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LLNL
Ground Water Project

2001 Annual Report

Technical Editors

V. Dibley
M. Dresen*
L. Berg
R. Bainer
E. Folsom

Contributing Authors

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Environmental Protection Department
Environmental Restoration Program and Division

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Table of Contents

Summary Summm-1
1. Introduction 1
2. Regulatory Compliance 1
  2.1. CERCLA Documents 1
  2.2. Milestones and Activities 1
  2.3. Community Relations 2
3. Field Investigations 3
  3.1. Ground Water Sampling 3
  3.2. Source Investigations 4
  3.3. Well Installation and Hydraulic Tests 4
4. Ground Water Flow and Transport Modeling 4
  4.1. HSU 1B/2 Model 4
  4.2. Deeper HSU Models 5
  4.3. Electro-Osmosis Modeling 5
5. Summary of Remedial Action Program 5
  5.1. Treatment Facility A 6
    5.1.1. Performance Summary 7
    5.1.2. Field Activities 8
  5.2. Treatment Facility B 8
    5.2.1. Performance Summary 8
    5.2.2. Field Activities 8
  5.3. Treatment Facility C 9
    5.3.1. Performance Summary 9
    5.3.2. Field Activities 10
  5.4. Treatment Facility D 10
    5.4.1. Performance Summary 11
    5.4.2. Field Activities 11
    5.4.3. Field-Scale Pilot Test 11
  5.5. Treatment Facility E 12
    5.5.1. Performance Summary 13
    5.5.2. Field Activities 13
    5.5.3. Field-Scale Pilot Test(s) 13
  5.6. Treatment Facility G 13

5.6.1. Performance Summary....14
5.6.2. Field Activities....14
5.7. Treatment Facility 406....14
5.7.1. Performance Summary....14
5.7.2. Field Activities....15
5.8. Vapor Treatment Facility 518....15
5.8.1. Performance Summary....15
5.8.2. Field Activities....16
5.9. Ground Water Treatment Facility 518 North....16
5.9.1. Performance Summary....16
5.9.2. Field Activities....16
5.10. Treatment Facility 5475....16
5.10.1. Performance Summary....17
5.10.2. Field Activities....18
5.11. Vapor Treatment Facility 5475....18
5.11.1. Performance Summary....18
5.11.2. Field Activities....18
6. Ground Water Discharges During 2001....18
7. Trends in Ground Water Analytical Results....19
7.1. 2001 VOC Trends....19
7.2. Trends Over the Last Five Years....20
8. References....22

List of Figures

Figure 1. Locations of Livermore Site monitor wells, extraction wells, and treatment facilities, December 2001.

Figure 2. Comparison of 2001 HSU 3B measured (top) and simulated (bottom) aqueous TCE concentrations, LLNL and vicinity.

Figure 3. Comparison of 2001 HSU 5 measured (top) and simulated (bottom) aqueous TCE concentrations, LLNL and vicinity.

Figure 4. Total VOC mass removed from the Livermore Site subsurface over time.

Figure 5. Ground water elevation contour map based on water levels collected from 133 wells completed within HSU 1B showing estimated hydraulic capture areas, LLNL and vicinity, November 2001.

Figure 6. Ground water elevation contour map based on water levels collected from 178 wells completed within HSU 2 showing estimated hydraulic capture areas, LLNL and vicinity, November 2001.

Figure 7. Ground water elevation contour map based on water levels collected from 76 wells completed within HSU 3A showing estimated hydraulic capture areas, LLNL and vicinity, November 2001.

Figure 8. Ground water elevation contour map based on water levels collected from 33 wells completed within HSU 3B showing estimated hydraulic capture areas, LLNL and vicinity, December 2001.

Figure 9. Ground water elevation contour map based on water levels collected from 36 wells completed within HSU 4 showing estimated hydraulic capture areas, LLNL and vicinity, November 2001.

Figure 10. Ground water elevation contour map based on water levels collected from 50 wells completed within HSU 5 showing estimated hydraulic capture areas, LLNL and vicinity, December 2001.

Figure 11. Isoconcentration contour map of total VOCs for 136 wells completed within HSU 1B based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 46 borehole locations.

Figure 12. Isoconcentration contour map of total VOCs for 187 wells completed within HSU 2 based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 104 borehole locations.

Figure 13. Isoconcentration contour map of total VOCs for 96 wells completed within HSU 3A based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 148 borehole locations.

Figure 14. Isoconcentration contour map of total VOCs for 55 wells completed within HSU 3B based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 108 borehole locations.

Figure 15. Isoconcentration contour map of total VOCs for 43 wells completed within HSU 4 based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 64 borehole locations.

Figure 16. Isoconcentration contour map of total VOCs for 55 wells completed within HSU 5 based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 94 borehole locations.

Figure 17. TFA extraction well, pipeline and discharge locations.

Figure 18. TFA East extraction well, pipeline and discharge locations.

Figure 19. TFB extraction well, pipeline and discharge locations.

Figure 20. TFC extraction well, pipeline and discharge locations.

Figure 21. TFC Southeast extraction well, pipeline and discharge locations.

Figure 22. TFD extraction well, pipeline and discharge locations.

Figure 23. TFD West extraction well, pipeline and discharge locations.

Figure 24. TFD East extraction well, pipeline and discharge locations.

Figure 25. TFD Southeast extraction well, pipeline and discharge locations.

Figure 26. TFD South extraction well, pipeline and discharge locations.

Figure 27. TFD Southshore extraction well, pipeline and discharge locations.

Figure 28A. TFD PTU10 wells and pipeline configuration for the electro-osmosis system.

Figure 28B. Electro-osmosis schematic diagram.

Figure 29. TFD PTU10 extraction well, pipeline and discharge locations.

Figure 30. TFD STU10 extraction well, pipeline and discharge locations.

Figure 31. TFE East extraction well, pipeline and discharge locations.

Figure 32. TFE Northwest extraction well, pipeline and discharge locations.

Figure 33. TFE Southwest extraction well, pipeline and discharge locations.

Figure 34. TFE Southeast extraction well, pipeline and discharge locations.

Figure 35. TFE West extraction well, pipeline and discharge locations.

Figure 36. TFG-1 extraction well, pipeline and discharge locations.

Figure 37. TF406 extraction well, pipeline and discharge locations.

Figure 38. TF518 North extraction well, pipeline and discharge locations.

Figure 39. Former TF518 extraction wells, pipelines and discharge location.

Figure 40. TF5475-1 (CRD-1), and TF5475-3 (CRD-2) extraction and injection wells.

Figure 41. TF5475-2 extraction well, pipeline and discharge locations.

List of Tables

Table 1. Livermore Site Wells installed in 2001.

Table 2. Wells in which hydraulic tests were conducted in 2001.

Table 3. 2001 Livermore Site Remediation Action Implementation Plan milestones.

Table 4. Summary of 2001 VOC remediation.

Table 5. Summary of cumulative VOC remediation.

Appendices

Appendix A—Well Construction and Closure Data.. A-1

Appendix B—Hydraulic Test Results..B-1

Appendix C—2002 Ground Water Sampling Schedule C-1

Appendix D—2001 Drainage Retention Basin Annual Monitoring Program Summary D-1

Summary

Significant 2001 Lawrence Livermore National Laboratory (LLNL) Livermore Site Ground Water Project (GWP) restoration activities included:

1. U.S. Department of energy (DOE)/LLNL operated 25 ground water and 2 soil vapor treatment facilities in the Treatment Facility A (TFA), Treatment Facility B (TFB), Treatment Facility C (TFC), Treatment Facility D (TFD), Treatment Facility E (TFE), Treatment Facility G (TFG), Treatment Facility 406 (TF406), Treatment Facility 5475 (TF5475), and Treatment Facility 518 (TF518) areas in 2001. The facilities, extraction wells, estimated flow rates, volumes of extracted ground water and vapor, and VOC mass removed in 2001 are listed by treatment facility area in Table Summ-1.
2. Five new wells were installed and eight hydraulic tests were conducted in 2001. There are now 84 ground water extraction wells (77 operated in 2001), 4 soil vapor extraction wells (2 operated in 2001), and 502 monitor wells at the Livermore Site.
3. During 2001, 77 ground water extraction wells operated at an average flow rate of 764,100 gal per day. Vapor treatment facilities treated an average flow of 23,740 standard cubic ft per day from 2 soil vapor extraction wells. Together, the ground water and vapor treatment facilities removed approximately 215 kilograms (kg) of volatile organic compound (VOC) mass in 2001 compared to 269 kg in 2000.
4. Since remediation began in 1989, approximately 1,729 million gal of ground water and over 33 million cubic feet of vapor have been treated, removing more than 1,238 kg of VOCs. The cumulative volumes of treated ground water and soil vapor and estimated total VOC mass removed by the Livermore Site ground water and vapor treatment facilities since 1989 are summarized in Table Summ-2.
5. Remediation construction activities in 2001 included:
   - The ion-exchange system at TFC was modified to improve TFC efficiency and reduce down-time and associated costs.
   - The TFD Marine pipeline started operation six days ahead of its regulatory milestone. The TFD Southshore treatment facility capacity was increased by installing a larger air stripper and associated piping to accommodate flow from the new TFD Marina pipeline.
   - Two new treatment facilities were activated in the TFE area. Operation of TFE Southeast was delayed until March 19, 2001 with regulatory concurrence due to the Federal Continuing Budget Resolution. TFE West was activated on April 30, 2001, four days ahead of its regulatory milestone.
   - Phase 3 of the TF5475 catalytic reductive dehalogenation (CRD) treatment system was completed nine days ahead of its regulatory milestone. This milestone consisted of connecting extraction well W-1610 and injection well W-1609, both in hydrostratigraphic unit (HSU) 5, to treatment unit CRD-2.

6. Ground water VOC plumes were aggressively remediated as part of the Engineered Plume Collapse strategy in 2001, resulting in significant reductions in VOC concentrations. Remediation highlights in 2001 include:

   - VOC concentrations in the HSU 1B, 2 and 3A plumes along the western margin of the Livermore Site in the TFA, TFB, and TFC areas continued to decline in response to ground water extraction.
   - Offsite HSU 1B wells are now below Maximum Contaminant Levels (MCLs) for all compounds of concern with the exception of two wells, which had maximum 2001 perchloroethylene (PCE) concentrations just slightly above the MCL.
   - All offsite TFA HSU 3A wells are now below MCLs for all VOCs of concern.
   - Hydraulic containment of the western TFE HSU 2 VOC plume was established in April 2001 when TFE West began treating ground water extracted from well W-305.
   - With continued pumping in the TFG area, we anticipate that trichloroethylene (TCE) should fall below its MCL in all HSU 2 wells in 2002.

7. Over the last 5 years, VOC plume sizes have decreased significantly in several areas to include:

   - The area within the 5 part per billion (ppb) HSU 1B offsite PCE plume has been reduced by 50%, and an estimated 66% of the VOC mass has been removed.
   - The TFA area HSU 2 PCE plume has decreased in size by more than 40%, and about 48% of the estimated VOC mass has been removed.
   - In the western TFD and northern TFE areas, the maximum HSU 4 TCE concentrations are now below 500 ppb, and the area within the 100 ppb contour has diminished by about 80%.
   - In the eastern TFE area, the area of the HSU 2 TCE plume within the 100 ppb contours has been reduced by about 50%.
   - In the B-518 and TF406 areas, pumping from HSU 5 has reduced TCE concentrations below 50 ppb, and the area within the 10 ppb TCE contour has been reduced by at least 60%.

8. Three-dimensional (3-D) ground water flow and transport modeling was used in 2001 to 1) help site extraction well W-1701 to capture the leading edge of the offsite PCE plume, and 2) evaluate the role of the Recharge Basin in the overall remediation of HSUs 1B and 2. Four new two-dimensional models were developed for HSUs 3A, 3B, 4, and 5 to prepare a larger 3-D model for the entire site. DOE/LLNL continued to develop a mathematical model that couples ground water and electro-osmotic flow processes to help evaluate field data from the electro-osmosis pilot test conducted in the TFD area.

Table Summ-1. Extraction wells, extraction rates, and estimated VOC mass removed during 2001.

Treatment facilities	Operating extraction wells	Estimated average flow rate	Volume ground water and vapor treated	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-605, W-609, W-614, W-712, W-714, W-903, W-904, W-1001, W-1004, W-1009	205 gpm	107.8 Mgal	10.2
TFA East	W-254			
TFB	W-357, W-610, W-620, W-621, W-704, W-1423	59 gpm	31.2 Mgal	6.9
TFC	W-701, W-1015, W-1104	38 gpm	20.0 Mgal	7.2
TFC Southeast	W-1213			
TFD	W-351, W-906, W-907, W-1206, W-1208	139 gpm	73.0 Mgal	90.1
TFD West	W-1215, W-1216			
TFD East	W-1301, W-1303, W-1306, W-1307			
TFD Southeast	W-314, W-1308			
TFD South	W-1503, W-1504, W-1510			
TFD Southshore	W-1523, W-1601, W-1602, W-1603			
PTU10	W-1551, W-1552, W-1651, W-1654			
STU10	W-1550			
TFE East	W-566, W-1109	63 gpm	33.2 Mgal	25.4
TFE Northwest	W-1211, W-1409			
TFE Southwest	W-1518, W-1520, W-1522			
TFE Southeast	W-359			
TFE West	W-292, W-305			
PTU4	W-1418, W-1422			
TFG-1	W-1111	2.85 gpm	1.5 Mgal	0.3
TF406	W-1310	20.2 gpm	10.6 Mgal	0.9
TF5475-1	W-1302	0.19 gpm	0.1 Mgal	1.1
TF5475-2	W-1415			
TF5475-3	W-1606, W-1608, W-1610			
VTF5475	SVI-ETS-504	16.3 scfm	8,568 kft^3	70.2
TF518-North	W-1410	3.2 gpm	1.7 Mgal	0.7
VTF518	SVB-518-204	0.2 scfm	104 kft^3	2.6
2001 Totals		531* gpm 16.5 scfm	279* Mgal 8,672 kft^3	215.5

Notes:
Mgal = Millions of gallons.
kft^3 = Thousands of cubic feet.
kg = Kilograms.
gpm = Gallons per minute.
scfm = Standard cubic feet per minute.
* = Rounded number.

Table Summ-2. Summary of cumulative VOC remediation.

Treatment facility area	Volume of ground water treated (Mgal)	Volume of soil vapor treated (kft^3)	Estimated total VOC mass removed (kg)
TFA	916.3	–	147
TFB	175.0	–	52.2
TFC	126.8	–	47.3
TFD	324.7	–	432
TFE	115.9	–	121
TFG	15.3	–	3.0
TF406	46.2	–	6.7
TF5475	0.42	–	4.2
VTF5475	–	18,219	268
TF518	8.5	–	3.7
VTF518	–	15,011	153
Total	1,729*	33,230	1,238*

Notes:

kg = Kilograms.

kft^3 = Thousands of cubic feet.

Mgal = Millions of gallons.

* = Rounded number.

1. Introduction

This report summarizes the Lawrence Livermore National Laboratory (LLNL) Livermore Site Ground Water Project (GWP) activities for the year 2001 in six sections: Regulatory Compliance; Field Investigations; Ground Water Flow and Transport Modeling; Summary of Remedial Action Program, including discussions of treatment facility activities; Ground Water Discharges during 2001; and Trends in Ground Water Analytical Results. The 2001 GWP quarterly self-monitoring reports (Bainer and Abbott, 2001; Bainer and Joma, 2001a, 2001b, 2002a) 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 drilled in 2001 are shown in boxes and in larger type. Five wells were installed in 2001 as shown in Table 1. Hydraulic tests were conducted on seven wells in 2001 as shown in Table 2.

Appendices A through D present Well Construction and Closure Data, Hydraulic Test Results, the 2001 Ground Water Sampling Schedule, and the 2001 Drainage Retention Basin (DRB) Annual Monitoring Program Summary, respectively. Ground water volatile organic compound (VOC) analyses, water level elevations, and the Treatment Facility 406 (TF406) area ground water fuel hydrocarbon (FHC) analyses are available on request.

2. Regulatory Compliance

In 2001, 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 environmental restoration and community activities as discussed below.

2.1. CERCLA Documents

As required by the FFA, DOE/LLNL issued the Ground Water Project 2000 Annual Report (Aarons et al., 2001) on schedule on March 31, 2001. DOE/LLNL also issued six final Remedial Project Managers' (RPMs') meeting summaries. Quarterly self-monitoring data were reported in letter reports (Bainer and Abbott, 2001; Bainer and Joma, 2001a, 2001b, 2002a).

2.2. Milestones and Activities

Table 3 presents the 2001 Remedial Action Implementation Plan (RAIP) milestones (Table 5 in Dresen et al., 1993) for the Livermore Site. Three milestones were completed ahead of schedule, and one was delayed with regulatory concurrence since new work was not authorized under the Federal Continuing Budget Resolution at the beginning of Fiscal Year 2001.

Environmental Restoration activities in 2001 also included:

- Continuing to implement Engineered Plume Collapse (EPC) to accelerate mass removal and cleanup at the Livermore Site. EPC incorporates hydrostratigraphic unit analysis, smart pump and treat, source isolation, and treatment of VOCs in fine-grained sediments.
- Initial testing of electro-osmosis (EO) in the Treatment Facility D (TFD) Helipad area for source area cleanup as part of the Phased Source Remediation (PSR) strategy.
- Finalizing a revised Consensus Statement in March 2001.
- Working with city agencies and local neighbors to install and perform an hydraulic test on new offsite well W-1701.
- Working with the Operations and Regulatory Affairs Division to install well W-1705 to monitor for leaks around the onsite gasoline station underground tanks.
- Maintaining the Recharge Basins to improve infiltration.
- Providing the Alameda Flood Control and Water Conservation District Zone 7 ground water level elevations for use in analyzing their water levels in the Mocho 1 Subbasin.
- Moving stored core from past drilling operations to a core storage/archive facility that provides better protection from the elements.
- Improving the longevity of ion-exchange canisters used for chromium treatment by placing them before the air stripper.
- Participating in design reviews for proposed modifications to the DRB.
- Disposing soil stockpiled for potential use for the DRB Retrofit project.

2.3. Community Relations

The Community Work Group (CWG) met once in 2001 to discuss the DOE budget, technology deployments, the Consensus Statement, and progress of the Livermore Site cleanup. Correspondence and communication continued with CWG members throughout the year. DOE/LLNL met twice with members of Tri-Valley Communities Against a Radioactive Environment (CAREs) and their scientific advisor as part of the activities funded by an Environmental Protection Agency Technical Assistance Grant.

Other Livermore Site community relations activities in 2001 included communications and meetings with neighbors, local, regional, and national interest groups, and other community organizations; making public presentations; producing and distributing the Environmental Community Letter; maintaining the Information Repositories and the Administrative Record; conducting tours of the site environmental activities; and responding to public and news media inquiries. In addition, community questions were addressed via electronic mail, and project documents, letters, and public notices were posted on a public website at www-envirinfo.llnl.gov.

3. Field Investigations

3.1. Ground Water Sampling

In 2001, the GWP collected 1,198 water samples during 878 sampling events. These samples were analyzed for VOCs, FHCs, polychlorinated biphenyls (PCBs), metals, radionuclides, or combinations of these analytes depending on the contaminants of concern.

Livermore Site ground water sampling frequency recommendations are updated quarterly using a cost-effective sampling algorithm that evaluates trends in contaminant levels in each well over an 18-month period. The sampling frequency is determined by the treatment facility Subproject 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 annual change [<10 parts per billion (ppb) per year] are sampled annually or biennially (every two years).
- Wells exhibiting moderate annual change (≥10 ppb but <30 ppb per year) are sampled semiannually (twice a year).
- Wells showing large annual change (≥30 ppb) are sampled quarterly.
- Wells with less than 18 months of analytical history are sampled quarterly for the first 18 months. After 18 months, algorithm logic and input from the Subproject Leaders are used to determine the sampling frequency.
- Data consistency is also considered in assigning sampling frequency.

Sampling methods for the 1,198 samples collected from approximately 379 wells during the year vary depending on the well yield and data quality objectives of each well. Substantial cost reduction is achieved through the use of low-volume and specific-depth grab sampling methods and devices. Sampling methods used in 2001 were:

- Three volume pre-sample purge (three casing volumes removed by electric submersible pump prior to sampling): 251 events.
- Low-volume pre-sample purge (less than one casing volume removed by electric submersible pump prior to sampling): 47 events.
- Specific-depth grab sampling (sample collected from a specific point within the screened interval with an EasyPump): 462 events.
- Other (grab samples with bailer, grab samples with electronic submersible pump, etc.): 118 events.

Wells identified as “Guard Wells” in the Compliance Monitoring Plan (Nichols et al., 1996) are sampled quarterly using a three casing volume pre-sample purge method when applicable. All sampling methods are determined by the Hydrogeology Group and Subproject Leaders and based on data quality objectives. The sampling schedule for 2002 is presented in Appendix C.

LLNL utilizes a cost-effective sampling device developed at LLNL (EasyPump) to replace existing higher cost sampling devices when they fail and when considered appropriate by the facility hydrogeologist. In 2001, the EasyPump was used to collect 462 samples or 53% of the sampling events. Use of the EasyPump saved several thousand dollars per well in pump replacement costs, reduced technician sampling time by an average of 70%, and produced no wastewater for treatment and disposal. The need to collect and treat over 50,000 gallons of purge water was eliminated by using the EasyPump in 2001. The Purge Water Management System, developed through collaborative efforts between Savannah River and LLNL, is being used in several locations to reduce production of waste water.

3.2. Source Investigations

Source investigations were not conducted in 2001.

3.3. Well Installation and Hydraulic Tests

Well installation and hydraulic testing conducted in 2001 are listed in Tables 1 and 2 and are discussed by treatment facility area in Section 5.

4. Ground Water Flow and Transport Modeling

Ground water flow and contaminant transport models are used at the Livermore Site to optimize remediation system design and operation, to support ongoing subsurface characterization activities, and to improve our ability to forecast, monitor, and interpret the progress of the ground water remediation program. In 2001, we continued to improve our three-dimensional (3-D) ground water models for the Livermore Site, and began developing new models to extend our evaluation capabilities to include deeper hydrostratigraphic units (HSUs). Continued use of the existing models and development of new models in 2001 are described below.

4.1. HSU 1B/2 Model

In 2001, DOE/LLNL continued to use the 3-D ground water flow and transport model of HSUs 1B and 2 to evaluate perchloroethylene (PCE) and trichloroethylene (TCE) transport throughout the Livermore Site. The model was used to optimize well extraction rates, evaluate potential capture zones of proposed extraction wells, and evaluate plume migration and hydraulic interference patterns under increased pumping conditions. Prior to drilling, the proposed location of extraction well W-1701 was evaluated using the model to help ensure that the well would capture the leading edge of the PCE plume along Arroyo Seco (Fig. 1). The long-term hydraulic test conducted in this well showed that model predictions were representative and that well W-1701 fully captures the PCE plume. The model was also used to evaluate the role of the Recharge Basin (Fig. 1) on the overall remediation of HSUs 1B and 2. This model was revised to include recent well pumping histories, changing boundary conditions, and refined flow and transport parameters to improve simulation results.

4.2. Deeper HSU Models

In 2001, four new two-dimensional (2-D) models were developed for deeper HSUs 3A, 3B, 4, and 5. The primary purpose of the individual 2-D models is to understand the flow and transport characteristics of each HSU separately before incorporating them into a larger 3-D model for the entire site. The 2-D models proved very useful in identifying the boundary conditions of these HSUs in terms of recharge and discharge locations, as well as areas of vertical communication. To accurately simulate the impact of source areas in these HSUs, distributed hydraulic conductivity fields were used. The hydraulic conductivity fields were generated using inverse modeling techniques utilizing ground water elevation data. Figures 2 and 3 compare the model results of TCE simulations to the measured data for 2001 in HSUs 3B and 5, respectively. Preliminary calibration results indicate general correlation between simulated and measured TCE distributions. Due to the hydrogeologic complexity of the deeper HSUs, some differences in TCE distribution are observed, mostly in the source areas, and we are in the process of resolving discrepancies between the simulated and measured data.

Further refinement and improved calibration to minimize the differences will enable production level use of these models to support remediation decisions.

4.3. Electro-Osmosis Modeling

DOE/LLNL continued to develop a mathematical model to simulate flow and transport that couples ground water and electro-osmotic flow processes. The model is intended to aid in evaluating the field data from the electro-osmotic remediation pilot test site in the Helipad area (discussed in Section 5.4.3) to optimize extraction and injection rates. The results of this study are further discussed in McNab et al. (2001).

5. Summary of Remedial Action Program

This section summarizes activities performed during 2001 to support the CERCLA Remedial Action Program at the Livermore Site. These activities include treatment system design, new construction, modifications to existing systems, treatment facility performance, treatability tests, well installation, well abandonment, and hydraulic tests.

In 2001, DOE/LLNL operated ground water treatment facilities in the Treatment Facility A (TFA), Treatment Facility B (TFB), Treatment Facility C (TFC), TFD, Treatment Facility E (TFE), Treatment Facility G (TFG), TF406, Treatment Facility 518 (TF518), and Treatment Facility 5475 (TF5475) areas (Fig. 1). A total of 77 ground water extraction wells supplied water to 25 treatment facilities at a combined average flow rate of about 530 gallons per minute (gpm). In 2001, these facilities treated about 279 million gallons of ground water and removed about 142 kilograms (kg) of VOCs (Table 4) compared to 165 kg in 2000. Since remediation began in 1989, approximately 1,729 million gallons of ground water have been treated, and about 817 kg of VOCs have been removed from the ground water (Fig. 4 and Table 5).

In addition, DOE/LLNL operated two vapor treatment facilities (VTFs), VTF518 and VTF5475. Two vapor extraction wells at two locations operated at a combined average flow rate of 16.5 standard cubic ft per minute (scfm). In 2001, these facilities treated about 8,672 thousand standard cubic ft (scf) of vapor and removed an estimated 73 kg of VOCs (Table 4) compared to about 104 kg in 2000. Since initial operation, the two vapor treatment facilities have treated over 33,000 thousand scf of vapor and removed over 420 kg of VOCs (Fig. 4 and Table 5).

The combined ground water and soil vapor treatment systems have removed over 1,238 kg of VOC mass from the subsurface since remediation began in 1989.

Treatment facility performance is evaluated using several different data sets. Figures 5 through 10 show the estimated hydraulic capture areas in HSUs 1B, 2, 3A, 3B, 4 and 5, respectively, based on 2001 ground water elevation data. Figures 11 through 16 show third quarter total VOC isoconcentrations in the same six HSUs since third quarter data were the most recent and complete data set when this report was prepared. Contaminant concentration trends (Section 7) are also used to evaluate treatment facility performance and hydraulic capture. Figures 17 through 41 show treatment facilities, extraction wells, pipelines, discharge points, and self-monitoring program sampling locations.

Several different types of treatment facilities were operated at the Livermore Site in 2001. These include:

- Treatment Facilities (TFs) located in buildings,
- Vapor Treatment Facilities (VTFs),
- Portable Treatment Units (PTUs),
- Miniature Treatment Units (MTUs),
- Granular activated-carbon (GAC) Treatment Units (GTUs),
- Solar-powered Treatment Units (STUs), and
- Catalytic Reductive Dehalogenation treatment units (CRDs).

The 2001 performance of each Livermore Site treatment facility is discussed below.

5.1. Treatment Facility A

Two treatment facilities, TFA and TFA East (TFA-E), located in the southwestern portion of the Livermore Site (Figs. 1, 17, and 18) operated in 2001 in the TFA area. TFA is located near the intersection of Vasco Road and East Avenue (Figs. 1 and 17). TFA-E is located along West Perimeter Drive in the southwestern corner of LLNL (Figs. 1 and 18).

In 2001, TFA treated ground water from 21 extraction wells, including seven HSU 1B wells (W-262, W-408, W-520, W-601, W-602, W-1001, W-1004), thirteen HSU 2 wells (W-109, W-415, W-457, W-518, W-522, W-603,W-605, W-609, W-614, W-714, W-903, W-904 and W-1009), and one HSU 3A well (W-712) (Fig. 17).

TFA treats ground water using a large-capacity air-stripping system that was installed in 1997. The effluent air from the stripper is passed through GAC filters to remove VOCs, and the treated air is vented to the atmosphere. TFA is permitted by the San Francisco Regional Water Quality Control Board (RWQCB) to treat up to 500 gpm of ground water. From 1989 to 1997, TFA processed VOCs in ground water using an ultraviolet/hydrogen peroxide system. Ground water treated at TFA is discharged to the Recharge Basin, located about 2,000 ft southeast of TFA on DOE property administered by Sandia National Laboratories, California (Figs. 1 and 17). TFA complied with all permits throughout 2001.

From 1989 through September 1994, TFA treated ground water from well W-415. The TFA North and TFA Arroyo Pipelines connected nine additional extraction wells to TFA in September 1994. The TFA South Pipeline connected eight additional extraction wells to TFA in July 1995. The TFA North Pipeline connected one additional extraction well to TFA in June 1998, and two additional extraction wells in July 1998. In January 2001, ground water extraction was halted from seven of the eight TFA South Pipeline wells because all VOCs of concern have been below Maximum Contaminant Levels (MCLs) for at least three consecutive quarters.

Since September 2001, TFA has operated at less than optimal capacity because the Recharge Basin percolation capacity decreased from greater than 300 gpm for a single Recharge Basin cell to about 200 gpm for both cells combined. The decreased percolation capacity may be due to buildup of organic matter and some silt accumulation in the bottom of the Recharge Basin. DOE/LLNL is considering changing the TFA discharge location to Arroyo Las Positas using a six-inch diameter discharge pipeline that would extend northward to TFB. This new discharge location would allow TFA to operate at full capacity, thereby more effectively capturing the TFA source area and cleaning up the offsite plumes, as well as avoiding the limitations and maintenance of the Recharge Basin (Bainer and Joma, 2002b).

TFA-E, which began operating in August 1999, uses a solar-powered pump to extract ground water from one HSU 2 well (W-254) (Fig. 18). The ground water is treated by a series of aqueous-phase GAC canisters and is discharged to Arroyo Seco (Fig. 18). TFA-E complied with all permits throughout 2001.

5.1.1. Performance Summary

During 2001, the two TFA area facilities operated at an average flow rate of 205 gpm and treated 107.8 million gallons of ground water (down from about 141 million gallons in 2000) containing an estimated 10.2 kg of VOCs (Table 4). Since system startup in 1989, TFA has treated about 916 million gallons of ground water and has removed about 147 kg of VOC mass from the subsurface (Table 5).

The TFA area extraction wells hydraulically control the VOC plume in HSU 1B based on the capture zone analysis shown on the ground water elevation contour map (Fig. 5) and the total VOC isoconcentration map (Fig. 11). Pumping continues at offsite HSU 1B extraction well W-408 to ensure hydraulic control of the HSU 1B VOC plume at well W-1425 where the PCE concentration was 6 ppb in January 2001. Despite reduced TFA treatment capacity, pumping from offsite HSU 2 extraction wells W-109 and W-904 was maintained at about 15 to 35 gpm, respectively, to help maintain hydraulic control of the HSU 2 VOC plume at well W-404 (Figs. 6 and 12) where the PCE concentration was 28 ppb in October 2001. Although VOC concentrations are declining in HSU 3A in the TFA area, hydraulic control in this HSU is diminished by the reduced TFA capacity discussed above.

5.1.2. Field Activities

In 2001, monitor well W-1701 was completed in HSU 2 in the TFA West area north of Arroyo Seco, and hydraulic tests were conducted to evaluate hydraulic communication with well W-404. The tests confirmed hydraulic communication with well W-404. Well construction details are provided in Table A-1 of Appendix A, and the results of the hydraulic tests are presented in Appendix B.

5.2. Treatment Facility B

One treatment facility operated in 2001 in the TFB area, located in the west-central portion of the Livermore Site, north of Mesquite Way near Vasco Road (Figs. 1 and 19). In 2001, TFB treated ground water from six extraction wells, consisting of three HSU 1B wells (W-610, W-620, and W-704), and three HSU 2 wells (W-357, W-621, and W-1423) (Fig. 19). Extraction well W-655 was not pumped at all in 2001 since all contaminants of concern remained below MCLs.

TFB treats ground water using a large-capacity air-stripping system installed in 1998. The effluent air from the stripper is passed through GAC filters to remove VOCs, and the treated air is vented to the atmosphere. Chromium, which requires treatment only during the wet season (December 1–March 31) based on the current chromium influent concentration and metals discharge requirements (Berg et al., 1997), is removed by an ion-exchange unit. From 1990 to 1998, TFB processed VOCs in ground water using an ultraviolet/hydrogen peroxide system.

Treated ground water from TFB is discharged into the north-flowing drainage ditch parallel to Vasco Road that empties into Arroyo Las Positas (Figs. 1 and 19). TFB was in compliance with all permits during 2000.

From 1990 through September 1995, TFB treated ground water extracted from wells W-357 and W-704. The TFB North Pipeline, TFB East Pipeline, and TFB West Pipeline connected four additional extraction wells to TFB in September 1995 (Fig. 19). Well W-1423 was connected to the TFB East Pipeline in July 1999.

5.2.1. Performance Summary

During 2001, TFB operated at an average flow rate of 59 gpm and treated over 31 million gallons of ground water containing an estimated 6.9 kg of VOCs (Table 4). Since system startup in 1990, TFB has treated about 175 million gallons of ground water and removed about 52 kg of VOC mass from the subsurface (Table 5).

The TFB area extraction wells hydraulically control the VOC plumes in HSUs 1B and 2 based on the capture zone analysis shown on the ground water elevation contour maps (Figs. 5 and 6), the total VOC isoconcentration maps (Figs. 11 and 12) for each HSU, and stable or declining VOC concentrations.

5.2.2. Field Activities

No new monitor wells or extraction wells were installed and no hydraulic tests were conducted in the TFB area during 2001.

5.3. Treatment Facility C

Two treatment facilities, TFC and TFC Southeast (TFC-SE), operated in 2001 in the TFC area, located in the northwestern portion of the Livermore Site (Figs. 1, 20, and 21). In 2001, TFC treated ground water from three HSU 1B extraction wells (W-701, W-1015, and W-1104). Three other extraction wells (W-1102, W-1103, and W-1116) were not operated in 2001 because of relatively low VOC concentrations, and since they are within the capture zones of the three operating extraction wells (Figs. 5 and 11). TFC-SE (PTU1) is located south of West Gate Drive and treats ground water from one HSU 1B well (W-1213) (Figs. 1 and 21).

TFC and TFC-SE remove VOCs from ground water using air stripping. The effluent air from the stripper is treated with GAC prior to discharge to the atmosphere. Chromium in the ground water is treated using ion-exchange during the wet season (December 1–March 31) based on the current chromium influent concentration and metals discharge requirements (Berg et al., 1997).

As discussed in Section 5.3.1, significant changes were made in 2001 to the TFC water treatment process to increase the efficiency of the ion-exchange resin and to protect the facility equipment from the buildup of calcium carbonate and iron oxide scale.

Treated ground water from TFC is discharged into a north-flowing pipeline that empties into Arroyo Las Positas (Fig. 20). Treated ground water from TFC-SE is discharged into a storm sewer and a north-flowing drainage ditch that also empties into Arroyo Las Positas (Fig. 21). TFC and TFC-SE complied with all permits throughout 2001.

From 1993 through September 1996, TFC treated ground water extracted from well W-701. The TFC North Pipeline connected five additional extraction wells to TFC in September 1996. TFC-SE began operation in January 1997.

5.3.1. Performance Summary

During 2001, the two TFC area facilities operated a combined average flow rate of 38 gpm and treated 20 million gallons of ground water containing an estimated 7.2 kg of VOCs (Table 4). Since system start up in 1993, the combined TFC area facilities have treated over 126 million gallons of ground water and removed over 47 kg of VOC mass from the subsurface (Table 5).

In the central and western TFC area, VOCs are confined to HSU 1B. The TFC area extraction wells hydraulically control the VOC plumes in HSU 1B based on the capture zone analysis shown on the ground water elevation contour map (Fig. 5) and the total VOC isoconcentration map (Fig. 11).

Significant changes were made in 2001 at TFC to increase the efficiency of the ion-exchange resin and to protect the facility equipment. The resin columns were placed before the anti-scalant injection system and the air strippers. In addition, new pressure release valves at the well heads, a new pre-filtration unit and two larger (30 ft^3) ion-exchange resin columns were added to the system. These changes will improve the efficiency of TFC operations and reduce equipment maintenance down-time and the associated costs.

5.3.2. Field Activities

In 2001, monitor well W-1704 was completed in HSU 2 southwest of the West Traffic Circle (Fig. 1). Well construction details for well W-1704 are provided in Table A-1 of Appendix A. Hydraulic tests were conducted on proposed extraction wells W-368 and W-413 in preparation for the upcoming TFC East milestone in 2002. Results of the hydraulic tests are presented in Appendix B.

5.4. Treatment Facility D

Eight treatment facilities operated in 2001 in the TFD area, located in the northeastern portion of the Livermore Site, near the DRB (Fig. 1). These facilities are TFD, TFD West (TFD-W), TFD East (TFD-E), TFD Southeast (TFD-SE), TFD South (TFD-S), TFD Southshore (TFD-SS), PTU10, and STU10. The latter two are discussed further in Section 5.4.3. TFD treated ground water from five extraction wells, consisting of one HSU 2 well (W-906), one HSU 3A well (W-1208), two HSU 4 wells (W-351 and W-1206), and one HSU 5 well (W-907) (Fig. 22). TFD-W, located south of North Inner Loop Road, treats ground water from two HSU 2 extraction wells (W-1215 and W-1216) (Fig. 23). TFD-E, located east of the DRB, treats ground water from four extraction wells, including two HSU 2 wells (W-1303 and W-1306), one HSU 3A well (W-1301), and one HSU 4 well (W-1307) (Fig. 24). TFD-SE, located north of Avenue K and east of South Inner Loop Road, treats ground water from two extraction wells, HSU 2 well W-1308 and HSU 4 well W-314 (Fig. 25). TFD-S, located south of South Inner Loop Road and the DRB, treats ground water from three extraction wells, including HSU 2 well W-1510, HSU 3A/3B well W-1504, and HSU 4 well W-1503 (Fig. 26). TFD-SS is located south of the DRB and treats ground water from three extraction wells, including HSU 2 well W-1602, HSU 3B well W-1601, and HSU 4 well W-1523 (Fig. 27). In 2001, TFD-SS was expanded to include HSU 3A well W-1603, which is connected to the facility by the TFD Marina pipeline. Connection to this pipeline eliminates the need for a TFD Marina facility immediately south of the DRB (Fig. 27).

TFD, TFD-W, TFD-E, TFD-SE, TFD-S, and TFD-SS process ground water for VOC treatment using air stripping. The effluent from the air strippers is treated with GAC prior to venting to the atmosphere. Treated ground water from TFD and TFD-E is discharged into either the DRB or an underground storm drain downstream of the DRB weir, and flows northward to Arroyo Las Positas (Figs. 22 and 24). Treated ground water from TFD-W is discharged into a nearby underground storm drain that also empties into Arroyo Las Positas (Fig. 23). TFD-SE treated ground water is discharged to the DRB in one of two ditches, as shown on Figure 25.

Treated ground water from TFD-S is discharged into a drainage ditch that flows north into the DRB (Fig. 26). Treated ground water from TFD-SS is discharged into an underground storm drain that also flows north into the DRB (Fig. 27). All TFD facilities were in compliance with all permits throughout 2001.

TFD began operation in September 1994, treating ground water from wells W-351, W-906, and W-907. Wells W-1206 and W-1208 were connected to TFD in April 1998. TFD-W (PTU6) was activated in April 1997, TFD-E (PTU8) began operating in September 1997, TFD-SE (PTU11) was activated in March 1998, TFD-S (PTU2) was activated in June 1999, and TFD-SS (MTU-2) began operating in June 2000. In July 2001, the TFD-SS capacity was increased by installing a larger (PTU-sized) air stripper and associated piping to accommodate additional flow from the TFD Marina pipeline. The modified TFD-SS treatment unit is now designated PTU-12.

5.4.1. Performance Summary

During 2001, the TFD area facilities operated at an average flow rate of 139 gpm to treat about 73 million gallons of ground water containing an estimated 90.1 kg of VOCs (Table 4). Since system start up in 1994, the TFD facilities have treated over 324 million gallons of ground water and removed about 432 kg of VOC mass from the subsurface (Table 5). These data include facilities used in field-scale pilot tests (Section 5.4.3).

The TFD area extraction wells hydraulically control VOCs in HSUs 2, 3A, 3B, 4, and 5 based on the capture zone analysis shown on the ground water elevation contour maps (Figs. 6, 7, 8, 9, and 10) and the total VOC isoconcentration maps (Figs. 12, 13, 14, 15, and 16) for each HSU. Distal VOC plumes in HSUs 1B and 2 in the western TFD area should be hydraulically controlled once the planned TFC-E treatment facility is operating (scheduled for 2002). Source contol has been achieved in HSUs 3A and 5, but additional wells are needed to capture the distal VOC plumes in these HSUs.

5.4.2. Field Activities

In 2001, monitor well W-1703 was completed in the Lower Livermore Formation downgradient of TFD (Fig. 1). Construction details for well W-1703 are provided in Table A-1 of Appendix A. Results of a one-hour drawdown test conducted on well W-1703 are presented in Appendix B.

In February and early March 2001, well W-1603 was temporarily connected to TFD-E and pumped at 16 gpm to assist with planning to meet the TFD Marina pipeline milestone.

5.4.3. Field-Scale Pilot Test

Electro-osmosis (EO) was tested from September 2000 to February 2001 to evaluate its ability to help remove VOCs from fine-grained sediments in a source area near the Helipad in the TFD area (Figs. 28A and 28B). EO uses a direct current passed between electrodes to induce water flow from the anode (positive electrode) to the cathode (negative electrode). Contaminated ground water is then extracted from the cathode well(s) and treated. At the Helipad site, a nine-well array was constructed with three cathode wells in the center and three anode wells on each side (Figs. 28A and 28B). Ground water was extracted at the cathode wells and treated at PTU10. Results from this test suggest a measurable increase in contaminant influx to the extraction wells when EO operated (McNab et al., 2001), but additional testing is required to determine if this technology is cost effective.

When not connected to the EO pilot test, PTU10, located northeast of the DRB at the TFD Helipad area, continued to operate by treating ground water from wells W-1551 (HSU 3A/3B), W-1552 (HSU 3A/3B), W-1651 (HSU 3A/3B), and W-1654 (HSU 3A/3B) in 2001 to expedite VOC mass removal and source area cleanup (Fig. 29). In 2001, PTU10 operated at a flow rate of about 1.5 gpm, and treated about 0.80 million gallons of ground water containing an estimated 3.7 kg VOCs. These data are included in the TFD ground water volume and VOC mass totals presented in Tables 4 and 5, and total mass removed in Figure 4.

STU10 continued to treat ground water from well W-1550 (HSU 3A/3B) during 2001. STU10 is located in a parking lot east of the DRB and discharges treated ground water into the DRB via an underground storm drain (Fig. 30). In 2001, STU10 operated at a flow rate of about 1.1 gpm, and treated about 0.56 million gallons of ground water containing an estimated 3.0 kg of VOCs. These data are included in the TFD ground water volume and VOC mass totals presented in Tables 4 and 5, and total mass removed in Figure 4.

5.5. Treatment Facility E

Six treatment facilities, TFE East (TFE-E), TFE Northwest (TFE-NW), TFE Southwest (TFE-SW), TFE Southeast (TFE-SE), TFE West (TFE-W), and PTU4 operated in 2001 in the TFE area, located in the east-central portion of the Livermore Site (Fig. 1). The latter facility is discussed further in Section 5.5.3. TFE-E is located south of the DRB and South Inner Loop Road and treats ground water from two extraction wells, W-1109 (HSU 2) and W-566 (HSU 5) (Fig. 31). TFE-NW is located south of the South Inner Loop Road, immediately west of Southgate Drive (Fig. 32). TFE-NW treats ground water from two extraction wells, W-1409 (HSU 2) and W-1211 (HSU 4). TFE-SW, located south of the DRB and South Inner Loop Road, treats ground water from three extraction wells, HSU 2 well W-1518, HSU 3B well W-1522, and HSU 4 well W-1520 (Fig. 33). TFE-SE is located south of the DRB and South Outer Loop Road and treats ground water from HSU 5 well W-359 (Fig. 34). TFE-W, located south of South Inner Loop Road and east of Southgate Drive, treats ground water from HSU 2 extraction well W-305 and HSU 3B extraction well W-292 (Fig. 35).

TFE-E and TFE-NW use PTUs equipped with air strippers to treat VOCs in ground water. The effluent air is treated with GAC to remove VOCs prior to venting to the atmosphere. Treated ground water from TFE-E is discharged into a drainage ditch that flows north into the DRB (Fig. 31). Treated ground water from TFE-NW is discharged into an underground storm drain that flows north into Arroyo Las Positas (Fig. 32).

TFE-SW, TFE-SE, and TFE-W use MTUs equipped with air strippers to treat VOCs in ground water. The effluent air is treated with GAC to remove VOCs prior to venting to the atmosphere. Treated ground water from TFE-SW is discharged into a drainage ditch that flows north into the DRB (Fig. 33). Treated ground water from TFE-SE is discharged into an underground storm drain that flows west and the north into Arroyo Las Positas (Fig. 34). Treated ground water from TFE-W is discharged into an underground storm drain that flows north into Arroyo Las Positas (Fig. 35).

TFE-E (PTU3) began operation in November 1996, TFE-NW (PTU9) was activated in June 1998, and TFE-SW began operation in June 2000. Two new treatment facilities were added to the TFE area in 2001. Operation of TFE-SE, located south of the DRB and South Outer Loop Road (Fig. 34), was delayed with regulatory concurrence until March 19, 2001, due to the Federal Continuing Budget Resolution. TFE-W, located south of South Inner Loop Road and east of Southgate Drive (Fig. 35), was activated April 30, 2001, four days ahead of the RAIP milestone date.

TFE-E, TFE-NW, TFE-SW, TFE-SE, and TFE-W were in compliance with all permits throughout 2001, except for one sample collected from TFE-SE in October 2001. All previous and prior samplings have been non-detect.

5.5.1. Performance Summary

During 2001, the TFE area facilities operated at an average flow rate of 63 gpm and treated over 33 million gallons of ground water containing an estimated 25.4 kg of VOCs (Table 4). Since system startup in 1996, the combined TFE facilities have treated over 115 million gallons of ground water and removed about 121 kg of VOC mass from the subsurface (Table 5).

The TFE-E, TFE-NW, TFE-SW, TFE-SE, and TFE-W extraction wells hydraulically contain some portions of VOC plumes in HSUs 2 and 3A and most of the VOC plumes in HSUs 3B, 4, and 5 based on the capture zone analysis shown on the ground water elevation contour maps (Figs. 6, 7, 8, 9, and 10) and the total VOC isoconcentration maps (Figs. 12, 13, 14, 15, and 16) for each HSU. Hydraulic control of VOC plumes in HSUs 3B, 4, and 5 in the western and southern portion of the TFE area was established in 2001 with the operation of TFE-SE and TFE-W.

5.5.2. Field Activities

No new wells were installed in the TFE area during 2001. Results of one-hour drawdown tests conducted on monitor wells W-1508, W-1512, and W-1604 are presented in Appendix B.

5.5.3. Field-Scale Pilot Test(s)

During 2001, portable hydraulic testing treatment unit PTU4 continued to treat water from wells W-1418 (HSU 4) and W-1422 (HSU 3B) in the northern part of the TFE area to expedite VOC mass removal and site cleanup (Fig. 1). The facility complied with all permits throughout 2001. Wells W-1418 and W-1422 pumped at a combined flow rate of about 10.3 gpm, and PTU4 treated about 5.39 million gallons of ground water containing an estimated 5.7 kg of VOCs. These data are included in the TFE ground water volume and VOC mass data presented in Tables 4 and 5, and total mass removed data in Figure 4.

5.6. Treatment Facility G

TFG-1 is located in the south-central portion of the Livermore Site, near Avenue B, about 300 ft north of East Avenue (Figs. 1 and 36). TFG-1, activated in April 1996, treats ground water from HSU 2 extraction well W-1111.

Prior to May 1999, TFG-1 treated VOCs in ground water using a PTU equipped with an air stripper, and the effluent air was treated with GAC to remove VOCs prior to venting to the atmosphere. In May 1999, the PTU at TFG-1 was replaced by GAC Treatment Unit 1 (GTU1), which uses three 450-lb GAC canisters in series to process water from well W-1111. Ground water is no longer treated for hexavalent chromium since influent concentrations have consistently been below the 22 ppb discharge limit since March 1997.

Treated ground water from TFG-1 is discharged to an underground storm drain located about 50 ft north of TFG-1 that empties into Arroyo Seco (Fig. 36). TFG-1 was in compliance with all permits in 2001.

5.6.1. Performance Summary

During 2001, TFG-1 operated at an average flow rate of 2.85 gpm, treating approximately 1.5 million gallons of ground water containing an estimated 0.3 kg of VOCs (Table 4). Since system startup in 1996, TFG-1 has treated over 15 million gallons of ground water and removed about 3 kg of VOC mass from the subsurface (Table 5).

TFG-1 extraction well W-1111 hydraulic controls VOCs in HSU 2 in the TFG area based on the capture zone analysis shown on the ground water elevation contour map (Fig. 6) and the total VOC isoconcentration map for HSU 2 (Fig. 12).

5.6.2. Field Activities

No new boreholes or wells were drilled and no hydraulic tests were conducted in the TFG area during 2001.

5.7. Treatment Facility 406

TF406 is located in the south-central portion of the Livermore Site, east of Southgate Drive near East Avenue (Figs. 1 and 37). In 2001, TF406 treated ground water from HSU 5 extraction well W-1310. Pumping was discontinued in September 2000 from HSU 4 extraction wells GSW-445 and W-1309 since concentrations had declined below MCLs for all VOCs of concern, and to reduce the dewatering of HSU 4 in the Southeastern corner of the Site. These wells were not pumped in 2001 since TCE concentrations in both wells remained below MCLs.

TF406 uses PTU5 equipped with an air stripper to treat VOCs in ground water. GAC removes VOCs from effluent air prior to discharge to the atmosphere. All treated ground water is discharged to an underground storm drain that flows north to Arroyo Las Positas (Fig. 37). TF406 was in compliance with all permits throughout 2001.

When activated in August 1996, TF406 processed ground water from extraction wells GSW-445 and W-1114. In 1997, well W-1114 was inadvertently damaged and destroyed by adjacent drilling activities, and new extraction wells W-1309 and W-1310 were installed. TF406 began processing ground water from wells W-1309 and W-1310 in February 1998. As described above, water is no longer pumped from wells GSW-445 and W-1309.

Passive bioremediation continued in the TF406 area during 2001 to remediate FHCs in HSUs 3A and 3B. Active ground water extraction and treatment for residual dissolved FHCs at former Treatment Facility F (TFF) was discontinued in 1996 with regulatory agency concurrence (RWQCB, 1996).

5.7.1. Performance Summary

During 2001, TF406 operated at an average flow rate of 20.2 gpm, treating over 10 million gallons of ground water containing an estimated 0.9 kg of VOCs (Table 4). Since system startup in 1996, TF406 has treated over 46.2 million gallons of ground water and removed about 6.7 kg of VOC mass from the subsurface (Table 5).

The TF406 and TF518-North (see Section 5.9) extraction wells provide significant hydraulic control of VOC plumes in HSUs 3B and 5 in the TF406 area based on the capture zone analysis shown on the ground water elevation contour maps (Figs. 8 and 10) and the total VOC isoconcentration maps (Figs. 14 and 16) for each HSU. The VOC plume in HSU 3A should be hydraulically controlled once treatment facility TF406-Northwest (TF406-NW) is installed in 2002.

5.7.2. Field Activities

A multiple-screen monitor well, W-1705, was installed in the future TF406-NW area in 2001 (Fig. 1). Well W-1705 is equipped with a Water FLUTe, an instrumented membrane system (IMS) that allows collection of depth-specific water level and ground water chemistry data from multiple HSUs at one location. Well W-1705 is screened in HSUs 2, 3A, 3B, and 5, and well construction details are provided in Table A-1 of Appendix A. Data from this well will be used to design TF406-NW. No hydraulic tests were performed in the TF406 area in 2001.

5.8. Vapor Treatment Facility 518

Vapor treatment facility VTF518 is located north of East Avenue in the southeast portion of the Livermore Site (Fig. 1). Soil vapor extracted from the vadose zone is passed through a series of GAC canisters to remove VOCs, and the effluent air is discharged to the atmosphere. VTF518 was in compliance with its Bay Area Air Quality Management District permit throughout 2001.

VTF518 began operation in September 1995 by treating soil vapor from extraction well SVB-518-201 (Fig. 1). In 1997, extraction well SVB-518-303 was added to the system. Since 1998, the flow rate from primary extraction well SVB-518-201 has dropped from about 29 scfm to less than 2 scfm. The majority of vapor flow during this period was from secondary extraction well SVB-518-303 (Fig. 1). VTF518 was shut down in August 1999 due to lack of flow from primary extraction well SVB-518-201. Field investigations indicated that the reduced vapor flow was most likely due to a significant increase in moisture in shallow sediments, which severely restricted air flow from the vadose zone. It is suspected that above average rainfall since 1995 resulted in the re-appearance of a perched water-bearing zone that had been observed in the 1980s.

Soil vapor extraction (SVE) was restarted at about 0.6 scfm in July 2000 using existing well SVB-518-204. The vacuum produced by VTF518 caused an upwelling of the perched water which contained up to 80 parts per million (ppm) VOCs. The perched water was extracted from vapor extraction wells SVB-518-204 and SVB-518-303 on a periodic basis during 2001 to expedite mass removal, and to attempt to remove the excess moisture. This water was collected in a tank and transported to TFD for treatment.

5.8.1. Performance Summary

From January through May 2001, VTF518 operated at an average flow rate of 0.2 scfm, treating about 104 thousand cubic ft (kft^3) of vapor containing an estimated 2.6 kg of VOCs (Table 4). In addition, approximately 375 gallons of water containing about 0.02 kg of VOCs was extracted from the two vapor extraction wells at VTF518 in 2001. Since system start up in 1995, VTF518 has treated approximately 15,000 kft^3 of vapor and removed about 153 kg of VOC mass from the subsurface (Table 5).

5.8.2. Field Activities

In November 2001, a new IMS was installed in borehole B-1616, now referred to as IMS-518-1616. The IMS is used to monitor soil moisture and vapor pressures and collect soil vapor samples at various depths. Since 1995, two other IMS sampling/monitor wells, SEA-518-301 and SEA-518-304, have been used for similar vadose zone monitoring. Data collected in November and December from IMS-518-1616 indicate that recharge from rainfall occurs much more rapidly than expected. Moisture responses were seen within an hour at a depth of 8 ft, and up to depths of 40 ft within a few hours of rainfall events. Potential explanations for this rapid infiltration are currently being evaluated.

5.9. Ground Water Treatment Facility 518 North

One ground water treatment facility, TF518 North (TF518-N), operated in the TF518 area in 2001. TF518-N is located south of the South Outer Loop Road, north of Building 411 (Figs. 1 and 38). TF518-N treats ground water from HSU 4 extraction well W-1410. Another treatment facility, TF518 (Fig. 39) extracted ground water from wells W-211 and W-112, but was removed in June 2000 after HSU 5 became de-watered in the southeastern portion of the Livermore Site. HSU 5 remained de-watered throughout 2001.

TF518-N employs a series of aqueous-phase GAC canisters to treat VOCs in ground water. Treated ground water from TF518-N is discharged into an underground storm drain that flows north and ultimately empties into Arroyo Las Positas (Fig. 38).

5.9.1. Performance Summary

During 2001, TF518-N operated at an average flow rate of 3.2 gpm, treating 3.2 million gallons of ground water containing an estimated 0.7 kg of VOCs (Table 4). Since system startup in January 2000, TF518-N has processed approximately 8.5 million gallons of ground water containing an estimated 3.7 kg of VOCs (Table 5).

The extraction wells provide hydraulic control of VOC plumes in HSUs 4 and 5 based on the capture zone analysis shown on the ground water elevation contour maps (Figs. 9 and 10) and the total VOC isoconcentration maps (Figs. 15 and 16). The sustained de-watering in HSU 5 impacts hydraulic control by widening the capture areas.

5.9.2. Field Activities

No new boreholes or wells were drilled and no hydraulic tests were conducted in the TF518 area during 2001.

5.10. Treatment Facility 5475

Three ground water treatment facilities operated in 2001 in the Trailer 5475 (T5475) area, located in the east-central portion of the Livermore Site (Fig. 1). TF5475-1, activated in September 1998, treats ground water by *in situ* CRD from HSU 3A extraction well W-1302 (Fig. 40). TF5475-2 (STU5), activated in March 1999, is located west of T5475 and treats ground water from HSU 2 well W-1415 (Fig. 41). TF5475-3, activated in September 2000, is located west of T5475 and treats ground water from two HSU 3A extraction wells, W-1606 and W-1608 (Fig. 40). Phase 3 of CRD treatment at T5475, completed nine days ahead of the September 28, 2001 RAIP milestone date, added HSU 5 well W-1610 (Fig. 40) to TF5475-3.

TF5475-1 uses a down-hole CRD unit (CRD-1) to treat VOCs in ground water. This technology treats VOCs in ground water while keeping the ground water containing tritium in the T5475 area in the subsurface. CRD technology is based on the reaction of dissolved hydrogen on a palladium catalyst. When in contact with VOC-bearing ground water, the VOCs are reduced to ethane, methane, or ethene, and free chloride ions. Because of the relatively rapid CRD reaction rates, treatment takes place during one pass through the unit. CRD-1 operates in extraction well W-1302, a dual-screened well where ground water containing VOCs and tritium is extracted from the lower screened interval for VOC treatment, and is reinjected into the same HSU via the upper screened interval after treatment. CRD-1's destruction efficiency ranged from 95.0 to 98.1% in 2001.

TF5475-2 employs STU5 that uses a direct current (DC)-powered pump to extract ground water through a series of aqueous-phase GAC canisters for treatment. Since tritium is not a contaminant of concern at TF5475-2, treated ground water from TF5475-2 is discharged into an underground storm drain that flows north into Arroyo Las Positas via the DRB (Fig. 41). TF5475-2 complied with all permit requirements throughout 2001.

TF5475-3, uses CRD-2 to treat VOCs in ground water. It is similar in design to CRD-1 except that it is an above-ground treatment unit rather than deployed in a well. TF5475-3 was designed as a closed loop system to prevent tritium in HSU 3A from being released above ground. Following activation in 2000, ground water was extracted from wells W-1606 and W-1608, processed in CRD-2, and then returned to the subsurface using reinjection wells W-1605 and W-1607. TF5475-3 was shut down in May of 2001 to prepare for Phase 3 of TF5475 CRD.

Phase 3 of CRD treatment at facility TF5475-3 uses the CRD-2 treatment unit to treat ground water pumped from HSU 5 extraction well W-1610 in a closed loop system. The treated water is then re-injected into HSU 5 well W-1609. The CRD-2 destruction ranged from 93.4 to 99.3% in 2001. HSU 3 extraction well W-1606 is currently inactive because it cannot sustain flow due to de-watering of HSU 3A in the T5475 area. TF5475-3 resumed operation on September 19, 2001.

During 2001, ground water tritium activities in all T5475 area wells remained below the MCL and continued to decrease by natural decay. VOC concentrations in T5475 area wells were stable or decreasing in 2001.

5.10.1. Performance Summary

During 2001, the TF5475 area facilities operated at an average flow rate of 0.19 gpm to treat about 0.1 million gallons of ground water containing an estimated 1.1 kg of VOCs (Table 4). Since system start up in 1998, the combined TF5475 facilities have treated about 0.42 million gallons of ground water and removed about 4.2 kg of VOC mass from the subsurface (Table 5).

5.10.2. Field Activities

No new boreholes or wells were drilled and no hydraulic tests were conducted in the T5475 area during 2001.

5.11. Vapor Treatment Facility 5475

VTF5475 is located north of TF5475-3 in the east-central portion of the Livermore Site, and treats soil vapor from vadose zone well SVI-ETS-504 (Fig. 1). VTF5475 began operation in January 1999.

Soil vapor is extracted from the vadose zone and treated at VTF5475 using GAC. Due to elevated tritium concentrations in the vadose zone, VTF5475 is a closed loop system to prevent above ground tritium releases. The vapor stream is heated to reduce the humidity of the tritiated vapor prior to entering the GAC. This minimizes the sorbtion of tritium containing water on the GAC. Following removal of VOCs from the air-stream, tritiated vapor is re-injected into the subsurface at soil vapor inlet well SVI-ETS-505 (Fig. 1). Tritium absorbed by the GAC during VOC treatment is handled as mixed waste. Because no effluent vapor from VTF5475 is released to the atmosphere, the Bay Area Air Quality Management District has granted the facility an exemption from air discharge requirements.

5.11.1. Performance Summary

During 2001, VTF5475 operated at an average flow rate of 16.3 scfm and treated over 8,500 kft^3 of vapor containing an estimated 70.2 kg of VOCs (Table 4). Since system start up in 1999, VTF5475 treated about 18,210 kft^3 of vapor containing an estimated 268 kg of VOCs (Table 5).

5.11.2. Field Activities

Two IMS sampling/monitor wells, SEA-ETS-506 and SEA-ETS-507, continued to monitor vadose zone remediation in the VTF5475 area. The IMS system is used to collect vapor pressure, soil temperature, soil moisture, and soil vapor concentration data from various discrete depths.

6. Ground Water Discharges During 2001

Treated ground water is discharged to the following surface features:

- The Recharge Basin south of East Avenue,
- Arroyo Las Positas, and
- Arroyo Seco.

In 2001, approximately 107 Mgal of treated ground water from TFA was discharged to the Recharge Basin at an average flow rate of 205 gpm. About 170 Mgal of treated ground water was discharged to Arroyo Las Positas from various treatment facilities. An estimated 2 Mgal of treated ground water from TFA-E and TFG-1 was discharged into Arroyo Seco. Treated ground water discharged to Arroyo Seco infiltrated into the ground on LLNL property. Ground water from the EO test at TFD, TF5475-1, and TF5475-3 was returned to the subsurface via wells into the same HSU from which it was extracted.

7. Trends in Ground Water Analytical Results

7.1. 2001 VOC Trends

In 2001, the decrease in size and concentration observed in the Livermore Site VOC plumes is consistent with the 142 kg of VOC removed by the ground water extraction wells during 2001 (Table 4). Most of the observed trends in VOC concentrations are attributed to active ground water extraction and remediation. Notable results of VOC analyses of ground water received from January 2001 through December 2001 are discussed below. Well locations are shown on Figure 1.

Concentrations on the western margin of the site either declined or remained unchanged during 2001, indicating continued effective hydraulic control of the western site boundary plumes in the TFA, TFB, and TFC areas. The size of the offsite TFA HSU 1B and 2 VOC plumes remained largely unchanged in 2001, although the concentrations have declined. However, all offsite TFA HSU 3A wells are now below MCLs for all VOCs of concern. In the TFB area, significant concentration reductions were observed in both HSUs 1B and 2. Total VOC concentrations declined below 50 ppb in all monitor wells in the TFB area in 2001. TCE concentrations in HSU 1B well W-269 declined from 20 ppb in 2000 to 10 ppb in 2001, and TCE concentrations in HSU 2 well W-308 declined from 26 in 2000 to 2 ppb. In the TFC area, HSU 1B concentrations remained essentially unchanged.

In the central and eastern parts of the TFD area, HSU 2 VOC concentrations continued to decline in response to pumping the TFD extraction wells. TCE concentrations in HSU 2 extraction well W-906 decreased from 750 ppb in 1995 to 37 ppb in October 2001, and TCE in nearby monitor well W-355 decreased from 3,100 ppb in April 1992 to 37 ppb in November 2001. In the northern TFD area, Freon 11 concentrations have declined below the 150 ppb MCL in all HSU 2 monitor wells except well W-423, where the Freon 11 concentration in July 2001 was 420 ppb.

VOC concentrations in HSU 3A TFD area wells also continued to decline in 2001. TCE in extraction well W-1550 decreased from 4,000 ppb in October 1999 to 870 ppb in November 2001. TCE in extraction well W-1552 declined from 9,900 ppb in September 1999 to 1,500 ppb in October 2001.

In the southern TFD and northern TFE areas, VOC concentrations in HSU 4 continue to show significant decreases due to pumping at HSU 4 extraction wells W-1418 and W-1503. TCE in well W-1418 declined from 750 ppb in 1998 to 85 ppb in November 2001. TCE in well W-1503 declined from 2,100 ppb in 1999 to 290 ppb in October 2001.

Westward migration of the HSU 2 VOC plume was observed along the western margin of the TFE area in 2001. TCE in piezometer SIP-331-001 increased from below 0.5 ppb in July 1999 to 20 ppb in March 2001. Hydraulic containment of the western TFE HSU 2 VOC plume was established in April 2001 when TFE-W was activated and ground water extraction began at

HSU 2 extraction well W-305. We anticipate that concentrations should begin to stabilize then decline over the next several years in response to pumping well W-305.

In the TFE-E area, HSU 2 VOC concentrations continued to decline in response to ground water extraction. TCE in HSU 2 extraction well W-1109 decreased from 1,744 ppb in January 1998 to 250 ppb in October 2001. In nearby HSU 2 monitor well W-257, TCE concentrations decreased from a maximum of 6,400 ppb in 1988 to 130 ppb in July 2001.

In the TF5475 area, significant VOC concentration decreases continued in 2001. TCE in piezometer SIP-ETS-204 declined from a maximum of 21,000 ppb in November 1997 to 110 ppb in May 2001. TCE in monitor well W-1225 declined from 2,900 ppb in March 1997 to 70 ppb in September 2001. However, TCE in monitor well W-1117 increased from 43 ppb in November 1995 to 1,600 ppb in November 2001.

In the TF518 and TF406 areas, the offsite HSU 5 VOC concentrations continued to decrease in response to pumping of the TF406 extraction wells. TF518 was dismantled and removed after HSU-5 became de-watered in the southeastern portion of the Livermore Site. TCE in offsite monitor well W-219 declined from 100 ppb in October 1997 to 1.4 ppb in October 2001. TCE in another offsite monitor well, W-225, declined from over 2,100 ppb in 1987 to 2.5 ppb in October 2001.

In the TFG area, VOC concentrations in HSU 2 wells continued to decline in response to pumping HSU 2 extraction well W-1111. TCE is the only VOC of concern that is not below its MCL in all HSU 2 wells. TCE in well W-1111 declined from 54 ppb in March 1996 to 5.1 ppb in November 2001. TCE in nearby monitor well W-464 declined from 110 ppb in March 1992 to 1.2 ppb in November 2001. With continued ground water extraction at well W-1111, we anticipate that TCE should fall below the 5 ppb MCL in all HSU 2 wells during 2002.

During 2001, tritium ground water activities in all wells remained below the MCL and continued to decrease in activity in the T5475 area.

7.2. Trends Over the Last Five Years

As part of the upcoming second Livermore Site Five-Year Review, chemical trends were reviewed over the 1996 to 2001 time period. During this time, the size and VOC concentrations in contaminant plumes at the Livermore Site decreased significantly in areas where ground water extraction and treatment have been implemented, as described below. Where ground water extraction is not occurring (e.g., in the northern TFD area), contaminant plumes have migrated, increased in size, or are unchanged.

The chemical trends discussed below are based on comparison of VOC isoconcentration maps from the third quarter of 1996 and the third quarter of 2001.

Along the western margin of the Livermore Site, comprehensive hydraulic containment of all contaminant plumes that were migrating offsite has been achieved. Due to ground water extraction at TFA, TFB, and TFC, no HSU 1B, 2, or 3A contaminant plumes have increased in size or have migrated further west over the past five years in these areas. Some of the highlights of cleanup on the western side of the site include:

- Offsite HSU 3A wells are now below MCLs for all compounds of concern. Offsite HSU 1B wells are now below MCLs for all compounds of concern with the exception of two wells, W-571 and W-1425 (Fig. 1), which have maximum 2001 PCE concentrations of 6.2 and 6 ppb, respectively, compared to the 5 ppb MCL.
- Over the last five years, the area inside the 5 ppb HSU 1B offsite PCE plume has been reduced by 50%, from 20 acres to 10 acres, due to active pumping at TFA HSU 1B extraction wells. We estimate that 66% of the mass of the plume has been removed during this time period. Over the same time interval, the offsite TFA HSU 2 PCE plume decreased in size from 45 acres to 26 acres, and about 48% of the estimated plume mass has been removed by pumping the TFA HSU 2 extraction wells.
- In the TFA South area, all ground water extraction wells are now below MCLs for all compounds of concern and have been shut off since no additional ground water treatment is required in this area.
- The westernmost offsite HSU 2 plume, located near well W-404 (Fig. 6), has not migrated or has declined in concentration in response to TFA pumping, and appears to remain outside the capture areas of existing extraction wells. We will continue to monitor VOC migration in HSU 2 in the upcoming year.
- VOC concentrations in the TFA source area have declined significantly over the last five years, with concentrations at source area monitor well W-1107 declining from 2,700 ppb to 19 ppb PCE. In the high concentration distal plume immediately downgradient of the source area where TFA-E is located, PCE concentrations in well W-254 have decreased from 470 ppb in 1996 to 110 ppb in 2001 (Fig. 11).

To the east where the EPC strategy has been implemented over the last five years, significant declines in the concentration and areal extent of plumes are observed. Some of the cleanup highlights are:

- In the TFD area where EPC has been implemented the longest, the area within the 100 ppb TCE contour in HSU 2 has decreased by over half in the last 5 years, with maximum concentrations now below 500 ppb. TCE in monitor wells W-355 and W-1207 have declined from 230 and 91 ppb in 1996 to 37 and 5 ppb, respectively, in 2001.
- In the western TFD and northern TFE areas, the maximum TCE concentrations in HSU 4 are now below 500 ppb. The area within the 100 ppb TCE contour has been diminished by about 80% while the plume has contracted eastward toward the source areas.
- In the northern TFD area, a rapidly moving Freon 11 HSU 2 plume is being captured and treated by extraction wells at TFD-W. A Freon 11 HSU 3A plume in the same area, where active local remediation has not yet begun, has moved westward toward TFC and is increasing in concentration. The HSU 3A Freon 11 plume is being further evaluated to determine an appropriated course of action.
- A large, relatively low concentration HSU 2 TCE plume centered around the West Traffic Circle has remained largely unchanged over the last five years (Fig. 12). The areal extent and concentrations within this plume should begin to diminish with the activation of TFC-E in 2002.

- In the eastern TFE area, the area of the HSU 2 TCE plume area within the 100 ppb contour has been reduced by half. However in the western TFE area, where remediation has just been implemented at TFE-W, the HSU plume has moved westward. Over the next few years, this plume should be hydraulically contained and begin to diminish in size due to pumping at TFE-W and by pumping at a planned facility in the northern TFG area.
- In the TFG-1 area, concentrations are now below MCLs for all compounds of concern in HSU 2 wells except for extraction well W-1111, which is now at the 5 ppb TCE MCL. We anticipate that cleanup will be completed within the southern TFG area within the next 1–2 years.
- In the TF518 and TF406 areas, ground water extraction in HSU 5 has resulted in the elimination of the 100 and 50 ppb TCE contours for all areas south of East Avenue. The area within the 10 ppb TCE contour in the same area has decreased by at least 60% as the plume contracts northward toward the source areas.
- Ground water cleanup of HSU 4 in the southern part of the TF406 area now appears to be complete. All HSU 4 wells in the area are below MCLs for all compounds of concern and the extraction wells have been shut off. The wells will be restarted if concentrations increase above an MCL over the next two years.

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Figures

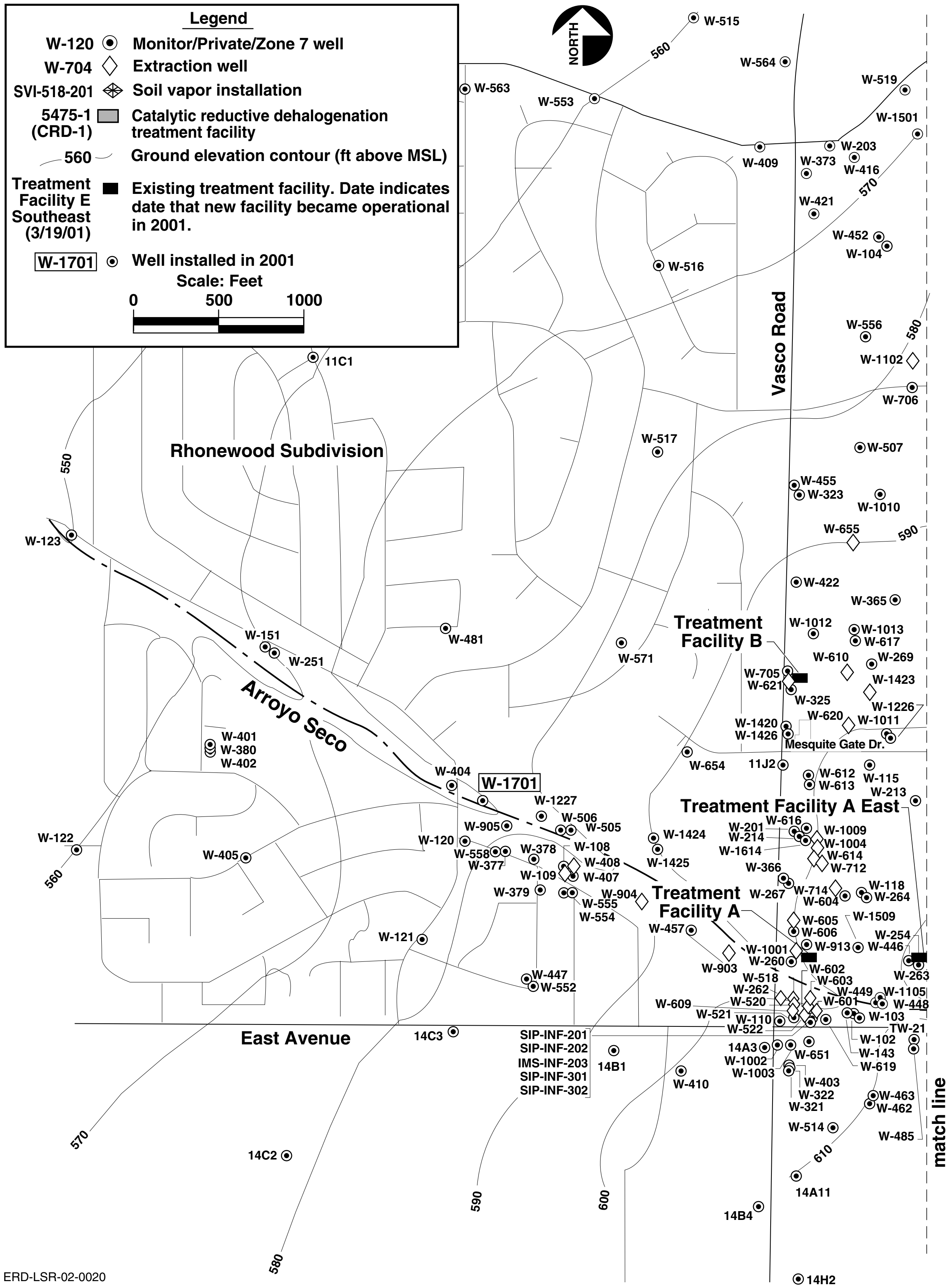

Figure 1. Locations of Livermore Site monitor wells, extraction wells, and treatment facilities, December 2001.

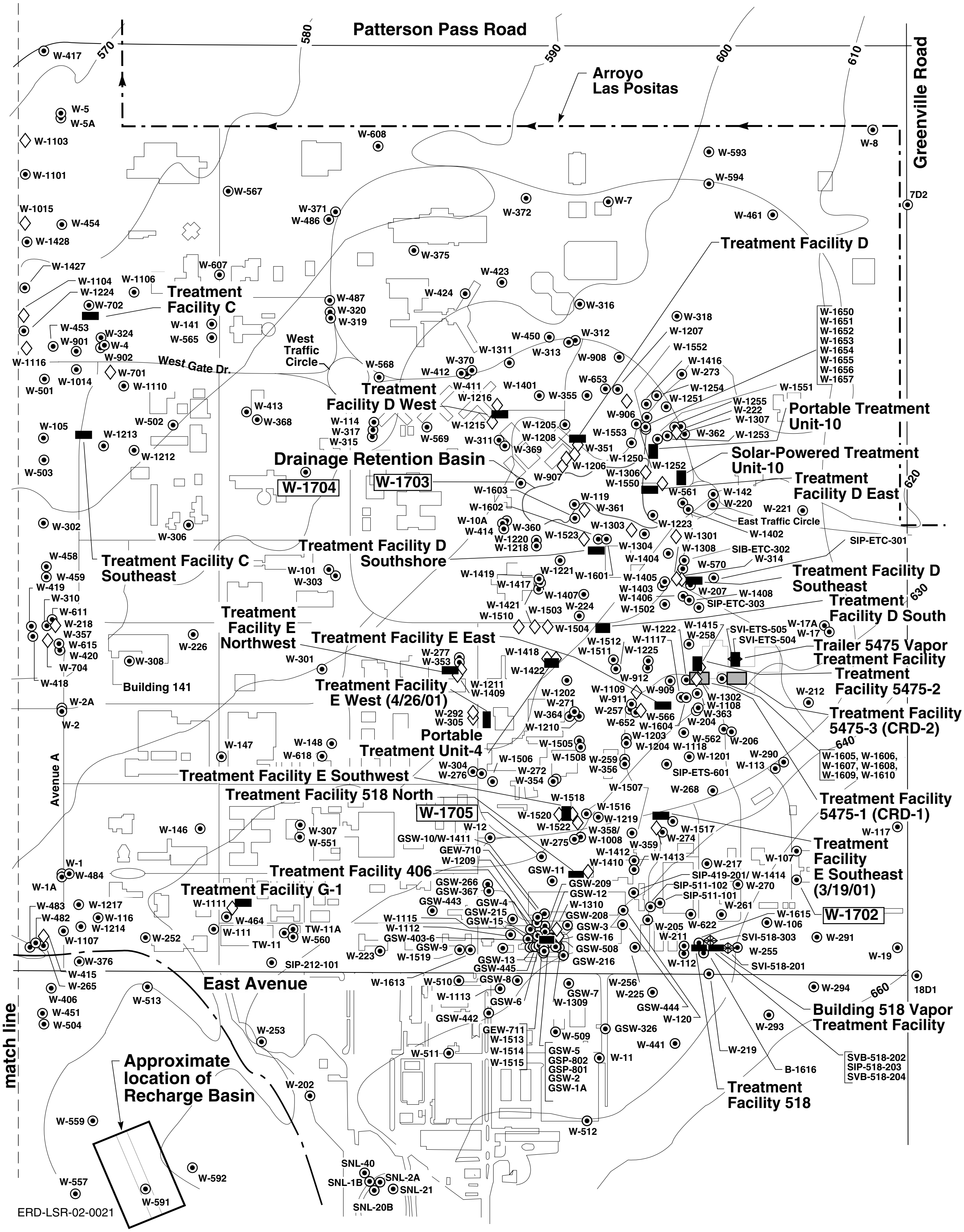

Figure 1 (continued).

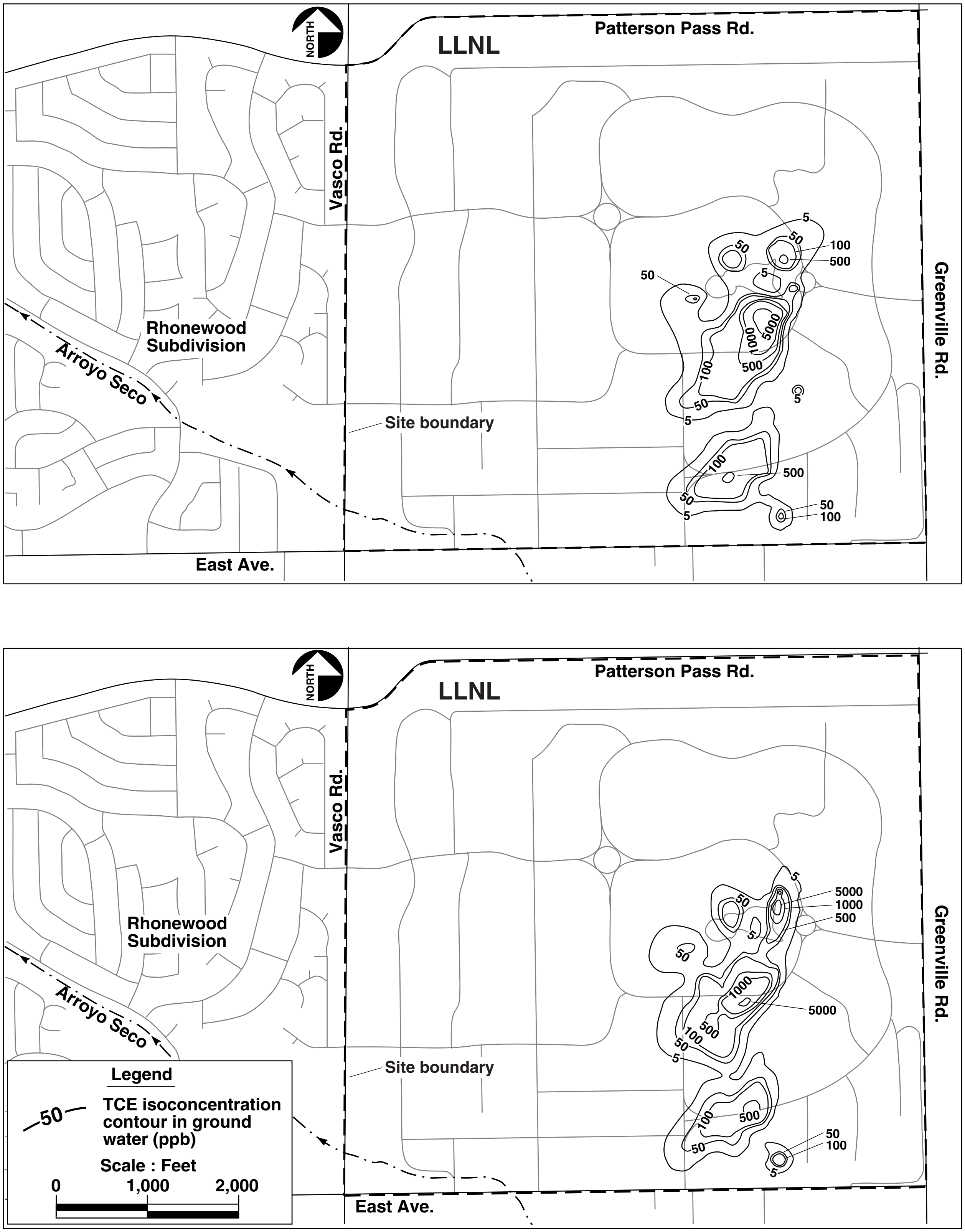

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Figure 2. Comparison of 2001 HSU 3B measured (top) and simulated (bottom) aqueous TCE concentrations, LLNL and vicinity.

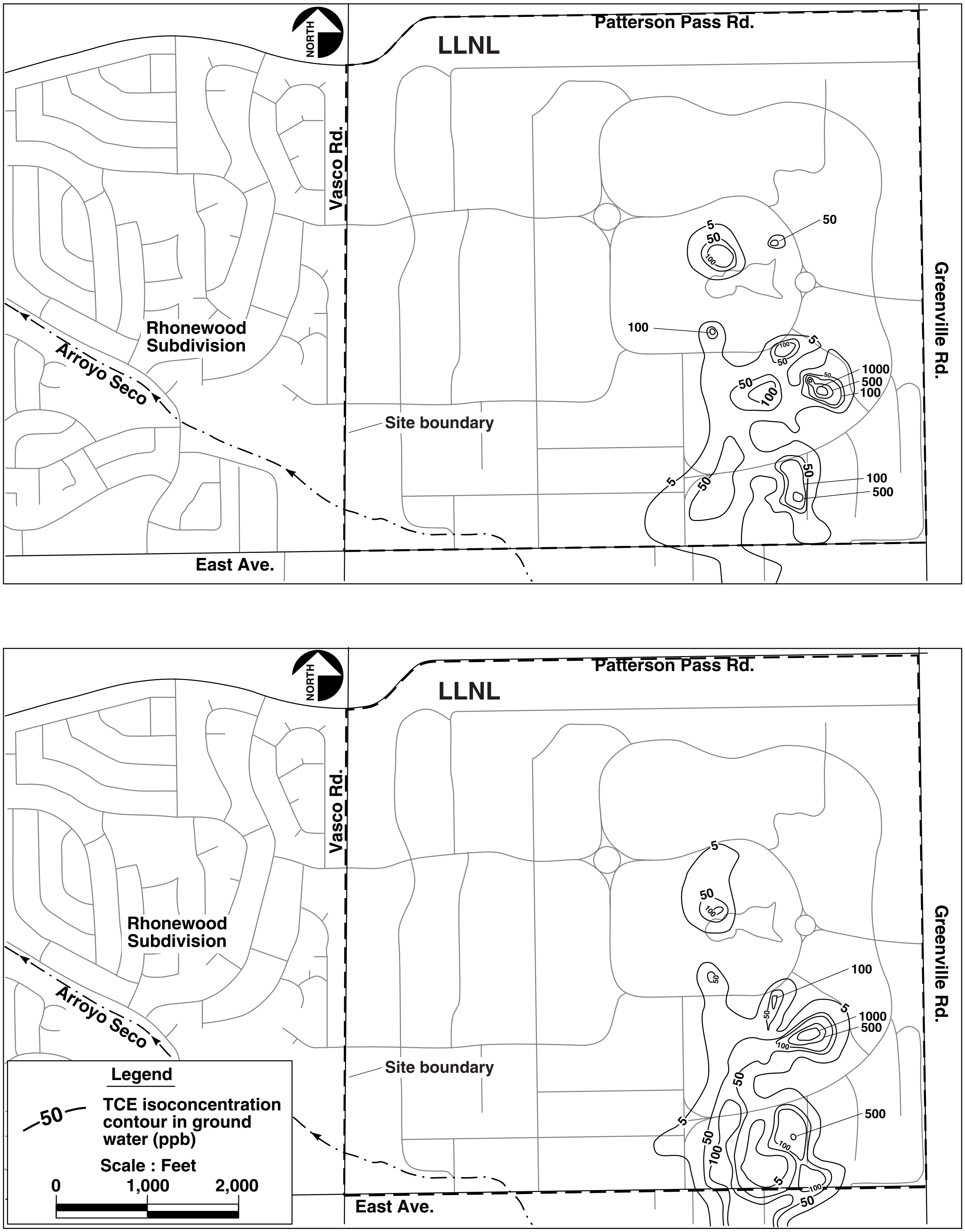

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Figure 3. Comparison of 2001 HSU 5 measured (top) and simulated (bottom) aqueous TCE concentrations, LLNL and vicinity.

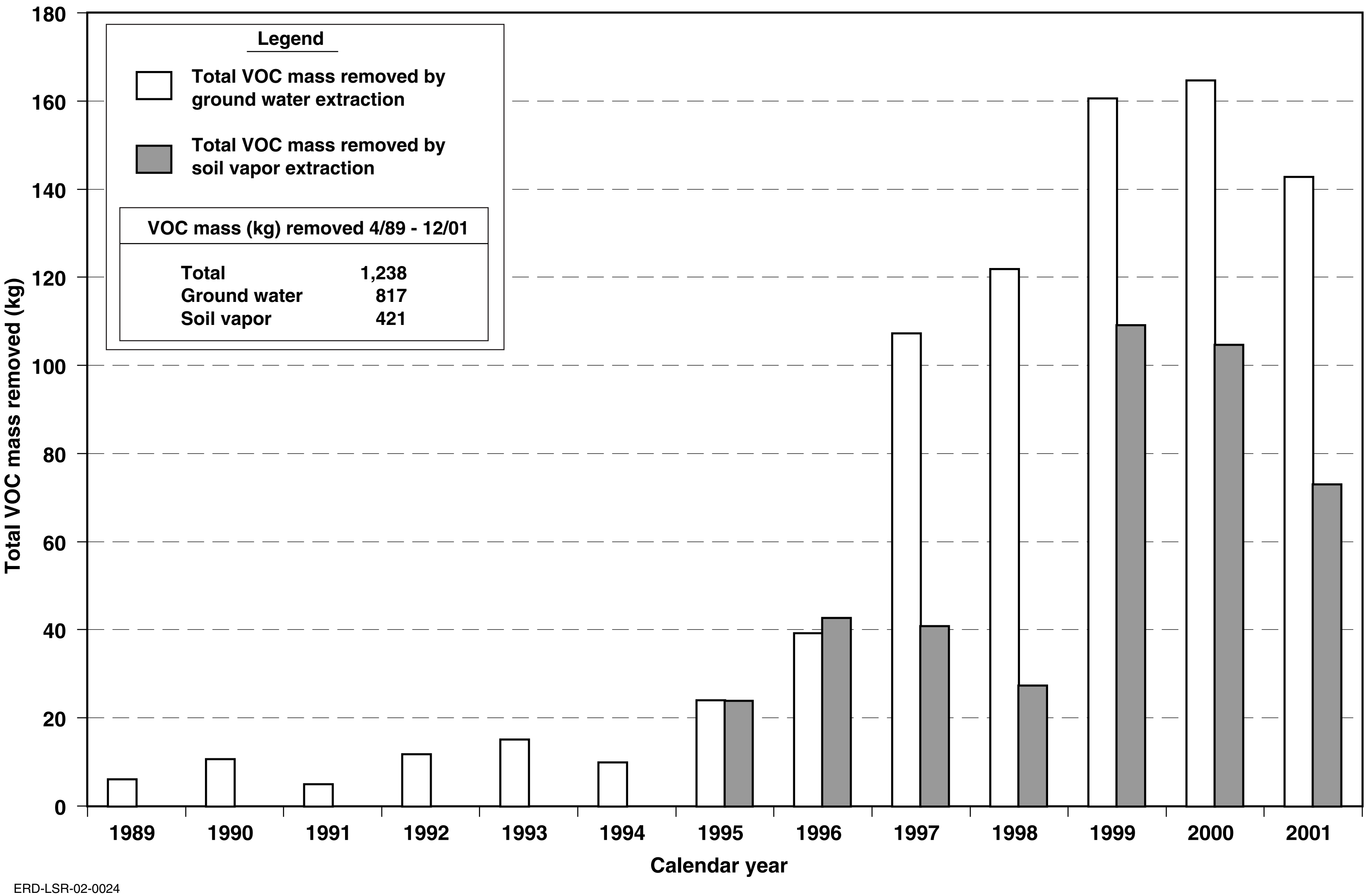

Figure 4. Total VOC mass removed from the Livermore Site subsurface over time.

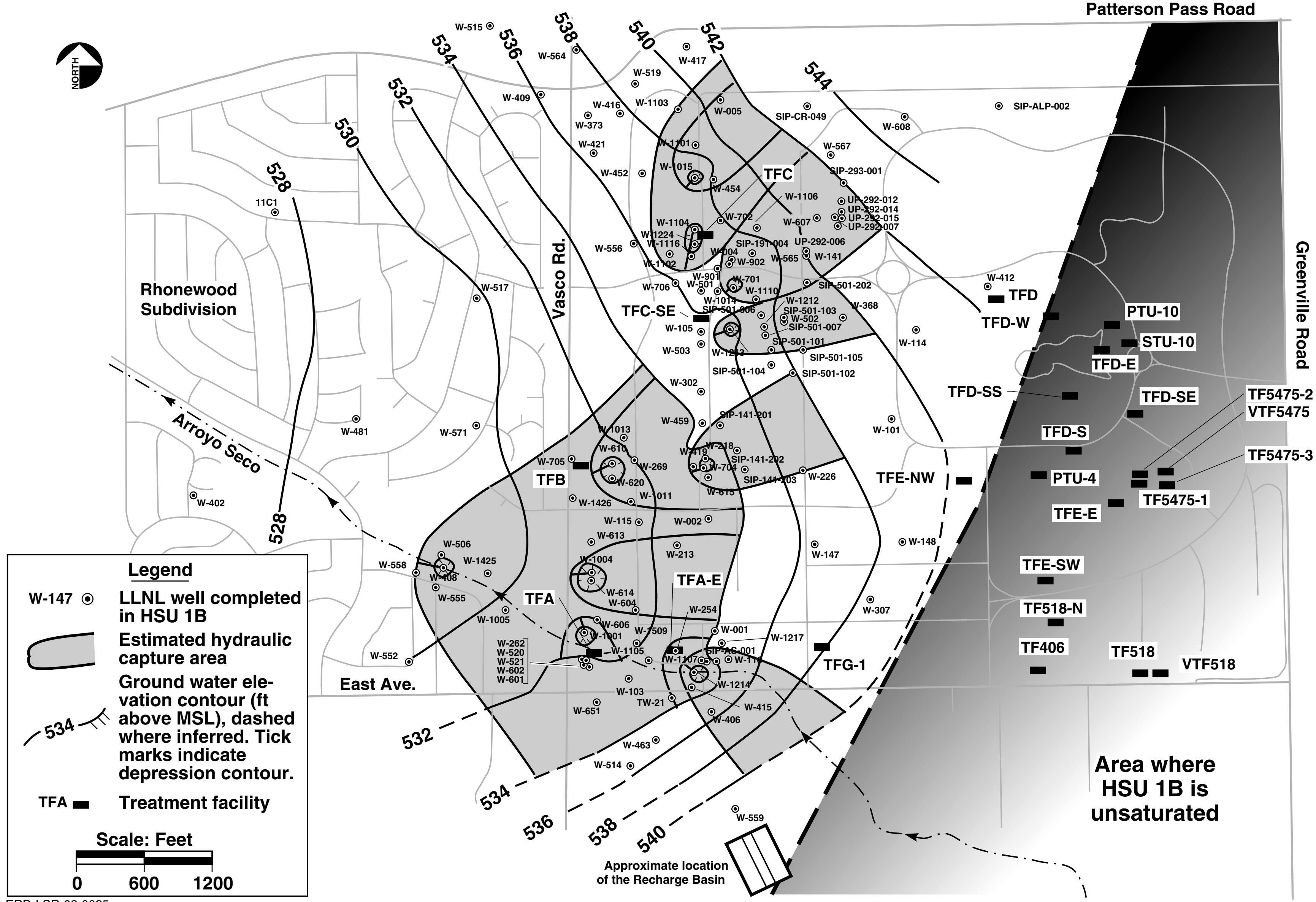

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Figure 5. Ground water elevation contour map based on water levels collected from 133 wells completed within HSU 1B showing estimated hydraulic capture areas, LLNL and vicinity, November 2001.

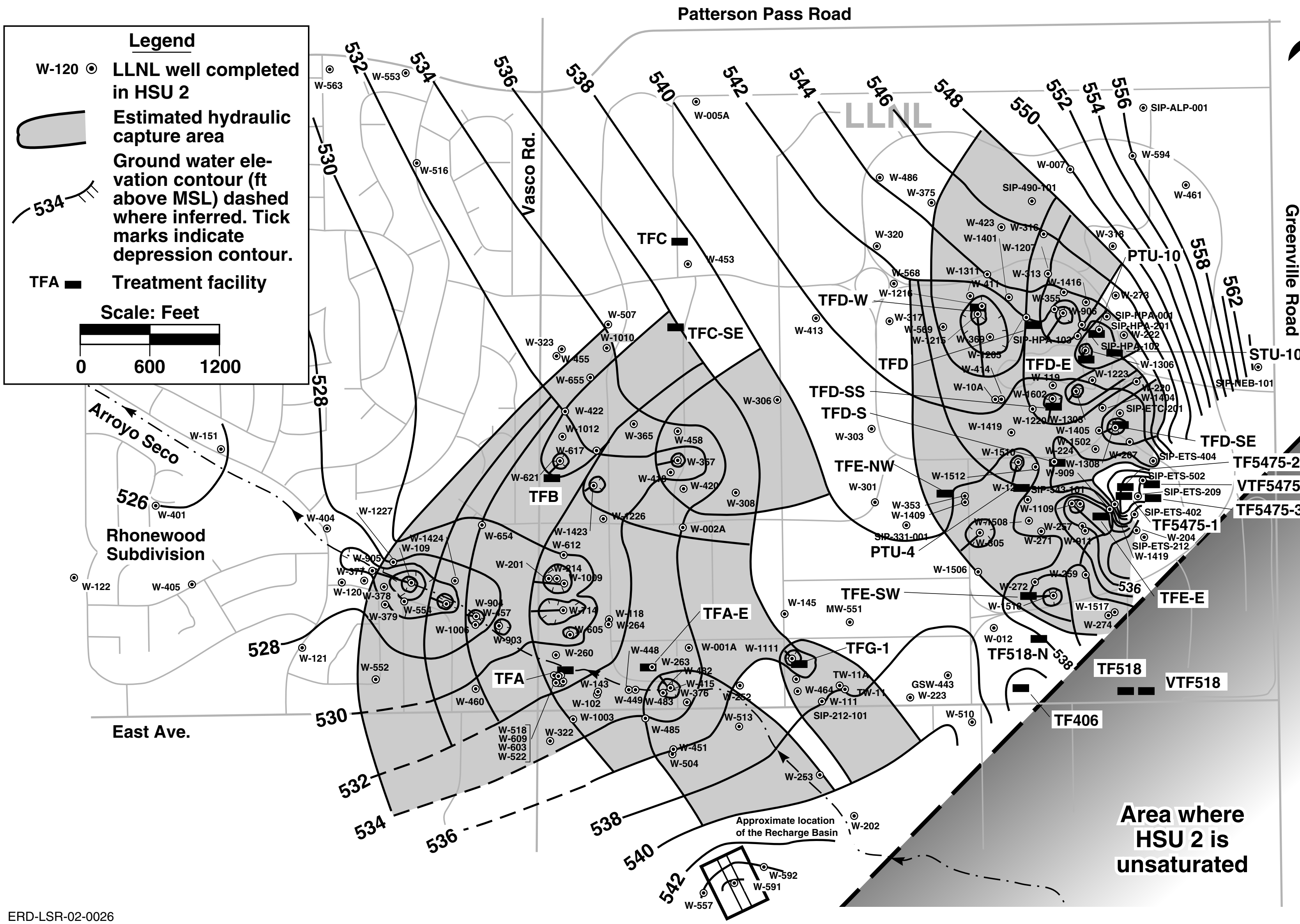

Figure 6. Ground water elevation contour map based on water levels collected from 178 wells completed within HSU 2 showing estimated hydraulic capture areas, LLNL and vicinity, November 2001.

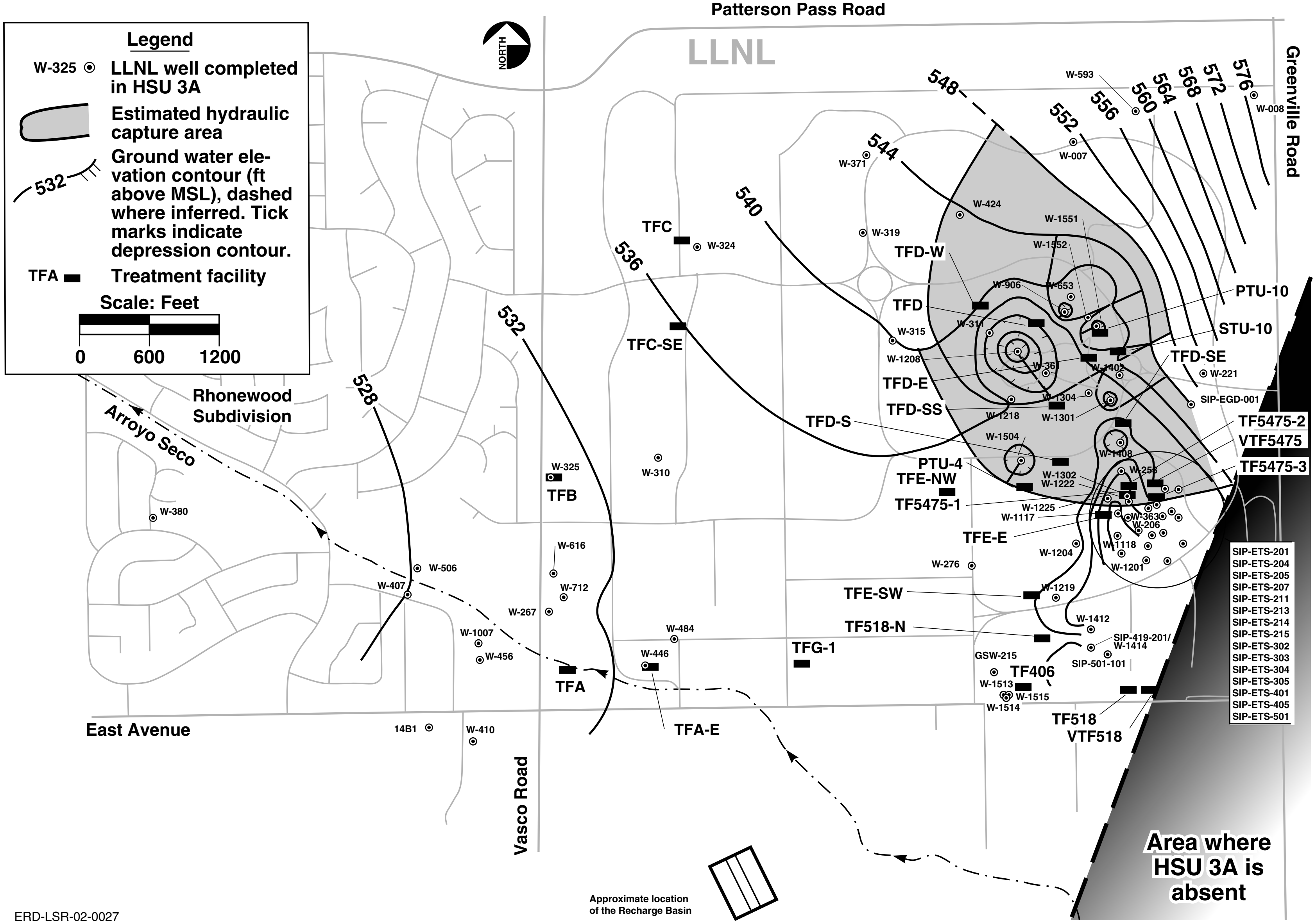

Figure 7. Ground water elevation contour map based on water levels collected from 76 wells completed within HSU 3A showing estimated hydraulic capture areas, LLNL and vicinity, November 2001.

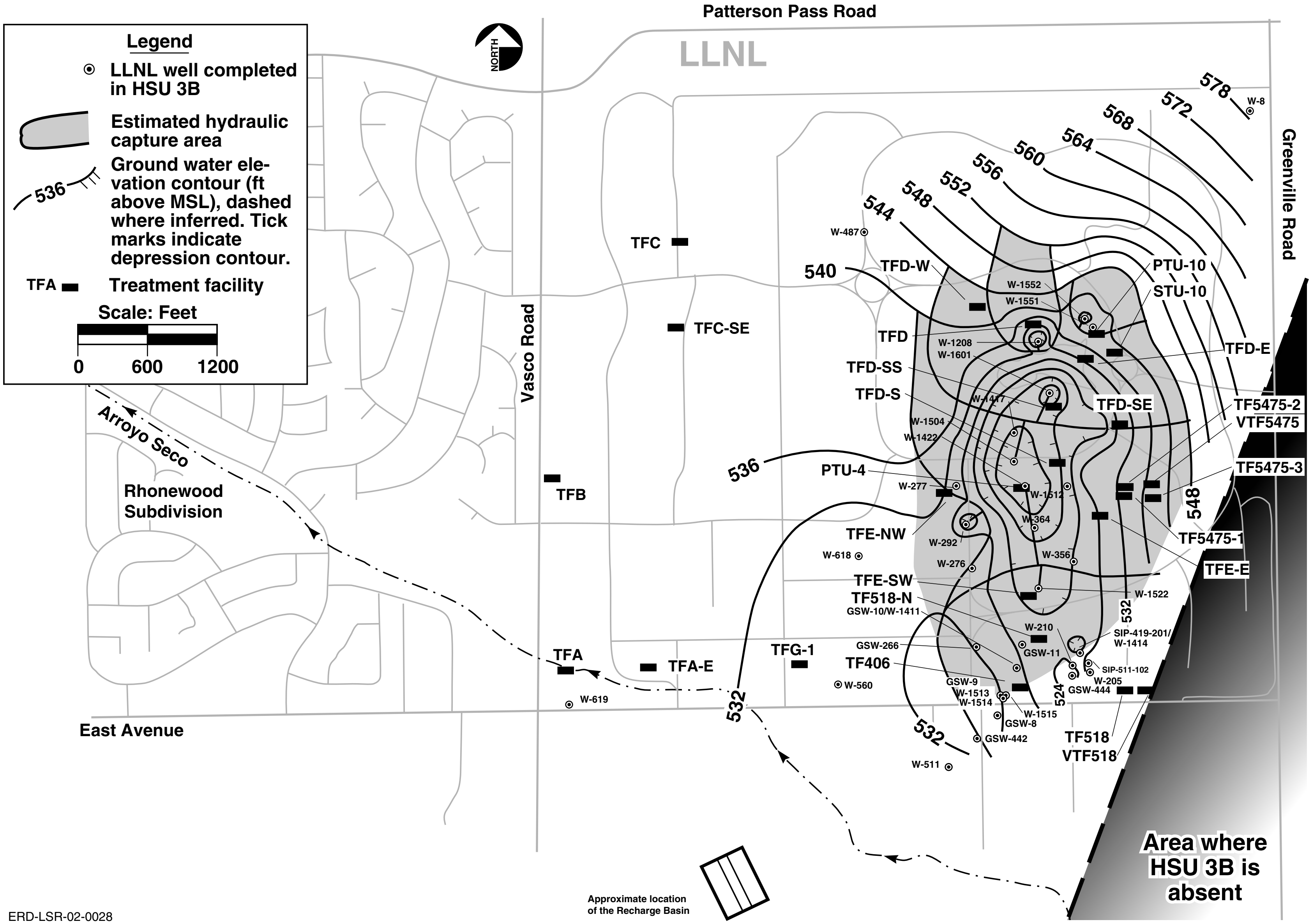

Figure 8. Ground water elevation contour map based on water levels collected from 33 wells completed within HSU 3B showing estimated hydraulic capture areas, LLNL and vicinity, December 2001.

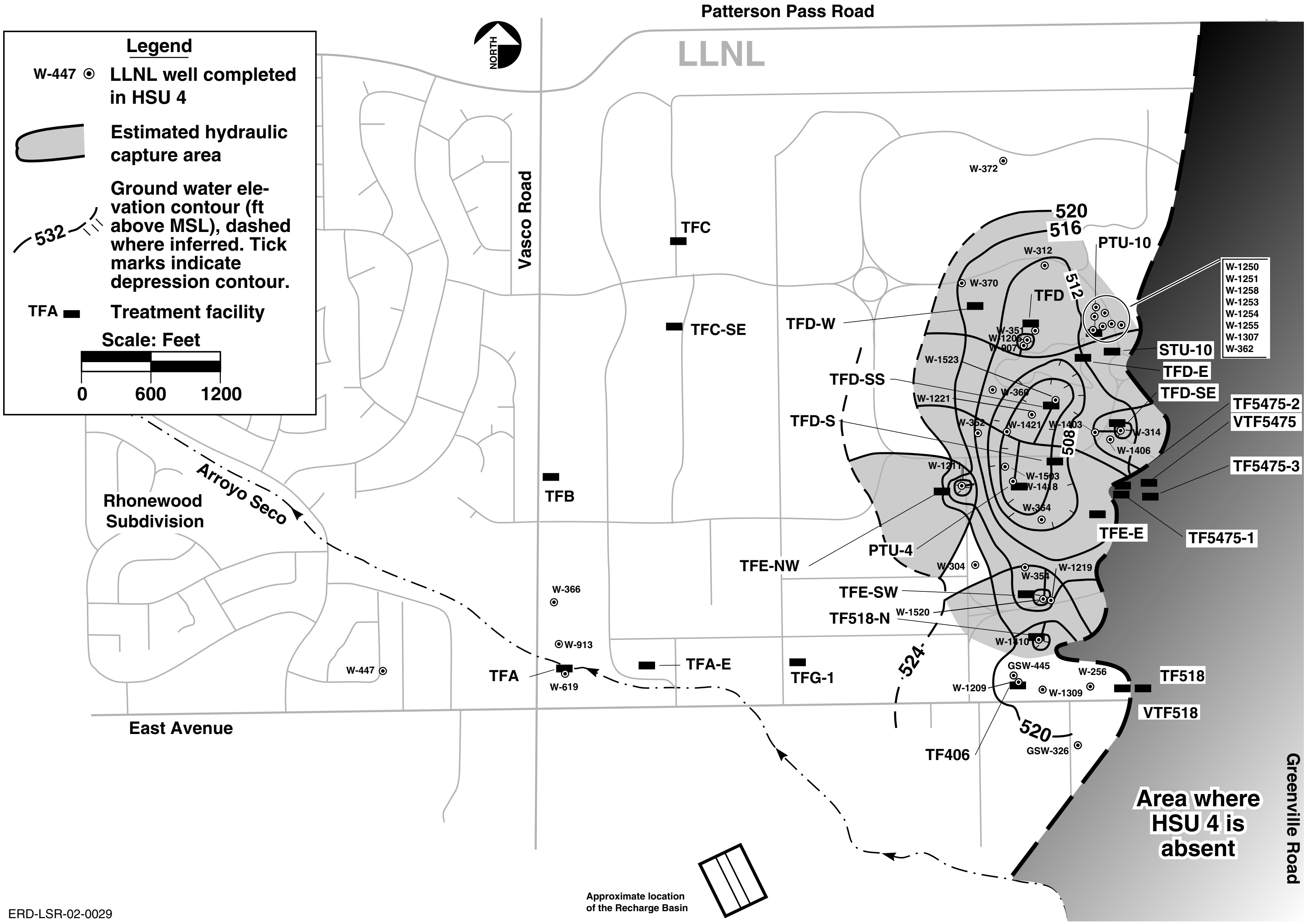

Figure 9. Ground water elevation contour map based on water levels collected from 36 wells completed within HSU 4 showing estimated hydraulic capture areas, LLNL and vicinity, November 2001.

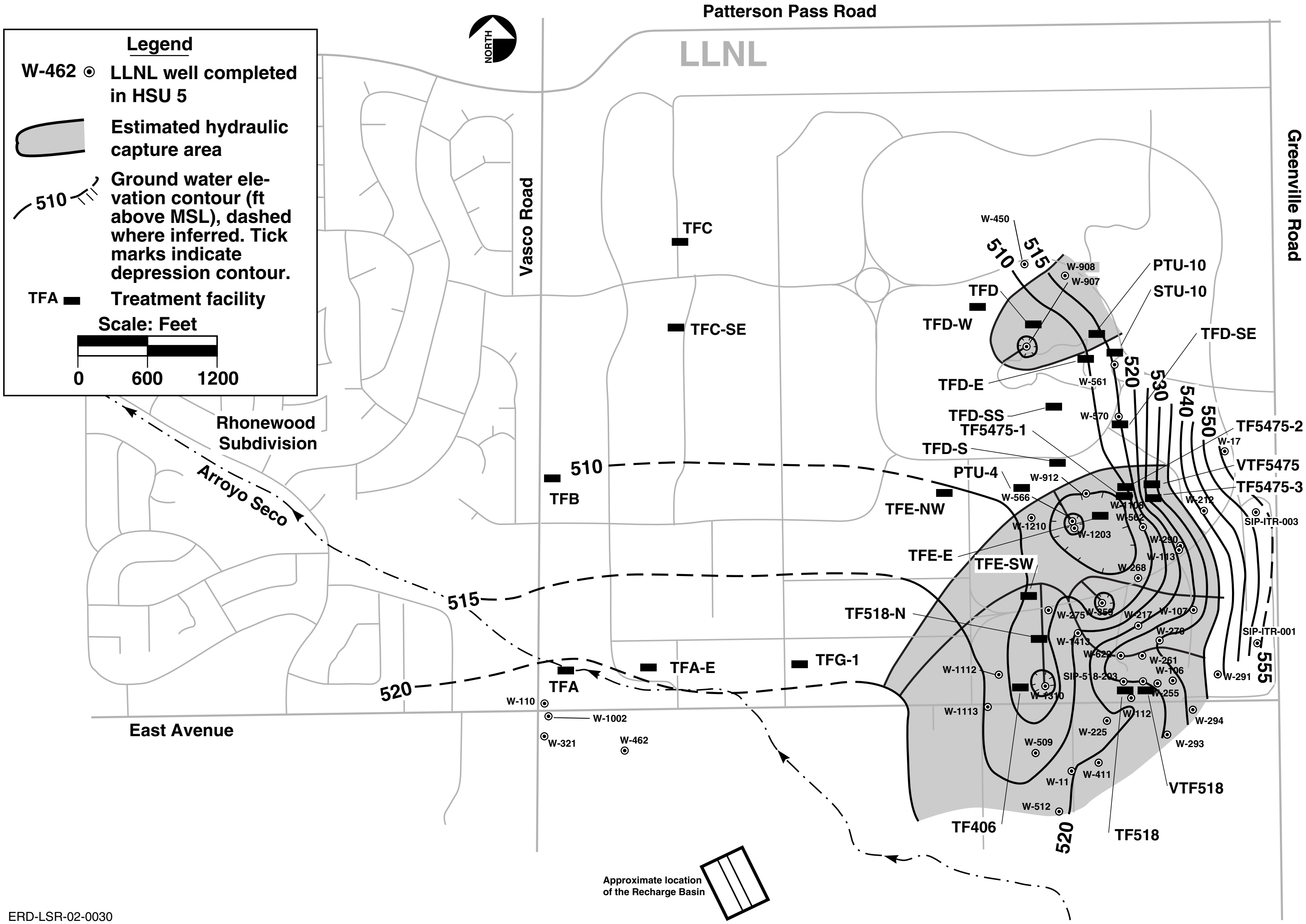

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Figure 10. Ground water elevation contour map based on water levels collected from 50 wells completed within HSU 5 showing estimated hydraulic capture areas, LLNL and vicinity, December 2001.

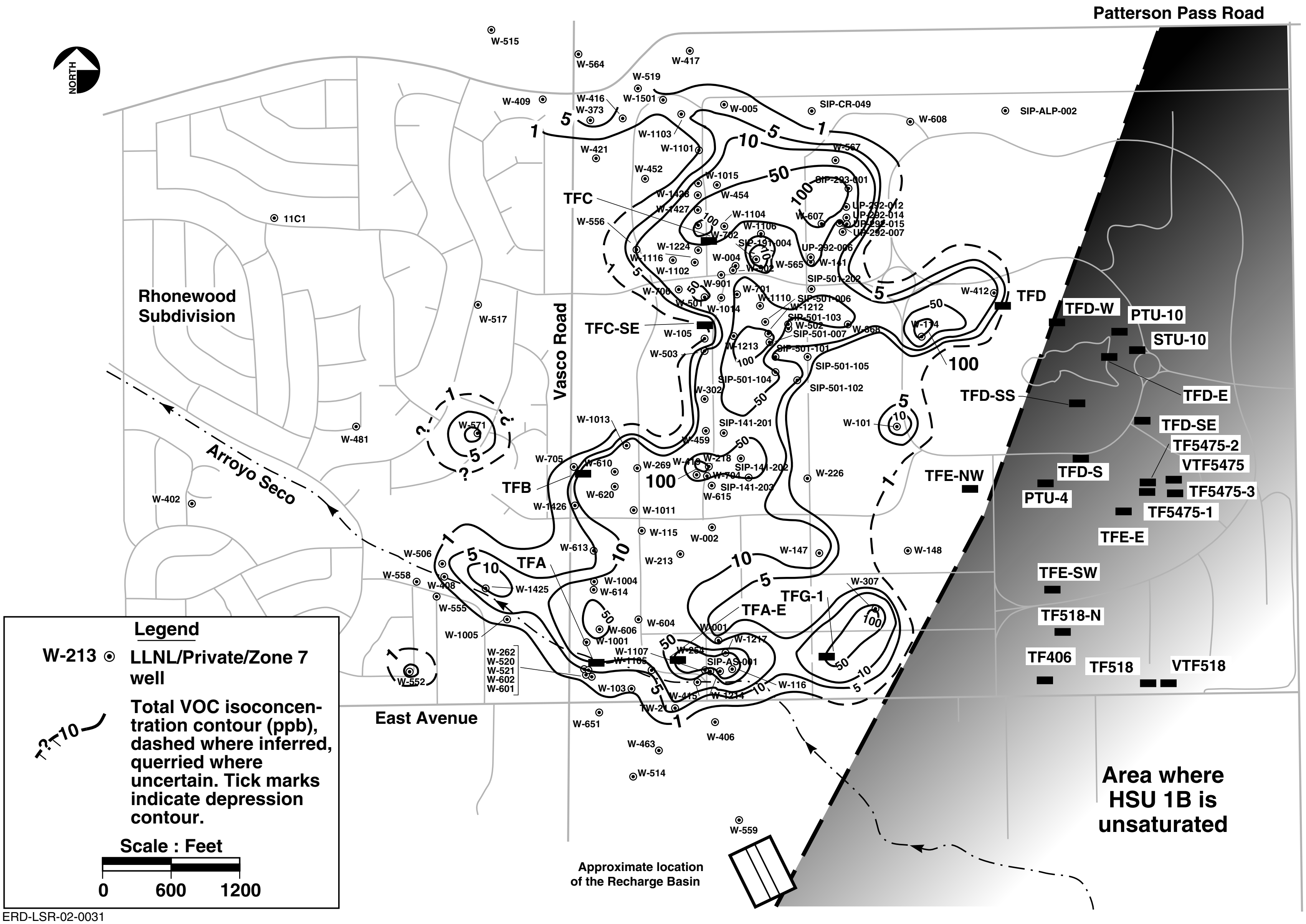


Figure 11. Isoconcentration contour map of total VOCs for 136 wells completed within HSU 1B based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 46 borehole locations.

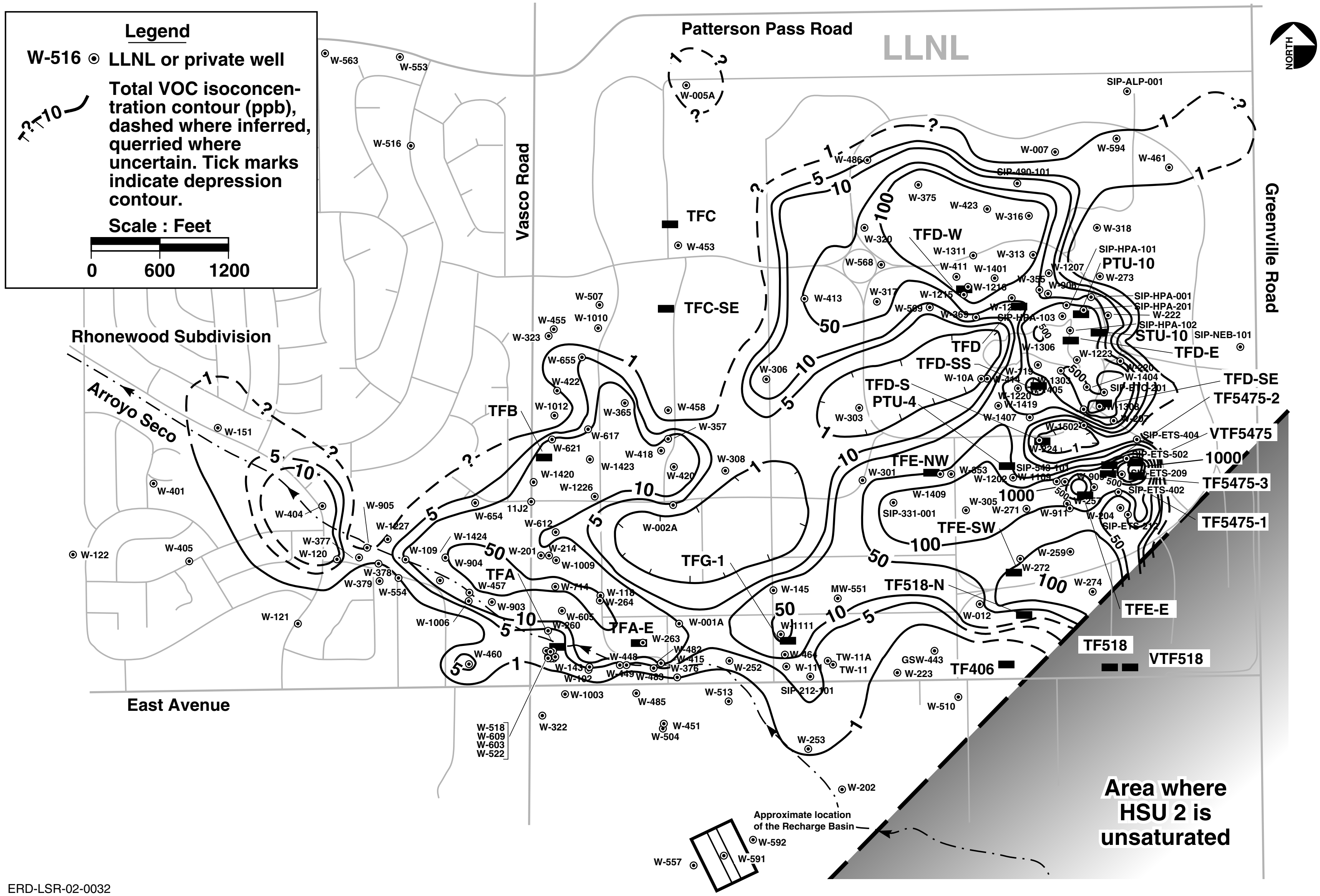
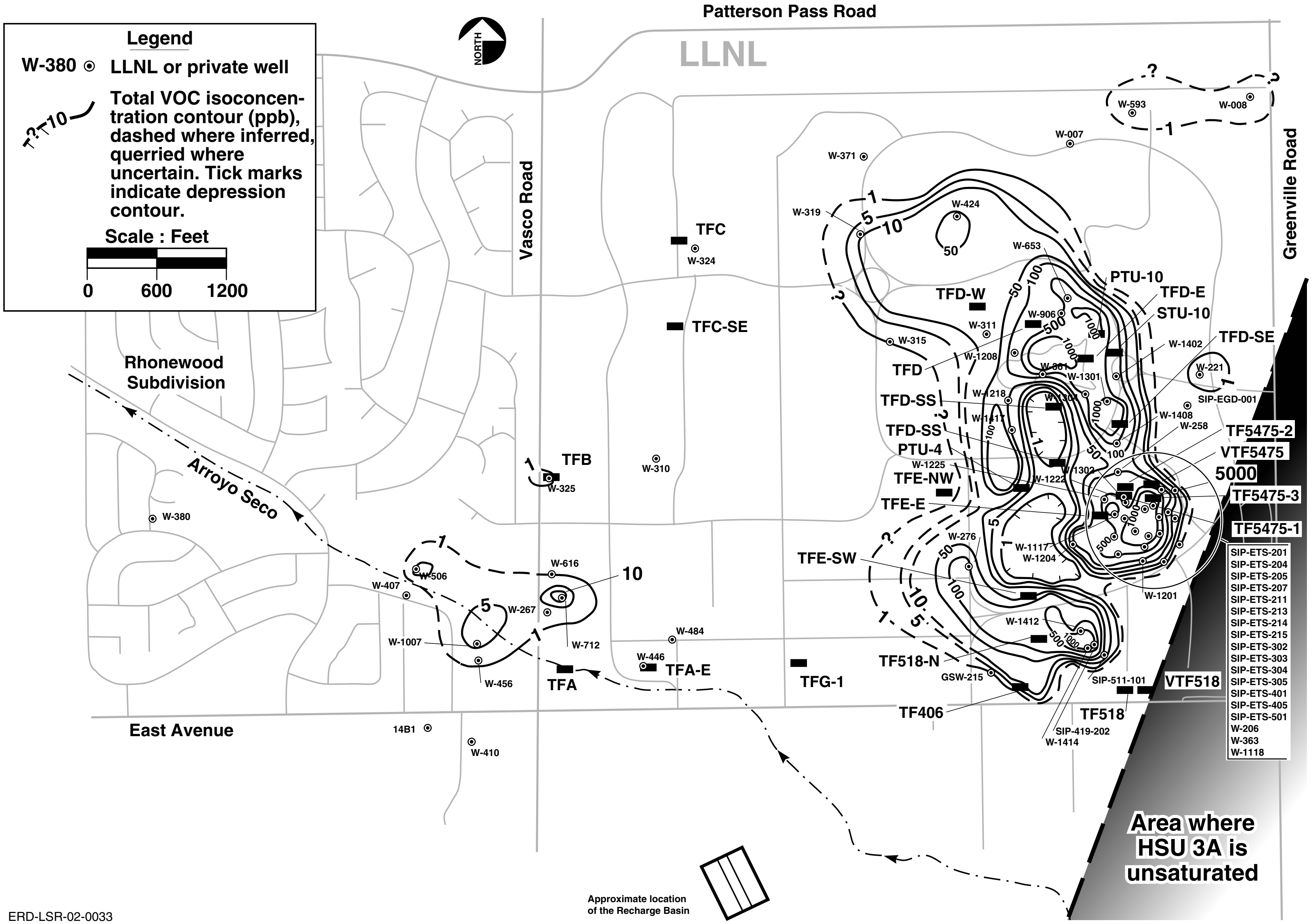
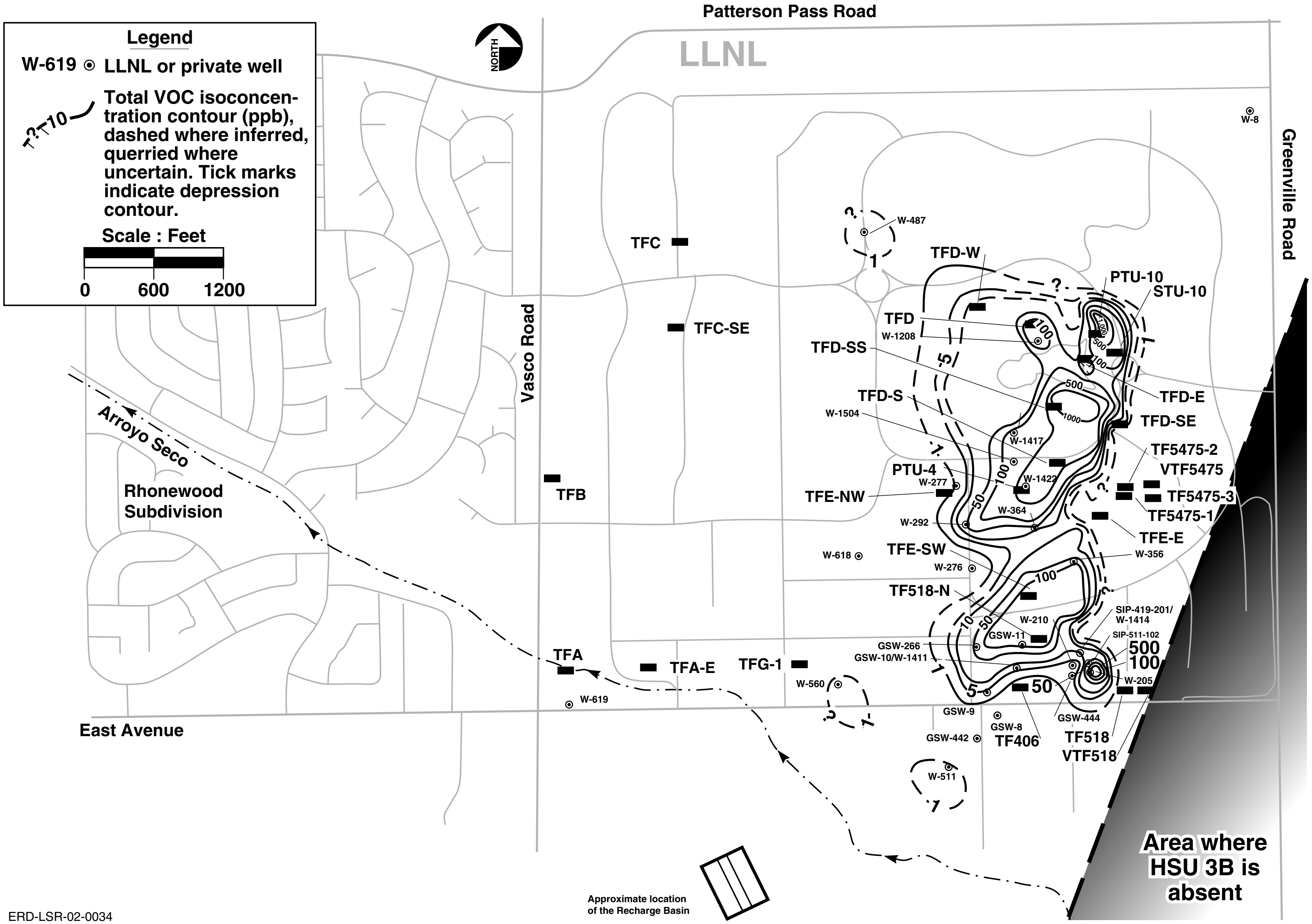


Figure 12. Isoconcentration contour map of total VOCs for 187 wells completed within HSU 2 based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 104 borehole locations.



ERD-LSR-02-0033

Figure 13. Isoconcentration contour map of total VOCs for 96 wells completed within HSU 3A based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 148 borehole locations.



ERD-LSR-02-0034

Figure 14. Isoconcentration contour map of total VOCs for 55 wells completed within HSU 3B based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 108 borehole locations.

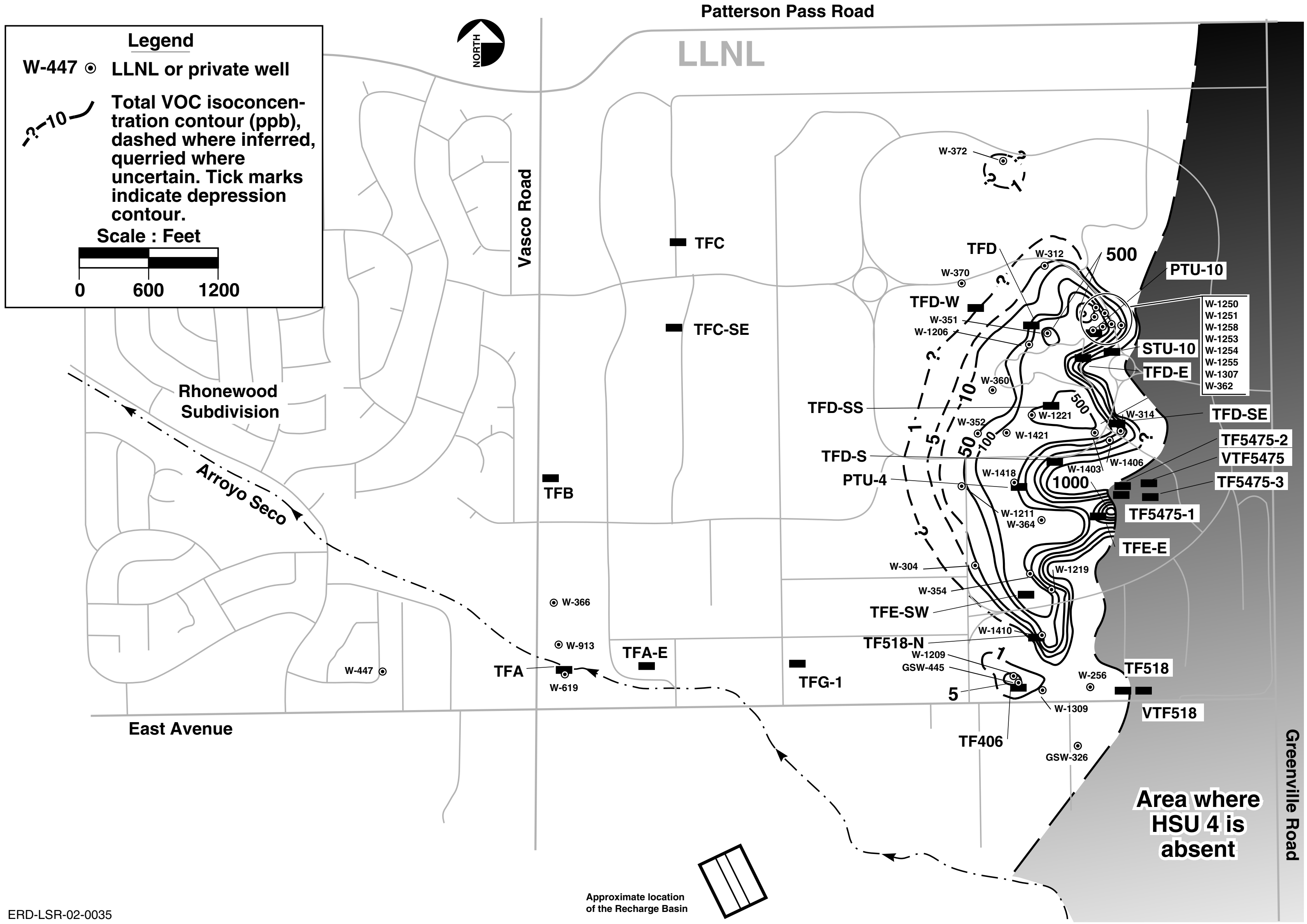


Figure 15. Isoconcentration contour map of total VOCs for 43 wells completed within HSU 4 based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 64 borehole locations.

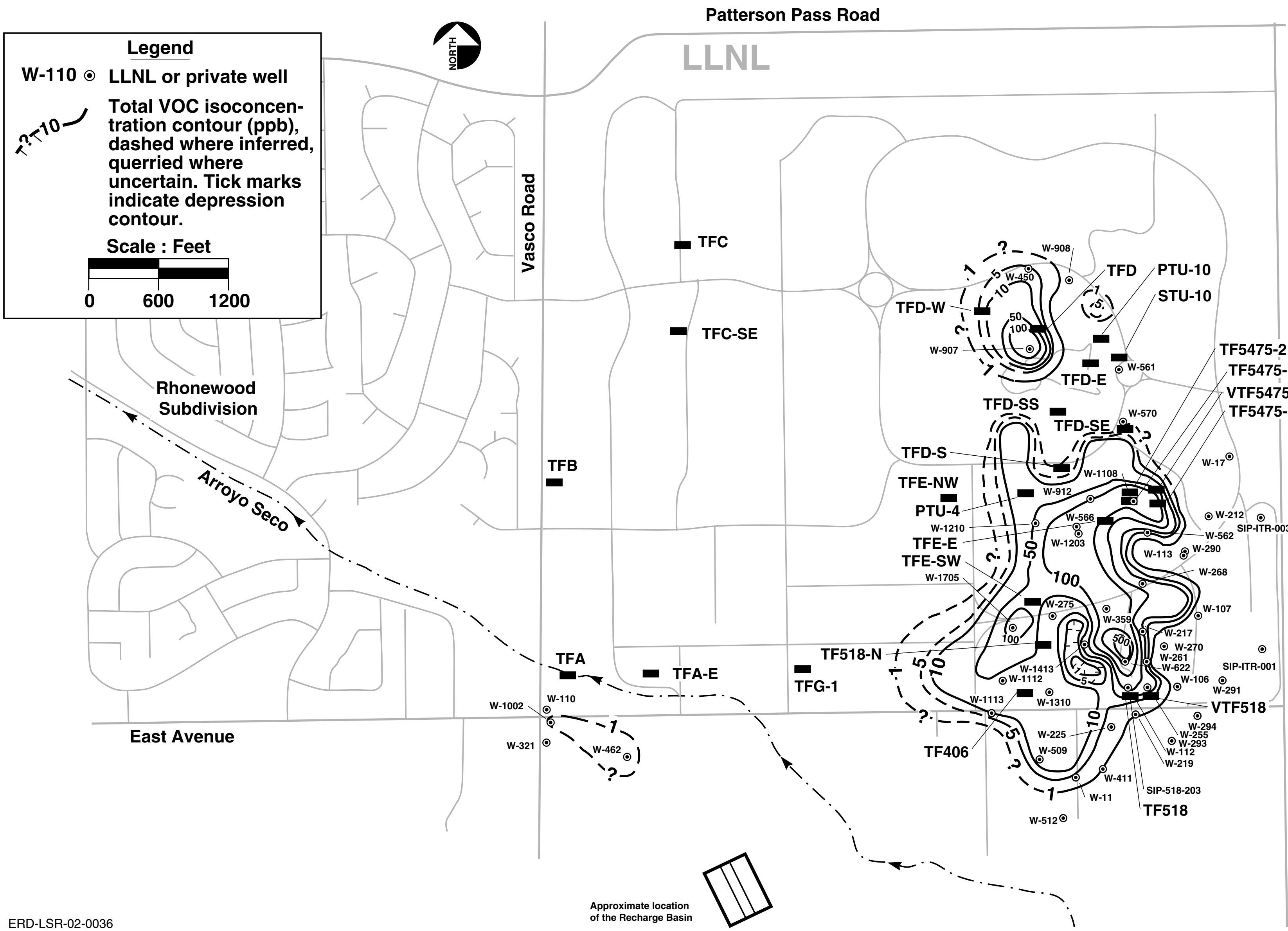
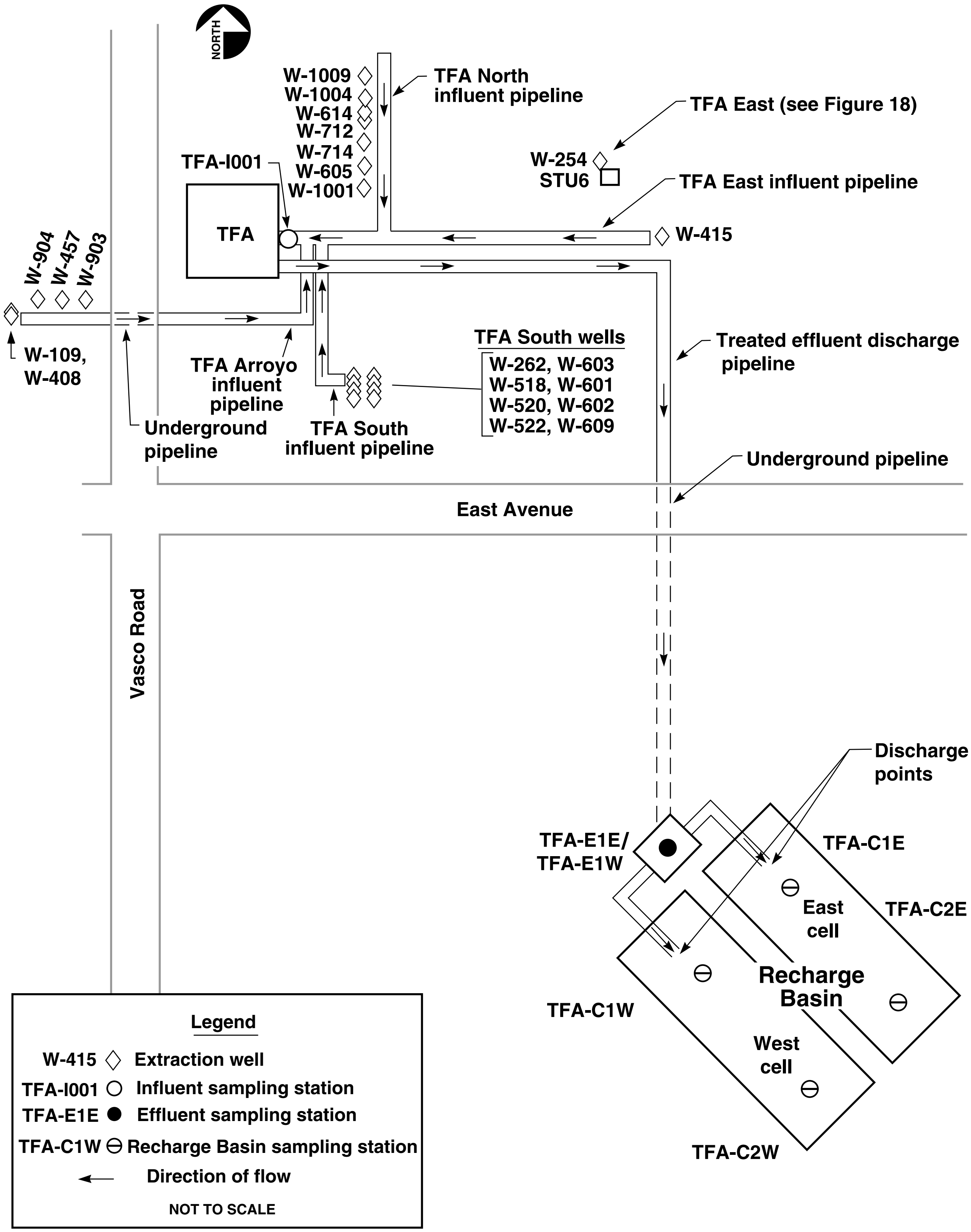
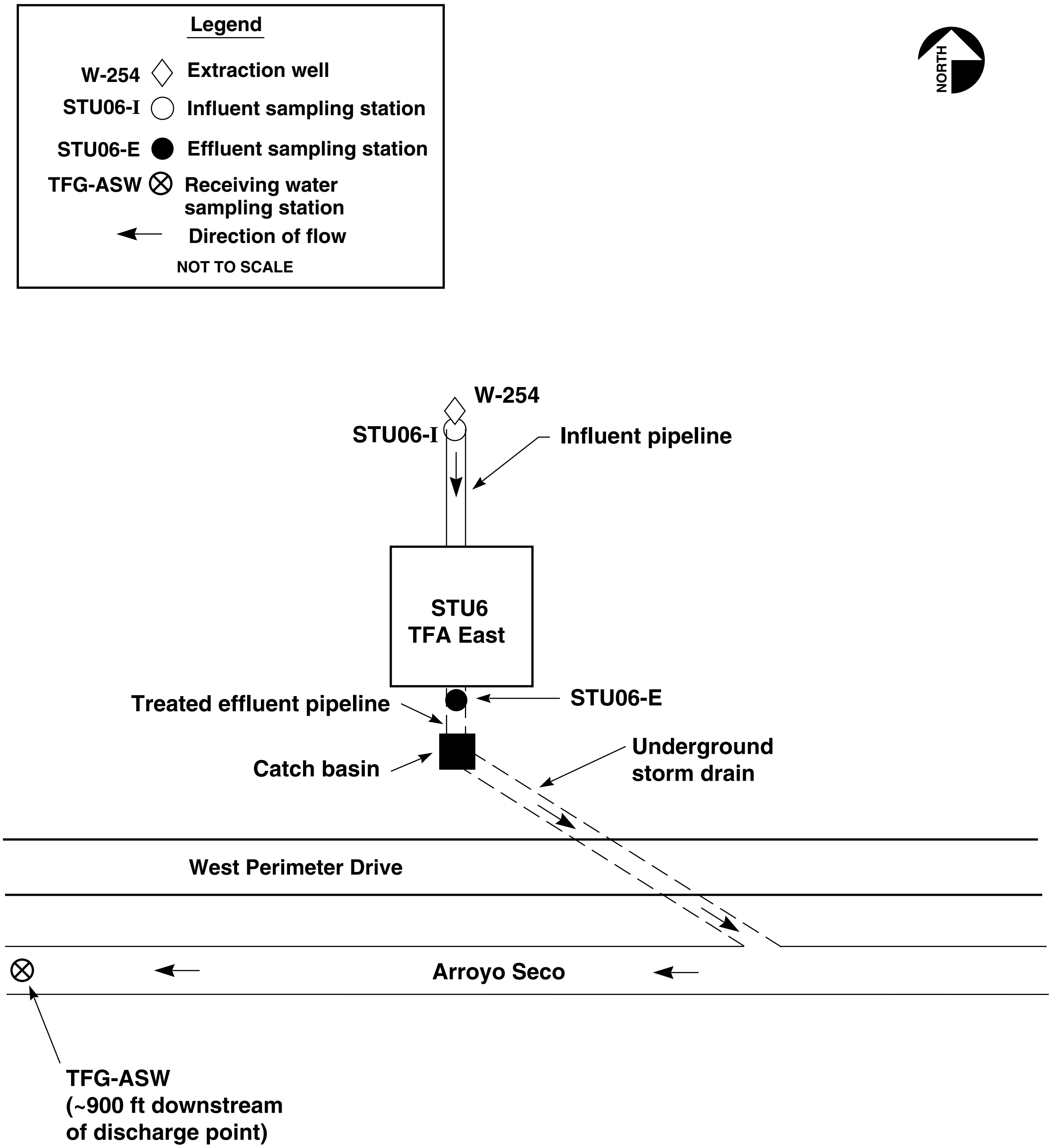


Figure 16. Isoconcentration contour map of total VOCs for 55 wells completed within HSU 5 based on samples collected in the third quarter of 2001 (or the next most recent data), and supplemented with soil chemistry data from 94 borehole locations.



ERD-LSR-02-0037

Figure 17. TFA extraction well, pipeline and discharge locations.



ERD-LSR-02-0038

Figure 18. TFA East extraction well, pipeline and discharge locations.

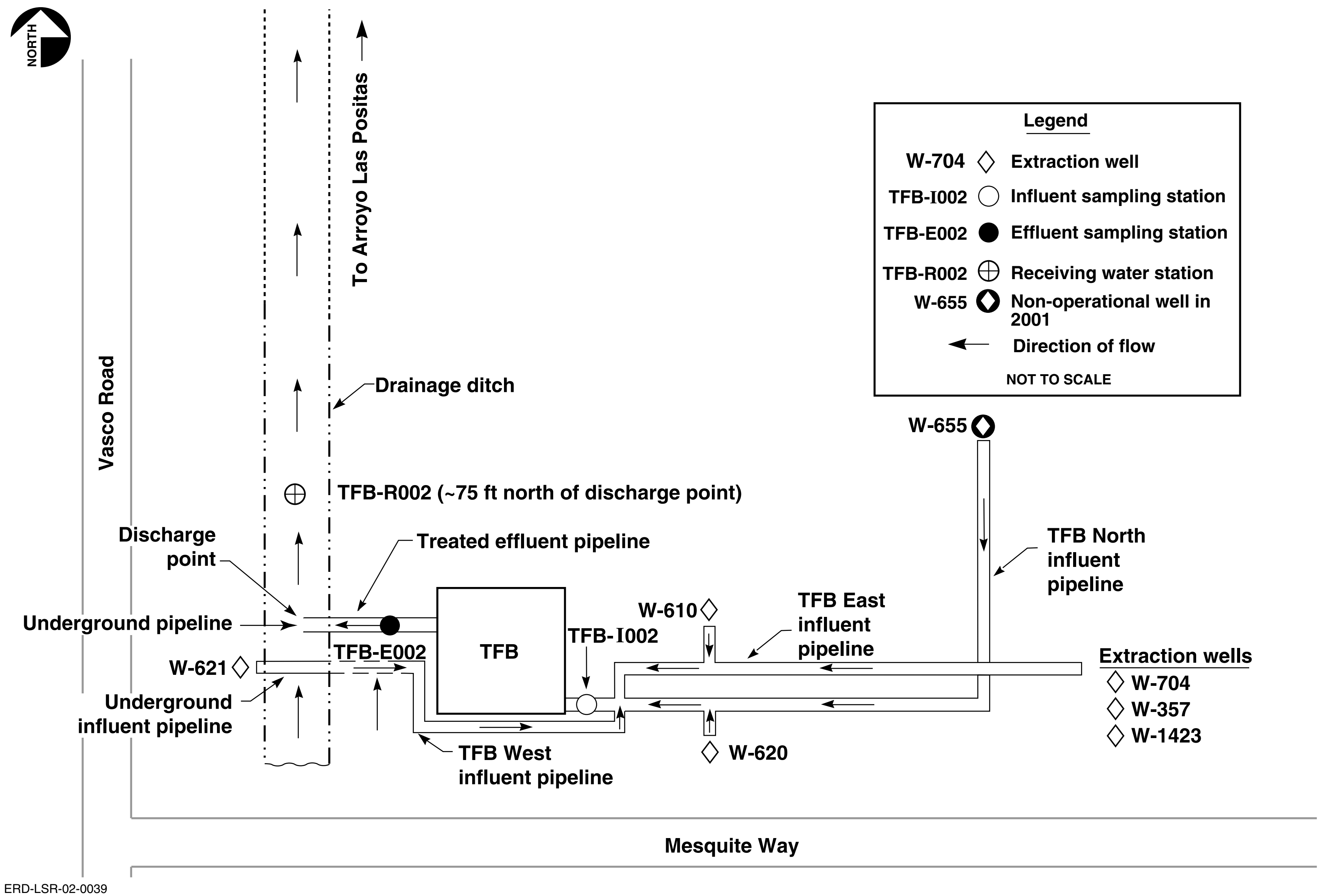


Figure 19. TFB extraction well, pipeline and discharge locations.

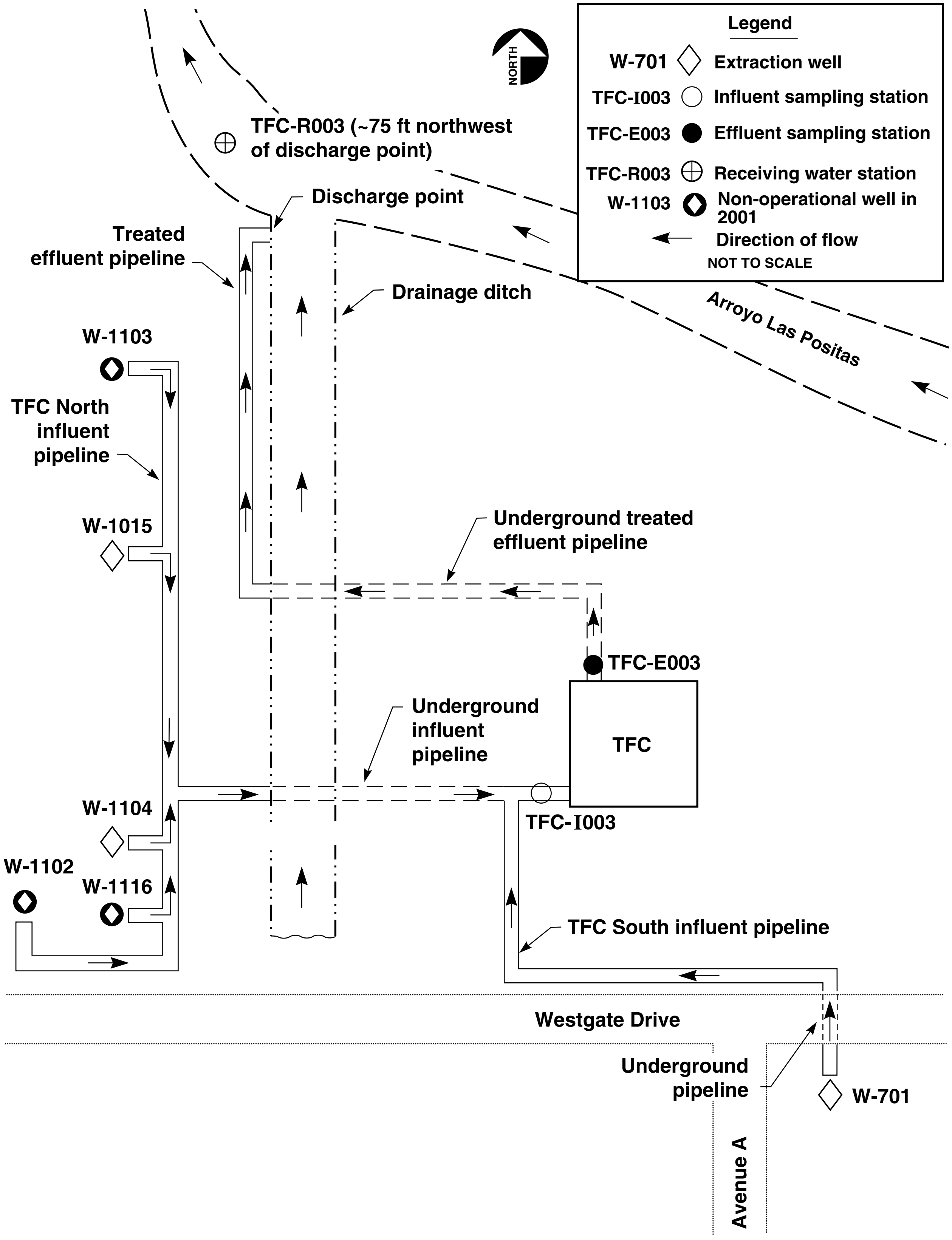


Figure 20. TFC extraction well, pipeline and discharge locations.

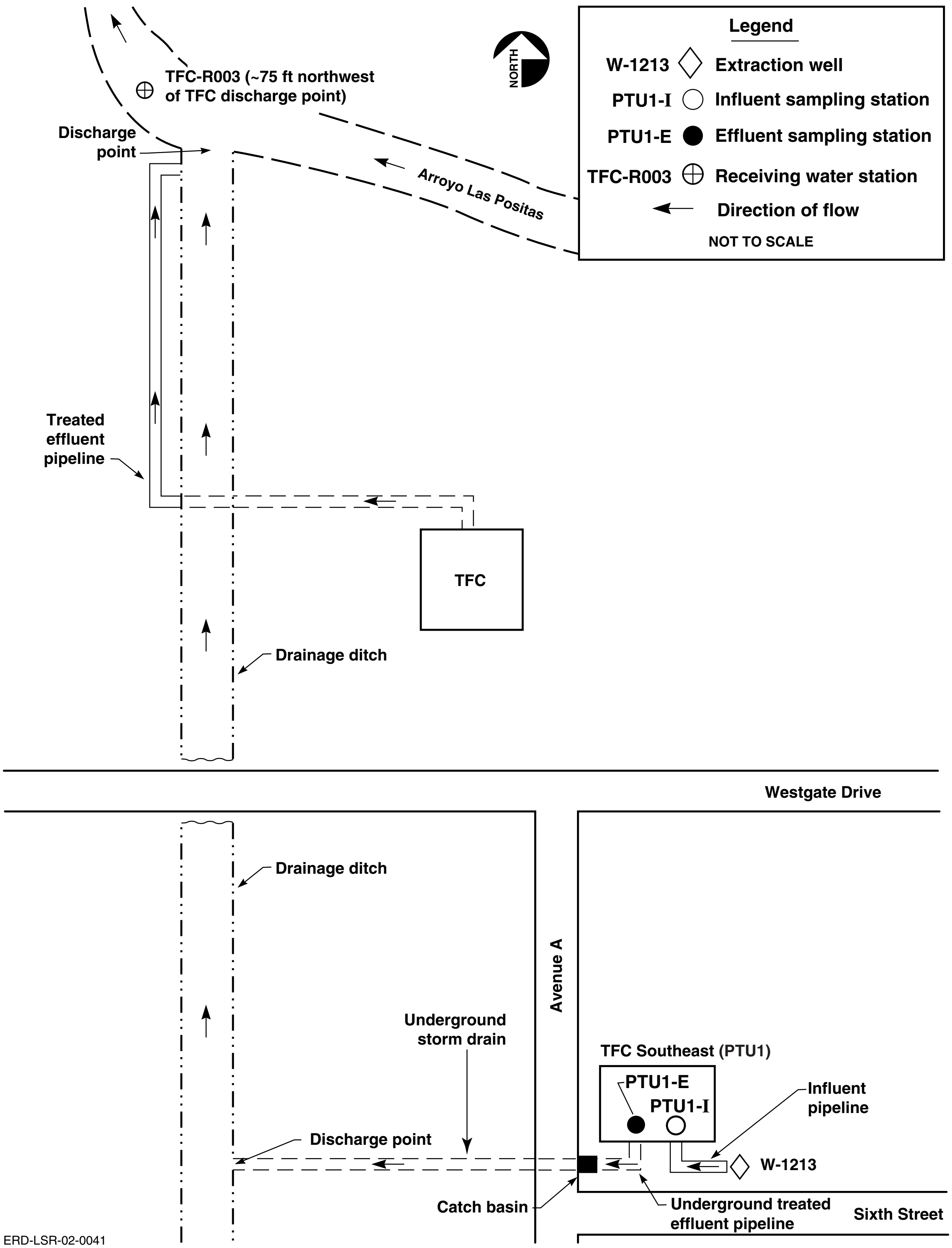


Figure 21. TFC Southeast extraction well, pipeline and discharge locations.

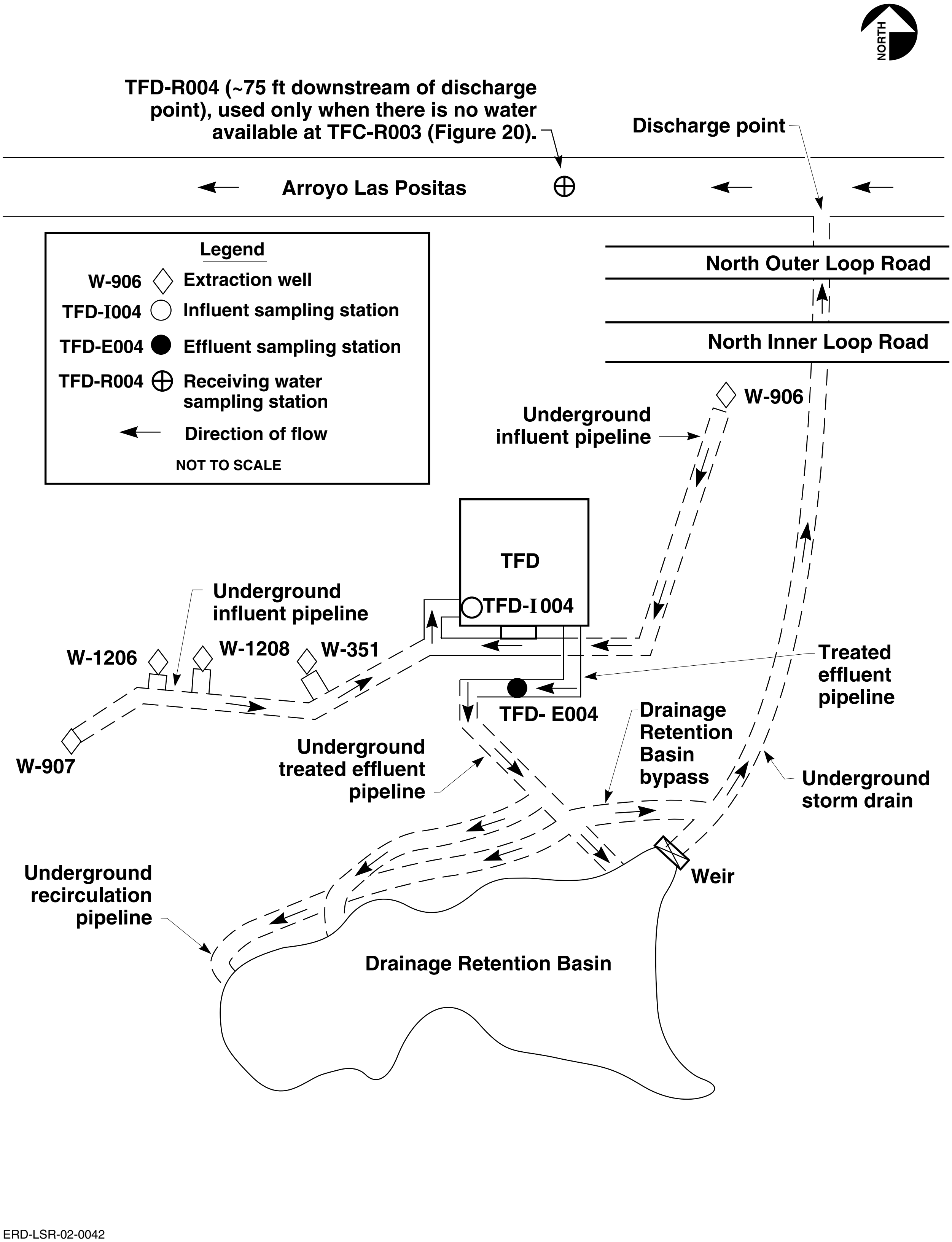
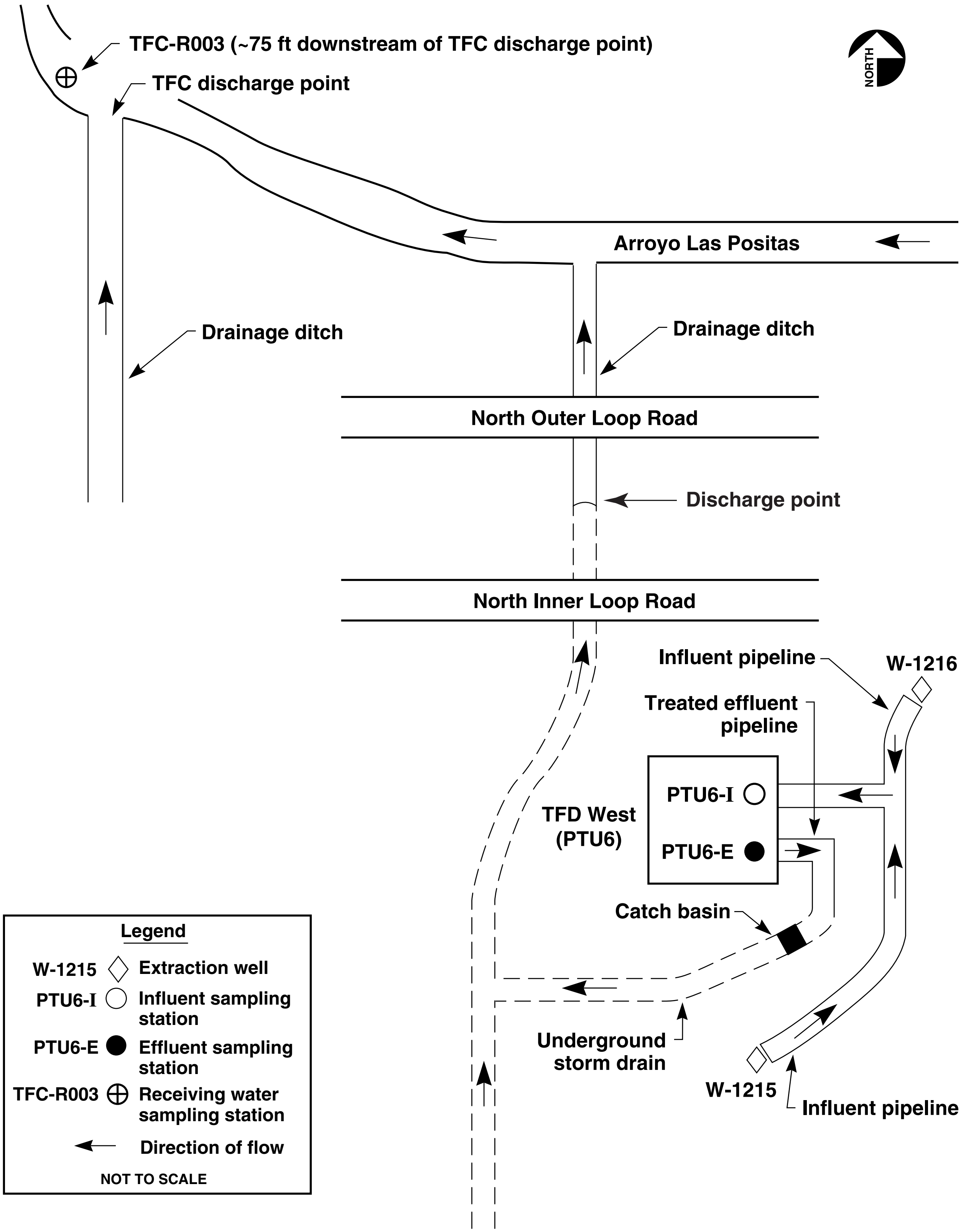
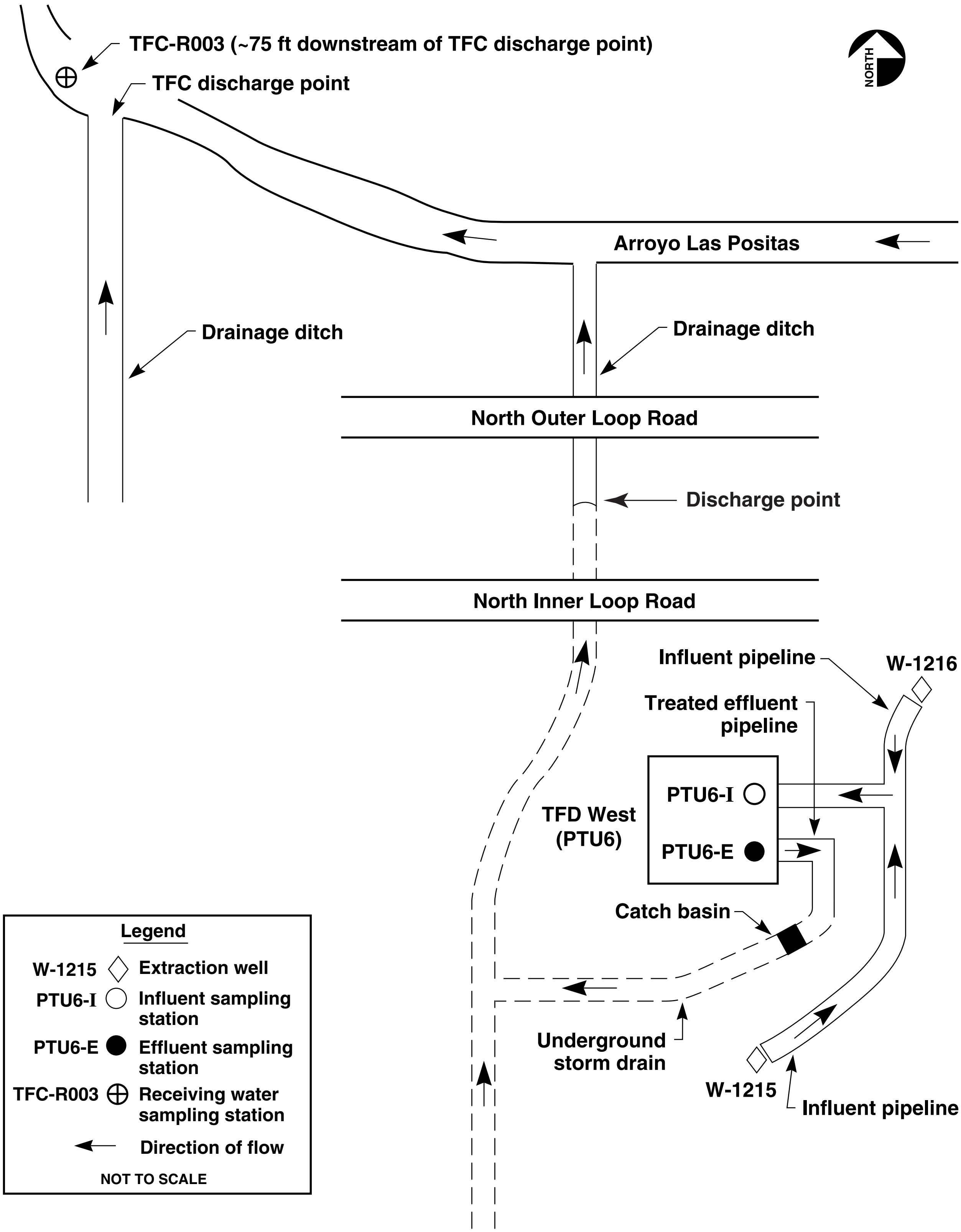


Figure 22. TFD extraction well, pipeline and discharge locations.



ERD-LSR-02-0043

Figure 23. TFD West extraction well, pipeline and discharge locations.



ERD-LSR-02-0043

Figure 23. TFD West extraction well, pipeline and discharge locations.

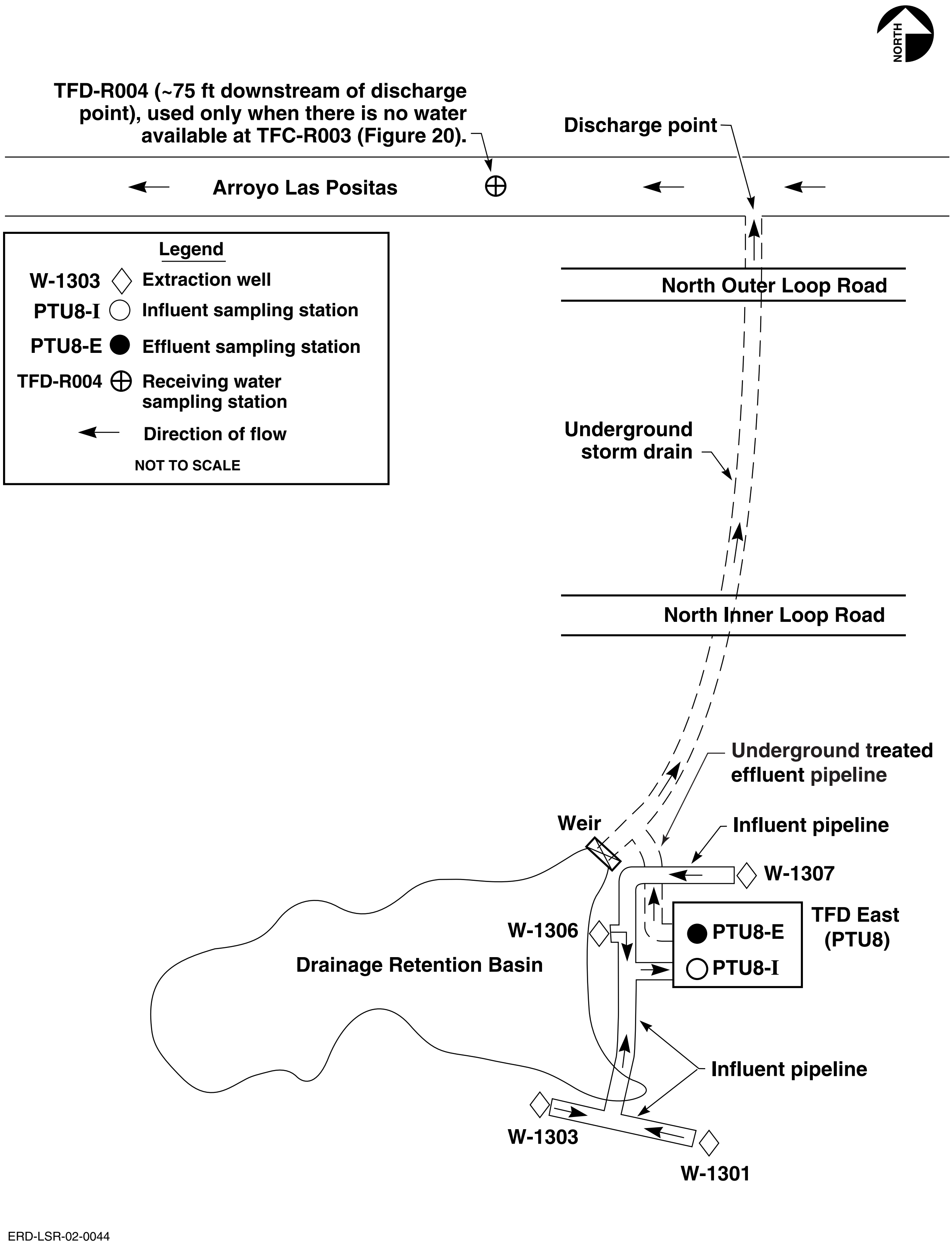


Figure 24. TFD East extraction well, pipeline and discharge locations.

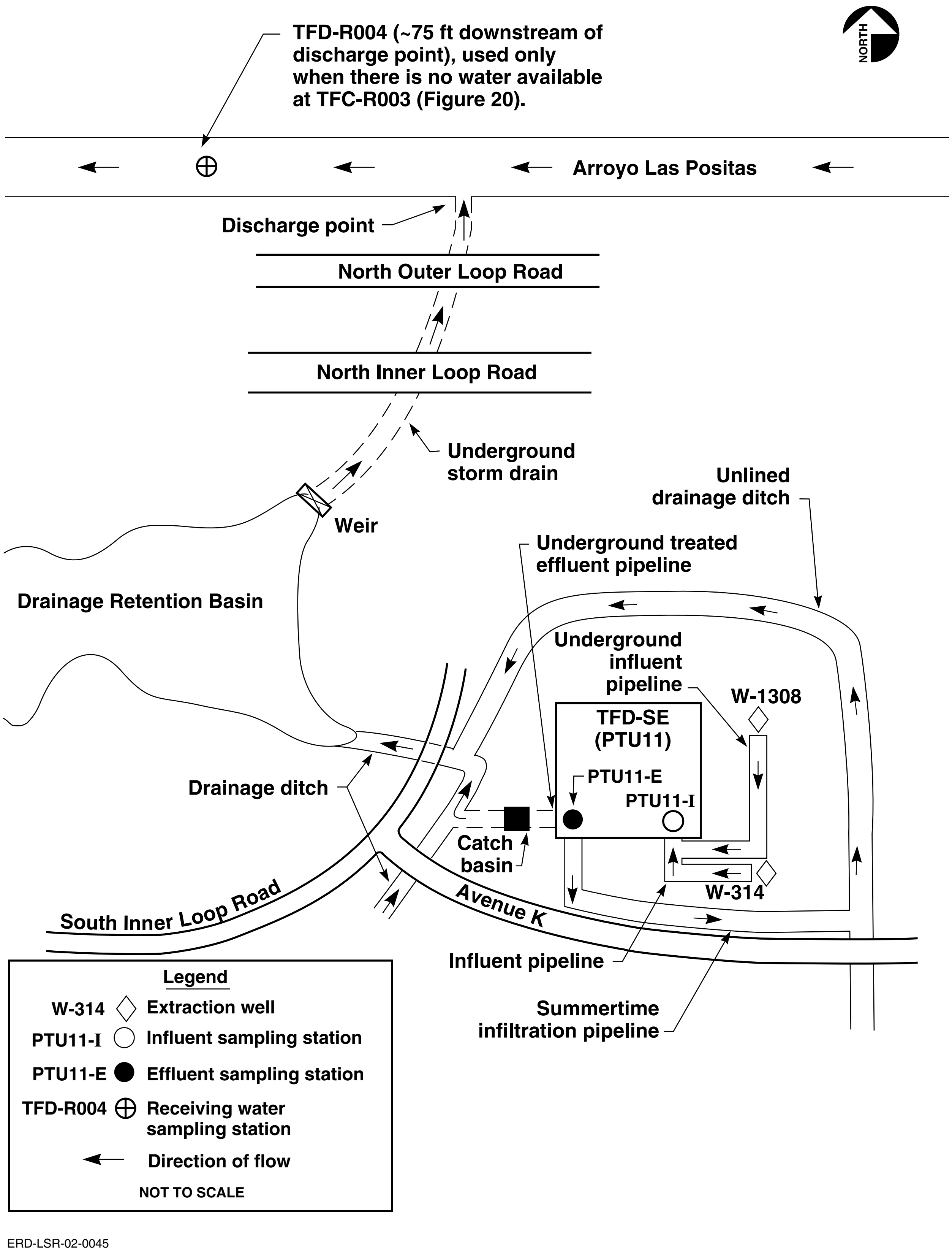


Figure 25. TFD Southeast extraction well, pipeline and discharge locations.

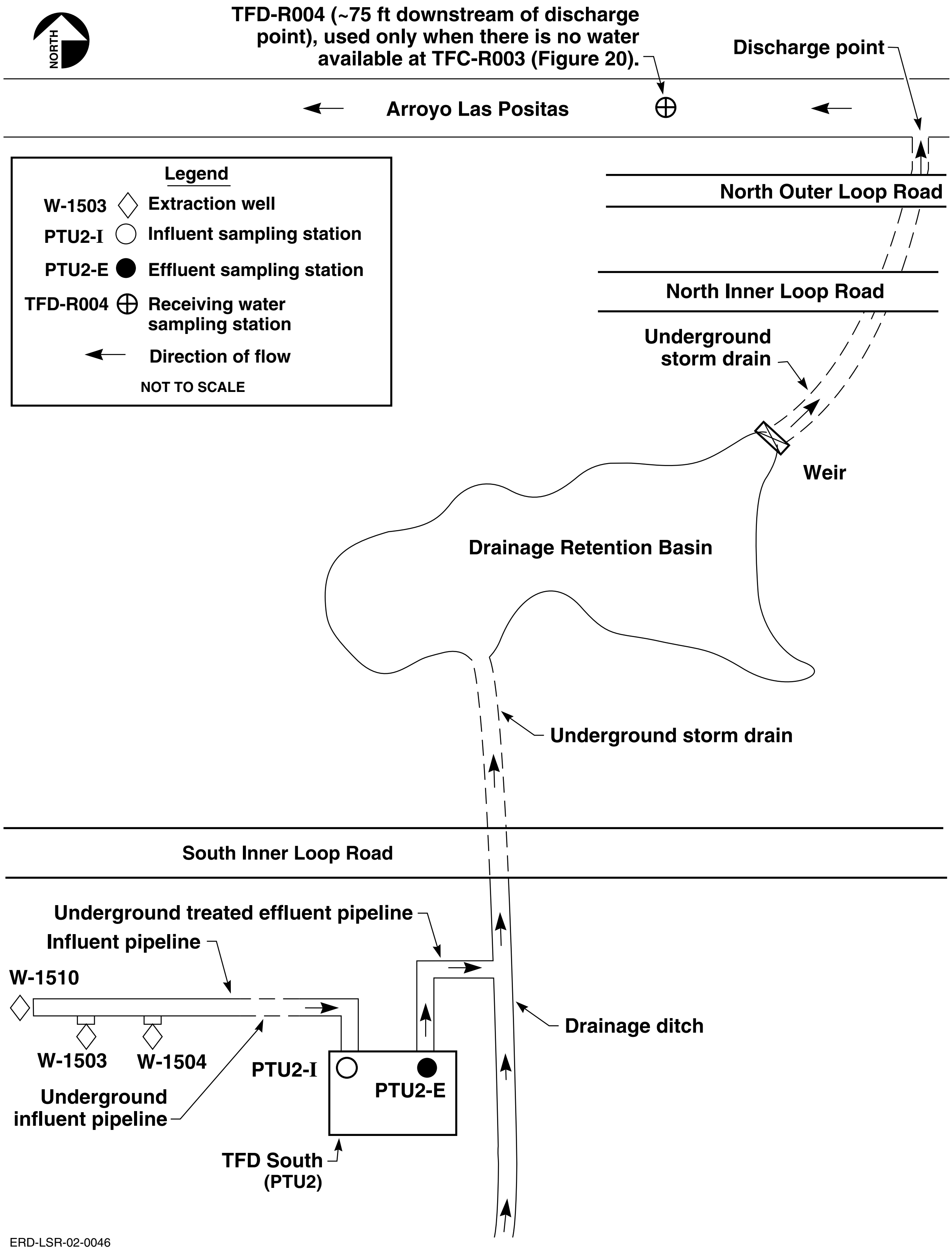


Figure 26. TFD South extraction well, pipeline and discharge locations.

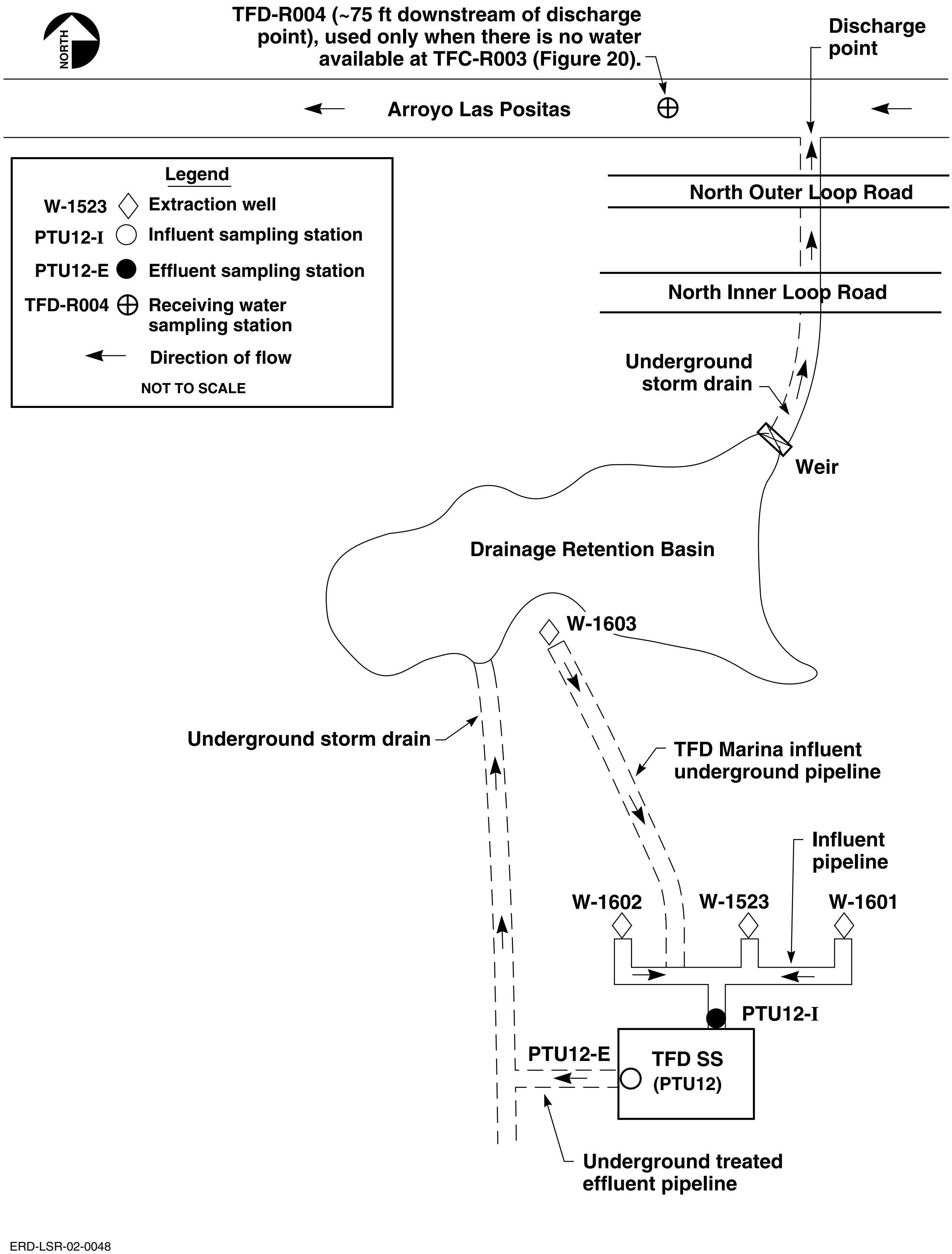


Figure 27. TFD Southshore extraction well, pipeline and discharge locations.

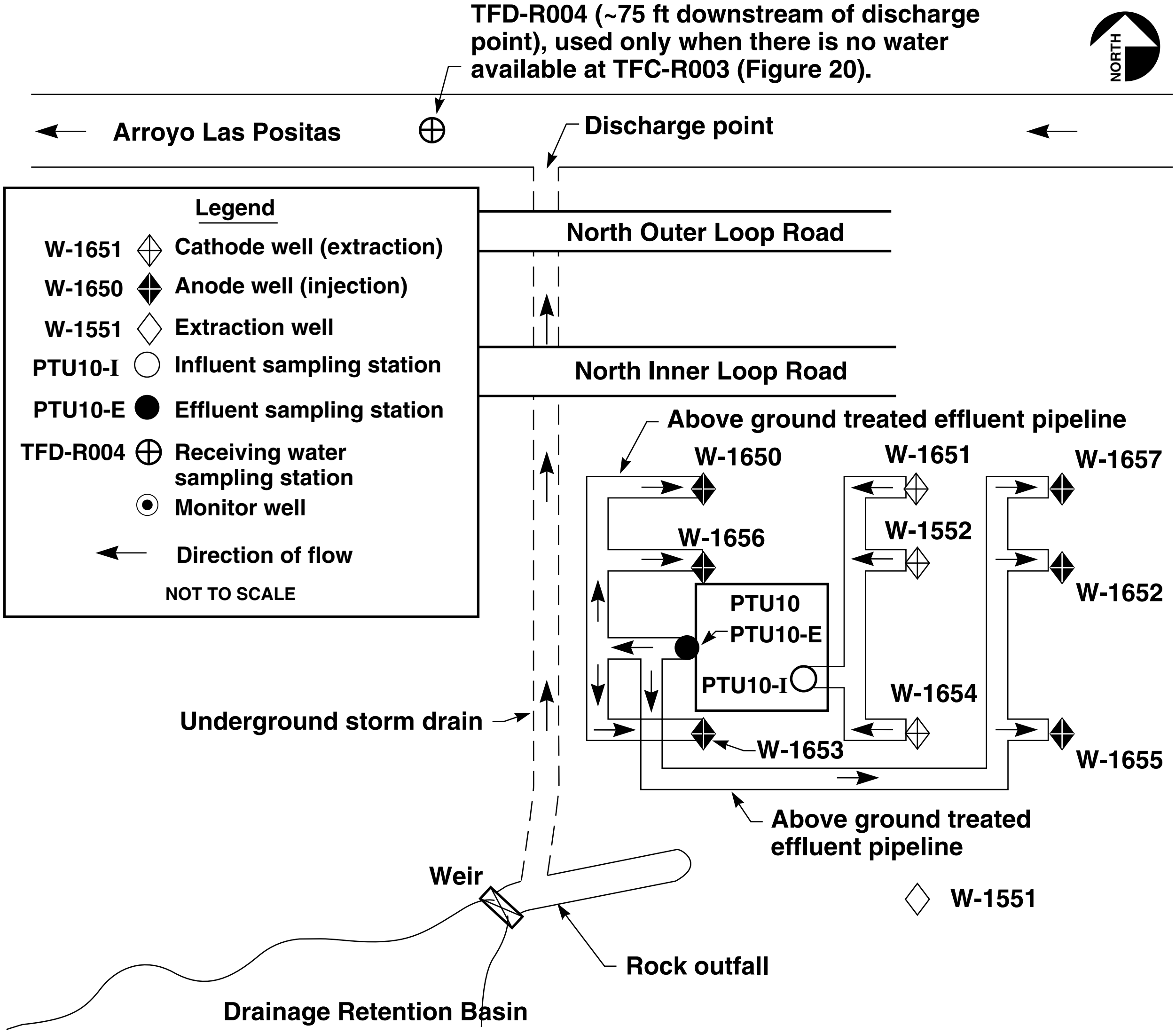
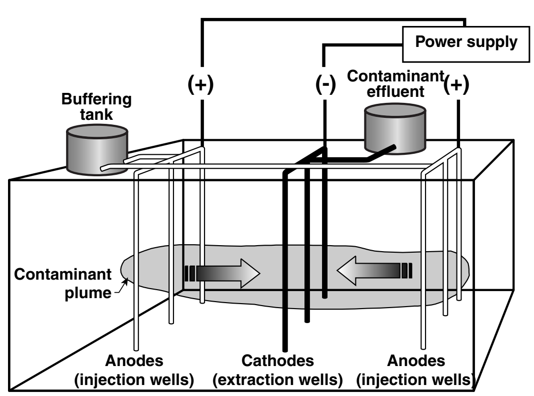
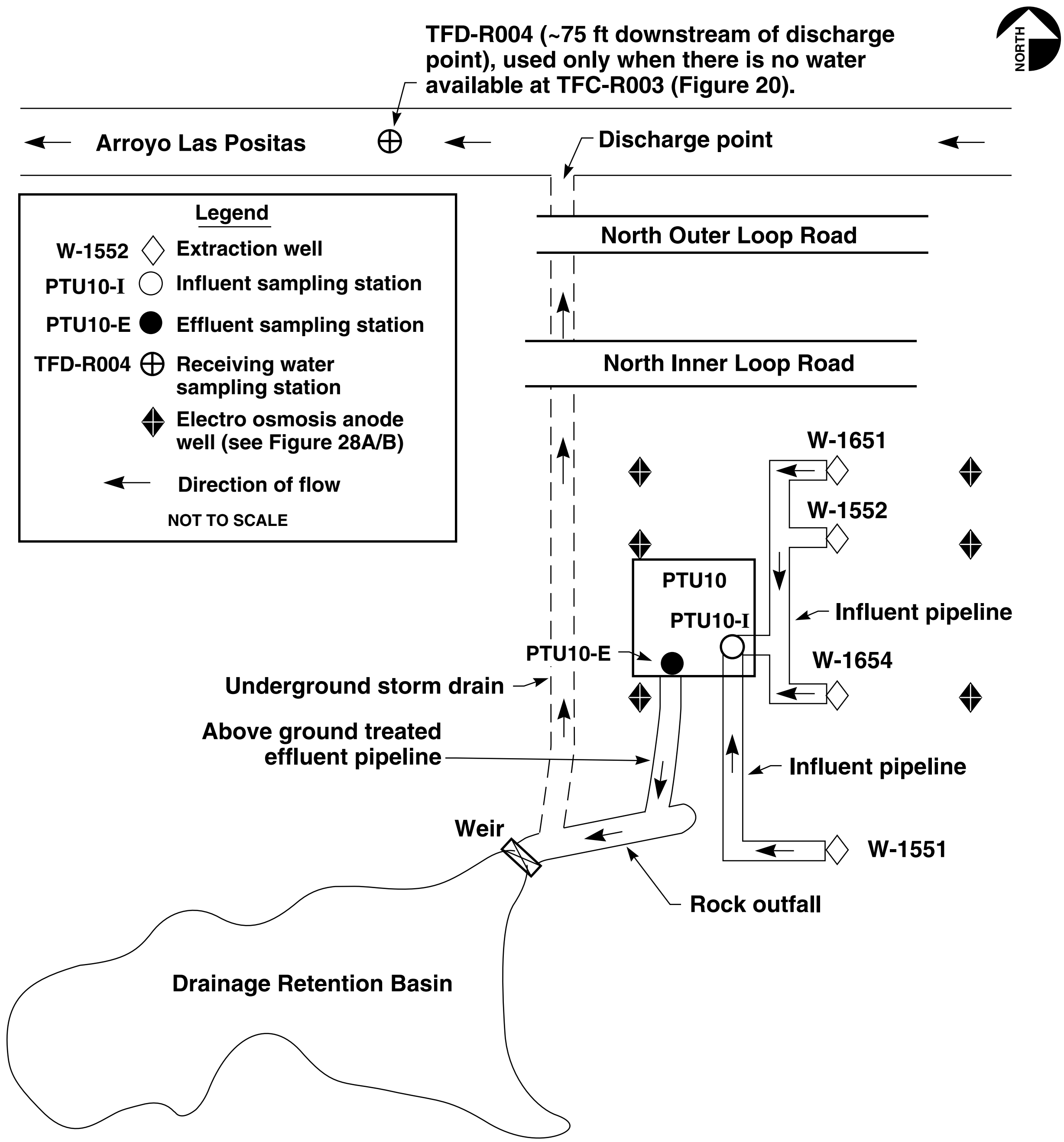


Figure 28A. TFD PTU10 wells and pipeline configuration for the electro-osmosis system.



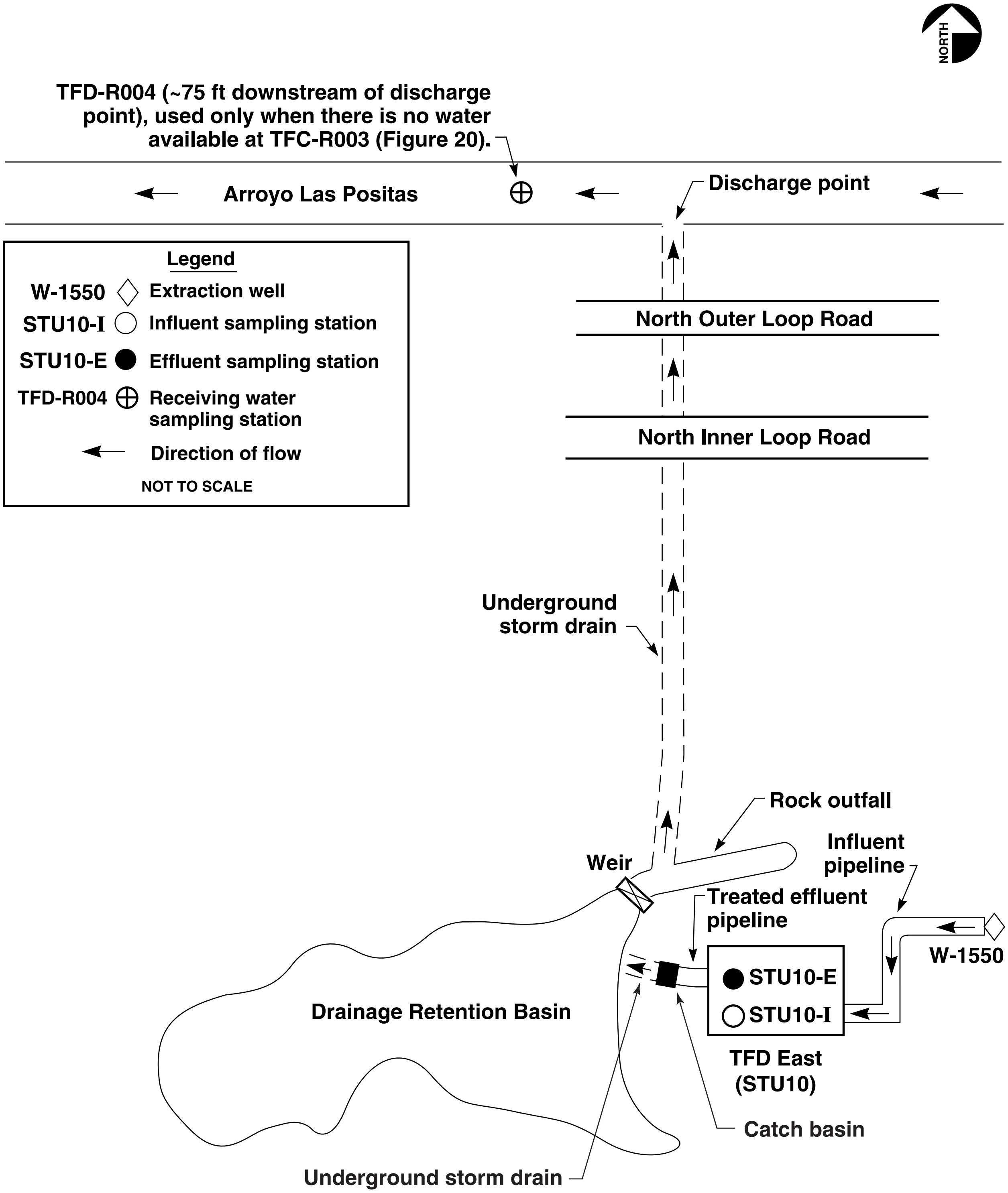
ERD-LSR-02-0060

Figure 28B. Electro-osmosis schematic diagram.



ERD-LSR-02-0047

Figure 29. TFD PTU10 extraction well, pipeline and discharge locations.



ERD-LSR-01-0049

Figure 30. TFD STU10 extraction well, pipeline and discharge locations.

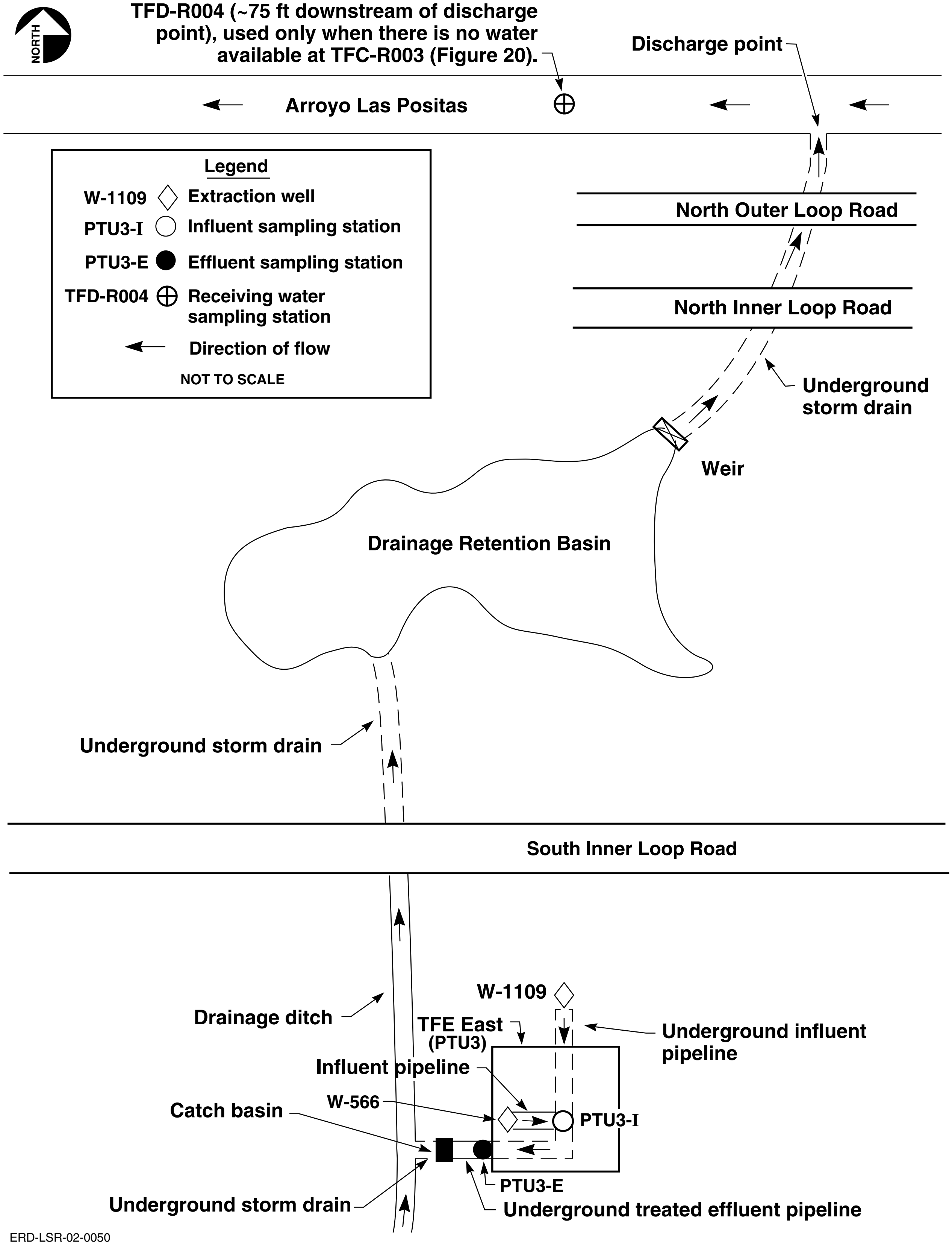
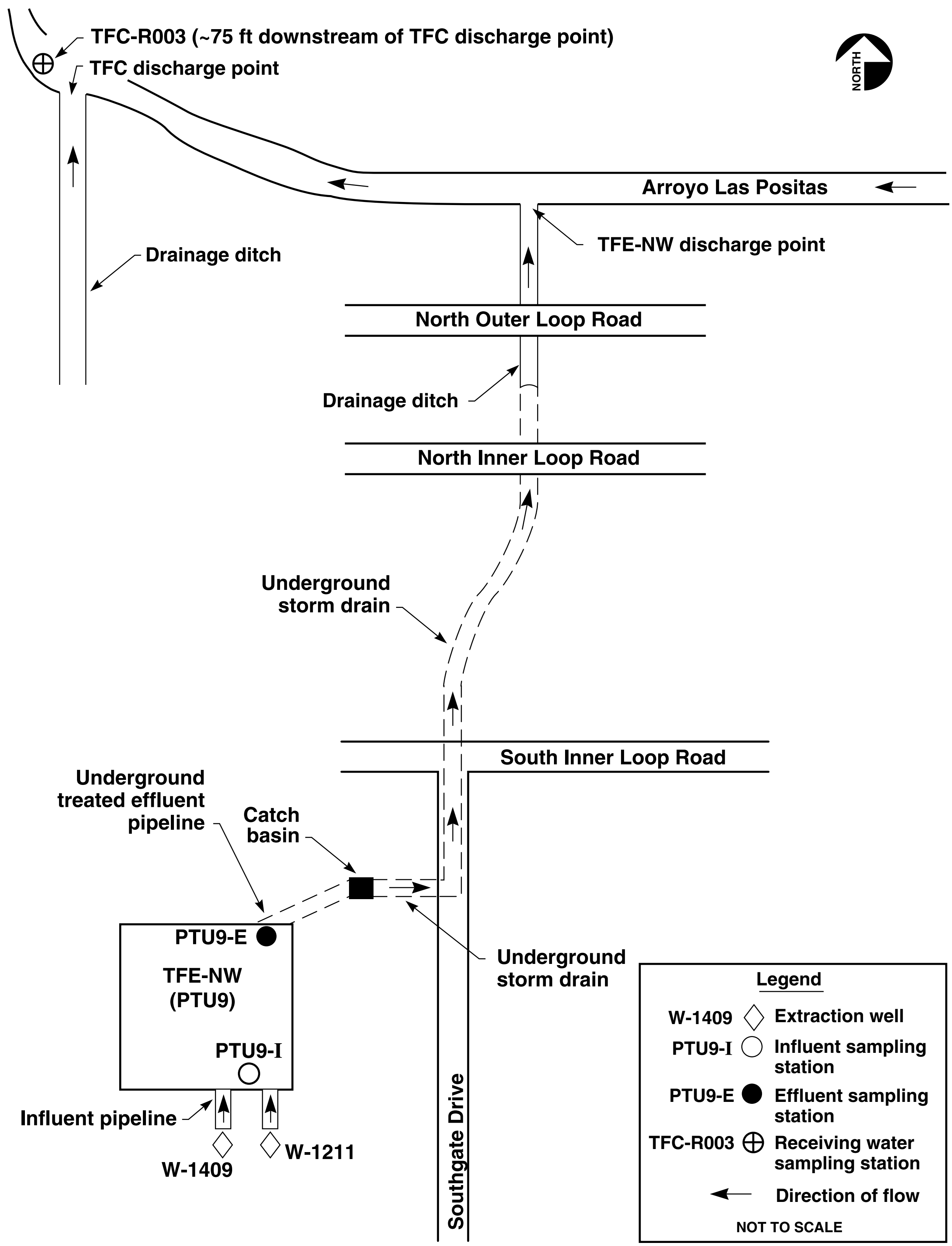


Figure 31. TFE East extraction well, pipeline and discharge locations.



ERD-LSR-02-0051

Figure 32. TFE Northwest extraction well, pipeline and discharge locations.

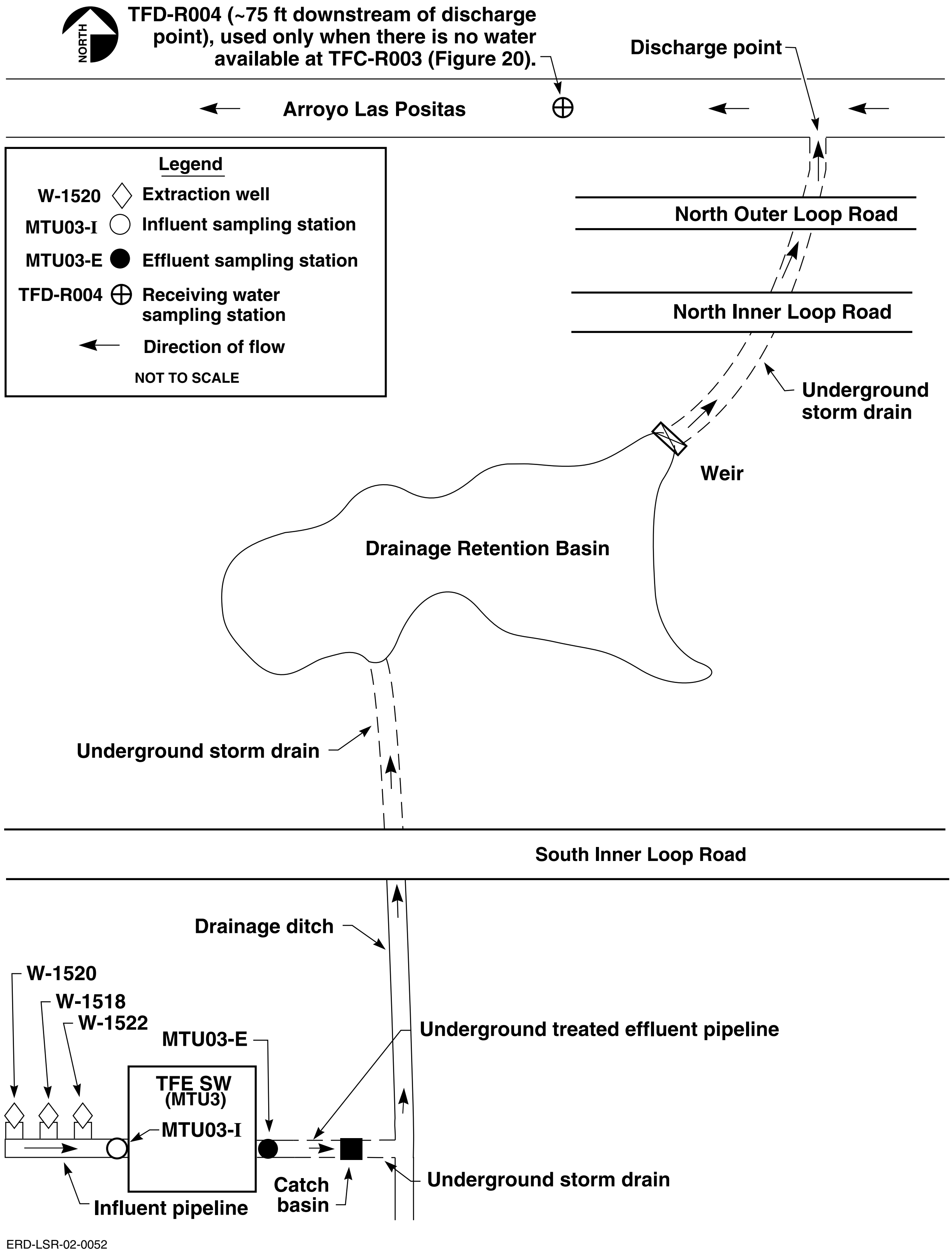


Figure 33. TFE Southwest extraction well, pipeline and discharge locations.

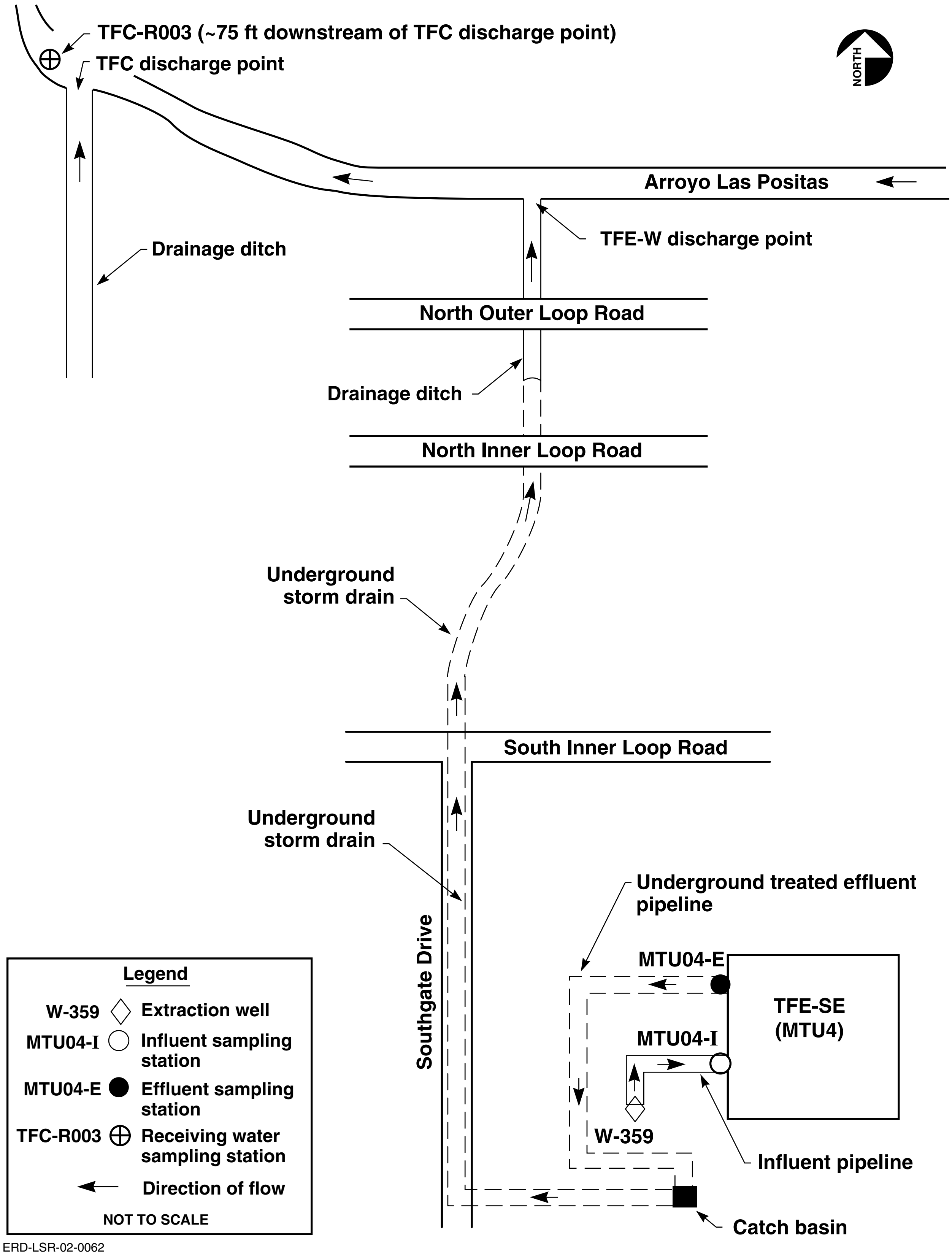


Figure 34. TFE Southeast extraction well, pipeline and discharge locations.

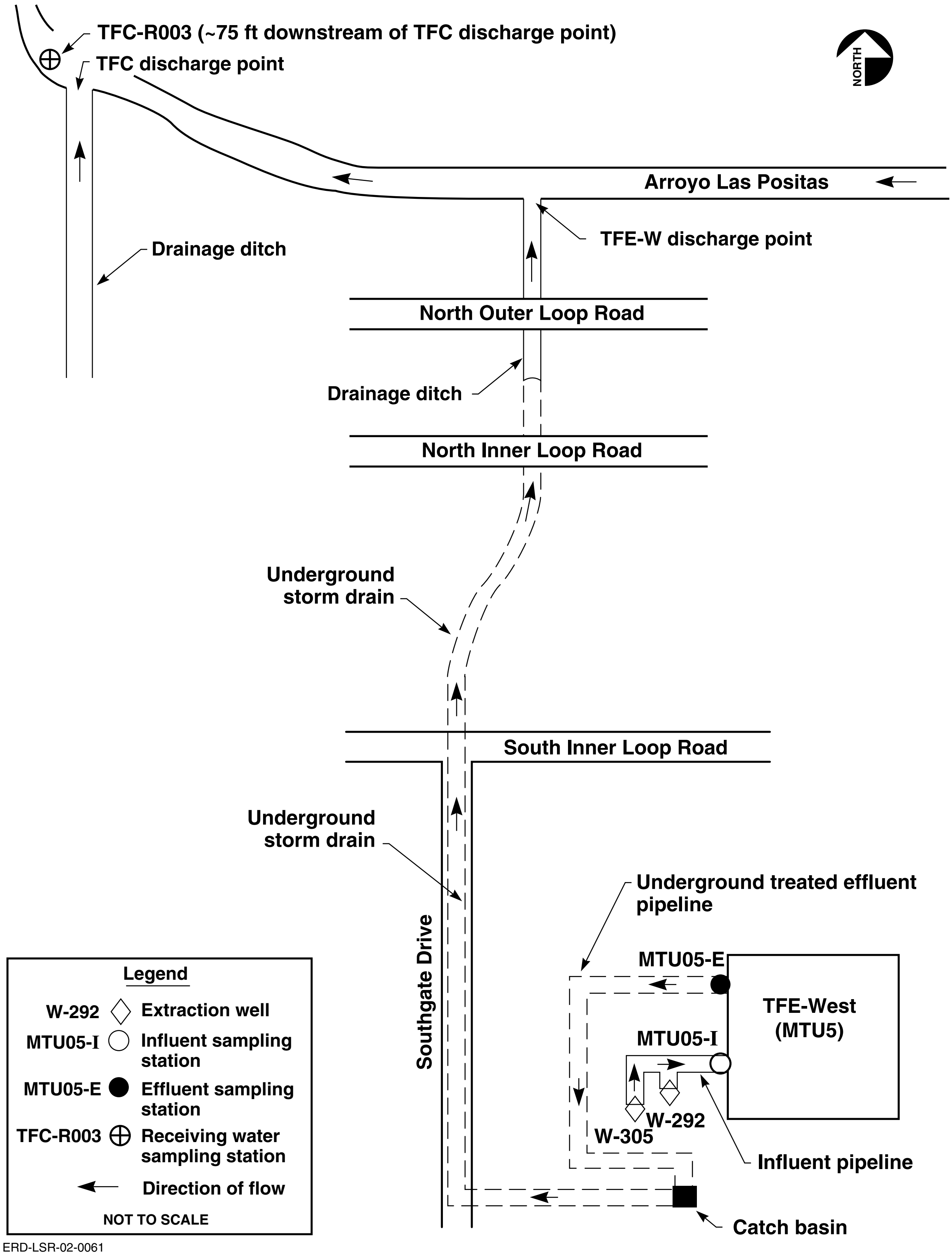


Figure 35. TFE West extraction well, pipeline and discharge locations.

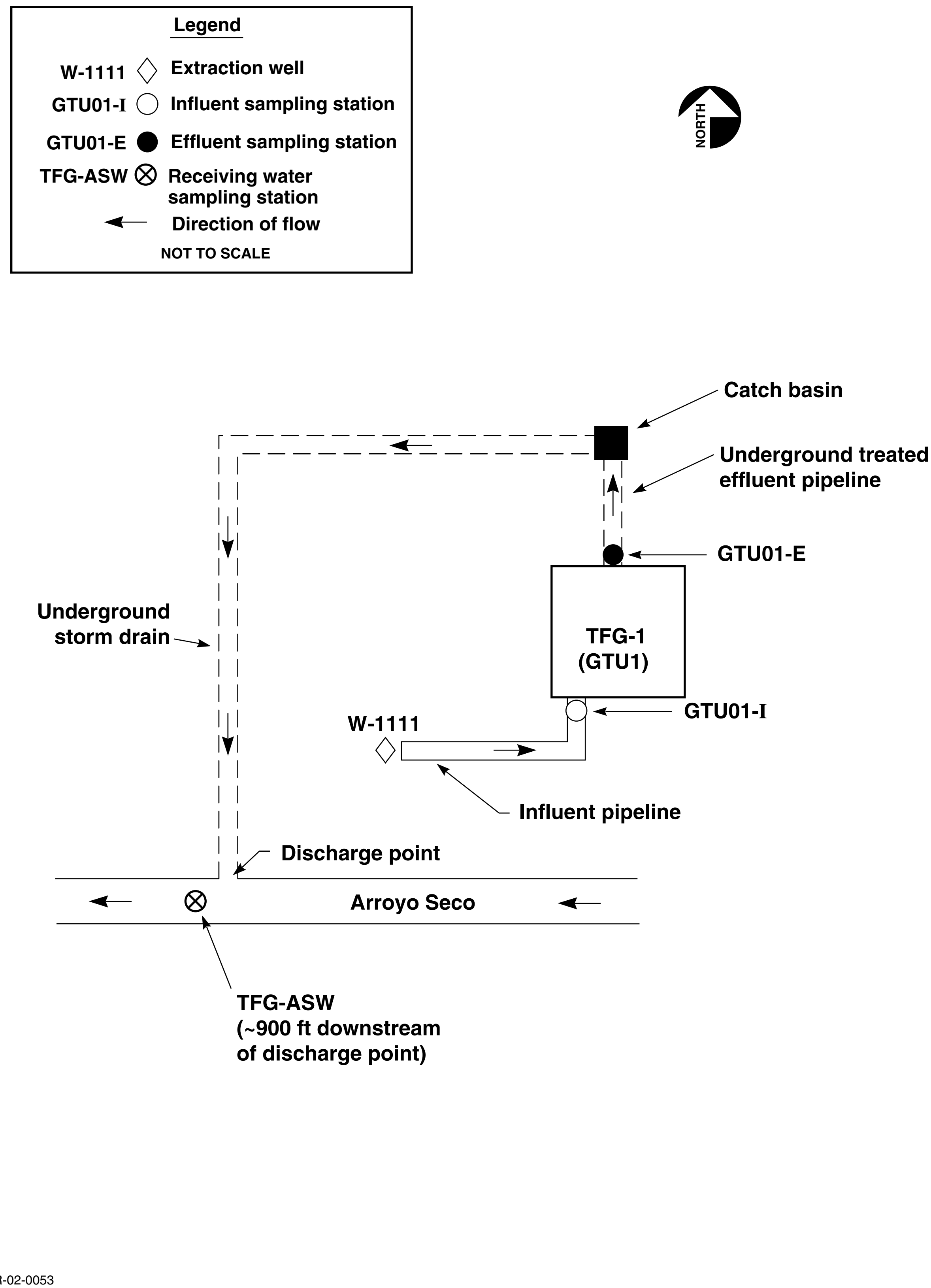


Figure 36. TFG-1 extraction well, pipeline and discharge locations.

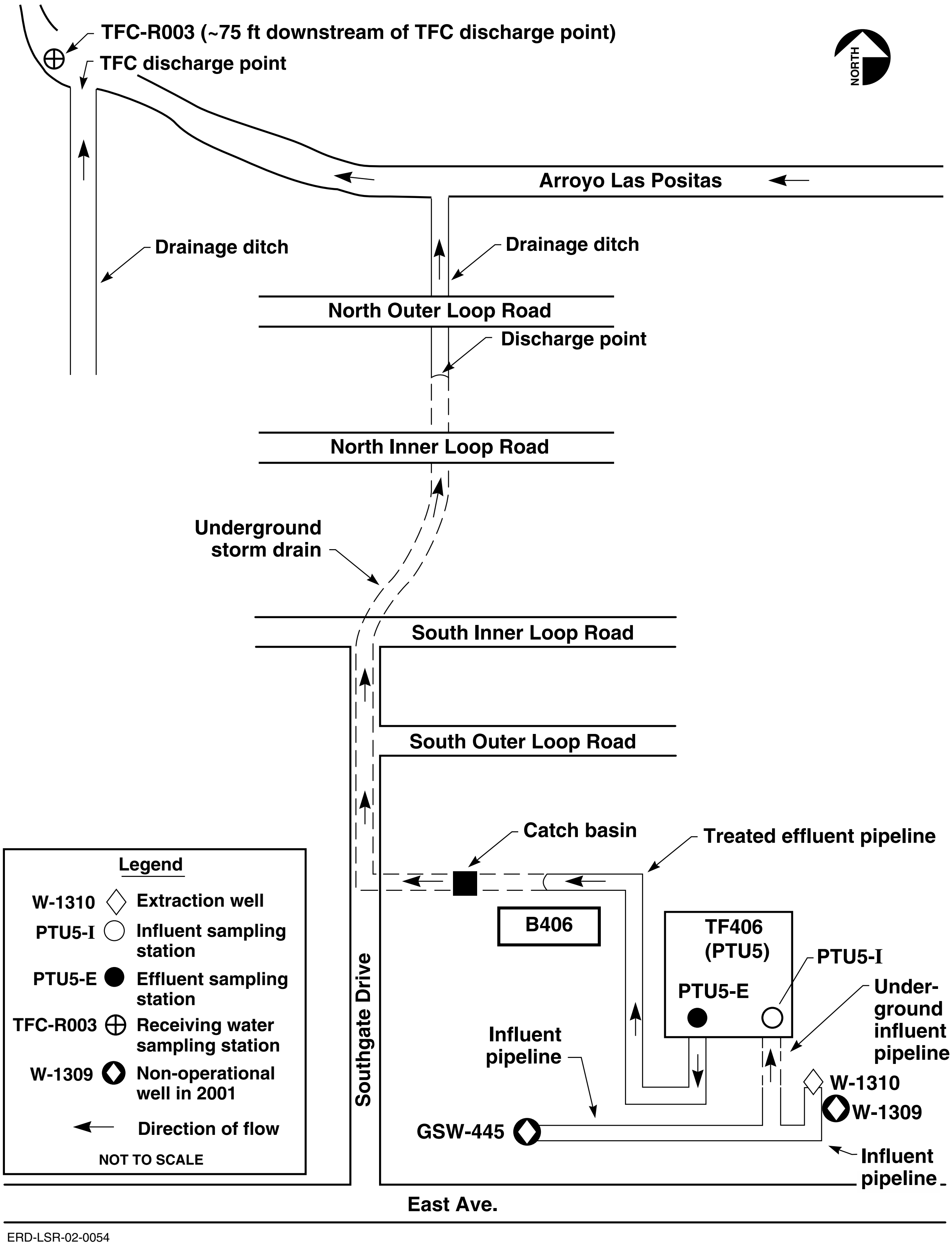


Figure 37. TF406 extraction well, pipeline and discharge locations.

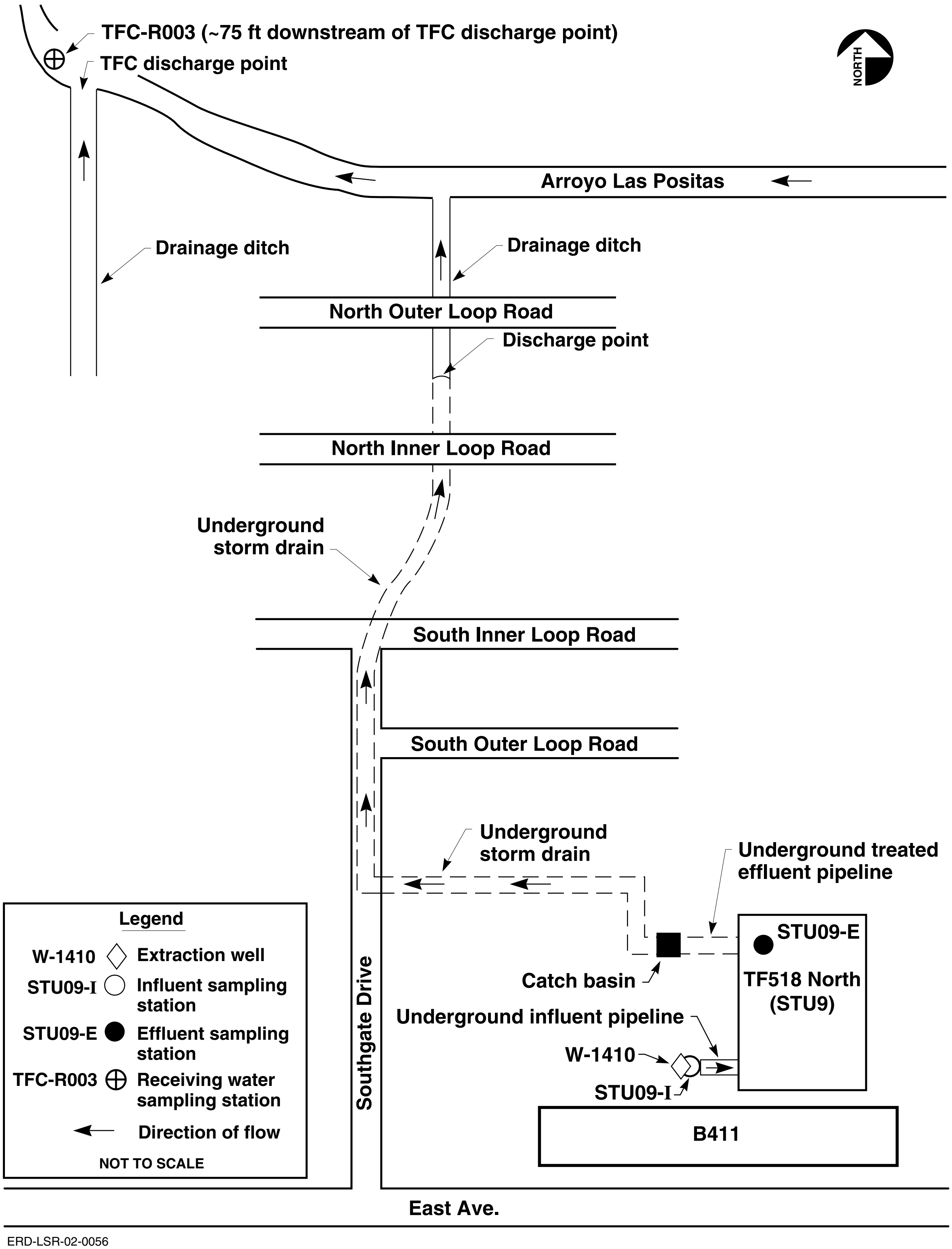


Figure 38. TF518 North extraction well, pipeline and discharge locations.

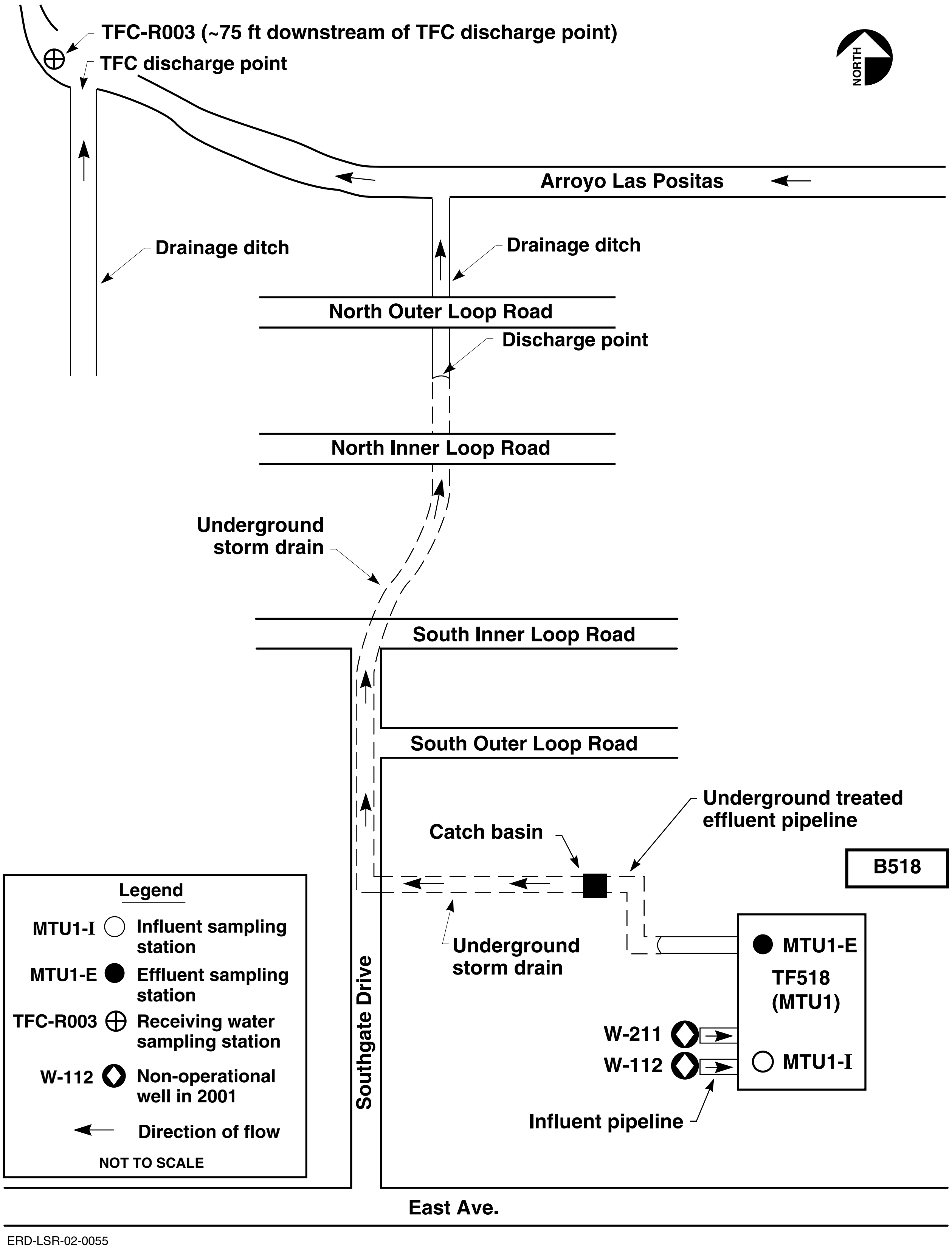


Figure 39. Former TF518 extraction wells, pipelines and discharge location.

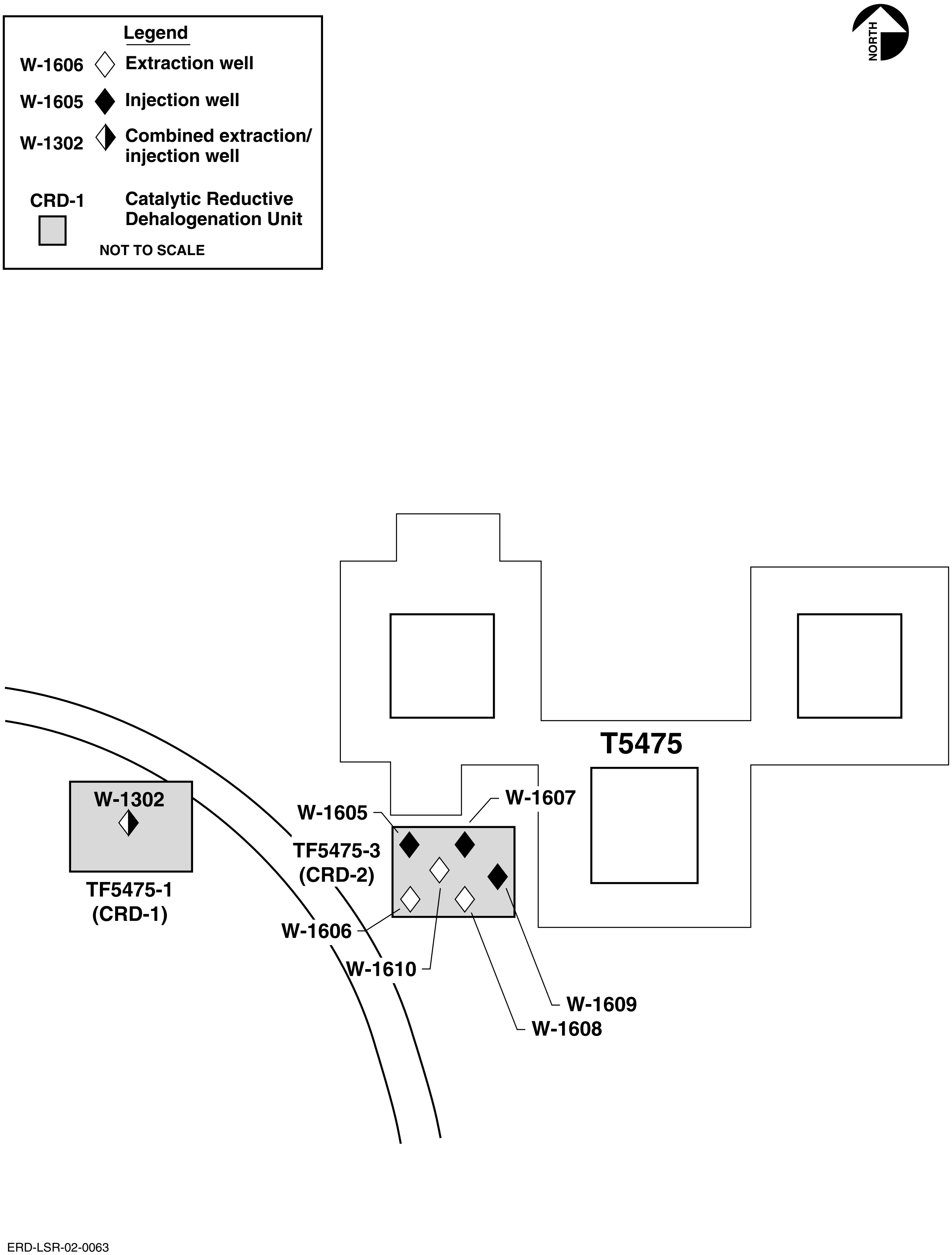
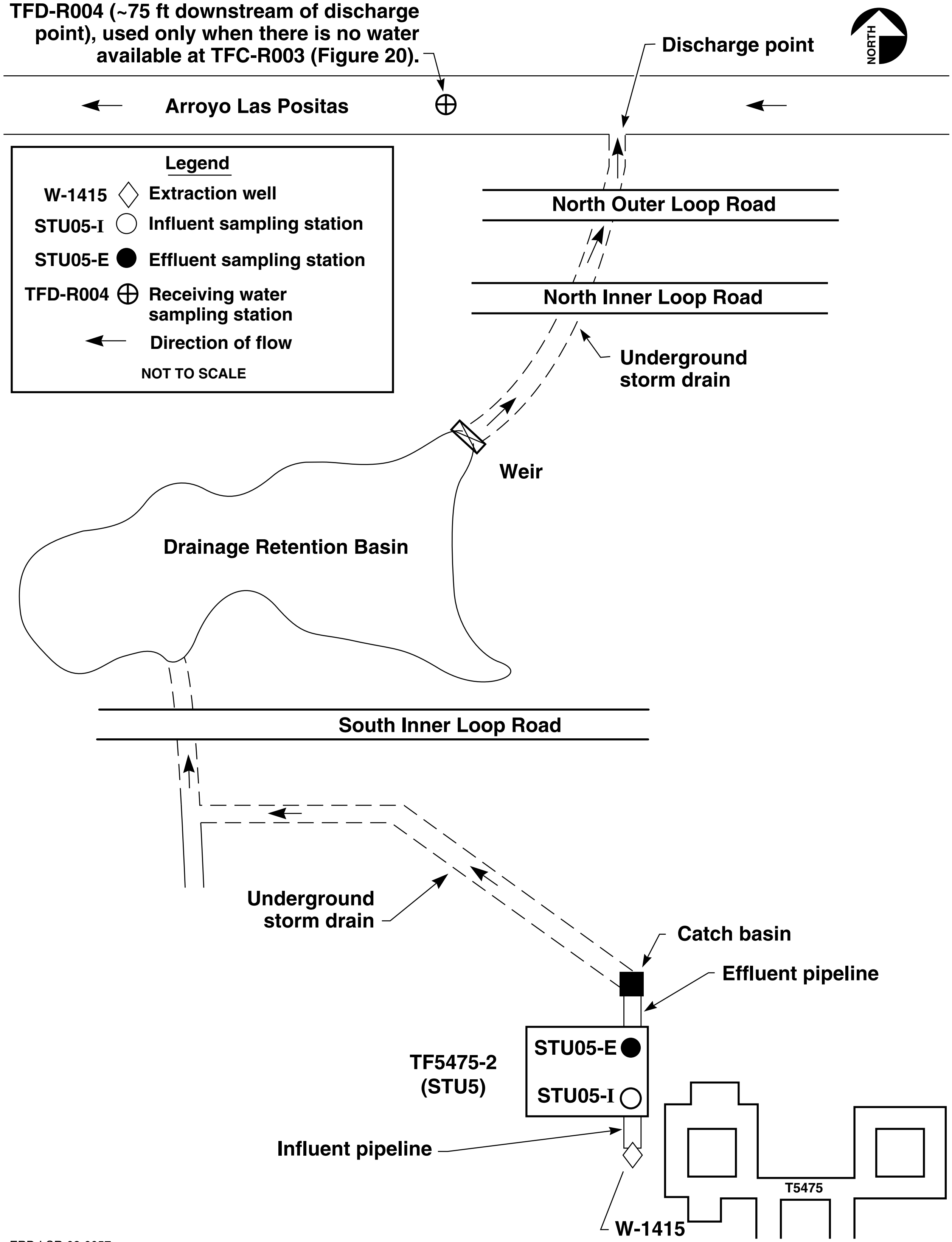


Figure 40. TF5475-1 (CRD-1), and TF5475-3 (CRD-2) extraction and injection wells. Note: wellhead influent and effluent sampling ports not shown in this diagram.



ERD-LSR-02-0057

Figure 41. TF5475-2 extraction well, pipeline and discharge locations.

Tables

Table 1. Livermore Site wells installed in 2001.

Treatment facility area	Well
TFA	W-1701
TFB	None
TFC	W-1704
TFD	W-1703
TFE	None
TF406	W-1705
TFG	None
TF518	W-1702
TF5475	None

Note:

See Figure 1 for well locations.

Table 2. Wells in which hydraulic tests were conducted in 2001.

Treatment facility area	Well(s)
TFA	W-1701
TFB	None
TFC	W-368, W-413
TFD	W-1703
TFE	W-1508, W-1512, W-1604
TF406	None
TFG	None
TF518	None
TF5475	None

Note:

See Figure 1 for well locations.

Table 3. 2001 Livermore Site Remedial Action Implementation Plan milestones.

Milestone	Milestone date	Completion date
Begin operation of Treatment Facility E Southeast miniature treatment unit (MTU)	01/31/01[a]	03/19/01[a]
Begin operation of Treatment Facility E West MTU	04/30/01	04/26/01
Begin operation of Treatment Facility D Marina Pipeline	07/31/01	07/25/01
Begin operation of TF5475 catalytic reductive dehalogenation Phase 3	09/28/01	09/19/01

[a] Delayed with regulatory agency concurrence due to the Federal Continuing Budget Resolution.

Table 4. Summary of 2001 VOC remediation.

Treatment facility area	Volume of ground water treated (Mgal)	Volume of soil vapor treated (Kft^3)	Estimated total VOC mass removed (kg)
TFA	107.8	–	10.2
TFB	31.2	–	6.9
TFC	20.0	–	7.2
TFD	73.0	–	90.1
TFE	33.2	–	25.4
TFG	1.5	–	0.3
TF406	10.6	–	0.9
TF5475	0.1	–	1.1
VTF5475	–	8,568	70.2
TF518	1.7	–	0.7
VTF518	–	104	2.6
Total	279*	8,672	216*

Notes:

kg = Kilograms.

kft^3 = Thousands of cubic feet.

Mgal = Millions of gallons.

* = Rounded number.

Table 5. Summary of cumulative VOC remediation.

Treatment facility area	Volume of ground water treated (Mgal)	Volume of soil vapor treated (Kft^3)	Estimated total VOC mass removed (kg)
TFA	916.3	–	147
TFB	175.0	–	52.2
TFC	126.8	–	47.3
TFD	324.7	–	432
TFE	115.9	–	121
TFG	15.3	–	3.0
TF406	46.2	–	6.7
TF5475	0.42	–	4.2
VTF5475	–	18,210	268
TF518	8.5	–	3.7
VTF518	–	15,011	153
Total	1,729*	33,221	1,238*

Notes:

kg = Kilograms.

kft^3 = Thousands of cubic feet.

Mgal = Millions of gallons.

* = Rounded number.

Appendix A

Well Construction and Closure Data

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California.

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
Monitor Wells						
W-1	21-Oct-80	122.5	116.0	95–100	1B/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 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 88–98	2/3A	NA
W-8	14-May-81	110.0	105.0	72–77 92–102	3A/3B	NA
W-10A	08-Sep-80	110.7	110.0	85–95 100–105	2	NA
W-11	03-Jun-81	252.0	191.0	136–141 177–187	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	127–132 147–157	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
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

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
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	7	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
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

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
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-255	05-Dec-85	187.0	124.0	115–124	5	1
W-256	19-Dec-85	187.0	137.0	132–137	5	<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	3A	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	3A	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
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

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
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-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-353	12-Nov-86	205.0	101.0	95.5–101	2	1
W-354	24-Nov-86	185.0	179.0	163–179	4/5	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-360	24-Feb-87	260.0	204.5	181.5–204.5	4	30
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

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
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
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

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
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-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-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
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

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
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	1B	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	1B	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
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-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

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
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	126.0	90.0	77–90	1B	2
W-706	16-Jan-91	178.0	84.0	71–84	1B	2
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
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	2
W-911	20-Dec-93	180.0	113.5	73.5–108.5	2	3
W-912	07-Oct-93	239.0	174.0	168–174	5	3
W-913	08-Dec-93	454.0	255.0	235–255	4	25
W-1002	31-Jan-94	292.5	260.0	246–260	5	16
W-1003	08-Feb-94	184.0	147.0	140–147	2	1.5
W-1008	13-Apr-94	246.0	238.0	229.5–238	7	10
W-1010	24-May-94	463.0	142.0	128–142	2	20
W-1011	06-Jun-94	106.0	89.0	75–89	1B	3
W-1012	20-Jun-94	161.0	117.0	96–112	2	5
W-1013	29-Jun-94	147.0	73.0	65–73	1B	1.4

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
W-1014	12-Jul-94	99.0	89.0	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	110.0	93.0	78–93	1B	3.5–4
W-1106	08-Feb-95	245.0	86.0	76–85	1B	15
W-1107	06-Mar-95	199.5	93.0	74–88	1B	<0.5
W-1108	27-Mar-95	250.0	156.0	142–156	5	12
W-1110	04-May-95	252.0	92.2	68–92	1B	7
W-1112	28-Jun-95	263.0	210.0	201–210	5	3
W-1113	18-Jul-95	260.0	214.0	204–214	5	2.5
W-1115	12-Oct-95	126.5	118.2	108–118	3A	1
W-1117	11-Sep-95	154.0	132.3	122–132	3A	1
W-1118	27-Sep-95	225.0	125.0	115–125	3A	3.5
W-1201	18-Oct-95	225.0	133.0	125–133	3A	1
W-1202	26-Oct-95	99.3	99.0	83–99	2	5⁺
W-1203	07-Nov-95	224.0	206.2	196–206	5	18⁺
W-1204	20 Nov-95	225.0	126.2	118–126	3A	2.5
W-1205	27-Nov-95	91.0	82.0	72–82	2	<0.5
W-1207	13-Dec-95	92.0	90.0	70–90	2	<0.5
W-1209	26-Jan-96	210.0	164.0	148–164	4	3
W-1210	12-Feb-96	250.0	223.0	213–223	5	3
W-1212	19-Mar-96	150.0	75.0	52–75	1B	3
W-1214	22-Apr--96	180.0	100.0	80–100	1B	2
W-1217	15-May-96	182.0	98.5	78–98	1B	<0.5
W-1218	29-May-96	240.0	145.5	127–145	3A	6.7
W-1219	04-Jun-96	201.0	142.0	138–142	4	<0.5
W-1220	12-Jun-96	120.0	117.0	90–112	2	18
W-1221	01-Jul-96	220.0	172.0	162–172	4	4
W-1222	26-Jun-96	175.0	125.5	115–125	3A	6
W-1223	23-Jul-96	175.0	102.0	87–97	2	4
W-1224	05-Sep-96	125.0	104.5	99–104	1B	4.3
W-1225	14-Aug-96	150.0	121.2	113–121	3A	2
W-1226	06-Aug-96	155.0	126.5	116–126	2	1
W-1227	09-Oct-96	200.0	134.0	126–134	2	11

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
W-1250	07-Jun-96	210.0	200.0	130–135	4	0.85
W-1251	03-Jul-96	210.0	200.0	134–139	4	1.3
W-1252	25-Jul-96	208.0	202.3	135–140	4	<0.5
W-1253	15-Aug-96	206.0	200.1	127–132	4	<0.5
W-1254	15-Aug-96	125.0	200.0	131–141	4	26
W-1255	27-Aug-96	208.0	200.7	124–129	4	<0.5
W-1304	20-Feb-97	149.5	125.0	120–125	3A	0.75
W-1311	25-Sep-97	153.0	120.5	100–120	2	14
W-1401	15-Oct-97	250.0	120.0	105–120	2	7
W-1402	04-Nov-97	135.0	112.0	102–112	3A	4
W-1403	12-Nov-97	175.0	142.5	132–142	3B	3.5
W-1404	20-Nov-97	162.0	97.7	87–97	2	3.1
W-1405	24-Nov-97	100.0	97.8	87–97	2	4.5
W-1406	15-Dec-97	201.0	150.0	139.2–149.2	4	9.2
W-1407	12-Dec-97	224.0	118.7	105–118	2	1.5
W-1408	12-Jan-98	134.0	128.0	118–128	3A	3.8
W-1411	04-Feb-98	133.0	128.0	114–128	3A	10
W-1412	11-Feb-98	201.0	107.0	92–107	3A	0.75
W-1413	26-Mar-98	163.5	157.7	147–157	5	1
W-1414	31-Mar-98	128.0	107.5	97–107	3A	0.1
W-1416	02-Jun-98	194.5	105.0	85–100	2	10
W-1417	23-Apr-98	225.0	155.0	130–150	3A	20
W-1419	11-May-98	175.0	115.5	90–110	2	4.5
W-1420	17-June-98	177.5	112.0	102–112	2	10
W-1421	28-May-98	230.0	172.0	156–167	3B	3
W-1424	20-Aug-98	225.0	146.0	126–146	2	6.2
W-1425	31-Aug-98	115.0	100.5	88.5–100.5	1B	1
W-1426	09-Sep-98	89.0	85.0	70–85	1B	8
W-1427	22-Sep-98	104.0	80.2	70–80	1B	17
W-1428	29-Sep-98	104.0	78.4	63–78	1B	25
W-1501	13-Oct-98	126.0	86.0	72–86	1B	7.5
W-1502	28-Oct-98	204.0	98.7	88–98	2	1.7

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
W-1503	18-Nov-98	234.0	181.5	171–181	4	25
W-1504	14-Dec-98	168.0	162.5	140–160.4	3A/3B	21.7
W-1505	21-Jan-99	276.0	184.5	174–184	4	15
W-1506	8-Feb-99	160.0	120.0	110–120	2	3
W-1507	19-Feb-99	201.5	169.5	159–169	5	0.5
W-1508	3-Mar-99	135	128.5	118–128	2	0.75
W-1509	22-Mar-99	175	88.5	73–88	1B	8
W-1510	7-Apr-99	114.5	113.5	93–113	2	5
W-1511	22-Apr-99	229	146	138–146	3B	15
W-1512	29-Apr-99	100	98.5	88–98	2	0.5
W-1513	10-May-99	122	120	108–120	2/3A	0.1
W-1514	19-May-99	127.5	126	103–121	2/3A	6.5
W-1515	3-Jun-99	130	121.5	102–120	2/3A	3
W-1516	22-Jun-99	204.5	200	188–200	5	10
W-1517	29-Jun-99	154	122.4	87–97	2	0.1
W-1519	28-Jul-99	245	238	222–237	5	30
W-1553	12-Aug-99	153	130	98–125	3A/3B	0.5
W-1604	30-Nov-99	194	148.7	138–148	4	8
W-1605	07-Mar-00	120.5	112	90–107	3A	<0.5
W-1607	10-Feb-00	155.4	112	90–107	3A	<0.5
W-1609	17-Apr-00	155	135	110–130	5	0.5
W-1610	04-May-00	155.3	135	110–130	5	0.5
W-1613	27-Apr-00	219	174.3	168.5–173.5	3B	7
W-1614	18-May-00	100	89.8	79–89	1B	3
W-1615	17-Aug-00	55	48	15–48	1B/2	NA
W-1616	16-Aug-00	55	NA	NA	1B/2	NA
W-1701	3-Jul-01	185	180.8	140–155	2	10.5
				165–175	2	10.5
W-1702	15-Jun-01	15	14.25	4–13	1B	NA
W-1703	23-Aug-01	358	341.5	331–341	LL	36
W-1704	19-Sep-01	240	118.8	98–118	2	1

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
W-1705	16-Oct-01	225	208.8	93–103	2	5
				123–128	3A	5
				138–143	3B	5
				203–208	5	5
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
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	3A	12
GSW-2	14-Feb-85	113.0	107.0	87–107	2	NA
GSW-3	07-Feb-85	115.0	105.0	85–105	2	NA
GSW-4	22-Feb-85	112.0	106.0	86–106	2	NA
GSW-5	19-Mar-85	110.0	104.0	94–104	2	NA
GSW-6	28-Feb-86	212.0	137.0	121–137	3A	6
GSW-7	14-Mar-86	176.5	123.4	110.8–123.4	3A	2
GSW-8	01-Apr-86	176.0	133.0	127.5–133	3A	2
GSW-9	14-Apr-86	197.5	152.5	147–152.5	3B	1
GSW-11	07-May-86	182.5	126.0	116–126	3A	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	3A	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	2	–
				120–130	3A	–
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	2	–
				120–130	3A	–

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
GSW-208	06-Feb-86	211.0	123.0	108–118	3A	<2
GSW-209	27-Feb-86	204.0	135.2	112.8–132.8	3A	2
GSW-215	22-Apr-86	213.5	133.5	127–133.5	3A	2
GSW-216	09-May-86	193.0	120.5	110.5–120.5	3A	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	3A	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
Dynamic Stripping Project Wells[c]						
GSP-SNL-001	07-Jan-92	147.0	104.0	99–104	2	NA
			131.0	118–131	3A	NA
GEW-808	05-Jun-92	164.0	150.0	50–140	2/3A	25
GIW-813	25-Jun-92	140.7	87.0	67–87	2	NA
			104.0	89–99	2	
			127.0	107–127	2/3A	NA
GIW-814	19-Jun-92	149.6	106.5	86.5–106.5	2	NA
			117.0	110–120	3A	
			132.0	121–141	3A	NA
GIW-815	15-Jun-92	143.0	97.0	77–97	2	NA
			117.0	102–112	2/3A	
			132.0	112.8–132	3A	NA
GEW-816	03-Jun-92	161.7	150.0	50–140	2/3A	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	3A	NA
GIW-819	10-Jul-92	150.0	98.6	78.6–98.6	2	NA
			123	108–118	3A	
			141	121–141	3A	NA

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
GIW-820	16-Jul-92	143.3	105	85–105	2	NA
			132	112–132	3A	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	NA
HW-GP-103	23-Aug-93	138.0	137.5	71.5–132.5	2/3A	NA
HW-GP-104	02-Sep-93	138.0	137.2	72.2–132.2	2/3A	NA
HW-GP-105	28-Sep-93	138.0	137.5	72.5–132.5	2/3A	NA
TEP-GP-106	21-Sep-93	137.5	135.5	NA	NA	NA
Extraction Wells						
GSW-445	09-Dec-87	319.0	161.0	155–161	4	3
W-109	02-Apr-85	289.0	147.0	137–147	2	12
W-112	10-May-85	129.0	123.5	111–123.5	5	4
W-254	21-Nov-85	277.0	91.5	84.5–91.5	1B	5
W-262	20-Mar-86	256.0	100.0	91–100	1B	7
W-314	20-Mar-87	228.0	142.0	129–142	4	9.5
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-359	10-Feb-87	195.0	150.5	138–150.5	5	10
W-361	05-Mar-87	257.0	135.0	125–135	3A	4
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/2	>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

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
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
W-605	08-Dec-89	246.0	136.0	130–136	2	10
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	2	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 88–97	1B	20
W-712	29-Aug-91	200.0	185.5	170–185.5	3A	8
W-714	02-Jul-91	135.0	128.0	107–128	2	7.5
W-903	28-Apr-93	223.0	145	132–140	2	20
W-904	06-May-93	212.0	154.0	121–133 140–149	2	20
W-906	27-Jul-93	200.0	132.0	58–132	2/3A	10
W-907	02-Sep-93	239.0	220.0	172.7–188.8 204.5–215.0	4 5	25 NA
W-1001	20-Dec-93	105.0	92.0	85–92	1B	1.4
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 92–98	1B	35+

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
W-1109	11-Apr-95	121	113	94–108	2	3
W-1111	01-Jun-95	152	129	88–108	1B/2	10.5
				120–124	2	NA
W-1116	17-Aug-95	214	101	72–98	1B	9
W-1206	06-Dec-95	220.0	191.0	174–186	4	40+
W-1208	09-Jan-96	166.0	163.0	135–163	3A/3B	40
W-1211	05-Mar-96	273.0	205.0	185–200	4	25+
W-1213	02-Apr-96	129.0	76.0	64–76	1B	5+
W-1215	17-Apr-96	175.0	120.0	103–120.5	2	8.5
W-1216	07-May-96	200.0	124.0	94–124	2	14
W-1301	04-Dec-96	180.0	120.3	112–120	3A	15
W-1302	21-Jan-97	145.0	138.9	116.5–122.2	3A	7.5
				125.8–133.8		
W-1303	06-Feb-97	199.5	107	78–102	2	10
W-1306	06-May-97	200	106	81–101	2	3.3
W-1307	07-Feb-97	150	142	126–136	4	20
W-1308	22-Jul-97	150.0	116.0	81–111	2	7
W-1309	11-Aug-97	220.0	157.0	142–152	4	6.0
W-1310	08-Sep-97	220.0	198.0	173–193	5	28
W-1409	23-Jan-98	143	140	76–140	2	20
W-1410	20-Feb-98	205.0	133.0	126–131	4	8
W-1415	15-Apr-98	182.0	104.8	74.5–104.5	2	2
W-1418	05-May-98	252.5	190.0	176–190	4	9
W-1422	14-May-98	173.5	169.0	162–169	3A/3B	10
W-1423	08-Jul-98	175.0	134.5	99.5–109.5	2	22.4
				119.5–129.5		
W-1503	18-Nov-98	234.0	181.5	171–181	4	25
W-1504	14-Dec-98	168.0	162.5	140–160.4	3A/3B	21.7
W-1510	7-Apr-99	114.5	113.5	93–113	2	5
W-1513	10-May-99	122	120	108–120	2/3A	0.1
W-1514	19-May-99	127.5	126	103–121	2/3A	6.5
W-1515	3-Jun-99	130	121.5	102–120	2/3A	3
W-1518	6-Jul-99	184	112	84–107	2	3

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
W-1520	23-Jul-99	178.3	173	160–168	4	3.5
W-1522	9-Aug-99	169	161	141–156	3B	9
W-1523	1-Aug-99	216	172.3	164–172	4	15
W-1550	22-Jun-99	200	130	98–125	3A/3B	10
W-1551	8-Jul-99	153	129	93–124	3A/3B	10.5
W-1552	27-Jul-99	153.5	130	97–125	3A/3B	2
W-1601	18-Oct-99	169	160	150–155	3B	3.5
W-1602	27-Oct-99	115.5	110.7	80–90 100–110	2	8
W-1603	10-Nov-99	144	140	130–135	3A	17.2
W-1606	27-Jan-00	175	112	90–107	3A	<0.5
W-1608	25-Feb-00	155	112	90–107	3A	<0.5
W-1650	03-Jan-00	145	126	96–121	3A/3B	2
W-1651	27-Jan-00	145	129	94–124	3A/3B	1
W-1652	09-Feb-00	145	127	92–122	3A/3B	0.33
W-1653	24-Feb-00	145	124.5	93.5–119.5	3A/3B	1.2
W-1654	25-Feb-00	146.5	128	93–123	3A/3B	0.8
W-1655	08-Mar-00	145	125	90–125	3A/3B	1.3
W-1656	14-Mar-00	145	125	95–120	3A/3B	5
W-1657	23-Mar-00	145	128	95–123	3A/3B	<1
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	1B	NA
				102–108	2	
11Q4	NA	NA	NA	NA	NA	NA
11Q5	NA	NA	NA	NA	NA	NA
14A3	07-Dec-77	NA	110	100–105	1B	NA
14A11[d]	NA	NA	NA	NA	NA	NA
14B1	13-Aug-59	300	234	146–149	2	NA
				192–195	3A	–
				198	3A	–

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
				200	3A	–
				203	3A	–
				205	3A	–
				207	3A	–
				209–213	3A	–
				226	3A	–
				230	3B	–
				234	3B	–
14B4	Aug-60	NA	260	143–148	2	NA
				155–159	2	–
				186–189	3A	–
				205–215	3A	–
				245–250	4	–
14B7	NA	NA	NA	NA	NA	NA
14H1	NA	NA	288	NA	NA	NA
14H2[d]	NA	NA	NA	NA	NA	NA
18D1[d]	NA	NA	NA	NA	7	NA
Source Investigation Piezometers						
SIP-141-201	02-Feb-96	77	74.2	57–74	1B	NA
SIP-141-202	12-Feb-96	80	74	64–74	1B	NA
SIP-141-203	20-Feb-96	87	83	72–83	1B	NA
SIP-191-001	15-Apr-94	50	45	40–45	1A	NA
SIP-191-002	21-Apr-94	50	61	45–61	1B	NA
SIP-191-003	26-Apr-94	50.5	45	35–45	1B	NA
SIP-191-004	29-Apr-94	57.5	53.5	47.5–53.5	1B	NA
SIP-191-005	04-May-94	54	48	42–48	1A	NA
SIP-191-101	18-Nov-94	68.5	64	58–64	1B	NA
SIP-212-101	14-Mar-96	94	90.5	87–90.5	2	NA
SIP-293-001	05-Dec-90	56.5	50	45–50	1B	NA
SIP-331-001	21-Sep-91	122	116.5	106.5–116.5	2	NA
SIP-419-101	08-Sep-98	127	123	112–123	3B	NA
SIP-419-202	06-Mar-96	110	106.5	97–106.5	3A	NA
SIP-490-102	08-Nov-95	75	73.5	53.5–73.5	2	NA
SIP-501-004	20-0ct-94	60	56.9	48–56.9	1B	NA

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
SIP-501-006	11-Nov-92	59.5	56	50–56	1B	NA
SIP-501-007	16-Nov-92	64	59	53–59	1B	NA
SIP-501-101	10-May-94	77.5	73	69–73	1B	NA
SIP-501-102	16-May-94	77	73	67–73	1B	NA
SIP-501-103	20-Mar-94	63	57.5	51–57.5	1B	NA
SIP-501-104	15-Jul-94	67	62	50–62	1B	NA
SIP-501-105	01-Sep-94	73	68	63–68	1B	NA
SIP-501-201	29-Nov-94	65	58.5	54–58.5	1B	NA
SIP-501-202	01-Jul-95	70	64.5	58–64.5	1B	NA
SIP-511-101	25-Jan-96	110	106.7	100–106.7	3A	NA
SIP-511-102	02-Apr-96	114	110.3	108–110	3B	NA
SIP-514-107	03-Jan-90	21.5	17	9–17	1B	NA
SIP-514-109	05-Jan-90	21.5	20	7–22	1B	NA
SIP-514-112	08-Jan-90	21.5	18	7–18	1B	NA
SIP-514-114	09-Jan-90	21.5	17	4–17	1B	NA
SIP-514-116	10-Jan-90	21.5	17	7–17	1B	NA
SIP-514-117	11-Jan-90	21.5	17.5	7–17.5	1B	NA
SIP-514-119	12-Jan-90	21.5	16	6–16	1B	NA
SIP-514-123	17-Jan-90	26.5	23	11.5–23	1B	NA
SIP-514-124	18-Jan-90	21.5	17	6–17	1B	NA
SIP-514-125	19-Jan-90	21.5	15	6–15	1B	NA
SIP-514-126	18-Jan-90	26.5	21.5	4–21.5	1B	NA
SIP-518-203	19-Sep-95	127	127	121–127	5	NA
SIP-543-101	31-Jan-95	111	104	43–103	2	NA
SIP-ALP-001	03-May-90	66	60	45–60	2	NA
SIP-ALP-002	07-May-90	62	57.5	47.5–57.5	1B/2	NA
SIP-AS-001	30-Apr-90	100	100.5	81–90.5	1B	NA
SIP-CR-049	26-Feb-90	42	40	36–40	1B	NA
SIP-EGD-001	16-Oct-90	101.5	85	75–85	2	NA
SIP-ETC-201	26-Mar-96	106	101	81–101	2	NA
SIP-ETC-301	12-Apr-99	102	83	76–82	2	NA
SIP-ETC-303	24-May-99	111	88.1	82–88	2	NA
SIP-ETS-201	05-Feb-91	95	90	85–90	3A	NA
SIP-ETS-204	07-May-91	93	97	87–97	3A	NA
SIP-ETS-205	20-Jun-91	103	95	89.5–95	3A	NA

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
SIP-ETS-209	25-Jul-91	96.6	90	79.75–90	2	NA
SIP-ETS-211	06-Aug-91	103	98.5	95–98.5	3A	NA
SIP-ETS-212	14-Aug-91	106.5	1023	97.5–1023	2	NA
SIP-ETS-213	15-Nov-91	118.5	116.5	108.5–116.5	3A	NA
SIP-ETS-214	22-Nov-91	101	101	86–101	3A	NA
SIP-ETS-215	03-Dec-91	94.5	94.5	84.5–94.5	3A	NA
SIP-ETS-302	30-Mar-92	117.4	113	97–113	3A	NA
SIP-ETS-303	02-Apr-92	110.7	102	95–102	3A	NA
SIP-ETS-304	27-Aug-92	100	97	90–97	3A	NA
SIP-ETS-306	11-Sep-92	101	93	80.5-93	3A	NA
SIP-ETS-401	02-Aug-95	122	121	116–121	3A	NA
SIP-ETS-402	08-Aug-95	110	107	97–107	2	NA
SIP-ETS-404	22-Aug-95	99	95.5	83.5–95.5	2	NA
SIP-ETS-405	29-Aug-95	126	123	114.5–123	5	NA
SIP-ETS-501	16-Nov-95	110	106.5	100–1006.5	3A	NA
SIP-ETS-502	05-Dec-95	95	88	80–88	2	NA
SIP-ETS-601	07-Jun-99	115.5	104.9	98.3–104.8	2	NA
SIP-HPA-001	20-Apr-90	92.75	75	65–75	2	NA
SIP- HPA-003	19-Apr-90	91.5	66	61–66	2	NA
SIP- HPA-102	08-Dec-94	76	72	67–72	2	NA
SIP-HPA-103	01-Mar-95	77	72.5	67–72.7	2	NA
SIP- HPA-201	14-May-96	97.5	76	71–76	2	NA
SIP-IES-001	16-Sep-92	50.2	46.5	44–46.5	1B	NA
SIP-IES-002	05-Oct-92	41.5	39.2	33–39.2	1A	NA
SIP-INF-201	30-Jun-98	85.9	85.0	64.9–84.6	1B	NA
SIP-INF-202	02-Jul-98	86.3	85.2	64.9–84.8	1B	NA
SIP-INF-301	24-Mar-99	97	95.4	60–95	1B	NA
SIP-INF-302	29-Mar-99	97	88.4	53–88	1B	NA
SIP-ITR-001	19-Apr-91	121.6	115	105–115	5	NA
SIP-ITR-002	02-Apr-91	100	84	79–84	5	NA
SIP-ITR-003	25-Apr-91	121.5	106	98.5–106	5	NA
SIP-NEB-101	23-Sep-92	68.7	66	57–66	2	NA
UP-292-006	07-Nov-90	74	57.5	47.5–57.5	1B	NA
UP-292-007	26-Nov-90	71	56	46–56	1B	NA
UP-292-012	31-Oct-91	67.7	60	45–60	1B	NA

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
UP-292-014	07-Nov-91	66	66	50–66	1B	NA
UP-292-015	11-Nov-91	61.5	60.5	49.5–60.5	1B	NA
UP-292-020	30-Oct-92	68.5	64	56.5–64	1B	NA
SIP-PA-002	29-Jan-90	16.5	16.5	4–16.5	1B	NA
SIP-PA-003	26-Jan-90	18	14	4–14	1B	NA
SIP-PA-005	04-Jan-90	11.5	8	3–8	1B	NA
SIP-PA-006	04-Jan-90	13.5	12	5–12	1B	NA
SIP-PA-007	04-Jan-90	11.5	5	1–5	1B	NA
SIP-PA-010	25-Jan-90	11.5	9	3–9	1B	NA
SIP-PA-012	29-Jan-90	11.5	9	2–9	1B	NA
SIP-PA-013	24-Jan-90	16.5	13	8–13	1B	NA
SIP-PA-015	25-Jan-90	21.5	17.5	2–17.5	1B	NA
SIP-PA-016	24-Jan-90	11.5	11.5	7–11.5	1B	NA
SIP-PA-017	24-Jan-90	16.5	14	7–14	1B	NA
SIP-PA-018	25-Jan-90	11.5	8	6–8	1B	NA
SIP-PA-019	26-Jan-90	16.5	12	2–12	1B	NA
SIP-PA-021	23-Jan-90	11.5	10	2–10	1B	NA
SIP-PA-024	23-Jan-90	16.5	15	5–15	1B	NA
SIP-PA-025	23-Jan-90	11.5	7	4–7	1B	NA
SIP-PA-026	29-Jan-90	11.5	10	2–10	1B	NA
SIP-PA-027	29-Jan-90	8.5	7	2–7	1B	NA
SIP-PA-028	23-Jan-90	11	8	5–8	1B	NA
SIP-PA-030	24-Jan-90	11.5	8	4–8	1B	NA
SIP-PA-034	04-Jan-90	6.5	5	3–5	1B	NA
SIP-PA-035	04-Jan-90	11.5	11.5	6.5–11.5	1B	NA
Soil Vapor Installations						
IMS-INF-203	08-Jul-98	63	63	NA[e]	1A	NA
SVI-518-101	21-Sep-90	125	61	55–61	2	NA
SVI-518-202	03-Nov-93	120.6	73.8	19–73.8	1B/2	NA
SVI-518-204	05-Nov-93	121.5	46	24–46	1B/2	NA
SEA-518-301	11-Sep-95	102.6	100	NA[e]	1B/2/5	NA
SVI-518-302	22-Jun-95	104.5	39.3	11–39	1B	NA
SEA-518-304	11-Sep-95	100	50	NA[e]	1B/2/5	NA
SEA-ETS-305	03-Sep-92	85	85	NA[e]	1B/2	NA
SVI-ETS-505	18-Jul-96	80.5	77.5	45–75	2	NA

Table A-1. Well construction data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date completed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU[a] monitored	Well development flow rate (gpm)[b]
SEA-ETS-506	24-Jul-96	75	66	NA[e]	1B/2	NA
SEA-ETS-507	30-Jul-96	75	66	NA[e]	1B/2	NA
Soil Vapor Extraction						
SVI-ETS-504	09-Jul-96	76.5	67	42–67	2	NA
SVI-518-201	03-Mar-93	59.8	50	34–50	1B/2	NA
SVI-518-303	29-Jun-95	104.5	42	6–40	1B	NA

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."

= Wells installed in 2001.

NA = Not applicable or not available.

LL = Lower Livermore HSU.

[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. Therefore, the screened intervals listed 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

[e] Instrumented membrane systems (IMS)(formerly FLUTe/SEAMIST membranes) with vapor ports set at varying depths.

Table A-2. Well closure data, LLNL Livermore Site and vicinity, Livermore, California.

Well number	Date installed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU monitored	Closure date
Monitor Wells						
W-14A	26-Aug-80	111.0	109.0	80,95,105	2	11-Dec-87
W-15	17-Nov-80	285.0	267.0	239–265	7	13-May-88
W-18	22-Aug-80	161.0	152.5	80–90	2	11-Nov-85
				100–105	2	
				112–117	3A	
				128–133	5	
				143–153	5	
W-149	23-Aug-85	201.0	169.0	161–169	2	29-Aug-96
W-150	13-Sep-85	212.0	162.0	157–162	2	11-Apr-90
W-352	29-Oct-86	235.0	201.0	181–201	4	18-Dec-97
W-358	04-Feb-87	248.0	239.0	230–239	7	15-Apr-94
W-456	09-Jun-88	343.0	180.5	172–180.5	3A	15-Nov-00
W-460	22-Jul-88	361.0	140.5	135–140.5	2	15-Nov-00
W-1005	14-Mar-94	192.0	110.0	98–110	1B	14-Nov-00
W-1006	10-Mar-94	154.0	149.0	141–149	2	14-Nov-00
W-1007	31-Mar-94	199.5	182.0	172–182	3A	14-Nov-00
W-1114	07-Aug-95	223	205	177–200	5	22-Apr-97
GSW-1	05-Feb-85	112.0	109.0	85–106	3A	06-Jun-86
GSW-10	29-Apr-86	205.5	127.5	114–127.5	3B	27-Jan-98
GSW-20	18-May-84	134.0	101.3	95–101.3	3A	03-Sep-87
Extraction Wells						
GEW-711	24-May-91	167.5	157.0	94–137	3A,3B	16-Jun-92
Other Wells						
1N1	15-Jan-48	600	600	427–442	7	21-Oct-88
				450–453	1B	
				465–469	NA	
				500–515	NA	
				575–588	NA	
11A1	08-Jun-76	66	64.7	54.7–59.7	NA	18-Aug-88
2R9 (11A5)[a]	NA	NA	NA	NA	NA	19-Jul-88
11BA[b]	NA	NA	NA	NA	NA	10-Jun-87

Table A-2. Well closure data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date installed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU monitored	Closure date
11H1	04-Nov-41	NA	519	157–161	NA	31-Oct-88
				169–177	NA	
				224–228	NA	
				243–245	NA	
				254–256	NA	
				306–314	NA	
				319–327	NA	
				339–342	NA	
				414–419	NA	
				424–431	NA	
				477–479	NA	
11H4	05-Apr-60	272	272	166–170	NA	07-Oct-88
				174–176	NA	
				183–185	NA	
				200–202	NA	
				211–214	NA	
				224–230	NA	
				250–252	NA	
				260–265	NA	
11J1	1941	160	NA	NA	NA	03-Aug-88
11J4[c]	1965	NA	NA	NA	NA	11-Oct-88
11K1	06-Jan-42	NA	621	247–255	NA	26-Sep-88
				272–276	NA	
				297–304	NA	
				322–339	NA	
				554–557	NA	
				580–602	NA	
11K2	NA	NA	232	NA	NA	03-Oct-88
11Q2	NA	NA	264	NA	NA	16-Aug-88
11Q3	NA	NA	120	NA	NA	10-Aug-88
11Q6[c]	NA	NA	280	NA	NA	11-Jan-89
11R3	08-May-61	140	117	NA	NA	03-Sep-85
11R4	NA	NA	NA	NA	NA	03-Sep-85
11R5[c]	NA	NA	NA	NA	NA	26-Jul-85

Table A-2. Well closure data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date installed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU monitored	Closure date
12M1	09-Dec-42	702	702	375–378	NA	15-Apr-84
				420–426	NA	
				452–473	NA	
				560–564	NA	
				609–621	NA	
				626–657	NA	
12N1	14-Apr-42	702	681	392–399	NA	24-Jan-89
				514–518	NA	
				527–536	NA	
				666–670	NA	
				678–681	NA	
13D1[c]	29-Oct-56	NA	400	200–400	NA	23-Aug-88
14A1[c]	12-Jul-43	246	227	102–107	NA	13-Sep-88
				113–119	NA	
				144–148	NA	
				176–179	NA	
				188–190	NA	
				192–194	NA	
				219–222	NA	
				223–227	NA	
14A2[c]	15-Nov-56	NA	229	122–130	NA	12-Sep-88
				140–150	NA	
				160–180	NA	
14A4[c]	15-Jun-59	NA	252	167–170	NA	29-Aug-88
				175–179	NA	
				192–202	NA	
				235–246	NA	
14A8	NA	NA	86	NA	NA	22-Jul-88
14B2	22-Aug-56	NA	312	185–312	NA	11-Nov-88
14B8	NA	NA	385	NA	NA	23-Oct-89
TEP-GP-001	21-Jan-92	165.0	97.0 117.0 160.5	87–97 107–117	3A 3B	09-Feb-93

Table A-2. Well closure data, LLNL Livermore Site and vicinity, Livermore, California (cont.).

Well number	Date installed	Borehole depth (ft)	Casing depth (ft)	Perforated interval(s) (ft)	HSU monitored	Closure date
TEP-GP-003	28-Jan-92	161.0	129.5 161.0	124.5–129.5	3B	13-Feb-93
TEP-GP-004	05-Feb-92	161.0	106.0 134.0 161.0	96–106 124–134	3A 3B	13-Feb-93
TEP-GP-005	18-Feb-92	161.0	124.5 161.0	114.5–124.5	3B	13-Feb-93
TEP-GP-006	26-Feb-92	161.0	127.0 161.0	107–127	3B	13-Feb-93
TEP-GP-007	13-Mar-92	161.0	161.0			NA
TEP-GP-008	03-Mar-92	161.0	110.0 161.0	100–110	3A	13-Feb-93
TEP-GP-009	06-May-92	161.7	107.0 130.5 161.0	98–107 120.5–130.5	3A 3B	13-Feb-93
TEP-GP-010	24-Mar-92	161.0	124.5	114.5–124.5	3B	12-Feb-93
TEP-GP-011	07-Apr-92	161.0	108.0 161.0	98–108	3A	13-Feb-93
TEP-GP-002	24-Jun-92	161.4	133.0 161.0	102–112.5 122–133	3A 3B	NA
Source Investigation Piezometers						
SIP-ETC-302	22-Apr-99	104	89.4	79–89	2	26-Apr-99
SIP-ETS-105	11-Feb-90	110	103	87–103	3A	18-Nov-93
SIP-ETS-207	11-Jul-91	103.5	98.5	89.75–98.5	3A	05-Jan-00
SIP-PA-029	22 -Jan-90	11.5	7	5-7	1B	18-Nov-93
SIP-419-201	29-Feb-96	126	107	97–107	3A/3B	25-Mar-98
SIP-490-101	01-Nov-95	59	56	53–56	2	21-Dec-95
SIP-514-101	28-Dec-89	26	22	7–22	1B	03-Sep-96
UP-292-001	03-Dec-90	54.6	49.5	44.5–49.5	1B	25-Sep-95

Notes and footnotes appear on following page.

Notes:

NA = Not applicable or not available.

[a] **Well 11A5 was renamed 2R9 by the Alameda County Flood Control and Water Conservation District, Zone 7 in November 1997. Well 11A5 now corresponds to monitor well W-409.**

[b] **Well not recognized by Alameda County Flood Control and Water Conservation District, Zone 7.**

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

11J81 ------> 11J4

11R81 ------> 11R5

11Q81 ------> 11Q6

13D81 ------> 13D1

14A81 ------> 14A1

14A82 ------> 14A2

14A83 ------> 14A4

Appendix B

Hydraulic Test Results

Table B-1. Results of hydraulic tests conducted in 2001[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-368	31-Jul-2001	Step	6.0	2,600	350	Fair
W-413	30-Aug-2001	Drawdown	20.0	9,400	790	Good
W-1508	28-Jun-2001	Slug	NA	160	16	Good
W-1512	21-Jun-2001	Slug	NA	230	23	Good
W-1604	2-Apr-2001	Drawdown	4.0	1,600	220	Fair
W-1701	23-Jul-2001	Drawdown	9.0	160	40	Good
W-1701	26-Sep-2001	Longterm	15.0	60	15	Fair
W-1703	25-Oct-2001	Drawdown	12.0	16,000	2,300	Fair

Note:

NA = Not applicable.

[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 is dependent on the character of the data obtained. The slug test results were obtained using the method of Cooper et al. (1967). (See references on following page.)

[b] "Drawdown" denotes 1-hr pumping tests; "Longterm" denotes 24- to 48-hr pumping tests; "slug" denotes monitoring and recovery after an instantaneous change in ground water elevations; "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.

Appendix B

References

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Appendix C

2002 Ground Water Sampling Schedule

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule.

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-001	O	2-03	
W-001A	O	1-03	
W-002	O	4-03	
W-002A	O	2-03	
W-004	O	2-03	
W-005	O	3-03	
W-005A	O	4-03	
W-007	E	4-02	
W-008	O	2-03	WGMG
W-010A	O	2-03	
W-011	O	2-03	
W-012	A	3-02	
W-017	E	1-02	WGMG
W-017A	E	4-02	
W-019	E	4-02	
W-101	O	1-03	WGMG
W-102	O	3-03	
W-103	E	4-02	
W-104	Q	1-02	
W-105	O	4-03	
W-106	E	4-02	
W-107	E	4-02	
W-108	O	3-03	
W-110	Q	1-02	
W-111	O	2-03	
W-113	E	4-02	
W-114	Q	1-02	
W-115	O	4-03	
W-116	Q	1-02	
W-117	E	4-02	
W-118	O	4-03	
W-119	Q	1-02	WGMG
W-120	A	4-02	
W-121	Q	1-02	WGMG
W-122	E	1-02	
W-123	E	1-02	
W-141	E	2-02	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-142	O	1-03	
W-143	Q	1-02	
W-146	O	4-03	
W-147	O	3-03	WGMG
W-148	O	4-03	WGMG
W-151	Q	1-02	WGMG
W-201	A	3-02	
W-202	A	1-02	
W-203	E	2-02	
W-204	A	1-02	WGMG
W-205	Q	1-02	
W-206	Q	1-02	
W-207	Q	1-02	
W-210	E	1-02	
W-211	Q	1-02	
W-212	E	4-02	
W-213	E	4-02	
W-214	E	2-02	
W-217	Q	1-02	
W-218	Q	1-02	
W-219	A	4-02	
W-220	A	1-02	
W-221	A	2-02	WGMG
W-222	A	3-02	
W-223	O	4-03	
W-224	O	1-03	
W-225	A	4-02	
W-226	A	2-02	WGMG/NPDES
W-251	Q	1-02	
W-252	O	4-03	
W-253	O	1-03	
W-255	E	2-02	
W-256	E	4-02	
W-257	Q	1-02	
W-258	Q	1-02	
W-259	Q	1-02	
W-260	A	1-02	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-261	A	1-02	
W-263	Q	1-02	
W-264	S	2-02	
W-265	O	3-03	
W-267	O	2-03	
W-268	Q	1-03	
W-269	A	3-02	
W-270	O	4-03	
W-271	Q	1-02	
W-272	Q	1-02	
W-273	O	4-03	
W-274	Q	1-02	
W-275	Q	1-02	
W-276	S	2-02	
W-277	A	3-02	
W-290	E	4-02	
W-291	O	1-03	
W-293	A	2-02	
W-294	O	2-03	
W-301	A	2-02	WGMG
W-302	O	1-03	
W-303	O	2-03	
W-304	A	4-02	
W-306	O	2-03	WGMG/NPDES
W-307	A	4-02	WGMG/NPDES
W-308	Q	1-02	
W-310	O	1-03	
W-311	A	4-02	
W-312	O	2-03	
W-313	Q	1-03	
W-315	Q	1-02	
W-316	Q	1-02	
W-317	Q	1-02	
W-318	Q	1-02	
W-319	O	1-03	
W-320	A	1-02	
W-321	O	4-03	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-322	Q	1-02	
W-323	Q	1-02	
W-324	E	2-02	
W-325	O	1-03	
W-353	S	2-02	
W-354	Q	1-02	
W-355	Q	1-02	
W-356	Q	1-02	
W-360	Q	1-02	
W-361	Q	1-02	
W-362	Q	1-02	
W-363	Q	1-02	WGMG
W-364	Q	1-02	
W-365	O	2-03	
W-366	O	2-03	
W-368	A	2-02	
W-369	S	1-02	
W-370	O	4-03	
W-371	O	3-03	
W-372	A	1-02	
W-373	O	2-03	WGMG
W-375	Q	1-02	
W-376	O	2-03	
W-377	E	2-02	
W-378	S	2-02	
W-379	S	2-02	
W-380	O	1-03	
W-401	E	2-02	
W-402	O	1-03	
W-403	A	1-02	
W-404	Q	1-02	
W-405	Q	1-02	
W-406	O	4-03	
W-407	Q	1-02	
W-409	A	4-02	
W-410	Q	1-02	
W-411	Q	1-02	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-412	O	3-03	
W-413	S	1-02	
W-414	O	3-03	
W-416	E	2-02	
W-417	O	4-03	
W-418	A	4-02	
W-419	Q	1-02	
W-420	A	1-02	
W-421	Q	1-02	
W-422	E	4-02	
W-423	Q	1-02	
W-424	Q	1-02	
W-446	O	4-03	
W-447	O	4-03	
W-448	O	2-03	
W-449	O	4-03	
W-450	S	2-02	
W-451	E	1-02	
W-452	E	4-02	
W-453	A	1-02	
W-454	S	1-02	
W-455	A	3-02	
W-458	E	4-02	
W-459	O	2-03	
W-461	Q	1-02	
W-462	O	4-03	
W-463	E	1-02	
W-464	Q	1-02	
W-481	Q	1-02	
W-482	A	2-02	
W-483	O	2-03	
W-484	E	4-02	
W-485	E	2-02	
W-486	O	2-03	
W-487	O	1-03	
W-501	S	1-02	
W-502	A	2-02	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-503	O	4-03	
W-504	O	4-03	
W-505	A	2-02	
W-506	A	1-02	
W-507	O	3-03	
W-509	S	1-02	
W-510	O	1-03	
W-511	L	1-03	
W-512	O	1-03	
W-513	A	2-02	
W-514	O	4-03	
W-515	Q	1-02	
W-516	A	2-02	
W-517	Q	1-02	
W-519	O	4-03	
W-521	O	1-03	
W-551	A	4-02	
W-552	O	2-03	
W-553	E	4-02	
W-554	O	2-03	
W-555	O	2-03	
W-556	O	2-03	
W-557	E	4-02	
W-558	Q	1-02	
W-559	A	4-02	
W-560	O	4-03	
W-561	E	2-02	
W-562	A	2-02	
W-563	A	3-02	
W-564	Q	1-02	
W-565	O	4-03	
W-567	A	4-02	
W-568	A	3-02	
W-569	S	2-02	
W-570	E	4-02	
W-571	E	2-02	WGMG
W-591	E	4-02	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-592	O	3-03	
W-593	O	1-03	
W-594	O	1-03	
W-604	A	3-02	
W-606	A	2-02	
W-607	A	1-02	
W-608	A	3-02	
W-611	Q	1-02	
W-612	S	2-02	
W-613	O	2-03	
W-615	A	3-02	
W-616	E	1-02	
W-617	E	4-02	
W-618	Q	1-02	
W-619	O	3-03	
W-622	Q	1-02	
W-651	Q	1-02	
W-652	O	2-03	
W-653	Q	1-02	
W-654	O	4-03	
W-702	O	1-03	
W-705	A	4-02	
W-706	O	4-03	
W-750	A	4-02	
W-901	A	2-02	
W-902	A	4-02	
W-905	O	3-03	
W-908	O	1-03	
W-909	Q	1-02	
W-911	Q	1-02	
W-912	S	2-02	
W-913	Q	1-02	
W-1002	A	4-02	
W-1003	O	4-03	
W-1008	E	4-02	
W-1010	O	4-03	
W-1011	O	2-03	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-1012	O	2-03	WGMG
W-1013	O	3-03	
W-1014	Q	1-02	
W-1101	O	2-03	
W-1105	O	2-03	
W-1106	S	1-02	
W-1107	Q	1-02	
W-1108	Q	1-02	
W-1110	S	2-02	
W-1112	Q	1-02	
W-1113	S	1-02	
W-1115	A	1-02	
W-1117	Q	1-02	
W-1118	Q	1-02	
W-1201	Q	1-02	
W-1202	Q	1-02	
W-1203	S	1-02	
W-1204	Q	1-02	
W-1205	Q	1-02	
W-1207	A	4-02	
W-1209	Q	1-02	
W-1210	E	4-02	
W-1212	Q	1-02	
W-1214	Q	1-02	
W-1217	Q	1-02	
W-1218	Q	1-02	
W-1219	S	1-02	
W-1220	Q	2-02	
W-1221	Q	1-02	
W-1222	Q	1-02	
W-1223	Q	1-02	
W-1224	O	2-03	
W-1225	Q	1-02	
W-1226	O	4-03	
W-1227	E	2-02	
W-1250	Q	1-02	
W-1251	Q	1-02	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-1252	Q	1-02	
W-1253	Q	1-02	
W-1254	Q	1-02	
W-1255	Q	1-02	
W-1304	Q	1-02	
W-1311	Q	1-02	
W-1401	Q	1-02	
W-1402	Q	1-02	
W-1403	Q	1-02	
W-1404	Q	1-02	
W-1405	Q	1-02	
W-1406	Q	1-02	
W-1407	Q	1-02	
W-1408	Q	1-02	
W-1411	Q	1-02	
W-1412	Q	1-02	
W-1413	A	1-02	
W-1414	Q	1-02	
W-1415	Q	1-02	
W-1416	S	2-02	
W-1417	S	1-02	
W-1419	S	1-02	
W-1420	A	4-02	
W-1421	Q	1-02	
W-1424	A	3-02	
W-1425	A	1-02	
W-1426	A	4-02	
W-1427	Q	1-02	
W-1428	A	4-02	
W-1501	A	3-02	
W-1502	A	4-02	
W-1505	Q	1-02	
W-1506	S	1-02	
W-1507	A	2-02	
W-1508	Q	1-02	
W-1509	S	3-02	
W-1511	Q	1-02	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
W-1512	Q	1-02	
W-1513	Q	1-02	
W-1514	Q	1-02	
W-1515	Q	1-02	
W-1516	S	1-02	
W-1517	A	2-02	
W-1519	A	3-02	
W-1553	Q	1-02	
W-1604	Q	1-02	
W-1605	Q	1-02	
W-1609	Q	1-02	
W-1610	Q	1-02	
W-1613	A	3-02	
W-1614	A	3-02	
W-1701	Q	1-02	
W-1702	Q	1-02	
W-1703	Q	1-02	
W-1704	Q	1-02	
W-1705	Q	1-02	
TW-11	Q	1-02	
TW-11A	A	4-02	
TW-21	O	4-03	
11C1	A	1-02	
14A11	O	1-03	
14A3	E	4-02	
14B1	E	3-02	WGMG
14B4	O	2-03	
14C1	Q	1-02	
14C2	O	4-03	
14C3	A	3-02	
14H1	E	2-02	
18D1	O	2-03	
GEW-710	A	1-02	
GSW-006	A	2-02	
GSW-007	O	4-03	
GSW-008	O	2-03	
GSW-009	Q	1-02	

Table C-1. 2002 LLNL Livermore Site VOC ground water sampling schedule (cont.)

Well number	VOC sampling frequency	Next quarter sample date	Additional analytes (Q1-02)
GSW-011	Q	1-02	
GSW-013	O	3-03	
GSW-215	Q	1-02	
GSW-216	Q	1-02	
GSW-266	S	3-02	
GSW-326	O	2-03	
GSW-367	A	1-02	
GSW-442	E	4-02	
GSW-443	A	3-03	
GSW-444	A	1-02	

Notes:

All analyses are by EPA Method 601 for purgeable halocarbons.

E = Even years.

O = Odd years.

A = Annual.

S = Semiannual.

Q = Quarterly.

L = Lapsed: well not sampled in 9 or more previous quarters.

NPDES = National Pollutant Discharge Elimination System.

WGMG = LLNL Water Guidance and Monitoring Group. This work is related to the environmental surveillance monitoring programs carried out at DOE sites to complement restoration activities.

Appendix D

2001 Drainage Retention Basin Annual Monitoring Program Summary

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2001 Drainage Retention Basin Annual Monitoring Program Summary

This Appendix summarizes the 2001 LLNL Operations and Regulatory Affairs Division routine maintenance activities, maintenance monitoring, and discharge data for the Drainage Retention Basin (DRB). The DRB is an artificial water body that was originally designed with a 43 acre-ft capacity. In 2000, the DRB was re-surveyed and shown to have an actual capacity of about 37 acre-ft (approximately 12 million gallons). The DRB is located in the central portion of the Livermore Site (Fig. D-1), and receives storm water runoff and treated ground water discharges.

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, as requested by the California Regional Water Quality Control Board (RWQCB)–San Francisco Bay Region. In addition, samples of each dry season release event are collected. 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). Release samples are used to determine compliance with discharge limits established in the CERCLA *Record of Decision for the Lawrence Livermore National Laboratory, Livermore Site* (DOE, 1992) and the *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory, Livermore Site* (Berg et al., 1997).

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).

Complete analytical results of samples collected within the basin and from releases are reported in the LLNL Livermore Site Project Quarterly Self-Monitoring Reports for 2001.

D.1. Drainage Retention Basin Maintenance Monitoring

Samples collected during 2001 within the DRB at sample location CDBE did not meet the MALs for ammonia nitrogen (as N), chemical oxygen demand, dissolved oxygen, manganese, nitrate, oxygen saturation, pH, specific conductance, temperature, total dissolved solids, total phosphorus (as phosphorus), and transparency. A summary of these constituents is provided in Table D-1.

Table D-1. Constituents monitored at CDBE exceeding management action levels (MALs) in 2001.

Analysis	Management action level	Maximum 2001 value	Minimum 2001 value	Samples not meeting MALs/ samples collected
Ammonia Nitrogen (mg/L)	>0.1	0.3	<0.025	1/10
Chemical Oxygen Demand (mg/L)	>20	41	<20	2/4
Dissolved Oxygen (% saturation)	<80	176	39.7	17/42
Dissolved Oxygen (mg/L)	<5	18.8	3.98	3/45
Manganese (mg/L)	>0.5	30	0.014	1/10
Nitrate (as N) (mg/L)	>0.2	2.2	0.42	10/10
pH (units)	<6.0 and >9.0	9.24	8.17	3/10
Specific conductance (μmhos)	>900	1120	753	6/10
Temperature (degrees C)	<15 and >26	24.6	8.5	12/42
Total Dissolved Solids (mg/L)	>360	690	423	10/10
Total Phosphorous (as P) (mg/L)	>0.02	0.18	<0.05	10/10
Transparency (meters)	<0.914	4.27	0.152	6/45

In general, the water quality in the DRB continued to improve during 2001 over previous years. This may be related to continuation of a management strategy implemented in 2000 that focuses on stabilizing the water level to reduce the stress to the overall aquatic system. In 2001, growth of a greater variety and quantity of submerged and emergent vegetation, although not an ideal native species composition, has been observed. By the end of 2001, the second year of this new management strategy, DRB monitoring indicated substantially increased water clarity. The clarity of the water increased from a recorded high of 2.0 meters in 2000 to a high of 4.27 recorded in May 2001. Additionally, lower chlorophyll “a” concentrations (indicating less biomass during algae blooms), and decreasing nutrient and phosphorus concentrations were also observed during 2001.

Ammonia nitrogen exceeded its MAL only once during 2001, and that measurement was recorded from a sample collected just after the DRB was drained. The presence of ammonia in the water usually indicates that anaerobic activity is occurring. Lower dissolved oxygen levels in the middle and lower levels of the DRB support evidence of anaerobic or anoxic activity. Chemical oxygen demand was above the MAL for two of the four quarters during 2001. The oxygen demand is most likely a result of increasing organic debris associated with annual algae bloom cycles and decaying organic debris from runoff during winter storms.

Total phosphorous was also above the MAL throughout 2001 and reached a maximum of 0.18 milligrams per liter (mg/L) in June 2001. Though this concentration is still well above MAL of 0.02 mg/L, it is substantially below the maximum 1998 concentration of 1.9 mg/L that occurred prior to changing the method of treating scaling in the treatment units from *JP-7* (a phosphate based anti sealing agent) to *Belsperse 161*.

Nitrate as nitrogen concentrations also continued to be above the MAL during 2001. Nitrate is introduced into the DRB with winter storm flows and in treated ground water discharges.

Although nutrient levels have been high since 1994, chlorophyll “a”, which indicates the level of alga growth, remains well below the 10 mg/L MAL, ranging from <1 micrograms per liter (µg/L) to 23 µg/L in 2001. An aquatic system is considered to be eutrophic when chlorophyll “a” levels exceed 10 µg/L. However, the chlorophyll “a” concentration, and therefore the algae mass, decreased substantially from last year’s high of 42.7 µg/L to 23.0 µg/L in 2001. Chronic toxicity tests on fish, daphnid, and algae, collected October 2001, showed only a small amount of toxicity for the daphnid *Ceriodaphnia dubia* (2 toxic units).

Semiannual and annual maintenance sampling was conducted during April and October 2001, respectively. Quarterly sampling was conducted in January, April, July, and October. Results for oil and grease, PCBs, volatile organic compounds, total organic carbon, gross alpha, gross beta, and tritium all met their MALs. Only three organic compounds, bromacil (2.2 µg/L), diethyl phthalate (3.9 µg/L) and diuron (5.4 µg/L), were detected in samples collected from the DRB. The pesticides bromacil and diuron were detected on April 9, while diethyl phthalate was detected in the sample collected on October 4, 2001.

Semi-annual biological monitoring continued throughout 2001, as reported in the LLNL *Site Annual Environmental Report.*

D-2. Drainage Retention Basin Discharge Monitoring

Releases from the DRB occurred continuously throughout the year except during brief periods to coordinate with work within the DRB or downstream. Starting December 15, 2000 through January 5, 2001, the DRB was completely dewatered as part of an LLNL’s bullfrog management strategy. Releases did not resume until the DRB had refilled. The first wet season release sampling occurred on March 2, 2001.

Dry season release samples were collected four times between June and September of 2001. The first release of the 2001–2002 wet season was collected on November 12, 2001. Discharges from the DRB were below discharge limitations for all parameters except pH. Discharge samples collected at CDBX exceeded the pH limit of 8.5 units in four of the six wet and dry season monitoring events. The minimum recorded pH was 8.21, and the maximum value was 9.07. Corresponding samples collected at the site outfall (WPDC) exceeded the discharge limit in two of the six sampling events. The minimum pH value at the outfall was 7.77 and the maximum pH value was 9.03.

Samples were collected in conjunction with storm water monitoring on December 20, 2001. Analytical data, including the measured pH value, are not yet available for this release event.

In a letter dated March 22, 2001 (Steenhoven, 2001), LLNL provided the RWQCB information indicating sediments in the DRB contain polychlorinated biphenyls (PCBs) at a median concentration of 43 parts per billion. Subsequently, Michael Rochette of the RWQCB requested that LLNL begin monitoring for PCBs in DRB releases to verify that PCBs were not detectable in the water. He also requested that turbidity readings be taken at sample location CDBX at the time of manual releases along with turbidity readings before and during these releases at sample location WPDC. LLNL began monitoring for PCBs in all release samples collected at sample locations CDBX and WPDC on June 26, in conjunction with the first dry season sampling event. None of the 2001 DRB discharge samples contained detectable concentrations of PCBs.

DRB discharge water was sampled for both VOCs and herbicides. The only organic compounds above detection limits were glyphosate, bromacil, diuron and diethy phthalate. Glyphosate was detected in the March release sample at both CDBX (14 µg/L) and WPDC (22 µg/L). Glyphosate is the active ingredient in the herbicides *Round Up* and *Rodeo*. Bromacil, another herbicide, was detected in both the March release samples from CDBX (4.4 µg/L) and WPDC (23 µg/L). Diuron, also an herbicide, was detected in the March samples collected at CDBX (5.4 µg/L) and WPDC (13 µg/L). The November 12, 2001 discharge samples collected at CDBX contained detectable levels of glyphosate and diuron (32 µg/L and 1.4 µg/L, respectively). Diethyl phthalate was detected in the sample from CDBX at the analytical limit of detection of 2.0 µg/L.

During the winter dewatering of the DRB, LLNL followed a work plan submitted to and approved by the RWQCB. The work plan identified discharge limits developed specifically for the dewatering activity. LLNL monitored discharges twice a day for the duration of the dewatering activity. On the last day of discharge, one of the filter bags that LLNL installed to remove sediments burst. As a result, the last reading collected on January 5, 2001, exceeded the discharge limit for turbidity. To prevent additional sediment discharge to Arroyo Las Positas, the remaining discharge from the DRB was redirected away from the storm drainage system to an open area where the water percolated into the ground.

D-3. Future Activities

LLNL is in the process of evaluating alternative methods to manage the DRB. Currently LLNL is considering changing the current open water configuration of the DRB into a managed wetland system to achieve improved water quality. This project is complete through the Title II design level. LLNL is exploring possible funding sources for the actual construction of the wetland system. The *Drainage Retention Basin Management Plan* will be amended to reflect any change to the DRB operations.

D-4. References

Berg, L., E. Folsom, M. Dresen, R. Bainer, A. Lamarre (Eds.) (1997), *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory Livermore Site*, Lawrence Livermore National Laboratory, Livermore, Calif. (UCRL-AR-125927).

Steenhoven, J. C. (2001), Deputy Division Leader, Environmental Restoration Division, LLNL "Drainage Retention Basin Retrofit Project," letter to Dennis Mishek, DOD/DOE Section Leader, San Francisco Regional Water Quality Control Board, March 22, 2001.

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).

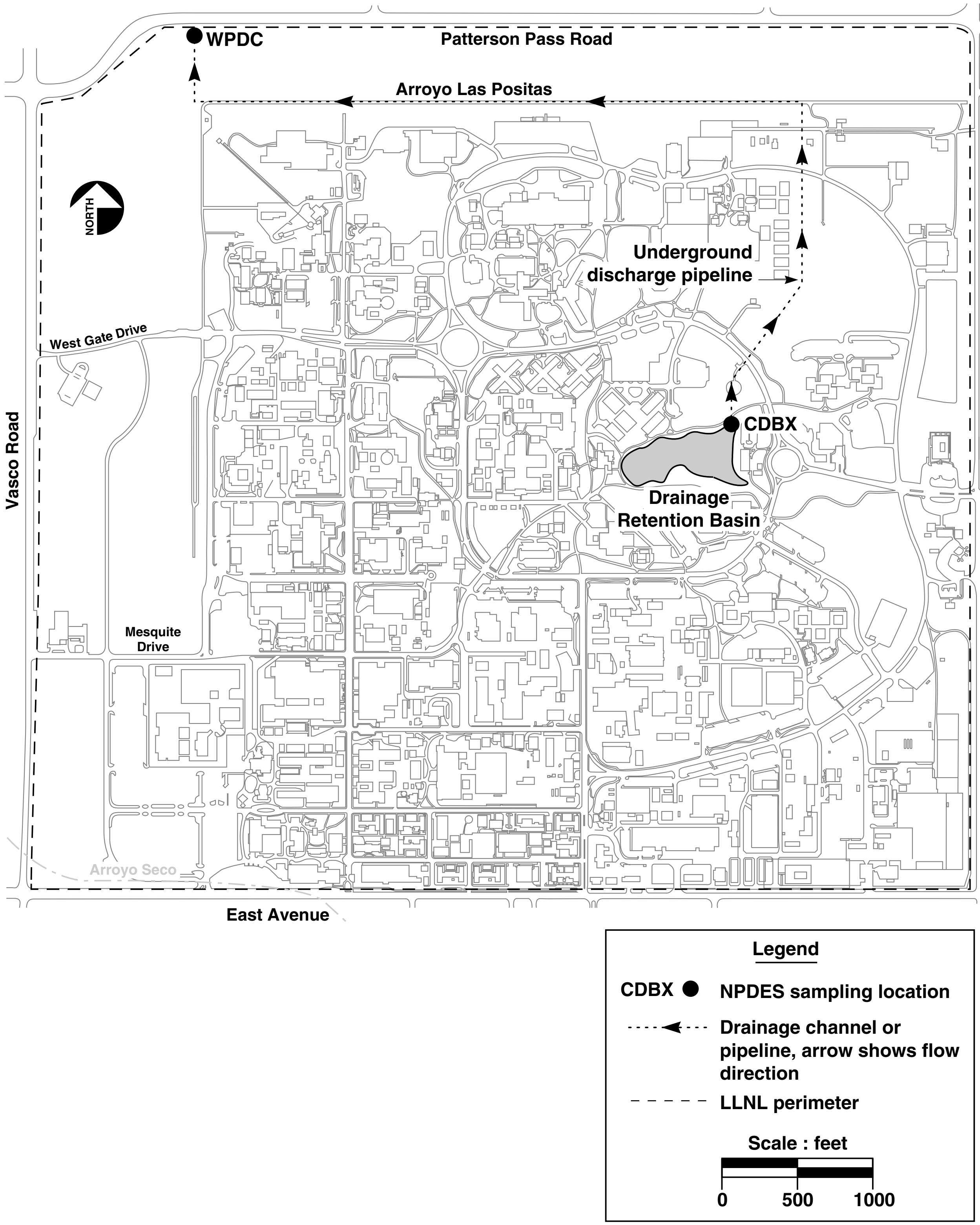

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Figure D-1. Location of the Drainage Retention Basin showing discharge sampling locations.

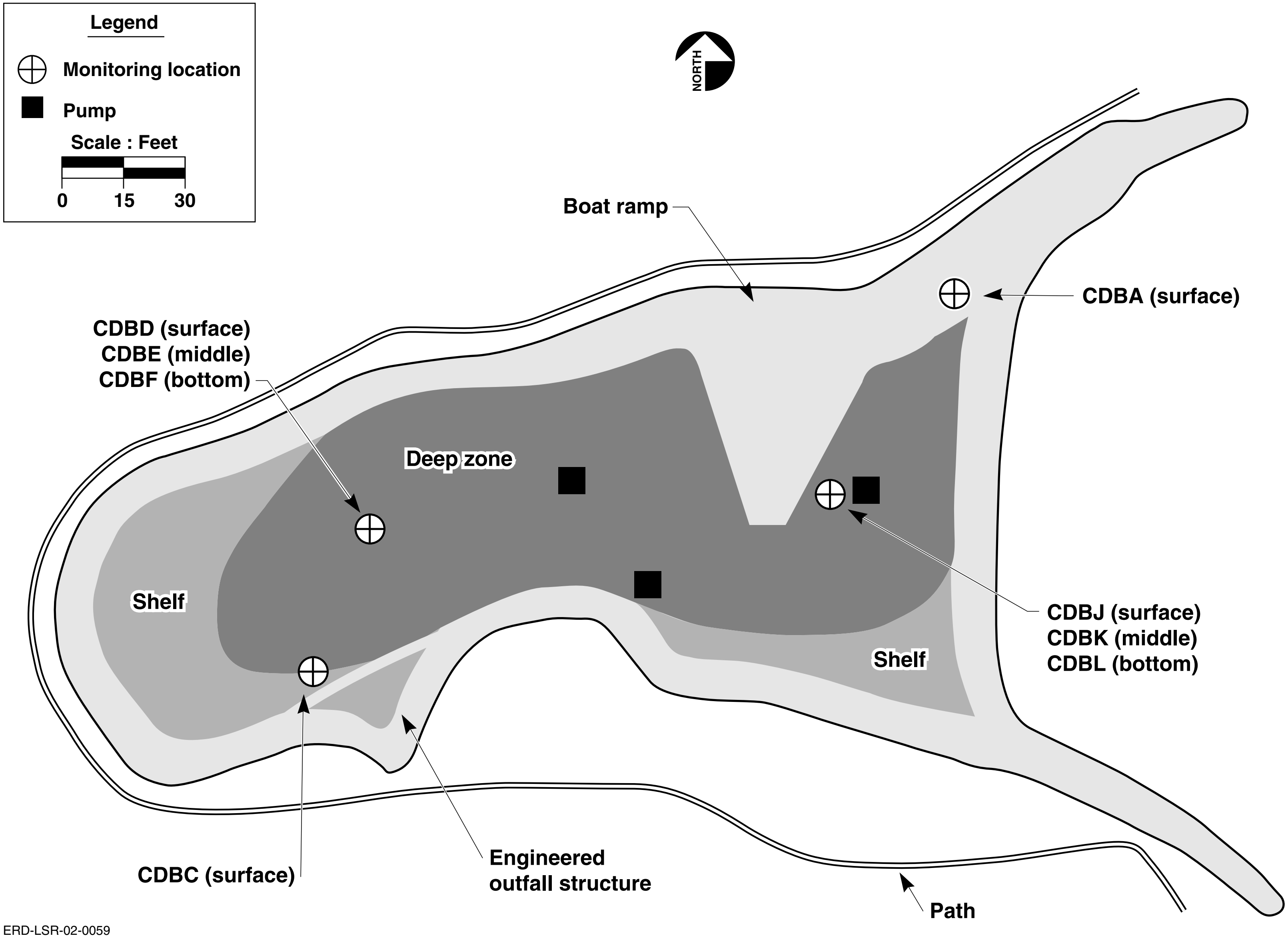

Figure D-2. Monitoring locations in the Drainage Retention Basin.