GROUNDWATER MONITORING

9

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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 compliance and surveillance groundwater monitoring programs to comply fully with environmental regulations, applicable U.S. Department of Energy (DOE) orders, and the requirements of the Ground Water 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 (compliance monitoring) and to assess the impact, if any, of LLNL operations on groundwater resources (surveillance monitoring).

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 remediation monitoring of groundwater, discussed in Chapter 8, is carried out under Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) restoration efforts. Surveillance monitoring of soil and sediment under the GWPMP is described in Chapter 10. Additional LLNL programs address potential contaminant sources such as the sanitary sewer system (Chapter 6) and underground storage tanks (briefly discussed in Chapter 2).

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 at Site 300 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 the 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 the city of 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, including uranium-238, to past operations, while other contaminants such as nitrate and perchlorate are the objects of continuing study. Present-day administrative, engineering, and maintenance controls at both LLNL sites are specifically tailored to prevent releases of chemicals to the environment.

The Compliance Groundwater Monitoring Program at Site 300 complies with numerous federal and state controls. Compliance monitoring of groundwater is required at Site 300 in order 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. Compliance monitoring is specified in Waste Discharge Requirement (WDR) orders issued by the Central Valley Regional Water Quality Control Board (CVRWQCB) and in landfill closure and post-closure monitoring plans. (See **Table 2-3** for a summary of LLNL permits)

The WDRs and post-closure 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 semiannual monitoring of groundwater, monitoring of various influent waste streams, and visual inspections. LLNL performs the maintenance necessary to ensure the physical 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 compliance monitoring network.

Tables 9-1a and 9-1b in the Data Supplement list the analytical methods and reporting limits that are used to detect organic and inorganic constituents in groundwater (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods). Table 9-1c in the Data Supplement

shows the approximate analytical reporting limits for various radioactive gamma-ray emitters using the less-sensitive EPA Method 901.1.

Surveillance Monitoring of 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, contain small amounts of HTO from natural sources, past worldwide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL. (See Chapters 4 and 5 for further discussion of air emissions, and Chapter 7 for further discussion of rain and storm water runoff.)

Groundwater is recharged at the Livermore site, primarily from arroyos by rainfall (see also Chapter 7). Groundwater flow beneath the Livermore site is generally southwestward. Groundwater flow 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 in the annual *LLNL Ground Water Project* report (Dibley et al. 2003).

Groundwater samples were obtained during 2002 from 23 of 25 water wells in the Livermore Valley (see **Figure 9-1**) and measured for tritium activity. Two wells were either dry or could not be sampled during 2002.

Livermore Site Perimeter

LLNL designed a surveillance monitoring program to complement the Livermore Site Ground Water Project (discussed in Chapter 8). The intent of the surveillance monitoring 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 upgradient (background) monitoring wells (wells W-008, W-221, and W-017) near the eastern boundary of the site and seven (downgradient) 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 groundwater Treatment Facilities A, B, and C (see **Figure 8-1**), meet the requirements of DOE Order 5400.1. The western perimeter wells are screened (that is, where groundwater is drawn from) in the uppermost aquifers near the areas where groundwater is being remediated.

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) dipping gently westward, 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 are screened.

Two of the background wells, W-008 and W-221, are screened partially in HSU 3A; well W-017 is considered a background well for the deeper HSU 5. These background wells were sampled and analyzed three times in 2002 for pesticide and herbicide compounds that are used on site and off site, for nitrate, and for certain radioactive constituents. They were also sampled and analyzed twice for hexavalent chromium (chromium(VI)) during 2002.

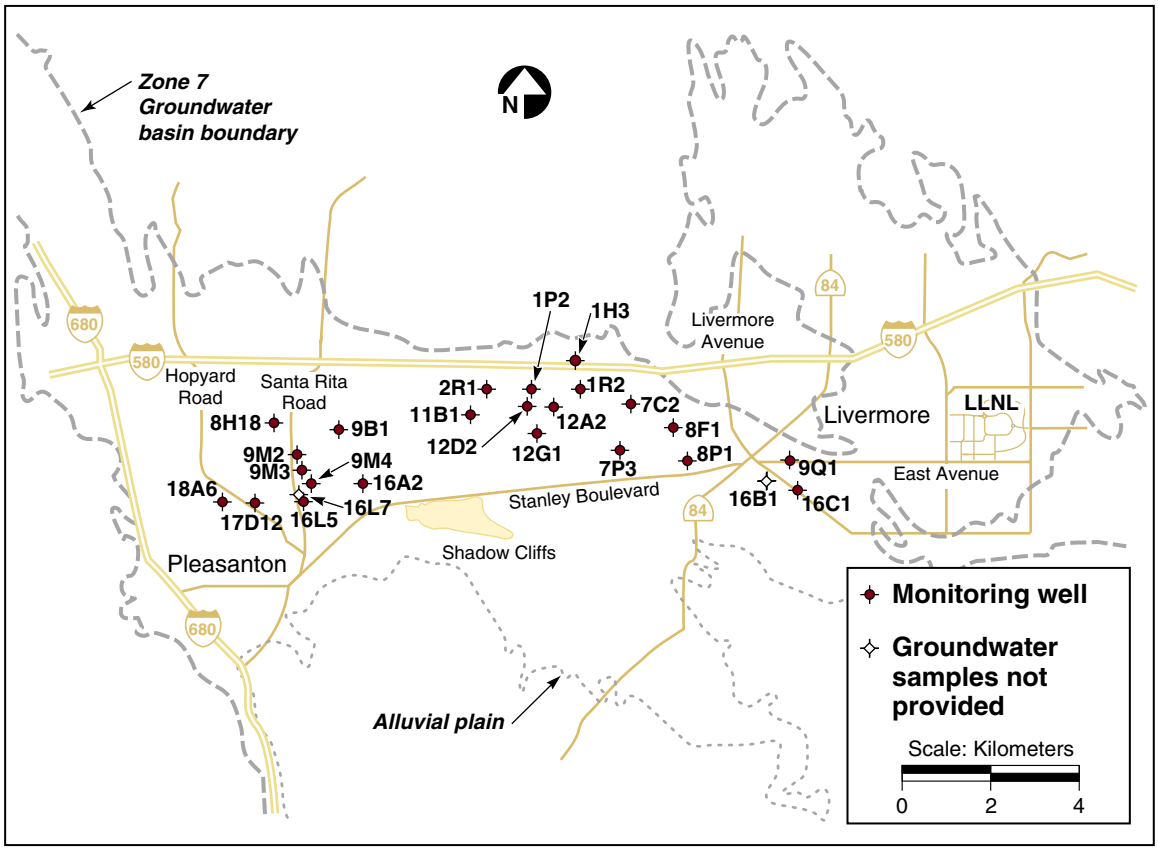

Figure 9-1. Locations of off-site tritium monitoring wells in the Livermore Valley, 2002

Except for well 14B1, the seven western downgradient wells are screened in shallower HSUs 1B and 2, the uppermost water-bearing HSUs at the western perimeter. (Because it was originally a production well, well 14B1 is screened over a depth range that includes HSUs 2, 3A, and 3B.) These wells were sampled and analyzed at least once for pesticides, herbicides, radioactive constituents, nitrate, and chromium(VI).

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. Wells selected for monitoring are screened in the uppermost aquifers, and are situated downgradient from and as near as possible to the potential release locations.

Within the Livermore Site, 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 2002 for copper, lead, zinc, americium-241, plutonium-238, plutonium–239, 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

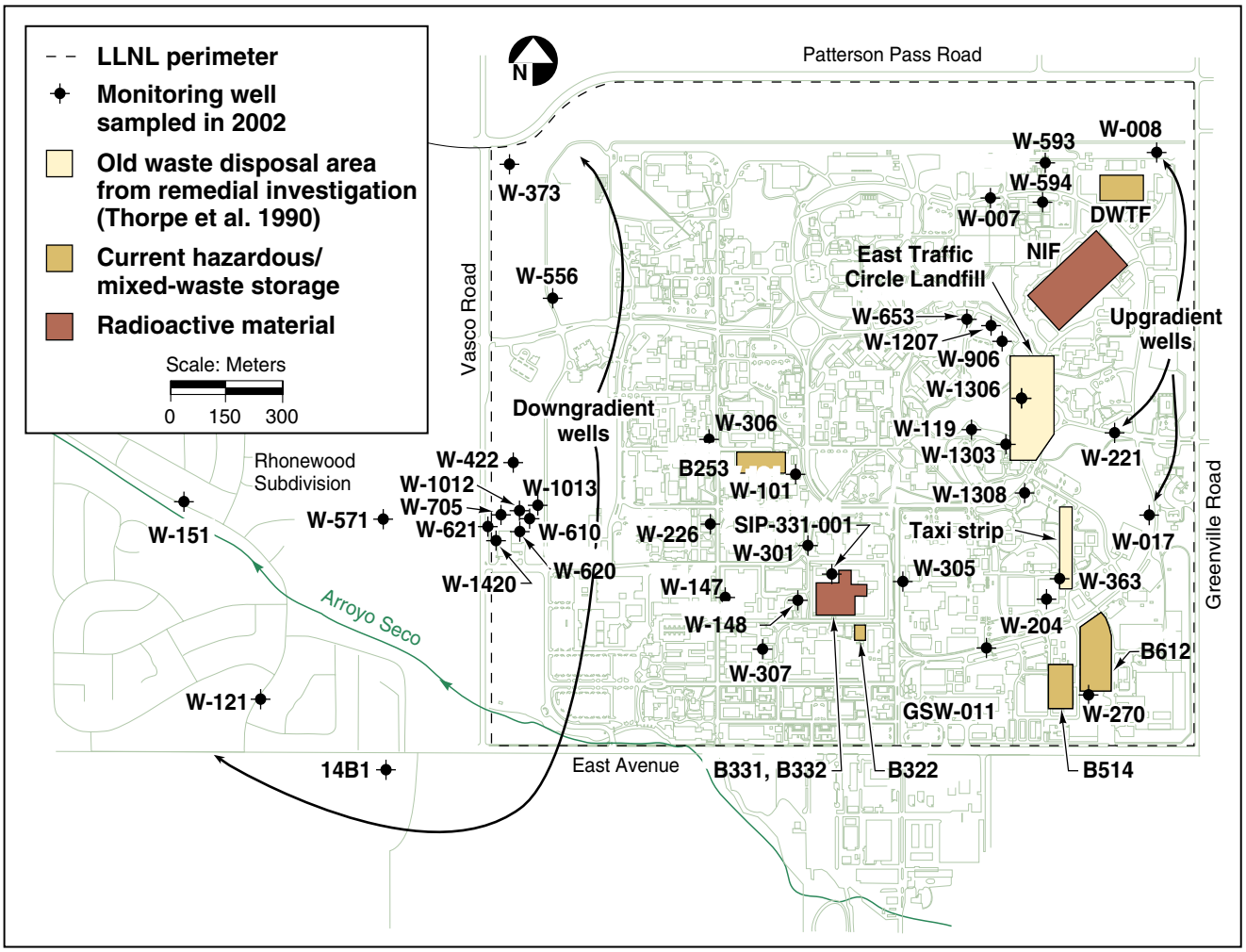

Figure 9-2. Locations of routine surveillance groundwater monitoring wells at the Livermore site

W-1308) within and downgradient from the East Traffic Circle Landfill were analyzed for the same elements as in the Taxi Strip Area. The locations of all of these wells are shown in **Figure 9-2**.

Although the National Ignition Facility (NIF, **Figure 9-2**) has not yet begun full operations, it is prudent to obtain a baseline of groundwater quality prior to start of operations. NIF operations will use significant quantities of tritium. Analyses were conducted on groundwater samples collected from wells W-653 and W-1207 (screened in HSUs 3A and 2, respectively) downgradient of NIF for minerals, selected metals, gross alpha and beta radiation, radium-226, and tritium.

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 wells W-007, W-593 (screened in HSU 3A), and W-594 during 2002 and were analyzed for minerals, selected metals, americium-241, plutonium-238, plutonium-239,

radium-226, and tritium. Monitoring wells W-007 and W-594 (screened in HSUs 2/3A and 2, respectively) were added to this monitoring network in 2002.

The hazardous waste/mixed waste storage facilities around Buildings 514 and 612 are a potential source of contamination. They are monitored by well GSW-011 (screened in HSU 3A). Groundwater from this well was sampled and analyzed for selected trace metals, general minerals, americium-241, plutonium-238, plutonium-239, radium-226, and tritium in 2002.

Groundwater samples were obtained downgradient from areas where 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 total 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.

Groundwater samples were 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, which are screened in HSUs 1B and 2, respectively.

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 than migrate into the groundwater. Tritium, as HTO, could migrate into groundwater if spilled in sufficient quantities. Upgradient of these facilities, well W-305 is screened in HSU 2; downgradient wells W-101, W-147, and W-148 are screened in HSU 1B; and SIP-331-001 and well W-301 are screened in HSU 2.

Surveillance and Compliance Monitoring of Site 300

For surveillance and compliance groundwater monitoring at Site 300, LLNL uses DOE CERCLA wells and springs on site and private wells and springs off site. Representative groundwater samples are obtained at least once per year at every monitoring location; 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.

Figure 9-3 shows the locations of numerous wells, four Barcad devices, and three springs at or near Site 300 that are used for groundwater surveillance monitoring. The locations of additional compliance monitoring wells are shown in **Figures 9-4** through **9-11**. Groundwater from the shallowest water-bearing zone is the target of most of the monitoring because it would be the first to show contamination from LLNL operations at Site 300. Deeper water-bearing zones are monitored at four locations (K1-02A, K2-01A, K2-02A, and K2-02B) by means of Barcad devices installed in the deeper 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

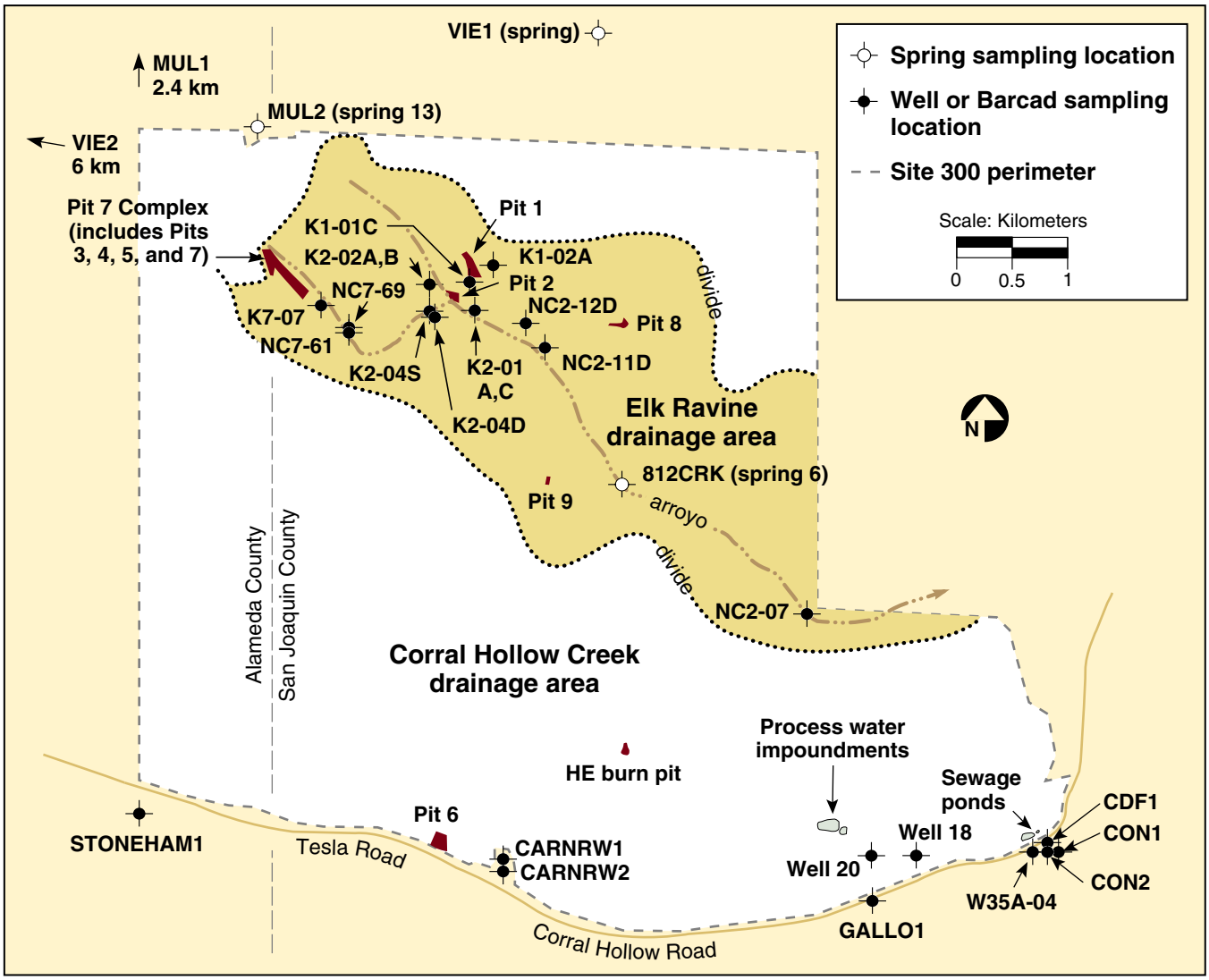

Figure 9-3. Locations of surveillance groundwater wells, Barcads, and springs at Site 300

VIE2 is located 6 km west of Site 300 in the upper 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 primarily for CERCLA site-characterization studies, continue to be used to monitor closed landfills, a former open-air high explosives (HE) burn pit, two connected surface water impoundments, and two connected sewer ponds (**Figure 9-3**). 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 process water impoundments, and the sewage ponds are located in the southern portion of Site 300 in the Corral Hollow Creek drainage area. Two on-site water supply wells, identified as wells 18 and 20, are also used for

surveillance monitoring purposes. Well 20 provides potable water to the site. Well 18 is maintained as a standby potable supply well.

Brief descriptions of the Site 300 groundwater monitoring networks are given below. Networks of wells and Barcads within the Elk Ravine drainage area are described first, followed by the well networks in the Corral Hollow Creek drainage area. Subsets of CERCLA wells and Barcads, installed mainly for site characterization, 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. (See Chapter 8 for a summary of Site 300 stratigraphy and hydrogeology.)

Groundwater measurements made during 2002 for compliance purposes and published elsewhere are not contained in the Data Supplement accompanying this report. Instead, the compliance reports containing those data tables and data graphs have been copied onto the CD that contains this Environmental Report. Active links to these reports are included in the "Results" section of this chapter.

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 in the Elk Ravine drainage area collects in arroyos and quickly infiltrates into the ground. Groundwater from wells and Barcads in the Elk Ravine drainage area is monitored for COCs because of the system of surface and underground flows that connects the entire Elk Ravine drainage area. The area contains eight closed landfills known as Pits 1 through 5 and 7 through 9 and firing tables where explosives tests are conducted. None of the closed landfills has a liner, which is consistent with disposal practices in the past when the landfills were constructed. 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 Pit 7 landfill, which was closed under the Resource Conservation and Recovery Act (RCRA) in 1993, are specified in Waste Discharge Requirements Order No. 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 main objective of this monitoring is the early detection of any new release of COCs from Pit 7 to groundwater.

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

As planned for compliance purposes, LLNL obtained groundwater samples every three months (quarterly) during 2002 from the Pit 7 monitoring well network. 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

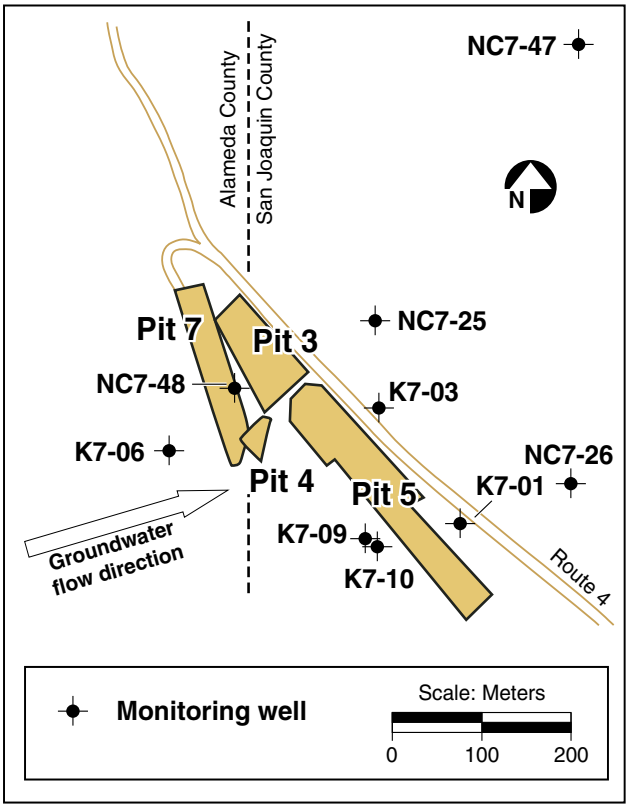

Figure 9-4. Locations of Pit 7 compliance groundwater monitoring wells

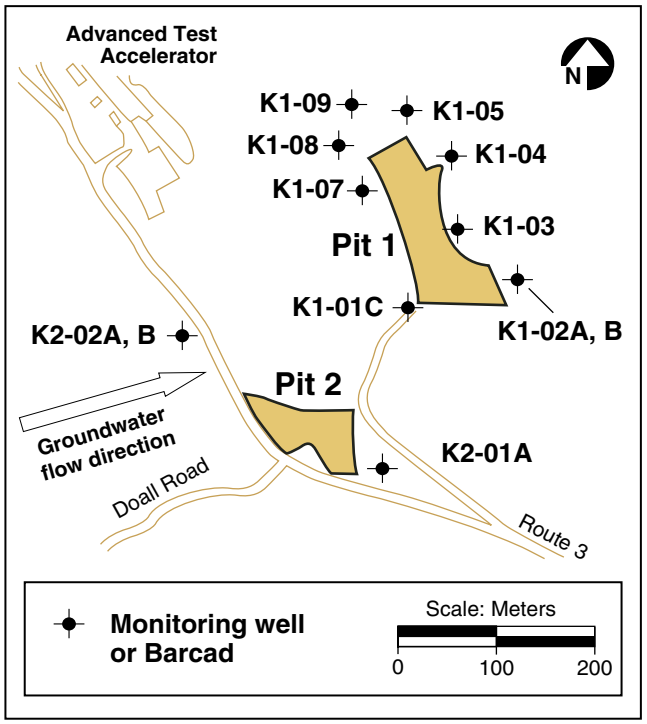

Figure 9-5. Locations of Pit 1 compliance and Pit 2 surveillance groundwater monitoring wells

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.

Elk Ravine: Groundwater samples were obtained twice during 2002 from the widespread Elk Ravine surveillance monitoring network. Samples were analyzed for inorganic constituents (mostly metallic elements), VOCs (EPA method 601), general radioactivity (gross alpha and beta), tritium and uranium activity, and explosive compounds (HMX and RDX).

Pit 2: The closed Pit 2 landfill lies in the upper portion of Elk Ravine, about 320 m above sea level (**Figure 9-3** and **Figure 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 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 2002 from the Pit 2 monitoring network (comprising four Barcads and one well) 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). Well K1-01C serves as a downgradient Pit 2 monitoring well and an upgradient Pit 1 monitoring well (**Figure 9-5**). Groundwater samples from this well were obtained quarterly during 2002 and were analyzed for a larger suite of COCs dictated by the

compliance monitoring plans for Pits 1 and 7. Analyses for the presence of an even larger set of COCs were made on the groundwater samples obtained from well K1-01C during the fourth quarter of 2002. These additional analyses included common pesticides (EPA method 608), PCBs (EPA method 8082), and extractable (semi-volatile) organic compounds (EPA method 625).

Pit 1: Monitoring requirements for the Pit 1 landfill, which was closed under the Resource Conservation and Recovery Act (RCRA) in 1993, are also specified in 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 main objective of this monitoring is the early detection of any release of COCs from Pit 1 to groundwater.

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**. The eight wells are K1-01C, K1-02B, K1-03, K1-04, K1-05, K1-07, K1-08, and K1-09.

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2002 from the Pit 1 monitoring well network. 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.

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.

Approximately 40 m^3 of untreated debris from the firing table were placed in the pit until 1974 when the pit was covered with a layer of native soil. 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 five 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).

Construction and other operations in the vicinity of Pit 8 limited access to the monitoring wells during 2002, and well K8-05 was dry throughout the year. Groundwater samples obtained in June from well K8-01 were analyzed for inorganic COCs (mostly metallic elements), VOCs (EPA method 601), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), and explosive compounds (HMX and RDX). Groundwater samples from well K8-03B obtained in July

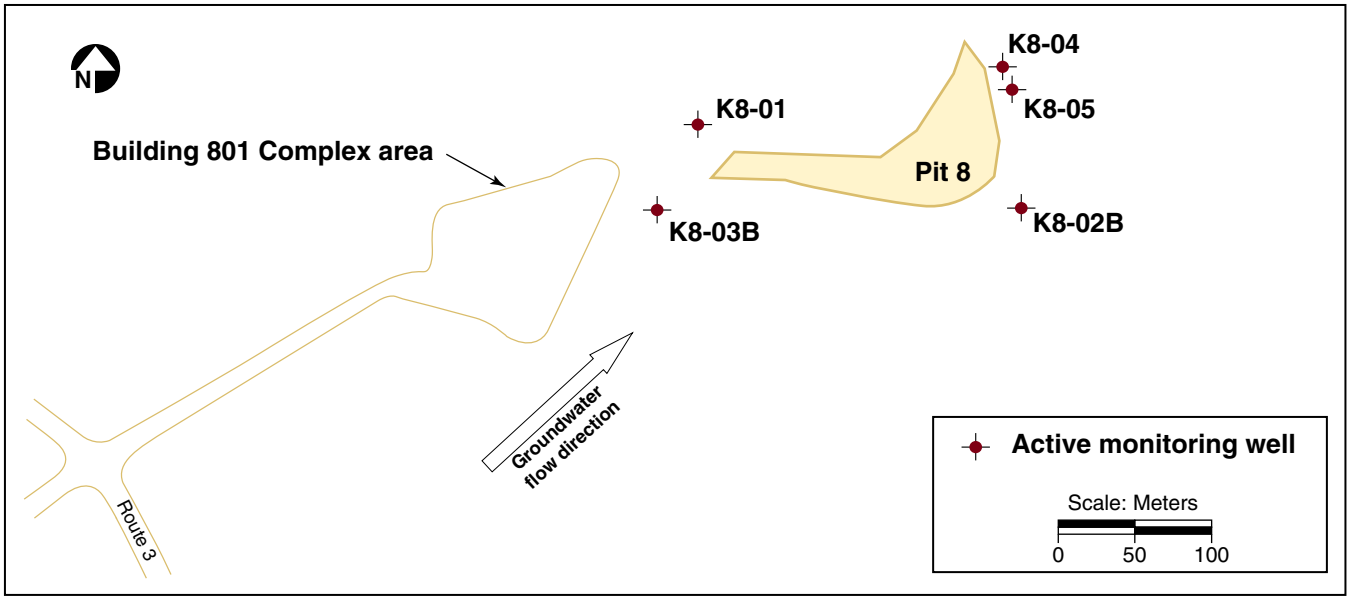

Figure 9-6. Locations of Pit 8 surveillance groundwater monitoring wells

were analyzed for VOCs (EPA method 601), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), and explosive compounds (HMX and RDX). Groundwater samples from well K8-04 obtained in June were analyzed for VOCs (EPA method 601) and tritium activity.

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 9-7 shows the locations of the four surveillance wells used to monitor the groundwater in the vicinity of Pit 9. Groundwater flows east-northeasterly 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

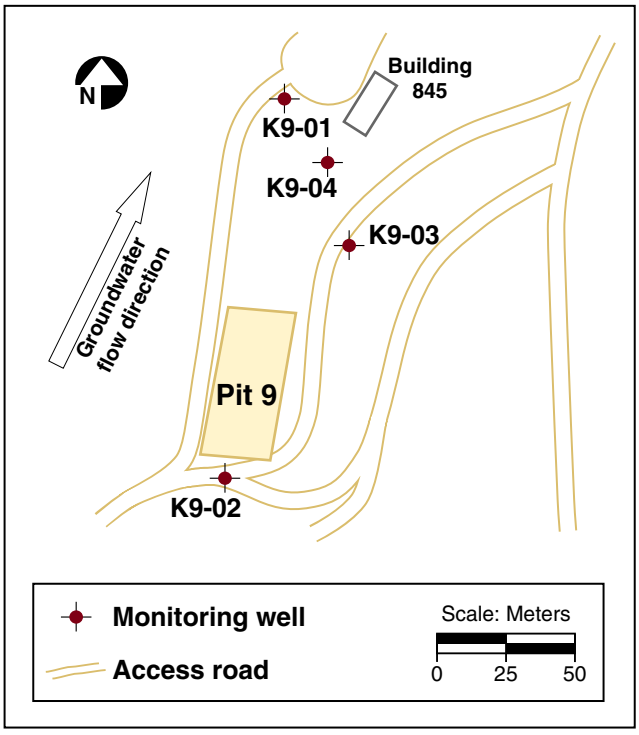

Figure 9-7. Locations of Pit 9 surveillance groundwater monitoring wells

As planned for surveillance purposes, LLNL obtained groundwater samples once (annually) during 2002 from all four Pit 9 monitoring wells. Groundwater samples 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. 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) 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 of the underlying sedimentary rocks. Groundwater seepage velocities are less than 10 m/y. Depths to the water table range from 10 to 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, which operate under CERCLA, were implemented at the Pit 6 landfill during 1998 to ensure compliance with all regulations: (1) the Detection Monitoring Program, 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), monitors the movement and fate of historical releases (see Chapter 8 for a summary of CAMP monitoring results for Pit 6). **Figure 9-8** shows the locations of Pit 6 and the wells used to monitor groundwater there.

To comply with permit requirements, LLNL obtained groundwater samples quarterly during 2002 from the Pit 6 monitoring well network. Samples were analyzed for inorganic COCs (mostly metals), general radioactivity (gross alpha and beta), activity of certain radioisotopes (tritium and uranium), VOCs (EPA method 624), extractable organics (EPA method 625), pesticides (EPA method 608), and PCBs (EPA method 8082A). Field measurements of groundwater depth,

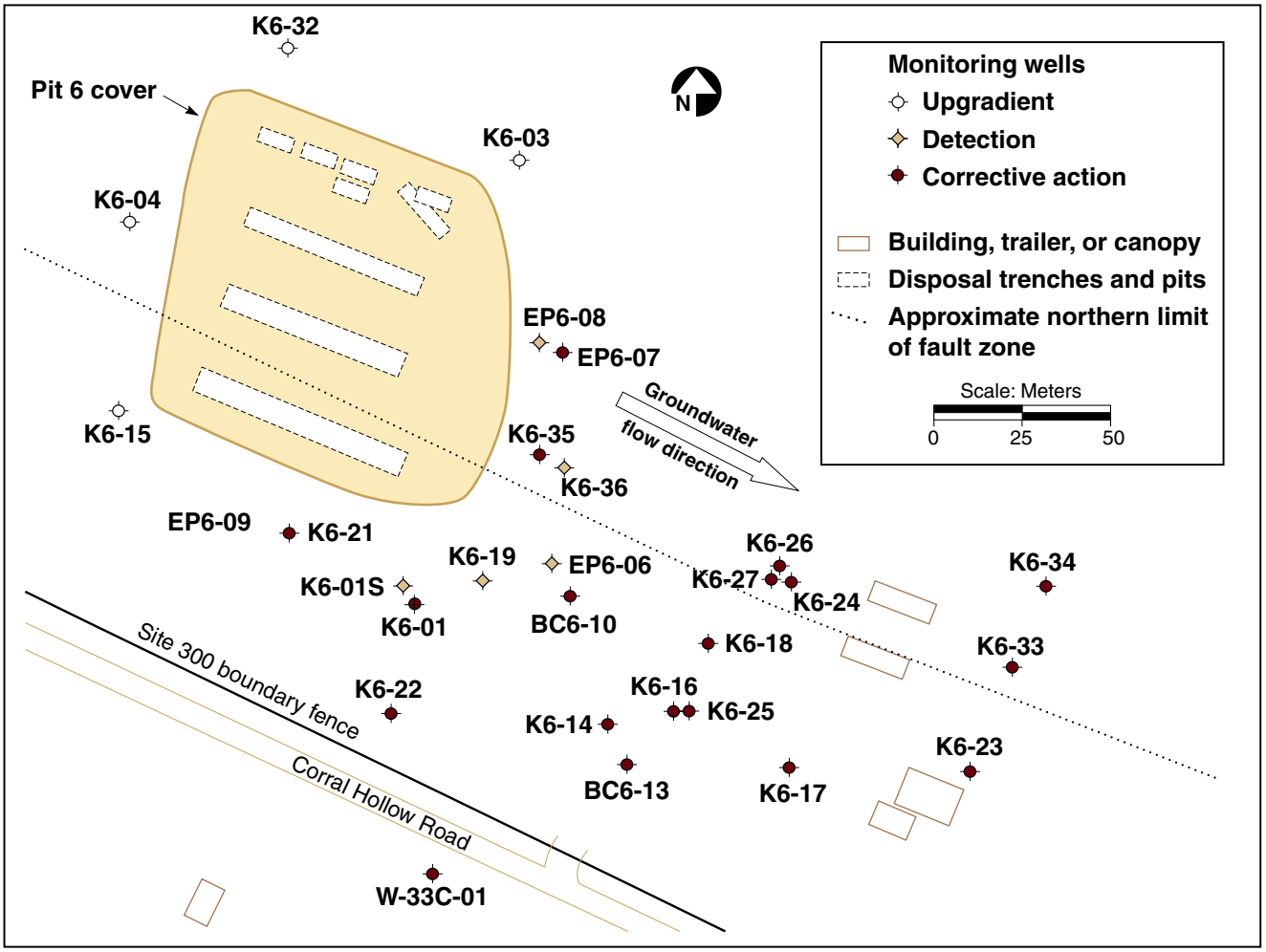

Figure 9-8. Locations of Pit 6 compliance groundwater monitoring wells

temperature, pH, and specific conductance were obtained at each well at the time of sample collection.

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 *Revisions to the Post-Closure Permit Application for the Building 829 HE Open Burn Facility – Volume 1* (LLNL 2001).

The former 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 (see **Figure 9-9**). The facility included three shallow unlined pits constructed in unconsolidated sediments that cap

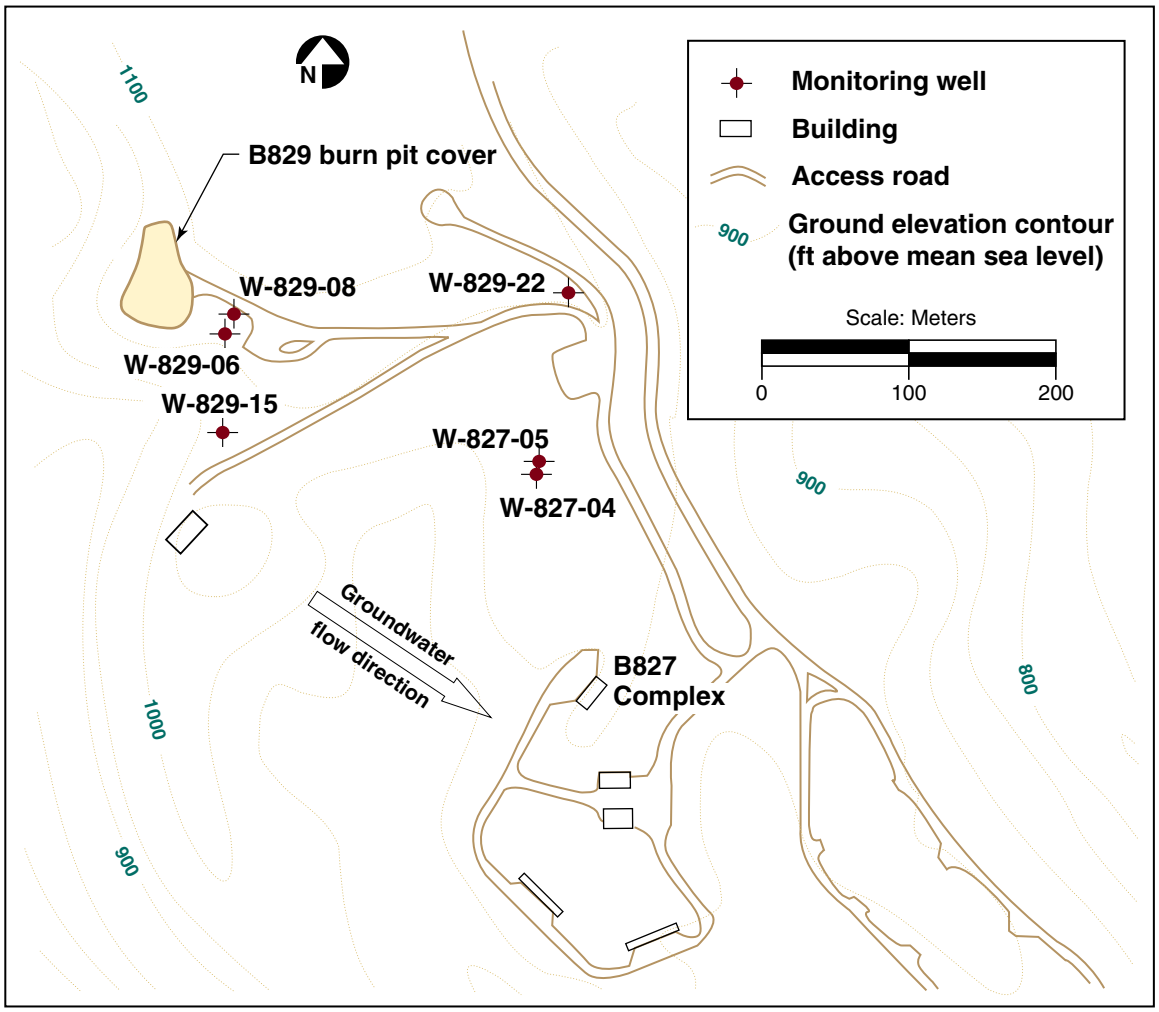

Figure 9-9. Locations of Building 829 closed burn pit compliance groundwater monitoring wells

burn explosives waste generated at Site 300. The facility was covered with an impervious cap in 1998 following RCRA guidance.

Surface water drains southward from the facility toward Corral Hollow Creek. The nearest site boundary lies about 1.6 km 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, is perched within the Neroly upper siltstone/claystone aquitard ($Tnsc_2$). The deeper zone, at a depth of about 120 m, 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 post-closure 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 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, W-827-04, W-827-05, W-829-15, and W-829-22, are screened in the deep regional aquifer downgradient of the closed facility.

As planned for compliance purposes, LLNL obtained groundwater samples quarterly during 2002 from the Building 829 monitoring well network. As in past years of this monitoring program, deep well W-827-04 remained dry throughout 2002. Groundwater samples from the three other wells screened in the deep regional aquifer were analyzed quarterly for inorganic COCs (mostly metals), general minerals, turbidity, explosive compounds (HMX, RDX, and TNT), VOCs (EPA method 624), extractable organics (EPA method 625), pesticides (EPA method 608), herbicides (EPA method 615), general radioactivity (gross alpha and beta), radium activity, 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 for explosive compounds and VOCs. During the first two quarters of 2002, however, well W-829-08 appeared to be dry. This condition was initially attributed to a gradually lowering water table in the perched zone, consistent with similar observations at other Site 300 locations. Further examination revealed an obstruction in the pump line, and well W-829-08 was returned to service for the third and fourth quarters of 2002.

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 2002, while well 18 was maintained as a standby water supply well. Both wells are screened in the Neroly lower sandstone aquifer ($Tnbs_1$). 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.

Historically, 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, LLNL obtained groundwater samples quarterly during 2002 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: Waste Discharge Requirements Order No. 96-248 (WDR 96-248) establishes the basis for compliance monitoring of the two adjacent surface impoundments at Site 300 (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 the leachate collection systems. Influent monitoring complements administrative control of chemicals that could degrade the polyethylene liners of the impoundments. A three-tiered monitoring program comprising weekly visual inspections of the leachate collection systems, quarterly inspections of lysimeters, and quarterly sampling of monitoring wells is in place to detect any release of chemicals from the surface impoundments.

LLNL is required to obtain groundwater samples quarterly from four monitoring wells (see **Figure 9-10**) and has established 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 regulated by effluent discharge limits specified in WDR 96-248. Discharges to the surface impoundments occur after samples are obtained, except for

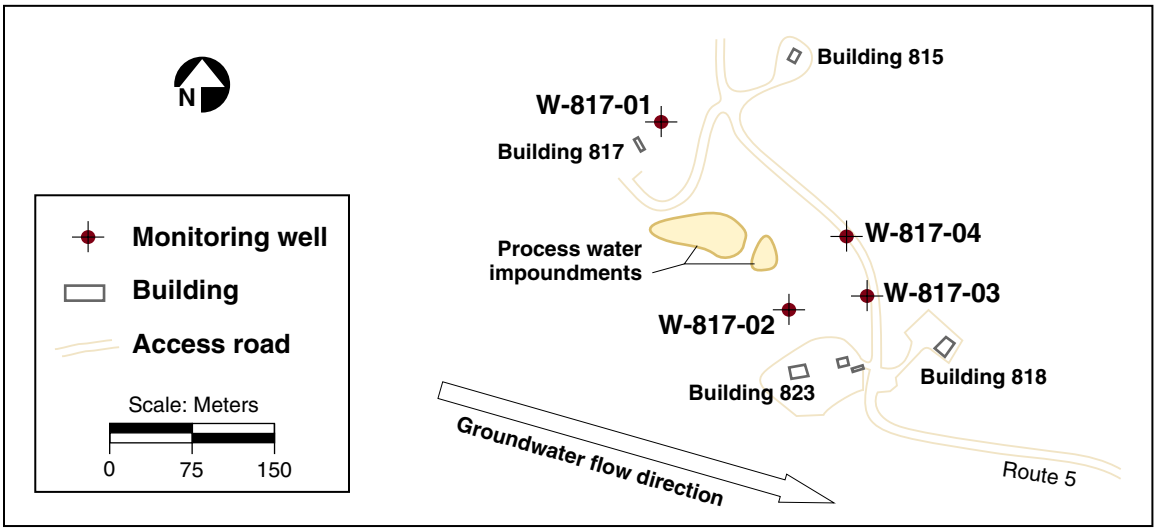

Figure 9-10. Locations of compliance groundwater monitoring wells in the Explosives Process Area

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 the concentrations of any metals present.

Sewage Evaporation and Percolation Ponds: Site 300 is not serviced by a publicly owned treatment works as is the Livermore site; therefore, alternative 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 the MRP for WDR 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 discharge location DSWP. These sampling locations are shown in **Figure 9-11.**

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, LLNL obtained groundwater samples from two off-site springs and ten off-site wells during 2002. 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 potable water supply well in the Altamont Hills. 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 W35A-04, are adjacent to the site on the south (**Figure 9-3**). Well W35A-04 is a DOE CERCLA well that was installed off site for monitoring purposes only. The

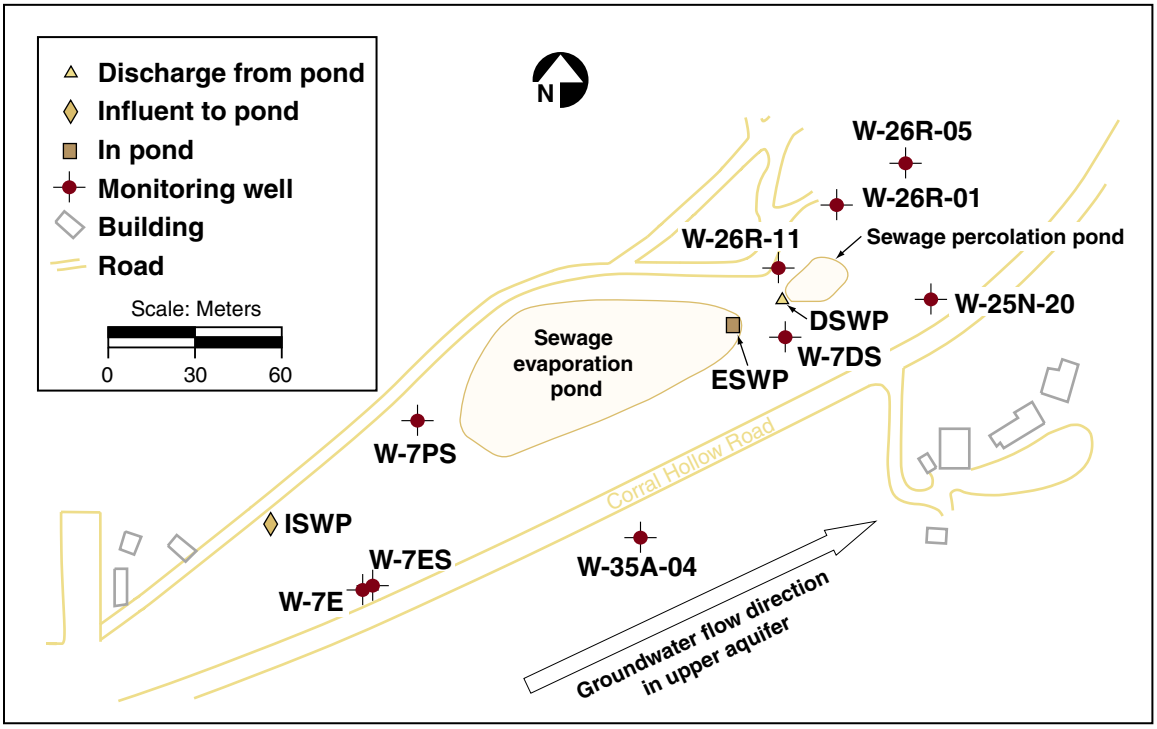

Figure 9-11. Sewage evaporation and percolation ponds, compliance groundwater monitoring wells, and wastewater monitoring locations

remaining seven wells south of Site 300 are privately owned and were constructed to supply water either for human consumption, stock watering, or fire suppression. They are monitored to determine the background contents of the groundwater beneath the Corral Hollow Creek flood plain.

Groundwater samples were obtained quarterly during 2002 at six of the 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 2002 from the remaining off-site surveillance monitoring locations—MUL1, MUL2, and VIE1 (north of Site 300); VIE2 (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 2002). 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. Typically, analytical methods approved by the U.S. Environmental Protection Agency (EPA) are used to measure dissolved constituents in water because they are both accurate and sensitive. (See Data Supplement Tables 9-1a, 9-1b, and 9-1c for the U.S. EPA or other standard analytical methods used to measure chemicals and radioactivity in groundwater.) All the chemical and radioactivity analyses of groundwater samples were performed during 2002 by California-certified analytical laboratories.

At Site 300, wastewater samples from the photographic and explosives process areas, sewage evaporation pond influent and overflow, and water in the 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). Duplicates, field blanks, and trip blanks were obtained for quality assurance/quality control purposes.

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

Results

This section presents the monitoring results for the Livermore site, Site 300, and adjacent areas.

Livermore Site and Environs

Livermore Valley

Tritium measurements of Livermore Valley groundwaters are contained in the Data Supplement, Table 9-2. They continue to show very low and decreasing activities compared with the 740 Bq/L (20,000 pCi/L) maximum contaminant level (MCL) established for drinking water in California with the exception of 2002. As in past years, the maximum tritium activity measured off site was in the groundwater at well 11B1, located about 11 km west of LLNL (see **Figure 9-1**). The measured activity there was 3.4 Bq/L in 2002, which is equal to 0.5% of the MCL. **Figure 9-12** shows the history since 1988 of the maximum tritium activity measured in the Livermore Valley wells sampled. Continuing monitoring will determine future needs.

Livermore Site Perimeter

Constituent measurements for the Livermore site background wells and perimeter wells are contained in the Data Supplement, Tables 9-3 through 9-5. No pesticide or herbicide organic compounds were detected above analytical reporting limits in the groundwater during 2002. The inorganic compounds detected include dissolved trace metals and minerals, which occur naturally in the groundwater at variable concentra-

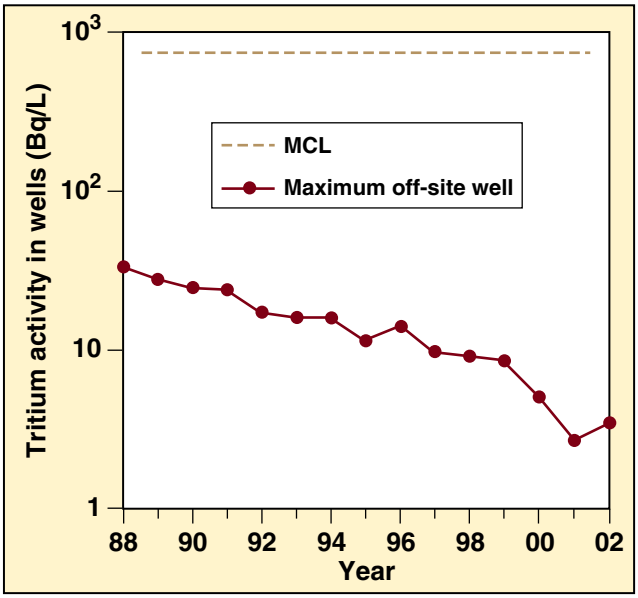

Figure 9-12. Trend of tritium activity in Livermore Valley wells, 1988 to 2002. The drinking water MCL of 740 Bq/L is also shown.

tions. The concentrations detected in the groundwater samples from the background wells represent background values for 2002.

In March 1996, nitrate was first detected at a concentration level of 75 mg/L in a groundwater sample obtained from western perimeter monitoring well W-1012 (screened in HSU 2) (see **Figure 9-2**). This level is greater than the MCL of 45 mg/L; concentrations of nitrate detected in groundwater samples from this well since 1996 have exceeded 45 mg/L. Concentrations of nitrate detected in samples from this well in 2002 were 78 to 80 mg/L. Those are the highest nitrate concentrations measured in any surveillance monitoring well during 2002.

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 below the MCL at 40 mg/L, in downgradient monitoring well W-571 (see Data Supplement Table 9-4). Monitoring well W-571 is off site and downgradient to the west, and is screened in HSU 1B. During 2002, concentrations of nitrate in on-site shallow background wells W-008 and W-221 ranged from 23 mg/L to 30 mg/L. Detected concentrations of nitrate in western perimeter wells, with the exception of well W-1012, ranged from 13 to 40 mg/L.

Nitrate was not detected at concentrations greater than the MCL in any other western perimeter surveillance monitoring well (besides on-site monitoring well W-1012) during 2002. 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 perimeter monitoring wells since 1996. The nitrate may originate as an agricultural residue (Thorpe et al. 1990).

Nitrate concentrations were also analyzed in groundwater samples collected from seven additional monitoring wells (**Figure 9-2**), screened in HSUs 1B and 2. Nitrate results from those seven wells and from wells W-1012 and W-571 are listed in Data Supplement, Table 9-6. Other than well W-1012, no groundwater sample had a nitrate concentration exceeding the MCL.

Of the selected trace metal analytes, no concentration analyzed in any groundwater sample collected in 2002 exceeded its California or federal MCL. Since monitoring began in 1989, concentrations of chromium(VI) in groundwater samples collected from western perimeter well W-373 in previous years had exceeded the California MCL of 50 µg/L. 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. The concentration of

48 µg/L for chromium(VI) in the January 2002 sample is the lowest since monitoring began in that well in 1989

Activities of naturally occurring total uranium (uranium-234+235+238) continued to be highest in the background wells during 2002. Activities of total uranium in those wells were measured as 0.17 ± 0.01 Bq/L to 0.24 ± 0.02 Bq/L (32% of California's MCL of 0.74 Bq/L, or 20 pCi/L). (See Data Supplement Table 9-3.) Activities of total uranium are lower, from 0.025 ± 0.004 Bq/L (in well W-121) to 0.12 ± 0.01 Bq/L (16% of California's MCL in well W-1012), in groundwater from each of the western perimeter monitoring wells. Uranium-238 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 exceeding the MCL.

Livermore Site

Constituent measurements for the Livermore site wells are contained in the Data Supplement, Tables 9-7 through 9-14. No concentrations of americium or plutonium radioisotopes were detected above the radiological laboratory's minimum detectable activities. Concentrations of tritium and radium isotopes remain well below drinking water MCLs. The trace metals copper, lead, and zinc were not detected in samples from any of these monitoring wells in 2002.

Monitoring results from the wells near NIF and DWTF show very little concentrations of tritium present and only minor concentrations of gross alpha and gross beta radiation in the groundwater samples collected. Monitoring will continue near these facilities to determine baseline conditions.

No significant contamination was detected in the sample collected from well GSW-011 downgradient from Buildings 514 and 612 in 2002.

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 dissolved chromium of 15 µg/L, greater than 10 µg/L, the highest concentration of chromium(VI) measured in any background well from 1996 through 2002. Dissolved chromium was also detected at elevated concentrations in groundwater samples from well W-306, which is downgradient from the Building 253 catch basin. Concentrations were measured as 10 µg/L at well W-226 and 40 µg/L at well W-306. The accumulated sediment in the catch basin is a potential source of several metals (Jackson 1997). No concentrations of either dissolved chromium or chromium(VI) exceeded the MCL of 50 µg/L for total chromium in drinking water.

In August 2002, the tritium activity was 110 ± 11 Bq/L (about 15% of the MCL) in the groundwater sampled at well W-148, downgradient from the Tritium Facility (Building 331). Groundwater tritium activities had reduced to 98 ± 11 Bq/L or less, by December 2002 in all of the wells sampled downgradient of Building 331. The relatively elevated tritium activity in the groundwater sampled at well W-148 in August 2000 (115 ± 5.0 Bq/L) was concluded to be most likely related to local infiltration of storm water containing elevated tritium activity. Tritium activities in groundwater of this area have been cyclic since that time. LLNL continues to collect groundwater samples from these wells periodically for surveillance purposes, primarily to demonstrate that their tritium and plutonium contents remain below environmental levels of concern.

Site 300

The following are summaries of Site 300 groundwater surveillance and compliance monitoring results for 2002. Site 300 compliance monitoring

results for 2002 have been published previously (Brown 2002a,b,c, 2003; Christofferson and MacQueen 2002a,b,c, 2003; Christofferson et al. 2002a,b,c, 2003; Revelli 2003). Compliance monitoring results for Site 300 are discussed again in the following summaries. Surveillance monitoring data for 2002 have not been published elsewhere and are listed in the Data Supplement, Tables 9-15 through 9-27.

Elk Ravine Drainage Area

Pit 7: No new release of COCs to groundwater from Pit 7 is evident in the chemical data obtained during 2002. The COCs detected in groundwater include several metals, depleted uranium, tritium, and several VOCs. These are associated with releases that occurred prior to 2002. The primary sources of COCs detected by the network of Pit 7 monitoring wells are the closed landfills known as Pits 3 and 5, which are adjacent to Pit 7 (**Figure 9-4**). Natural sources in the rocks and sediments surrounding Pit 7 also have contributed arsenic, barium, uranium, and, possibly nitrate to the groundwater. In the past, especially during the El Niño winters of 1982–83 and 1997–98, excessive seasonal rainfall caused groundwater levels to rise into Pit 3 and Pit 5 from beneath, leading to the release of COCs, mainly tritium in the form of HTO. Because of reduced rainfall since 1998, groundwater elevations have fallen generally at Site 300, thus reducing the potential for releases to occur by this mechanism. CERCLA modeling studies indicate that tritium and other COCs released in the past will not reach off-site aquifers at concentrations above MCLs. See Chapter 8 for a review of CERCLA concerns regarding groundwater contamination in the upper reaches of the Elk Ravine drainage area. For a detailed account of Pit 7 compliance monitoring during 2002, including tables and graphs of groundwater COC analytical data, see Christofferson and MacQueen (2003).

Elk Ravine: As in past years, no new release of COCs from LLNL operations in Elk Ravine to groundwater is indicated by the chemical and radioactivity data obtained during 2002. The major source of contaminated groundwater beneath Elk Ravine is from historical operations in the Building 850 firing table area (Webster-Scholten 1994, Taffet et al. 1996). Constituent measurements for the Elk Ravine drainage area surveillance monitoring network are listed in the Data Supplement, Table 9-15.

The arsenic concentration in the groundwater monitored beneath the Elk Ravine drainage area is generally above the MCL of 10 µg/L for arsenic in drinking water. Concentrations range up to 42 µg/L (well NC2-07). Earlier CERCLA characterization studies determined that the arsenic is from natural sources, particularly from the dissolution of the mineral arsenopyrite, which is a component of the underlying volcanogenic sediments and sedimentary rocks (Raber and Carpenter 1983). It should be noted that there are no wells in this area that are used for potable domestic, livestock, or industrial water supply. However, a perennial spring in Elk Ravine, which is utilized by the indigenous wildlife there, contains concentrations of arsenic up to 33 µg/L (location 812CRK).

Tritium activity was above background level in many of the shallow groundwater surveillance samples obtained during 2002 from Elk Ravine. Tritium, as HTO, has been released in the past in the vicinity of Building 850 (see **Figure 8-17** for a map showing the extent of tritium plumes beneath the Elk Ravine drainage area). The largest HTO plume, which extends eastward more than a kilometer from a source beneath the Building 850 firing table area to the vicinity of Pits 1 and 2, is confined to shallow depths in the Neroly lower blue sandstone unit and overlying alluvium. This confinement is illustrated by comparing the tritium activity of 1700 Bq/L at well NC7-61, which

samples the shallowest water-bearing zone, and the tritium activity of 1.8 Bq/L at well NC7-69, which samples the next deeper water-bearing zone in this area.

The majority of the Elk Ravine surveillance network tritium measurements made during 2002 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 1998). For example, tritium activity in groundwater at well NC7-61 decreased from 6500 Bq/L in 1996 to 1700 Bq/L in 2002. CERCLA modeling studies indicate that the tritium will decay to background levels before it can reach a site boundary. Note that the tritium plume has not reached the perennial spring location 812CRK.

Except in the immediate vicinity of Pit 7, groundwater surveillance measurements of gross alpha, gross beta, and uranium radioactivity in Elk Ravine are all low and are indistinguishable from background levels. (Note that gross beta measurements do not detect the low-energy beta emission from tritium decay.) Additional detections of nonradioactive elements including arsenic, barium, chromium, selenium, vanadium, and zinc are all within the ranges of concentrations typical of groundwater elsewhere in the Altamont Hills.

Pit 2: As in past years, no release of a COC from Pit 2 to groundwater is indicated by the surveillance monitoring data obtained during 2002. Constituent measurements for the Pit 2 surveillance monitoring network are contained in Data Supplement Tables 9-16a and 9-16b.

Several metals were detected at low concentrations. Most were below analytical reporting limits, which are in the parts per billion (ppb) range. Arsenic exceeded its MCL but was within the range of background level concentrations for this area of Site 300 (Webster-Scholten 1994). The radioactivity measurements show only low background-level activities for gross alpha, gross beta, and tritium. A distal lobe of the tritium plume extending from the Building 850 firing table is responsible for the tritium activity of 15 Bq/L measured downgradient of Pit 2 in the groundwater sampled at well K1-01C. Tritium activity was not detectable at Barcad K2-01A, which samples a deeper water- bearing zone in this area.

Pit 1: As in past years, no release of COCs to groundwater from Pit 1 is evident in the monitoring data collected during 2002. A detailed account of Pit 1 compliance monitoring during 2002, including tables and graphs of groundwater COC analytical data, appears in a separate report; see Christofferson and MacQueen (2003).

Tritium activity measured above background level (about 4 Bq/L) in the groundwater at Pit 1 monitoring wells K1-01C (15 Bq/L), K1-02B (170 Bq/L), K1-03 (25 Bq/L), and K1-08 (11 Bq/L) during 2002 (see **Figure 9-5**). The tritium activity in the groundwater sampled at these wells represents a distal lobe of the Building 850 tritium plume (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 2002 in groundwater samples from Pit 1 compliance monitoring wells 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 measured in 1999 to 57 µg/L in 2002 in groundwater at Pit 1 monitoring wells K1-05 (17 µg/L), K1-08 (19 µg/L), and K1-09 (57 µg/L). 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 to the west of the affected wells (Webster-Scholten 1994, Taffet et al. 1996).

Pit 8: As in past years, no release of a COC to groundwater from Pit 8 is indicated by the surveillance monitoring data obtained during 2002. Constituent measurements for the Pit 8 surveillance monitoring network are contained in Data Supplement Table 9-17.

The VOC TCE was detected below the 5 µg/L MCL for TCE in wells K8-01, K8-03B, and K8-04. A relatively small VOC plume exists beneath this area (see **Figure 8-9** for a map showing the extent of the VOC plume), which originated prior to 1981 from waste discharged to a dry well upgradient of Pit 8, near Building 801 (Webster-Scholten 1994). Arsenic, chromium, and vanadium were detected in concentrations similar to their natural levels in groundwater elsewhere in the Altamont Hills. Tritium activity, uranium activity, and gross alpha and beta radioactivity were measured at low background levels. The nitrate concentration of 64 mg/L in the groundwater monitored at well K8-01 exceeded the MCL of 45 mg/L for nitrate (as NO_3) in drinking water. The nitrate source is unknown. A site-wide CERCLA study of nitrate in groundwater continued through 2002.

Pit 9: As in past years, no evidence for a release from Pit 9 is indicated by the surveillance monitoring data obtained during 2002. Constituent measurements for the Pit 9 surveillance monitoring network are contained in the Data Supplement, Table 9-18. COCs were either not detected or were indistinguishable from background level concentrations in the groundwater sampled at the Pit 9 monitoring wells.

Corral Hollow Creek Drainage Area

Pit 6: No new release of COCs from Pit 6 is indicated by the chemical analyses of groundwater samples obtained from Pit 6 monitoring wells during 2002. For a detailed account of Pit 6 compliance monitoring during 2002, including tables of groundwater analytical data and map figures showing the distribution of COC plumes, see *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill, Annual Report for 2002* (Christofferson et al. 2003).

COCs that were released prior to constructing an impermeable cap over the closed landfill in 1997 continued to be detected in the groundwater at low concentrations. These COCs include tritium, perchlorate, TCE, PCE, and cis-1,2-dichloroethene (cis-1,2-DCE). All contaminant plumes associated with Pit 6 are relatively small and are confined to shallow depths. None has been detected beyond the Site 300 boundary.

Building 829 Closed HE Burn Facility: No new release of COCs to groundwater from the closed HE burn facility is indicated by the monitoring data obtained during 2002. For a detailed account of compliance monitoring of the closed HE burn pit during 2002, including tables and graphs of groundwater COC analytical data, see *LLNL Experimental Test Site 300—Compliance Monitoring Program for the Closed Building 829 Facility—Annual Report 2002* (Revelli 2003).

The well network used to monitor the Building 829 facility samples two zones containing groundwater: a shallow perched water-bearing zone, which is not present directly below the capped burn pits, and a much deeper regional aquifer. As in the past, analyses of groundwater samples obtained from the perched groundwater beneath the closed facility show evidence of past contamination.

Two wells, W-829-06 and W-829-08, are used to monitor the perched groundwater. Although well W-829-08 was not in service the first two quarters of 2002, well W-829-06 provided a sufficient quantity of groundwater throughout 2002 for the required analyses. The primary contaminant in the perched groundwater is TCE. The maximum TCE concentration measured during 2002 was 240 µg/L. The other contaminant, 1,2-dichloroethene (1,2-DCE), was measured at a maximum concentration of 2.8 µg/L during 2002.

Both TCE and 1,2-DCE have decreased considerably by natural attenuation from maximum concentrations of 1000 µg/L and 13 µg/L, respectively, measured in 1993.

The analytical results from wells W-827-05, W-829-15, and W-829-22 in the deep regional aquifer are generally typical of the values seen in previous years. The postclosure plan inorganic constituents that were detected during 2002 show concentrations that represent background level concentrations of substances dissolved from natural sources in the underlying rocks. Only arsenic and molybdenum were detected at 1-to-4 ppb above the previously determined background concentrations for the deep aquifer beneath the HE Burn Area. However, these constituents (found at Site 300 in naturally occurring minerals) are present in other uncontaminated Site 300 wells at background levels above those reported for the HE Burn Area. (A fourth deep well, W-827-04, was dry during 2002.)

Water Supply Wells: Quarterly measurements of groundwater at Site 300 water supply wells 18 and 20 do not differ significantly from previous years. Constituent measurements for these supply wells are in the Data Supplement, Tables 9-19 and 9-20.

As in past years, TCE was detected during 2002 at low concentrations in the groundwater at standby well 18. The maximum concentration measured was 0.3 µg/L, which is equal to 6% of the MCL for TCE. The source of the TCE has not yet been identified.

As in past years, well 20, the main potable water supply well at Site 300, showed no evidence of contamination. A detection of the explosive compound HMX at a concentration of 13 µg/L occurred first quarter, but three subsequent quarterly analyses showed no HMX above the reporting level concentration of 5 µg/L. Gross alpha, gross beta, and tritium activities in water samples from production wells 18 and 20 are very low and are indistinguishable from background level activities.

Explosives Process Area: No release of water to ground from the surface impoundments occurred during 2002. Two releases of wastewater containing minor concentrations of metals to ground occurred in 2002. For a detailed account of compliance monitoring of the Site 300 surface impoundments, including tables of groundwater measurements, see *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248, Annual/Fourth Quarter Report 2002* (Brown 2003).

The two leachate collection and removal systems were monitored weekly for the presence of liquids to identify potential leaks. None was observed during 2002. No water has been observed in the leachate collection and removal system since liner repairs were made in 1997. No water was found in any of the five lysimeters that are installed beneath the facility.

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 of it 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.

As in the past, groundwater concentrations of nitrate continued to exceed the drinking water MCL in samples from all surface impoundment monitoring wells during 2002. Concentrations of arsenic continue to be detected at concentrations at or near its drinking water MCL in these same wells during 2002. 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 these constituents (except for arsenic) is discussed in Chapter 8 of this document.

During 2002, all discharges into the surface impoundments were in compliance with discharge concentration limits. Groundwater concentrations of some inorganic COCs were higher than the statistical limits during 2002. LLNL determined that concentrations of these COCs increased because of a change in geochemical conditions within the aquifer. LLNL continues to monitor and to track these concentrations. For details, see Brown (2003).

Percolation Pits: During 2002, 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 2003).

Sewage Evaporation and Percolation Ponds: All wastewater parameters for the sewage evaporation and percolation ponds complied with permit provisions and specifications throughout 2002. There was one continuous overflow to the percolation pond during 2002. This was sampled and reported to the CVRWQCB. For details, see Brown (2003).

All of the groundwater monitored constituents were also in compliance with permit limits. LLNL has not yet determined the origin of elevated nitrate concentrations, but a study of nitrate occurrence at Site 300 is continuing under CERCLA auspices, and LLNL continues to monitor these wells and nearby off-site wells for nitrate concentrations (see also Chapter 8).

Off-Site Water Supply Wells: Generally, no COC attributable to LLNL operations at Site 300 was detected in the off-site groundwater samples. Constituent measurements for the off-site water supply wells are contained in the Data Supplement, Tables 9-21 through 9-27.

Arsenic and barium were widely detected at the off-site locations, but their concentrations were below MCLs and their occurrence is consistent with natural sources in the rocks. Scattered detections of metals are probably related to metals used in pumps and supply piping. This is particularly true of the upgradient STONEHAM1 well, which was used little during 2002, because its private owner had departed the area. The grab sample from the well showed considerable concentrations of arsenic, barium, chromium, copper, nickel, selenium, and zinc (see Data Supplement, Table 9-27).

As in past years, TCE was detected at concentrations up to 0.63 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 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 2002, 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 measured off site in the Livermore Valley was 3.4 Bq/L (74 pCi/L), in well 11B1 (see Data Supplement Table 9-2).

Of the Livermore on-site monitoring wells, no inorganic data exceeded primary MCLs with the exception of nitrate in monitoring well W-1012 (see **Figure 9-2**).

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 2002 exceeded California's MCL of 45 mg/L. Nitrate above the MCL has not migrated off site. LLNL continues to monitor nitrate concentrations at this well and monitoring well W-571, which is off-site and about 350 m downgradient from well W-1012.

Measurements of arroyo sediments at the Livermore site made in 2002 do not indicate that LLNL activities have an adverse impact on groundwater or public health (see Chapter 10).

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 Explosives Process Area will not migrate off site. Plans to remediate TCE, explosive compounds such as RDX, perchlorates, and nitrate are 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 exception of a small plume in the General Services Area that extends minimally off site along Corral Hollow

Road, all of the TCE-bearing groundwater is onsite. 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.

LLNL is investigating various remedial methods to remove depleted uranium, nitrate, and perchlorate from the groundwater adjacent to several source areas within Site 300 (see Chapter 8 for locations).

HTO has been released to groundwater from several landfills and a firing table in the northwestern part of Site 300. The boundaries of the slowly moving HTO plumes lie entirely within the site. 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 migrate off site (Taffet et al. 1996).