8

Ground Water

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Introduction

Ground waters in the Livermore Valley and in the Altamont Hills are sampled and analyzed regularly by Lawrence Livermore National Laboratory. The objectives are to:

1. Assess the progress of LLNL remediation efforts in areas of known ground water contamination.
2. Assess the effectiveness of current LLNL activities designed to protect the environment, especially waste management practices.
3. Conform with the requirements of the Ground Water Protection Management Program.

Remediation efforts result from LLNL actions to comply with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA; see Chapter 2 for a summary of CERCLA activities). Operational monitoring complies with waste discharge requirements issued under California's Porter-Cologne Water Quality Control Act. Compliance monitoring is required by numerous federal and state controls (see Chapter 2, **Table 2-7**, for a summary of LLNL permits). Surveillance monitoring of ground water is performed to demonstrate compliance with DOE Order 5400.1, part of the U.S. Department of Energy's (DOE's) commitment to protect the environment at its sites.

For surveillance monitoring purposes, LLNL determines the number and locations of surveillance wells, the constituents of concern (COCs) to be monitored, the frequency of sampling, and the analytical methods to be used. This allows LLNL to design a comprehensive, cost-effective monitoring program. A wide range of COCs is monitored in ground water to confirm that current LLNL operations do not significantly impact local water resources. Because it looks at very low COC concentrations, surveillance monitoring can detect any slow-to-develop contamination resulting from past LLNL operations. 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. The surveillance networks include private off-site wells and on-site CERCLA wells.

Additional ground waters are monitored regularly at Site 300 to comply with state-issued permits associated with closed landfills containing solid wastes from past LLNL operations and with continuing discharges of liquid waste from current operations. This compliance monitoring uses networks of ground water wells that meet regulatory requirements.

LLNL's program of surveillance and compliance ground water monitoring follows an annual plan. Depending on their location and purpose, ground waters are sampled quarterly, semiannually, or annually for specific COCs. Standard operating procedures (SOPs) are followed when collecting samples of ground water to minimize the effects of sampling on analytical results (Dibley and Depue 1997).

Ground Water Regime

Livermore Site

Physiographic Setting

The Livermore Valley is the most prominent valley within the Diablo Range. It is an east-west trending structural and topographic trough bounded on the west by Pleasanton Ridge and on the east by the Altamont Hills. The valley is approximately 25 km long and averages 11 km in width. The valley floor is 220 m at its highest elevation along the eastern margin and gradually dips to 92 m at the southwest corner. The valley floor is covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays with an average thickness of about 100 m.

The Livermore Valley Ground Water Basin encompasses 7700 hectares. The prominent streams are Arroyo del Valle, Arroyo Las Positas, Arroyo Seco, Arroyo Mocho, Alamo Creek, South San Ramon Creek, and Tassajara Creek. Arroyo del Valle and Arroyo Mocho drain the largest areas and are the largest streams. Arroyo Mocho now flows the entire year with water supplied by the Alameda County Flood Control and Water Conservation District Zone 7. The streams converge westward at Arroyo de la Laguna, which flows southward out of the valley into the Sunol Valley Ground Water Basin (Thorpe et al. 1990).

The Livermore Valley ground water system is a sequence of semiconfined aquifers. Ground water moves downslope from the valley uplands toward the east-west axis of the valley. It then flows generally westward toward the southwest portion of the basin. From there, ground water historically flowed south into the Sunol Valley Ground Water Basin. The largest quantities of ground water are pumped from the central and western portions of the Livermore Valley, where the valley fill is thickest.

The valley-fill sediments make up two aquifers: the Livermore Formation and its overlying alluvium. The Livermore formation averages about 1000 m in thickness and occupies an area of approximately 250 km^2. The alluvium averages about 100 m in thickness. The alluvium is the principal water-producing formation within the valley.

The quality of ground water in the Livermore Valley reflects the surface water that recharges the aquifers. The chemical character of the ground water ranges from excellent (low sodium, magnesium, or calcium bicarbonate content) to poor (high sodium chloride content). In the eastern part of the valley, poor quality ground water results from recharge via Altamont Creek, which drains marine sediments to the east of the valley. High concentrations of naturally occurring minerals there, especially boron, render this ground water unsuitable for irrigation.

Drainage Retention Basin

In 1990, a drainage retention basin was constructed near the center of the Livermore site to catch and retain treated ground water and storm water runoff. The Drainage Retention Basin (DRB) is lined to prevent infiltration in this area. Surface drainage at the Livermore site is discussed in detail in Chapter 7.

Hydrogeology

Sediment types at the Livermore site are grouped into four categories—clay, silt, sand, and gravel—based on dominant particle size. Ground water flow beneath the site is primarily in sand and gravel lenses and channels, bounded by the less permeable clays and silts. The alluvial setting has been mapped into seven hydrostratigraphic units (HSUs) beneath the Livermore site using data collected over the years. HSUs can be defined as sedimentary sequences whose permeable layers show evidence of hydraulic connection. The HSUs of concern beneath the Livermore site are the Quaternary alluvial deposits of the upper Livermore member of the Livermore Formation. HSUs 1B, 2, and 3A (in order of increasing depth, see **Figure 8-1**) contain contaminants, which are primarily solvents (Hoffman et al. 1998).

Based on borehole lithologic data, a series of buried sand and gravel-filled stream channels have been identified at the site. The sand and gravel deposits, which are highly permeable, are present in narrow bands at the site and are interpreted as braided stream deposits, similar to strata deposited by the present day Arroyo Mocho.

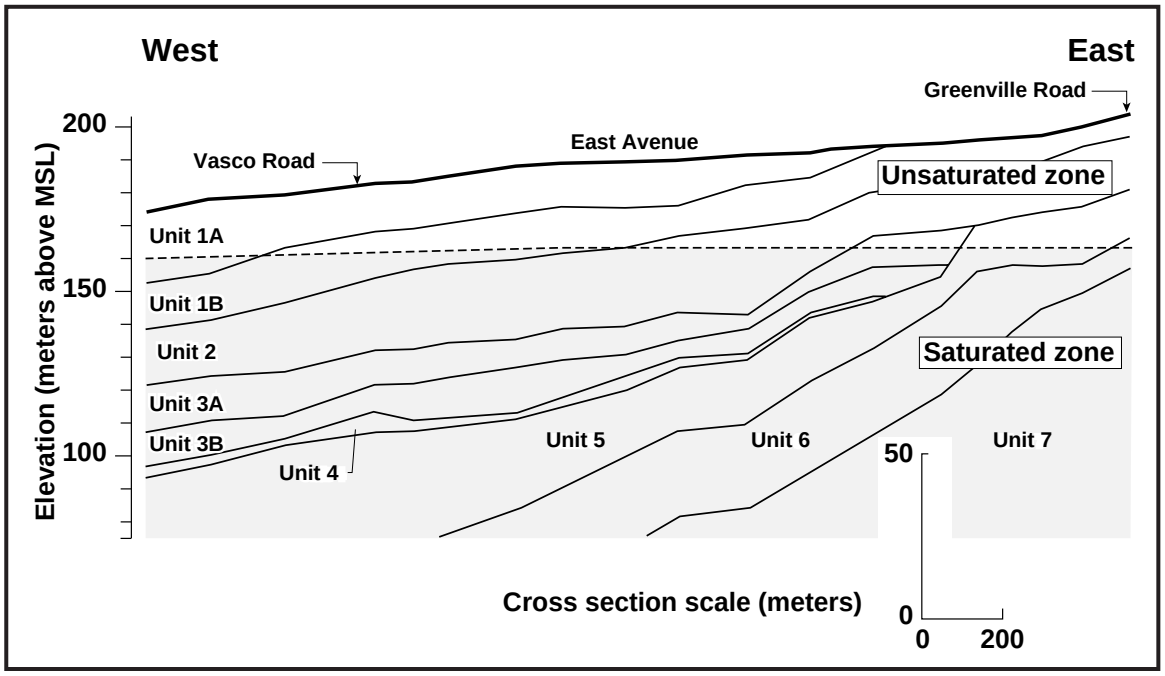

Figure 8-1. Cross section for the Livermore site showing hydrostratigraphic units.

In 1997, the depth to ground water below ground surface ranged from 34.5 m (113 ft, in HSU 5) at the southeast corner of the site to 6 m (20 ft, in HSU 1B) at the northwest corner and 11 m (37 ft, in HSU 2) at the northeast corner (Hoffman et al. 1998). Ground water levels have responded to variations in annual rainfall and resource use. Decreases in ground water use from the 1960s to 1985 caused the water table to rise. Heavy rains caused rises in 1986, 1993, 1994, 1995, 1996, and 1997 while drier-than-normal winters caused declines between 1987 and 1991.

Ground water is recharged at the Livermore site mainly from arroyos and from direct rainfall. Recharge enters primarily through the arroyos (see also Chapter 7). Ground water flow at the Livermore site is generally westward. The hydrogeology of the Livermore site is discussed in detail in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990) and Ground Water Project reports.

The conceptual model presented in the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* suggests that ground water generally flows towards two destinations from the Livermore site. Ground water from the north half flows west and northwest and eventually discharges to Arroyo Las Positas near First Street in Livermore, about 2 km northwest of the Livermore site. Ground water from the southern half flows generally westward toward the gap between the Mocho I and Mocho II subbasins, about 2 km west of the Livermore site. Ground water velocities at the Livermore site range from 15 to 20 m (49 to 66 ft) per year.

Site 300

Physiographic Setting

Site 300 is located in the sparsely populated Altamont Hills, which are part of the Coast Ranges Physiographic Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east.

Rocks exposed in the region are classified into three groups:

- Late Tertiary-Quaternary (0–5 million years ago)—Alluvium and semilithified sediments, mainly of continental origin.
- Early to late Tertiary (5–65 million years ago)—Shallow marine and continental sedimentary and volcaniclastic rocks.
- Jurassic-Cretaceous (65–180 million years ago)—Great Valley sequence (marine sedimentary rocks and ophiolites); Franciscan Complex (sheared and variably metamorphosed sedimentary and igneous rocks).

Distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate, are exposed extensively within Site 300. These rocks are mapped as the late Miocene Neroly Formation (Huey 1948; Dibblee 1980). The Neroly Formation is also present in the subsurface beneath the southeastern portion of Site 300.

The Neroly Formation is the principal hydrologic unit within Site 300 and has therefore been the focus of the detailed geologic and hydrogeologic studies conducted during recent years (summarized in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300*, hereafter referred to as Final SWRI Report [Webster-Scholten 1994]). The Neroly Formation is about 150 m thick beneath Site 300.

The floodplain of Corral Hollow Creek lies along the southern boundary of Site 300, underlying portions of the western and eastern General Services Area (GSA). The floodplain also makes small incursions into Site 300 in the vicinity of closed landfill Pit 6. Floodplain alluvium consists dominantly of coarse cobble and boulder-bearing gravel derived from sources to the south, with lenses and local cappings of sandy silt and silty clay.

The bedrock sequence within Site 300 has been slightly deformed into several gentle, low-amplitude folds. The locations and characteristics of these folds, in combination with the regional fault and fracture patterns, may locally influence ground water flow within the site and have therefore been studied as part of the CERCLA investigations.

Hydrogeology

Site 300 is semiarid, with an average annual rainfall of 27 cm (10.5 in). The site is underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock comprises interbedded conglomerates, sandstones, siltstones, and claystones (**Figure 8-2**). Most ground water primarily occurs in the Neroly Formation upper and lower blue sandstone units ($Tnbs_2$ and $Tnbs_1$) and in the underlying Cierbo Formation (Tmss) Ground water can also be present in permeable Quaternary alluvium valley fill (Qal) during the winter rainy season. Some ground water is present as perched water-bearing zones beneath hilltops. The perched water-bearing zones primarily occur in the unconsolidated sediments of the Miocene-age nonmarine unit (Tps) in the Buildings 833 and 834 areas, and in the Explosives Process Area. Fine-grained siltstone and claystone

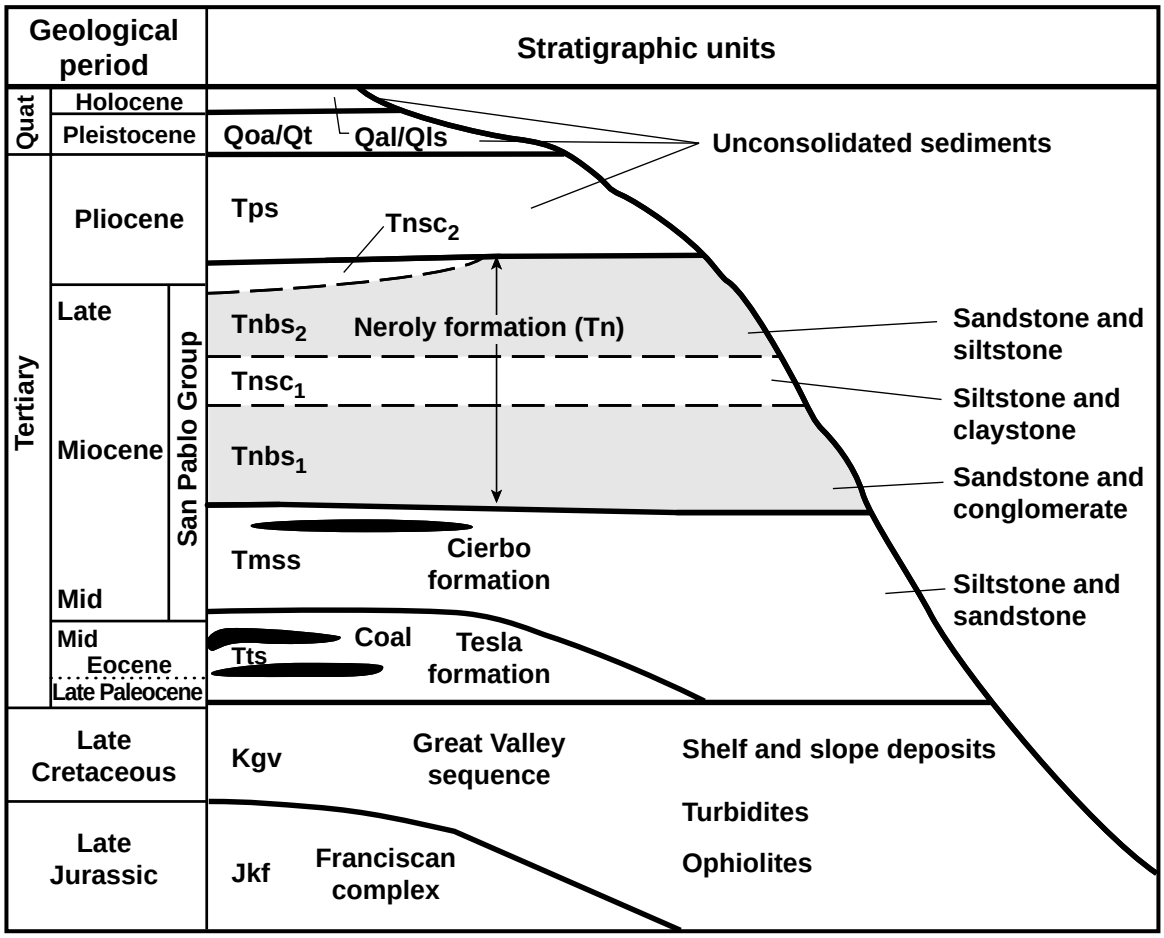

Figure 8-2. Site 300 stratigraphy. Stratigraphic codes are in standard geological notation (Webster-Scholten 1994). (For example, $Tnbs_1$ stands for the tertiary [circa 10 million-year-old] Neroly lower blue sandstone unit.)

interbeds in $Tnbs_1$ and Tmss act as aquitards, confining layers, or perching horizons. Ground water is present under confined conditions in the southern half of the site, but is generally unconfined elsewhere.

Recharge occurs where saturated alluvium valley fill is in contact with underlying permeable bedrock, and where bedrock strata crop out. Local recharge occurs on hilltops, creating the perched water-bearing zones in the Building 832 and Building 834 areas. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

Ground water flow in the bedrock follows the inclination, or dip, of the layers. The tectonic forces that uplifted the Altamont Hills faulted, gently folded, and tilted the once-horizontal sedimentary strata. A major structure, the east-west trending Patterson anticline, occupies a central location within the site. North of the anticline, bedrock ground water flows generally east-northeast. South of the anticline, bedrock ground water flows roughly south-southeast.

The Cierbo Formation (Tmss) is saturated beneath Doall Ravine, the Building 851 Area, and the southern part of the East Firing Area. The Tmss is unsaturated or does not otherwise yield water to wells in other parts of the East and West Firing areas. The thickness of the Cierbo Formation is not well-known because most boreholes are not deep enough to completely penetrate this formation. Some of the deeper wells in the GSA penetrate the uppermost Tmss. Similar to the $Tnbs_1$, the continuity of saturation between the northwest and southeast areas of Site 300 is undetermined. Ground water in the Tmss occurs under unconfined to artesian conditions.

The Tps unit is the youngest bedrock unit identified at Site 300 and is generally present only on hilltops. Where present, ground water is frequently perched, discontinuous, and ephemeral. The exception to this condition exists in the Explosives Process Area, where the extent of saturation in Tps sediments is significant. Ground water in the Tps unit is generally unconfined, although water under confined conditions does occur locally.

Quaternary alluvium (Qal) is present as valley fill in ravines throughout Site 300, but is saturated only in the Corral Hollow Creek stream channel, in Doall Ravine in the West Firing Area, and in southern Elk Ravine in the East Firing Area near a spring. Saturated Quaternary terrace alluvium deposits (Qt) are present at Pit 6, the GSA, and in the Building 832 Canyon area; some of these ground water occurrences are ephemeral. Small quantities of ground water are present in some local landslide (Qls) deposits.

Surveillance Ground Water Monitoring of Livermore Valley

Livermore Site

LLNL Perimeter

To complement the Livermore Ground Water Project, LLNL designed the surveillance monitoring program to detect possible releases from beneath the Livermore site as a whole. The external portion of this surveillance ground water monitoring program makes use of two upgradient monitoring wells (W-008 and W-221) in the eastern portion of the site, and seven downgradient monitoring wells near and past the western boundary of the site (**Figure 8-3**). These downgradient wells are located in the regions of Treatment Facility A (W-121, W-151, and 14B1), Treatment Facility B (W-571 and W-1012), and Treatment Facility C (W-373 and W-556). This configuration was adopted in 1996

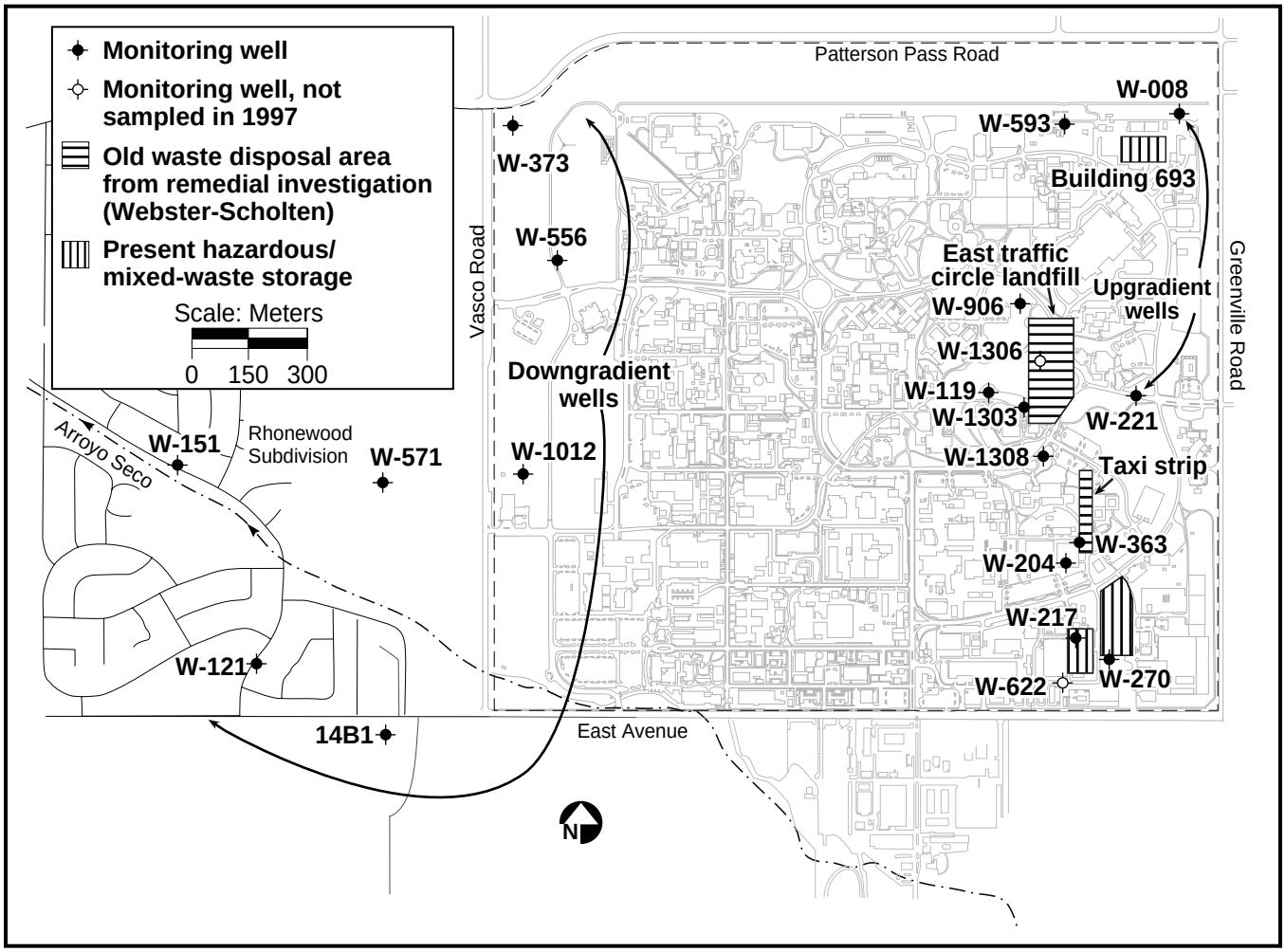

Figure 8-3. Locations of routine surveillance ground water monitoring wells at the Livermore site, 1997.

to monitor the uppermost aquifers (HSUs 1B and 2) within that area. The intent of this network is to monitor for possible contaminants other than volatile organic compounds (VOCs), which are handled under the Livermore Site Ground Water Project. These wells were sited to satisfy Resource Conservation and Recovery Act (RCRA) monitoring requirements and California Code of Regulations Title 22 monitoring requirements.

For the Livermore Ground Water Project, the constituents of concern (COCs) are VOCs, primarily trichloroethene (TCE) and tetrachloroethene (or perchloroethylene [PCE]). **Figure 8-4** shows the VOC isoconcentration contours in hydrostratigraphic unit (HSU) 2 in 1997. **Figure 8-5** shows a ground water elevation map for HSU 2 (Hoffman et al. 1998). This map shows that ground water within HSU 2 generally flows to the west-southwest toward Arroyo Seco during December and that cones of depression surrounding the treatment facilities are prominent. The cone of depression around Treatment Facility A, near Arroyo Seco, is especially prominent. Tables 8-1, 8-2,

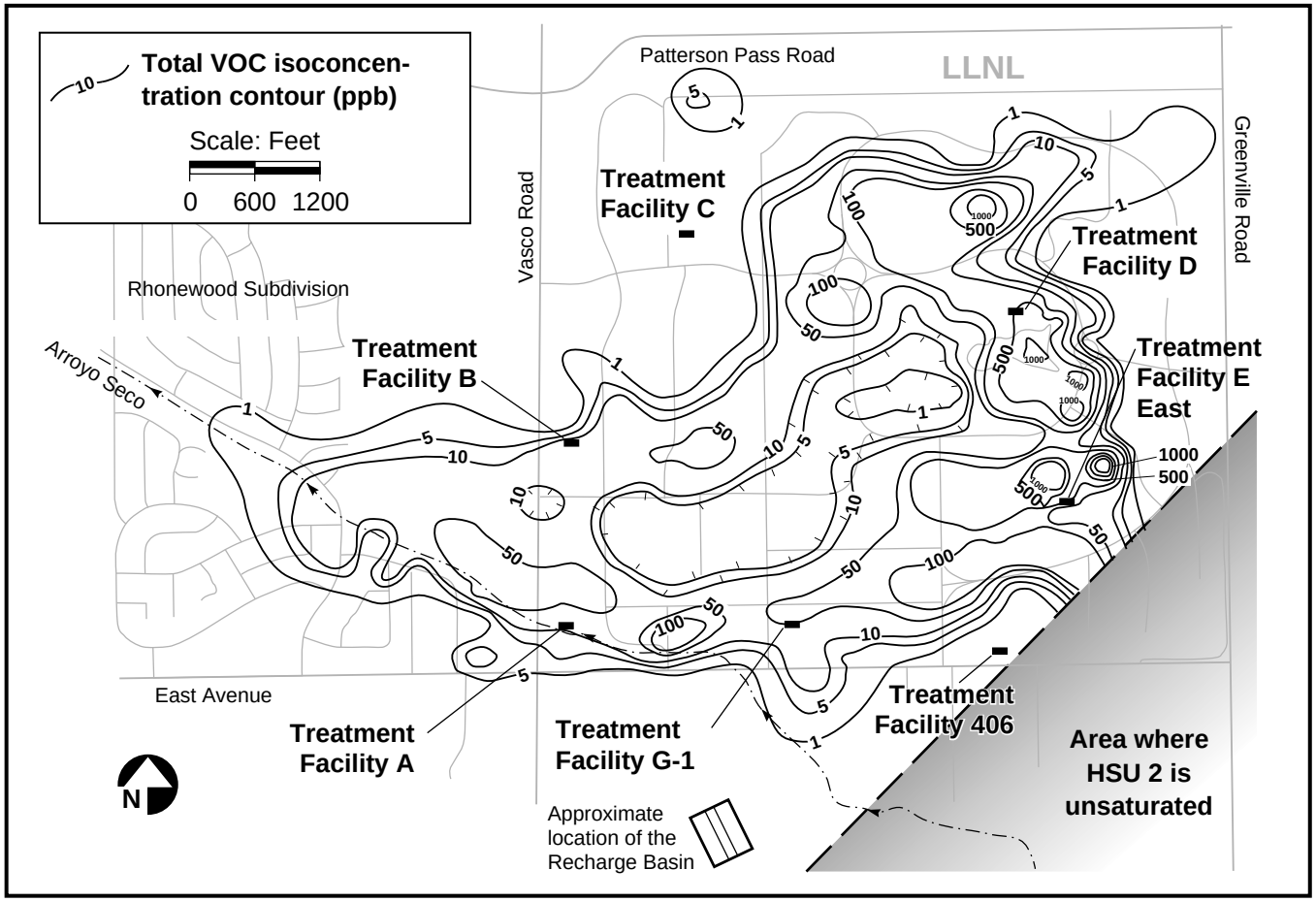

Figure 8-4. Distribution of VOCs for 170 sampling locations in hydrostratigraphic unit 2 (HSU 2), at Livermore site and vicinity, fourth quarter 1997.

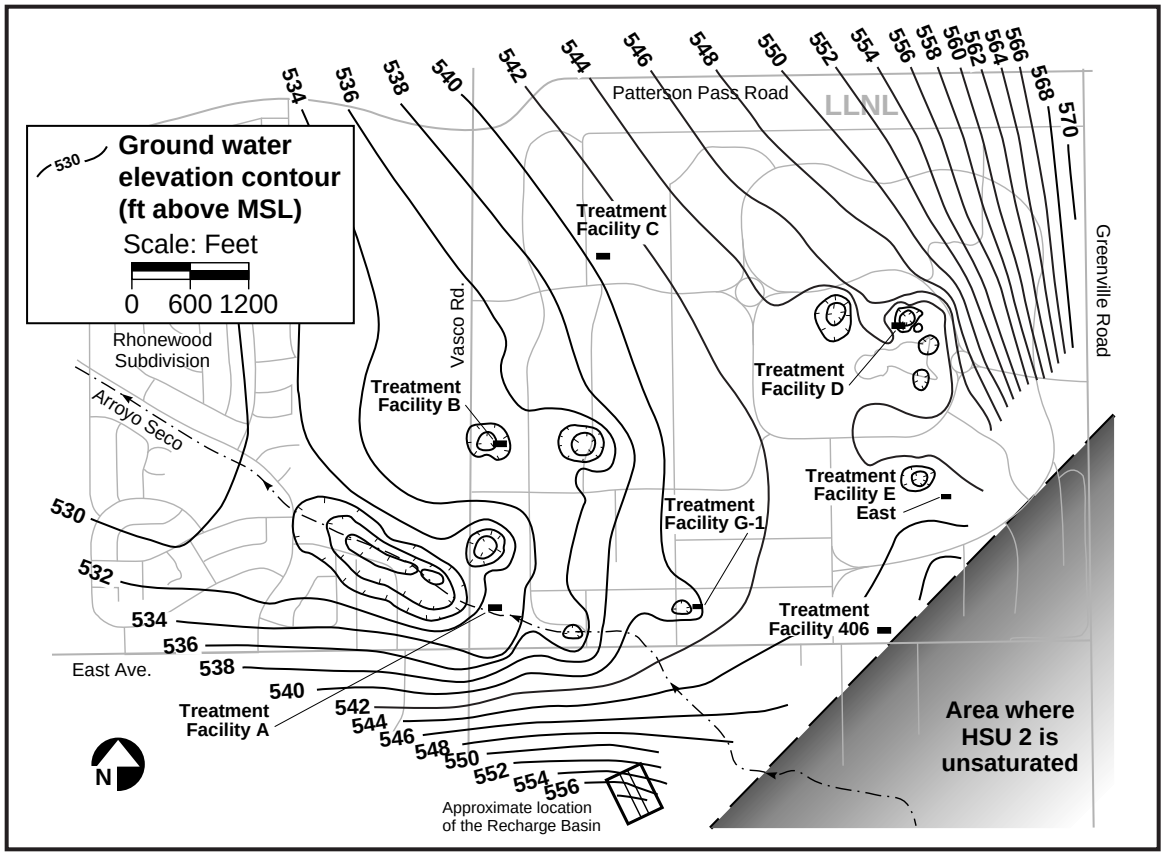

Figure 8-5. Ground water elevation contour map based on water levels collected from 152 wells completed within HSU 2, LLNL and vicinity, December 1997 (from Hoffman et al. 1998).

and 8-3 in the Data Supplement (formerly Volume 2) respectively show the analytical methods and reporting limits for inorganic constituents (including specific radioisotopes analyzed by alpha spectroscopy and other sensitive methods), organic constituents, and radioactive constituents analyzed by gamma ray spectroscopy.

The two upgradient wells were sampled and analyzed quarterly in order to obtain sufficient data for statistical analyses; the seven downgradient wells were sampled and analyzed semiannually. Each well was sampled and analyzed for metals and minerals, gross alpha and beta, tritium, and radioisotopes. These routine surveillance monitoring analytical detections are presented in the Data Supplement (Tables 8-4 through 8-12). The second-year monitoring efforts will help establish baseline conditions for future monitoring and the presence of contaminants, including radioactive materials, in the ground water at levels of concern to public health or to the environment.

External Monitoring Results

Neither cyanide (via EPA Method 335.2), pesticides nor herbicides (via EPA Methods 547 and 632) were detected. Bis(2-ethylhexyl)phthalate, a plasticizer, was detected via EPA Method 507 for the first time in September samples collected from downgradient monitoring Wells W-556 and W-1012 near the western site boundary at concentrations of 5 μg/L and 21 μg/L, respectively. Butyl benzyl phthalate was detected in the method blank for both of these samples. Furthermore, bis(2-ethylhexyl)phthalate was not detected in the duplicate sample, also collected from Well W-1012. Di-*n*-octylphthalate, another plasticizer, was detected in a ground water sample collected from Well W-008 during the first quarter at a concentration of 12 μg/L. This compound was detected by EPA Method 625 for semivolatile organic compounds. Phthalate esters are common laboratory contaminants (see Dibley and Depue 1997). Benzoic acid was detected in monitoring Well W-373 in the northwest corner of the site. Concentrations detected in ground water samples were 39 μg/L and 57 μg/L in March and September samples, respectively. Although benzoic acid is a moderately strong organic acid, the lowest pH measured with a field meter in September was 7.19.

The inorganic compounds monitored in the ground water, including dissolved trace metals and minerals, are naturally occurring compounds at variable concentrations. **Table 8-1** shows the concentrations of four anions in the two upgradient wells and the seven perimeter downgradient wells. (See Tables 8-4 through 8-12 in the Data Supplement.)

Table 8-1. Concentration ranges for four anions in upgradient and downgradient monitoring wells.

Flow	Concentration range (mg/L)			
	Bicarbonate	**Bromide**	**Chloride**	**Fluoride**
Upgradient	121–350	0.76–1.7	272–498	0.71–1.4
Downgradient	180–260	0.24–0.71	75.5–160	0.21–0.95

Concentrations of boron are an order of magnitude higher in the upgradient wells, in the northeastern portions of the site, than in the downgradient wells. Boron reached a high concentration of 9.2 mg/L in monitoring Well W-008 in June 1997. This additional information further documents the poor ground water quality in the upgradient portions of the site put first discussed in Chapter 3 of the *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990).

In 1996, nitrate was detected at concentrations ranging from 75 to 85 mg/L in ground water samples collected from monitoring Well W-1012 (screened in HSU 2). Concentrations of nitrates analyzed in water samples collected from this well in 1997

ranged from a high of 93.0 mg/L from a sample collected in March to a low of 76.6 mg/L from a sample collected in September (see the Data Supplement, Table 8-13). This is compared with nitrate concentrations ranging from 17.7 to 27 mg/L (see the Data Supplement, Table 8-5) from ground water samples collected from upgradient monitoring Well W-221 (screened in the adjacent HSU 3A). Well W-1012 lies within LLNL's boundary. Nitrate was found at a concentration of 31.4 mg/L in monitoring Well W-571, off site to the west about 300 m, in September 1997 (see the Data Supplement, Table 8-12). This is below California's drinking water maximum contaminant level (MCL) of 45 mg/L. Nitrate concentrations detected during 1997 monitoring range from 25.3 to 93 mg/L and are presented in the Data Supplement, Table 8-13. These nitrates may be agricultural residue according to the CERCLA report (Thorpe et al. 1990). Monitoring of these nitrates continues in 1998.

Concentrations of some nonradioactive dissolved metals detected in a few monitoring wells may be of concern. Dissolved chromium(VI) levels in monitoring Well W-373 remain at levels greater than California's MCL of 50 µg/L. (Dissolved chromium[VI] in all other wells monitored was found at concentrations less than the MCL.) Ground water in the area of Treatment Facility C has been treated for chromium(VI) since October 1993 (see Chapter 7). Dissolved nickel was detected at a concentration of 0.024 mg/L June 1996 (Harrach et al. 1997). During 1997, dissolved nickel was again detected in ground water samples collected from Well W-221. Nickel concentrations of 0.036 mg/L, 0.040 mg/L, and 0.013 mg/L were found in samples collected during the second, third, and fourth quarters, respectively. Ground water samples collected from Wells W-593 and W-1012 during 1997 contained nickel at concentrations from 0.003 mg/L to 0.007 mg/L. The primary drinking water MCL for nickel is 0.1 mg/L. Concentrations of the following dissolved metals were not detected above laboratory reporting limits during 1997: aluminum, antimony, arsenic, beryllium, cadmium, cobalt, lead, manganese, mercury, molybdenum, selenium, silver, and thallium.

None of the ground water samples from surveillance monitoring wells had concentrations of radioactivity or radioisotopes that exceeded a drinking water MCL. The highest tritium activity detected in 1997, 11.4 Bq/L (307 pCi/L), which is 1.5% of the tritium MCL, was found in monitoring Well W-373 (see the Data Supplement, Table 8-10).

Internal Monitoring

The succeeding locations, unlike the routine surveillance locations previously discussed, include areas where releases to ground may have occurred in the recent past. Monitoring wells screened in the uppermost aquifers are situated downgradient from, and as near as possible to, the potential release locations.

Two potential sources of ground water contamination, initially investigated prior to the remedial investigation (Thorpe et al. 1990), were added to the surveillance monitoring network during 1997 (see **Figure 8-3**). These areas are the Taxi Strip Area and the East Traffic Circle Landfill. Radioactively contaminated liquid wastes were deposited into four disposal pits in the Taxi Strip Area from 1953 through about 1976 (Thorpe et al. 1990). Contaminants detected in the soils were americium-241, uranium-235, cesium-137, cobalt-60, europium-152, thorium-232, unspecified transuranics, and VOCs (Buerer 1983). About 3000 cubic meters of contaminated soil and sediments were moved to the Nevada Test Site (Thorpe et al. 1990) when the area was cleaned up. Ground water samples from monitoring Wells W-204 (screened in HSU 2) and W-363 (screened in HSU 3A) downgradient from the Taxi Strip Area were collected and analyzed for plutonium, thorium, and uranium isotopes, and for radioisotopes via gamma spectroscopy during the third quarter of 1997. During 1998, ground water samples from these monitoring wells will be analyzed for the same radioisotopes, gross alpha/beta radiation, americium-241, radium-226, radium-228, tritium, strontium-90, dissolved metals, and general minerals.

Polychlorinated biphenyls (PCBs), nonradioactive metals, and various radionuclide contaminants were initially detected in the soil at the East Traffic Circle Landfill. Gamma spectroscopy revealed cesium-137, depleted uranium (D-38), radium-226, thorium-232, uranium-238, americium-241, and cobalt-60 in the soil (McConachie et al. 1986). LLNL collected and disposed of 11,000 cubic meters of debris and soil with metal shavings, broken bottles, and capacitors. Of this, approximately 6 cubic meters of material containing low-level radioactive waste was disposed of at the Nevada Test Site (Thorpe et al. 1990). Ground water samples from monitoring Wells W-119, W-906, W-1303, and W-1308 (screened in HSUs 2 and 3A) downgradient from the East Traffic Circle Landfill were collected and analyzed for plutonium, thorium, and uranium, and for radioisotopes via gamma spectroscopy during the third quarter of 1997. During 1998, ground water samples from these monitoring wells are being analyzed for gross alpha/beta radiation, radioisotopes, PCBs, dissolved metals, and general minerals.

All surveillance monitoring analytical data for the LLNL Taxi Strip Area and the East Traffic Circle Landfill are presented in the Data Supplement, Tables 8-15 through 8-20.

Another potential source of contamination is the Mixed-Waste Storage Facility present in the area of Building 693 (see **Figure 8-6**). Ground water samples were collected from monitoring Wells W-594, W-593, and W-007 (screened in HSUs 2 and 3A) downgradient from this facility during the third quarter of 1997. These samples were analyzed for plutonium, thorium, and uranium, and for radioisotopes via gamma spectroscopy. Those analytical results are presented in the Data Supplement, Tables 8-21 through 8-23. During 1998, ground water samples from monitoring Well W-593 (believed to provide

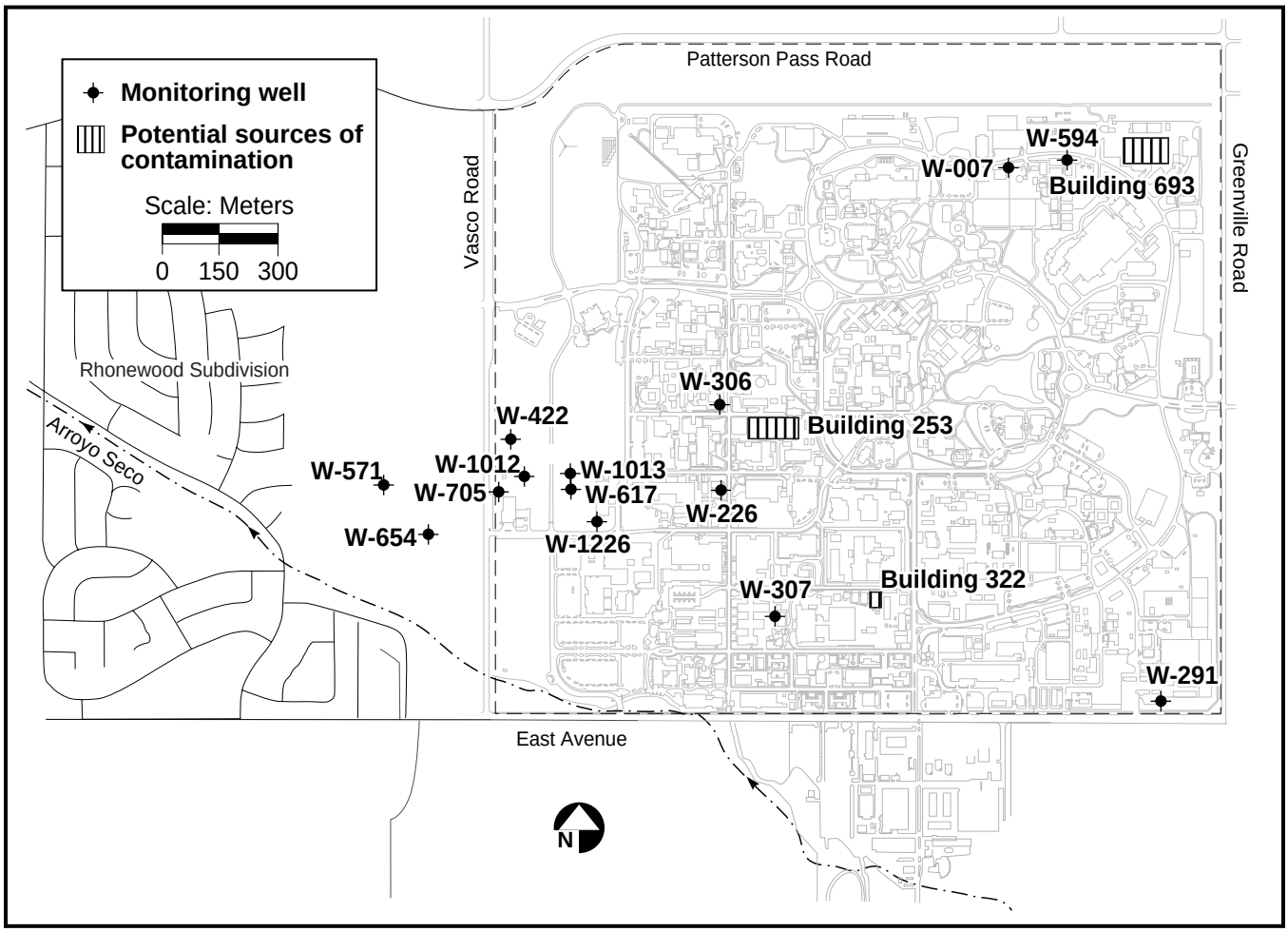

Figure 8-6. Locations of nonroutine surveillance ground water monitoring wells at the Livermore site, 1997.

the most representative ground water samples) are being analyzed for these same radioisotopes, gross alpha/beta radiation, americium-241, radium-226, radium-228, tritium, strontium-90, PCBs, dissolved metals, and general minerals.

During the first quarter, ground water samples were collected from monitoring Wells W-217 and W-270, downgradient from the Building 514 mixed-waste and hazardous waste storage area. These samples were analyzed for radium-226 and for radioisotopes via gamma spectroscopy to ensure that the hazardous and mixed-waste operations in this area have not added radioisotopes to ground water in concentrations harmful to humans or the environment. Analytical results are presented in the Data Supplement, Tables 8-24 and 8-25, respectively.

Ground water samples were also collected from the areas downgradient from two documented releases of metals to ground. Samples were collected from monitoring

Well W-307 (screened in HSU 1B), downgradient from where metals released from a fume hood on the roof of Building 322 leaked down onto the ground. Soil samples collected from the area of the Building 322 release showed elevated concentrations (in comparison with LLNL's site background levels) of chromium, copper, lead, nickel, zinc, and occasionally other metals (see the Data Supplement, Table 8-26). Ground water samples were also collected downgradient from where sediments containing metals (including mercury and chromium) had accumulated in a storm water catch basin near Building 253. These ground water samples were collected from monitoring Wells W-226 and W-306 screened in HSUs 1B and 2, respectively. Analytical results for dissolved metals for samples collected from those monitoring wells are presented in the Data Supplement, Tables 8-27 and 8-28. (See **Figure 8-6**.)

In addition, LLNL monitored several wells surrounding Well W-1012 that had elevated concentrations of nitrates (from 75 to 85 mg/L) in 1996 (Harrach et al. 1997). Analytical results of nitrate concentrations in ground water samples collected from monitoring Wells W-1012, W-1013, W-705, W-617, W-654, W-1226, and W-422 are presented in the Data Supplement, Table 8-13.

Internal Monitoring Results

Alpha spectroscopy is a very sensitive method of measurement for plutonium, thorium, and uranium activities. Uranium results are usually positive since uranium occurs naturally in the sediments at and surrounding LLNL. However, none have exceeded drinking water MCLs that have been measured to date. Plutonium radioisotopes were not detectable in filtered ground water samples, since plutonium is neither soluble nor mobile in the subsurface. However, thorium radioisotopes were detected in filtered ground water samples collected from Wells W-204, downgradient from the Taxi Strip Area, and W-594, downgradient from the Mixed-Waste Storage Unit near Building 693 (see the Data Supplement, Tables 8-15 and 8-21, respectively). No MCLs exist for thorium radioisotopes.

Analysis of ground water samples from the internal monitoring wells by gamma spectroscopy is intended to detect radioisotopes not detected by alpha spectroscopy. Gamma spectroscopy is not a sensitive analytical tool, especially with the low environmental levels of radioisotopes. Nearly every analytical result from gamma spectroscopy has positive results for the radioisotopes bismuth-214 and lead-214. Both are very short-lived radioactive daughters of the uranium-234–thorium-230–radium-226 series, and really indicate the presence of the parent radioisotopes rather than a release of the daughter isotope. In monitoring Well W-119, downgradient from the East Traffic Circle Landfill, gamma spectroscopy detected americium-241 at 0.34 Bq/L (9.1 pCi/L) (see the Data Supplement, Table 8-17), but with an estimated error of 100%. Another ground water sample was subsequently collected from this well and analyzed for

americium-241 by the very sensitive alpha spectroscopy; the resulting calculated concentration was 0.002 Bq/L (0.06 pCi/L). Therefore, it is reasonable to assume that the activity for americium-241 estimated by gamma spectroscopy is invalid because of the large associated error.

Dissolved chromium was detected at elevated concentrations in Wells W-226 and W-306 downgradient from the area of the Building 253 catch basin. Chromium concentrations were 28 μg/L in Well W-226 and 46 μg/L in Well W-306. The sediments that had accumulated in the catch basin are a possible source of the chromium. Elevated concentrations of metals are absent in Well W-307 downgradient from the Building 322 release.

Off Site

LLNL has monitored tritium in water hydrologically downgradient of LLNL since 1988 (**Figure 8-7**). Tritium is potentially the most mobile contaminant emanating from LLNL in ground water. Rain and storm water runoff in the Livermore Valley recharges local aquifers and contains small amounts of tritium from natural sources, past world-wide atmospheric nuclear weapons tests, and atmospheric emissions from LLNL and Sandia National Laboratories (SNL/California). (See Chapters 4, 5, and 7 for further discussion of air emissions, rain, and storm water runoff.)

Measurements in water samples collected during the summer of 1997 from 21 wells in the Livermore Valley show tritium levels were very low compared with the 740 Bq/L (20,000 pCi/L) MCL established by the State of California.

Tritium was measured at <1.20 to 2.77 Bq/L (<32.3 to 74.9 pCi/L) in ground water samples from on-site upgradient monitoring wells and from <1.15 to 11.4 Bq/L (<31.3 to 307 pCi/L) in external downgradient monitoring wells. The highest tritium activity measured off site was in a ground water sample from Well 12D2, located about 10 km west of LLNL. The activity in that sample in 1997 was 9.51 Bq/L (257 pCi/L). This represents a very slight increase of less than 4% from its measurement of 9.18 Bq/L (248 pCi/L) in 1996. However, tritium activity in ground water samples from Well 11B1 that had the highest tritium activity of 13.9 Bq/L (377 pCi/L) in 1996 decreased by more than 40% to a tritium activity of 8.29 Bq/L (224 pCi/L) in 1997. This is a slightly greater decrease than can be accounted for by simple radioactive decay. Dilution is another likely source of decreasing activities.

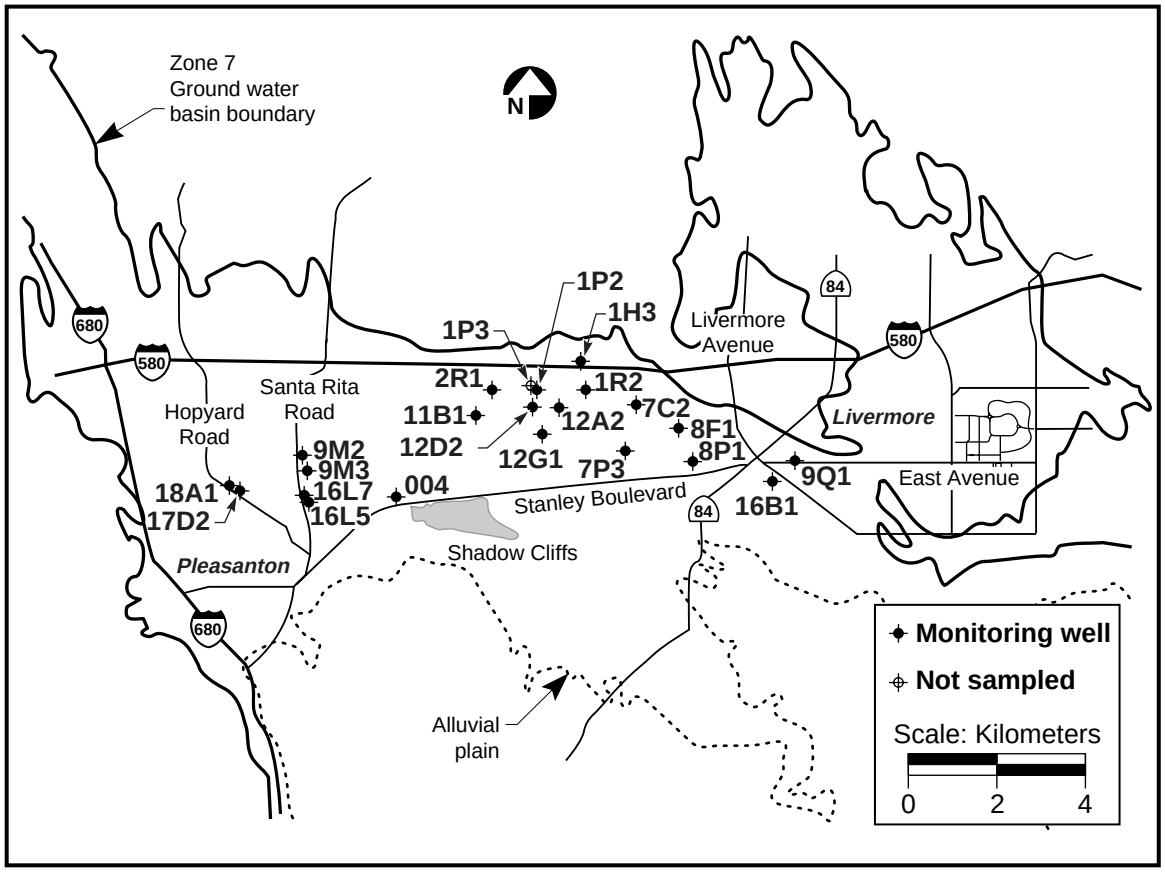

Figure 8-7. Locations of off-site surveillance ground water monitoring wells in the Livermore Valley.

Tritium activity has shown a decreasing trend overall in Livermore Valley ground waters downgradient of LLNL. The median activities of tritium in ground water samples from these downgradient wells increased from 3.45 Bq/L (93.2 pCi/L) in 1988 to 4.59 Bq/L (124 pCi/L) in 1989. By 1997, the median activity had dropped to 3.36 Bq/L (90.8 pCi/L), based on the 10 positive detections of tritium). This decrease in median activity is approximately equal to that expected through radioactive decay of tritium, which has a half-life of 12.3 years.

Surveillance Ground Water Monitoring of Site 300

Surveillance monitoring of ground water at Site 300 requires samples from DOE wells on site and from private wells off site. Ground water samples are routinely measured for the following COCs: various elements, primarily metals; a wide range of organic compounds; nitrate; general radioactivity (gross alpha and gross beta); uranium activity; and tritium activity. Analytical methods for COCs are selected for their high sensitivity.

Typically, EPA-approved methods are used for ground water analysis. (See the Data Supplement, Tables 8-1, 8-2 , and 8-3, for a complete list of COCs and the EPA methods, or other standard methods, used to measure COCs in ground water samples.)

Figure 8-8 shows 33 ground water sampling locations, which utilize wells and springs. At several locations there are as many as three distinct water-bearing zones. Although most of the sampling locations collect ground water from the uppermost water-bearing zone, four multiple-completion surveillance installations (K1-01, K1-02, K2-01, and K2-02) are fitted with Barcad devices that provide representative water samples from deeper water-bearing zones at those locations.

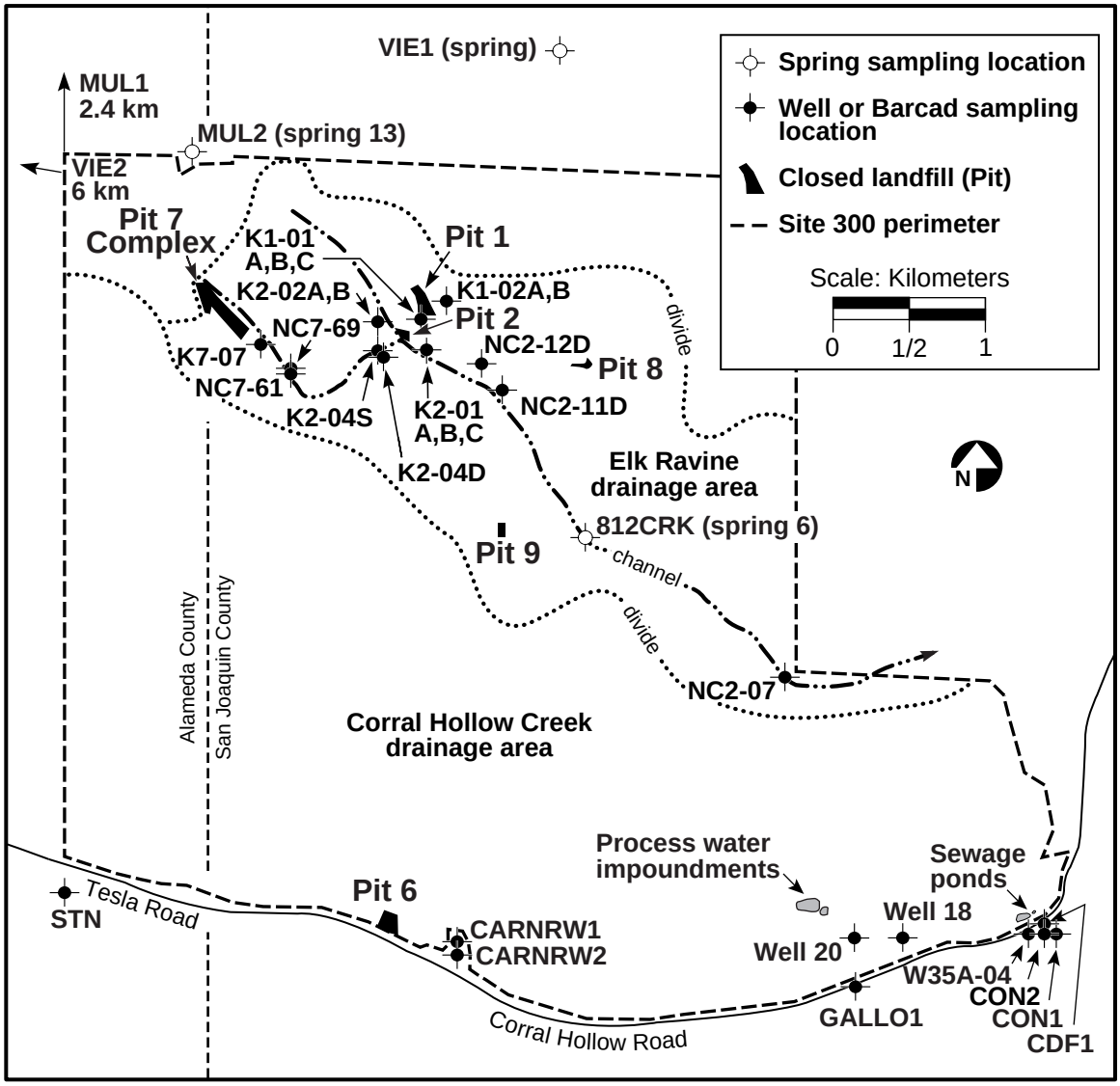

Figure 8-8. Locations of surveillance ground water wells, Barcads, and springs, Site 300, 1997.

Barcads are identified according to depth in **Figure 8-8** by the capital letters A, B, C, separated by commas at the end of an installation's identifier code. For multiple water-bearing zones, the Barcad that samples the deepest, or deeper, water-bearing zone is designated "A."

Of 31 surveillance sampling locations, 12 are off site. Three locations, including spring MUL2 and VIE1, are north of Site 300 in the Altamont hills. Well VIE2 is located 6 km west of Site 300 in the upper reaches of the Livermore Valley watershed. The remaining eight off-site surveillance locations are wells located immediately south of the Site 300 boundary in, or adjacent to, the Corral Hollow Creek floodplain.

Many on-site wells that were originally installed for CERCLA characterization studies during the 1980s remain in use as surveillance monitoring wells for several closed landfills (pits) that are not otherwise covered by WDR permits. Six wells monitor Pit 6. Five wells monitor Pit 8. Four wells monitor Pit 9. Seven Barcads in four multiple completions monitor Pit 2 (K2-01A and B, K2-02A and B, K1-01A and B, and K1-02A. Barcads K1-01C and K1-02B (**Figure 8-12**) monitor the uppermost water-bearing zone at Pit 1 for compliance purposes. Ten on-site surveillance locations, including one spring (812CRK), are located along the system of fault-marked ravines and arroyos that make up the Elk Ravine drainage area. Closed landfill Pits 1, 2, 3, 4, 5, 7, 8, and 9 are located in the Elk Ravine drainage area. Pit 6 lies in the Corral Hollow Creek drainage area. Surveillance monitoring also includes two on-site water production wells, Well 18 and Well 20. Well 20 provides potable water to Site 300. Well 18 is maintained as a standby supply well.

Brief descriptions of the surveillance networks are given below, together with a summary of ground water monitoring results for 1997. Tables of the ground water measurements made during 1997 are contained in the Data Supplement. Detailed descriptions of Site 300 geology, hydrogeology, and extent of ground water contamination can be found in Site 300 SWRI reports (Webster-Scholten 1994; Taffet et al. 1996).

Pit 6

The unlined, closed Pit 6 landfill covers an area of about 1 hectare adjacent to the southern boundary of Site 300 about 200 m above sea level (**Figures 8-8** and **8-9**). From 1964 to 1973, 1500 cubic meters (2000 cubic yards) of solid waste were buried in nine separate trenches. The trenches were not lined, consistent with historical disposal practices. Three larger trenches contain 1300 cubic meters (1700 cubic yards) of solid waste that includes empty drums, glove boxes, lumber, ducting, and capacitors. Six smaller trenches contain 230 cubic meters (300 cubic yards) of biomedical waste,

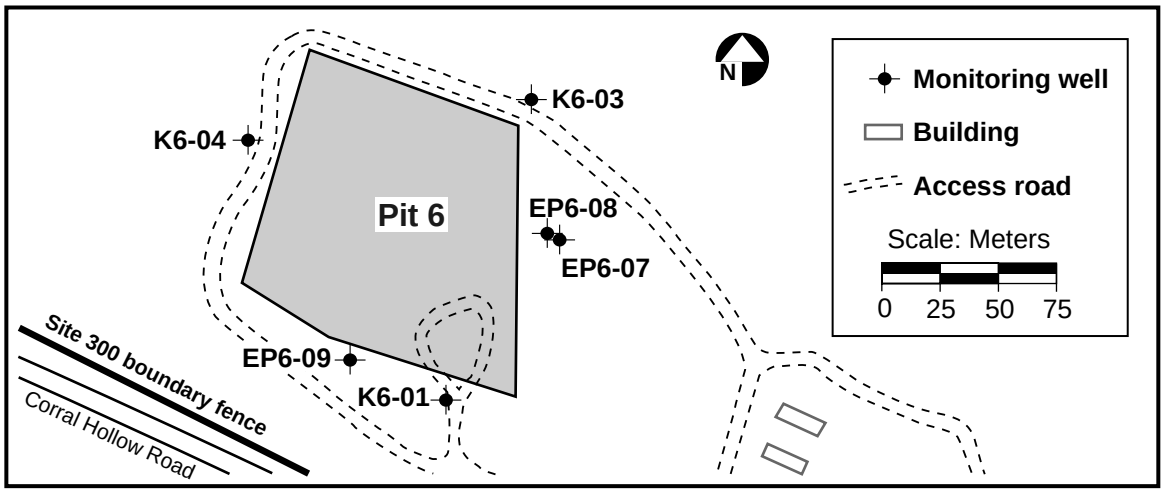

Figure 8-9. Locations of surveillance ground water monitoring wells, Pit 6, 1997.

including animal carcasses and animal waste. During 1997, a multilayered cap was constructed over Pit 6, and a drainage control system was installed around the cap. The cap and drainage systems prevent rainwater from percolating through the buried waste.

The Pit 6 disposal trenches were constructed in Quaternary terrace deposits (Qt in **Figure 8-2**) above and north of the Corral Hollow Creek floodplain. Tertiary Neroly sedimentary rocks ($Tnbs_1$ in **Figure 8-2**) lie beneath the terrace deposits. Surface runoff from the pit area is southward to Corral Hollow Creek. Ground water flows southward beneath the pit, following the south-dipping sedimentary rocks. Measured depths to the water table during 1997 were in the range of 10 to 20 m. Ground water flow turns southeastward beneath the southern margin of the landfill where movements along the Carnegie Fault have brought vertically dipping strata on the south into contact with the gently southward dipping strata to the north. A deposit of terrace gravel in a trough within the vertically dipping strata acts as a channel for the ground water after it passes beneath Pit 6 (Webster-Scholten 1994).

During 1997, six wells were used to collect ground water in the vicinity of Pit 6 for surveillance purposes (**Figure 8-9**). Well K6-03 is hydrologically upgradient from Pit 6, Wells K6-04, EP6-07, and EP6-08 are cross-gradient, and Wells EP6-09 and K6-01 are downgradient.

Surveillance ground water samples were collected twice during 1997 from the six monitoring wells. The samples were analyzed for 17 elements, mostly metals; nitrate; VOCs; pesticides and polychlorinated biphenyls (PCBs); explosives compounds; general radioactivity (gross alpha and gross beta); tritium (^3H) activity; and total uranium activity.

Analytical data are presented for each of the six monitoring wells in the Data Supplement, Tables 8-29 through 8-34. Metals were generally not detected above analytical reporting limits (RLs). Of the elements detected, only beryllium exceeded a maximum contaminant level (MCL) on one occasion, but this measurement was discounted, based on quality assurance data received from the analytical laboratory. Arsenic, barium, chromium, and selenium were detected at concentrations consistent with natural concentrations in the area ground water (Webster-Scholten 1994). Mercury was detected once at 0.24 µg/L, less than the MCL of 2.0 µg/L.

Trichloroethene (TCE) was detected at 16 µg/L, above its MCL of 5 µg/L in Well EP6-09 (see the Data Supplement, Table 8-34). This surveillance well monitors a shallow, slowly moving plume of TCE-bearing ground water that extends 125 m southeast from Pit 6, parallel to Corral Hollow Road (see Chapter 2, **Figure 2-2**). The TCE plume has been characterized, and its fate has been assessed in several CERCLA investigation reports (Webster-Scholten 1994; Ferry et al. 1998).

All surveillance network measurements during 1997 for gross alpha, gross beta, tritium, and uranium were at background activities, and were below their respective MCLs in drinking water. During 1997, tritium activity of about 50 Bq/L was measured in one CERCLA monitoring well, located about 25 m southeast of surveillance monitoring Wells EP6-07 and EP6-08. (For reference, the MCL for tritium is 740 Bq/L, and the background activity in the Pit 6 area is about 2 Bq/L.) The extent of the tritium-bearing ground water is probably very limited, because it is not detected above background in other nearby monitoring wells. A post-closure plan for monitoring TCE, tritium, and other COCs near Pit 6 using an expanded network of 28 CERCLA wells will be implemented the second quarter of 1998 (Ferry et al. 1998).

Pit 8

Pit 8 is located adjacent to the Building 801 firing table, where explosives experiments were conducted from 1958 to 1974. Approximately 40 cubic meters of untreated debris from the firing table was placed in the pit during that time, and a final cover was installed in 1974. Debris may contain HTO, depleted uranium (D-38), lead, and beryllium. The debris was originally dumped on the ground surface, which was later leveled and compacted by bulldozer. It was covered with about 1 m of locally obtained silt with small amounts of clay, sand, and gravel. A drainage ditch was constructed around the landfill to protect the cover from erosion.

Figure 8-10 shows the Building 801 and Pit 8 areas. The pit is located in a narrow ravine within the Elk Ravine drainage area about 330 m above sea level. It is bordered by an earthen dam on its west side at the locations of monitoring Wells K8-01 and K8-03.

Surficial materials at Pit 8 consist of colluvial soils and shallow ravine fills. The landfill was constructed in the unconsolidated Tps formation. Blue sandstone and interbedded siltstones and claystones of the Neroly Formation underlie the landfill area. The landfill is about 0.5 km northeast of the Elk Ravine fault shear zone, 1.2 km northeast of the Patterson anticline, and 0.5 km southwest of a subparallel syncline that plunges southeast. At the landfill, outcropping beds strike N25°W and dip slightly northeast. Chemical analysis of soil and rock samples collected from this area during CERCLA remedial investigations showed no elevated concentrations of COCs (Webster-Scholten, 1994). However, low concentrations of TCE have been detected in ground water samples from upgradient Well K8-01 since 1987.

The water table lies about 40 to 50 m below ground surface at Pit 8. Ground water flows east-northeasterly at a rate of about 20 m / year beneath Pit 8. Monitoring Wells K8-01 and K8-03B are hydrologically upgradient from Pit 8. Wells K8-02B, K8-04, and K8-05 are downgradient.

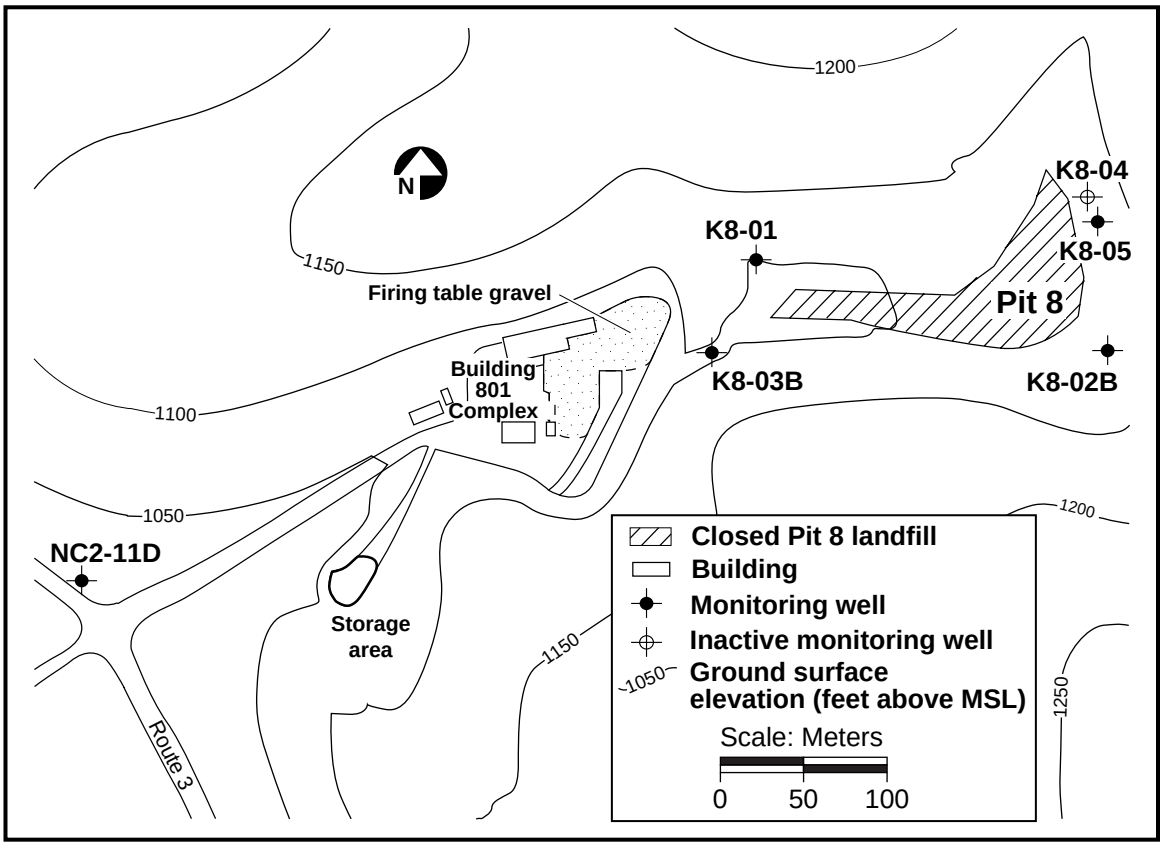

Figure 8-10. Locations of surveillance ground water monitoring wells, Pit 8, 1997.

Wells K8-01, K8-02B, and K8-03B produced sufficient sample water for analysis during 1997. Wells K8-01 and K8-02B were sampled twice. Well K8-03B was inaccessible during the second half of 1997 due to construction activities. Well K8-04 could not be sampled during 1997 because a bent casing prevented a bailer sampler from reaching ground water. Well K8-05 is screened in a perched water-bearing zone that did not yield sufficient water for analysis during 1997. Ground water samples were analyzed primarily for 17 elements (mostly metals). Volatile organic compounds (VOCs), tritium, and total uranium, were measured four times for Wells K8-01 and K8-02B. Gross alpha and gross beta were measured once in a ground water sample from Well K8-01. Analytical results for Pit 8 wells are shown in the Data Supplement, Table 8-35.

Arsenic, chromium, selenium, and vanadium were detected in concentrations similar to their natural abundances in ground water in the Altamont Hills. As in the past, the solvent TCE and its probable decomposition product, 1,2-DCA, were detected at levels approaching one half of their MCLs. The TCE is believed to have originated prior to 1981 in wastes discharged to a dry well upgradient from Pit 8 near Building 801 (Webster-Scholten 1994). No evidence for a release from Pit 8 is indicated by the monitoring data collected during 1997.

Pit 9

The inactive, closed Pit 9 landfill is centrally located within Site 300 about 340 m above sea level. Similar to the other closed landfills, the closed Pit 9 landfill contains firing table gravels with explosive experiment debris (mainly from the adjacent Building 845 firing table). Surface runoff from Pit 9 is northward to the Elk Ravine arroyo.

Figure 8-11 shows the locations of the four surveillance wells used to monitor the ground water in the vicinity of Pit 9. Ground water 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. Wells K9-01, K9-03, and K9-04 are downgradient.

Well K9-02 is screened at the contact between $Tnbs_1$ and Tmss. Wells K9-01, K9-03, and K9-04 are screened in Tmss, just below its contact with $Tnbs_1$.

For surveillance purposes, Pit 9 monitoring Wells K9-01, K9-02, and K9-03 were sampled once during 1997. The ground water samples were analyzed for 17 elements, mostly metals; nitrate; explosives compounds; volatile organic compounds; general radioactivity (gross alpha and gross beta); total uranium activity; and tritium (^3H) activity.

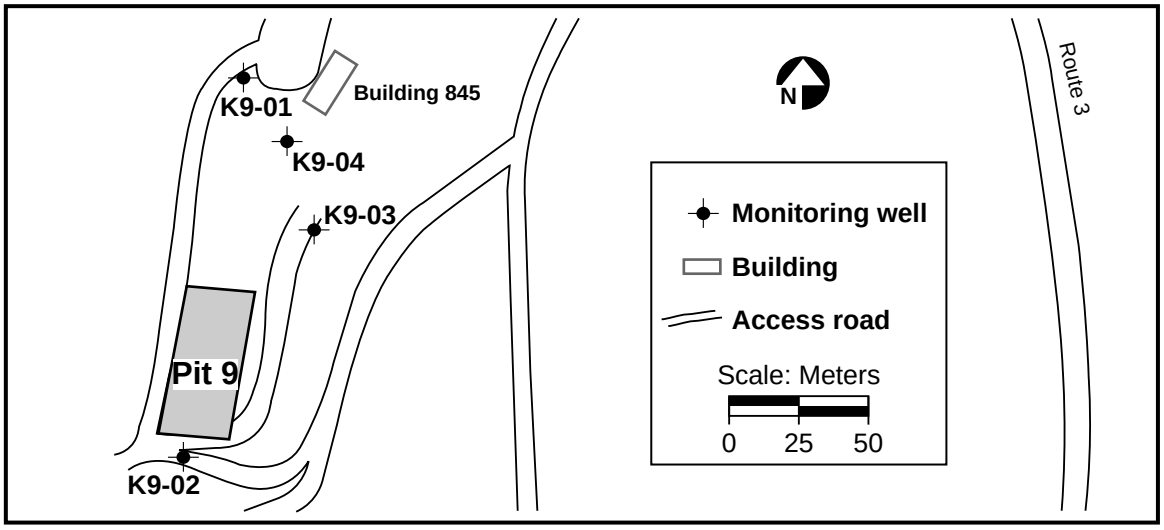

Figure 8-11. Locations of surveillance ground water monitoring wells, Pit 9, 1997.

Constituents of concern data for the four Pit 9 surveillance monitoring wells are presented in the Data Supplement, Table 8-36. No measurement exceeded an MCL for drinking water. COCs were either not detected, or were indistinguishable from natural background concentrations. No evidence for a release from Pit 9 is indicated by the monitoring data collected during 1997.

Pit 2

The unlined, closed Pit 2 landfill lies in the upper portion of Elk Ravine, about 320 m above sea level (**Figures 8-8** and **8-12**). The landfill primarily contains gravels and debris from hydrodynamic tests of explosive devices conducted at the Building 801 and 802 firing tables. The waste material contains depleted uranium (D-38), a manufactured form of uranium consisting mostly of the nonfissionable ^{238}U isotope. Trace amounts of beryllium, thorium, and tritium may also be present in the buried waste. Surface runoff from the Pit 2 area flows southerly into the Elk Ravine arroyo. Ground water flows east-northeast at a depth of about 25 m beneath Pit 2, following the dip of the $Tnbs_1$ and Tmss sedimentary rocks (**Figure 8-2**).

Multiple completion K1-01 is hydrologically downgradient from Pit 2. It contains one stovepipe well (K1-01C) and two Barcads (K1-01A and -01B, see **Figure 8-12**) that sample three separate water-bearing intervals within the underlying Tmss claystones and sandstones. Well K1-01C, which taps the shallowest water-bearing zone, also serves as one of two upgradient ground water monitoring points for the Pit 1 landfill to the

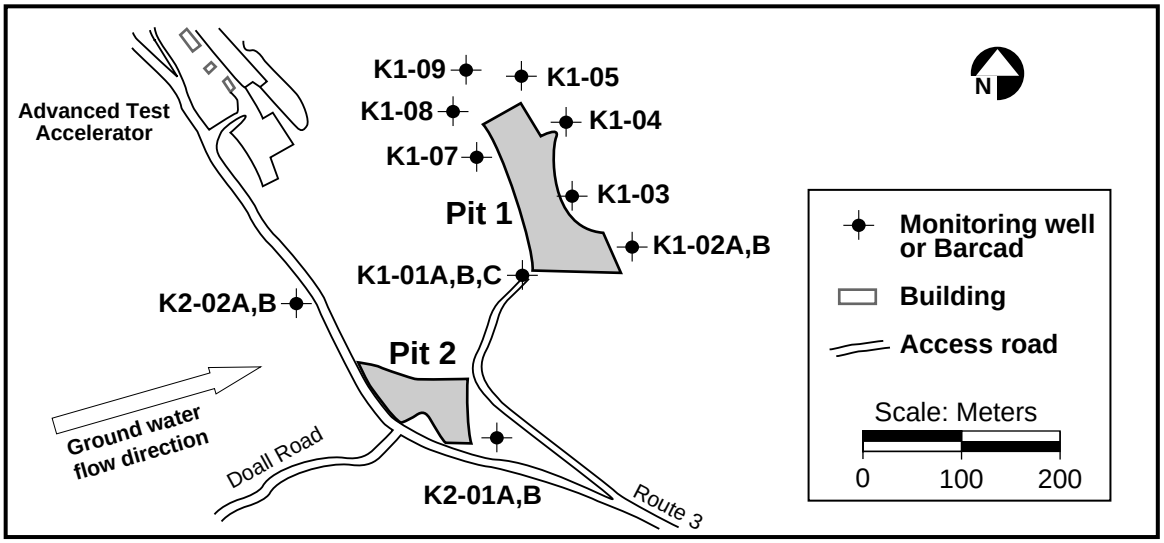

Figure 8-12. Locations of Pit 1 compliance ground water monitoring wells (K1-01C, -07, -02B, -03, -04, -05, -08, and -09) and Pit 2 surveillance Barcads (K1-01A and B, K1-02A, K2-01A and B, and K2-02A and B), 1997.

northeast of Pit 2. Multiple completions K2-01 and K2-02 are hydrologically cross-gradient from Pit 2, and water samples from them represent (presumably) the upgradient ground water. K2-01A, K2-02A, and Well K2-02B are screened in Tmss. Barcad K2-01B is screened in $Tnbs_1$.

For surveillance purposes at Pit 2, ground water samples were collected twice (semiannually) during 1997. Barcads K1-01A and -01B could only be sampled once during 1997. The Barcads became inoperative during the second half of 1997, a condition that persists and may not be correctable. Ground water samples collected from the Barcads and wells were analyzed for 17 elements, mostly metals; volatile organic compounds; nitrate; explosives compounds; general radioactivity (gross alpha and gross beta); tritium (^3H) activity; and total uranium activity.

Analytical data for the five Barcads and the wells are presented in the Data Supplement, Tables 8-37 through 8-43. Metals were generally not detected above analytical reporting limits. None exceeded a drinking water MCL. The arsenic and barium concentrations measured are within the range of natural background concentrations found in ground waters elsewhere at Site 300 and throughout the Altamont Hills (Webster-Scholten 1994).

The radioactivity and radioisotope measurements show only low background activities for gross alpha and gross beta. Tritium activities were at low background levels in all water-bearing zones near Pit 2 (~2 Bq/L), except for the intermediate zone sampled by Barcad K2-01B (7 Bq/L) (**Figure 8-8**). This activity is associated indirectly with a

shallower plume of tritium-bearing water that extends from the Building 850 firing table to Pit 2 (see **Figure 8-13**) (Webster-Scholten 1994; Taffet et al. 1996). The incursion of the shallow, tritium-bearing ground water into the Pit 2 area is recorded in ground water samples from surveillance Well K2-01C that showed a tritium activity of about 550 Bq/L during 1997 (see Elk Ravine Drainage Area). The trace of tritium detected in the K1-02B sample suggests that the shallow and intermediate-depth water-bearing zones are weakly connected, perhaps along the nearby Elk Ravine fault. No evidence for a release of COCs to ground water from Pit 2 is indicated by the monitoring data collected during 1997.

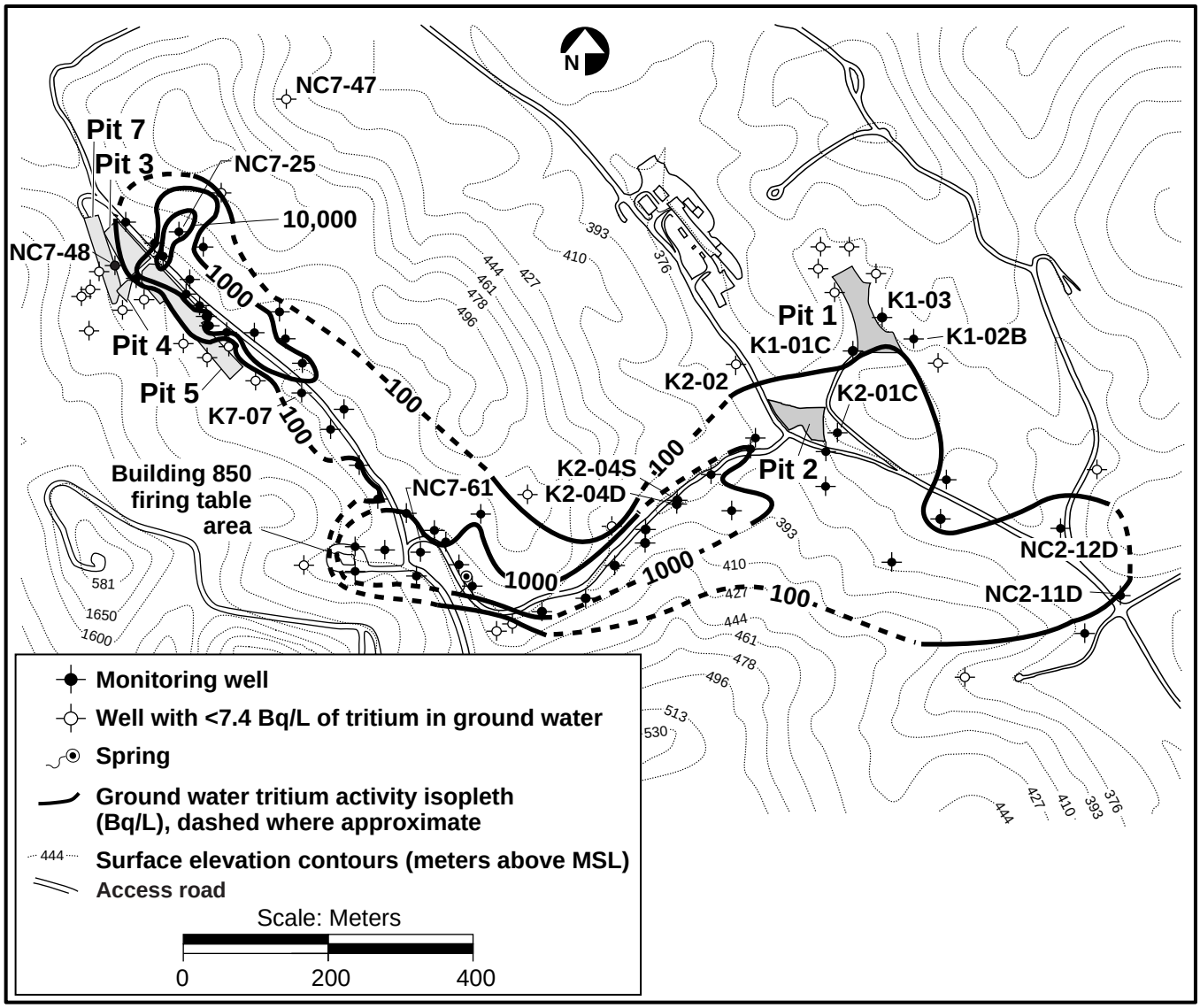

Figure 8-13. Map showing 1997 distribution of tritiated ground water extending from the Pit 7 Complex and the Building 850 firing table area to Doall Ravine and Elk Ravine, 1997.

Elk Ravine Drainage Area

The Elk Ravine drainage area includes most of northern Site 300, the area between the drainage divides shown in **Figure 8-8**. Surface runoff from closed landfills within the Elk Ravine drainage area (Pits 1, 2, 3, 4, 5, 7, 8, and 9) is collected in arroyos. Typically, surface water in arroyos infiltrates quickly. With sufficient seasonal rainfall, unconfined ground water can flow southeast on and within the Quaternary alluvial valley-fill deposits (Qal) that floor the Pit 7 Complex valley. Surface runoff from the Pit 7 Complex landfills at the highest elevation flows southeast to Doall Road, where it is deflected northeastward into Doall Ravine by a landslide deposit (Qls). At the northeastern end of Doall Ravine, this runoff combines with channeled runoff from the Advanced Test Accelerator (ATA) Building 865 area. From this confluence point, the arroyo trends southeasterly within Elk Ravine. Near Well NC2-07, channeled runoff turns easterly, away from the trend of the Elk Ravine fault, and flows off site for approximately 2 km to its confluence with Corral Hollow Creek. Except for Doall Ravine, the arroyos and valley-fill deposits traverse and follow faults, especially the extensive Elk Ravine Fault, which may provide pathways to the underlying ground water. Thus, ground waters from wells that lie within the Elk Ravine drainage area are monitored for COCs. The monitored wells are (from highest to lowest elevation) K7-07, NC7-61, NC7-69, K2-04D, K2-04S, K2-01C, NC2-12D, NC2-11D, and NC2-07. The 812CRK sampling location is a natural spring (also known as Spring 6). It is located in the main Elk Ravine arroyo on the Elk Ravine Fault. Individual well locations are discussed below.

Well K7-07 is located in the Pit 7 Complex valley. It is a shallow well, screened in both $Tnbs_1$ and Qal. This well is cross-gradient from landfill Pits 3, 4, 5, and 7, with respect to unconfined flow in the valley-fill deposits (Qal) and to surface runoff. Wells NC7-61 and NC7-69 are screened in separate water-bearing zones beneath the upper reaches of Doall Ravine. Well NC7-61 is screened in $Tnbs_1$ (shallower zone), and Well NC7-69 is screened in Tmss (deeper zone). Wells K2-04D, K2-04S, and K2-01C are located near the intersection of Elk and Doall Ravines. They are screened in $Tnbs_1$. Wells NC2-12D and NC2-11D are located in Elk Ravine below its intersection with Doall Ravine. Well NC2-11D is screened at the contact between $Tnbs_1$ and Tmss. NC2-07 is the furthest downstream surveillance well in the Elk Ravine drainage area. It is screened in $Tnbs_1$.

For surveillance purposes, ground water samples were collected at six-month intervals (semiannually) during 1997 from monitoring wells in Elk Ravine and from the 812CRK spring. The samples were analyzed for 17 elements, mostly metals; explosive compounds; volatile organic compounds; nitrate; general radioactivity (gross alpha and gross beta); tritium (^3H) activity; and total uranium activity.

Surveillance analytical data for the ground water samples obtained during 1997 from monitoring wells in the Elk Ravine drainage area are given in the Data Supplement,

Tables 8-44 through 8-53. Generally, surveillance monitoring of Elk Ravine during 1997 shows no evidence of any new or slow-to-develop release of COCs to ground water in this area, except for nitrate. Nitrate was measured above the MCL of 45 mg/L in two samples of ground water, one each from monitoring Wells NC7-61 and K2-04S. No VOCs or HE compounds were detected. None of the elements detected exceeded an MCL. Arsenic, barium, selenium, and vanadium were detected ubiquitously at low concentrations consistent with natural sources for these elements in the rocks. Gross alpha and beta activities were low and were indistinguishable from natural background, as was total uranium activity. Tritium activity was above background in many of the ground water samples.

LLNL remedial investigators have previously concluded that tritium, as tritiated water (HTO), is released occasionally from the Pit 3 and 5 landfills and soil moisture from beneath the firing table at Building 850. Tritiated water has been released from Pit 3 and Pit 5 during wetter-than-normal winters when ground water rises and contacts firing table wastes contained in these two unlined landfills. A major release of HTO occurred during the unusually wet winter of 1982/1983 (Webster-Scholten 1994), and additional releases occurred during the wet winters of 1986/1987, 1992/1993, 1994/1995, and 1995/1996 (Taffet et al. 1996). HTO is also transported to ground water beneath the Building 850 firing table gravels by percolating water from rain (Taffet et al. 1996). The configuration of the tritium-bearing ground water plumes at Site 300, updated for 1997, are shown in **Figure 8-13**. The HTO plumes are shallow and appear to be confined to the Neroly lower blue sandstone unit ($Tnbs_1$ and Qal). Continuing CERCLA studies show that despite additional releases the tritium contents and extents of the plumes are generally diminishing over time because of natural decay of tritium and dispersive mixing.

Wells 18 and 20

Wells 18 and 20 are located in the southeastern part of Site 300 (**Figure 8-8**). Both are deep, high-production water wells. Well 20 supplied potable water at the site during 1997, while Well 18 was maintained as a standby water supply well. Both wells are screened in the Neroly Formation lower blue sandstone unit ($Tnbs_1$). The Well 18 completion zone extends upwards into a fine-grained aquitard unit ($Tnsc_1$) in the Neroly Formation that separates $Tnbs_1$ from the overlying upper blue sandstone unit ($Tnbs_2$). Each well can produce up to 1500 L/min of potable water.

For surveillance purposes, ground water samples were collected quarterly from these two on-site supply wells. Water samples from Well 20 were analyzed for 17 elements, mostly metals; nitrate; explosives compounds, volatile organic compounds

(EPA Method 502.2); general radioactivity (gross alpha and gross beta); and tritium (^{3}H) activity. Water samples from standby Well 18 were analyzed for volatile organic compounds (EPA Method 502.2); general radioactivity (gross alpha and gross beta); and tritium (^{3}H).

Surveillance analytical data for the two on-site potable water supply wells are presented in the Data Supplement, Tables 8-54 and 8-55. No metals of concern were detected in Well 20 during 1997, except zinc at 29 parts per billion (ppb) in the first-quarter water sample and chromium at 1.3 ppb in the third-quarter water sample. Both detections were far below MCLs of 5000 ppb for zinc and 50 ppb for chromium. Neither metal was detected above reporting limits of 20 ppb for zinc and 1 ppb for chromium during the second and fourth quarters.

As in past years, TCE was detected below the MCL of 5 ppb in the third and fourth quarter samples from Well 18, at 0.43 ppb and 0.86 ppb, respectively. 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 activities.

Off-Site Supply Wells

For surveillance purposes during 1997, ground water samples were obtained from 12 off-site locations. Eleven of these locations are adjacent to Site 300. A distant well, VIE2, located at a private residence 6 km west of Site 300, is typical of potable water supply wells 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 water production wells, CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STN, and W-35A-04, are adjacent to the site on the south (**Figure 8-8**). W-35A-04 is a CERCLA well installed by LLNL for monitoring only. Wells CARNRW2, GALLO1, and STN supply potable water. Well CDF1 formerly supplied water for fire fighting.

Ground water samples were collected quarterly during 1997 at six off-site well locations. Of these, CARNRW1 and CON2 samples were analyzed only for volatile organic compounds (EPA Method 601), while CARNRW2, CDF1, CON1, and GALLO1 samples were analyzed quarterly for 17 elements, mostly metals; explosives compounds; volatile organic compounds; inorganic compounds; general radioactivity (gross alpha and gross beta); and tritium (^{3}H) activity. Uranium activity was measured during the third and fourth quarters. Additional measurements of pesticides (EPA Method 608), herbicides (EPA Method 615), and semivolatile organic compounds (EPA Method 625) were made during the third quarter.

Ground water samples collected from six off-site locations—MUL1, MUL2, STN, VIE1, VIE2, and W-35A-04—were analyzed once (annually) during 1997 for 17 elements, mostly metals; nitrate; volatile organic compounds; semivolatile organic compounds, pesticides, herbicides, explosives compounds; general radioactivity (gross alpha and gross beta); and tritium (^{3}H) activity. In addition to the analyses listed above, uranium isotope activities were determined for the MUL1 and STN ground water samples.

Surveillance analytical data for the 12 off-site water supply locations are presented in the Data Supplement, Tables 8-56 to 8-62. Generally, no COC positively attributable to LLNL activities was detected in the off-site ground water samples. Arsenic and barium were widely detected at these locations, but their concentrations were below MCLs and were 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.

Low concentrations of trihalomethanes (THMs) were detected in fourth-quarter water samples from the CARNRW2 monitoring well. The THMs are by-products produced by the chlorination units that purify water at Carnegie Park. The fourth quarter samples were collected downstream of the chlorination units.

As in past years, TCE was detected below the MCL of 5 ppb in the ground water samples collected from the GALLO1 surveillance well during the third and fourth quarters. LLNL remedial investigators concluded that the low concentration of TCE in the GALLO1 well water was probably due to a localized surface spill on the property, possibly from solvents used on a pump truck or another vehicle used to service the private well (Webster-Scholten 1994). Except for gross alpha in the annual STN well sample analysis, radioactivity measurements are indistinguishable from natural background activities. In the past, the STN well has shown elevated natural uranium activity. Total uranium activity for 1997 can account for the gross alpha activity, if the relatively large errors in the two different measurements are considered.

Ground Water Compliance Monitoring at Site 300

Ground water compliance monitoring at Site 300 is specified in Waste Discharge Requirement (WDR) orders issued by the Central Valley Regional Water Quality Control Board (Central Valley RWQCB) and in Resource Conservation and Recovery Act (RCRA) Closure and Post-Closure Monitoring Plans (Rogers / Pacific Corporation 1990) approved by the California EPA Department of Toxic Substances Control (DTSC). The WDRs and post-closure plans specify the wells to be monitored, the COCs to be measured, measurement frequency, analytical methodology, and the frequency and form of required reports.

Ground water compliance monitoring programs are carried out at Site 300 in response to the LLNL Site 300 RCRA Closure and Post-Closure Monitoring Plan for Landfill Pits 1 and 7, and WDR Order Numbers 93-100 and 96-248. Compliance monitoring and reporting allow LLNL to evaluate operations of closed RCRA Landfill Pits 1 and 7, the Explosives Process Area Class II surface impoundments (hereafter surface impoundments), the sewage evaporation and percolation ponds (hereafter sewage ponds), and five percolation pits, and assure that they are consistent with regulatory requirements. WDR Order No. 93-100 and the Post-Closure Monitoring Plan establish the basis for the compliance monitoring network around Pits 1 and 7. Tables 8-63 to 8-66 in the Data Supplement list Pit 1 and 7 data pertaining to WDR Order No. 93-100 and post-closure monitoring. WDR Order No. 96-248 establishes the basis for compliance monitoring of the surface impoundments and the sewage ponds with their percolation pits. These monitoring programs include quarterly and semiannual monitoring of the ground water wells in each ground water monitoring network, monitoring of various influent waste streams to the surface impoundments and the sewage ponds, and visual observations of the sewage ponds and percolation pits. Each compliance monitoring network requires quarterly and annual reports of ground water analytical results, inspection findings, and maintenance activities.

Landfill Pits 1 and 7

Pit 1 Area

Figure 8-12 shows the RCRA-closed Pit 1 landfill and the eight compliance wells used to monitor the ground water in the vicinity of the inactive landfill. Pit 1 lies in the upper part of the Elk Ravine drainage area about 300 m above sea level. The RCRA cap constructed on Pit 1 in 1992 includes a layer of impermeable clay to prevent rainwater from infiltrating the landfill and potentially contacting the buried waste. A water-diversion channel made of concrete surrounds the landfill. Its purpose is to reduce local storm water infiltration by collecting runoff from the cap and the surrounding area and diverting it to Elk Ravine.

Ground water flows east-northeast beneath Pit 1, following the dip of the underlying sedimentary rocks. The eight Pit 1 compliance monitoring wells are used to collect representative ground water samples from the shallowest water-bearing zone, which is either in the Neroly Formation lower blue sandstone unit ($Tnbs_1$), or is beneath $Tnbs_1$ in the Cierbo Formation (Tmss in **Figure 8-2**).

With respect to Pit 1 and the direction of ground water flow, Wells K1-01C and K1-07 are hydrologically upgradient; Wells K1-02B, K1-03, K1-04, and K1-05 are downgradient; and K1-08 and K1-09 are cross-gradient.

For compliance monitoring purposes, representative samples of ground water were collected quarterly from Pit 1 monitoring wells and were analyzed for various COCs, fulfilling the requirements of WDR Order No. 93-100 Revision 1 (CVRWQCB 1993, 1996) and the RCRA Post-Closure Monitoring Plan (Rogers / Pacific Corporation 1990). Tables 8-63 and 8-64 in the Data Supplement contain the Pit 1 COC measurements made during 1997. Quarterly measurements were made for 10 elements, mostly metals; general radioactivity (gross alpha and gross beta); the radioisotopes tritium, radium-226, uranium (234, 235, and 238), and thorium (228 and 232) and explosives compounds (cyclotetramethyltetramine [HMX], and hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]). The measurements of the three uranium isotope were summed to give total uranium activity. Semiannual measurements were made for an additional seven elements, mostly metals; pH; specific conductance; ground water elevation; and nitrate. Annual measurements were made for VOCs (EPA Method 601); purgeable organic compounds (EPA Method 624); extractable organic compounds (EPA Method 625); pesticides and PCBs (EPA Method 608); total dissolved solids (TDS); total organic carbon (TOC); and total organic halides (TOX).

Pit 7 Complex Area

Nine compliance wells monitor the Pit 7 Complex, which comprises four adjacent closed landfills (**Figure 8-14**). Pits 3, 4, and 5 were closed before RCRA became effective. Pit 7 was closed under RCRA during 1992 / 1993. The complex of closed landfills is located in the Pit 7 Complex valley about 400 m above sea level. From 1963 to 1988, the landfills received waste gravels from firing tables at Site 300. The gravels contained concrete, cable, plastic, wood, tritium, depleted uranium, beryllium, lead, and other metals in trace amounts. In 1988, 9440 cubic meters of gravel were removed from six firing tables at Site 300 and were placed in Pit 7 (Lamarre and Taffet 1989d). These were the last solid wastes to be placed in landfills at Site 300. (Since 1988, spent firing table gravel has been shipped to LLNL's Nevada Test Site for disposal.)

RCRA closure of Pit 7 was completed in February 1993. Closure included construction of an impermeable cap, runoff diversion channels, and a ground water interceptor trench to reduce local ground water recharge from rain. The RCRA cap over landfill Pit 7 also covers Pit 4 and about 30% of Pit 3.

Ground water beneath the Pit 7 Complex Area flows east-northeast, following the dip of the underlying sedimentary rocks.

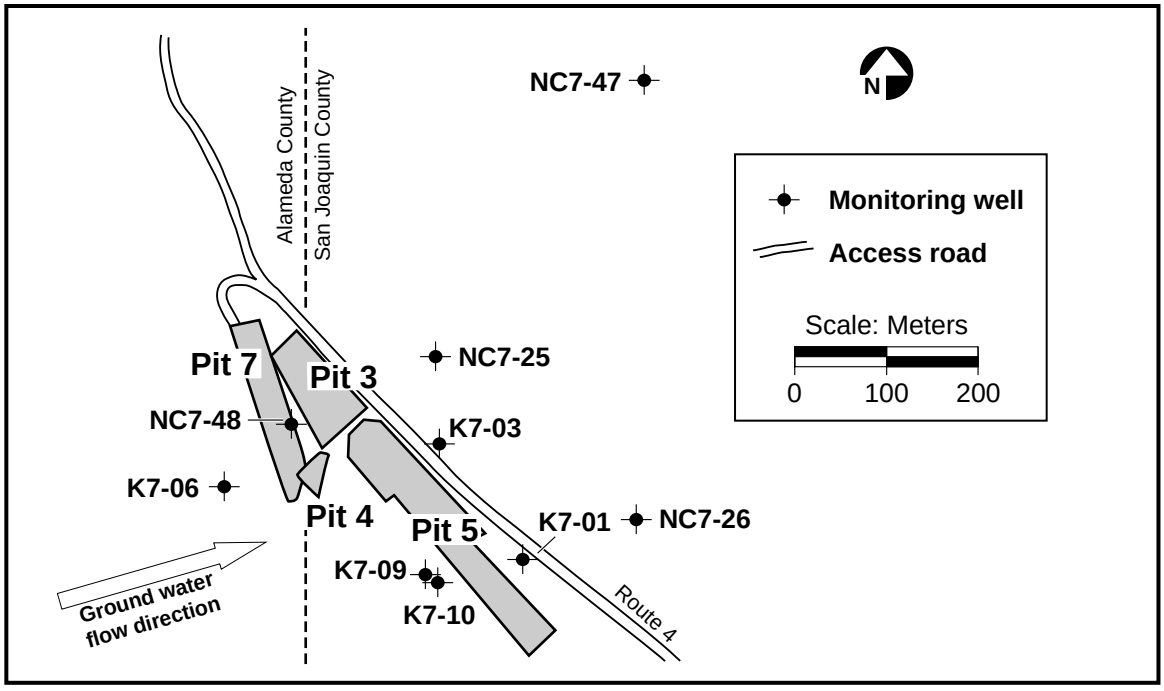

Figure 8-14. Locations of compliance ground water monitoring wells, Pit 7 Complex.

Monitoring Well K7-06 is hydrologically upgradient from Pit 7; wells K7-09 and K7-10 are cross-gradient; and wells K7-01, K7-03, NC7-25, NC7-26, NC7-47, and NC7-48 are downgradient. Wells K7-01, K7-10, and NC7-26 are screened in the Neroly lower blue sandstone ($Tnbs_1$). The remaining wells are screened beneath $Tnbs_1$ in the Cierbo claystones and sandstones (Tmss).

Representative ground water samples were collected quarterly from Pit 7 monitoring wells and were analyzed for various COCs, fulfilling the requirements of WDR Order No. 93-100 Revision 1 (CVRWQCB 1993, 1996) and the RCRA Post-Closure Monitoring Plan (Rogers / Pacific Corporation 1990). The Pit 7 compliance analytical data for 1997 are presented in the Data Supplement, Tables 8-65 and 8-66. Quarterly measurements were made for 10 elements, mostly metals; general radioactivity (gross alpha and gross beta); the radioisotopes tritium, radium-226, uranium (234, 235, and 238), and thorium (228 and 232); explosives compounds (cyclotetramethyltetramine [HMX], and hexahydro-1,3,5-trinitro-1,3,5-triazine [RDX]); volatile organic compounds (EPA Method 601); and ground water elevation. The measurements of the three uranium isotopes were summed to give total uranium activity.

Pit Monitoring Summary

Monitoring Well NC7-25 is located close to tritium sources in Pits 3 and 5 (**Figure 8-14**). The 1997 peak tritium activity was 27 times the MCL for tritium activity in drinking water. However, none of the wells in this area supplies water for purposes other than monitoring.

As in past years, four organic COCs were detected in the ground water at low concentrations during 1997. They are trichloroethene (TCE), 1,1-dichloroethene (1,1-DCE), trichlorofluoromethane (Freon 11), 1,1,2-trichloro-1,2,2-trifluoroethane (Freon 113).

TCE was detected below the MCL of 5 μg/L in ground water at Pit 7 Wells K7-01 and K7-03. A TCE breakdown product, 1,1-DCE, was detected below the MCL of 6 μg/L in the ground water sampled at Pit 7 monitoring Well K7-03. Previous CERCLA investigations link the TCE in the ground water to wastes buried in Pit 5 (Webster-Scholten 1994; Taffet et al. 1996).

Freon 11 was detected below the MCL of 150 μg/L in ground water at Pit 7 Well NC7-48. Freon 11 has been detected at low concentrations since the second quarter of 1992. Pit 7 is the likely source of the Freon 11, because it is the only landfill upgradient of Well NC7-48.

Freon 113 was detected below the MCL of 1200 μg/L in the ground water at Pit 1 Wells K1-05 , K1-08, and K1-09. Previous CERCLA investigations link the Freon 113 to past spills in the ATA Building 865 area (Webster-Scholten 1994; Taffet et al. 1996).

Barium concentrations in the range of 70–80 μg/L exceeded the permitted statistical limit (SL) of 70 μg/L in the ground water at Pit 7 Well NC7-25. (For reference, the MCL for barium is 1000 μg/L.) CVRWQCB was notified by letter of this finding (Galles 1997). Previous CERCLA investigations conclude that, prior to capping Pit 7 in 1992, wastes buried there may have contributed additional barium to naturally occurring barium in the ground water (Taffet et al. 1996).

Tritium activity continued to exceed the permitted SL of 11.4 Bq/L in the ground water at Pit 1 monitoring Well K1-03. Previous CERCLA investigations link the tritium to a source beneath the Building 850 firing table area, about 1 km upgradient from Pit 1 (**Figure 8-13**).

During 1997, as in the past, tritium activities in ground water samples from three Pit 7 monitoring wells exceeded the 740 Bq/L drinking water MCL. These wells are K7-01, K7-03, and NC7-25. Previous CERCLA investigators conclude that tritium was released during the unusually wet winter of 1982/1983 from sources in Pits 3 and 5 (Webster-Scholten 1994) with additional minor releases occurring during the wet winters of 1985/1986, 1992/1993, and 1994/1995 (Taffet et al. 1996; Christofferson and MacQueen 1997). The highest tritium activity measured in a compliance monitoring ground water

sample for 1997 was 19,800 Bq/L (27 times MCL) in a fourth-quarter sample collected from monitoring Well NC7-25 (**Figure 8-13**).

As has occurred in the past, total uranium activity exceeded the permitted SL of 1.22 Bq/L in the fourth-quarter ground water sample from Pit 7 Well NC7-25. Previous mass spectroscopy measurements at LLNL of ground water samples from Well NC7-25 show that uranium is present in the isotopic ratios of natural uranium, which indicates that this uranium probably came from natural sources in the rocks.

During 1997, as in the past, total uranium activity exceeded the MCL of 0.74 Bq/L, and gross alpha activity exceeded the MCL of 0.56 Bq/L in the ground water samples from Pit 7 Wells NC7-25 and NC7-48. Total uranium activity accounts for the gross alpha activity. Previous mass spectroscopy measurements of ground water samples from Well NC7-48 showed that the uranium present is a mixture of naturally occurring uranium and depleted uranium. Previous CERCLA studies conclude that depleted uranium has been released to ground water in the past from Pit 5 and from Pit 7 prior to its closure in 1993 (Taffet et al. 1996).

Surface Impoundments in Explosives Process Area

Release Detection

A three-tiered monitoring network is in place to detect releases of chemicals from the surface impoundments in the Explosives Process Area. The primary means of release detection consists of weekly visual inspections for leachate flow at the outfalls of perforated pipes installed in a sand layer between the inner impermeable layer liner of high-density polyethylene and an outer impermeable liner of compacted clay. Secondary release detection consists of quarterly inspections of lysimeters, installed beneath the clay liners, for the presence of liquids. Monitoring wells comprise a tertiary release detection system and a means of estimating the impact to ground water. Data pertaining to analyses of ground water samples collected beneath the surface impoundments are found in the Data Supplement, Tables 8-68 to 8-75.

Leachate Collection. The two leachate collection and removal systems were monitored for the presence of liquids, which would indicate a leak in a surface impoundment liner. As previously reported (Harrach et al. 1996), a leak was discovered in the upper surface impoundment's polyethylene liner in June 1995. The leak allowed water to seep into a leachate collection pipe and from an outlet pipe into the lower surface impoundment. Repairs to the system were completed in December 1995. Water continued to flow from the upper surface impoundment's leachate collection system until October 1996, when the leak rate fell to zero, where it has remained.

Over the course of 1997, LLNL tested an experimental electrical sensing system at the surface impoundments. This testing led to the discovery of a tear in the liner of the lower surface impoundment on September 12, 1997. Repairs were made on October 23. These repairs included patching the tear in the lower surface impoundment and rewelding a seam of the upper surface impoundment as a precautionary measure. No liquid has been collected in the system since these repairs were made.

Lysimeters. Five lysimeters installed in the vadose zone beneath the liners of the impoundments were operated quarterly during 1997 to extract water for analysis. No water was recovered. If water had been found in the lysimeters or the leachate collection systems, it would have been analyzed for aluminum, arsenic, barium, bicarbonate alkalinity, cadmium, calcium, carbonate alkalinity, chloride, chromium, cobalt, copper, fluoride, hydroxide alkalinity, iron, lead, magnesium, manganese, molybdenum, nickel, nitrate, pH, potassium, RDX, HMX, silver, sodium, specific conductance, sulfate, total dissolved solids, total alkalinity, total hardness, and zinc.

Monitoring Wells. The Monitoring and Reporting Program (MRP) for the surface impoundments, contained in WDR 96-248, requires that ground water samples be collected quarterly from four monitoring wells and establishes statistical concentration limits for COCs in ground water beneath the surface impoundments. The COCs and their concentration limits for ground water beneath the surface impoundments are contained in the Data Supplement, Tables 8-68 through 8-71.

MRP 96-248 requires compliance monitoring of the ground water underlying the two connected surface impoundments (**Figure 8-15**). The four ground water monitoring wells used are screened in the Neroly Formation upper blue sandstone layer ($Tnbs_2$). The direction of ground water flow is approximately southeasterly, following the local attitude (dip) of the formations. Well W-817-01 is hydrologically upgradient of the surface impoundments. Wells W-817-02, W-817-03, and W-817-04 are downgradient. Ground water samples are collected quarterly from these monitoring wells for analyses of the COCs specified in WDR 96-248. All 1997 analyses under MRP 96-248 for COCs and for other constituents, except for nondetections, are presented in the Data Supplement, Tables 8-68 through 8-75.

The high performance liquid chromatography method (EPA Method 8330) is used to analyze for energetic compounds. Analyses of ground water from upgradient monitoring Well W-817-01 indicated HMX at concentrations between 14 and 35 µg/L. HMX was not detected above the analytical reporting limit of 1 to 5 µg/L in any of the ground water samples from the downgradient monitoring wells. Ground water samples from three wells contained detectable concentrations of the energetic compound RDX above the analytical reporting limit of 0.85 µg/L. The ground water samples containing

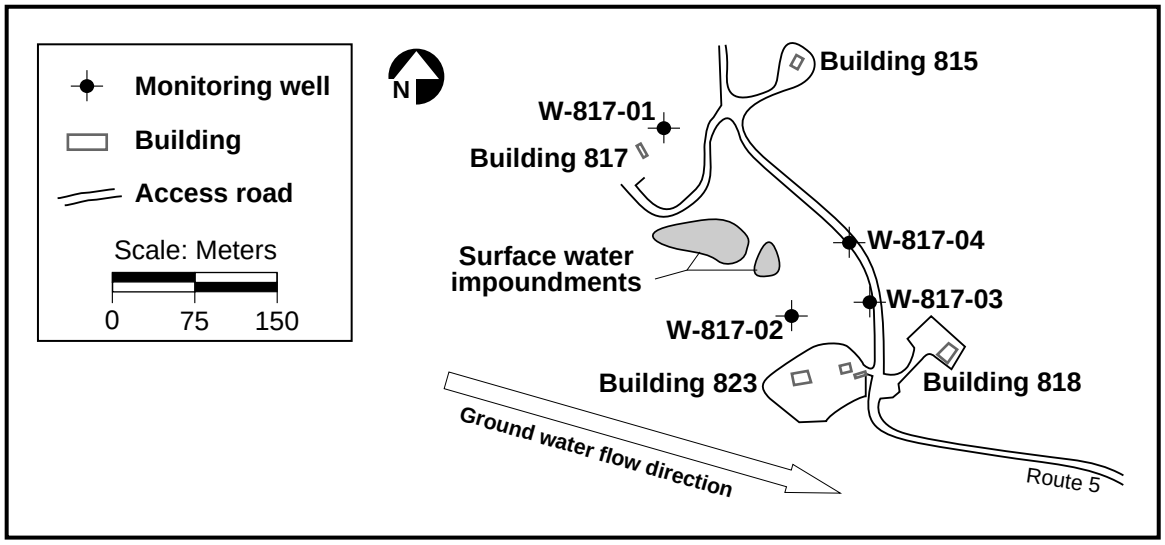

Figure 8-15. Locations of compliance ground water monitoring wells in the Explosives Process Area.

RDX were from upgradient Well W-817-01 (from 21 to 85 µg/L) and from downgradient Wells W-817-03 (5 to 8 µg/L) and W-817-04 (4.4 to 8.7 µg/L). RDX and HMX originate at closed disposal sites upgradient of the present surface impoundments (Raber and Carpenter 1983; Webster-Scholten 1994). The concentrations observed in the downgradient wells do not exceed their statistical limits (SLs). Additional compounds were detected by EPA Method 8330, but do not have SLs or MCLs, and are presented in the Data Supplement, Tables 8-72 through 8-75.

Ground water concentrations of TCE continued to exceed the drinking water MCL of 5 µg/L in samples from Wells W-817-03 and W-817-04 during 1997. The TCE detected in ground water samples from these wells has migrated in the ground water from past spills at Building 815, upgradient of the impoundments (Webster-Scholten 1994). No SL was developed for TCE, because it has not been discharged to the surface impoundments.

Ground water analyses of metals were carried out using inductively coupled plasma and graphite-furnace atomic-absorption spectroscopy EPA methods. Analyses of other inorganics were carried out using other EPA-approved methods. Ground water concentrations of arsenic and nitrates continued to exceed drinking water MCLs in samples from all the surface impoundment monitoring wells during 1997. Concentrations of both arsenic and nitrates in ground water have historically exceeded their respective MCLs (0.050 mg/L for arsenic and 45 mg/L for nitrates) in this area. Background concentrations of arsenic in ground water monitoring wells upgradient from the surface impoundments have been measured at concentrations above the drinking water MCL (Webster-Scholten 1994). Because of the wide range of measured concentrations, arsenic is

the only compound for which statistical analysis of variance (ANOVA) is used each quarter to determine if a significant increase has occurred. For ANOVA, four individual samples are collected from each well and analyzed for arsenic. During 1997, ANOVA indicated some significant differences in arsenic concentrations upgradient and downgradient from the surface impoundments. 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 an ongoing CERCLA study.

For the WDR 96-248 COCs, analytical results are in the Data Supplement, Tables 8-68 through 8-71.

Concentrations of zinc analyzed in ground water samples from monitoring Well W-817-02 have exceeded the SL of 0.076 mg/L for zinc since the fourth quarter of 1996. Like the arsenic discussed previously, this zinc exceedance of WDR permit limits resulted in the implementation of an overall CERCLA study of zinc occurrence and concentrations at Site 300.

Influent Monitoring

Photographic Process Rinse Water Discharges. WDR 96-248 established limits for discharges into the surface impoundments and required monitoring of the photoprocess and chemistry area wastewater retention tanks that discharge to the surface impoundments, as well as direct discharges occurring from the Explosives Process Area to the surface impoundments. During 1997, all discharges into the surface impoundments were consistent with discharge limits.

Retention tanks containing photographic process rinse water from Buildings 801, 823, 850, and 851 are sampled to confirm that discharges are consistent with the limitations specified in WDR 96-248. Discharges to the surface impoundments occur after samples are collected. Rinse water from the Building 823 retention tanks is discharged automatically to the surface impoundments. The Building 823 retention tank had two spills in 1997 (March 27 and July 16) due to equipment failures. These spills should have no impact on underlying ground water quality since the total volume spilled was only 26.5 liters (7 gallons) or less (see Chapter 2). Monitored constituents for the photographic processes were all below discharge concentration limits (see the Data Supplement, Tables 8-76 through 8-78).

Chemistry Area Wastewater Discharges. Wastewater from the Chemistry Area (Buildings 825, 826, and 827 Complex) is held in retention tanks until analytical results indicate compliance with the WDR permit. Analyses of discharges from the Chemistry Area during 1997 are presented in the Data Supplement, Table 8-79. Monitored constituents for the Chemistry Area discharges were all below discharge concentration limits.

Explosives Process Area Discharges. Process water discharges to the Explosives Area impoundments are analyzed for constituents 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 area wastewater from Buildings 806/807, 809, and 817. WDR 96-248 requires annual analysis of this waste stream at Buildings 806/807, 809, and 817. A spill from the retention tank at Building 817 occurred on July 16 when the drain plugged with algae. This spill also had no impact on the underlying ground water because the total volume spilled was only 19 liters (5 gallons) (see Chapter 2). Explosives Process Area discharges from Building 809 were sampled in September 1997. Analytical results presented in the Data Supplement, Table 8-67, include metals, VOCs, semivolatile organic compounds, and energetic compounds. All monitored constituents were below discharge concentration limits.

Sewage Evaporation and Percolation Ponds

The environmental monitoring required for the sewage evaporation and percolation ponds is also specified in the MRP 96-248 contained in WDR 96-248.

Quarterly samples of wastewater flowing into the sewage evaporation pond are collected for analysis from a location upgradient of the pond in terms of sewage flow (sampling location ISWP). See **Figure 8-16.** The sample collection location is a manhole that captures all waste streams before they flow into the pond. The samples are analyzed for electrical conductivity or specific conductance, pH, and biochemical oxygen demand (BOD).

All required wastewater monitoring parameters for the sewage evaporation and percolation ponds were in compliance with specified limits throughout 1997. See **Tables 8-2** and **8-3**. The water level in the sewage evaporation pond was maintained below the minimum freeboard requirement of 0.61 m (2 ft). There were no discharges from the evaporation pond into the percolation pond during the year. Consequently, no samples were taken at the DSWP sampling location.

Ground water monitoring includes semiannual sampling and analysis from upgradient monitoring Wells W-7E, W-7ES, and W-7PS; from cross-gradient ground water monitoring Well W-35A-04; and from downgradient ground water monitoring Wells W-26R-01, W-26R-11, W-26R-05, W-25N-20, and W-7DS (**Figure 8-16**). Monitoring Wells W-7PS, W-26R-11, and W-35A-04 are screened in Quaternary alluvium (Qal); Wells W-7E and W-26R-01 are screened in the $Tnbs_1$; and the four remaining wells are screened in both Qal and $Tnbs_1$. Ground water samples were collected from the wells from April 28

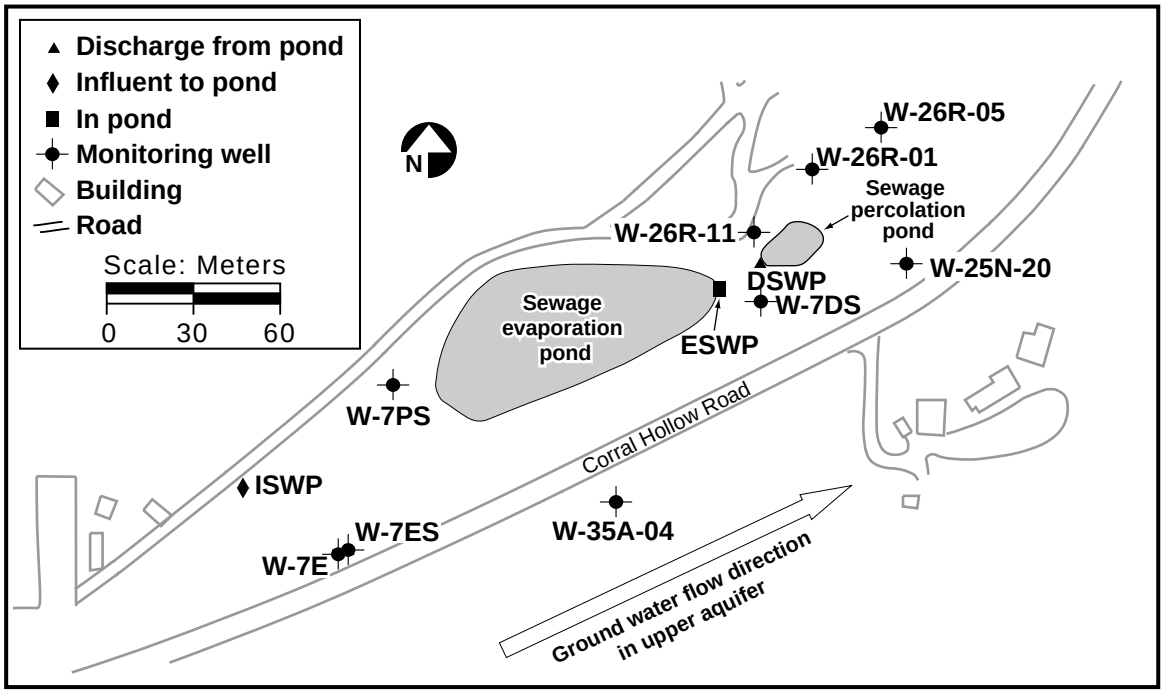

Figure 8-16. Locations of compliance ground water monitoring wells in the area of the sewage evaporation and percolation ponds.

Table 8-2. Sewage pond monitoring results, location ESWP.

Parameter	Permit limits	First quarter	Second quarter	Third quarter	Fourth quarter
pH (pH units)	none	10.0	10.0	9.3	9.8
Conductivity (μmho/cm)	none	5600	9100	12,000	10,000
Dissolved oxygen (mg/L)	1.0	24	9.4[a]	10/11.4[b]	16

[a] Field measurement reported. Laboratory analysis was invalid because the sample hold time was exceeded.

[b] The second number is the result of a field measurement the analytical laboratory staff conducted.

Table 8-3. Wastewater effluent monitoring results, location ISWP.

Parameter	Permit limits	First quarter	Second quarter	Third quarter	Fourth quarter
pH (pH units)	6.5 < pH < 10	8.3	8.4	8.3	8.1
Conductivity (μmho/cm)	none	2000	2000	2100	1500
Biochemical oxygen demand (mg/L)	none	500	230	500	240

through May 7, and again from November 3 through 19, and analyzed for conductivity, nitrate, total and fecal coliform, pH, and general minerals. The ground water analytical data for the sewage pond monitoring network are presented in the Data Supplement, Tables 8-80 and 8-81. All of the monitored constituents are in compliance with permitted limits.

MRP 96-248 requires monthly inspections of the percolation pits at Buildings 806A, 827A, 827C, 827D, and 827E. It also requires sampling and analysis for metals if an overflow occurs.

Monthly inspection reports for the percolation pits located at 806A, 827A, 827D, and 827E indicated that they performed as designed throughout 1997 and there were no overflows.

Ground Water Remediation

This section discusses monitoring directed by CERCLA ground water projects. Treatment Facility A (TFA) discharges to ground water are discussed here. Treatment facilities that discharge to surface water are discussed in Chapter 7.

Livermore Site

Treatment Facility A (TFA) is located in the southwestern part of LLNL near Vasco Road (**Figure 2-1**, Chapter 2). Waste Discharge Requirement (WDR) No. 88-075 requires a sampling program for TFA (**Table 8-4**). From 1989 to mid-1997, VOCs were removed from ground water using UV / H_2O_2 treatment technology and an air stripper. In June 1997, this system was replaced with a large capacity air-stripping system. In operation since September 1989, TFA has treated more than 1400 ML of ground water, removing about 93 kg of VOC mass from the subsurface. During 1997, TFA treated about 480 ML of ground water containing an estimated 18 kg of VOCs. Treated ground water was discharged to the Recharge Basin located about 600 m southeast of TFA on DOE SNL / California property (**Figure 8-4**).

On several occasions in 1997, while attempting to maximize ground water treatment and capture with the UV / H2O2 system, TFA exceeded its waste discharge requirement (WDR) limit of 5 ppb total VOCs in ground water effluent. These discharges were reported to the Regional Water Quality Control Board, and at no time did VOCs in TFA discharge exceed a maximum contaminant level (MCL). Since startup of the new system, TFA has not exceeded the 5 ppb total VOC WDR limit.

Table 8-4. Treated ground water discharge limits identified in WDR Order No. 88-075 for Treatment Facility A (TFA).

Constituent	Discharge limit[a]
Metals (μg/L)	
Antimony	1460
Arsenic	500
Beryllium	0.68
Boron	7000
Cadmium	100
Chromium(III)	1700×10^3
Chromium(VI)	500
Copper	2000
Iron	3000
Lead	500
Manganese	500
Mercury	20
Nickel	134
Selenium	100
Silver	500
Thallium	130
Zinc	20,000
Volatile organic compounds (μg/L)	
Total volatile organic compounds	5
Acid extractable organic compounds (μg/L)	
2,4-Dimethylphenol	400
Phenol	5
2,4,6-Trichlorophenol	5
Base/neutral extractable organic compounds (μg/L)	
1,4-Dichlorobenzene	5
Naphthalene	620
Phenanthrene	5
Pyrene	5

a These limits are instantaneous maximum values.

Site 300

Building 834 Complex. The Building 834 Complex is located in the eastern portion of Site 300. An isolated, perched, water-bearing zone that contains TCE in excess of the MCL of 5 ppb has been defined and reported (Bryn et al. 1990; Landgraf et al. 1994). The TCE remediation system at this site is operated as a CERCLA Removal Action. Ground water treatment and discharge is monitored in compliance with Central Valley RWQCB

Substantive Requirements for the Building 834 Removal Action. Air emissions are stipulated to be no greater than 6 ppm / hr, and are regulated under an Authority to Construct permit from the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD). Limitations on effluents discharged from ground water treatment operations are listed in **Table 8-5**.

Table 8-5. Site 300 Building 834 ground water treatment surface discharge effluent limitations.

Parameter	Building 834 Treatment Facility
VOCs[a]	
Maximum daily (per compound)	5.0 μg/L
Monthly median	0.5 μg/L
pH	Between 6.5 and 8.5
Location discharge	Treated effluent will be discharged by air misting east of Building 834.
Total petroleum hydrocarbons	
Daily maximum contaminant level	100 μg/L
Monthly median	50 μg/L
Flow rate (30-day average daily dry weather maximum discharge limit)	7580 L
Mineralization	Mineralization must be controlled to no more than a reasonable increment.
Methods and detection limits	
VOCs	Method EPA 601/602[b]
Tetrabutyl orthosilicate (TBOS)	Modified EPA Method 8015, discharge limit = 100 μg/L[c]

a The sum of VOC concentrations in a single sample shall not exceed 5.0 μg/L and the monthly median value of the sum of VOC concentrations shall not exceed 0.5 μg/L.

b Confirmatory VOC identifications were sometimes required during treatment facility characterization, and EPA 624 analyses were requested in addition to the EPA 601/602 analyses.

c Detection limits for TBOS are currently ~100 μg/L by a modified EPA 8015 procedure.

Ground Water Protection Management Program

LLNL's Ground Water Protection Management Program (GWPMP) is a multifaceted effort to eliminate or minimize adverse impacts of LLNL operations on ground water (Brandstetter 1997). U.S. Department of Energy (DOE) Order 5400.1 and the to-be promulgated 10 CFR 834 require all DOE facilities to prepare a GWPMP that describes the site's ground water regime, and areas of known contamination and remediation activities and programs to monitor the ground water and monitor and control potential sources of ground water contamination. Much of the ground water monitoring and

remediation at the Livermore site is carried out under CERCLA restoration efforts, and the Livermore Site Ground Water Project and is summarized in Chapter 2 of this volume. This section describes LLNL's efforts to comply with DOE Order 5400.10.

Areas of Special Concern

The objectives of the GWPMP include monitoring the impact of current operations and eliminating or minimizing adverse impacts from ongoing operations on ground water. The approach is to detect contaminants before they can enter the ground water. In order to determine the areas with the greatest potential to contaminate ground water, LLNL evaluated the following three factors:

1. Current processes and operations that could contaminate areas where there is rapid communication between surface water and ground water.
2. Current and planned best management practices (BMPs) that minimize the risk of ground water contamination.
3. Current and new monitoring to provide early warning of potential ground water contamination.

With these considerations, five areas have been identified as being at risk for ground water contamination:

- The arroyos (Arroyo Las Positas and Arroyo Seco) that cross the site.
- The storm drain system.
- Soil around underground storage tanks.
- Soil around the sanitary sewer systems.
- The ground water beneath the hazardous waste management (HWM) buildings, Building 514 and Building 612, that may be subject to spills.

Soil and Sediment Surveillance Monitoring

Soil monitoring in the arroyos and storm water network was one of the items targeted in the GWPMP surveillance monitoring because "...recharge of natural runoff through the stream beds of arroyos accounts for the majority (about 42%) of resupply to the Livermore Valley ground water basin..." (Webster-Scholten 1994). Infiltrating rainwater may carry with it any dissolved constituents that may be present. Programs already exist that address the sanitary sewer system, the building drains, and underground storage tanks.

LLNL has developed background levels for total and soluble metals in soils and sediments (**Table 8-6**) and de minimis (or designated) concentrations for soluble metals (**Table 8-7**) and organics (**Table 8-8**) (Folks 1997; Marshack 1991). Soils with total metal concentrations below background and no detected organics are considered acceptable for reuse on site. If the concentration for a metal is above the total metal background value, then the soluble concentration for the metal is compared to the soluble background value. If the metal concentration is below the soluble metal background value, the soil is acceptable for reuse on site. If a metal exceeds both the total and soluble background values, or if there are any detected organics, the designated level methodology (DLM) described below is used to determine the soluble levels of contaminants that would not adversely impact ground water beyond its beneficial uses by application of a simple attenuation factor and

Table 8-6. Background screening concentration values for metals in soils at the Livermore site.

Metal	Background screening value
Total (mg/kg)	
Antimony	1.12
Arsenic	8.51
Barium	308
Beryllium	0.62
Cadmium	1.59
Chromium	72.4
Chromium(VI)	Any detection
Cobalt	14.6
Copper	62.5
Lead	43.7
Mercury	0.14
Molybdenum	Any detection
Nickel	82.8
Selenium	Any detection
Silver	Any detection
Thallium	Any detection
Vanadium	65.2
Zinc	75.3

Metal	Background screening value
Soluble (mg/L)	
Antimony	Any detection
Arsenic	0.237
Barium	16.7
Beryllium	Any detection
Boron	To be determined
Cadmium	Any detection
Chromium	0.727
Cobalt	0.985
Copper	2.6
Iron	To be determined
Lead	0.987
Manganese	To be determined
Mercury	0.0063
Molybdenum	Any detection
Nickel	1.68
Selenium	Any detection
Silver	Any detection
Thallium	Any detection
Vanadium	1.22
Zinc	4.52

Table 8-7. De minimis concentration levels for metals found in Livermore site soils.

Constituent	Water quality objective (mg/L)	Reference	Attenuation factor	De minimis level (mg/L)
Metals				
Antimony	0.006	Cal Primary MCL	100	0.06
Arsenic	0.050	Cal Primary MCL	100	0.5
Barium	1.0	Cal Primary MCL	100	10
Beryllium	0.004	Cal Primary MCL	100	0.04
Cadmium	0.005	Cal Primary MCL	100	0.05
Chromium	0.05	Cal Primary MCL	100	0.5
Cobalt	5	RWQCB Basin Plan	100	50
Copper	1	RWQCB Basin Plan	1000	100[(a)]
Lead	0.015	EPA	1000	1.5
Mercury	0.002	Cal Primary MCL	100	0.02
Molybdenum	0.05	RWQCB Basin Plan	100	0.5
Nickel	0.1	Cal Primary MCL	100	1
Selenium	0.05	Cal Primary MCL	100	0.5
Silver	0.1	Cal Secondary MCL	100	1
Thallium	0.002	Cal Primary MCL	100	0.02
Vanadium	1	RWQCB Basin Plan	100	10
Zinc	5	Cal Secondary MCL	1000	500[(a)]

a Hazardous waste limit is 25 mg/L for copper and 250 mg/L for zinc. Soils with soluble concentrations at or above these values would be disposed of as a hazardous waste and not reused on site.

specific water quality objectives. The San Francisco Bay RWQCB and LLNL agreed upon an attenuation factor of 100 except for certain metals; the attenuation factor for copper, lead and zinc is 1000. Any constituents with soluble concentrations above these de minimis levels may adversely impact the ground water beneath. LLNL has developed and the San Francisco Bay RWQCB has approved this site-specific DLM for beneficial reuse of soils generated from construction projects at the Livermore site. If the concentration of a constituent in soil is above its background level, the DLM can be used to determine if the constituent will adversely affect ground water quality. This same process is applied below to determine if constituent concentrations in arroyo sediments are protective of ground water quality.

Table 8-8. De minimis concentration levels for nonmetal constituents of concern found in Livermore site soils.

Constituent	Water quality objective	Reference	Attenuation factor	De minimis level
Organics (μg/L)				
1,2-Dichlorobenzene	600	EPA Primary MCL	100	3000
1,3-Dichlorobenzene	130	CA DHS Action Level	100	650
1-4-Dichlorobenzene	5	Cal Primary MCL	100	25
1,1-Dichloroethane	5	Cal Primary MCL	100	25
1-2-Dichloroethane	0.5	Cal Primary MCL	100	2.5
1,1-Dichloroethene	6	Cal Primary MCL	100	30
1,2-Dichloroethene	6	Cal Primary MCL	100	30
cis-1,2-Dichloroethene	6	Cal Primary MCL	100	30
trans-1,2-Dichloroethene	10	Cal Primary MCL	100	50
1,1,1-Trichloroethane	200	Cal Primary MCL	100	1000
1,1,2-Trichloroethane	5	Cal Primary MCL	100	25
Benzene	1	Cal Primary MCL	100	5
Carbon tetrachloride	0.5	Cal Primary MCL	100	2.5
Chloroform	100	EPA Primary MCL	100	500
Diesel oil/kerosene	100	SNARL[(a)]	100	500
Ethyl benzene	700	Cal Primary MCL	100	3500
Freon 11 (trichlorofluoromethane)	150	Cal Primary MCL	100	750
Freon 12 (dichlorodifluoromethane)	1000	CA DHS Action Level	100	5000
Freon 113 (1,1,2-trichloro-1,2,2-trifluoroethane)	1200	Cal Primary MCL	100	6000
Gasoline	5	Other[(b)]	100	25
Methylene chloride	5	Cal Primary MCL	100	25
MTBE	35	CA DHS Action Level	100	175
Oil and grease	25,000	Other	100	125,000
Tetrachloroethene (PCE)	5	Cal Primary MCL	100	25
Toluene	150	Cal Primary MCL	100	750
Trichloroethene (TCE)	5	Cal Primary MCL	100	25
Xylene(s)	1750	Cal Primary MCL	100	8750
PCB (total)	0.5	Cal Primary MCL	100	2.5
Vinyl chloride	0.5	Cal Primary MCL	100	2.5
Radioactivity (BqL)				
Gross alpha	0.56	Cal Primary MCL	100	5.6
Gross beta	1.9	Cal Primary MCL	100	19
Tritium	740	Cal Primary MCL	100	7400

a SNARL = Suggested No Adverse Response Level.

b Other = Taste and odor threshold for gasoline, and the California Ocean Plan Water Quality Objectives for Oil and Grease.

In 1997, LLNL sampled sediments in the shallow vadose zones in the arroyos at three influent locations (ASS2, ALPE, and GRNE), the two effluent locations (ASW and WPDC), and two on-site locations (CDB and EDB) in the settling basins upstream of the Drainage Retention Basin (see **Figure 9-3**, Chapter 9). Samples were analyzed for organics using EPA Method 8240 for both total and soluble metals using California's Waste Extraction Test (see Tables 8-82 to 8-84 in the Data Supplement). Analytical results for a variety of radioisotopes are summarized in Chapter 9, Soil and Sediment Monitoring, **Table 9-1**. Radiological analyses were also conducted at additional locations. In this section, arroyo sediment sample results are discussed; for a description of methods and a discussion of 1997 soil and sediment sampling radiological results, see Chapter 9.

No organic constituents were detected in 1997 arroyo sediment sampling. Total barium, selenium, and silver concentrations were above their respective total background concentrations in one sample each, but in all three cases the soluble concentrations were below the soluble background values. Therefore, these constituent concentrations are no threat to ground water quality. In addition, the detection limit for one total beryllium analysis and for all total antimony analyses were higher than the background value. However, in each case the soluble concentration was below the soluble background value, again indicating that these constituent concentrations are protective of ground water quality.

For radioisotopes, LLNL has developed de minimis levels for tritium and for gross alpha and gross beta radiation. All tritium results were below the de minimis levels (gross alpha and gross beta radiation analyses were not conducted in 1997). Thus, the sediment data indicate no adverse impact on ground water through the arroyos that cross the Livermore site.

CERCLA Remedial Actions

Livermore Site

An extensive investigation of the remediation options for the contaminated areas discussed above is summarized in the *CERCLA Feasibility Study Report for the LLNL Livermore Site* (Isherwood et al. 1990). *The Record of Decision for the Lawrence Livermore National Laboratory Livermore Site* (U.S. Department of Energy 1992) documents the remedial options selected for implementation. The selected remedies for ground water contamination involve pumping the ground water to the surface for treatment with a combination of ultraviolet light / hydrogen peroxide, air stripping, and granulated activated carbon. The selected remedies for contaminants in the unsaturated zone are vacuum-induced venting with surface treatment of the vapors by catalytic oxidation or activated-carbon filtration. The goal of the remedial action is to clean the ground water to the levels specified in the applicable, relevant, and appropriate requirements

developed for this project and outlined in the Record of Decision (ROD). A description of the remediation efforts during 1997 can be found in Chapter 2 of this report.

Site 300

Investigation of the remediation options for the contaminated areas at Site 300 is discussed in the Final SWRI Report (Webster-Scholten 1994). It includes a thorough compilation of all pre-1992 ground water and soil investigation information for the entire site and contains a detailed assessment of potential human health and ecological hazards or risks resulting from contamination of soil, rock, and ground water. New characterization, summary, and feasibility study or engineering evaluation/cost analysis reports have been, or will be, prepared for portions of the individual study areas, where the Final SWRI Report or more recent studies indicate that unacceptable potential hazards or risks exist. A summary of the remediation efforts and studies conducted during 1997 can be found in Chapter 2 of this report.

Environmental Impacts

The impact of LLNL Livermore site and Site 300 operations on off-site ground waters is minimal. With the exception of VOCs being remediated under CERCLA at both sites, LLNL operations appear to have little or no adverse effect on the surrounding ground waters.

Livermore Site

Ground water monitoring at the LLNL Livermore site and in the Livermore Valley indicates that LLNL operations, both past and present, have minimal impact on ground water beyond the site boundary. VOC plumes that were advancing to the west and southwest are being pulled back to the site and treated.

During 1997, concentrations of no compound or element detected in ground water in any off-site well monitored exceeded primary drinking water MCLs for any of the monitored constituents. None of the analytical measurements of radioactivity exceeded MCLs. The maximum tritium activity of 11.4 Bq/L (307 pCi/L), only 1.5% of the MCL, was detected in the ground water sample collected from on-site Well W-373 in September. The maximum tritium activity measured off site in the Livermore Valley was only 9.5 Bq/L (257 pCi/L), in 1997.

Of the Livermore on-site monitoring wells, no inorganic data exceeded primary MCLs, with the exceptions of chromium in monitoring Well W-373 and nitrates in monitoring

Well W-1012. Chromium(VI) in ground water in the vicinity of monitoring Well W-373 is being treated in Treatment Facility C (TFC), and this treatment is monitored separately. The LLNL Ground Water Project reports on the treatment of ground water in the vicinity of the treatment facilities. Ground water samples collected from Well W-1012 in March, June, and September 1997 all exceeded California's MCL of 45 mg/L. Nitrates above the MCL have not migrated off site. An investigation to determine the source of nitrate in the vicinity of Well W-1012 is continuing in 1998.

Site 300

Ground water monitoring at Site 300 and adjacent properties in the Altamont Hills shows that past and present LLNL operations have minimal impact on ground water beyond the site boundaries.

VOCs, primarily the solvent TCE, have been released historically to shallow ground water at numerous locations at Site 300 (see Chapter 2, **Figure 2-2**; Webster-Scholten 1994; Taffet et al. 1996; Ferry et al. 1998; and references cited therein). With the exceptions of the two small plumes in the General Services Area (GSA) area that extend minimally off site along Corral Hollow Road, all of the TCE-bearing ground water is on site. The plume extending off site from the Eastern GSA area is being pumped back to the site and cleansed of TCE.

Tritiated water and depleted uranium have been released to ground water from landfills and several firing tables in the northern part of Site 300. The boundaries of the slowly moving ground water plumes lie entirely within the site boundaries. Fate and transport models predict that the tritium will decay naturally to an activity below the drinking water MCL before the tritium-bearing ground water reaches a site boundary (Webster-Scholten 1994; Taffet et al. 1996).

Maximum uranium activities that could reach potential exposure points (hypothetical ground water supply wells) at the northern boundary of Site 300 are estimated to be 0.08 Bq/L from plumes originating at Pits 5 and 7, and 0.05 Bq/L at the eastern boundary of Site 300 from the plume originating at Building 850. These conservatively estimated maximum activities are small when compared with the 0.74 Bq/L California MCL for uranium in drinking water. The predicted incremental lifetime cancer risks from the released uranium are less than one-in-a-million at the hypothetical exposure points on the Site 300 boundary (Taffet et al. 1996). The VOCs, tritium, nitrate, Freon, and depleted uranium in the shallow ground water beneath Site 300 present no current health risks, because the contaminated water is not used for potable domestic, livestock, or industrial water supplies.