulic capture areas, LLNL and vicinity, fourth quarter of 1996.**

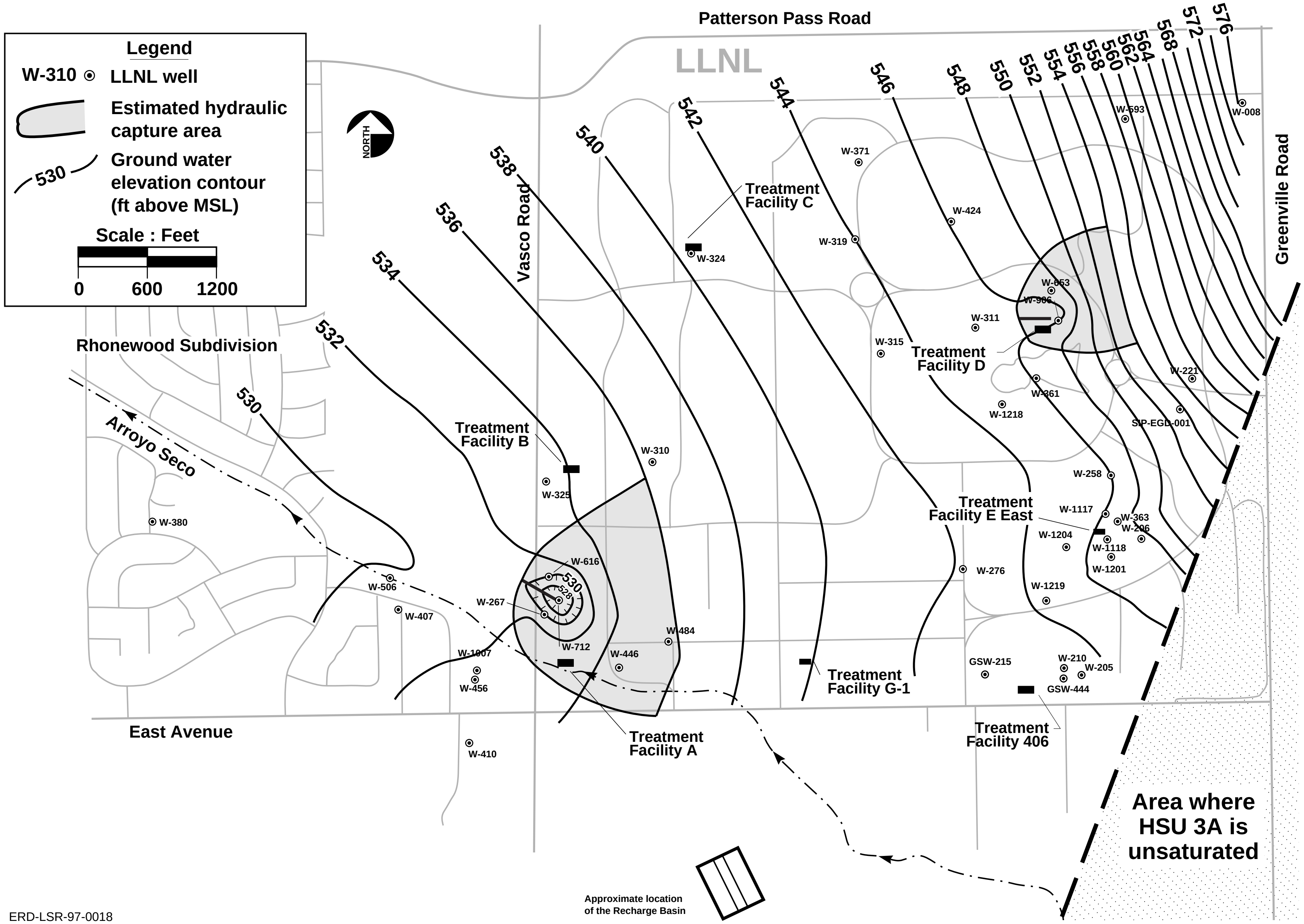



**Figure 7. Ground water elevation contour map based on water levels collected from 52 of the wells completed within HSU 3A showing estimated HSU 3A hydraulic capture areas, LLNL and vicinity, fourth quarter of 1996.**

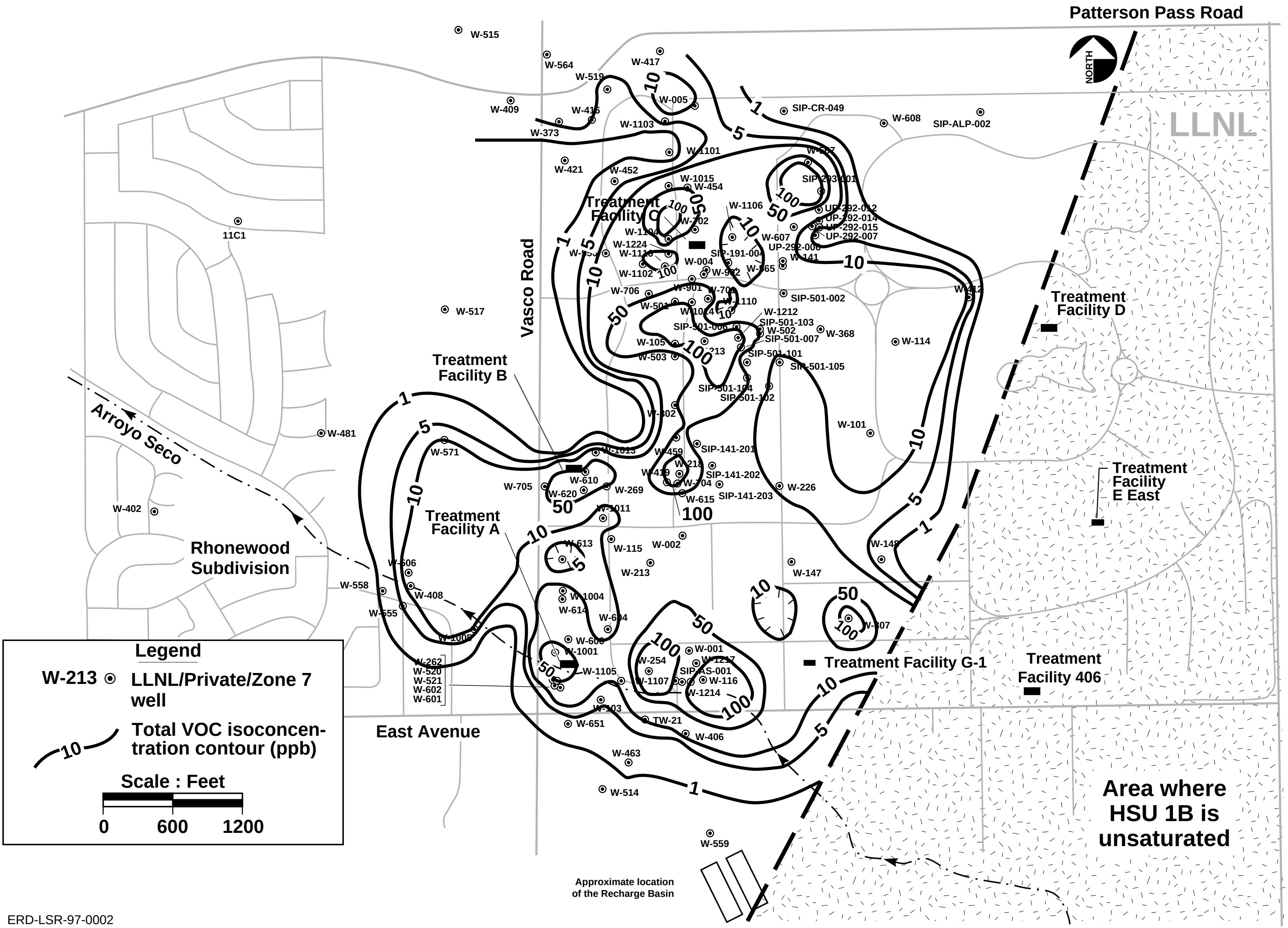



**Figure 8. Isoconcentration contour map of total VOCs for 107 wells completed within HSU 1B based on samples collected in the fourth quarter of 1996 (or the next most recent data.)**

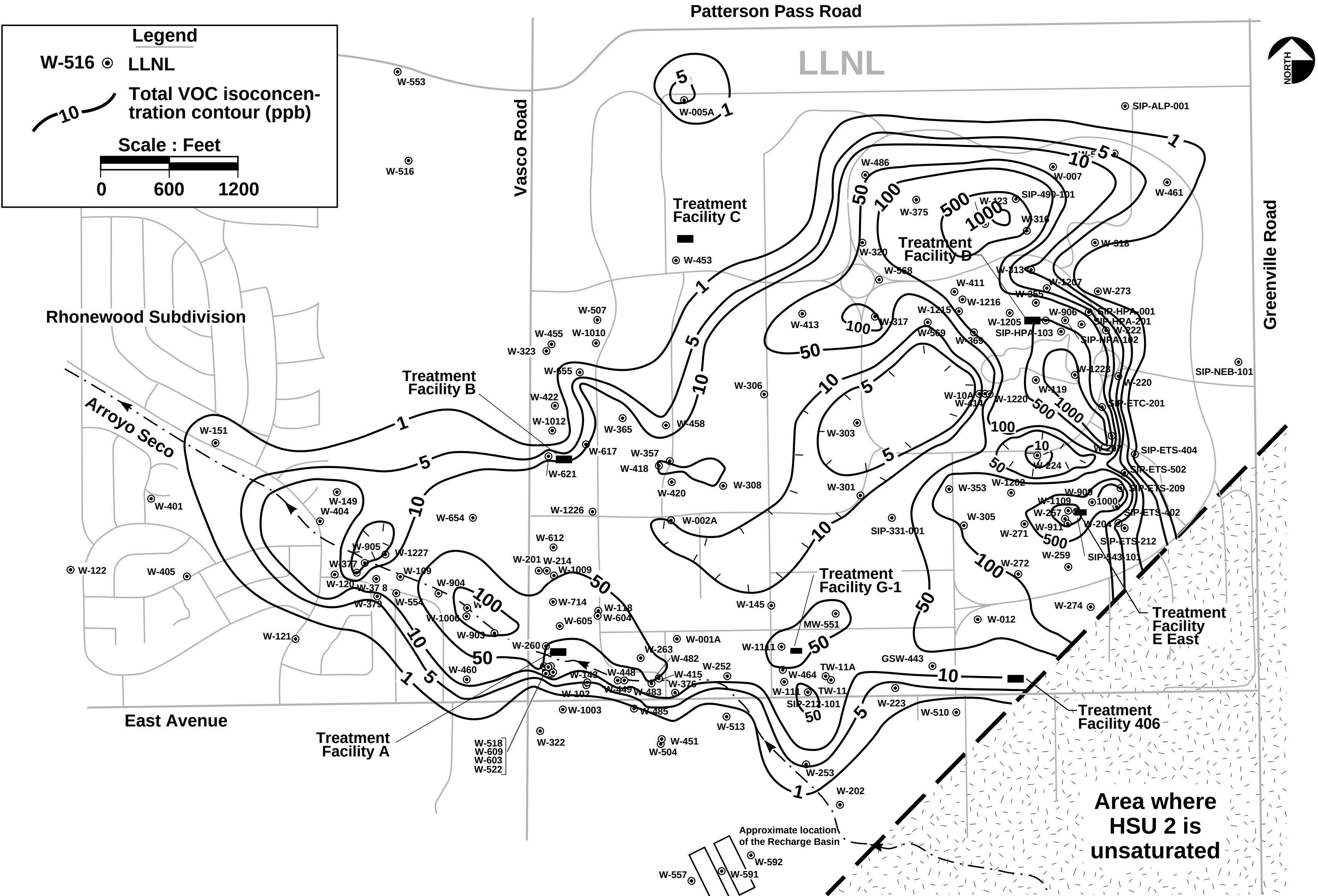



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**Figure 9. Isoconcentration contour map of total VOCs for 154 wells completed within HSU 2 based on samples collected in the fourth quarter of 1996 (or the next most recent data.)**

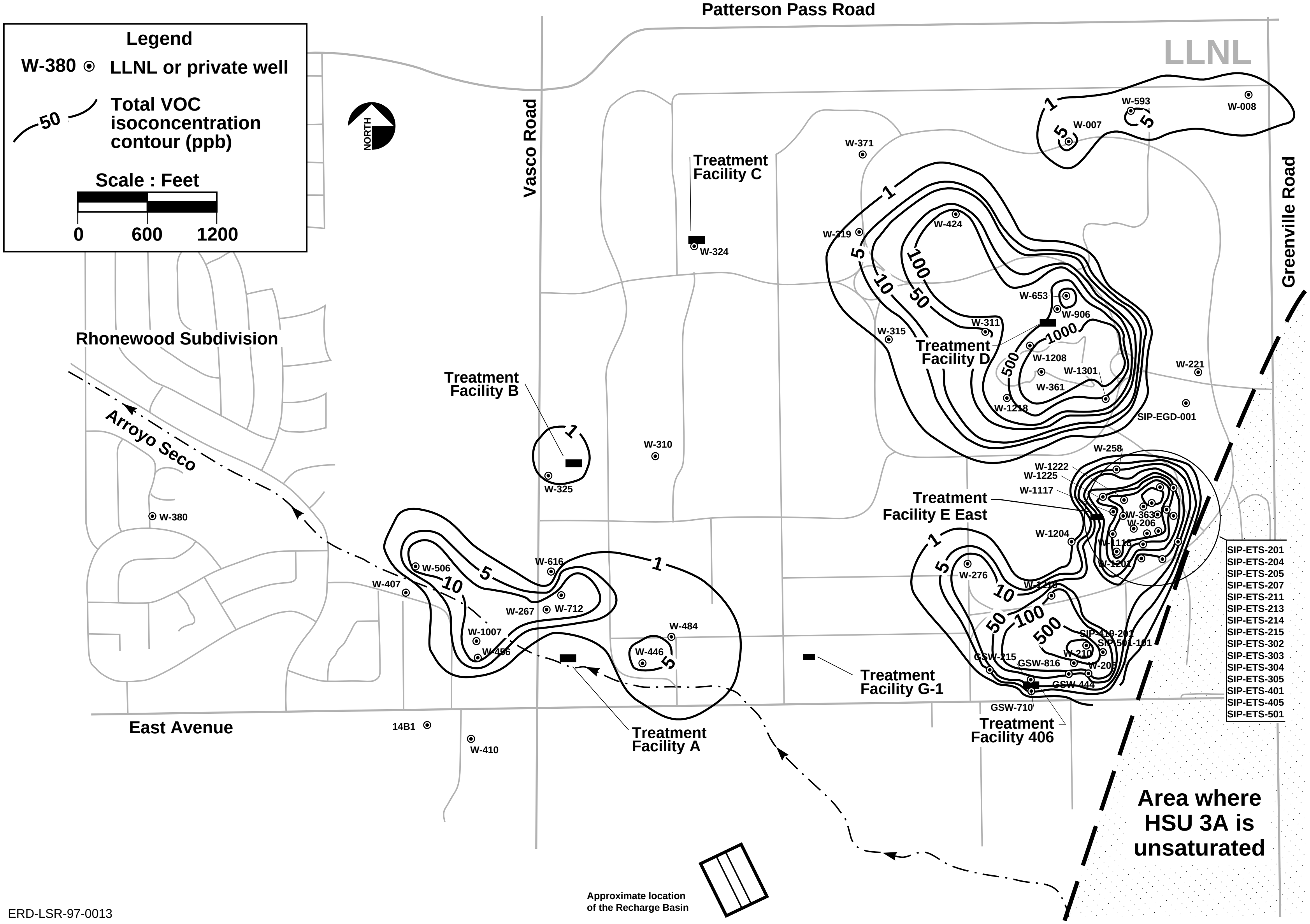


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**Figure 10. Isoconcentration contour map of total VOCs for 64 wells completed within HSU 3A based on samples collected in the fourth quarter of 1996 (or the next most recent data.)**

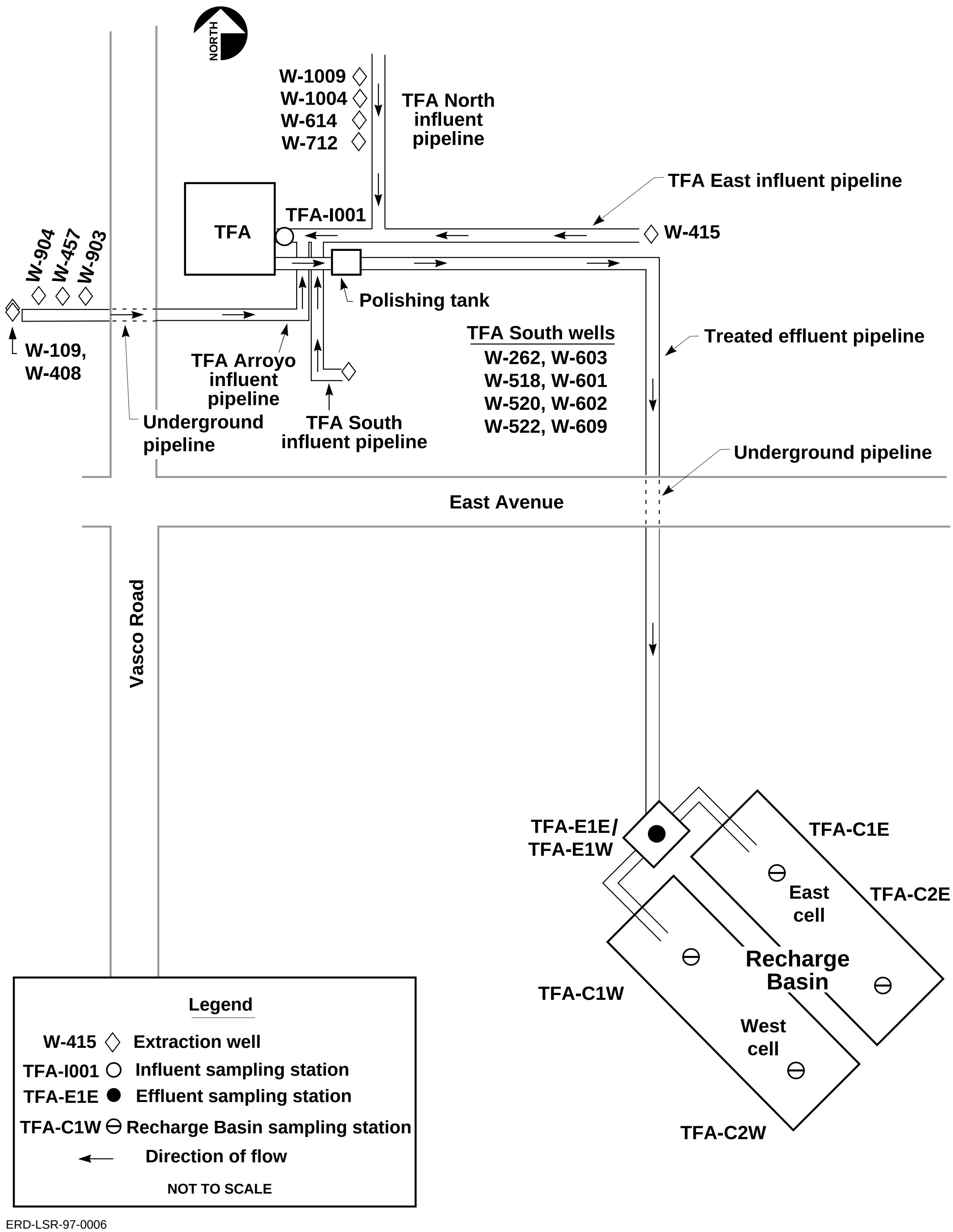


**Figure 11. 1996 TFA extraction wells, pipelines, and discharge location.**

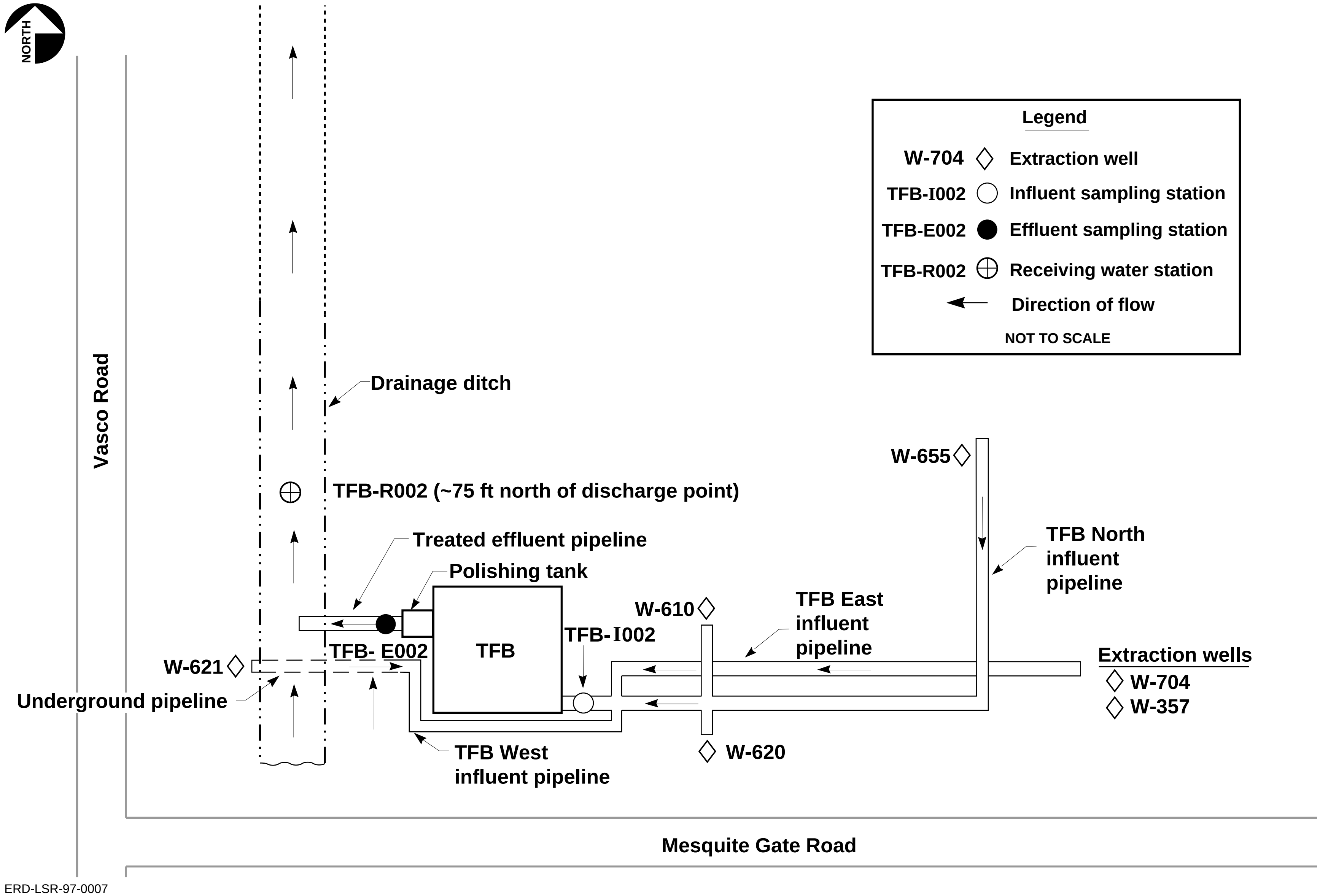


Figure 12. 1996 TFB extraction wells, pipelines, and discharge location.

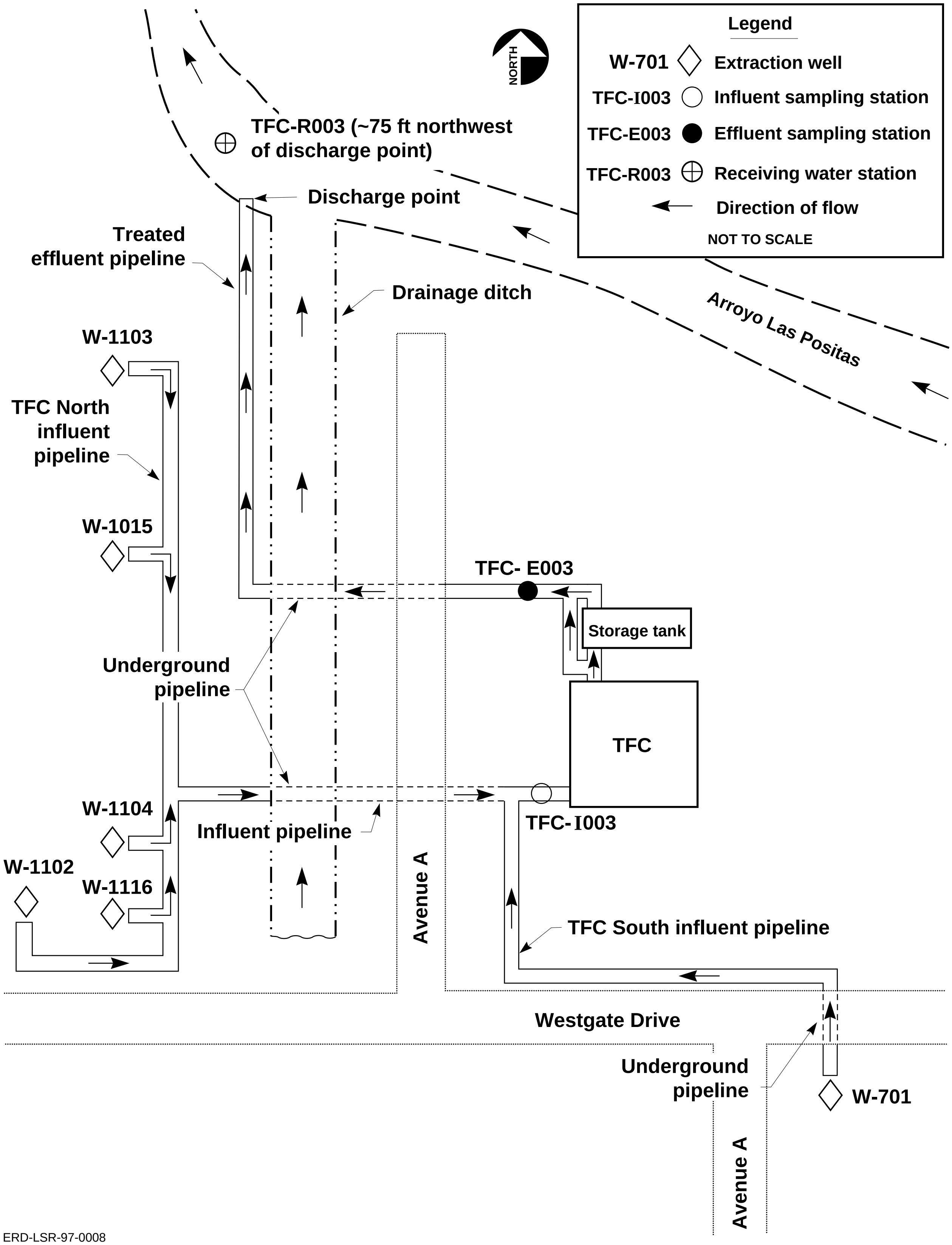


**Figure 13. 1996 TFC extraction wells, pipelines, and discharge location.**

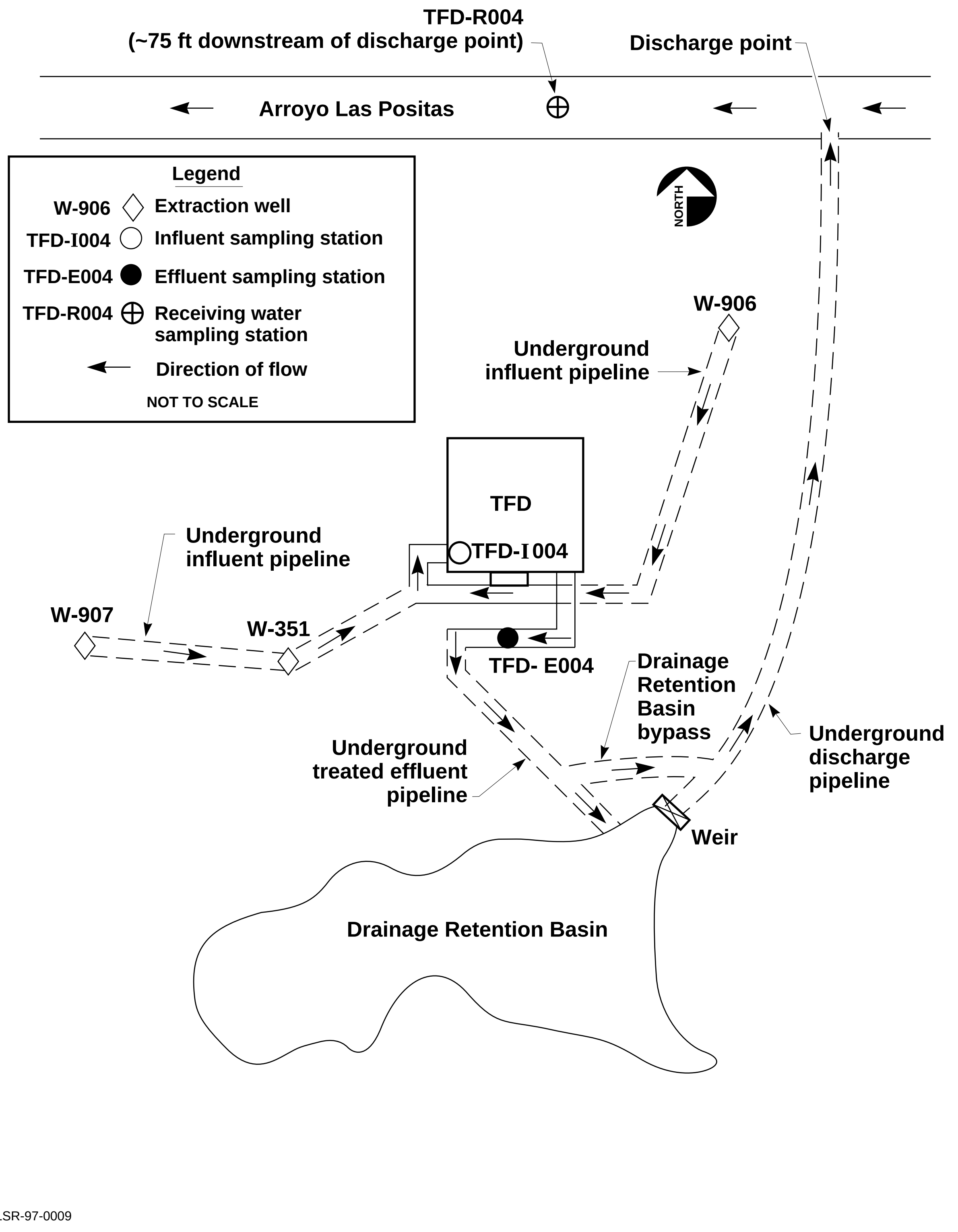


**Figure 14. 1996 TFD extraction wells, pipelines, and discharge location.**

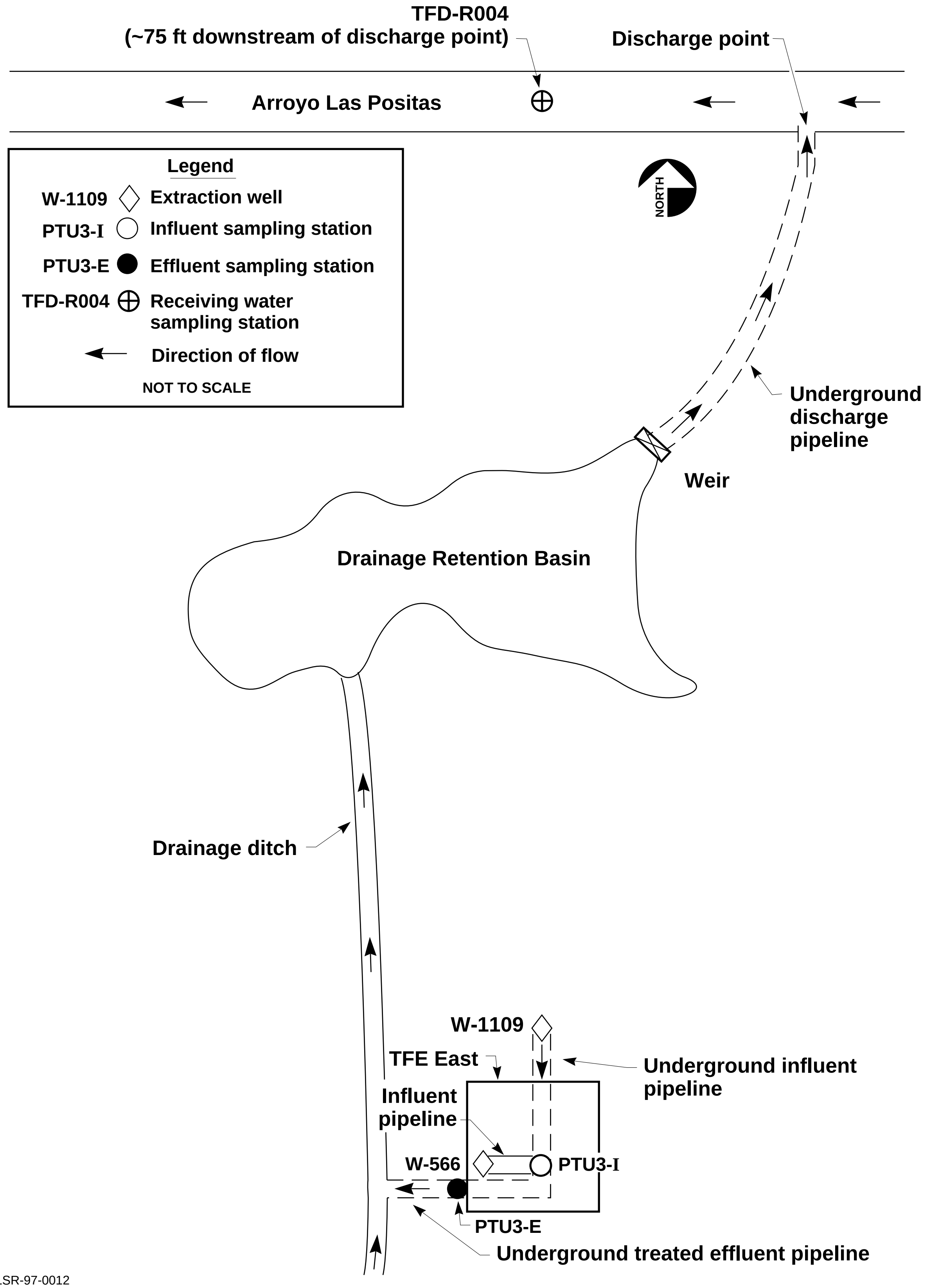


**Figure 15. 1996 TFE East extraction wells, pipelines, and discharge location.**

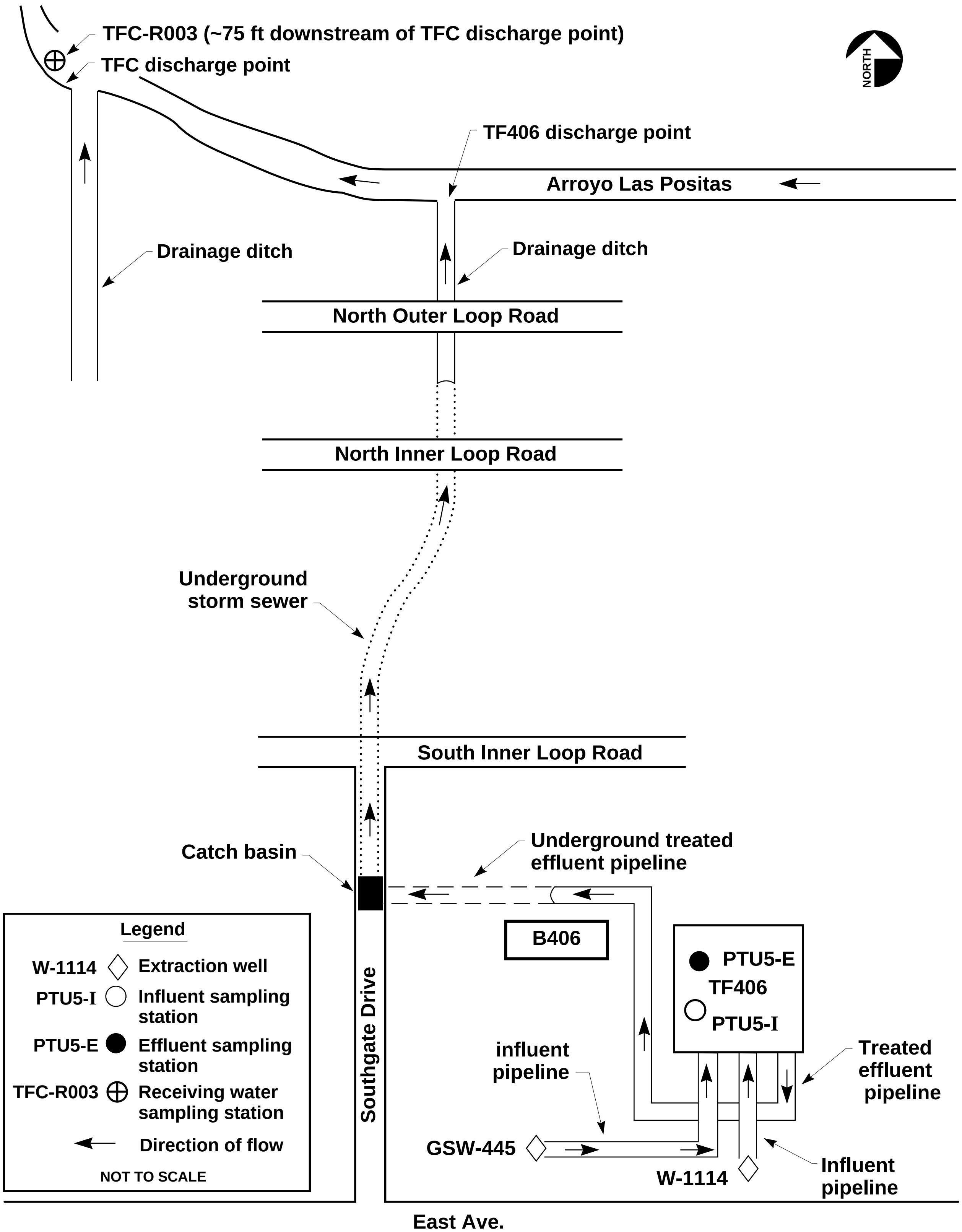


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**Figure 16. 1996 TF406 extraction wells, pipelines, and discharge location.**

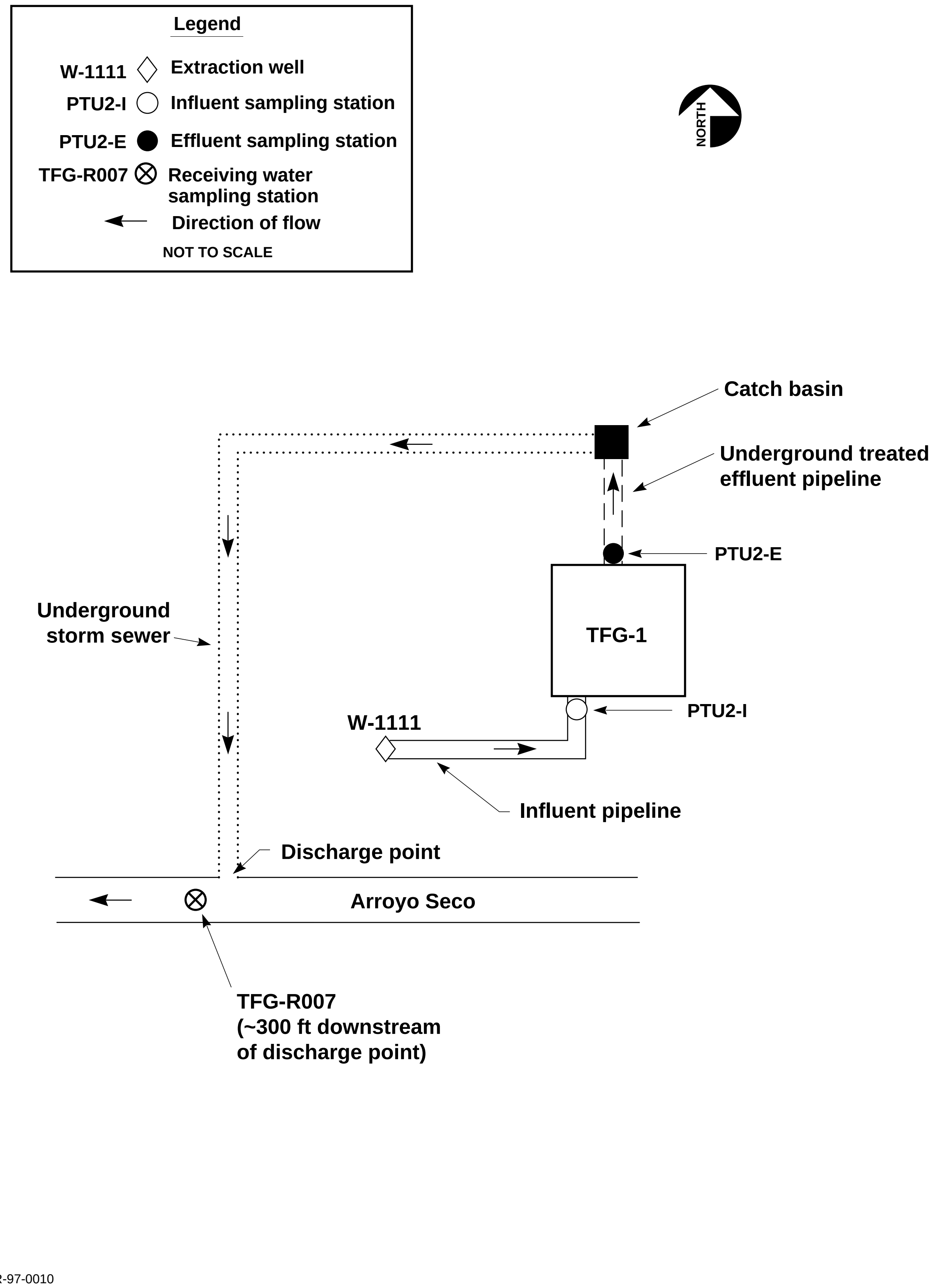


**Figure 17. 1996 TFG-1 extraction well, pipelines, and discharge location.**

# Tables

**Table 1. 1996 Livermore Site RAIP milestones.**

| Milestone | RAIP due date | Completion date |
|---|---|---|
| Issue CMP | 01/29/96 | 01/25/96 |
| Begin operation of TFG-1 | 04/18/96 | 04/17/96 |
| Submit Draft CP to the regulatory agencies | 07/01/96 | 06/20/96 |
| Begin operation of TF406 PTU | 08/30/96 | 08/27/96 |
| Submit Draft Final CP to regulatory agencies | 10/29/96 | 10/22/96 |
| Begin operation of TFE East PTU | 11/27/96 | 11/25/96 |
| Issue CP | 11/28/96 | 11/15/96 |

**Table 2. 1996 Livermore Site source investigation drilling.**

| Area | Borehole(s) | Completion(s) | Well completion type |
|---|---|---|---|
| Building 419 | 2 | 2 | Piezometer |
| T-5475 | 5 | 4 | 2 FLUTe and<br>2 vapor extraction/injection |
| TF406 | 2 | 2 | Piezometer |
| TFA | 2 | 2 | Monitor |
| TFB | 3 | 3 | Piezometer |
| TFD | 1 | 1 | Piezometer |
| TFD/ACI | 1 | 1 | Piezometer |
| TFE | 2 | 2 | Monitor |
| TFG | 1 | 1 | Piezometer |
| Total | 19 | 18 | |

Table 3. Summary of 1996 VOC remediation.

| Treatment facility | Volume of ground water treated (Mgal) | Volume of soil vapor treated ($Kft^3$) | Estimated total VOC mass removed (kg) |
|---|---|---|---|
| TFA | 92.1 | – | 16.8 |
| TFB | 14.8 | – | 7.7 |
| TFC | 4.4 | – | 2.4 |
| TFD | 10.7 | – | 12.1 |
| TFE | 0.5 | – | 0.8 |
| TF406 | 0.4 | – | 0.2 |
| TFG | 0.9 | – | 0.2 |
| VTF518 | – | 1,550 | 42.0 |
| Total | 124 | 1,550 | 82.2 |

Notes:

kg = Kilograms.

$Kft^3$ = Thousands of cubic feet.

Mgal = Millions of gallons.

Table 4. Summary of cumulative VOC remediation.

| Treatment facility | Volume of ground water treated (Mgal) | Volume of soil vapor treated ($Kft^3$) | Estimated total VOC mass removed (kg) |
|---|---|---|---|
| TFA | 261.9 | – | 75.0 |
| TFB | 48.4 | – | 20.1 |
| TFC | 12.9 | – | 6.2 |
| TFD | 12.8 | – | 18.1 |
| TFE | 0.5 | – | 0.8 |
| TF406 | 0.4 | – | 0.2 |
| TFG | 0.9 | – | 0.2 |
| VTF518 | – | 1,870 | 66.0 |
| Total | 338 | 1,870 | 187 |

Notes:

kg = Kilograms.

$Kft^3$ = Thousands of cubic feet.

Mgal = Millions of gallons.

# Appendix A

# Well Construction and Closure Data

**Table A-1. Well construction data, Lawrence Livermore National Laboratory and vicinity, Livermore, California.**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| *Monitor Wells* | | | | | | |
| W-1 | 21-Oct-80 | 122.5 | 116.0 | 95-100 | 2 | NA |
| W-1A | 12-Apr-84 | 180.0 | 156.0 | 145-156 | 2 | NA |
| W-2 | 29-Aug-80 | 102.5 | 101.0 | 86-101 | 1B | NA |
| W-2A | 02-Apr-84 | 185.0 | 164.0 | 150-164 | 2 | NA |
| W-4 | 28-Jul-80 | 92.0 | 90.0 | 75-90 | 1B | NA |
| W-5 | 24-Oct-80 | 93.5 | 90.0 | 56-71<br>81-86 | 1B | NA |
| W-5A | 09-Apr-84 | 115.0 | 105.0 | 95-105 | 2 | NA |
| W-7 | 03-Oct-80 | 110.5 | 100.5 | 76-81<br>88-98 | 2/3A | NA |
| W-8 | 14-May-81 | 110.0 | 105.0 | 72-77<br>92-102 | 3A/3B | NA |
| W-10A | 08-Sep-80 | 110.7 | 110.0 | 85-95<br>100-105 | 2 | NA |
| W-11 | 03-Jun-81 | 252.0 | 191.0 | 136-141<br>177-187 | 5 | NA |
| W-12 | 14-Aug-80 | 115.75 | 115.0 | 99-114 | 2 | NA |
| W-17 | 08-Oct-80 | 114.0 | 114.0 | 94-109 | 5 | NA |
| W-17A | 20-May-81 | 181.4 | 160.0 | 127-132<br>147-157 | 7 | NA |
| W-19 | 19-Sep-80 | 164.75 | 161.0 | 147-157 | 7 | NA |
| W-101 | 25-Jan-85 | 77.0 | 72.0 | 62-72 | 1B | 1 |
| W-102 | 12-Feb-85 | 396.5 | 171.5 | 151.5-171.5 | 2 | 40 |
| W-103 | 14-Feb-85 | 96.0 | 89.5 | 79.5-89.5 | 1B | 5 |
| W-104 | 21-Feb-85 | 61.5 | 56.5 | 38.75-56.5 | 1B | 2.5 |
| W-105 | 26-Feb-85 | 69.0 | 62.0 | 42-62 | 1B | 0.7 |
| W-106 | 06-Mar-85 | 144.0 | 134.5 | 127.5-134.5 | 5 | 0.1-0.2 |
| W-107 | 13-Mar-85 | 128.0 | 122.0 | 115-122 | 5 | 1-3 |
| W-108 | 21-Mar-85 | 113.5 | 69.0 | 57-69 | 1A | 10 |
| W-110 | 26-Apr-85 | 371.0 | 365.0 | 340-365 | 5 | 6 |
| W-111 | 02-May-85 | 122.0 | 117.0 | 97-117 | 2 | 1.5 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-112 | 10-May-85 | 129.0 | 123.5 | 111-123.5 | 5 | 4 |
| W-113 | 16-May-85 | 124.0 | 115.0 | 100-115 | 5 | 0.9 |
| W-114 | 23-May-85 | 70.5 | 63.0 | 51-63 | 1B | 0.5 |
| W-115 | 03-Jun-85 | 106.0 | 95.0 | 88-95 | 1B | 1.1 |
| W-116 | 14-Jun-85 | 181.0 | 91.0 | 86-91 | 1B | 0.3 |
| W-117 | 27-Jun-85 | 202.0 | 148.0 | 138-148 | 7 | 0.2 |
| W-118 | 19-Jul-85 | 206.5 | 110.0 | 99-110 | 2 | 8 |
| W-119 | 02-Aug-85 | 139.0 | 102.5 | 87.5-102.5 | 2 | 3.3 |
| W-120 | 19-Aug-85 | 195.0 | 153.0 | 147-153 | 2 | 1 |
| W-121 | 23-Aug-85 | 194.0 | 171.0 | 159-171 | 2 | 3.75 |
| W-122 | 17-Aug-85 | 189.0 | 132.0 | 125-132 | 2 | 15 |
| W-123 | 01-Oct-85 | 174.0 | 47.7 | 37.3-47.7 | 1A | 5 |
| W-141 | 23-Mar-85 | 61.5 | 60.0 | 45-60 | 1B | 0.8 |
| W-142 | 29-Mar-85 | 74.2 | 72.0 | 62-72 | 2 | 0.8 |
| W-143 | 12-Apr-85 | 130.0 | 126.0 | 121-126 | 2 | 0.8 |
| W-146 | 16-Jul-85 | 225.0 | 125.0 | 115-125 | 2 | 5 |
| W-147 | 26-Jul-85 | 137.0 | 87.0 | 77-87 | 1B | 0.5 |
| W-148 | 08-Aug-85 | 152.0 | 98.0 | 83-98 | 1B | 0.5 |
| W-151 | 30-Sep-85 | 237.0 | 157.5 | 148.5-157.5 | 2 | 1.5 |
| W-201 | 17-Oct-85 | 211.0 | 161.0 | 151-161 | 2 | 14 |
| W-202 | 07-Nov-85 | 191.0 | 109.0 | 99-109 | 2 | 0.5 |
| W-203 | 15-Nov-85 | 87.0 | 41.0 | 31-41 | 1A | 3 |
| W-204 | 22-Nov-85 | 110.0 | 110.0 | 100-110 | 2 | 5+ |
| W-205 | 09-Dec-85 | 180.0 | 117.0 | 107-117 | 3B | <0.1 |
| W-206 | 19-Dec-85 | 188.0 | 118.0 | 106-118 | 3A | <0.5 |
| W-207 | 24-Jan-86 | 150.0 | 85.0 | 69-85 | 2 | <0.5 |
| W-210 | 11-Mar-86 | 176.0 | 113.0 | 108-113 | 3B | <0.5 |
| W-211 | 19-Mar-86 | 215.5 | 193.0 | 183-193 | 6 | 1 |
| W-212 | 28-Mar-86 | 183.0 | 136.0 | 124-136 | 5 | 1 |
| W-213 | 04-Apr-86 | 174.0 | 100.0 | 94-100 | 1B | 2 |
| W-214 | 11-Apr-86 | 146.0 | 141.5 | 134-141.5 | 2 | 20+ |
| W-217 | 20-May-86 | 200.0 | 112.5 | 98.5-112.5 | 5 | <0.5 |
| W-218 | 30-May-86 | 201.0 | 71.0 | 64.5-71 | 1B | 6 |
| W-219 | 13-Jun-86 | 214.0 | 148.0 | 141-148 | 5 | 2 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-220 | 25-Jun-86 | 196.0 | 92.5 | 82.5-92.5 | 2 | <0.5 |
| W-221 | 07-Jul-86 | 178.0 | 95.0 | 82-95 | 3A | 2 |
| W-222 | 17-Jul-86 | 197.0 | 83.0 | 63-83 | 2 | 5 |
| W-223 | 15-Aug-86 | 202.0 | 153.0 | 146-153 | 2 | 5.2 |
| W-224 | 26-Aug-86 | 199.0 | 88.0 | 78-88 | 2 | 3 |
| W-225 | 09-Sep-86 | 238.0 | 166.0 | 152-166 | 5 | 2.5 |
| W-226 | 25-Sep-86 | 173.0 | 86.0 | 71-86 | 1B | <0.25 |
| W-251 | 03-Oct-85 | 50.0 | 47.5 | 35.5-47.5 | 1A | 2 |
| W-252 | 18-Oct-85 | 197.0 | 126.0 | 108-126 | 2 | 3 |
| W-253 | 30-Oct-85 | 180.0 | 128.0 | 112.5-128 | 2 | 1 |
| W-254 | 21-Nov-85 | 277.0 | 91.5 | 84.5-91.5 | 1B | 5 |
| W-255 | 05-Dec-85 | 187.0 | 124.0 | 115-124 | 5 | 1 |
| W-256 | 19-Dec-85 | 187.0 | 137.0 | 132-137 | 4 | <0.5 |
| W-257 | 15-Jan-86 | 197.0 | 96.5 | 82.5-96.5 | 2 | <0.5 |
| W-258 | 31-Jan-86 | 157.0 | 121.5 | 116.5-121.5 | 3A | 0.5 |
| W-259 | 07-Feb-86 | 200.0 | 99.0 | 93.5-99 | 2 | <0.5 |
| W-260 | 27-Feb-86 | 215.0 | 151.0 | 141-151 | 2 | 3.5 |
| W-261 | 12-Mar-86 | 225.0 | 118.5 | 109-118.5 | 5 | <0.5 |
| W-263 | 07-Apr-86 | 146.0 | 130.0 | 123-130 | 2 | 2 |
| W-264 | 14-Apr-86 | 170.0 | 151.0 | 141-151 | 2 | 20+ |
| W-265 | 25-Apr-86 | 216.0 | 211.0 | 205-211 | 3B | 3 |
| W-267 | 27-May-86 | 196.0 | 179.0 | 172.5-179 | 3A | 1 |
| W-268 | 04-Jun-86 | 213.0 | 150.5 | 138-150.5 | 5 | 1 |
| W-269 | 16-Jun-86 | 185.0 | 92.0 | 79-92 | 1B | 2 |
| W-270 | 26-Jun-86 | 185.0 | 127.0 | 113-127 | 5 | <0.5 |
| W-271 | 07-Jul-86 | 201.0 | 112.0 | 105-112 | 2 | 2.1 |
| W-272 | 18-Jul-86 | 226.0 | 110.0 | 95-110 | 2 | 1 |
| W-273 | 11-Aug-86 | 203.0 | 84.0 | 64-84 | 2 | 3 |
| W-274 | 21-Aug-86 | 217.0 | 95.0 | 90-95 | 2 | <0.5 |
| W-275 | 05-Sep-86 | 262.0 | 184.0 | 179-184 | 5 | 4 |
| W-276 | 17-Sep-86 | 267.0 | 170.0 | 153.5-169.5 | 3B | 12 |
| W-277 | 03-Oct-86 | 254.0 | 169.0 | 163-169 | 3B | 1.1 |
| W-290 | 08-Jul-86 | 181.0 | 126.0 | 119.5-126 | 5 | <0.5 |
| W-291 | 24-Jul-86 | 194.0 | 137.0 | 127-137 | 5 | <0.5 |
| W-292 | 14-Aug-86 | 250.0 | 184.5 | 176-184.5 | 3B | 9 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-293 | 27-Aug-86 | 229.0 | 155.0 | 145-155 | 5 | <1 |
| W-294 | 15-Sep-86 | 251.0 | 139.0 | 122-139 | 5 | 1 |
| W-301 | 07-Oct-86 | 203.0 | 141.0 | 136-141 | 2 | 5.5 |
| W-302 | 22-Oct-86 | 191.0 | 83.5 | 78-83.5 | 1B | 2 |
| W-303 | 28-Oct-86 | 197.0 | 128.0 | 124-128 | 2 | 15 |
| W-304 | 12-Nov-86 | 207.0 | 200.0 | 195-200 | 4 | 1 |
| W-305 | 18-Nov-86 | 146.0 | 138.0 | 128-138 | 2 | 20 |
| W-306 | 04-Dec-86 | 207.0 | 110.0 | 98-110 | 2 | 8.5 |
| W-307 | 15-Dec-86 | 214.0 | 102.0 | 93-102 | 1B | 1 |
| W-308 | 13-Jan-87 | 194.0 | 113.0 | 107-113 | 2 | 2 |
| W-309 | 20-Jan-87 | 73.0 | NA | NA | NA | NA |
| W-310 | 04-Feb-87 | 202.0 | 184.5 | 176.5-184.5 | 3A | 10 |
| W-311 | 20-Feb-87 | 226.5 | 147.5 | 134.5-147.5 | 3A | 5 |
| W-312 | 05-Mar-87 | 224.5 | 168.0 | 160-168 | 4 | 25 |
| W-313 | 12-Mar-87 | 99.0 | 85.0 | 80-85 | 2 | 5.5 |
| W-314 | 20-Mar-87 | 228.0 | 142.0 | 129-142 | 4 | 9.5 |
| W-315 | 03-Apr-87 | 215.0 | 156.0 | 141-156 | 3A | 15 |
| W-316 | 15-Apr-87 | 196.0 | 71.0 | 66-72 | 2 | 3 |
| W-317 | 20-Apr-87 | 100.0 | 95.0 | 88-95 | 2 | 7 |
| W-318 | 28-Apr-87 | 200.0 | 81.0 | 74-81 | 2 | 0.5 |
| W-319 | 05-May-87 | 198.0 | 125.0 | 119-125 | 3A | 25 |
| W-320 | 11-May-87 | 106.0 | 99.0 | 94-99 | 2 | 3 |
| W-321 | 29-May-87 | 356.0 | 321.5 | 305-321.5 | 5 | 60 |
| W-322 | 01-Jul-87 | 565.5 | 152.0 | 142-152 | 2 | 4 |
| W-323 | 04-Aug-87 | 200.0 | 127.0 | 122-127 | 2 | 7 |
| W-324 | 17-Aug-87 | 219.0 | 189.0 | 184-189 | 3A | 15 |
| W-325 | 28-Aug-87 | 312.0 | 170.0 | 158-170 | 3A | 4 |
| W-352 | 29-Oct-86 | 235.0 | 201.0 | 181-201 | 4 | 12.5 |
| W-353 | 12-Nov-86 | 205.0 | 101.0 | 95.5-101 | 2 | 1 |
| W-354 | 24-Nov-86 | 185.0 | 179.0 | 163-179 | 4 | 8 |
| W-355 | 05-Dec-86 | 202.0 | 107.0 | 102-107 | 2 | 2 |
| W-356 | 18-Dec-86 | 237.0 | 137.0 | 133-137 | 3B | 6 |
| W-359 | 10-Feb-87 | 195.0 | 150.5 | 138-150.5 | 5 | 10 |
| W-360 | 24-Feb-87 | 260.0 | 204.5 | 181.5-204.5 | 4 | 30 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-361 | 05-Mar-87 | 257.0 | 135.0 | 125-135 | 3A | 4 |
| W-362 | 13-Mar-87 | 151.0 | 145.0 | 131-145 | 4 | 12 |
| W-363 | 24-Mar-87 | 195.0 | 129.0 | 117-129 | 3A | <0.5 |
| W-364 | 31-Mar-87 | 195.0 | 165.0 | 155-165 | 3B,4 | 5 |
| W-365 | 09-Apr-87 | 187.0 | 125.0 | 120-125 | 2 | 8.5 |
| W-366 | 20-Apr-87 | 273.0 | 251.0 | 240-251 | 4 | 13 |
| W-368 | 06-May-87 | 206.0 | 78.0 | 70-78 | 1B | 3 |
| W-369 | 14-May-87 | 204.0 | 113.0 | 107-113 | 2 | 2 |
| W-370 | 29-May-87 | 286.0 | 208.0 | 196.5-208 | 4 | 5 |
| W-371 | 12-Jun-87 | 233.0 | 162.0 | 155-162 | 3A | 1.5 |
| W-372 | 25-Jun-87 | 218.0 | 152.5 | 147.5-152.5 | 4 | 1 |
| W-373 | 06-Jul-87 | 178.0 | 99.0 | 89-99 | 1B | 7 |
| W-375 | 29-Jul-87 | 223.0 | 71.0 | 65-71 | 2 | 0.75 |
| W-376 | 27-Aug-87 | 249.0 | 172.0 | 162-172 | 2 | 2 |
| W-377 | 04-Sep-87 | 159.0 | 144.0 | 141.5-144 | 2 | 2.5 |
| W-378 | 09-Sep-87 | 155.0 | 150.0 | 146-150 | 2 | 5 |
| W-379 | 14-Sep-87 | 155.0 | 150.0 | 146-150 | 2 | 5 |
| W-380 | 01-Oct-87 | 195.0 | 182.0 | 170-182 | 3A | 10 |
| W-401 | 05-Nov-87 | 159.0 | 153.0 | 109-153 | 2 | 25 |
| W-402 | 13-Oct-87 | 104.0 | 102.0 | 92-102 | 1B | 40 |
| W-403 | 16-Nov-87 | 585.0 | 495.0 | 485-495 | 7 | 3 |
| W-404 | 04-Dec-87 | 245.0 | 158.0 | 150-158 | 2 | 33 |
| W-405 | 04-Jan-88 | 244.0 | 162.0 | 132-162 | 2 | 50 |
| W-406 | 20-Jan-88 | 213.0 | 94.0 | 79-84 | 1B | 2 |
| W-407 | 04-Feb-88 | 215.0 | 205.0 | 192-205 | 3A | 4 |
| W-409 | 07-Mar-88 | 272.0 | 78.0 | 71-78 | 1B | 30 |
| W-410 | 30-Mar-88 | 369.0 | 205.0 | 193-205 | 3A | 35 |
| W-411 | 12-Apr-88 | 192.0 | 138.0 | 131-138 | 2 | 8 |
| W-412 | 18-Apr-88 | 104.0 | 74.0 | 67-74 | 1B | 2.5 |
| W-413 | 28-Apr-88 | 163.0 | 115.0 | 100-115 | 2 | 25 |
| W-414 | 20-May-88 | 179.0 | 74.0 | 69.5-74 | 2 | 0.5 |
| W-416 | 10-Jun-88 | 152.0 | 80.5 | 72-80.5 | 1B | 30 |
| W-417 | 20-Jun-88 | 152.0 | 60.0 | 51-60 | 1B | 5 |
| W-418 | 24-Jun-88 | 124.0 | 118.0 | 108-118 | 2 | 2.5 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-419 | 29-Jun-88 | 82.0 | 75.5 | 62.5-75.5 | 1B | 3 |
| W-420 | 26-Jul-88 | 127.0 | 111.0 | 105-111 | 2 | 5 |
| W-421 | 23-Aug-88 | 181.0 | 90.0 | 75-90 | 1B | 4.5 |
| W-422 | 02-Sep-88 | 203.0 | 139.5 | 133-139.5 | 2 | 5 |
| W-423 | 09-Sep-88 | 308.0 | 118.0 | 106-118 | 2 | 14 |
| W-424 | 04-Oct-88 | 208.0 | 144.0 | 137-144 | 3A | 3 |
| W-441 | 14-Oct-87 | 250.0 | 144.0 | 135-144 | 5 | 2.5 |
| W-446 | 18-Dec-87 | 202.0 | 196.0 | 186-196 | 3A | 3 |
| W-447 | 05-Feb-88 | 353.0 | 274.0 | 256-274 | 4 | 5 |
| W-448 | 17-Feb-88 | 235.0 | 127.5 | 120.5-127.5 | 2 | 15 |
| W-449 | 07-Mar-88 | 172.0 | 165.0 | 152-165 | 2 | 3 |
| W-450 | 21-Mar-88 | 300.0 | 200.0 | 193-200 | 5 | 2 |
| W-451 | 06-Apr-88 | 202.0 | 112.0 | 106-112 | 2 | 1.5 |
| W-452 | 15-Apr-88 | 210.0 | 79.5 | 64-79.5 | 1B | 5 |
| W-453 | 27-Apr-88 | 185.0 | 130.3 | 121-130 | 2 | 4 |
| W-454 | 09-May-88 | 196.0 | 83.5 | 73-83.5 | 1B | 3 |
| W-455 | 19-May-88 | 184.0 | 162.5 | 148-162.5 | 2 | 5 |
| W-456 | 09-Jun-88 | 343.0 | 180.5 | 172-180.5 | 3A | 2 |
| W-458 | 30-Jun-88 | 212.5 | 116.0 | 108-116 | 2 | 2 |
| W-459 | 20-Jul-88 | 76.0 | 73.0 | 59.5-73 | 1B | 1.5 |
| W-460 | 22-Jul-88 | 361.0 | 140.5 | 135-140.5 | 2 | 30 |
| W-461 | 16-Aug-88 | 133.0 | 51.5 | 41.5-51.5 | 2 | <0.5 |
| W-462 | 12-Sep-88 | 385.0 | 336.5 | 331-336.5 | 5 | 5 |
| W-463 | 16-Sep-88 | 93.0 | 92.5 | 87-92.5 | 1B | 5 |
| W-464 | 30-Sep-88 | 253.0 | 104.5 | 96-104.5 | 2 | 3.5 |
| W-481 | 04-Nov-88 | 224.5 | 105.0 | 100-105 | 1B | 2 |
| W-482 | 15-Jan-88 | 218.0 | 170.0 | 165-170 | 2 | <0.5 |
| W-483 | 26-Jan-88 | 140.0 | 130.0 | 115-130 | 2 | 2.5 |
| W-484 | 11-Feb-88 | 255.0 | 188.0 | 185-188 | 3A | 0.5 |
| W-485 | 25-Feb-88 | 249.0 | 157.0 | 151-157 | 2 | 2 |
| W-486 | 11-Mar-88 | 167.0 | 108.0 | 100-108 | 2 | 2 |
| W-487 | 17-Mar-88 | 180.0 | 151.0 | 148-151 | 3B | 1 |
| W-501 | 13-Oct-88 | 174.0 | 92.0 | 84-92 | 1B | 6.5 |
| W-502 | 25-Oct-88 | 158.0 | 59.0 | 55-59 | 1B | <0.5 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-503 | 02-Nov-88 | 187.0 | 80.0 | 74-80 | 1B | 1 |
| W-504 | 21-Nov-88 | 358.0 | 167.0 | 157-167 | 2 | 3 |
| W-505 | 15-Dec-88 | 278.0 | 180.0 | 167-180 | 3A | 60 |
| W-506 | 22-Dec-88 | 120.0 | 115.0 | 101-115 | 1B | 30 |
| W-507 | 18-Jan-89 | 158.0 | 139.0 | 129-139 | 2 | 50 |
| W-508 | 17-Feb-89 | 316.0 | 305.0 | 287-305 | 7 | 60 |
| W-509 | 03-Mar-89 | 305.0 | 184.0 | 179-184 | 5 | 1 |
| W-510 | 15-Mar-89 | 300.0 | 119.0 | 111-119 | 2 | <0.5 |
| W-511 | 31-Mar-89 | 316.0 | 176.0 | 167-176 | 3B | 1 |
| W-512 | 13-Apr-89 | 261.0 | 176.0 | 166-176 | 5 | 2.5 |
| W-513 | 26-Apr-89 | 259.0 | 115.0 | 102-115 | 2 | 1 |
| W-514 | 17-May-89 | 386.0 | 115.5 | 92-115.5 | 1B | 2 |
| W-515 | 30-May-89 | 211.0 | 78.0 | 68-78 | 1B | 3.5 |
| W-516 | 09-Jun-89 | 203.0 | 119.0 | 114-119 | 2 | 15 |
| W-517 | 20-Jun-89 | 215.0 | 88.0 | 80-88 | 1B | 6.7 |
| W-519 | 14-Aug-89 | 186.5 | 80.5 | 60-80.5 | 1B | 25 |
| W-521 | 13-Sep-89 | 166.0 | 95.0 | 86-95 | 1B | 1 |
| W-551 | 18-Oct-88 | 308.0 | 155.5 | 151-155.5 | 2 | 20 |
| W-552 | 25-Oct-88 | 70.5 | 64.0 | 48.5-64 | 1A | 3 |
| W-553 | 03-Nov-88 | 186.0 | 106.5 | 99-106.5 | 2 | 1 |
| W-554 | 22-Nov-88 | 239.0 | 141.5 | 126.5-141.4 | 2 | 60 |
| W-555 | 05-Dec-88 | 122.0 | 116.5 | 102.5-116.5 | 1B | 20 |
| W-556 | 15-Dec-88 | 192.0 | 81.5 | 76-81.5 | 1B | 6 |
| W-557 | 22-Dec-88 | 122.5 | 118.0 | 102-118 | 2 | 2 |
| W-558 | 17-Jan-89 | 117.0 | 110.5 | 101-110.5 | 1B | 20 |
| W-559 | 24-Jan-89 | 105.0 | 100.0 | 93-100 | 2 | 0.75 |
| W-560 | 07-Feb-89 | 263.0 | 206.5 | 201-206.5 | 3B | 10 |
| W-561 | 23-Feb-89 | 180.0 | 152.0 | 143-152 | 5 | 4 |
| W-562 | 08-Mar-89 | 263.0 | 158.0 | 145-158 | 5 | 2 |
| W-563 | 17-Mar-89 | 192.0 | 105.0 | 95-105 | 2 | 2 |
| W-564 | 30-Mar-89 | 184.0 | 85.0 | 79.5-85 | 1B | 3 |
| W-565 | 06-Apr-89 | 177.0 | 82.5 | 75-82.5 | 1B | 15 |
| W-567 | 27-Apr-89 | 194.0 | 61.5 | 51-61 | 1B | 10 |
| W-568 | 05-Jun-89 | 156.0 | 101.0 | 97-101 | 2 | 30 |
| W-569 | 16-May-89 | 215.0 | 109.5 | 101-109.5 | 2 | 4 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-570 | 09-Jun-89 | 180.0 | 175.0 | 161-175 | 5 | 1 |
| W-571 | 15-Jun-89 | 223.5 | 207.5 | 102-107 | 1B | 22 |
| W-591 | 29-Nov-88 | 112.0 | 107.5 | 97-107.5 | 2 | <0.5 |
| W-592 | 12-Dec-88 | 136.5 | 113.0 | 101-113 | 2 | 1.5 |
| W-593 | 06-Feb-89 | 159.0 | 92.5 | 82-92.5 | 3A | 1.5 |
| W-594 | 27-Feb-89 | 156.0 | 61.0 | 55-61 | 2 | 0.5 |
| W-604 | 27-Nov-89 | 111.0 | 83.0 | 76-82 | 1B | 0.5 |
| W-605 | 08-Dec-89 | 246.0 | 136.0 | 130-136 | 2 | 10 |
| W-606 | 21-Dec-89 | 145.0 | 89.0 | 73-89 | 1B | 2 |
| W-607 | 24-Jan-90 | 186.0 | 55.0 | 49-55 | 1B | 3 |
| W-608 | 07-Feb-90 | 162.0 | 66.0 | 55-66 | 1B | 3 |
| W-611 | 04-Apr-90 | 161.0 | 98.0 | 87.5-98 | 1B | 2 |
| W-612 | 19-Apr-90 | 222.0 | 136.0 | 126-136 | 2 | 10 |
| W-613 | 02-May-90 | 93.0 | 88.0 | 81.5-88 | 1B | 7 |
| W-615 | 01-Jun-90 | 121.0 | 99.0 | 91-99 | 1B | 3 |
| W-616 | 14-Jun-90 | 255.0 | 188.0 | 178-188 | 3A | 8 |
| W-617 | 26-Jun-90 | 200.0 | 110.0 | 103-110 | 2 | 6 |
| W-618 | 17-Jul-90 | 357.0 | 205.0 | 201-205 | 3B | 10 |
| W-619 | 07-Aug-90 | 330.0 | 252.0 | 232-252 | 3B/4 | 30 |
| W-622 | 28-Sep-90 | 206.0 | 112.0 | 104-112 | 5 | <0.5 |
| W-651 | 22-Feb-90 | 155.0 | 89.0 | 82-89 | 1B | 0.5 |
| W-652 | 15-Mar-90 | 318.0 | 256.0 | 245-256 | 7 | 2 |
| W-653 | 29-Mar-90 | 225.0 | 128.0 | 122-128 | 3A | 0.5 |
| W-654 | 11-Apr-90 | 240.0 | 158.0 | 140-158 | 2 | 20 |
| W-702 | 24-Oct-90 | 180.5 | 95.0 | 77-95 | 1B | 10 |
| W-703 | 03-Dec-90 | 586.0 | 325.0 | 298-325 | 5 | 10 |
| W-705 | 26-Dec-90 | 126.00 | 90.0 | 77-90 | 1B | 2 |
| W-706 | 16-Jan-91 | 178.0 | 84.0 | 71-84 | 1B | 2 |
| W-714 | 02-Jul-91 | 135.0 | 128.0 | 107-128 | 2 | 7.5 |
| W-901 | 24-Feb-93 | 97.8 | 88.0 | 79-83 | 1B | 1 |
| W-902 | 22-Jan-93 | 95.5 | 88.0 | 80-83 | 1B | 1 |
| W-905 | 07-Apr-93 | 221.0 | 144.5 | 134-144 | 2 | 4 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-908 | 18-Aug-93 | 239.0 | 197.0 | 180-197 | 5/6 | <0.5 |
| W-909 | 04-Nov-93 | 252.0 | 113.5 | 80.5-108.5 | 2/3A | 2 |
| W-911 | 20-Dec-93 | 180 | 113.5 | 73.5-108.5 | 2 | 3 |
| W-912 | 07-Oct-93 | 239 | 174 | 168-174 | 5 | 3 |
| W-913 | 08-Dec-93 | 454 | 255 | 235-255 | 4 | 25 |
| W-1001 | 20-Dec-93 | 105 | 92 | 85-92 | 1B | 1.4 |
| W-1002 | 31-Jan-94 | 292.5 | 260 | 246-260 | 5 | 16 |
| W-1003 | 08-Feb-94 | 184.0 | 147 | 140-147 | 2 | 1.5 |
| W-1005 | 14-Mar-94 | 192.0 | 110.0 | 98-110 | 1B | 20 |
| W-1006 | 10-Mar-94 | 154.0 | 149.0 | 141-149 | 2 | 15 |
| W-1007 | 31-Mar-94 | 199.5 | 182.0 | 172-182 | 3A | 2 |
| W-1008 | 13-Apr-94 | 246 | 238 | 229.5-238 | 7 | 10 |
| W-1010 | 24-May-94 | 463 | 142 | 128-142 | 2 | 20 |
| W-1011 | 06-Jun-94 | 106 | 89 | 75-89 | 1B | 3 |
| W-1012 | 20-Jun-94 | 161 | 117 | 96-112 | 2 | 5 |
| W-1013 | 29-Jun-94 | 147 | 73 | 65-73 | 1B | 1.4 |
| W-1014 | 12-Jul-94 | 99 | 89 | 65-89 | 1B | 30 |
| W-1101 | 10-Nov-94 | 200.0 | 79.0 | 76.0-79.0 | 1B | 0.5 |
| W-1105 | 17-Jan-95 | 110 | 93 | 78-93 | 1B | 3.5-4 |
| W-1106 | 08-Feb-95 | 245 | 86 | 76-85 | 1B | 15 |
| W-1107 | 06-Mar-95 | 199.5 | 93 | 74-88 | 1B | <0.5 |
| W-1108 | 27-Mar-95 | 250 | 156 | 142-156 | 5 | 12 |
| W-1110 | 04-May-95 | 252 | 92.2 | 68-92 | 1B | 7 |
| W-1112 | 28-Jun-95 | 263 | 210 | 201-210 | 5 | 3 |
| W-1113 | 18-Jul-95 | 260 | 214 | 204-214 | 5 | 2.5 |
| W-1115 | 12-Oct-95 | 126.5 | 118.2 | 108-118 | 3A | 1 |
| W-1117 | 11-Sep-95 | 154 | 132.3 | 122-132 | 3A | 1 |
| W-1118 | 27-Sep-95 | 225 | 125 | 115-125 | 3A | 3.5 |
| W-1201 | 18-Oct-95 | 225 | 133 | 125-133 | 3A | 1 |
| W-1202 | 26-Oct-95 | 99.3 | 99 | 83-99 | 2 | $5^+$ |
| W-1203 | 07-Nov-95 | 224 | 206.2 | 196-206 | 5 | $18^+$ |
| W-1204 | 20 Nov-95 | 225 | 126.2 | 118-126 | 3A | 2.5 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-1205 | 27-Nov-95 | 91 | 82 | 72-82 | 2 | <0.5 |
| W-1206 | 06-Dec-95 | 220 | 191 | 174-186 | 4 | $40^{+}$ |
| W-1207 | 13-Dec-95 | 92 | 90 | 70-90 | 2 | <0.5 |
| W-1208 | 09-Jan-96 | 166 | 163 | 135-163 | 3A/3B | 40 |
| W-1209 | 26-Jan-96 | 210 | 164 | 148-164 | 4 | 3 |
| W-1210 | 12-Feb-96 | 250 | 223 | 213-223 | 5 | 3 |
| W-1211 | 05-Mar-96 | 273 | 205 | 185-200 | 4 | $25^{+}$ |
| W-1212 | 19-Mar-96 | 150 | 75 | 52-75 | 1B | 3 |
| W-1213 | 02-Apr-96 | 129 | 76 | 64-76 | 1B | $5^{+}$ |
| W-1214 | 22-Apr--96 | 180 | 100 | 80-100 | 1B | 2 |
| W-1215 | 17-Apr-96 | 175 | 120 | 103-120.5 | 2 | 8.5 |
| W-1216 | 07-May--96 | 200 | 124 | 94-124 | 2 | 14 |
| W-1217 | 15-May--96 | 182 | 98.5 | 78-98 | 1B | <0.5 |
| W-1218 | 29-May-96 | 240 | 145.5 | 127-145 | 3A | 6.7 |
| W-1219 | 04-Jun-96 | 201 | 142 | 138-142 | 3A | <0.5 |
| W-1220 | 12-Jun-96 | 120 | 117 | 90-112 | 2 | 18 |
| W-1221 | 01-Jul-96 | 220 | 172 | 162-172 | 4 | 4 |
| W-1222 | 26-Jun-96 | 175 | 125.5 | 115-125 | 3A | 6 |
| W-1223 | 23-Jul-96 | 175 | 102 | 87-97 | 2 | 4 |
| W-1224 | 05-Sep-96 | 125 | 104.5 | 99-104 | 1B | 4.3 |
| W-1225 | 14-Aug-96 | 150 | 121.2 | 113-121 | 3A | 2 |
| W-1226 | 06-Aug-96 | 155 | 126.5 | 116-126 | 2 | 1 |
| W-1227 | 09-Oct-96 | 200 | 134 | 126-134 | 2 | 11 |
| W-1250 | 07-Jun-96 | 210 | 200 | 130-135 | 4 | 0.85 |
| W-1251 | 03-Jul-96 | 210 | 200 | 134-139 | 4 | 1.3 |
| W-1252 | 25-Jul-96 | 208 | 202.3 | 135-140 | 4 | <0.5 |
| W-1253 | 15-Aug-96 | 206 | 200.1 | 127-132 | 4 | <0.5 |
| W-1254 | 15-Aug-96 | 125 | 200 | 131-141 | 4 | 26 |
| W-1255 | 27-Aug-96 | 208 | 200.7 | 124-129 | 4 | <0.5 |
| W-1301 | 04-Dec-96 | 180 | 120.3 | 112-120 | 3A | 15 |
| TW-11 | 09-Jun-81 | 112.5 | 107.0 | 97-107 | 2 | NA |
| TW-11A | 16-Mar-84 | 163.0 | 160.0 | 133-160 | 2 | NA |
| TW-21 | 12-Jun-81 | 111.5 | 95.0 | 85-95 | 1B | NA |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| GEW-710 | 02-Aug-91 | 159.0 | 158.0 | 94-137 | 3A,3B | 25 |
| GSW-1A | 12-Jun-86 | 208.0 | 133.0 | 115-133 | 3B | 12 |
| GSW-2 | 14-Feb-85 | 113.0 | 107.0 | 87-107 | 3A | NA |
| GSW-3 | 07-Feb-85 | 115.0 | 105.0 | 85-105 | 3A | NA |
| GSW-4 | 22-Feb-85 | 112.0 | 106.0 | 86-106 | 3A | NA |
| GSW-5 | 19-Mar-85 | 110.0 | 104.0 | 94-104 | 3A | NA |
| GSW-6 | 28-Feb-86 | 212.0 | 137.0 | 121-137 | 3B | 6 |
| GSW-7 | 14-Mar-86 | 176.5 | 123.4 | 110.8-123.4 | 3B | 2 |
| GSW-8 | 01-Apr-86 | 176.0 | 133.0 | 127.5-133 | 3B | 2 |
| GSW-9 | 14-Apr-86 | 197.5 | 152.5 | 147-152.5 | 3B | 1 |
| GSW-10 | 29-Apr-86 | 205.5 | 127.5 | 114-127.5 | 3B | 8 |
| GSW-11 | 07-May-86 | 182.5 | 126.0 | 116-126 | 3B | 2 |
| GSW-12 | 27-May-86 | 205.0 | 191.0 | 186.5-191 | 5 | 1 |
| GSW-13 | 27-Jun-86 | 198.0 | 134.5 | 125-134.5 | 3B | 1 |
| GSW-15 | 14-Aug-87 | 148.0 | 145.0 | 20.5-28 | 1B | 3.5 |
| | | | | 38-44 | 1B | |
| | | | | 50-56 | 2 | |
| | | | | 60-64 | 2 | |
| | | | | 68-73 | 2 | |
| | | | | 77-83 | 2 | |
| | | | | 95-105 | 3A | |
| | | | | 120-130 | 3B | |
| GSW-16 | 19-Oct-87 | 146.0 | 145.0 | 23-28 | 1B | 20.5-30 |
| | | | | 38-43 | 1B | |
| | | | | 50-55 | 2 | |
| | | | | 61-66 | 2 | |
| | | | | 78-83 | 2 | |
| | | | | 95-105 | 3A | |
| | | | | 120-130 | 3B | |
| GSW-208 | 06-Feb-86 | 211.0 | 123.0 | 108-118 | 3B | <2 |
| GSW-209 | 27-Feb-86 | 204.0 | 135.2 | 112.8-132.8 | 3B | 2 |
| GSW-215 | 22-Apr-86 | 213.5 | 133.5 | 127-133.5 | 3A | 2 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| GSW-216 | 09-May-86 | 193.0 | 120.5 | 110.5-120.5 | 3B | 3 |
| GSW-266 | 08-May-86 | 220.0 | 166.0 | 159-166 | 3B | 1 |
| GSW-326 | 02-Oct-87 | 230.0 | 134.0 | 129-134 | 4 | 0.5 |
| GSW-367 | 29-Apr-87 | 159.0 | 124.0 | 114-124 | 2 | 2 |
| GSW-403-6 | 11-May-84 | 138.0 | 113.6 | 90-110 | 3A | NA |
| GSW-442 | 27-Oct-87 | 270.0 | 145.0 | 138-145 | 3B | 0.5 |
| GSW-443 | 09-Nov-87 | 291.0 | 141.0 | 123-141 | 2 | 5 |
| GSW-444 | 20-Nov-87 | 278.0 | 120.0 | 110-120 | 3B | 0.3 |
| GSW-445 | 09-Dec-87 | 319.0 | 161.0 | 155-161 | 4 | 3 |
| *Dynamic Stripping Project Wells*[c] | | | | | | |
| GSP-SNL-001 | 07-Jan-92 | 147.0 | 104.0 | 99-104 | 3A | NA |
| | | | 131.0 | 118-131 | 3B | NA |
| GEW-808 | 05-Jun-92 | 164.0 | 150.0 | 50-140 | 2/3A/3B | 25 |
| | | | | | 2/3A/3B | |
| GIW-813 | 25-Jun-92 | 140.7 | 87.0 | 67-87 | 2 | NA |
| | | | 104.0 | 89-99 | 3A | |
| | | | 127.0 | 107-127 | 3A/3B | NA |
| GIW-814 | 19-Jun-92 | 149.6 | 106.5 | 86.5-106.5 | 2/3A | NA |
| | | | 117.0 | 110-120 | 3A | |
| | | | 132.0 | 121-141 | 3B | NA |
| GIW-815 | 15-Jun-92 | 143.0 | 97.0 | 77-97 | 2/3A | NA |
| | | | 117.0 | 102-112 | 3A | |
| | | | 132.0 | 112.8-132 | 3B | NA |
| GEW-816 | 03-Jun-92 | 161.7 | 150.0 | 50-140 | 3A,3B | 40 |
| GIW-817 | 29-Jun-92 | 150.1 | 102.0 | 82-102 | 2/3A | NA |
| | | | 122.0 | 107-117 | 3A | |
| | | | 141.0 | 121-141 | 3B | NA |
| GIW-818 | 06-Jul-92 | 150.0 | 102 | 82-102 | 2/3A | NA |
| | | | 125 | 110-120 | 3A | |
| | | | 140 | 120-140 | 3B | NA |
| GIW-819 | 10-Jul-92 | 150.0 | 98.6 | 78.6-98.6 | 2/3A | NA |
| | | | 123 | 108-118 | 3A 3B | |
| | | | 141 | 121-141 | | NA |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| GIW-820 | 16-Jul-92 | 143.3 | 105 | 85-105 | 2/3A | NA |
| | | | 132 | 112-132 | 3A3B | NA |
| HW-GP-001 | 17-Apr-92 | 120.0 | 77.0 | 67-77 | 2 | NA |
| | | | 113.0 | 103-113 | 3A | NA |
| HW-GP-002 | 13-May-92 | 120.0 | 78.0 | 68-78 | 2 | NA |
| | | | 117.0 | 107-117 | 3A | NA |
| HW-GP-003 | 20-May-92 | 119.0 | 76.5 | 66.5-76.5 | 2 | NA |
| | | | 119.0 | 109-119 | 3A | NA |
| HW-GP-102 | 13-Aug-93 | 140.0 | 137.5 | 72.5-133.5 | 2/3A/3B | NA |
| HW-GP-103 | 23-Aug-93 | 138.0 | 137.5 | 71.5-132.5 | 2/3A/3B | NA |
| HW-GP-104 | 02-Sep-93 | 138.0 | 137.2 | 72.2-132.2 | 2/3A/3B | NA |
| HW-GP-105 | 28-Sep-93 | 138.0 | 137.5 | 72.5-132.5 | 2/3A/3B | NA |
| TEP-GP-106 | 21-Sep-93 | 137.5 | 135.5 | | | |
| *Extraction Wells* | | | | | | |
| W-109 | 02-Apr-85 | 289.0 | 147.0 | 137-147 | 2 | 12 |
| W-262 | 20-Mar-86 | 256.0 | 100.0 | 91-100 | 1B | 7 |
| W-351 | 17-Oct-86 | 191.0 | 151.0 | 146-152 | 4 | 2.9 |
| W-357 | 12-Jan-87 | 197.0 | 123.0 | 107-123 | 2 | 8 |
| W-408 | 16-Feb-88 | 131.0 | 122.5 | 101-122.5 | 1B | 35 |
| W-415 | 12-Aug-88 | 205.0 | 183.7 | 79-179 | 1B | >50 |
| W-457 | 22-Jun-88 | 289.0 | 149.5 | 130-149.5 | 2 | 20 |
| W-518 | 08-Aug-89 | 251.0 | 139.0 | 131-139 | 2 | 2.5 |
| W-520 | 30-Aug-89 | 160.0 | 101.5 | 94-101.5 | 1B | 12 |
| W-522 | 05-Oct-89 | 145.5 | 141.5 | 134-141.5 | 2 | 25 |
| W-566 | 19-Apr-89 | 317.0 | 207.0 | 197-207 | 5 | 12 |
| W-601 | 13-Oct-89 | 146.0 | 96.0 | 88-96 | 1B | 15 |
| W-602 | 06-Nov-89 | 168.0 | 100.0 | 90-100 | 1B | 10 |
| W-603 | 15-Nov-89 | 150.0 | 147.0 | 141-147 | 2 | 5 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| W-609 | 21-Feb-90 | 120.0 | 112.0 | 104-112 | 2 | 4 |
| W-610 | 16-Mar-90 | 453.0 | 84.5 | 69-84.5 | 1B | 4 |
| W-614 | 18-May-90 | 262.0 | 123.0 | 100-123 | 1B | 12 |
| W-620 | 30-Aug-90 | 206.0 | 88.5 | 75-88.5 | 1B | 5 |
| W-621 | 09-Sep-90 | 149.0 | 120.0 | 113-120 | 2 | 4 |
| W-655 | 25-Apr-90 | 193.0 | 130.0 | 121-129.5 | 2 | 2 |
| W-701 | 10-Oct-90 | 159.0 | 86.0 | 74-86 | 1B | 10 |
| W-704 | 01-Feb-91 | 135.0 | 107.0 | 67-76 | 1B | 20 |
| | | | | 88-97 | | |
| W-712 | 29-Aug-91 | 200.0 | 185.5 | 170-185.5 | 3A | 8 |
| W-903 | 28-Apr-93 | 223.0 | 145 | 132-140 | 2 | 20 |
| W-904 | 06-May-93 | 212.0 | 154.0 | 121-133 | 2 | 20 |
| | | | | 140-149 | | |
| W-906 | 27-Jul-93 | 200.0 | 132.0 | 58-132 | 2,3A | 10 |
| W-907 | 02-Sep-93 | 239.0 | 220.0 | 172.7-188.8 | 4 | 25 |
| | | | | 204.5-215.0 | 5 | NA |
| W-1004 | 23-Feb-94 | 99.0 | 97.0 | 71-91 | 1B | 7 |
| W-1009 | 02-May-94 | 191 | 140 | 134-140 | 2 | 20 |
| W-1015 | 10-Aug-94 | 437 | 94 | 84-94 | 1B | 20 |
| W-1102 | 29-Nov-94 | 163.0 | 95.5 | 76.0-94.0 | 1B | 8 |
| W-1103 | 15-Dec-94 | 200.0 | 82.0 | 70.0-82.0 | 1B | 3.5 |
| W-1104 | 18-Jan-95 | 165.0 | 99.0 | 77-87 | 1B | $35^+$ |
| | | | | 92-98 | | |
| W-1109 | 11-Apr-95 | 121 | 113 | 94-108 | 2 | 3 |
| W-1111 | 01-Jun-95 | 152 | 129 | 88-108 | 2 | 10.5 |
| | | | | 120-124 | 2 | NA |
| W-1114 | 07-Aug-95 | 223 | 205 | 177-200 | 5 | 8.5 |
| W-1116 | 17-Aug-95 | 214 | 101 | 72-98 | 1B | 9 |

**Table A-1. (Continued)**

| Well number | Date completed | Borehole depth (ft) | Casing depth (ft) | Perforated interval (ft) | HSU[a] monitored | Well development flow rate (gpm)[b] |
|---|---|---|---|---|---|---|
| *Other Wells* | | | | | | |
| 7D2 | 07-Jun-76 | 74 | 72.3 | 63.2-67.3 | 3A | NA |
| 11C1 | 08-Jun-76 | 68 | 66.2 | 56.2-61.2 | 1B | NA |
| 11H5 | 08-Nov-85 | NA | 255 | NA | NA | NA |
| 11J2 | 26-Apr-79 | 112 | 110 | 90-92 | 2 | NA |
| | | | | 102-108 | | |
| 11Q4 | NA | NA | NA | NA | NA | NA |
| 11Q5 | NA | NA | NA | NA | NA | NA |
| 14A3 | 07-Dec-77 | NA | 110 | 100-105 | NA | NA |
| 14A11[d] | NA | NA | NA | NA | NA | NA |
| 14B1 | 13-Aug-59 | 300 | 234 | 146-149 | NA | NA |
| | | | | 192-195 | | |
| | | | | 198 | | |
| | | | | 200 | | |
| | | | | 203 | | |
| | | | | 205 | | |
| | | | | 207 | | |
| | | | | 209-213 | | |
| | | | | 226 | | |
| | | | | 230 | | |
| | | | | 234 | | |
| 14B4 | Aug-60 | NA | 260 | 143-148 | NA | NA |
| | | | | 155-159 | | |
| | | | | 186-189 | | |
| | | | | 205-215 | | |
| | | | | 245-250 | | |
| 14B7 | NA | NA | NA | NA | NA | NA |
| 14H1 | NA | NA | 288 | NA | NA | NA |
| 14H2[d] | NA | NA | NA | NA | NA | |
| 18D1[d] | NA | NA | NA | NA | 7 | NA |

**Note: Notes and footnotes appear on the following page.**

## Table A-1. (Continued)

**Notes:** Boreholes B-707, B-708, B-709, B-713, B-715, and B-750 were drilled for the Dynamic Underground Stripping Demonstration Project "Clean Site."

**NA = Not applicable or not available.**

[a] **Hydrostratigraphic Units (HSUs) are numbered consecutively downward from ground surface. An HSU is defined as sediments that are grouped together based on the hydrogeologic and contaminant transport properties. The permeable layers within an HSU are considered to be in good hydraulic communication, whereas permeable layers in different HSUs are considered to be in poor hydraulic communication. HSU contacts are interpreted and are subject to change.**

[b] **Flow rate after 4 hours of air-lift pumping/surging.**

[c] **Wells installed for the Dynamic Underground Stripping Demonstration Project include extraction wells (GEW series), injection wells (GIW series), temperature monitoring wells (TEP series), and heating wells (HW series). TEP wells consist of two nested 1-in. inside diameter (ID) piezometers surrounding a blank fiberglass 2-in. ID casing instrumented with geophysical sensors. The screened intervals listed therefore refer to the two individual piezometers.**

[d] **Well number was changed in December 1988 to be consistent with Alameda County Flood Control and Water Conservation District, Zone 7 well identification. Well number changes made on this table are:**

**4A6 ------> 14H2**

**18D81 ------> 18D1**

**14A84 ------> 14A11**

# Appendix B

# Hydraulic Test Results

**Appendix B. Results of hydraulic tests.[a]**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-001 | 01-Dec-83 | Drawdown | 5.7 | 2,000 | 110 | Fair |
| W-001 | 23-Jan-85 | Drawdown | 7.1 | 3,100 | 170 | Good |
| W-001A | 22-Jan-85 | Drawdown | 1.4 | 190 | 19 | Good |
| W-002 | 01-Dec-83 | Slug | 0.0 | 110 | 34 | Poor |
| W-002A | 24-Jan-85 | Drawdown | 10.3 | 2,700 | 200 | Good |
| W-004 | 01-Dec-83 | Drawdown | 3.3 | 63 | 13 | Good |
| W-005 | 01-Dec-83 | Drawdown | 4.3 | 110 | 20 | Good |
| W-005 | 24-Jan-85 | Drawdown | 7.9 | 1,100 | 210 | Fair |
| W-005A | 23-Jan-85 | Drawdown | 13.0 | 1,300 | 130 | Poor |
| W-007 | 01-Dec-83 | Slug | 0.0 | 43 | 14 | Fair |
| W-008 | 01-Dec-83 | Drawdown | 2.9 | 29 | 4.9 | Fair |
| W-011 | 01-Dec-83 | Drawdown | 4.1 | 130 | 15 | Good |
| W-017 | 01-Dec-83 | Slug | 0.0 | 38 | 2.5 | Good |
| W-017 | 21-Feb-86 | Slug | 0.0 | 85 | 5.7 | Good |
| W-018 | 01-Dec-83 | Drawdown | 2.6 | 20 | 2.7 | Poor |
| W-102 | 25-Mar-86 | Drawdown | 6.4 | 1,100 | 72 | Good |
| W-102 | 05-Sep-86 | Drawdown | 24.0 | 770 | 53 | Good |
| W-102 | 15-Sep-86 | Longterm | 27.5 | 4,200 | 290 | Good |
| W-103 | 25-Apr-86 | Drawdown | 6.7 | 15,000 | 1,500 | Good |
| W-104 | 03-Mar-88 | Drawdown | 5.4 | 1,200 | 170 | Fair |
| W-104 | 25-Mar-88 | Drawdown | 3.3 | 450 | 45 | Fair |
| W-105 | 06-Apr-87 | Drawdown | 0.8 | 73 | 7.3 | Fair |
| W-106 | 19-Feb-86 | Slug | 0.0 | 7.4 | 1.3 | Excel |
| W-107 | 17-Jun-85 | Drawdown | 1.0 | 94 | 9.4 | Poor |
| W-108 | 29-Oct-85 | Drawdown | 7.9 | 750 | 63 | Poor |
| W-109 | 05-Mar-86 | Drawdown | 8.1 | 3,200 | 540 | Good |
| W-109 | 04-Sep-87 | Drawdown | 20.0 | 1,600 | 270 | Good |
| W-109 | 29-Sep-87 | Longterm | 11.6 | 130 | 22 | Fair |
| W-109 | 16-Oct-87 | Drawdown | 8.0 | 2,300 | 380 | Fair |
| W-110 | 18-Jun-85 | Drawdown | 5.0 | 1,300 | 130 | Good |
| W-111 | 13-Jun-85 | Drawdown | 1.0 | 370 | 37 | Good |
| W-111 | 21-Nov-85 | Drawdown | 1.0 | 37 | 2.3 | Good |
| W-112 | 18-Nov-86 | Drawdown | 13.4 | 2,100 | 170 | Fair |
| W-112 | 15-Dec-86 | Longterm | 13.2 | 3,100 | 260 | Fair |
| W-112 | 05-Nov-96 | Longterm | 13.7 | 3,250 | 260 | Fair |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-113 | 17-Apr-86 | Slug | 0.0 | 7.4 | 1.2 | Excel |
| W-115 | 05-Mar-86 | Drawdown | 1.1 | 180 | 30 | Good |
| W-116 | 24-Dec-85 | Slug | 0.0 | 37 | 7.5 | Good |
| W-117 | 20-Feb-86 | Slug | 0.0 | 2 | 0.4 | Good |
| W-118 | 05-Mar-86 | Drawdown | 10.0 | 2,100 | 240 | Good |
| W-119 | 08-Aug-85 | Drawdown | 2.0 | 1,600 | 100 | Good |
| W-120 | 22-Apr-86 | Drawdown | 1.1 | 23 | 5.6 | Poor |
| W-121 | 10-Sep-85 | Drawdown | 2.0 | 120 | 7.5 | Good |
| W-121 | 23-Sep-85 | Drawdown | 4.0 | 23 | 1.5 | Excel |
| W-121 | 14-Oct-85 | Drawdown | 3.0 | 34 | 2.2 | Excel |
| W-121 | 15-Oct-85 | Drawdown | 4.5 | 45 | 3.0 | Excel |
| W-122 | 28-Oct-85 | Drawdown | 10.8 | 490 | 49 | Good |
| W-123 | 28-Oct-85 | Drawdown | 5.8 | 40 | 4.4 | Poor |
| W-142 | 03-Mar-88 | Slug | 0.0 | 2,600 | 330 | Excel |
| W-143 | 03-Mar-88 | Slug | 0.0 | 1,200 | 240 | Excel |
| W-149 | 09-Sep-85 | Drawdown | 4.0 | 120 | 19 | Good |
| W-149 | 11-Sep-85 | Drawdown | 8.0 | 95 | 16 | Excel |
| W-149 | 11-Oct-85 | Drawdown | 4.8 | 58 | 9.7 | Excel |
| W-149 | 11-Oct-85 | Drawdown | 7.0 | 70 | 12 | Good |
| W-150 | 02-Oct-85 | Drawdown | 3.1 | 640 | 210 | Fair |
| W-150 | 03-Oct-85 | Drawdown | 6.0 | 720 | 240 | Fair |
| W-150 | 10-Oct-85 | Drawdown | 8.8 | 630 | 210 | Fair |
| W-150 | 10-Oct-85 | Drawdown | 12.0 | 620 | 210. | Fair |
| W-151 | 28-Oct-85 | Drawdown | 5.8 | 550 | 61 | Poor |
| W-201 | 05-Mar-86 | Drawdown | 10.0 | 740 | 86 | Excel |
| W-203 | 02-Mar-88 | Drawdown | 6.6 | 1,100 | 110 | Good |
| W-204 | 23-Jan-86 | Drawdown | 1.9 | 100 | 15 | Fair |
| W-205 | 14-Feb-86 | Slug | 0.0 | 5.90 | 1.9 | Good |
| W-205 | 18-Feb-86 | Slug | 0.0 | 5 | 1.9 | Good |
| W-206 | 14-Apr-86 | Slug | 0.0 | 120 | 11 | Good |
| W-207 | 02-Mar-88 | Slug | 0.0 | 380 | 32 | Excel |
| W-210 | 09-Jun-86 | Slug | 0.0 | 0.60 | 0.1 | Good |
| W-211 | 22-Oct-86 | Drawdown | 2.9 | 37 | 12 | Fair |
| W-211 | 08-Dec-86 | Longterm | 1.0 | 44 | 15 | Fair |
| W-212 | 12-May-86 | Drawdown | 0.8 | 18 | 3.1 | Poor |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-213 | 22-Apr-86 | Drawdown | 3.8 | 190 | 38 | Good |
| W-214 | 07-Oct-86 | Longterm | 27.6 | 2,300 | 350 | Good |
| W-217 | 15-Jul-86 | Slug | 0.0 | 750 | 120 | Good |
| W-218 | 17-Jun-86 | Drawdown | 11.7 | 6,400 | 1,100 | Good |
| W-218 | 12-Nov-86 | Longterm | 7.7 | 4,000 | 670 | Good |
| W-219 | 15-Jul-86 | Drawdown | 4.3 | 620 | 76 | Good |
| W-219 | 23-Feb-87 | Longterm | 5.2 | 66 | 8.0 | Fair |
| W-220 | 21-Aug-86 | Slug | 0.0 | 28 | 5.5 | Excel |
| W-221 | 05-Aug-86 | Drawdown | 2.1 | 120 | 16 | Fair |
| W-222 | 12-Aug-86 | Drawdown | 16.0 | 1,700 | 160 | Excel |
| W-222 | 08-Mar-85 | Longterm | 7.7 | 1,100 | 180 | Good |
| W-223 | 27-Aug-86 | Drawdown | 4.0 | 510 | 110 | Good |
| W-224 | 28-Oct-86 | Drawdown | 7.6 | 3,600 | 400 | Excel |
| W-225 | 23-Oct-86 | Drawdown | 4.0 | 85 | 11 | Good |
| W-225 | 12-Jan-87 | Longterm | 2.0 | 62 | 8.5 | Fair |
| W-226 | 31-Mar-87 | Slug | 0.0 | 1,700 | 160 | Fair |
| W-252 | 04-Nov-85 | Drawdown | 4.0 | 920 | 50 | Fair |
| W-252 | 19-Nov-85 | Drawdown | 5.6 | 800 | 43 | Fair |
| W-254 | 27-Jan-86 | Drawdown | 4.2 | 340 | 38 | Fair |
| W-254 | 27-Feb-86 | Drawdown | 3.2 | 370 | 41 | Good |
| W-255 | 21-Jan-86 | Drawdown | 5.0 | 2,800 | 250 | Fair |
| W-255 | 21-Jan-86 | Drawdown | 6.0 | 2,000 | 180 | Fair |
| W-255 | 06-Jan-87 | Longterm | 2.0 | 400 | 36 | Fair |
| W-256 | 11-Apr-86 | Slug | 0.0 | 11 | 5.5 | Good |
| W-257 | 15-Apr-86 | Slug | 0.0 | 120 | 24 | Good |
| W-258 | 05-Jun-86 | Slug | 0.0 | 35 | 9.0 | Excel |
| W-258 | 29-Oct-86 | Slug | 0.0 | 32 | 8.0 | Good |
| W-259 | 26-Mar-88 | Slug | 0.0 | 15 | 5.0 | Good |
| W-260 | 25-Mar-86 | Drawdown | 3.0 | 140 | 22 | Good |
| W-260 | 01-Oct-86 | Longterm | 1.4 | 120 | 18 | Good |
| W-261 | 27-May-86 | Slug | 0.0 | 7 | 2.3 | Excel |
| W-262 | 11-Apr-86 | Drawdown | 12.5 | 2,000 | 250 | Excel |
| W-262 | 23-Sep-86 | Longterm | 22.0 | 2,750 | 340 | Good |
| W-262 | 27-Apr-87 | Longterm | 23.1 | 6,800 | 810 | Good |
| W-263 | 22-Apr-86 | Drawdown | 1.2 | 37 | 7.4 | Poor |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-263 | 04-Nov-86 | Longterm | 1.8 | 76 | 15 | Excel |
| W-264 | 07-May-86 | Drawdown | 8.1 | 930 | 100 | Good |
| W-264 | 29-Oct-86 | Longterm | 23.0 | 480 | 50 | Good |
| W-265 | 19-May-86 | Drawdown | 0.7 | 180 | 34 | Fair |
| W-267 | 02-Jun-86 | Drawdown | 0.5 | 420 | 85 | Poor |
| W-268 | 14-Nov-86 | Drawdown | 5.0 | 230 | 18 | Good |
| W-269 | 14-Jul-86 | Drawdown | 5.0 | 570 | 95 | Good |
| W-270 | 30-Dec-86 | Slug | 0.0 | 14 | 2.0 | Good |
| W-271 | 04-Aug-86 | Drawdown | 5.5 | 340 | 76 | Fair |
| W-272 | 19-Aug-86 | Drawdown | 0.8 | 150 | 30 | Fair |
| W-273 | 27-Aug-86 | Drawdown | 3.2 | 600 | 90 | Good |
| W-274 | 25-Mar-85 | Slug | 0.0 | 38 | 7.6 | Fair |
| W-275 | 30-Oct-86 | Drawdown | 7.0 | 730 | 150 | Fair |
| W-275 | 02-Mar-87 | Longterm | 5.5 | 830 | 170 | Fair |
| W-276 | 21-Nov-86 | Drawdown | 13.0 | 960 | 110 | Good |
| W-276 | 04-May-87 | Longterm | 24.0 | 2,700 | 300 | Fair |
| W-277 | 03-Nov-86 | Drawdown | 0.9 | 74 | 25 | Fair |
| W-290 | 05-Jan-87 | Slug | 0.0 | 14 | 4.0 | Excel |
| W-291 | 27-Jan-87 | Slug | 0.0 | 25 | 7.1 | Fair |
| W-292 | 28-Aug-86 | Drawdown | 6.0 | 400 | 56 | Excel |
| W-294 | 29-Dec-86 | Drawdown | 5.3 | 5,300 | 29 | Fair |
| W-294 | 29-Dec-86 | Drawdown | 5.9 | 5,400 | 300 | Good |
| W-301 | 30-Oct-86 | Drawdown | 6.0 | 460 | 100 | Good |
| W-302 | 18-Nov-86 | Drawdown | 1.0 | 100 | 27 | Good |
| W-302 | 18-Nov-86 | Drawdown | 2.0 | 76 | 21 | Fair |
| W-303 | 12-Nov-86 | Drawdown | 11.1 | 210 | 70 | Good |
| W-304 | 13-Mar-87 | Drawdown | 0.9 | 74 | 25 | Fair |
| W-305 | 26-Nov-86 | Drawdown | 19.0 | 720 | 72 | Excel |
| W-305 | 18-May-87 | Longterm | 20.1 | 640 | 64 | Excel |
| W-306 | 31-Mar-87 | Drawdown | 9.5 | 270 | 68 | Good |
| W-307 | 26-Mar-87 | Drawdown | 0.9 | 66 | 33 | Fair |
| W-308 | 04-Dec-87 | Drawdown | 2.6 | 27 | 5.4 | Good |
| W-310 | 17-Feb-87 | Drawdown | 6.7 | 58 | 850 | Good |
| W-311 | 19-Mar-87 | Drawdown | 9.8 | 130 | 12 | Good |
| W-311 | 17-Nov-87 | Longterm | 9.9 | 370 | 26 | Good |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| 0W-312 | 27-Mar-87 | Drawdown | 20.5 | 1,800 | 300 | Poor |
| W-312 | 03-Nov-87 | Longterm | 18.8 | 1,700 | 280 | Good |
| W-313 | 25-Mar-87 | Drawdown | 7.9 | 3,000 | 600 | Good |
| W-313 | 05-Oct-87 | Longterm | 9.6 | 3,400 | 680 | Good |
| W-314 | 10-Apr-87 | Drawdown | 26.4 | 2,900 | 390 | Good |
| W-314 | 13-Jul-87 | Longterm | 13.6 | 2,500 | 330 | Fair |
| W-315 | 09-Apr-87 | Drawdown | 15.4 | 150 | 11 | Good |
| W-315 | 05-Jan-85 | Longterm | 24.5 | 571 | 41 | Excel |
| W-316 | 04-May-87 | Drawdown | 7.8 | 1,400 | 280 | Good |
| W-317 | 12-May-87 | Drawdown | 12.1 | 300 | 43 | Fair |
| W-317 | 15-Dec-87 | Longterm | 8.2 | 120 | 17.1 | Good |
| W-318 | 07-Aug-87 | Slug | 0.0 | 120 | 16 | Good |
| W-319 | 29-Jul-87 | Drawdown | 48.0 | 7,200 | 1,500 | Good |
| W-320 | 15-May-87 | Drawdown | 1.8 | 58 | 17 | Fair |
| W-320 | 15-May-87 | Drawdown | 3.0 | 22 | 3.7 | Fair |
| W-320 | 26-Jun-87 | Drawdown | 2.1 | 49 | 14 | Fair |
| W-321 | 28-Jul-87 | Drawdown | 40.0 | 6,600 | 450 | Good |
| W-322 | 03-Aug-87 | Drawdown | 3.1 | 85 | 15 | Good |
| W-323 | 11-Aug-87 | Drawdown | 3.4 | 205 | 59 | Good |
| W-324 | 10-Sep-87 | Drawdown | 6.6 | 200 | 50 | Good |
| W-325 | 10-Sep-87 | Drawdown | 6.0 | 160 | 13 | Excel |
| W-351 | 12-Nov-86 | Drawdown | 5.7 | 27 | 14 | Poor |
| W-352 | 30-Dec-86 | Drawdown | 20.0 | 280 | 14 | Good |
| W-352 | 07-Jul-87 | Longterm | 19.5 | 120 | 6.0 | Excel |
| W-353 | 20-Nov-86 | Drawdown | 2.1 | 60 | 17 | Good |
| W-354 | 30-Dec-86 | Drawdown | 17.6 | 2,000 | 220 | Fair |
| W-354 | 30-Dec-86 | Drawdown | 18.0 | 2,400 | 260 | Good |
| W-354 | 20-Apr-87 | Longterm | 17.8 | 310 | 34 | Good |
| W-355 | 29-Dec-86 | Drawdown | 2.1 | 19 | 5.0 | Fair |
| W-356 | 17-Mar-87 | Drawdown | 5.7 | 180 | 59 | Good |
| W-356 | 16-Jul-96 | Longterm | 4.9 | 230 | 57 | Poor |
| W-357 | 18-Feb-87 | Drawdown | 15.0 | 1,300 | 110 | Good |
| W-357 | 21-Jul-87 | Longterm | 9.2 | 210 | 18 | Good |
| W-358 | 18-Mar-87 | Drawdown | 9.2 | 210 | 32 | Excel |
| W-359 | 09-Mar-87 | Longterm | 19.0 | 2,800 | 290 | Fair |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-359 | 20-Mar-87 | Drawdown | 18.6 | 1,100 | 110 | Good |
| W-360 | 22-May-87 | Drawdown | 30.0 | 4,800 | 210 | Excel |
| W-361 | 16-Mar-87 | Drawdown | 4.3 | 67 | 11 | Good |
| W-361 | 12-Jan-85 | Longterm | 5.3 | 178 | 30 | Good |
| W-362 | 23-Mar-87 | Drawdown | 16.4 | 470 | 49 | Good |
| W-362 | 21-Sep-87 | Longterm | 13.6 | 370 | 39 | Good |
| W-363 | 24-Jul-87 | Slug | 0.0 | 20 | 3.0 | Excel |
| W-364 | 08-Apr-87 | Drawdown | 8.6 | 51 | 10 | Fair |
| W-364 | 01-Jun-87 | Longterm | 4.8 | 110 | 22 | Good |
| W-365 | 14-May-87 | Drawdown | 10.0 | 36 | 15 | Fair |
| W-366 | 11-May-87 | Drawdown | 19.0 | 780 | 92 | Fair |
| W-368 | 11-May-87 | Drawdown | 2.9 | 81 | 8.5 | Fair |
| W-369 | 25-Jun-87 | Drawdown | 7.0 | 580 | 96 | Good |
| W-369 | 10-Nov-87 | Longterm | 5.5 | 89 | 18 | Good |
| W-370 | 23-Jun-87 | Drawdown | 4.4 | 84 | 10 | Fair |
| W-371 | 24-Jun-87 | Drawdown | 3.3 | 15 | 3.0 | Good |
| W-372 | 23-Nov-87 | Slug | 0.0 | 310 | 62 | Excel |
| W-373 | 28-Jul-87 | Drawdown | 4.0 | 660 | 77 | Fair |
| W-373 | 28-Jul-87 | Drawdown | 6.5 | 50 | 6.0 | Poor |
| W-376 | 26-Jan-88 | Drawdown | 2.9 | 65 | 8.5 | Fair |
| W-380 | 23-Oct-87 | Drawdown | 4.0 | 33 | 4.7 | Excel |
| W-401 | 23-Oct-87 | Drawdown | 42.0 | 950 | 24 | Excel |
| W-402 | 22-Oct-87 | Drawdown | 41.0 | 13,500 | 1,400 | Good |
| W-403 | 03-Dec-87 | Drawdown | 9.7 | 370 | 26 | Good |
| W-404 | 04-Feb-85 | Drawdown | 45.0 | 3,200 | 530 | Good |
| W-405 | 16-Feb-85 | Drawdown | 47.2 | 546 | 14 | Good |
| W-406 | 28-Jan-85 | Drawdown | 7.4 | 7,500 | 940 | Fair |
| W-407 | 23-Feb-85 | Drawdown | 14.4 | 75 | 7.5 | Fair |
| W-408 | 05-Apr-85 | Drawdown | 45.0 | 43,000 | 3,100 | Good |
| W-409 | 22-Mar-85 | Drawdown | 20.0 | 230 | 38 | Good |
| W-410 | 28-Apr-85 | Drawdown | 35.0 | 6,800 | 570 | Fair |
| W-411 | 05-May-85 | Drawdown | 14.0 | 50 | 83 | Good |
| W-412 | 06-May-88 | Drawdown | 4.1 | 700 | 64 | Fair |
| W-414 | 27-Jul-85 | Slug | 0.0 | 150 | 38 | Good |
| W-416 | 11-Jul-85 | Drawdown | 50.0 | 2,600 | 330 | Good |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-417 | 27-Jun-88 | Drawdown | 5.3 | 340 | 57 | Fair |
| W-420 | 16-Aug-85 | Drawdown | 3.5 | 710 | 100 | Excel |
| W-421 | 12-Sep-85 | Drawdown | 4.8 | 320 | 27 | Excel |
| W-422 | 19-Sep-85 | Drawdown | 8.6 | 230 | 42 | Good |
| W-423 | 12-Oct-85 | Drawdown | 22.0 | 1,500 | 130 | Good |
| W-424 | 17-Oct-85 | Drawdown | 4.5 | 130 | 19 | Good |
| W-441 | 30-Oct-87 | Drawdown | 6.0 | 500 | 56 | Good |
| W-441 | 13-Apr-88 | Drawdown | 13.0 | 2,200 | 240 | Poor |
| W-441 | 19-Apr-88 | Longterm | 14.0 | 470 | 52 | Good |
| W-447 | 26-Feb-88 | Drawdown | 7.1 | 124 | 850 | Poor |
| W-448 | 24-Mar-85 | Drawdown | 24.5 | 4,200 | 600 | Good |
| W-449 | 21-Mar-85 | Drawdown | 6.2 | 170 | 11 | Good |
| W-450 | 14-Apr-88 | Drawdown | 3.3 | 38 | 650 | Fair |
| W-451 | 27-Apr-88 | Drawdown | 2.1 | 80 | 16 | Good |
| W-452 | 02-May-88 | Drawdown | 5.2 | 310 | 21 | Excel |
| W-453 | 03-May-88 | Drawdown | 5.8 | 67 | 7.4 | Fair |
| W-455 | 22-Jun-88 | Drawdown | 5.8 | 160 | 13 | Good |
| W-456 | 14-Jul-85 | Drawdown | 4.5 | 260 | 33 | Fair |
| W-457 | 29-Jul-85 | Drawdown | 20.5 | 450 | 24 | Excel |
| W-458 | 02-Aug-85 | Drawdown | 0.8 | 24 | 150 | Fair |
| W-460 | 01-Sep-85 | Drawdown | 17.0 | 1,900 | 380 | Fair |
| W-461 | 07-Sep-85 | Slug | 0.0 | 690 | 140 | Good |
| W-462 | 27-Sep-85 | Drawdown | 19.0 | 360 | 60 | Good |
| W-463 | 11-Oct-85 | Drawdown | 24.0 | 1,600 | 200 | Good |
| W-464 | 8-Nov-88 | Drawdown | 9.0 | 370 | 53 | Good |
| W-481 | 02-Dec-87 | Drawdown | 1.1 | 8 | 1.7 | Good |
| W-486 | 23-Mar-85 | Drawdown | 6.0 | 230 | 30 | Good |
| W-487 | 14-Apr-88 | Drawdown | 2.2 | 45 | 15 | Good |
| W-501 | 21-Oct-85 | Drawdown | 9.7 | 170 | 21 | Good |
| W-502 | 14-Nov-85 | Slug | 0.0 | 12 | 30 | Good |
| W-503 | 11-Nov-88 | Drawdown | 1.3 | 15 | 3.0 | Fair |
| W-504 | 08-Dec-85 | Drawdown | 10.0 | 590 | 84 | Good |
| W-505 | 21-Mar-89 | Drawdown | 34.2 | 653 | 76 | Good |
| W-506 | 10-Feb-89 | Drawdown | 31.0 | 7,423 | 460 | Good |
| W-507 | 06-Feb-89 | Drawdown | 39.0 | 2,900 | 290 | Good |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-508 | 29-Mar-89 | Drawdown | 30.0 | 47,000 | 2,600 | Good |
| W-509 | 11-May-89 | Drawdown | 0.9 | 10 | 2.0 | Fair |
| W-510 | 11-May-89 | Slug | 0.0 | 220 | 110 | Good |
| W-511 | 11-May-89 | Drawdown | 1.7 | 63 | 11 | Fair |
| W-512 | 27-Apr-89 | Drawdown | 2.9 | 85 | 9.4 | Good |
| W-513 | 09-May-89 | Drawdown | 0.6 | 33 | 3.0 | Fair |
| W-514 | 26-May-89 | Drawdown | 1.4 | 84 | 530 | Fair |
| W-515 | 06-Jun-89 | Drawdown | 2.8 | 37 | 4.2 | Fair |
| W-516 | 19-Jun-89 | Drawdown | 19.5 | 1,428 | 286 | Good |
| W-517 | 27-Jun-89 | Drawdown | 7.3 | 370 | 53 | Good |
| W-518 | 10-Aug-89 | Drawdown | 6.2 | 1,421 | 178 | Good |
| W-519 | 31-Aug-89 | Drawdown | 31.5 | 5,700 | 475 | Excel |
| W-520 | 24-Jan-90 | Drawdown | 22.8 | 3,300 | 560 | Excel |
| W-521 | 01-Feb-90 | Drawdown | 0.6 | 44 | 4.9 | Fair |
| W-522 | 05-Feb-90 | Drawdown | 20.0 | 3,700 | 620 | Fair |
| W-551 | 08-Nov-85 | Drawdown | 37.0 | 350 | 88 | Good |
| W-552 | 12-Dec-88 | Drawdown | 38.0 | 4,700 | 390 | Good |
| W-553 | 17-Nov-85 | Drawdown | 2.2 | 55 | 7.9 | Fair |
| W-554 | 10-Jan-89 | Drawdown | 21.5 | 1,800 | 150 | Good |
| W-555 | 28-Dec-88 | Drawdown | 14.0 | 460 | 23 | Fair |
| W-556 | 25-Jan-89 | Drawdown | 17.0 | 850 | 170 | Fair |
| W-557 | 23-Jan-89 | Drawdown | 1.2 | 570 | 36 | Poor |
| W-558 | 23-Mar-89 | Drawdown | 24.7 | 5,200 | 650 | Good |
| W-560 | 08-Mar-89 | Drawdown | 1.7 | 30 | 7.6 | Fair |
| W-561 | 13-Mar-89 | Drawdown | 1.1 | 12 | 2.1 | Fair |
| W-562 | 28-Mar-89 | Drawdown | 1.0 | 16 | 2.3 | Fair |
| W-563 | 31-Mar-89 | Drawdown | 1.1 | 14 | 2.3 | Fair |
| W-564 | 26-Apr-89 | Drawdown | 1.6 | 44 | 5.0 | Poor |
| W-565 | 18-Apr-89 | Drawdown | 15.6 | 1,600 | 260 | Good |
| W-566 | 02-May-89 | Drawdown | 17.0 | 780 | 86 | Good |
| W-566 | 31-Aug-93 | Longterm | 22.5 | 2580 | 520 | Fair |
| W-567 | 04-May-89 | Drawdown | 10.4 | 2,600 | 320 | Excel |
| W-568 | 20-Jun-89 | Drawdown | 18.3 | 620 | 160 | Fair |
| W-569 | 24-May-89 | Drawdown | 2.8 | 100 | 15 | Fair |
| W-570 | 08-Jun-89 | Drawdown | 1.1 | 7 | 1.1 | Fair |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-571 | 17-Jul-89 | Drawdown | 17.7 | 1,000 | 200 | Excel |
| W-592 | 23-Jan-89 | Drawdown | 2.2 | 2,200 | 280 | Poor |
| W-593 | 22-Feb-89 | Drawdown | 2.2 | 57 | 11.4 | Good |
| W-594 | 16-Mar-89 | Slug | 0.0 | 380 | 54 | Excel |
| W-601 | 08-Feb-90 | Drawdown | 22.5 | 6,900 | 770 | Excel |
| W-602 | 29-Jan-90 | Drawdown | 24.0 | 5,300 | 620 | Good |
| W-603 | 07-Feb-90 | Drawdown | 6.1 | 100 | 20 | Fair |
| W-604 | 20-Feb-90 | Slug | 0.0 | 380 | 63 | Good |
| W-605 | 28-Feb-90 | Drawdown | 4.8 | 50 | 12 | Good |
| W-606 | 21-Feb-90 | Slug | 0.0 | 120 | 20 | Fair |
| W-607 | 22-Feb-90 | Drawdown | 1.4 | 800 | 100 | Good |
| W-608 | 28-Feb-90 | Drawdown | 1.2 | 230 | 30 | Fair |
| W-609 | 09-Mar-90 | Drawdown | 6.7 | 470 | 70 | Good |
| W-610 | 28-Mar-90 | Drawdown | 5.8 | 5,500 | 380 | Good |
| W-611 | 16-Apr-90 | Drawdown | 3.5 | 1,000 | 110 | Fair |
| W-612 | 24-May-90 | Drawdown | 13.5 | 550 | 55 | Good |
| W-612 | 05-Apr-94 | Longterm | 14 | 230 | 40 | Good |
| W-613 | 23-May-90 | Drawdown | 4.8 | 2,550 | 360 | Good |
| W-614 | 07-Jun-90 | Drawdown | 6.7 | 1,650 | 130 | Good |
| W-615 | 21-Jun-90 | Drawdown | 1.3 | 130 | 19 | Fair |
| W-616 | 27-Jun-90 | Drawdown | 2.0 | 390 | 40 | Fair |
| W-617 | 12-Jul-90 | Drawdown | 2.8 | 53 | 6.8 | Good |
| W-618 | 01-Aug-90 | Drawdown | 1.9 | 24 | 4.8 | Fair |
| W-619 | 30-Aug-90 | Drawdown | 11.8 | 190 | 11 | Good |
| W-620 | 01-Oct-90 | Drawdown | 5.8 | 6,500 | 650 | Good |
| W-621 | 04-Oct-90 | Drawdown | 3.8 | 310 | 39 | Good |
| W-622 | 12-Oct-90 | Slug | 0.0 | 130 | 16 | Fair |
| W-651 | 16-Mar-90 | Slug | 0.0 | 530 | 180 | Fair |
| W-652 | 22-Mar-90 | Drawdown | 1.0 | 11 | 3.8 | Good |
| W-653 | 11-Apr-90 | Drawdown | 0.3 | 2 | 1.9 | Fair |
| W-654 | 25-Apr-90 | Drawdown | 21.7 | 390 | 25 | Fair |
| W-655 | 12-May-90 | Drawdown | 12.2 | 1,000 | 220 | Good |
| W-701 | 23-Oct-90 | Drawdown | 14.5 | 6,800 | 650 | Good |
| W-701 | 03-Oct-92 | Step | 16.5 | 5,200 | 430 | Good |
| W-701 | 01-Apr-93 | Drawdown | 24 | 3,700 | 370 | Good |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-702 | 29-Nov-90 | Drawdown | 2.5 | 150 | 30 | Good |
| W-702 | 25-Feb-93 | Step | 4.6 | 36 | 7 | Poor |
| W-703 | 19-Dec-90 | Drawdown | 7.0 | 230 | 9.1 | Good |
| W-704 | 04-Mar-91 | Drawdown | 19.0 | 1,800 | 140 | Fair |
| W-705 | 20-Feb-91 | Drawdown | 0.8 | 40 | 6.1 | Fair |
| W-706 | 29-Jan-91 | Drawdown | 0.2 | 8 | 1 | Fair |
| W-712 | 25-Feb-92 | Drawdown | 7.8 | 750 | 48 | Good |
| W-712 | 18-Mar-93 | Longterm | 15.1 | 1440 | 93 | Good |
| W-714 | 06-Dec-91 | Drawdown | 2.9 | 140 | 6.7 | Good |
| W-902 | 25-Mar-93 | Drawdown | 0.6 | 6 | 2 | Fair |
| W-909 | 18-Oct-95 | Drawdown | 2.7 | 150 | 5.1 | Good |
| W-911 | 02-Feb-96 | Drawdown | 1.4 | 53 | 2.1 | Good |
| W-912 | 10-Nov-95 | Drawdown | 4.1 | 65 | 11 | Poor |
| W-913 | 16-Aug-95 | Drawdown | 23.5 | 730 | 36 | Good |
| W-1001 | 13-Aug-95 | Drawdown | 1.3 | 170 | 25 | Fair |
| W-1007 | 23-Sep-95 | Drawdown | 1.6 | 13 | 1.3 | Fair |
| W-1010 | 10-Jul-95 | Drawdown | 20.3 | 1,650 | 140 | Fair |
| W-1011 | 11-Jul-95 | Drawdown | 3.8 | 240 | 17 | Good |
| W-1012 | 13-Jul-95 | Drawdown | 3.3 | 35 | 2.2 | Fair |
| W-1013 | 13-Jul-95 | Drawdown | 2.7 | 2,000 | 250 | Poor |
| W-1014 | 28-Aug-96 | Drawdown | 31.1 | 7,500 | 310 | Good |
| W-1101 | 22-Nov-95 | Drawdown | 0.8 | 9.9 | 3.3 | Good |
| W-1102 | 29-Jan-96 | Drawdown | 14.7 | 81 | 4.5 | Fair |
| W-1103 | 29-Nov-95 | Drawdown | 3 | 19 | 1.6 | Fair |
| W-1105 | 17-Jul-95 | Drawdown | 2.4 | 320 | 26 | Fair |
| W-1106 | 24-Jul-96 | Drawdown | 7.1 | 5,200 | 580 | Good |
| W-1108 | 03-Nov-95 | Drawdown | 12.3 | 950 | 68 | Good |
| W-1108 | 25-Jun-96 | Longterm | 11.6 | 1,030 | 75 | Poor |
| W-1109 | 26-Jun-95 | Drawdown | 8.7 | 460 | 33 | Fair |
| W-1109 | 04-Jun-96 | Longterm | 6.8 | 760 | 40 | Poor |
| W-1110 | 22-Jan-96 | Drawdown | 6.3 | 690 | 29 | Fair |
| W-1111 | 20-Oct-95 | Drawdown | 15.8 | 2,100 | 95 | Good |
| W-1112 | 24-May-96 | Drawdown | 6.4 | 94 | 10 | Fair |
| W-1113 | 26-Aug-96 | Drawdown | 1 | 5.5 | 0.4 | Good |
| W-1114 | 27-Oct-95 | Longterm | 15.1 | 270 | 12 | Fair |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| W-1116 | 23-Feb-96 | Drawdown | 6.6 | 290 | 11 | Fair |
| W-1117 | 23-Aug-96 | Drawdown | 0.7 | 3.4 | 0.34 | Fair |
| W-1118 | 18-Jan-96 | Drawdown | 5.6 | 350 | 35 | Good |
| W-1201 | 01-Nov-96 | Drawdown | 1 | 8.3 | 0.92 | Poor |
| W-1203 | 02-May-96 | Drawdown | 18.8 | 900 | 90 | Good |
| W-1204 | 22-Feb-96 | Drawdown | 1.3 | 17 | 2.2 | Poor |
| W-1209 | 17-May-96 | Drawdown | 0.98 | 11 | 0.69 | Good |
| W-1210 | 30-May-96 | Drawdown | 2.1 | 7.3 | 0.73 | Fair |
| W-1211 | 26-Jul-96 | Drawdown | 28.6 | 5,000 | 330 | Good |
| W-1212 | 14-May-96 | Drawdown | 1.9 | 35 | 2.5 | Good |
| W-1212 | 10-Sep-96 | Longterm | 1.3 | 85 | 3.6 | Poor |
| W-1213 | 22-Jul-96 | Drawdown | 11.6 | 500 | 42 | Fair |
| W-1213 | 30-Jul-96 | Longterm | 9.6 | 440 | 37 | Poor |
| W-1215 | 15-Aug-96 | Drawdown | 11.6 | 610 | 61 | Fair |
| W-1215 | 08-Oct-96 | Longterm | 9.8 | 3,000 | 300 | Poor |
| W-1216 | 14-Aug-96 | Drawdown | 11.4 | 210 | 21 | Good |
| W-1216 | 15-Oct-96 | Longterm | 11.1 | 130 | 4.4 | Poor |
| W-1218 | 11-Nov-96 | Drawdown | 5.8 | 83 | 4.6 | Fair |
| W-1220 | 13-Nov-96 | Drawdown | 20.3 | 2,600 | 120 | Good |
| W-1222 | 31-Oct-96 | Drawdown | 6.1 | 430 | 43 | Good |
| W-1254 | 19-Nov-96 | Longterm | 18.9 | 1,130 | 1.6 | Fair |
| TW-11 | 24-Jan-85 | Drawdown | 0.3 | 200 | 20 | Good |
| TW-11A | 24-Jan-85 | Drawdown | 10.0 | 3,100 | 110 | Fair |
| GSW-01 | 11-Dec-85 | Slug | 0.0 | 72 | 0.2 | Fair |
| GSW-01A | 14-Jul-86 | Drawdown | 13.4 | 12,000 | 790 | Good |
| GSW-02 | 17-Dec-85 | Slug | 0.0 | 240 | 10 | Good |
| GSW-03 | 23-Dec-85 | Slug | 0.0 | 510 | 41 | Good |
| GSW-04 | 19-Dec-85 | Slug | 0.0 | 17 | 0.9 | Good |
| GSW-05 | 12-Feb-86 | Slug | 0.0 | 99 | 9 | Excel |
| GSW-06 | 23-Jun-86 | Drawdown | 25.0 | 4,800 | 310 | Good |
| GSW-06 | 16-Jun-87 | Longterm | 20.0 | 5,500 | 350 | Good |
| GSW-07 | 03-Apr-86 | Drawdown | 4.3 | 230 | 23 | Excel |
| GSW-08 | 19-Nov-86 | Drawdown | 2.0 | 230 | 38 | Good |
| GSW-09 | 28-May-86 | Drawdown | 1.9 | 500 | 63 | Poor |
| GSW-10 | 22-May-86 | Drawdown | 14.3 | 21,000 | 2,000 | Good |

**Appendix B. (Continued)**

| Well | Date | Type of test[b] | Flow rate (Q) (gpm) | Transmis-sivity (T) (gpd/ft) | Hydraulic conductivity (K)[c] (gpd/sq ft) | Data quality[d] |
|---|---|---|---|---|---|---|
| GSW-11 | 02-Jun-86 | Drawdown | 4.7 | 390 | 45 | Excel |
| GSW-12 | 07-Jun-86 | Drawdown | 0.8 | 51 | 11 | Fair |
| GSW-13 | 04-Aug-86 | Slug | 0.0 | 110 | 13 | Excel |
| GSW-13 | 08-Aug-86 | Slug | 0.0 | 62 | 7 | Good |
| GSW-15 | 23-Feb-88 | Drawdown | 25.8 | 1,500 | 190 | Good |
| GSW-208 | 08-May-86 | Drawdown | 1.9 | 440 | 80 | Good |
| GSW-209 | 08-May-86 | Drawdown | 6.1 | 1,200 | 120 | Good |
| GSW-215 | 04-Jun-86 | Drawdown | 1.9 | 220 | 40 | Poor |
| GSW-216 | 16-Jan-92 | Drawdown | 10.5 | 3,500 | 440 | Fair |
| GSW-266 | 20-Jun-86 | Drawdown | 2.1 | 470 | 72 | Good |
| GSW-266 | 18-Nov-86 | Drawdown | 3.0 | 450 | 64 | Good |
| GSW-266 | 18-Nov-86 | Drawdown | 4.7 | 410 | 59 | Good |
| GSW-367 | 11-May-87 | Drawdown | 6.9 | 200 | 29 | Fair |
| GSW-403-6 | 08-Dec-85 | Slug | 0.0 | 4 | 0.2 | Good |
| GSW-442 | 23-Nov-87 | Drawdown | 1.2 | 32 | 4.6 | Good |
| W-702 | 25-Feb-93 | Step | 1-4.6 | 36 | 7 | Poor |
| GSW-443 | 30-Nov-87 | Drawdown | 10.3 | 260 | 8.7 | Good |
| GSW-444 | 28-Jan-88 | Slug | 0.0 | 9 | 0.86 | Good |
| GSW-445 | 26-Jan-85 | Drawdown | 4.7 | 43 | 4.30 | Fair |
| GEW-710 | 23-Sep-91 | Step | 36.0 | 4,800 | 220 | Excel |
| GEW-816 | 15-Aug-92 | Drawdown | 39.0 | 12,000 | 1,100 | Good |
| W-415 | 31-Aug-85 | Drawdown | 10.0 | 3,100 | 78 | Fair |
| W-704 | 03-May-91 | Drawdown | 19.0 | 1,800 | 140 | Fair |
| W-712 | 25-Feb-92 | Drawdown | 7.8 | 790 | 50 | Good |
| 11H4 | 15-Jan-85 | Drawdown | 24.6 | 2,000 | 77 | Good |
| 11H4 | 19-Jan-85 | Longterm | 29.5 | 1,780 | 18 | Good |
| 11J4 | 10-Jun-88 | Drawdown | 17.0 | 1,000 | 15 | Excel |
| 11J4 | 14-Jun-85 | Longterm | 16.0 | 1,100 | 16 | Good |
| 13D1 | 09-Feb-85 | Longterm | 50.0 | 4,800 | 48 | Excel |

Footnotes appear on following page.

## Appendix B. (Continued)

[a] **The pumping test results were obtained by using the analytic techniques of Theis (1935), Cooper and Jacob (1946), Papadopulos and Cooper (1967), Hantush and Jacob (1955), Hantush (1960), or Boulton (1963). The particular method used depends on the character of the data obtained. The slug test results were obtained using the method of Cooper et al. (1967). (See references below.)**

[b] **"DRAWDOWN" denotes one-hour pumping tests; "LONGTERM" denotes 24- to 48-hour pumping tests; "STEP" denotes a step drawdown test, flow rate given is the maximum or final step.**

[c] **K is calculated by dividing T by the thickness of permeable sediments intercepted by the sand pack of the well. This thickness is the sum of all sediments with moderate to high estimated conductivities determined from the geologic and geophysical logs of the well.**

[d] **Hydraulic test quality criteria:**

**Excel: High confidence that type curve match is unique. Data are smooth and flow rate well controlled.**

**Good: Some confidence that curve match is unique. Data are not too "noisy." Well bore storage effects, if present, do not significantly interfere with the curve match. Boundary effects can be separated from properties of the pumped zone.**

**Fair: Low confidence that curve match is unique. Data are "noisy." Multiple leakiness and other boundary effects tend to obscure the curve match.**

**Poor: Unique curve match cannot be obtained due to multiple boundaries, well bore storage, uneven flow rate, or equipment problems. Usually, the test is repeated.**

# References

Boulton, N. S. (1963), "Analysis of Data from Non-Equilibrium Pumping Tests Allowing for Delayed Yield from Storage," *Proc. Inst. Civ. Eng.* **26**, 469-482.

Cooper, H. H., Jr., J. D. Bredehoeft, and I. S. Papadopulos (1967), "Response of a Finite-Diameter Well to an Instantaneous Charge of Water," *Water Resour. Res.* **3**, 263-269.

Cooper, H. H., and C. E. Jacob (1946), "A Generalized Graphical Method of Evaluating Formation Constants and Summarizing Well Field History," *Am. Geophys. Union Trans.* **27**, 526-534.

Hantush, M. S. (1960), "Modification of the Theory of Leaky Aquifers," *The J. of Geophys. Res.* **65**, 3173-3725.

Hantush, M. S., and C. E. Jacob (1955), "Non-Steady Radial Flow in an Infinite Leaky Aquifer," *Am. Geophys. Union Trans.* **36** (1), 95-100.

Papadopulos, I. S., and H. H. Cooper, Jr. (1967), "Drawdown in a Well of Large Diameter," *Water Resour. Res.* **3**, 241-244.

Theis, C. V. (1935), "The Relation Between the Lowering of the Piezometric Surface and the Rate and Duration of Discharge of a Well Using Ground-Water Storage," *Am. Geophys. Union Trans.* **16**, 519-524.

# Appendix C

# 1997 Ground Water Sampling Schedule

**Table C-1. 1997 LLNL Livermore Site ground water sampling schedule.**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-001 | S | 2-97 | | E601 |
| W-001A | A | 4-97 | | E601 |
| W-002 | A | 3-97 | | E601 |
| W-002A | A | 4-97 | | E601 |
| W-004 | A | 4-97 | | E601 |
| W-005 | B | 4-98 | | E601 |
| W-005A | B | 3-98 | | E601 |
| W-007 | B | 3-98 | | E601 |
| W-008 | Q | 1-97 | WGMG | E601 |
| W-010A | B | 3-98 | | E601 |
| W-011 | S | 1-97 | | E601 |
| W-012 | S | 2-97 | | E601 |
| W-017 | B | 4-98 | | E601 |
| W-017A | B | 3-98 | | E601 |
| W-019 | B | 4-98 | | E601 |
| W-101 | B | 4-98 | | E601 |
| W-102 | B | 1-98 | | E601 |
| W-103 | A | 3-97 | | E601 |
| W-104 | Q | 1-97 | | E601 |
| W-105 | A | 4-97 | | E601 |
| W-106 | A | 3-97 | | E601 |
| W-107 | A | 4-97 | | E601 |
| W-108 | B | 2-98 | | E601 |
| W-110 | Q | 1-97 | | E601 |
| W-111 | A | 4-97 | | E601 |
| W-112 | Q | 1-97 | | E601 |
| W-113 | B | 4-98 | | E601 |
| W-114 | A | 1-97 | | E601 |
| W-115 | B | 3-98 | | E601 |
| W-116 | Q | 1-97 | | E601 |
| W-117 | B | 4-98 | | E601 |
| W-118 | S | 1-97 | | E601 |
| W-119 | Q | 1-97 | | E601 |
| W-120 | Q | 1-97 | | E601 |
| W-121 | Q | 1-97 | WGMG | E601 |
| W-122 | A | 4-97 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-123 | B | 2-97 | | E601 |
| W-141 | B | 2-98 | | E601 |
| W-142 | Q | 1-97 | | E601 |
| W-143 | S | 2-97 | | E601 |
| W-146 | A | 4-97 | | E601 |
| W-147 | B | 4-98 | | E601 |
| W-148 | B | 4-98 | | E601 |
| W-151 | Q | 1-97 | WGMG | E601 |
| W-201 | S | 2-97 | | E601 |
| W-202 | A | 4-97 | | E601 |
| W-203 | B | 2-98 | | E601 |
| W-204 | A | 1-97 | E906 | E601 |
| W-205 | Q | 1-97 | | E601 |
| W-206 | Q | 1-97 | E906 | E601 |
| W-207 | Q | 1-97 | | E601 |
| W-210 | Q | 1-97 | NPDESMET; E906 | E601 |
| W-211 | S | 2-97 | | E601 |
| W-212 | B | 4-98 | | E601 |
| W-213 | A | 3-97 | | E601 |
| W-214 | S | 2-97 | | E601 |
| W-217 | Q | 1-97 | WGMG; E903+E904 | E601 |
| W-219 | S | 1-97 | | E601 |
| W-220 | S | 1-97 | | E601 |
| W-221 | A | 4-97 | WGMG | E601 |
| W-222 | Q | 1-97 | | E601 |
| W-223 | A | 1-97 | | E601 |
| W-224 | A | 1-97 | | E601 |
| W-225 | Q | 1-97 | | E601 |
| W-226 | B | 4-98 | | E601 |
| W-251 | Q | 1-97 | | E601 |
| W-252 | A | 3-97 | | E601 |
| W-253 | A | 4-97 | | E601 |
| W-254 | Q | 1-97 | | E601 |
| W-255 | S | 2-97 | | E601 |
| W-256 | A | 1-97 | | E601 |
| W-257 | Q | 1-97 | E906 | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-258 | A | 4-97 | | E601 |
| W-259 | Q | 1-97 | E906 | E601 |
| W-260 | Q | 1-97 | | E601 |
| W-261 | A | 3-97 | | E601 |
| W-263 | Q | 1-97 | | E601 |
| W-264 | S | 2-97 | | E601 |
| W-265 | A | 2-97 | | E601 |
| W-267 | S | 1-97 | | E601 |
| W-268 | A | 4-97 | | E601 |
| W-269 | A | 4-97 | | E601 |
| W-270 | A | 4-97 | WGMG; E903+E904 | E601 |
| W-271 | Q | 1-97 | | E601 |
| W-272 | A | 3-97 | | E601 |
| W-273 | B | 3-98 | | E601 |
| W-274 | Q | 1-97 | | E601 |
| W-275 | S | 2-97 | | E601 |
| W-276 | A | 3-97 | | E601 |
| W-277 | A | 1-97 | | E601 |
| W-290 | B | 4-98 | | E601 |
| W-291 | B | 4-98 | | E601 |
| W-292 | Q | 1-97 | | E601 |
| W-293 | A | 2-97 | | E601 |
| W-294 | A | 2-97 | | E601 |
| W-301 | B | 2-98 | | E601 |
| W-302 | B | 3-98 | | E601 |
| W-303 | B | 1-98 | | E601 |
| W-304 | A | 3-97 | | E601 |
| W-305 | A | 2-97 | | E601 |
| W-306 | B | 4-98 | | E601 |
| W-307 | S | 2-97 | | E601 |
| W-308 | B | 4-98 | | E601 |
| W-310 | B | 3-98 | | E601 |
| W-311 | Q | 1-97 | | E601 |
| W-312 | A | 1-97 | | E601 |
| W-313 | A | 1-97 | | E601 |
| W-314 | S | 2-97 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-315 | Q | 1-97 | | E601 |
| W-316 | Q | 1-97 | | E601 |
| W-317 | S | 2-97 | | E601 |
| W-318 | A | 2-97 | | E601 |
| W-319 | B | 4-98 | | E601 |
| W-320 | A | 1-97 | | E601 |
| W-321 | B | 3-98 | | E601 |
| W-322 | Q | 1-97 | | E601 |
| W-323 | Q | 1-97 | | E601 |
| W-324 | B | 2-98 | | E601 |
| W-325 | B | 4-98 | | E601 |
| W-352 | PTU | PTU | | E601 |
| W-353 | A | 3-97 | | E601 |
| W-354 | Q | 1-97 | | E601 |
| W-355 | Q | 1-97 | | E601 |
| W-356 | Q | 1-97 | | E601 |
| W-359 | Q | 1-97 | | E601 |
| W-360 | Q | 1-97 | | E601 |
| W-361 | Q | 1-97 | | E601 |
| W-362 | A | 2-97 | | E601 |
| W-363 | Q | 1-97 | E906 | E601 |
| W-364 | A | 3-97 | | E601 |
| W-365 | S | 1-97 | | E601 |
| W-366 | B | 1-98 | | E601 |
| W-368 | A | 1-97 | | E601 |
| W-369 | Q | 1-97 | | E601 |
| W-370 | A | 2-97 | | E601 |
| W-371 | B | 3-98 | | E601 |
| W-372 | A | 3-97 | | E601 |
| W-373 | A | 3-97 | WGMG | E601 |
| W-375 | S | 2-97 | | E601 |
| W-376 | B | 2-98 | | E601 |
| W-377 | A | 2-97 | | E601 |
| W-378 | Q | 1-97 | | E601 |
| W-379 | A | 2-97 | | E601 |
| W-380 | B | 4-98 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-401 | B | 2-98 | | E601 |
| W-402 | B | 4-98 | | E601 |
| W-403 | B | 3-98 | | E601 |
| W-404 | Q | 1-97 | | E601 |
| W-405 | Q | 1-97 | | E601 |
| W-406 | A | 1-97 | | E601 |
| W-407 | Q | 1-97 | | E601 |
| W-409 | S | 2-97 | | E601 |
| W-410 | Q | 1-97 | | E601 |
| W-411 | S | 2-97 | | E601 |
| W-412 | B | 4-98 | | E601 |
| W-413 | A | 1-97 | | E601 |
| W-414 | B | 3-98 | | E601 |
| W-416 | B | 2-98 | | E601 |
| W-417 | B | 2-98 | | E601 |
| W-418 | A | 4-97 | | E601 |
| W-419 | Q | 1-97 | | E601 |
| W-420 | S | 2-97 | | E601 |
| W-421 | Q | 1-97 | | E601 |
| W-422 | A | 3-97 | | E601 |
| W-423 | Q | 1-97 | | E601 |
| W-424 | Q | 1-97 | | E601 |
| W-441 | Q | Collapsed | | |
| W-446 | S | 2-97 | | E601 |
| W-447 | Q | 1-97 | | E601 |
| W-448 | S | 2-97 | | E601 |
| W-449 | S | 2-97 | | E601 |
| W-450 | A | 1-97 | | E601 |
| W-451 | B | 1-98 | | E601 |
| W-452 | B | 4-98 | | E601 |
| W-453 | B | 3-98 | | E601 |
| W-454 | Q | 1-97 | | E601 |
| W-455 | A | 3-97 | | E601 |
| W-456 | A | 2-97 | | E601 |
| W-458 | B | 4-98 | | E601 |
| W-459 | A | 4-97 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-460 | S | 2-97 | | E601 |
| W-461 | Q | 1-97 | | E601 |
| W-462 | A | 3-97 | | E601 |
| W-463 | A | 3-97 | | E601 |
| W-464 | Q | 1-97 | | E601 |
| W-481 | Q | 1-97 | | E601 |
| W-482 | S | 2-97 | | E601 |
| W-483 | S | 2-97 | | E601 |
| W-484 | B | 3-98 | | E601 |
| W-485 | A | 2-97 | | E601 |
| W-486 | B | 1-97 | E906 | E601 |
| W-487 | A | 1-97 | | E601 |
| W-501 | S | 2-97 | | E601 |
| W-502 | B | 2-98 | | E601 |
| W-503 | A | 2-97 | | E601 |
| W-504 | A | 4-97 | | E601 |
| W-505 | A | 2-97 | | E601 |
| W-506 | Q | 1-97 | | E601 |
| W-507 | B | 3-98 | | E601 |
| W-509 | Q | 1-97 | | E601 |
| W-510 | B | 3-98 | | E601 |
| W-511 | A | 3-97 | | E601 |
| W-512 | S | 2-97 | | E601 |
| W-513 | A | 2-97 | | E601 |
| W-514 | B | 2-98 | | E601 |
| W-515 | Q | 1-97 | | E601 |
| W-516 | B | 4-98 | | E601 |
| W-517 | Q | 1-97 | | E601 |
| W-519 | B | 3-98 | | E601 |
| W-521 | Q | 1-97 | | E601 |
| W-551 | S | 2-97 | | E601 |
| W-552 | B | 4-98 | | E601 |
| W-553 | B | 4-98 | | E601 |
| W-554 | A | 2-97 | | E601 |
| W-555 | A | 2-97 | | E601 |
| W-556 | B | 3-98 | WGMG | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-557 | B | 3-98 | | E601 |
| W-558 | Q | 1-97 | | E601 |
| W-559 | A | 3-97 | | E601 |
| W-560 | A | 4-97 | | E601 |
| W-561 | A | 2-97 | | E601 |
| W-562 | B | 4-98 | | E601 |
| W-563 | B | 2-98 | | E601 |
| W-564 | Q | 1-97 | | E601 |
| W-565 | B | 4-98 | | E601 |
| W-567 | A | 1-97 | | E601 |
| W-568 | A | 3-97 | | E601 |
| W-569 | S | 1-97 | | E601 |
| W-570 | B | 3-98 | | E601 |
| W-571 | B | 3-98 | WGMG | E601 |
| W-591 | A | 3-97 | | E601 |
| W-592 | A | 2-97 | | E601 |
| W-593 | A | 1-97 | | E601 |
| W-594 | A | 1-97 | | E601 |
| W-604 | S | 2-97 | | E601 |
| W-605 | S | 1-97 | | E601 |
| W-606 | Q | 1-97 | | E601 |
| W-607 | S | 2-97 | | E601 |
| W-608 | A | 1-97 | | E601 |
| W-611 | A | 2-97 | | E601 |
| W-612 | S | 2-97 | | E601 |
| W-613 | S | 1-97 | | E601 |
| W-615 | A | 4-97 | | E601 |
| W-616 | S | 2-97 | | E601 |
| W-617 | S | 1-97 | | E601 |
| W-618 | Q | 1-97 | | E601 |
| W-619 | A | 3-97 | | E601 |
| W-622 | Q | 1-97 | NPDESMET; E906 | E601 |
| W-651 | Q | 1-97 | | E601 |
| W-652 | A | 1-97 | | E601 |
| W-653 | Q | 1-97 | | E601 |
| W-654 | S | 1-97 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-702 | Q | 1-97 | | E601 |
| W-705 | Q | 1-97 | | E601 |
| W-706 | B | 3-98 | | E601 |
| W-714 | Q | 1-97 | | E601 |
| W-750 | | 2-97 | | E601 |
| W-905 | A | 4-97 | | E601 |
| W-909 | Q | 1-97 | E906 | E601 |
| W-911 | Q | 2-97 | | E601 |
| W-912 | Q | 1-97 | | E601 |
| W-913 | Q | 1-97 | | E601 |
| W-1001 | Q | 1-97 | | E601 |
| W-1002 | Q | 1-97 | | E601 |
| W-1003 | A | 4-97 | | E601 |
| W-1005 | Q | 1-97 | | E601 |
| W-1006 | Q | 1-97 | | E601 |
| W-1007 | S | 2-97 | | E601 |
| W-1008 | A | 4-97 | | E601 |
| W-1010 | A | 4-97 | | E601 |
| W-1011 | Q | 1-97 | | E601 |
| W-1012 | A | 4-97 | WGMG | E601 |
| W-1013 | Q | 1-97 | | E601 |
| W-1014 | S | 2-97 | | E601 |
| W-1101 | Q | 1-97 | | E601 |
| W-1105 | Q | 1-97 | | E601 |
| W-1106 | Q | 1-97 | | E601 |
| W-1107 | Q | 1-97 | | E601 |
| W-1108 | Q | 1-97 | E906 | E601 |
| W-1110 | Q | 1-97 | | E601 |
| W-1112 | Q | 1-97 | | E601 |
| W-1113 | Q | 1-97 | | E601 |
| W-1115 | Q | 1-97 | | E601 |
| W-1117 | Q | 1-97 | E906 | E601 |
| W-1118 | Q | 1-97 | E906 | E601 |
| W-1201 | Q | 1-97 | E906 | E601 |
| W-1202 | Q | 1-97 | | E601 |
| W-1203 | Q | 1-97 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| W-1204 | Q | 1-97 | | E601 |
| W-1205 | Q | 1-97 | | E601 |
| W-1206 | Q | 1-97 | | E601 |
| W-1207 | Q | 1-97 | | E601 |
| W-1208 | PTU | PTU | | E601 |
| W-1209 | Q | 1-97 | | E601 |
| W-1210 | Q | 1-97 | | E601 |
| W-1211 | Q | 1-97 | | E601 |
| W-1212 | Q | 1-97 | | E624 |
| W-1214 | Q | 1-97 | | E601 |
| W-1215 | Q | 1-97 | | E601 |
| W-1216 | Q | 1-97 | | E601 |
| W-1217 | Q | 1-97 | | E601 |
| W-1218 | Q | 1-97 | | E601 |
| W-1220 | Q | 1-97 | | E601 |
| W-1221 | Q | 1-97 | | E601 |
| W-1222 | Q | 1-97 | E906 | E601 |
| W-1250 | Q | 1-97 | | E601 |
| W-1251 | Q | 1-97 | | E601 |
| W-1252 | Q | 1-97 | | E601 |
| W-1253 | Q | 1-97 | | E601 |
| W-1254 | Q | 1-97 | | E601 |
| W-1255 | Q | 1-97 | | E601 |
| TW11 | A | 3-97 | | E601 |
| TW11A | B | 3-98 | | E601 |
| TW21 | S | 2-97 | | E601 |
| 11C1 | B | 1-98 | | E601 |
| 14A11 | S | 1-97 | | E601 |
| 14A3 | S | 1-97 | | E601 |
| 14B1 | Q | 1-97 | WGMG | E601 |
| 14B4 | B | 1-98 | | E601 |
| 14C1 | B | 3-98 | | E601 |
| 14C2 | B | 3-98 | | E601 |
| 14C3 | Q | 1-97 | | E601 |
| 14H1 | B | 2-98 | | E601 |
| 18D1 | B | 2-98 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| 7D2 | Q | 1-97 | | E601 |
| GEW710 | Q | 1-97 | | E601 |
| GEW808 | Q | 1-97 | | E601 |
| GEW816 | Q | 1-97 | | E602 |
| GSW006 | Q | 1-97 | | E602/14d |
| GSW007 | A | 4-97 | | E601 |
| GSW008 | Q | 1-97 | | E602/14d |
| GSW009 | Q | 1-97 | | E602/14d |
| GSW011 | Q | 1-97 | | E602/14d |
| GSW013 | Q | 1-97 | | E602/14d |
| GSW215 | Q | 1-97 | | E602/14d |
| GSW266 | Q | 1-97 | | E602/14d |
| GSW326 | A | 4-97 | | E601 |
| GSW367 | S | 2-97 | | E601 |
| GSW442 | A | 4-97 | | E601 |
| GSW443 | S | 2-97 | | E624 |
| GSW444 | S | 2-97 | | E601 |
| HW-GP-103 | Q | 1-97 | | E601 |
| HW-GP-104 | Q | 1-97 | | E601 |
| SIP-141-201 | S | 2-97 | | E601 |
| SIP-141-202 | S | 2-97 | | E601 |
| SIP-141-203 | S | 2-97 | | E601 |
| SIP-191-003 | A | 4-97 | | E601 |
| SIP-191-004 | A | 4-97 | | E601 |
| SIP-212-101 | Q | 1-97 | E906 | E601 |
| SIP-293-001 | Q | 1-97 | E906 | E601 |
| SIP-331-001 | S | 2-97 | | E601 |
| SIP-419-101 | Q | 1-97 | NPDESMET; E906 | E601 |
| SIP-419-201 | Q | 1-97 | NPDESMET; E906 | E601 |
| SIP-419-202 | Q | 1-97 | NPDESMET; E906 | E601 |
| SIP-490-102 | A | 4-97 | | E601 |
| SIP-501-004 | A | 4-97 | | E601 |
| SIP-501-006 | Q | 1-97 | | E601 |
| SIP-501-007 | Q | 1-97 | | E601 |
| SIP-501-101 | A | 4-97 | | E601 |
| SIP-501-102 | A | 4-97 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| SIP-501-104 | A | 4-97 | | E601 |
| SIP-501-105 | A | 4-97 | | E601 |
| SIP-501-201 | Q | 1-97 | | E601 |
| SIP-501-202 | Q | 1-97 | | E601 |
| SIP-511-101 | Q | 1-97 | NPDESMET; E906 | E601 |
| SIP-511-102 | Q | 1-97 | NPDESMET; E906 | E601 |
| SIP-518-203 | Q | 1-97 | | E601 |
| SIP-543-101 | Q | 1-97 | | E601 |
| SIP-AS-001 | Q | 1-97 | | E601 |
| SIP-CR-049 | Q | 1-97 | | E601 |
| SIP-ETC-201 | Q | 1-97 | | E601 |
| SIP-ETS-201 | A | 4-97 | | E601 |
| SIP-ETS-204 | S | 1-97 | | E601 |
| SIP-ETS-205 | A | 3-97 | | E601 |
| SIP-ETS-207 | S | 2-97 | | E601 |
| SIP-ETS-209 | S | 2-97 | | E601 |
| SIP-ETS-211 | A | 4-97 | | E601 |
| SIP-ETS-212 | A | 4-97 | | E601 |
| SIP-ETS-213 | S | 2-97 | | E601 |
| SIP-ETS-214 | A | 4-97 | | E601 |
| SIP-ETS-215 | A | 4-97 | | E601 |
| SIP-ETS-302 | A | 4-97 | | E601 |
| SIP-ETS-303 | S | 2-97 | | E601 |
| SIP-ETS-304 | S | 2-97 | | E601 |
| SIP-ETS-306 | A | 4-97 | | E601 |
| SIP-ETS-401 | S | 2-97 | | E601 |
| SIP-ETS-402 | S | 2-97 | | E601 |
| SIP-ETS-404 | A | 4-97 | | E601 |
| SIP-ETS-405 | A | 4-97 | | E601 |
| SIP-ETS-501 | A | 4-97 | | E601 |
| SIP-ETS-502 | A | 4-97 | | E601 |
| SIP-HPA-001 | Q | 1-97 | | E601 |
| SIP-HPA-003 | Q | 1-97 | | E601 |
| SIP-HPA-102 | Q | 1-97 | | E601 |
| SIP-HPA-103 | Q | 1-97 | | E601 |
| SIP-HPA-201 | Q | 1-97 | | E601 |

**Table C-1. (Continued)**

| Well number | 1997 VOC sampling frequency | Next quarter sample date | Metals, RAD, etc. (1-97) | VOCs |
|---|---|---|---|---|
| UP-292-006 | Q | 1-97 | E906 | E601 |
| UP-292-007 | Q | 1-97 | E906 | E601 |
| UP-292-012 | Q | 1-97 | E906 | E601 |
| UP-292-015 | Q | 1-97 | E906 | E601 |

**Notes:**

S = Semiannual.
A = Annual.
B = Biennial.
Q = Quarterly.
E601 = EPA Method 601 for purgeable halocarbons.
E624 = EPA Method 624 for VOCs.
E602 = EPA Method 602 for aromatic volatile compounds.
E602/14d = EPA Method 602/14d for aromatic volatile compounds on 14-day turnaround.
E903+904 = Isotopic radium 226, 228.
E906 = EPA Method 906 for tritium.
NPDESMET = National Pollution Discharge Elimination System Metals.
WGMG = Water Guidance and Monitoring Group.

# Appendix D

# 1996 Drainage Retention Basin Annual Monitoring Program Summary

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# 1996 Drainage Retention Basin Annual Monitoring Program Summary

This Appendix summarizes the 1996 LLNL Operations and Regulatory Affairs Division routine maintenance activities, maintenance monitoring, and discharge data for the Drainage Retention Basin (DRB). The DRB, located in the central portion of the Livermore Site (Fig. D-1), is an artificial water body with about 43 acre-ft (approximately $1.4 \times 10^7$ gal) capacity, which was designed to receive storm water runoff and treated ground water. Discharge samples are collected at the first planned release of the rainy season and, at a minimum, in conjunction with one additional storm water monitoring event. Release water samples are collected at sample location CDBX and are compared with the LLNL Arroyo Las Positas outfall samples collected at sample location WPDC (Fig. D-1). Weekly maintenance field monitoring measurements are conducted at sample locations CDBA, CDBC, CDBD, CDBE, CDBF, CDBJ, CDBK, and CDBL (Fig. D-2). Monthly, quarterly, semi-annual and annual maintenance samples are collected at sampling location CDBE (Fig. D-2).

Maintenance samples are used as the basis for management decisions regarding the DRB. Management action levels (MALs) are specified in the *Drainage Retention Basin Management Plan, Lawrence Livermore National Laboratory* (Limnion Corp., 1991). The MAL is the concentration at which corrective management responses should be implemented. In most cases, short-term variances outside the normal range are not significant, and management response is required only if the objective is substantially exceeded.

Release samples are collected at the first release of the rainy season and during one additional release, in conjunction with storm water samples, as requested by the California Regional Water Quality Control Board-San Francisco Bay Region (CRWQCB-SF). Release samples are used to determine compliance with current discharge limits.

Complete analytical results of basin and release water samples are available upon request.

## D.1. Drainage Retention Basin Maintenance Monitoring

Samples collected during 1996 within the DRB at sample location CDBE did not meet the MALs for alkalinity, nitrate (as nitrogen), nitrite (as nitrogen), ammonia, phosphorus (as phosphate), turbidity, temperature, alkalinity, and iron. Results of the September 1996 CDBE tritium analysis are still pending.

Total phosphorous as phosphate was above the 0.02 milligrams per liter (mg/L) MAL each month in 1996 with concentrations ranging from <0.05 to 0.24 mg/L. Nitrate as nitrogen concentrations ranging from 0.2 mg/L to 0.6 mg/L also equaled or exceeded the 0.2 mg/L MAL every month during 1996. Nitrite as nitrogen concentrations remained below the 0.5 mg/L analytical reporting limit in January, February, May, June, and September. However, this analytical reporting limit is above the 0.2 mg/L MAL. In the remaining months, LLNL sent nitrite samples to two new laboratories which were able to obtain an analytical reporting limit of 0.1 mg/L. Samples collected during these months were below the 0.1 mg/L analytical reporting limit. Ammonia nitrogen concentrations were above the 0.1 mg/L MAL in January, February, May, July, and September. Detectable concentrations of ammonia nitrogen ranged from 0.02 mg/L to 3.9 mg/L.

Although nutrient levels have been increasing for the last two years, chlorophyll "a", which indicates the level of algae growth, remains well below the 10 mg/L MAL, ranging from <0.00096 mg/L to 0.0118 mg/L. This indicates nutrients are not the limiting factor for algae growth in the DRB. Two possible explanations for the low levels of algae growth are high turbidity and low alkalinity.

Turbidity is a measurement of water clarity and effects the photic zone where algae growth would be expected to be concentrated. The turbidity during 1996 remained persistently high, ranging from 0.146 meters (m) to 0.474 m as measured by a secchi disk. The high turbidity severely reduces light penetration and is likely limiting algae growth. Turbidity first dropped below the 0.914 m MAL during August 1994 and remained below the MAL in 1995 and 1996.

In January 1995, total alkalinity dropped below the MAL of not less than 50 mg/L for the first time since June 1993, and continued below the MAL throughout 1996 except during the month of September when it was 100 mg/L. Low alkalinity can result in an increase in the toxicity of certain dissolved metals, such as copper. The basin management plan (Limnion Corp., 1991) did not anticipate alkalinity dropping below 50 mg/L but recommends if this occurs that the alkalinity be adjusted to 75 to 100 mg/L using either hydrated lime or sodium sesquicarbonate.

LLNL began monitoring in March for active ingredients of commonly used herbicides which could also inhibit algae growth. Quarterly monitoring in March, July, and October detected low levels of Bromocil (13 to 36 μg/L) and Diuron (7 to 23 μg/L). March showed the highest levels, which then decreased during the remainder of the year.

During September 1995, LLNL conducted chronic toxicity tests on algae and fish to determine if the lack of algae growth was due to something other than turbidity. The results of the test using the algae Selanastrum capricornutum, indicated algae growth inhibition occurred at a 12.5% concentration of DRB water. The test using the fathead minnow, Pimephales promelas showed no chronic toxicity in up to 100% DRB water. Follow-up chronic toxicity testing in September 1996 indicated that DRB water had no chronic toxicity to the fathead minnow, and actually had a growth inducing effect on the algae. However, this contradicts what is observed in the DRB and could indicate that turbidity is still the main growth limiting factor. LLNL is continuing to look into the cause of the reduced algae growth within the DRB.

Dissolved oxygen remained above the MAL of 5 mg/L and mostly at or above the MAL of 80% saturation. Dissolved oxygen levels below 5 mg/L allow anaerobic bacteria to thrive, potentially releasing metals and nutrients from the sediments into the water.

Iron was the only metal that exceeded the current discharge limits. As reported in the *Annual Environmental Report* (Harrach, 1995), influent data indicate that the iron concentration at CDBE is within the range of storm water influent data. Iron was above its MAL of 3,000 μg/L from February through August. Concentrations of iron at location CDBE ranged from 2,100 μg/L to 10,000 μg/L in 1996.

Semiannual and annual maintenance sampling was conducted during April and September 1996. Quarterly sampling was conducted in January, April, July, and October. Results for chemical oxygen demand, oil and grease, total and fecal coliform bacteria, volatile organic compounds, semi-volatile organic compounds, total petroleum hydrocarbons, polynuclear aromatic compounds, ethylene dibromide and total organic carbon all met their MALs. Tritium results for the September sample are still pending. Gross alpha, and beta were consistent with background levels. Acute fish toxicity test using the fathead minnow (93% survival) met the 90% survival MAL.

## D-2. Drainage Retention Basin Discharge Monitoring

Two DRB release samples were collected in 1996. The November 19, 1996 release was a manual release and was the first of the rainy season. The release was necessary to prevent flooding of areas around the DRB and the upstream channels. The January 16, 1996 sample was collected from storm water overflowing the lowered weir gate and occurred concurrent with the 1995/96 storm water sampling event. Samples were collected during this release from locations CDBX and WPDC. Only discharges from CDBX are subject to the discharge limits established in the Record of Decision (DOE, 1992) as revised in an August 15, 1996 letter from the CRWQCB-SF (Bessette Rochette, 1996). Discharges from WPDC are monitored at the request of the CRWQCB-SF to evaluate the impact of the release as it flows through the main LLNL storm water drainage channel. Dry season (April 1–November 30) limits identified in the August 15, 1996 letter were used to evaluate the compliance of the November release, wet weather limits (December 1–March 31) were used to evaluate the compliance of the January release.

Samples collected at WPDC on January 16, 1996, are a combination of site runoff, surface water draining from offsite, ground water treatment facility discharges, and the release from the DRB. Samples collected on November 19, 1996 are a combination of DRB discharges and ground water treatment facility discharges.

In January 1996, LLNL began measuring the volume of water discharged from the DRB at CDBX with a flow meter installed in December 1995. A total 28 million gal of water was discharged from the DRB in the months of January, February, March, May, November and December. The largest single day discharge occurred on December 21, 1996 (3.6 million gal).

Samples collected from CDBX contained total petroleum hydrocarbons and iron above discharge limits. Sample results are still pending for tritium. Ethylene dibromide was below the analytical reporting limit. All other constituents were below discharge limits. Iron (3,200 and 3,900 μg/L) exceeded the 3,000 μg/L discharge limit at CDBX. Samples collected from WPDC exceeded the discharge limit for iron only in the January sample (9,700 μg/L). These concentrations for iron are within the range of iron concentrations reported in the storm water influent to the DRB. Total petroleum hydrocarbons exceeded the discharge limit of 50 μg/L for the first time. The analytical results indicated that total petroleum hydrocarbons indicative of diesel were detected at 68 μg/L. Total petroleum hydrocarbons indicative of gasoline were below the analytical reporting limit of 50 μg/L.

## D-3. References

Bessette Rochette, M. (1996), Letter from Michael Bessette Rochette, CRWQCB-SF Project Manager, to Paul Ko, DOE Project Manager, stating approval of changes to metals discharge limits and sampling frequencies, dated August 15, 1996.

Harrach, R. (1995), *Lawrence Livermore National Environmental Report 1995*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-50027-95).

Hoffman, J., P. McKereghan, J. Macdonald, B. Qualheim, R. Bainer, E. Folsom, and M. Dresen, (Eds.) (1995), *LLNL Ground Water Project 1994 Annual Report*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-115640-94-4).

The Limnion Corporation (1991), *Drainage Retention Basin Management Plan: Lawrence Livermore National Laboratory,* Concord, Calif.

U.S. Department of Energy (DOE) (1992), *Record of Decision for the Lawrence Livermore National Laboratory, Livermore Site*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-109105).

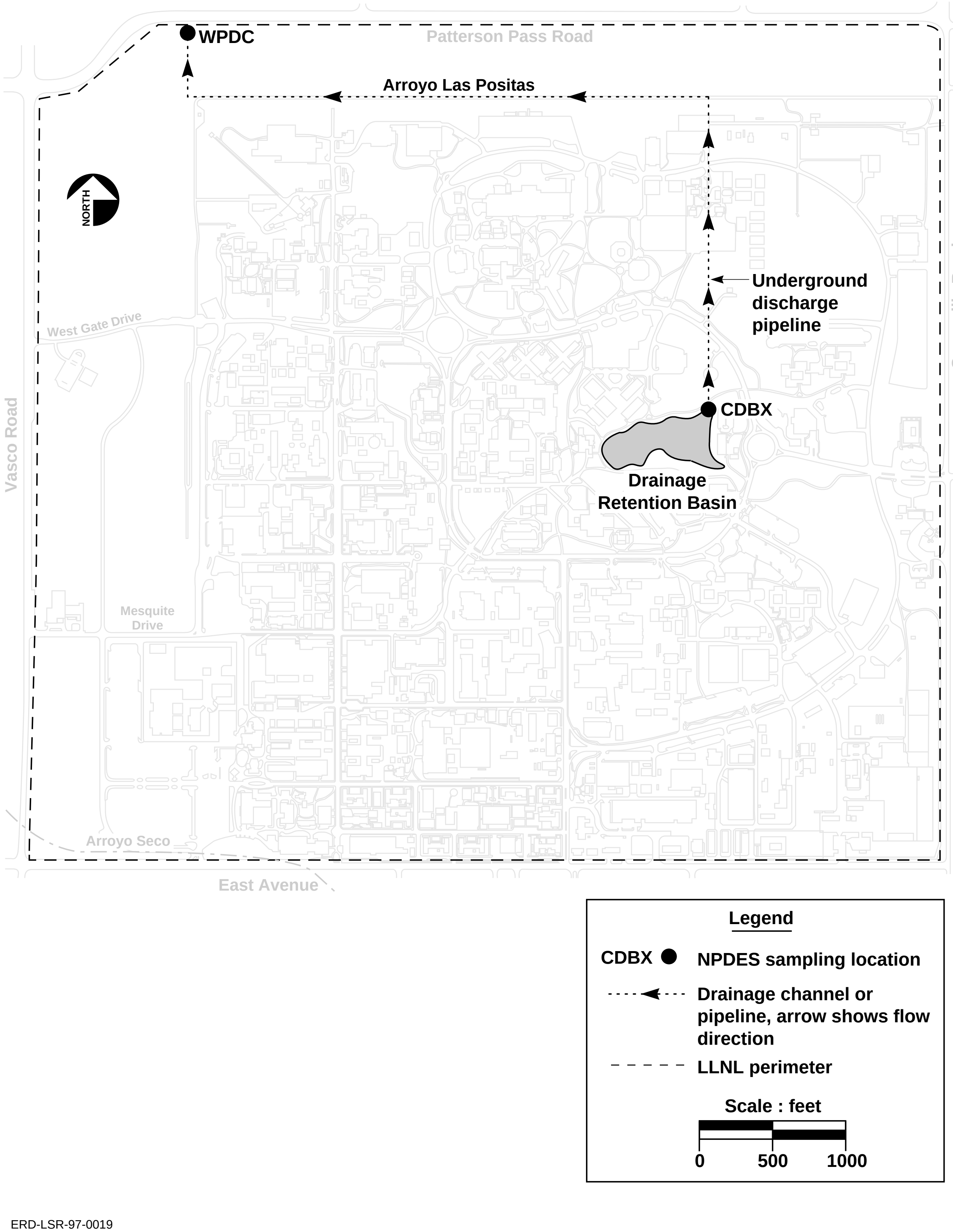


**Figure D-1. Location of the Drainage Retention Basin showing discharge locations.**

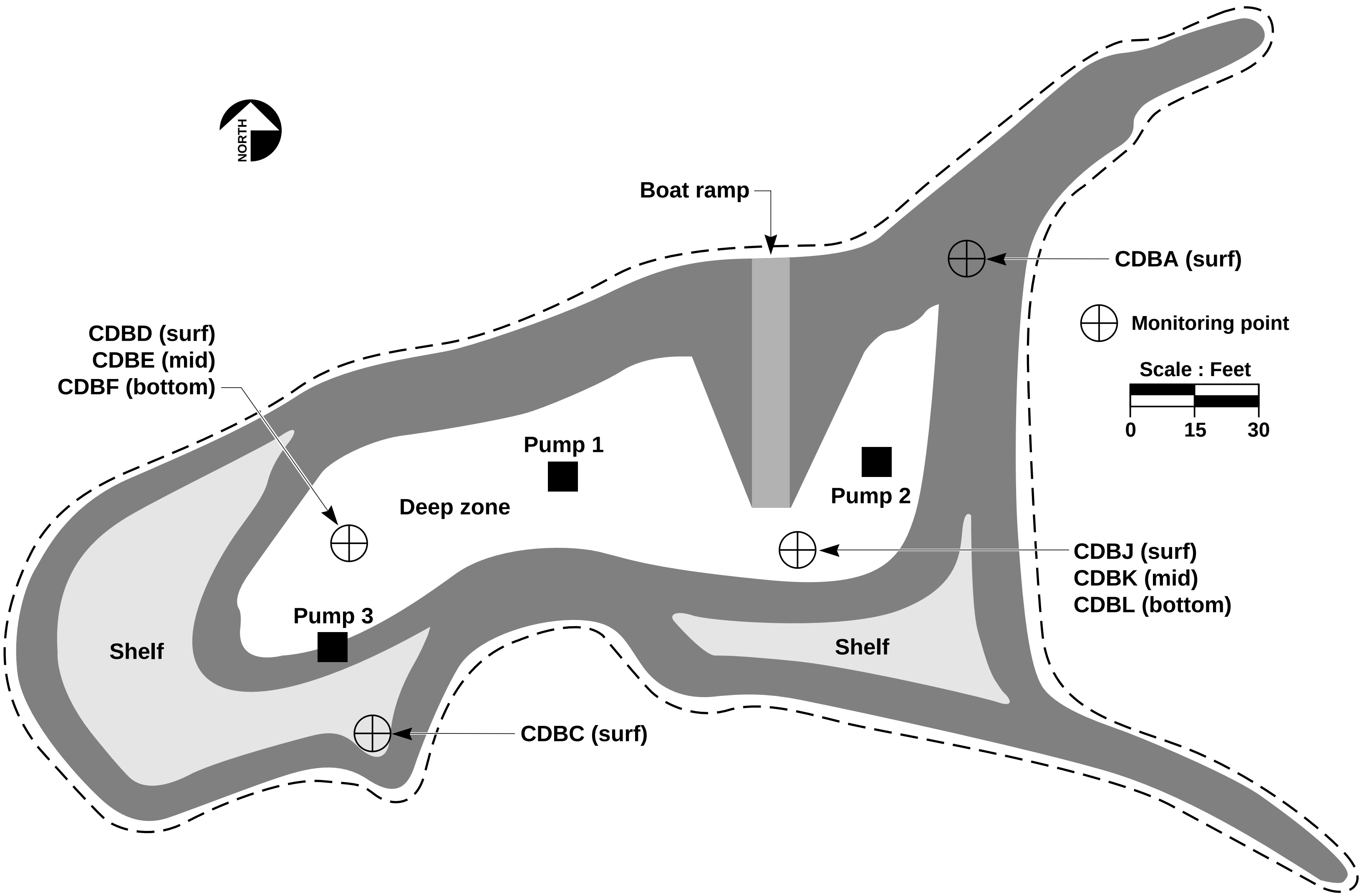


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**Figure D-2. Monitoring locations in the Drainage Retention Basin.**