Groundwater Monitoring

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Introduction

Lawrence Livermore National Laboratory regularly samples and analyzes groundwaters in the Livermore Valley and in the Altamont Hills. LLNL maintains multiple groundwater monitoring programs to comply fully with environmental regulations, applicable U.S. Department of Energy (DOE) orders, and the requirements of the Groundwater Protection Management Program (GWPMP). The objectives of the groundwater monitoring programs described in this chapter are to measure compliance with waste discharge requirements and postclosure plans and to assess the impact, if any, of current LLNL operations on groundwater resources.

DOE Order 5400.1 requires all DOE facilities to prepare a GWPMP that describes the site's groundwater regime, areas of known contamination, remediation activities, programs to monitor groundwater, and the means to monitor and control potential sources of groundwater contamination. Considerable groundwater monitoring and remediation, discussed in Chapter 8, are carried out under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) restoration efforts. Soil and sediment surveillance monitoring under the GWPMP is described in Chapter 10. Additional programs address the sanitary sewer system, building drains, and underground storage tanks.

Surveillance Monitoring

Groundwater monitoring at LLNL complies with DOE Order 5400.1, which affirms DOE's commitment to protect the environment. LLNL conducts surveillance monitoring of groundwater in the Livermore Valley and in the Altamont Hills through networks of wells and springs that include private wells off site and DOE CERCLA wells on site. The two monitored areas are not connected

hydrologically; they are separated by a major drainage divide and numerous faults. The Livermore site in the Livermore Valley drains to San Francisco Bay via Alameda Creek. Most of Site 300 drains to the San Joaquin River Basin via Corral Hollow Creek, with a small undeveloped portion in the north draining to the north and east toward Tracy. To maintain a comprehensive, cost-effective monitoring program, LLNL determines the number and locations of surveillance wells, the analytes to be monitored, the frequency of sampling, and the analytical methods to be used.

A wide range of analytes is monitored to assess the impact, if any, of current LLNL operations on local groundwater resources. Because surveillance monitoring is geared to detecting substances at very low concentrations in groundwater, it can detect contamination before it significantly impacts groundwater resources. Wells at the Livermore site, in the Livermore Valley, and at Site 300 in the Altamont Hills are included in LLNL's surveillance monitoring plan. Historically, the surveillance and compliance monitoring programs have detected relatively elevated concentrations of various metals, nitrate, perchlorate, and depleted uranium (uranium-238) in groundwater at Site 300. Subsequent CERCLA studies have linked several of these contaminants to past operations, while others are the objects of continuing study. Present-day administrative, engineering, and maintenance controls in place at both LLNL sites are specifically tailored to prevent damage to the environment.

Compliance Monitoring

The Compliance Groundwater Monitoring Program complies with numerous federal and state controls (see **Table 2-5**, for a summary of LLNL permits). Compliance monitoring of groundwater is conducted at Site 300 to satisfy state-issued permits associated with closed landfills containing solid wastes, and with continuing discharges of liquid waste to surface impoundments, sewage ponds, and percolation pits. Groundwater compliance monitoring at Site 300 is specified in Waste Discharge Requirement (WDR) orders issued by the Central Valley Regional Water Quality Control Board (CVRWQCB) and in landfill closure and postclosure monitoring plans. The WDRs and postclosure plans specify wells and effluents to be monitored, constituents of concern (COCs) and parameters to be measured, frequency of measurement, inspections to be conducted, and the frequency and form of required reports. These monitoring programs include quarterly and semi-annual monitoring of groundwater, monitoring of various influent waste streams, and visual inspections. LLNL performs the maintenance necessary to ensure the integrity of the closed facilities and their monitoring networks. LLNL conducts additional operational monitoring of wastewater effluents discharged to surface impoundments and sewage evaporation and percolation ponds to comply with WDRs issued under California's Porter-Cologne Water Quality Control Act. Quarterly and annual written reports of analytical results, inspection findings, and maintenance activities are required for each monitoring network.

Table 9-1a and 9-1b in the Data Supplement shows the analytical methods and reporting limits for inorganic constituents (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods), and organic constituents in groundwater.

Livermore Site and Environs

Livermore Valley

LLNL has monitored tritium in water hydrologically downgradient of the Livermore site since 1988. Tritiated water (HTO) is potentially the most mobile groundwater contaminant emanating from LLNL. Rain and storm water runoff in the Livermore Valley, which recharges local aquifers,

contains small amounts of tritium from natural sources, past worldwide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL. (See Chapters 4, 5, and 7 for further discussion of air emissions, rain, and storm water runoff.) Groundwater samples were obtained during 2000 from 20 of 23 wells in the Livermore Valley (see **Figure 9-1**) and measured for tritium activity.

Groundwater is recharged at the Livermore site, primarily from arroyos by rainfall (see also Chapter 7). Groundwater flow at the Livermore site, which is generally westward, is discussed generally in Chapter 1 and in detail in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and the annual *LLNL Groundwater Project* reports (Aarons et al. 2001).

Livermore Site Perimeter

LLNL designed a surveillance monitoring program to complement the Livermore Groundwater Project (discussed in Chapter 8). The intent of this network is to monitor for potential groundwater contamination from continuing LLNL operations. The perimeter portion of this surveillance groundwater monitoring network makes use of three background monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of

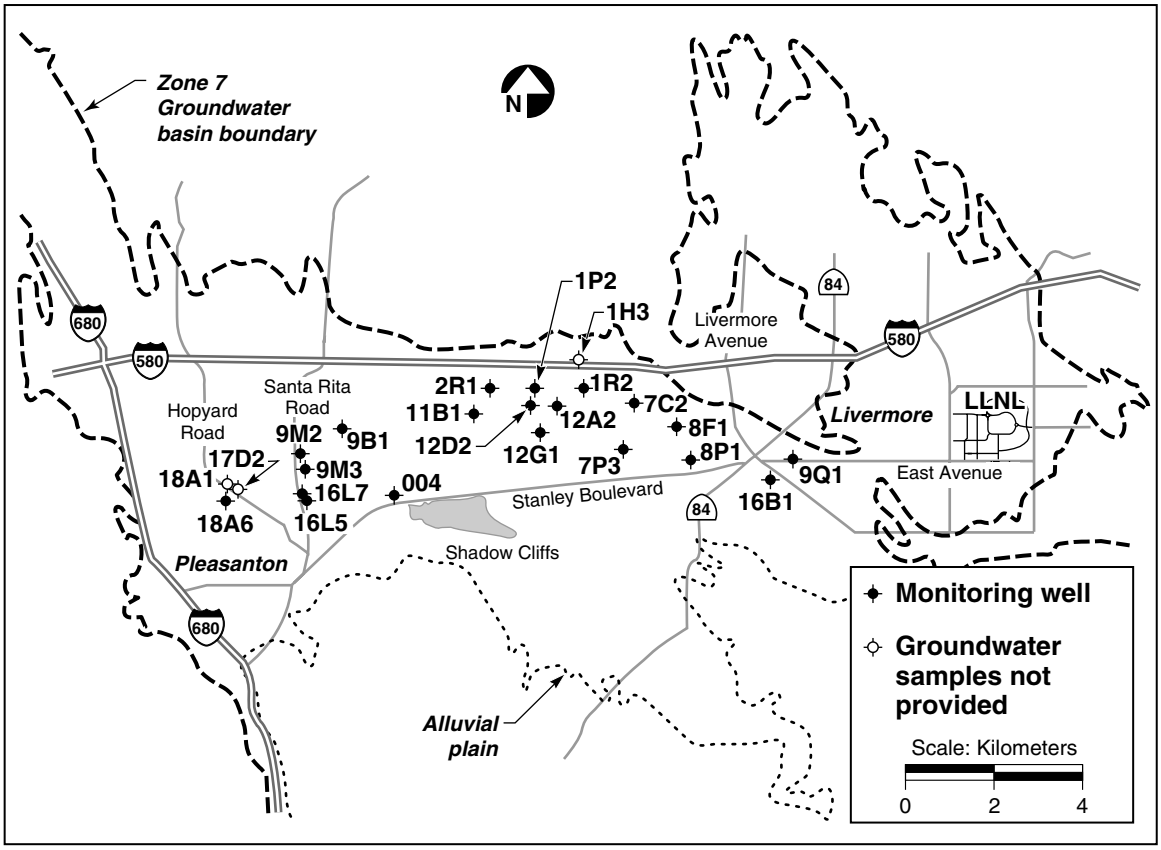

Figure 9-1. Locations of off-site tritium monitoring wells in the Livermore Valley

the site and of the seven monitoring wells located near the western boundary (wells 14B1, W-121, W-151, W-1012, W-571, W-556, and W-373) (see **Figure 9-2**). These seven wells, located in the regions of treatment Facilities A, B, and C (see **Figure 8-1**), meet the requirements of DOE Order 5400.1. These western wells are screened in the uppermost aquifers for COCs that are outside but very near the areas where groundwater is being treated.

The screened interval for each surveillance monitoring well is in the uppermost saturated aquifer (or aquifers) at that well location. As discussed in Chapter 8, the alluvial sediments have been divided into seven hydrostratigraphic units (HSUs), which are shown in **Figure 8-1**. Screened intervals for these monitoring wells range from the shallow HSU 1B, in which some of the western monitoring wells are screened, to the deeper HSU 5, in which background well W-017 (and some wells around Buildings 514 and 612) is screened.

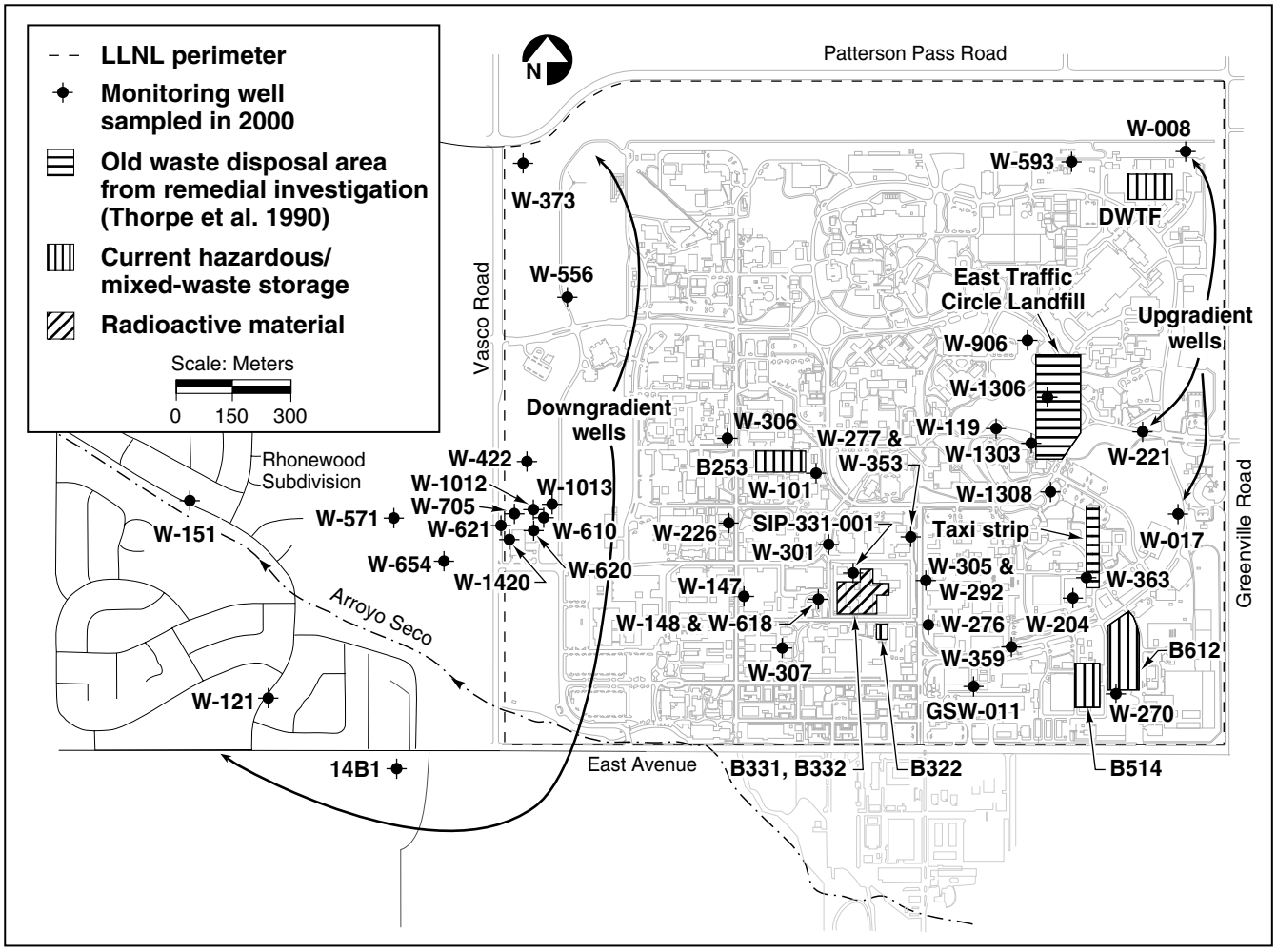

Figure 9-2. Locations of routine surveillance groundwater monitoring wells at the Livermore site

Two of the background wells, W-008 (screened in HSUs 3A/3B) and W-221 (screened in HSU 3A), were sampled and analyzed twice for pesticide and herbicide compounds used on site and once for all trace metals. They were also sampled and analyzed semiannually for minerals and quarterly for several radioactive constituents. Well W-017 is considered a background well for the deeper HSU 5 because it is screened in that HSU. It was sampled and analyzed once during the fourth quarter for minerals, hexavalent chromium, selected trace metals, and radioactive constituents. Sampling and analysis were carried out during the third quarter for the commonly used herbicides diuron and glyphosate.

The seven western downgradient wells screened in shallower HSUs 1B and 2 were sampled and analyzed annually for nonradioactive constituents and quarterly for many radioactive constituents. (Because it was originally a production well, well 14B1 is screened over three depth intervals in HSUs 2, 3A, and 3B.) Each well was sampled and the water analyzed for metals and minerals, pesticides and herbicides, gross alpha and beta, tritium, and other radioisotopes. Sampling and analysis were carried out during the third quarter for the commonly used herbicides diuron and glyphosate. Fourth-quarter sampling and analysis of groundwater from western wells were performed only at those wells and for those analytes that had previously been detected at concentrations that might be of concern. Routine surveillance monitoring data for 2000 are presented in the Data Supplement (Tables 9-2 through 9-11). These monitoring results help establish baseline conditions for future monitoring and detect the presence of any COCs that may adversely affect public health or the environment.

Livermore Site

Groundwater sampling locations within the Livermore site include areas where releases to the ground may have occurred in the recent past or where previously detected COCs have low concentrations that do not require CERCLA remedial action. Monitoring wells that are screened in the uppermost aquifers are situated downgradient from and as near as possible to the potential release locations.

The Taxi Strip Area and the East Traffic Circle Landfill are two potential sources of groundwater contamination. Surveillance monitoring wells for these two sites were added to the surveillance monitoring network in 1997 (see Figure 9-2). Samples from monitoring wells screened in HSUs 2 (W-204) and 3A (W-363) downgradient from the Taxi Strip Area were analyzed in 2000 for copper, lead, zinc, polychlorinated biphenyls (PCBs), radium-226, radium-228, and tritium. Samples from monitoring wells screened at least partially in HSU 2 (W-119, W-906, W-1303, W-1306, and W-1308) within and downgradient from the East Traffic Circle Landfill were analyzed for americium, plutonium, radium-226, radium-228, tritium, copper, lead, zinc, and PCBs. The locations of all of these wells are shown in Figure 9-2. All surveillance monitoring analytical data for the Taxi Strip Area and the East Traffic Circle Landfill are presented in Data Supplement Tables 9-12 through 9-18.

Another potential source of groundwater contamination is the Decontamination and Waste Treatment Facility (DWTF) in the northeastern portion of LLNL. Samples were obtained downgradient from this facility from well W-593 during 2000 and were analyzed for the same suite of analytes as the East Traffic Circle Landfill, except for PCBs (see Data Supplement Table 9-19).

The hazardous waste/mixed waste storage facilities around Buildings 514 and 612 are monitored by wells W-270 and W-359 screened in HSU 5 and well GSW-011 screened in HSU 3B. These wells were sampled and analyzed for selected trace metals, general minerals, and radioactive constituents in 2000. All surveillance monitoring analytical data from the Hazardous Waste Management Area are presented in Data Supplement Tables 9-20 through 9-22.

Groundwater samples were also obtained downgradient from areas where minor releases of metals to the ground have occurred. Samples were obtained from monitoring well W-307 (screened in HSU 1B), downgradient from a fume hood vent on the roof of Building 322, a metal plating shop. Soil samples obtained from the area show elevated concentrations (in comparison with LLNL's site background levels) of chromium, copper, lead, nickel, zinc, and occasionally other metals. LLNL removed contaminated soils near Building 322 in 1999 and replaced them with clean fill. The area was then paved over, making it less likely that metals will migrate from the site. Analytical results for dissolved metals in 2000 groundwater samples are presented in Data Supplement Table 9-23.

Groundwater samples were also obtained downgradient from a location where sediments containing metals (including cadmium, copper, lead, mercury, and zinc) had accumulated in a storm water catch basin near Building 253 (Jackson 1997). These samples were obtained from monitoring wells W-226 and W-306 screened in HSUs 1B and 2, respectively. Analytical results for dissolved metals in these samples are presented in Data Supplement Tables 9-24 and 9-25.

Additional surveillance groundwater sampling locations established in 1999 surround the area of the Plutonium Facility (Building 332) and the Tritium Facility (Building 331) (see **Figure 9-2**). Possible contaminants include plutonium-239 and americium-241 from the Plutonium Facility and tritium from the Tritium Facility. Both plutonium and americium are much more likely to bind to the soils, rather than to migrate into the groundwater. Tritium, in contrast, could migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305 is screened in HSU 2, downgradient well W-148 is screened in HSU 1B, and SIP-331-001 is screened in HSU 2. Radiological analytical results are presented in Data Supplement Tables 9-26 through 9-28.

LLNL sampled and analyzed additional monitoring wells for tritium in the area surrounding the Tritium Facility in 2000 because of the very high activities of tritium detected in storm water (see Chapter 7) and because tritium was detected at 110 Bq/L (3100 pCi/L) in a groundwater sample collected from well W-148 in August 2000. The locations of these wells are also shown in **Figure 9-2**. Tritium activities analyzed in groundwater samples collected from these wells and the HSU within which each well is screened are listed in the Data Supplement in Table 9-29.

Site 300

For surveillance and compliance groundwater monitoring at Site 300, LLNL uses DOE CERCLA wells on site and private wells and springs off site. Representative groundwater samples are obtained at least once per year; they are routinely measured for various elements (primarily metals), a wide range of organic compounds, nitrate, general radioactivity (gross alpha and gross beta), uranium activity, and tritium activity. Typically, analytical methods approved by the Environmental Protection Agency (EPA) are used because they are both accurate and sensitive. (See Data Supplement Table 9-1 for a complete list of COCs and for the EPA or other standard analytical methods used to measure them.)

Figure 9-3 shows the wells and springs at Site 300 that are groundwater surveillance sampling locations. Although groundwater from the uppermost water-bearing zone is the target of most of the sampling, deeper water-bearing zones are sampled at several locations by means of multiple-completion installations fitted with Barcad devices. Barcads are identified in **Figure 9-3** by the capital letters A, B, and C at the end of a monitoring installation's identifier code. ("A" is assigned to the Barcad that samples the deepest of three, or deeper of two, water-bearing zones.)

Twelve groundwater monitoring locations are off-site. Two are springs, identified as MUL2 and VIE1, which are located near the northern boundary of Site 300. Off-site surveillance well VIE2 is located 6 km west of Site 300 in the upper

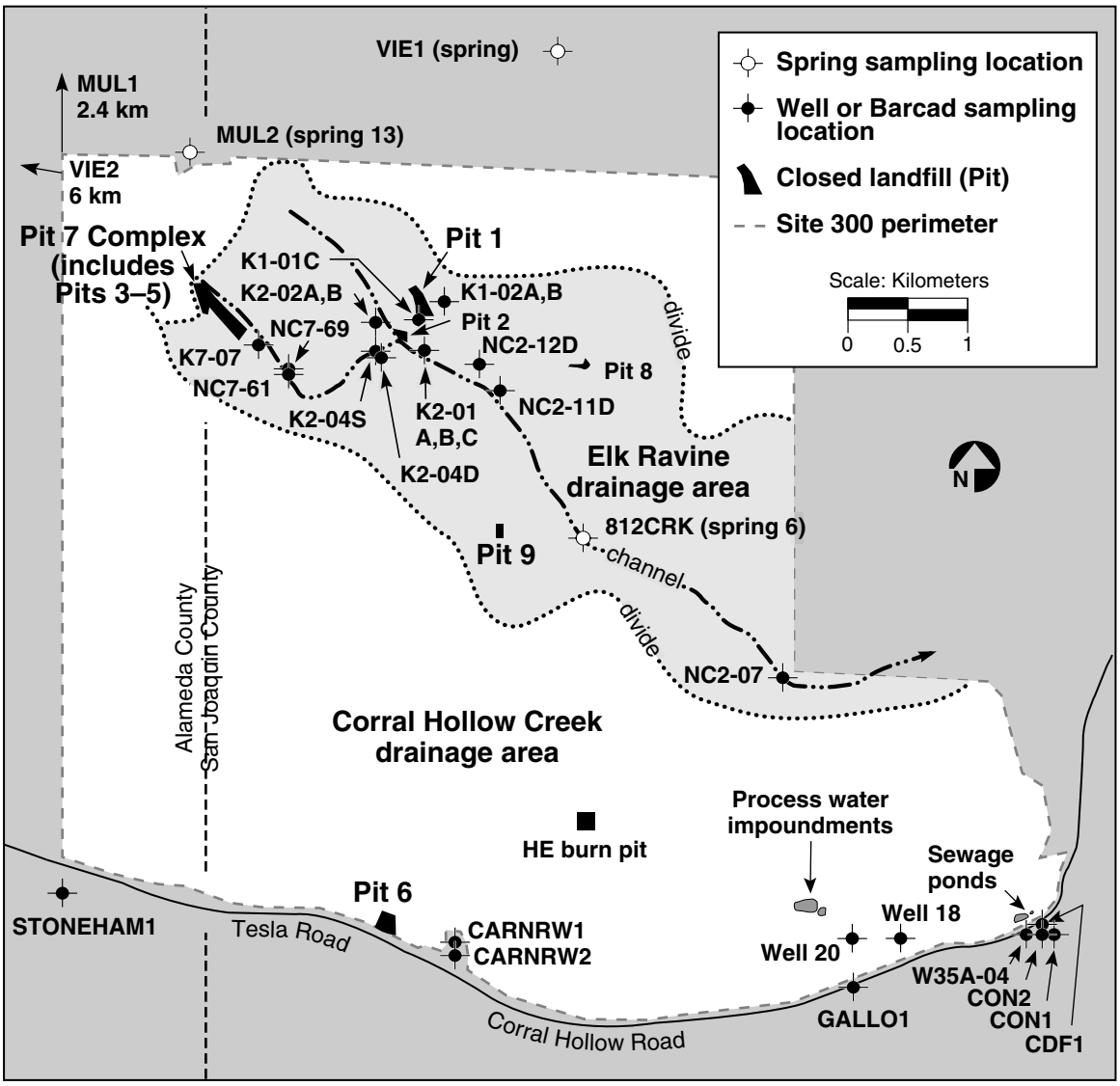

Figure 9-3. Locations of surveillance groundwater wells, Barcads, and springs at Site 300

reaches of the Livermore Valley watershed. Eight off-site surveillance locations are wells located near the southern boundary of Site 300 in or adjacent to the Corral Hollow Creek floodplain.

On-site wells installed for CERCLA characterization studies during the 1980s continue to be used to monitor the closed landfills, a former open-air burn pit, two connected surface water impoundments, and two connected sewer ponds. The closed landfills—identified as Pit 1, Pit 2, Pit 7 Complex, Pit 8, and Pit 9—are located in the northern portion of Site 300 in the Elk Ravine drainage area, while Pit 6, the former burn pit, the two surface impoundments, and the sewage ponds are located in the southern portion of Site 300 in the Corral Hollow Creek drainage area (**Figure 9-3**). Two on-site water supply wells, identified as well 18 and well 20, are also used for surveillance monitoring purposes. Well 20 provides potable water to the site. Well 18 is maintained as a standby supply well.

Brief descriptions of the Site 300 groundwater monitoring networks are given below. Networks within the Elk ravine drainage area are described first, followed by the networks in the Corral Hollow creek drainage area. CERCLA wells within Site 300 have been selected for compliance and surveillance monitoring use, based on their locations and our general understanding of local geologic and hydrogeologic conditions at Site 300 as described in Webster-Scholten (1994). (Also see Chapter 8 for a summary of Site 300 stratigraphy and hydrogeology.) With the exception of the monitoring data for the former burn pit near Building 829, groundwater measurements made during 2000 and published elsewhere are not listed in tables in the Data Supplement. References to the publications containing the remaining groundwater data collected during 2000 are cited in the References at the end of this volume.

Elk Ravine Drainage Area

The Elk Ravine drainage area, a branch of the Corral Hollow Creek drainage system, includes most of northern Site 300 (see **Figure 9-3**). Storm water runoff from closed landfills within the Elk Ravine drainage area (Pits 1–5 and 7–9) collects in arroyos and quickly infiltrates into the ground. Groundwater from wells that lie within the Elk Ravine drainage area are monitored for COCs because of the system of surface and underground flows that connects the entire Elk Ravine drainage area. The area contains Pits 1–5 and 7–9 and many firing tables where explosives tests are conducted. The following descriptions of monitoring networks within Elk Ravine begin with the headwaters area and proceed downstream. (See Chapter 8 for a review of groundwater contamination in this drainage area as determined from numerous CERCLA investigations.)

Pit 7 Complex: Monitoring requirements for the closed Pit 7 landfill in the Elk Ravine drainage area are specified in *Waste Discharge Requirements Order 93-100* (WDR 93-100), administered by the CVRWQCB (1993 and 1998) and in *LLNL Site 300 RCRA Closure and Post-Closure Plans—Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990).

The Pit 7 Complex area is located at an elevation of about 400 m in the most elevated portion of the Elk Ravine drainage area. The complex consists of four adjacent landfills identified as Pits 3, 4, 5, and 7 (see **Figure 9-4**). From 1963 to 1988, the landfills received waste gravels and debris from hydrodynamic tests of explosive devices conducted on firing tables at Site 300. The gravels contained concrete, cable, plastic, wood, tritium, depleted uranium (uranium-238), beryllium, lead, and other metals in trace amounts. In 1988, 9440 m^3 of gravel were removed from six firing tables at

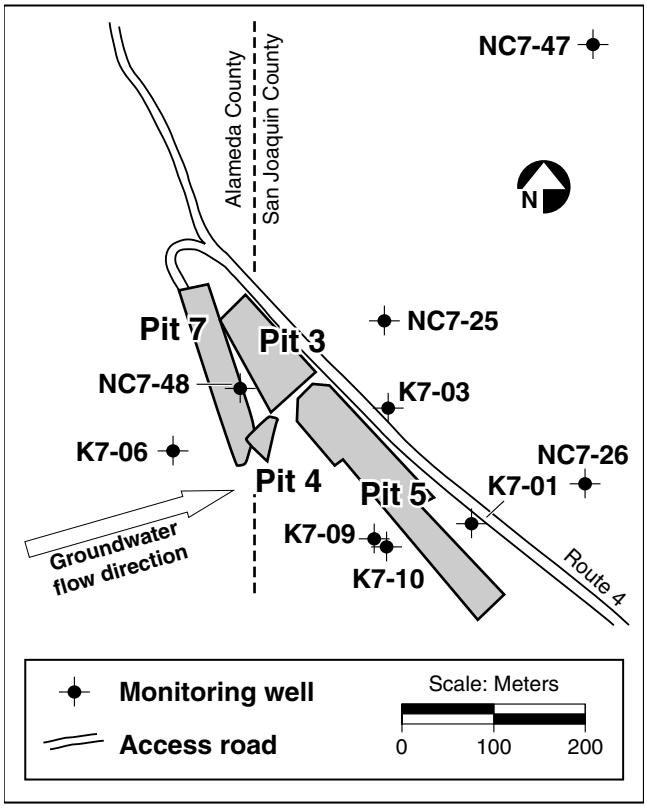

Figure 9-4. Locations of Pit 7 compliance groundwater monitoring wells

Site 300 and placed in Pit 7 (Lamarre and Taffet 1989). These were the last solid wastes to be placed in a landfill at Site 300.

The main objective of monitoring is the early detection of any release of COCs from Pit 7 to groundwater. All detected COCs are investigated. Most of the COCs detected by the Pit 7 monitoring network have been previously linked to historical releases from other pits near Pit 7. Detected COCs such as arsenic, barium, and uranium are released from the underlying rocks and sediments where they occur naturally. Comparison of new data with historical data helps analysts identify releases from wastes buried in Pit 7, versus releases from sources other than Pit 7, including natural sources. Most of the COCs detected during 2000 in the groundwater near Pit 7 were released historically from Pits 3 and 5 (Webster-Scholten 1994). (See Chapter 8 for a review of the stratigraphy, hydrogeology, and groundwater contamination in the Pit 7 area.)

As required by the monitoring and reporting program contained in WDR 93-100, LLNL obtained groundwater samples quarterly from Pit 7 monitoring wells during 2000 and analyzed them for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and volatile organic compounds (VOCs) (EPA Method 601). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection. Three quarterly reports and one annual report covering monitoring activities at Pit 7 during 2000 have been published previously (Christofferson and MacQueen 2000a, 2000b, 2000c, 2001). Tables and graphs of Pit 7 groundwater data for 2000 can be found in *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2000* (Christofferson and MacQueen 2001).

Elk Ravine: Groundwater samples were obtained twice during 2000 from the widespread Elk Ravine surveillance monitoring network. Samples were analyzed for inorganic constituents (mostly metallic elements), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), and, where possible, VOCs (EPA Method 601).

Pit 2: The closed Pit 2 landfill lies in the upper portion of Elk Ravine, about 320 m above sea level (**Figures 9-3** and **9-5**). The landfill contains primarily gravels and debris from hydrodynamic tests of explosive devices conducted at the Building 801 and 802 firing tables. The buried

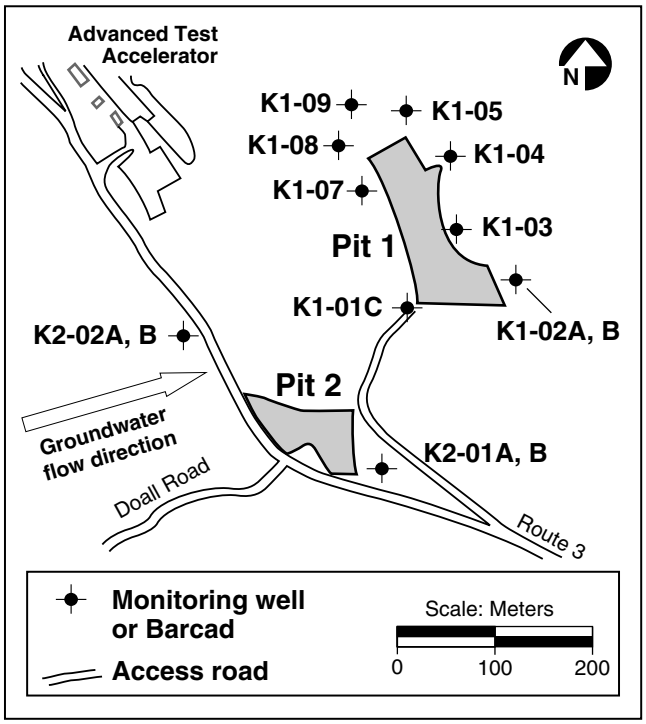

Figure 9-5. Locations of Pit 1 and Pit 2 groundwater monitoring wells

waste material contains depleted uranium (uranium-238), and trace amounts of beryllium, thorium, and possibly tritium.

As planned for surveillance purposes, LLNL obtained groundwater samples twice during 2000 from the Pit 2 monitoring network (comprising mostly Barcad installations) and analyzed them for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), and explosive compounds (HMX and RDX).

Pit 1: Monitoring requirements for the Pit 1 landfill, which was closed under the Resource Conservation and Recovery Act (RCRA), are specified in *Waste Discharge Requirements Order 93-100* (WDR 93-100) administered by the CVRWQCB (1993 and 1998) and in *LLNL Site 300 RCRA Closure and Post-Closure Plans— Landfill Pits 1 and 7* (Rogers/Pacific Corporation 1990).

Pit 1 lies in the Elk Ravine drainage area about 330 m above sea level. The Pit 1 landfill and the positions of the eight groundwater wells used to monitor it are shown in **Figure 9-5**.

As required by the monitoring and reporting program contained in WDR 93-100, LLNL obtained groundwater samples from Pit 1 monitoring wells every quarter during 2000. Samples were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium, radium, uranium, and thorium), explosive compounds (HMX and RDX), and VOCs (EPA Method 601). Every other quarter, analyses were conducted for an additional seven elements. Additional annual analyses were conducted on fourth-quarter samples for extractable organics (EPA Method 625), pesticides and PCBs (EPA Method 608), and herbicides (EPA Method 615). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of quarterly sample collection. Three quarterly reports and one annual report covering monitoring activities at Pit 1 during 2000 have been published previously (Christofferson and MacQueen 2000a, 2000b, 2000c, 2001). Tables and graphs containing Pit 1 groundwater data for 2000 can be found in *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 and 7, Annual Report for 2000* (Christofferson and MacQueen 2001).

Pit 8: The closed Pit 8 landfill is located in the Elk Ravine drainage area adjacent to the Building 801 firing table. Explosives experiments were conducted there from 1958 to 1998, at which time construction of a new enclosed firing facility began. Construction continued through 2000.

Approximately 40 m^3 of untreated debris from the firing table were placed in the pit until 1974 when the pit was closed. The debris buried there may contain trace amounts of tritium, depleted uranium (uranium-238), lead, and beryllium.

Figure 9-6 shows the Building 801 and Pit 8 areas and the locations of the monitoring wells. The pit is located in a narrow ravine within the Elk Ravine drainage area about 350 m above sea level. Chemical analysis of soil and rock samples obtained from this area during CERCLA remedial investigations detected no COCs above background level concentrations (Webster-Scholten 1994). However, low concentrations of trichloroethylene (TCE) have been detected in groundwater samples from Pit 8 surveillance monitoring wells, including upgradient well K8-01, since 1987. Previous remedial investigation links the TCE to a dry well near Building 801 that was once used to dispose liquid wastes (Webster-Scholten 1994).

Because of construction activities in the vicinity of Pit 8 during 2000, groundwater samples could be obtained only from surveillance monitoring wells K8-01 and K8-02B. Groundwater samples from the two surveillance wells were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), explosive compounds (HMX and RDX), pesticides (EPA Method 608), PCBs (EPA Method 8082A), and VOCs (EPA Method 601).

Pit 9: The Pit 9 landfill is centrally located within Site 300 about 340 m above sea level. Similar to the other closed landfills in Elk Ravine, the closed Pit 9 landfill contains firing table gravels and debris from explosives experiments conducted on the Building 845 firing table nearby.

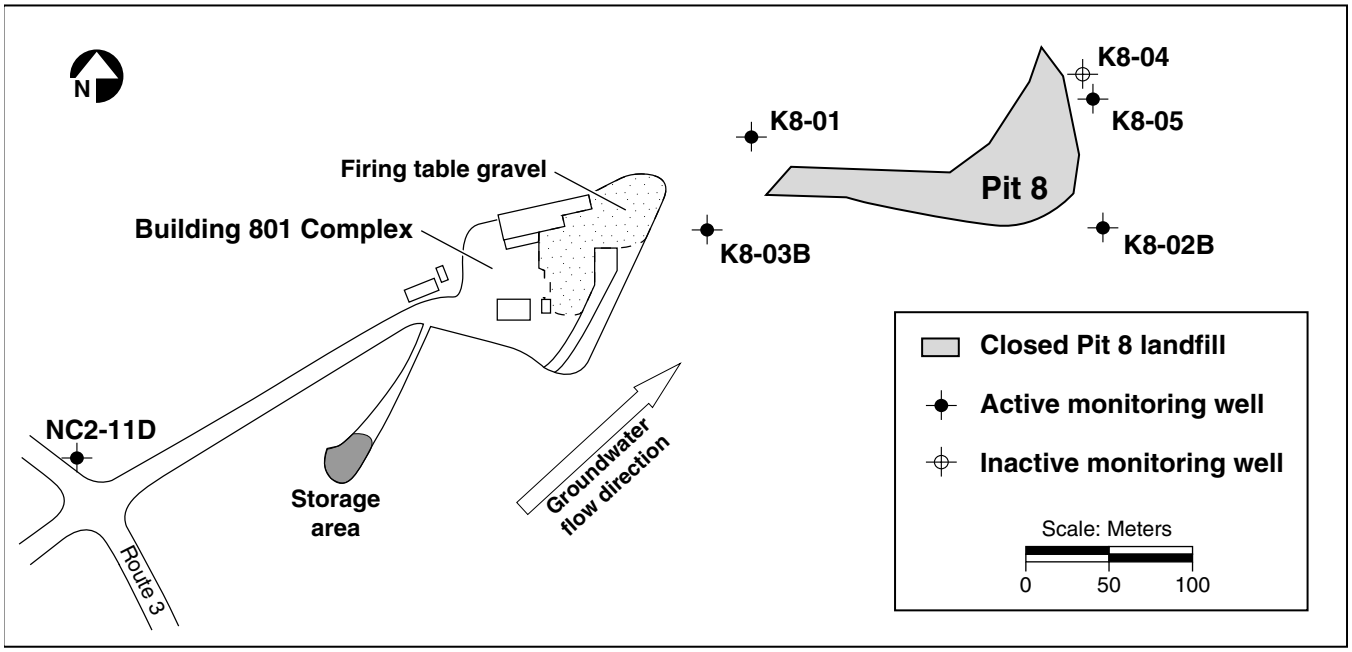

Figure 9-6. Locations of Pit 8 surveillance groundwater monitoring wells

Figure 9-7 shows the locations of the four surveillance wells used to monitor the groundwater in the vicinity of Pit 9. Groundwater flows east-north-easterly beneath Pit 9 in the Neroly lower blue sandstone unit ($Tnbs_1$). The water table lies about 40 m below the ground surface at Pit 9. Monitoring well K9-02 is hydrologically upgradient from Pit 9, and wells K9-01, K9-03, and K9-04 are downgradient.

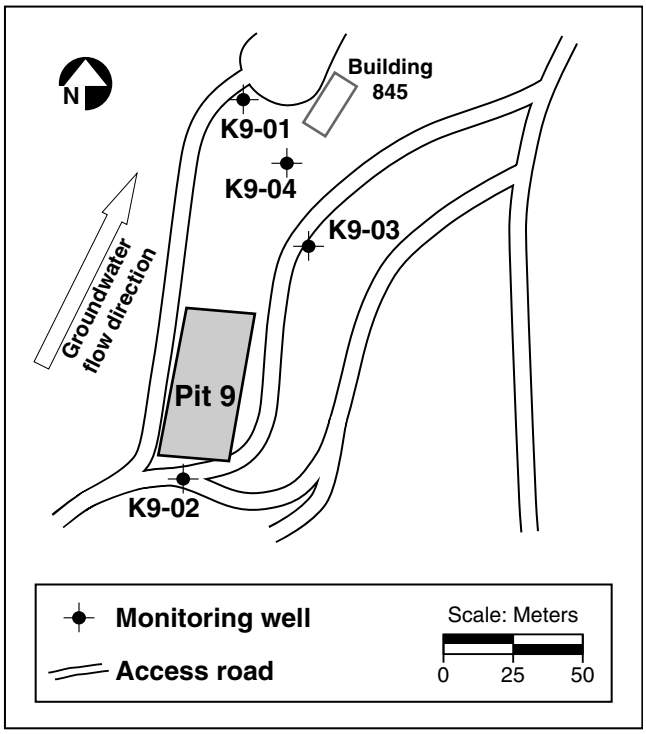

Figure 9-7. Locations of Pit 9 surveillance groundwater monitoring wells

As planned for surveillance purposes, the four Pit 9 monitoring wells were sampled once during 2000. Groundwater samples from the four wells were analyzed for inorganic COCs (mostly metallic elements), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), explosive compounds (HMX and RDX), and VOCs (EPA Method 601).

Corral Hollow Creek Drainage Area

This section describes the groundwater monitoring networks that are located in the southern half of Site 300 where runoff and groundwater flow south to Corral Hollow creek. (See Chapter 8 for a review of groundwater contamination in this drainage area as determined from numerous CERCLA investigations.)

Pit 6: Compliance monitoring requirements for the closed Pit 6 landfill in the Corral Hollow Creek drainage area are specified in the *Post-Closure Plan for the Pit 6 Landfill Operable Unit Lawrence Livermore National Laboratory Site 300* (Ferry et al. 1998). The closed Pit 6 landfill covers an area of about 1 hectare (2.5 acres), at an elevation of approximately 215 m above sea level. From 1964 to 1973, approximately 1500 m^3 of solid wastes were buried there in nine separate trenches. The trenches were not lined, consistent with historical disposal practices. Three larger trenches contain 1300 m^3 of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 m^3 of biomedical waste, including animal carcasses and animal waste. Minor releases of VOCs, primarily the solvent TCE and tritium, occurred prior to closure. During 1997, a multilayered cap was constructed over all the trenches, and a drainage control system was installed around the cap. The cap and the drainage control system are engineered to keep rainwater from contacting the buried waste (Ferry et al. 1998).

The Pit 6 disposal trenches were constructed in Quaternary terrace deposits (Qt) above and north of the Corral Hollow Creek flood plain. Surface runoff from the pit area flows southward to Corral Hollow Creek. The Carnegie-Corral Hollow Fault zone extends beneath the southern third of Pit 6. The northern limit of the fault zone is shown in **Figure 9-8**. Beneath the northern two-thirds of Pit 6, groundwater flows south-southeast, following the inclination (dip) of the underlying

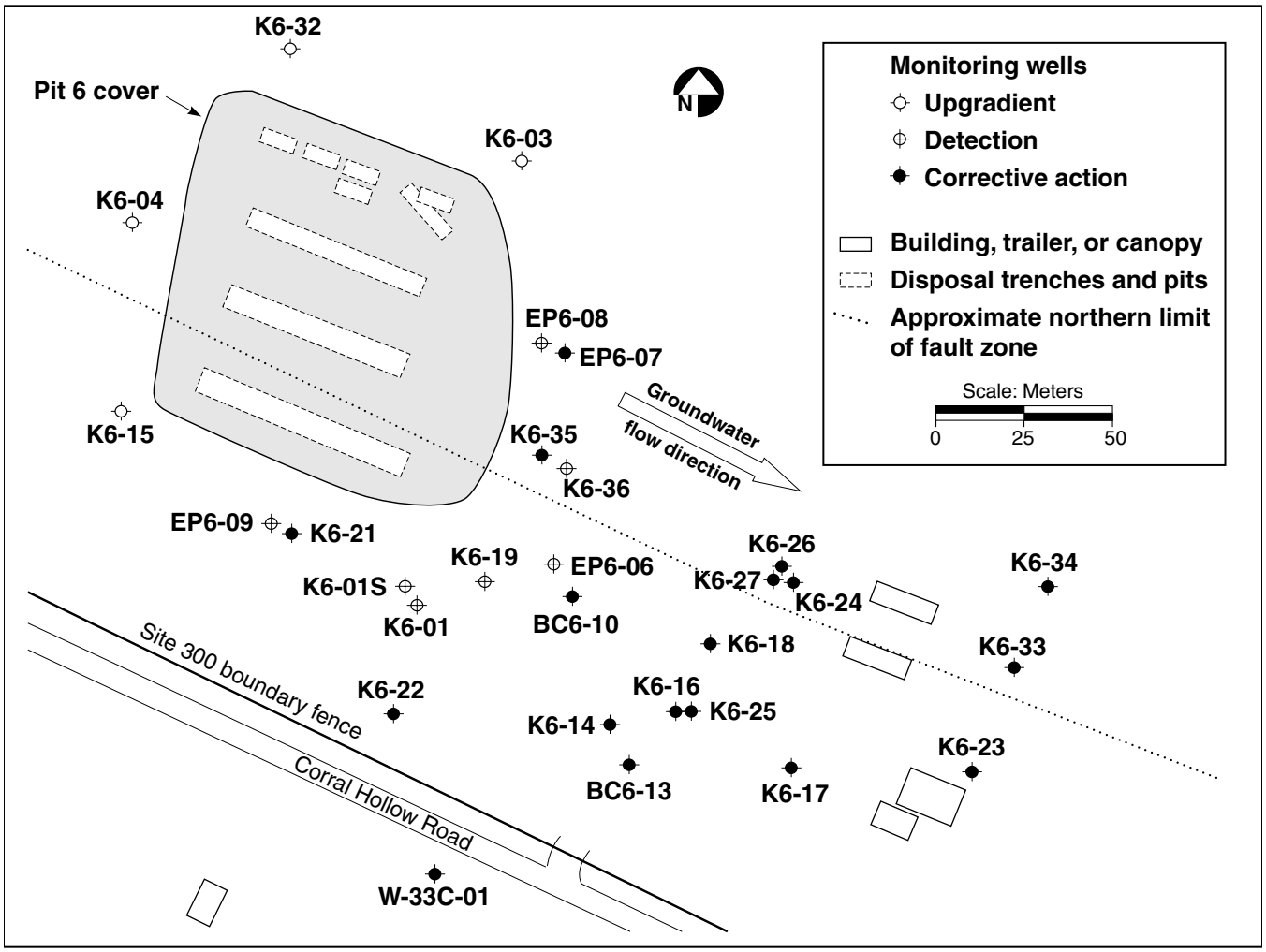

Figure 9-8. Locations of Pit 6 groundwater wells

sedimentary rocks. Groundwater seepage velocities are less than 10 m/y. Depths to the water table range from 10-20 m. Beneath the southern third of Pit 6, a trough containing terrace gravel within the fault zone provides a channel for groundwater to flow southeast, parallel to the Site 300 boundary fence (Webster-Scholten 1994). (See Chapter 8 for a review of the stratigraphy, hydrogeology, and groundwater contamination in the Pit 6 area.)

Two groundwater monitoring programs were implemented at the Pit 6 landfill during 1998 to ensure compliance with all regulations: (1) the Detection Monitoring Program (DMP), designed to detect any new release of COCs to groundwater from wastes buried in the Pit 6 landfill, and (2) the Corrective Action Monitoring Program (CAMP), which operates under CERCLA and monitors the movement and fate of existing releases (see Chapter 8 for a summary of CAMP monitoring results for Pit 6). During 2000, perchlorate was added to the list of 24 COCs, which include VOCs and radioisotopes, that are monitored in groundwater near Pit 6 (Ferry et al. 1998). **Figure 9-8** shows the locations of Pit 6 and the wells used to monitor groundwater there.

As required by the monitoring program contained in the postclosure plan, groundwater at the Pit 6 monitoring wells was sampled quarterly during 2000. Samples were analyzed for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium activity, uranium activity, VOCs (EPA Method 624), extractable organics (EPA Method 625), pesticides (EPA Method 608), and PCBs (EPA Method 8082A). Field measurements of groundwater depth, temperature, pH, and specific conductance were obtained at each well at the time of sample collection. Three quarterly reports and one annual report covering monitoring activities at Pit 6 during 2000 have been published previously (Christofferson and Taffet 2000, Christofferson et al. 2000a, 2000b, 2001). Tables listing the groundwater data obtained during year 2000 for Pit 6 can be found in Christofferson et al. 2001.

HE Process Area Closed Burn Pits: Compliance monitoring requirements for the closed burn pits in the Corral Hollow Creek drainage area are specified in the *Final Closure Plan for the High-Explosives Open Burn Treatment Facility at Lawrence Livermore National Laboratory Experimental Test Site 300* (Mathews and Taffet 1997) and in the *Post-Closure Permit Application for the Building 829 HE Open Burn Facility – Volume 1.* (LLNL 2000).

The former High-Explosives (HE) Open Burn Treatment Facility, part of the Building 829 Complex, is located on a ridge within the southeast portion of Site 300 at an elevation of about 320 m (1050 ft) (see **Figure 9-9**). The facility included three shallow unlined pits constructed in unconsolidated sediments that cap the ridge (Tps formation). The former burn facility was covered with an impervious cap during 1998 following RCRA guidance. The facility was used to thermally treat explosives waste generated by research operations at Site 300. Surface water drains southward from the facility toward Corral Hollow Creek. The nearest site boundary lies about 1.6 km (4500 ft) to the south at Corral Hollow Road. Stratified rocks of the Neroly (Tn) formation underlie the facility and dip southeasterly. Two water-bearing zones exist at different depths beneath the facility. The shallower zone, at a depth of about 30 m (100 ft), is perched within the Neroly upper siltstone/claystone aquitard ($Tnsc_2$). The deeper zone, at a depth of about 120 m (400 ft), represents a regional aquifer within the Neroly upper sandstone member ($Tnbs_2$). (See Chapter 8 for a review of the stratigraphy, hydrogeology, and groundwater contamination in this area.)

Based on groundwater samples recovered from boreholes, previous CERCLA remedial investigations determined that the perched groundwater beneath the burn facility was contaminated with VOCs, primarily TCE, but that the deeper regional aquifer was free of any contamination stemming from operation of the facility (Webster-Scholten 1994). Subsequent assays of soil samples obtained from shallow boreholes prior to closure revealed that low concentrations of HE compounds, VOCs, and metals exist beneath the burn pits (Mathews and Taffet 1997). Conservative transport modeling indicates that the shallow contamination will not adversely impact the regional aquifer, primarily because its downward movement is blocked by a 100-m-thick intervening aquitard. However, beginning in 1999, LLNL implemented the intensive groundwater monitoring program for this area described in the postclosure plan (Mathews and Taffet 1997) to track the fate of contaminants in the perched water-bearing zone and to watch the deep regional aquifer for the appearance of any potential contaminants from the closed burn facility.

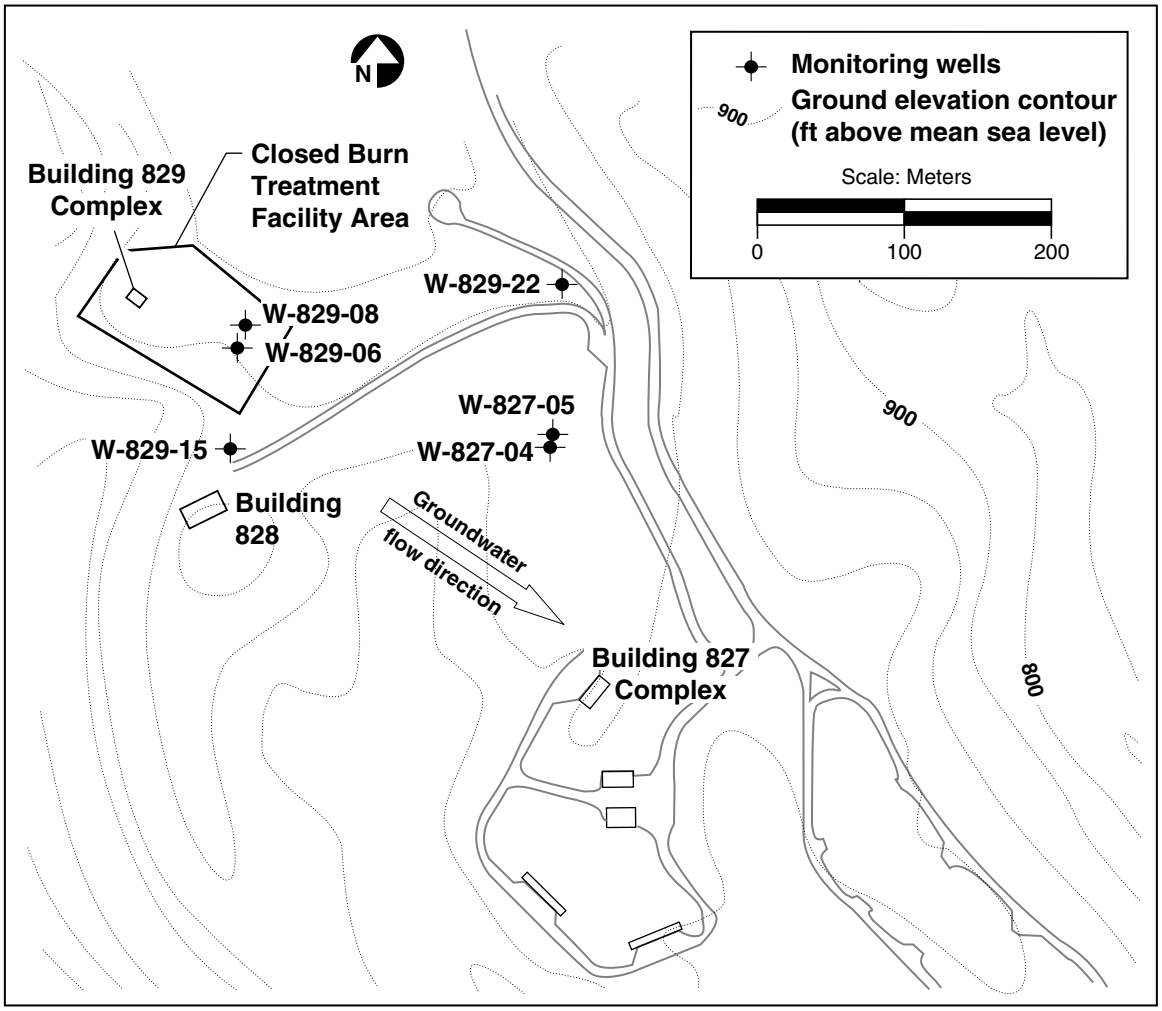

Figure 9-9. Locations of monitoring wells in Building 829 closed burn facility area

Figure 9-9 shows the locations of the closed burn treatment facility area and the six wells used to monitor the groundwater. Two wells, W-829-06 and W–829-08, are screened in the perched water-bearing zone beneath the former burn facility. The remaining four wells are screened in the deep regional aquifer downgradient of the closed facility. During 2000, quarterly samples were obtained from five of the six monitoring wells. One of the deep wells, W-827-04, was dry during 2000. Groundwater samples from the wells screened in the deep regional aquifer were analyzed quarterly for inorganic COCs (mostly metals), general minerals, explosive compounds (HMX, RDX, and TNT), VOCs (EPA Method 624), extractable organics (EPA Method 625), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and radium), total organic carbon (TOC), total organic halides (TOX), and coliform bacteria. Groundwater samples from the two wells screened in the shallow perched water-bearing zone were analyzed quarterly for explosive compounds and VOCs during 2000.

Water Supply Wells: Water supply wells 18 and 20 are located in the southeastern part of Site 300 (**Figure 9-3**). Both are deep, high-production wells. Well 20 supplied potable water at the site during 2000, while well 18 was maintained as a standby water supply well. Both wells are screened in the $Tnbs_1$. The well 18 screen extends upward into the aquitard unit ($Tnsc_1$) that separates the upper ($Tnbs_2$) and lower blue sandstone units of the Neroly Formation. Each well can produce up to 1500 L/min of potable water. For many years, well 18 groundwater samples have shown trace amounts of TCE. CERCLA studies have not yet determined the source of the TCE in well 18 (see Chapter 8 for the locations of TCE plumes at Site 300).

As planned for surveillance purposes, groundwater samples were obtained quarterly from these two on-site supply wells. Groundwater samples from well 20 were analyzed for inorganic COCs (mostly metals), VOCs (EPA Method 502.2), explosive compounds (HMX, RDX), general radioactivity (gross alpha and gross beta), and tritium activity. Groundwater samples from standby well 18 were analyzed for VOCs, general radioactivity (gross alpha and gross beta), and tritium.

Explosives Process Area: WDR Order No. 96-248 establishes the basis for compliance monitoring of the two adjacent surface impoundments (see **Figure 9-10**). This includes quarterly monitoring of the groundwater, monitoring of various influent waste streams to the surface impoundments, and visual observations of leachate collection and removal systems. Influent wastewater monitoring complements administrative controls that regulate the discharge of chemicals that could degrade the polyethylene liners of the impoundments. A three-tiered monitoring program comprising weekly visual inspections of the leachate collection and removal systems, quarterly inspections of lysimeters, and quarterly sampling of monitoring wells is in place to detect any release of chemicals from the surface impoundments in the Explosives Process Area.

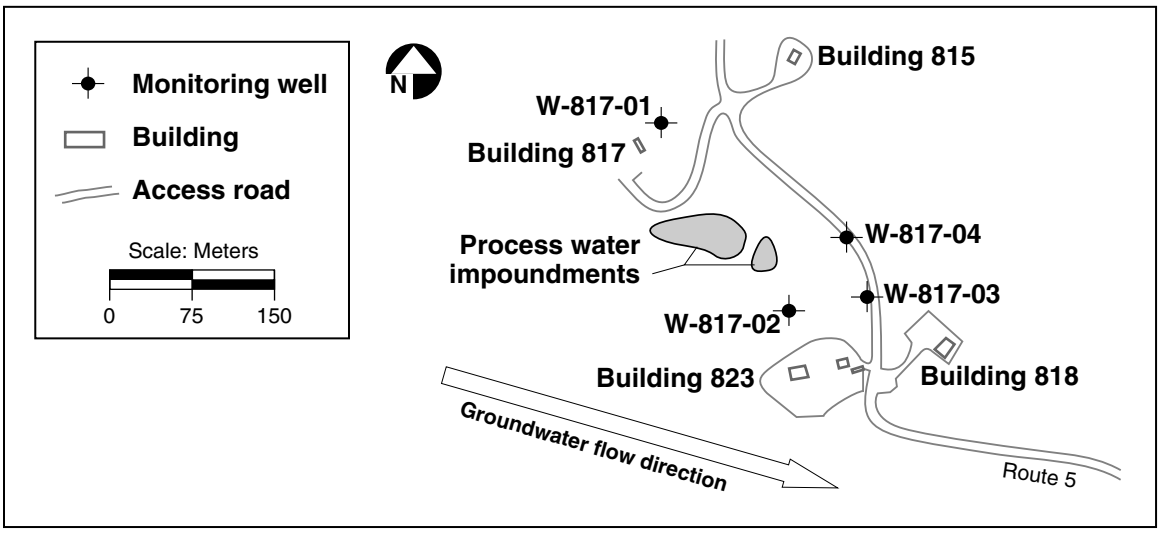

Figure 9-10. Locations of compliance groundwater monitoring wells in the Explosives Process Area

LLNL is required to obtain groundwater samples quarterly from four monitoring wells (see **Figure 9-10**) and to establish statistical concentration limits for COCs in groundwater beneath the surface impoundments. These requirements are part of the Monitoring and Reporting Program (MRP) for the surface impoundments detailed in WDR 96-248.

WDR 96-248 establishes limits for discharges of COCs into the surface impoundments and requires monitoring of the photographic process and chemistry area wastewater retention tanks that discharge to the surface impoundments as well as direct discharges to the surface impoundments from explosives processing. Influent streams are monitored at a prescribed frequency for area-specific COCs.

Retention tanks containing photographic process rinsewater from Buildings 801, 823, and 851 are sampled to confirm that discharges are consistent with effluent discharge limits specified in WDR 96-248. Discharges to the surface impoundments occur after samples are obtained, except for rinsewater from the Building 823 retention tanks, which is discharged automatically to the surface impoundments and sampled quarterly.

Samples of process wastewater from the Chemistry Area (Buildings 825, 826, and 827 Complex) are collected when the retention tanks are ready for discharge to the surface impoundments. The wastewater is held in retention tanks until analytical results indicate compliance with WDR 96-248.

Process water discharges to the surface impoundments are analyzed for COCs that have been found (or are likely to be found) in the process water from each specified building within the Explosives Process Area. This monitoring program includes process wastewater from Buildings 806/807, 809, and 817. WDR 96-248 requires annual analysis of this waste stream.

Percolation Pits: Percolation pits that are designed to accept discharges from mechanical equipment are located at Site 300 Buildings 806A, 827A, 827C, 827D, and 827E. In other remote Site 300 facilities, these types of waste streams are discharged to septic systems. These discharges are permitted by WDR 96-248, which specifies monthly observations and monitoring requirements for overflows. Overflows of the percolation pits, should they occur, are sampled and analyzed to determine if any metals are present.

Sewage Evaporation and Percolation Ponds: Site 300 is not serviced by a publicly owned treatment works (POTW) as is the Livermore site; therefore, alternate methods of treating and disposing of sanitary waste are necessary. Sewage generated at buildings in the General Services Area is discharged into a lined evaporation pond. The wastewater is disposed of through evaporation from the pond. However, during rare periods of high rainfall, treated wastewater may overflow into an unlined percolation pond, where it enters the ground and the shallow groundwater.

The environmental monitoring requirements for the sewage evaporation and percolation ponds (hereafter sewage ponds) are specified in MRP 96-248. The monitoring requirements include both wastewater monitoring and monitoring of the groundwater to detect potential impacts of the sewage on groundwater quality.

Wastewater is sampled quarterly at an influent location (ISWP) and within the pond (ESWP). Overflows are sampled as needed at location DSWP. The sampling locations are shown in **Figure 9-11.**

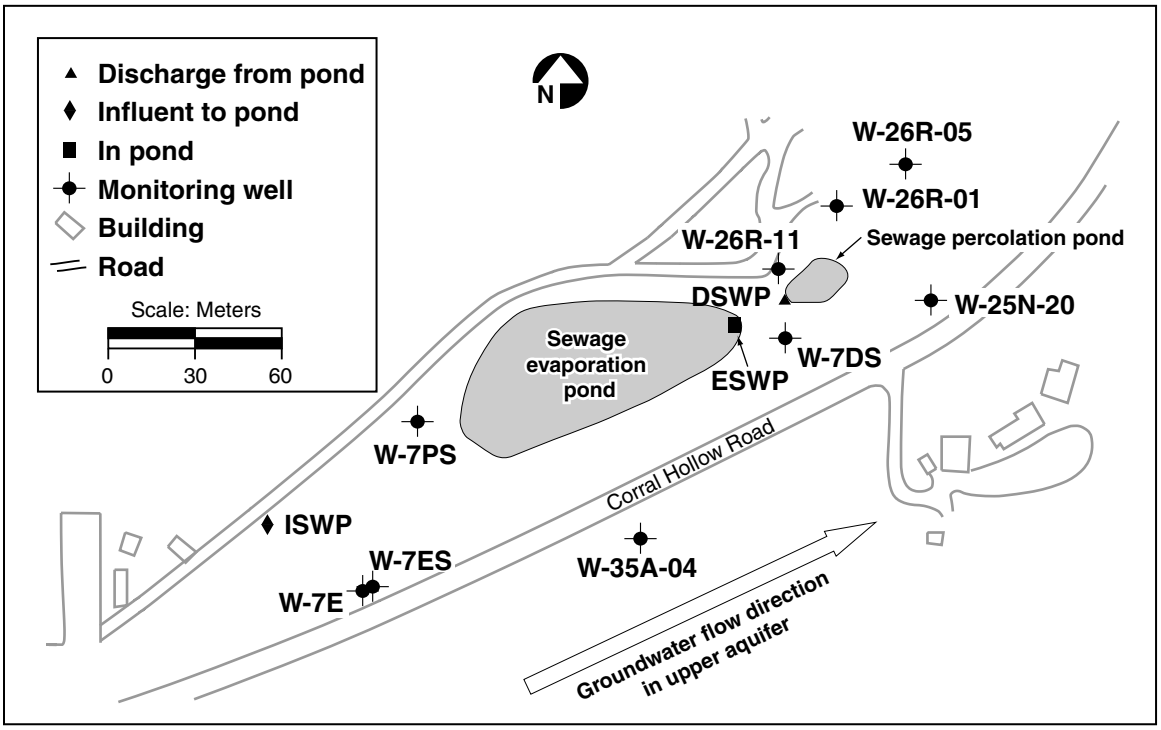

Figure 9-11. Sewage evaporation and percolation ponds, compliance groundwater monitoring wells, and wastewater monitoring locations

Nine groundwater monitoring wells are sampled semiannually to provide information on the groundwater quality in the vicinity of the sewage ponds (**Figure 9-11**). The wells are screened in three different geological formations: Qal, $Tnbs_1$, and $Tnsc_1$ (see Chapter 8). $Tnbs_1$ (Neroly Formation lower blue sandstone unit) is the regional aquifer.

Off-site Surveillance Wells and Springs: As planned for surveillance purposes, groundwater samples were obtained from two off-site springs and ten off-site wells during 2000. With the exception of one well, all off-site monitoring locations are near Site 300. The exception, well VIE2, is located at a private residence 6 km west of the site. It represents a typical Altamont Hills potable water supply well. One stock watering well, MUL1, and two stock watering springs, MUL2 and VIE1, are adjacent to Site 300 on the north. Eight wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W-35A-04, are adjacent to the site on the south (**Figure 9-3**). Seven of the wells to the south are privately owned and were constructed to supply water for human consumption, stock watering, or fire suppression. The exception is well W-35A-04, which is a DOE CERCLA well that was installed for monitoring purposes only.

Groundwater samples were obtained quarterly during 2000 at six off-site surveillance well locations south of Site 300. Of these, CARNRW1 and CON2 samples were analyzed for VOCs (EPA Method 601) and tritium. Samples from CARNRW2, CDF1, CON1, and GALLO1 were analyzed quarterly for inorganic COCs (mostly metals), general radioactivity (gross alpha and

beta), tritium activity, explosive compounds (HMX and RDX), and VOCs (EPA Method 502.2). Additional analyses were conducted on third-quarter samples for uranium activity and extractable organics (EPA Method 625).

Groundwater samples were obtained once (annually) during 2000 from six off-site surveillance monitoring locations—MUL1, MUL2, VIE1, and VIE2 (north and west of Site 300) and STONEHAM1 and W-35A-04 (south of Site 300). Samples were analyzed for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), tritium and uranium activity, explosive compounds (HMX and RDX), VOCs (EPA Method 502.2), extractable organics (EPA Method 625), and pesticides (EPA Method 608).

Sampling and Analytical Methods

Representative samples of groundwater were obtained from monitoring wells in accordance with the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)* (Dibley and Depue 2000). These protocols cover sampling techniques and specific information concerning the chemicals that are routinely searched for in groundwater. Different sampling techniques were applied to different wells depending on whether they were fitted with submersible pumps, had to be bailed, or contained Barcad devices. See the Data Supplement for sampling details.

At Site 300, wastewater samples from the photographic and explosives process areas, sewage evaporation pond influent, water in the pond, and overflow water from the percolation pits pond were obtained in accordance with the standardized procedures of the Operations and Regulatory Affairs Division (Tate et al. 1999). Standard sample handling and hygiene procedures were employed to prevent cross-contamination (e.g., wearing disposable gloves, decontaminating equipment between uses, and maintaining samples at 4 ± 2°C). Replicates, field blanks, and trip blanks were obtained for quality assurance/quality control purposes. Analyses were performed by state-certified contract analytical laboratories.

Technologists collected wastewater samples from retention tanks in the Chemistry Area associated with Buildings 825, 826, and 827 using Hazardous Waste Management Procedure 411. Wastewater was held in retention tanks until analytical results were reviewed for compliance with WDR 96-248. Some of the analyses were performed by LLNL, which is state-certified for some analyses. The remainder of the analyses were done by off-site contract laboratories late in the year.

Results

This section presents the monitoring results for the Livermore site and environs as well as Site 300.

Livermore Site and Environs

Livermore Valley

Measurements of water samples obtained during the summer of 2000 from 20 wells (some of the wells were either dry or not sampled for some other reason in 2000) in the Livermore Valley continue to show very low tritium levels compared with the 740 Bq/L (20,000 pCi/L) maximum contaminant level (MCL) established by the California Department of Health Services. For 2000, the highest tritium activity measured off site was 5.0 ± 2.0 Bq/L in a groundwater sample from well 12D2 (see **Figure 9-1**), located about 10 km west of LLNL (results are reported in Data Supplement Table 9-30). **Figure 9-12** shows the trend in maximum tritium activity in the Livermore Valley wells sampled. The maximum Livermore Valley tritium activity was measured in samples collected from well 11B1 from 1988 through 1996; the

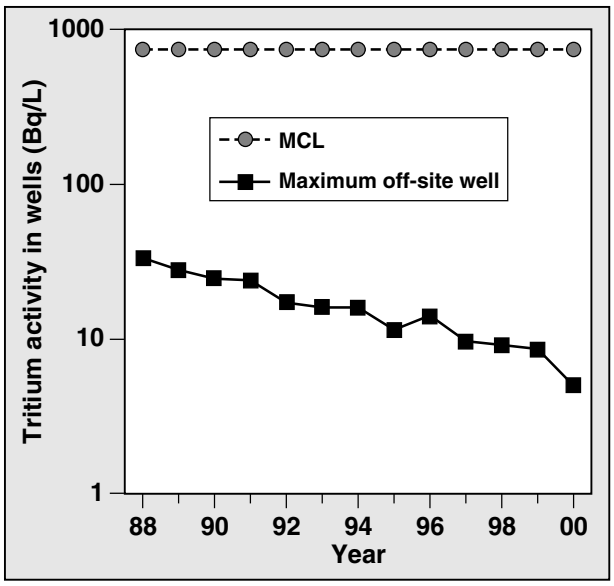

Figure 9-12. Trend of tritium activity in Livermore Valley wells, 1988 to 2000. Drinking water MCL of 740 Bq/L is also shown

maximum has varied between wells 11B1 and 12D2 from 1997 through 2000. Even the highest activity of 32.9 Bq/L for a water sample collected from well 11B1 in 1988 was less than 5% of the California's MCL.

Overall tritium activity has been decreasing in Livermore Valley groundwaters downgradient of LLNL. The median activities of tritium in groundwater samples from these downgradient wells decreased from 3.00 Bq/L in 1988 to 0.65 Bq/L in 2000.

Livermore Site Perimeter

Tritium activity ranged from –2.1 (calculated) Bq/L to 5.6 Bq/L in groundwater samples from on-site background monitoring wells and from –2.5 (calculated) to 13.1 Bq/L in western perimeter monitoring wells.

No pesticide or herbicide semivolatile organic compounds were detected in the groundwater during 2000.

The inorganic compounds detected, including dissolved trace metals and minerals, occur naturally in the groundwater at variable concentrations. **Table 9-1** shows the three anions with the highest

Table 9-1. Concentration ranges for three major anions in shallow background and western perimeter monitoring wells

Concentration range (mg/L)	Hydrologic flow	
	Background	Western perimeter
Bicarbonate (HCO^{3-})		
Range	230–340	190–280
Median	290	240
Chloride (Cl^-)		
Range	300–510	75–150
Median	385	87
Sulfate (SO_4^{2-})		
Range	97–340	26–64
Median	214	38

concentrations in the two shallower background wells, W-008 and W-221, and the seven western wells at LLNL. Concentrations of these major anions are higher in the background wells than in the western wells (see Tables 9-2 through 9-11 in the Data Supplement). Concentrations of chloride in shallow background wells W-008 and W-221 (Tables 9-2 and 9-3 in the Data Supplement) are higher than California's recommended secondary MCL of 250 mg/L, while chloride concentrations in none of the western wells exceed 250 mg/L. Likewise, sulfate concentrations in background well W-008 exceed California's recommended

secondary MCL of 250 mg/L, while sulfate concentrations in none of the western wells exceed 250 mg/L. Additionally, the boron concentration of 8.7 mg/L in background monitoring well W-008 in February 2000 is an order of magnitude higher than it is in the western wells. Poor groundwater quality in the background (eastern, especially northeastern) portions of the site has been described previously in the remedial investigations (Thorpe et al. 1990).

In March 1996, nitrate was first detected at concentrations greater than the MCL of 45 mg/L (75 mg/L) in a groundwater sample obtained from western perimeter monitoring well W-1012 (screened in HSU 2) (see **Figure 9-2**). From a groundwater sample collected in May 2000, the concentration of nitrate for this well was 97 mg/L (see Data Supplement Table 9-9). This is the highest nitrate concentration measured in any surveillance monitoring well during 2000. Because of the hydrologic influence of Treatment Facility B that pumps and treats groundwater from HSUs 1B and 2 (see Chapter 8), groundwater with high nitrate concentrations is restrained from moving off site to the west. The highest concentration measured in an off-site well was at or below the MCL at 37 mg/L, in downgradient monitoring wells W-151 and W-571 (see Data Supplement Tables 9-7 and 9-8). Monitoring well W-571 is off-site and downgradient from well W-1012, but is screened in HSU 1B; monitoring well W-151 is off-site and downgradient to the southwest, along Arroyo Seco, and is screened in HSU 2. During 2000, concentrations of nitrate in on-site shallow background wells W-008 and W-221 ranged from 19 mg/L to 34 mg/L. Detected concentrations of nitrate in western wells, with the exception of well W-1012, ranged from 12 to 37 mg/L.

LLNL sampled and analyzed for nitrate eight additional wells surrounding well W-1012 during the fourth quarter in order to better define the elevated nitrate concentrations. Monitoring wells W-1013, W-1420, W-422, W-610, W-620, W-621, W-654, and W-705 were sampled in addition to wells W-1012 and W-571. Each of the additional monitoring wells is screened in either HSU 1B or HSU 2. All nitrate monitoring results for that area in 2000 are presented in Data Supplement Table 9-31. Nitrate was not detected at concentrations greater than the MCL in any other surveillance monitoring well during 2000. Fluctuations in nitrate concentrations have occurred since regular surveillance monitoring began in 1996, but nitrate concentrations have not increased overall in groundwater from the western monitoring wells since 1996. The nitrate may originate as an agricultural residue (Thorpe et al. 1990).

Of the 21 trace metal analytes, seven – barium, chromium, copper, hexavalent chromium, nickel, selenium, and zinc – were detected in western perimeter surveillance wells during 2000. Only chromium and hexavalent chromium exceeded California's MCL of 50 µg/L in groundwater samples collected from western perimeter well W-373 in February (see Data Supplement Table 9-11). Groundwater samples collected from this well are from HSU 1B, and the nearby Treatment Facility C (see **Figure 8-1**) treats groundwater from HSU 1B for chromium. Consequently, concentrations of chromium (including hexavalent chromium) have been continually decreasing (see Data Supplement Tables 9-2 through 9-11).

A groundwater sample collected from on-site well W-1012 (0.49 ± 0.03 Bq/L, or 13.3 ± 0.92 pCi/L) exceeded the MCL for total radium of 0.185 Bq/L (5 pCi/L) (see Data Supplement Table 9-9). It is now the routine procedure at LLNL to collect and analyze two retest samples when such an overage occurs. The first retest sample was collected in October with an analytical result of 0.003 ± 0.004 Bq/L (see Data Supplement Table 9-9). The second was collected

early in 2001 and had an analytical result of <0.009 Bq/L. Therefore, the original result greater than the MCL was not confirmed.

Activities of naturally occurring total uranium (uranium-234 + 235 + 238) continued to be highest in the shallow background wells W-008 and W-221 during 2000. Activities of total uranium in those wells were measured as 0.20 ± 0.04 Bq/L to 0.25 ± 0.05 Bq/L (34% of California's MCL of 0.74 Bq/L, or 20 pCi/L). (See Data Supplement Tables 9-2 and 9-3). Activities of total uranium are lower, from 0.024 ± 0.013 Bq/L (in well W-121) to 0.23 ± 0.04 Bq/L (31% of California's MCL in well W-1012), in groundwater from each of the western monitoring wells (Data Supplement Tables 9-6 and 9-9). Uranium and its radioactive daughters, thorium-230, radium-226, and radon-222, occur naturally in the sediments and rock layers beneath and surrounding LLNL. Uranium activities did not exceed drinking water limits.

Livermore Site

Groundwater downgradient of potential sources showed possible impact from two releases of metals to the ground. Groundwater at well W-307 near Building 322 showed a maximum concentration of hexavalent chromium at 14 µg/L, slightly greater than 10 µg/L, the highest concentration of hexavalent chromium measured in shallow background well W-008 at various times from 1996 through 1999. Hexavalent chromium was detected at elevated concentrations in groundwater samples from wells W-226 and W-306, downgradient from the Building 253 catch basin. Concentrations were measured as 26 µg/L and 27 µg/L (at well W-226) and 40 µg/L and 41 µg/L (at well W-306) (see Data Supplement Tables 9-24 and 9-25). The accumulated sediment in the catch basin is a potential source of several metals (Jackson 1997). No concentrations of hexavalent chromium exceeded the MCL of 50 µg/L for chromium in drinking water.

The initial analytical results from well W-148, downgradient from both the Plutonium and Tritium Facilities, show radium-226 detected from a sample collected in March 2000 to be 0.30 ± 0.07 Bq/L (8.0 ± 1.8 pCi/L), which is above the MCL for total radium. LLNL again employed the retest procedure with two retest groundwater samples collected in August and October 2000. Analytical results for the retest samples were 0.048 ± 0.015 Bq/L and 0.008 ± 0.004 Bq/L, respectively. The original analytical result for radium-226 that was greater than the MCL was not confirmed.

In August 2000, the tritium activity was 115 ± 5.0 Bq/L (about 15% of the MCL) in the groundwater sampled at well W-148, downgradient from the Tritium Facility (Building 331). This relatively elevated tritium activity triggered additional sampling of groundwater from wells in the vicinity of Building 331 during the fourth quarter of 2000, including monthly samples from wells W-148 and W-301 (see **Figure 9-2**). The tritium activities of these additional groundwater samples are listed in Table 9-29 of the Data Supplement. Groundwater tritium activities were at or near background level by December 2000 in all the wells sampled downgradient of Building 331. The relatively elevated tritium activity in the groundwater sampled at well 148 in August 2000 is most likely related to local infiltration of storm water containing elevated tritium activity (see Chapter 7). No radioactivity of concern was detected for americium or plutonium radioisotopes in the groundwater sampled at the routine monitoring wells in this area (see Data Supplement Tables 9-26 through 9-28). LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that their tritium, americium, and plutonium contents remain below any environmental levels of concern.

Site 300

The following are summaries of Site 300 groundwater surveillance and compliance monitoring results for 2000. Site 300 compliance monitoring results for 2000 have been published previously (Brown 2000a, b, c, and 2001; Christofferson and MacQueen 2000a, b, c, and 2001; Christofferson and Taffet 2000; Christofferson et al. 2000a, 2000b, 2001). Compliance monitoring results for Site 300 are discussed again in the following summaries. Surveillance monitoring results for 2000 have not been published elsewhere.

Elk Ravine Drainage Area

Pit 7: Data collected during 2000 show no new release of constituents of concern (COCs) to groundwater from Pit 7. The few COCs detected in the groundwater are mostly from sources other than Pit 7 that were seasonally exposed to infiltrating stormwater or to rising groundwater. Groundwater elevations beneath the closed landfills have been generally falling since they peaked in 1998, because of reduced rainfall and recharge. Pits 3 and 5, which are adjacent to and downgradient from Pit 7 are the primary sources of the COCs detected by the network of Pit 7 monitoring wells. The COCs detected include metals, depleted uranium, tritium, and several volatile organic compounds (VOCs). Natural sources in the rocks and sediments surrounding Pit 7 have also contributed uranium and other elements to the groundwater.

Compliance monitoring results for 2000 suggest that zinc was released to groundwater from the RCRA-closed Pit 7 landfill. However, it is more likely that it came from waste buried in one of the other closed landfills nearby. Well K7-03 is located hydraulically downgradient of all four closed landfills constituting the Pit 7 Complex. It is improbable that there has been a postclosure release of zinc from Pit 7 because zinc was not detected at well NC7–48, which is located immediately downgradient of Pit 7 (**Figure 9-4**). It was likely released from waste buried in the closed Pit 5 landfill, which is upgradient and adjacent to well K7–03. Both Pits 3 and 5 are known to have been partially inundated by rising groundwater during the El Niño winter of 1997–1998, when the site received more than double the average seasonal rainfall (Ziagos and Reber-Cox 1998b), which likely released zinc and other COCs to groundwater.

As in the past, tritium activity in groundwater sampled at Pit 7 monitoring wells K7-01, K7-03, and NC7-25 remained above the MCL of 740 Bq/L throughout 2000. However, tritium activities generally decreased during 2000, following a peak activity of 28,500 Bq/L (770,000 pCi/L) measured in groundwater sampled at well NC7-25 during fourth quarter 1999. As in the past, the groundwater immediately downgradient of Pit 7 at well NC7-48 showed very low tritium activity. Historical tritium activity measurements of groundwater sampled at well NC7-48 indicate that no release of tritium has occurred from Pit 7 to groundwater since the well was completed in 1986.

The rising trend in tritium activity in the groundwater at well NC7-25 began in 1995. CERCLA investigations link the rising trend to seasonal releases of tritium in Pit 3, which began during the winter of 1992-93 and continued during successive winters through 1997-98, at which time Pit 3 was partially inundated from beneath by rising groundwater. (Taffet et al. 1996, Ziagos and Reber-Cox 1998b).

As in the past, three VOCs were detected in the groundwater sampled at Pit 7. Trichloroethene (TCE), which has an MCL of 5.0 µg/L, ranged between 2.0 and 5.6 µg/L in groundwater sampled at Pit 7 monitoring wells K7-01 and K7-03. The TCE is associated with past releases

from Pit 5 (Webster-Scholten 1994, Taffet et al. 1996). 1,1-Dichloroethene (1,1-DCE), which has an MCL of 6.0 µg/L, was detected each quarter at Pit 7 monitoring well K7-03 at low concentrations ranging from 1.0 µg/L to 1.6 µg/L. 1,1-DCE was detected in the fourth quarter at a concentration of 0.7 µg/L in groundwater sampled at well K7-01. If TCE or 1,1-DCE were released from Pit 7, we would expect to detect them in the groundwater sampled at well NC7-48, but we do not. Only one VOC, trichlorofluoromethane (Freon 11), which has an MCL of 150 µg/L, has been detected in groundwater sampled at well NC7-48. The maximum concentration measured during 2000 is 1.0 µg/L. Pit 7 is the probable source of the Freon 11, because it is the only landfill upgradient of monitoring well NC7-48.

Elk Ravine: Analytical results for the Elk Ravine drainage area surveillance monitoring network for 2000 are listed in Data Supplement Table 9-32 (see **Figure 9-3**). As in past years, arsenic, barium, chromium, selenium, vanadium, and zinc were detected at low concentrations typical of groundwater elsewhere in the Altamont Hills.

Tritium activity was above background level in many of the shallow groundwater surveillance samples obtained during 2000 from Elk Ravine. Tritium, as tritiated water (HTO), has been released in the past in the vicinity of Building 850 (Taffet et al. 1996). The HTO plumes at Site 300 are limited to shallow depths in the Neroly lower blue sandstone unit and overlying alluvium (see **Figure 8-12** for the CERCLA map of tritium plumes). As in past years, tritium activity was not discernible in groundwater samples from the deeper water-bearing zone monitored at surveillance well NC7-69.

The majority of the Elk Ravine surveillance network tritium measurements made during 2000 support earlier CERCLA studies that show that, despite additional releases, the tritium contents and extents of the plumes are generally diminishing over time because of natural decay and dispersion (Ziagos and Reber-Cox 1998b). LLNL observed small increases in tritium activity at the distal end of the plume (wells K2-01C, NC2-11D, and NC2-12D), while those wells monitoring the bulk of the plume (NC7-61, K2-04D, and K2-04S) show relatively large decreases in tritium activity over the past several years. For example, tritium activity in groundwater at well NC7-61 decreased from 6500 Bq/L in 1996 to 2500 Bq/L in 2000.

Surveillance measurements in Elk Ravine of gross alpha, gross beta, and uranium radioactivity were all low and indistinguishable from background levels. (Note that gross beta measurements do not detect the low-energy beta emission from tritium decay.)

Pit 2: No release of a COC from Pit 2 to groundwater is indicated by the surveillance monitoring data obtained during 2000. Analytical results for the Pit 2 surveillance monitoring network are presented in Data Supplement Table 9-33. Several metals were detected at low concentrations. Most were below analytical reporting limits, which are in the parts per billion (ppb) range. None exceeded an MCL. Arsenic and barium concentrations were within the range of natural (background level) concentrations in groundwaters at Site 300 (Webster-Scholten 1994). The radioactivity measurements show only low background-level activities for gross alpha, gross beta, and tritium. Anomalous tritium activities were measured in the fourth quarter for Barcad locations K1-02A (620 Bq/L) and K2-01A (210 Bq/L), but these were not confirmed by two sets of retest samples obtained from those locations. All four retest samples had tritium activities below the analytical reporting limit of about 4 Bq/L.

Pit 1: No new release of constituents of concern (COCs) to groundwater from Pit 1 is evident in the data collected during 2000.

Tritium activity measured above background levels in the groundwater at Pit 1 monitoring wells K1-01C, K1-02B, K1-03, and K1-08 during 2000 (see **Figure 9-5**). However, no release of tritium from Pit 1 is indicated by these measurements. Rather, the tritium activity represents a distal lobe of the Building 850 tritium plume, which extends eastward more than 1 km to Pit 1 (see **Figure 8-17** for a CERCLA map of the Building 850 tritium plume extending to Pit 1).

Measurements of radium, thorium, and uranium made during 2000 in groundwater samples from Pit 1 compliance monitoring wells all showed low activities indistinguishable from background levels.

The VOC 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113) decreased from a maximum concentration of 140 µg/L in 1999 to 80 µg/L in 2000 in groundwater at Pit 1 monitoring wells K1-05, K1-08, and K1-09. The drinking water MCL for this VOC is 1200 µg/L. Previous CERCLA investigations have linked the Freon 113 detected in Pit 1 monitoring wells to past spills of Freon in the Advanced Test Accelerator area, about 200 m west and cross-gradient from the affected wells (Webster-Scholten 1994, Taffet et al. 1996).

Pit 8: No release of a COC to groundwater from Pit 8 is indicated by the surveillance monitoring data obtained during 2000. Analytical results for the Pit 8 surveillance monitoring network are presented in Data Supplement Table 9-34. Two VOCs, TCE and 1,2-dichloroethane (1,2-DCA) were detected below their 5 µg/L MCLs. A relatively small VOC plume exists beneath this area (see Chapter 8), which originated prior to 1981 from waste discharged to a dry well upgradient of Pit 8, near Building 801 (Webster-Scholten 1994). Arsenic, chromium, selenium, and vanadium were detected in concentrations similar to their natural levels in groundwater elsewhere in the Altamont Hills.

Pit 9: No evidence for a release from Pit 9 is indicated by the surveillance monitoring data obtained during 2000. Analytical results for the Pit 9 surveillance monitoring network are presented in Data Supplement Table 9-35. COCs were either not detected or were indistinguishable from natural background level concentrations. Since annual surveillance monitoring of groundwater began there more than a decade ago, no evidence of a release of any COCs from Pit 9 has been recorded.

Corral Hollow Creek Drainage Area

Pit 6: No new release of COCs from Pit 6 is indicated by the DMP groundwater data collected during 2000. Designated COCs, including several VOCs and tritium that were released prior to pit closure, continued to be detected in the groundwater at low concentrations. Only two COC measurements exceeded statistical limits during 2000, and those were invalidated by retesting (total uranium, well EP6-09, and benzene, well EP6-06, third quarter 2000).

In 1998, detections of the VOC 1,2-DCA were reported as statistically significant evidence of a postclosure release from Pit 6 (Galles 1998). During the fall of 1998, water was pumped from well EP6-09 and VOCs were removed by air-sparging. Evidence of the success of this action was the decrease in TCE concentration to below the MCL in the groundwater at well EP6-09 and the subsequent disappearance of detectable concentrations of 1,2-DCA through 2000.

During 2000, only one measurement of TCE in groundwater at a DMP monitoring well exceeded the MCL of 5 µg/L for TCE in drinking water. That was the fourth-quarter measurement of

5.1 µg/L TCE in the groundwater sample from well K6-19. However, the groundwater sampled at this well continues to follow an historically decreasing trend of TCE concentration.

As in the past, the organic compound bis(2-ethylhexyl) phthalate, which is not a designated COC, was detected at concentrations up to 14 µg/L in groundwater sampled at two upgradient wells (K6-03 and K6-04) and at two downgradient wells (K6-19 and K6-36). The compound has been sporadically detected upgradient and downgradient of Pit 6 since postclosure monitoring began in 1998. The source of this compound is unknown. There is no record of it being placed in the pit, but it is known to have been used historically in explosives at Site 300. It may also have served as a dielectric in transformers and capacitors. The California state MCL for this compound is 4 µg/L. All of the detections are above the MCL.

Relatively elevated tritium activity is contained within a small volume of groundwater that is adjacent to and downgradient (southeast) of Pit 6. Monitoring of the small tritium plume is being conducted by LLNL under CERCLA auspices. Tritium activity remained above background levels in groundwater sampled at downgradient wells K6-19 and K6-36. The maximum activity recorded was 2160 pCi/L (80 Bq/L), which is less than 11% of the 20000 pCi/L (740 Bq/L) MCL for tritium in drinking water. This represents a decrease since 1999 when the maximum tritium activity measured at the point of compliance was 2500 pCi/L (93 Bq/L), or 13% of the MCL. The decrease can be attributed to dilution and to natural decay of tritium (12.3-yr half-life). Continued monitoring of tritium in the vicinity of Pit 6 is being conducted by LLNL under CERCLA auspices (see **Figure 8-12** for a CERCLA map of the small tritium plume).

Building 829 Closed HE Burn Facility: Analyses of groundwater samples obtained quarterly from the deep regional aquifer downgradient of the closed HE burn facility show no consistent evidence of contamination from past operation of the facility. The analytical results represent background level concentrations of substances dissolved from natural sources in the underlying rocks. Analytical results for 2000 for three of the four wells that are used to monitor the deep regional aquifer are listed in Data Supplement Table 9-36. (A fourth deep well, W-827-04, was dry during 2000.)

As in the past, analyses of groundwater samples obtained from the shallower perched groundwater beneath the closed facility do show evidence of contamination. Analytical results for 2000 for the two wells that are used to monitor the perched groundwater are listed in Data Supplement Table 9-37. The primary contaminant in the perched groundwater is TCE. TCE concentrations up to 330 µg/L were measured during 2000. A second contaminant is 1,2-DCE. The maximum 1,2-DCE concentration measured during 2000 is 2.6 µg/L. The perched water has a high total concentration of dissolved substances. Many of the inorganic analytes measured have natural sources in the surrounding rocks. The perched groundwater does not contain clearly anthropomorphic chemicals such as pesticides, PCBs, herbicides, or the explosives compounds that were burned at the facility and that are known to exist at shallow depth in the soil above the perched groundwater.

Water Supply Wells: Analytical results for Site 300 water supply wells 18 and 20 are presented in Data Supplement Tables 9-38 and 9-39. As in past years, TCE was detected during 2000 in surveillance groundwater samples from standby well 18 at a maximum concentration of 0.5 µg/L, which is 10% of the MCL of 5 µg/L for

TCE. The source of the TCE has not yet been identified. Gross alpha, gross beta, and tritium activities in water samples from both production wells are very low and are indistinguishable from natural background level activities. Lead was detected in the second quarter at a concentration of 9 µg/L in the routine well 20 water sample. However, the presence of lead was not confirmed by the analyses of the third and fourth quarter routine groundwater samples from well 20 in which lead was not detectable (<2 µg/L).

Explosives Process Area: The two leachate collection and removal systems were monitored weekly for the presence of liquids. In 2000, no water was recovered from the leachate collection and removal system. However, a potential leak was detected in the polyethylene liner of the lower surface impoundment by experimental electrical resistance tomography late in 1999. The presence of a hole in the liner was visually confirmed and repairs to the liner were made in January 2000 (Brown 2000a). No water has been observed in the leachate collection and removal system since liner repairs were made in 1997. No water was found in five lysimeters. Analytical results for all monitored constituents in Site 300 groundwater beneath the surface impoundments are contained in the *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2000* (Brown 2001).

The explosive compounds (HMX, RDX, and TNT) and perchlorate are the compounds most indicative of discharges to groundwater from the Explosives Process Area surface impoundments. However, prior to 1985, explosives wastewater was discharged into unlined ponds in the vicinity of the surface impoundments, where it infiltrated the soil and some reached groundwater. Because of this past practice, it is necessary to discriminate between new releases from the surface impoundments and past releases from the unlined ponds. Analyses of groundwater from upgradient monitoring well W-817-01 during 2000 showed HMX concentrations between 17.5 and 23.4 µg/L (see **Figure 9-10**). HMX was not detected above the analytical reporting limit that varied from 0.1 to 1.0 µg/L in any of the groundwater samples from the downgradient monitoring wells. Groundwater samples from all four wells contained detectable concentrations of the explosive compound RDX above the analytical reporting limit of 0.85 µg/L. The groundwater samples containing RDX were from upgradient well W-817-01 (from 48.0 to 61.7 µg/L) and lower concentrations in downgradient wells W-817-02, W-817-03 and W-817-04. The RDX and HMX originated at closed disposal sites upgradient of the present surface impoundments (Raber and Carpenter 1983, Webster-Scholten 1994). Other explosive compounds or components of explosive compounds, 4-amino-2,6-dinitrotoluene and perchlorate, were detected in upgradient well W-817-01 and in two downgradient wells in this monitoring network. Another component of explosive compounds, 2-amino-4,6-dinitrotoluene, was also detected sporadically in this monitoring network during 2000. The concentrations observed in the downgradient wells do not exceed their permitted limits, but concentrations of perchlorate often exceeded the California Department of Health Services' recommended limit of 18 µg/L in drinking water. The remediation of these compounds is discussed in Chapter 8.

As in the past, groundwater concentrations of nitrate continued to exceed the drinking water MCL in samples from all surface impoundment monitoring wells during 2000. Concentrations of arsenic continue to be detected at concentrations at or near its drinking water MCL in these same wells during 2000. Concentrations of both arsenic and nitrate in groundwater have historically exceeded their respective MCLs (0.050 mg/L for arsenic and 45 mg/L for nitrate) in this area. Background

level concentrations of arsenic in groundwater monitoring wells upgradient from the surface impoundments have been measured at concentrations above the drinking water MCL (Webster-Scholten 1994). Although the distribution of arsenic over time and throughout the area suggests a natural source, the occurrence and concentration of arsenic at Site 300 is the subject of a continuing CERCLA study. The remediation of all of these compounds (except for the element arsenic) is discussed in Chapter 8 of this document.

During 2000, all discharges into the surface impoundments were in compliance with discharge concentration limits with one exception: an inadvertent discharge of 2-butanone (methyl ethyl ketone, or MEK) on August 7, 2000, at a concentration above permitted effluent limits into the upper surface impoundment. LLNL took a grab sample from the upper surface impoundment three days after the discharge that verified that MEK was not present in the upper surface impoundment at the elevated concentration. LLNL notified the CVRWQCB by letter (Galles 2000a) and took the corrective actions specified in that letter to minimize the likelihood of such an occurrence in the future. Those corrective actions taken were discussed in the third quarter monitoring report under WDR 96-248 (Brown 2000c). See the *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2000* (Brown 2001).

Percolation Pits: During 2000, the percolation pits at Buildings 806A, 827D, and 827E operated normally with no overflows. Standing water was regularly noted in the Building 827C percolation pit inspections (Brown 2001).

Sewage Evaporation and Percolation Ponds: All wastewater parameters for the sewage evaporation and percolation ponds complied with permit provisions and specifications throughout 2000, and there were no overflows to the percolation pond.

All of the groundwater monitored constituents were also in compliance with permitted limits. Nitrate concentrations in downgradient monitoring well W-26R-05 decreased to 6.0 mg/L during the third quarter. LLNL has not been able to determine the origin of elevated nitrate concentrations, but a sitewide study of nitrate at Site 300 is continuing, and LLNL continues to monitor these wells and nearby off-site wells for nitrate concentrations (see also Chapter 8).

Off-Site Water Supply Wells: Analytical results for the off-site water supply wells for 2000 are presented in Data Supplement Tables 9-40 to 9-46. Generally, no COC attributable to LLNL activities was detected in the off-site groundwater samples. Arsenic and barium were widely detected at these locations, but their concentrations were below MCLs and consistent with natural sources in the rocks. Scattered detections of metals were all below MCLs and were probably related to metals used in pumps and supply piping.

As in past years, TCE was detected at concentrations up to 0.6 µg/L in the groundwater samples obtained from well GALLO1 (see **Figure 9-3**). Previous CERCLA remedial investigations concluded that the TCE in the GALLO1 well water was likely caused by a localized surface spill on the property, possibly solvents used to service the private well (Webster-Scholten 1994). (Surveillance monitoring of a similarly sited well, GALLO2, was terminated in 1991 because of

contamination from chemicals leaking from the pumping apparatus.) Radioactivity measurements of off-site groundwater are all indistinguishable from natural background activities.

Environmental Impacts

The overall impact of Livermore site and Site 300 operations on off-site groundwaters is minimal. With the exception of VOCs being remediated under CERCLA at both sites, current LLNL operations have no measurable impact on groundwaters beyond the site boundaries.

Livermore Site and Environs

Groundwater monitoring at the Livermore site and in the Livermore Valley indicates that LLNL operations have minimal impact on groundwater beyond the site boundary. (See Chapter 8 for CERCLA remediation activities with VOCs.) During 2000, neither radioactivity nor concentrations of elements or compounds detected in groundwater from any off-site monitoring well were confirmed as exceeding primary drinking water MCLs. The maximum tritium activity of 13.1 Bq/L (355 pCi/L), only 1.8% of the MCL, in any Livermore site perimeter well was detected in the groundwater sample collected from on-site well W-373 in July (see **Figure 9-2**). The maximum tritium activity measured off site in the Livermore Valley was even lower, 5.0 Bq/L (134 pCi/L), in well 12D2 (see **Figure 9-1**).

Of the Livermore on-site monitoring wells, no inorganic data exceeded primary MCLs, with the exceptions of chromium in monitoring well W-373 and nitrate in monitoring well W-1012 (see **Figure 9-2**). Hexavalent chromium in groundwater in the vicinity of monitoring well W-373 is being removed at Treatment Facilities B and C. The LLNL Ground Water Project reports on the treatment of groundwater in the vicinity of the treatment facilities (see Chapter 8). Concentrations of nitrate in groundwater samples collected from well W-1012 throughout 2000 exceeded California's MCL of 45 mg/L. Nitrate above the MCL has not yet migrated off site. LLNL continues to monitor this well and monitoring well W-571, which is off-site and about 350 meters downgradient from well W-1012, to determine if nitrate migrates off site at concentrations above the MCL.

The arroyo sediment data in Chapter 10 indicate no potential adverse impact on groundwater through the arroyos that cross the Livermore site.

Site 300

Groundwater monitoring at Site 300 and adjacent properties in the Altamont Hills shows minimal impact of LLNL operations on groundwater beyond the site boundaries.

Within Site 300, the chemicals detected in groundwater beneath the High Explosives Process Area will not migrate off site. Plans to remediate TCE, explosive compounds such as RDX, perchlorates, and nitrate are currently being implemented under CERCLA auspices (see Chapter 8). Additionally, LLNL is investigating the distribution and origins of arsenic and zinc in this area.

VOCs, primarily the solvent TCE, have been released historically to shallow groundwater at numerous locations at Site 300 (see Chapter 8 and references cited therein). With the exceptions of a small plume in the General Services Area area that extends minimally off site along Corral Hollow Road, all of the TCE-bearing groundwater is on-site. The plume extending off site from the Eastern

GSA area is being drawn back to the site by pumping, and the TCE is being removed from the groundwater.

Tritiated water (HTO) has been released to groundwater from several landfills and a firing table in the northwestern part of Site 300. The boundary of the slowly moving HTO plume lies entirely within the site boundaries. CERCLA modeling studies indicate that, given tritium's short half-life of 12.3 years, and the relatively slow rate of groundwater flow (5-15 m/yr), the activity of the released HTO will decrease to several orders of magnitude below the MCL of 740 Bq/L (20,000 pCi/L) before it can reach a site boundary and travel off site (Taffet et al. 1996).