UCRL-TR-106132 Rev. 4

LAWRENCE
LIVERMORE
NATIONAL
LABORATORY

Environmental Monitoring Plan

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This work was performed under the auspices of the U.S. Department of Energy by University of California, Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

Environmental Monitoring Plan
Revision History

Revision number	Date	Chapter(s) revised	Comments
4	September 2005	All	Reorganization and release of entire document.

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1 Introduction

1.1 Purpose of the Environmental Monitoring Plan

The purpose of the environmental monitoring plan (EMP) is to promote the early identification of, and response to, potential adverse environmental impacts associated with DOE operations. Environmental monitoring supports the Integrated Safety Management System (ISMS) to detect, characterize, and respond to releases from DOE activities; assess impacts; estimate dispersal patterns in the environment; characterize the pathways of exposure to members of the public; characterize the exposures and doses to individuals and to the population; and to evaluate the potential impacts to the biota in the vicinity of the DOE activity.

In addition, the EMP addresses the analytical work supporting environmental monitoring to ensure the following.

- A consistent system for collecting, assessing, and documenting environmental data of known and documented quality
- A validated and consistent approach for sampling and analysis of radionuclide samples to ensure laboratory data meets program-specific needs and requirements within the framework of a performance-based approach for analytical laboratory work
- An integrated sampling approach to avoid duplicative data collection

Until recently, environmental monitoring at Lawrence Livermore National Laboratory (LLNL) was required by DOE Order 5400.1, which was cancelled in January 2003. LLNL is in the process of adopting the ISO 14001 Environmental Management Systems standard, which contains requirements to perform and document environmental monitoring. The ISO 14001 standard is not as prescriptive as DOE Order 5400.1, which expressly required an EMP. LLNL will continue to prepare the EMP because it provides an organizational framework for ensuring that the work is conducted appropriately.

The environmental monitoring addressed by the plan includes preoperational characterization and assessment, and effluent and surveillance monitoring. Additional environmental monitoring is conducted at LLNL as part of the compliance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA, also known as Superfund). This EMP does not address the technical requirements for such monitoring.

1.2 Mission of the Laboratory

LLNL is a premier research and development institution for science and technology applied to national security. It is responsible for ensuring that the nation's nuclear weapons remain safe, secure, and reliable. LLNL also applies its expertise to prevent the spread and use of weapons of mass destruction and strengthen homeland security.

LLNL's national security mission requires special multidisciplinary capabilities that are also used to pursue programs in advanced defense technologies, energy, environment, biosciences, and basic science to meet important national needs. These activities enhance the competencies needed for our defining national security mission.

The Laboratory serves as a resource to the U.S. government and is a partner with industry and academia. Safe, secure, and efficient operations and scientific and technical excellence in our programs are necessary to sustain public trust in the Laboratory.

Its primary mission is to ensure that the nation's nuclear weapons remain safe, secure, and reliable, and to prevent the spread and use of nuclear weapons worldwide. Programs in advanced technologies, energy, environment, biosciences, and basic science apply LLNL's unique capabilities and enhance the competencies needed for this national security mission. LLNL's mission also involves working with industrial and academic partners to increase national competitiveness and improve science education. LLNL's mission is dynamic and has changed over the years to meet new national needs.

LLNL's policy is to perform work in a manner that protects the health and safety of employees and the public, preserves the quality of the environment, and prevents property damage. The environment, safety, and health are to be priority considerations in the planning and execution of all work activities at the Laboratory (LLNL 2001). Furthermore, it is the policy of LLNL to comply with applicable ES&H laws, regulations, and requirements. Under Contract 48, Appendix F*,* the Laboratory commits to minimizing its waste streams and to avoiding adverse impacts to the environment from its operations (UC/DOE 2001).

1.3 Environmental Protection Department

All LLNL staff members have responsibilities that include environmental protection and environmental compliance. The level of responsibility is dependent upon the position held by the individual. Document 2.1, *Laboratory and ES&H Policies, General Worker Responsibilities, and Integrated Safety Management*, in the LLNL *Environment, Safety, and Health (ES&H) Manual* lists these responsibilities for all levels of staff; however, the Laboratory has designated the Environmental Protection Department (EPD) as the lead organization with responsibility for helping the Laboratory to ensure that operations do not adversely affect the environment or public health. The primary mission of EPD is to support existing operations and related research and development activities at LLNL in the areas of environmental monitoring, environmental regulatory compliance, environmental restoration, and radioactive and hazardous waste management. EPD assists LLNL programs to develop environmentally sound practices in their everyday tasks through such activities as:

- Conducting environmental evaluations and addressing requirements under the National Environmental Policy Act (NEPA), California Environmental Quality Act (CEQA), and related federal and state requirements.
- Identifying and developing methods to monitor, prevent, reduce, and clean up air emissions, wastewater discharges, and hazardous wastes.
- Obtaining the permits or exemptions for air, water, and hazardous waste activities.
- Ensuring environmental compliance through environmental monitoring, risk assessment, and analysis for Laboratory sites.
- Evaluating the impact of ongoing Laboratory operations on the surrounding environment by sample collection, analysis, data reduction, and other simulation modeling methods for water and air.
- Developing and conducting cost-effective restoration and remediation.
- Designing and applying appropriate, cost-effective treatment technologies to manage hazardous and nonhazardous waste streams.
- Developing and implementing waste minimization and pollution abatement strategies.
- Coordinating Laboratory-wide decontamination and decommissioning activities.

EPD has developed an integrated, multidisciplinary approach to carry out its mission. The combined expertise in the scientific, engineering, technical, and management fields allows the department to provide a comprehensive, balanced range of resources and disciplines to address environmental issues, identify best management practices, solve environmental problems, and prevent environmental damage. EPD experts provide quality assurance and environmental education, ensure regulatory compliance, and facilitate community relations and public participation.

EPD supports LLNL programs by five Environmental Support Teams (ESTs). Each EST includes representatives from various environmental specialties. These teams evaluate operations, determine potential environmental impacts, and provide guidance on environmental regulations and DOE orders for existing and proposed projects. ESTs assist programs in planning, implementing, and operating projects and in understanding and meeting their environmental obligations.

The Environmental Protection Department is divided into three operating divisions:

- The Radioactive and Hazardous Waste Management (RHWM) Division implements the technologies necessary to manage all hazardous, radioactive, and mixed wastes generated at LLNL facilities. This responsibility includes the design and acquisition of new facilities as well as the investigation of new and more cost-effective methodologies for hazardous waste handling, stabilization, treatment, certification, and disposal.
- The Environmental Restoration Division (ERD) investigates and remediates soil and groundwater contaminated by past activities of LLNL and its predecessors at the Livermore site and Site 300 facilities. ERD directs groundwater and soil monitoring efforts associated with CERCLA compliance, monitoring more than 600 wells and conducting soils sampling at those well sites.
- The Operations and Regulatory Affairs Division (ORAD) helps Laboratory programs to operate in an environmentally sound manner and to meet environmental compliance requirements. ORAD is responsible for obtaining environmental permits, evaluating environmental laws and regulations, and drafting environmental guidelines for LLNL personnel. ORAD staff also advises Laboratory personnel concerning interactions and inspections involving federal, state, and local environmental regulatory agencies.

ORAD also has responsibility for the surveillance and effluent monitoring programs described in this EMP. ORAD personnel develop and apply monitoring techniques, source evaluations, and computer models to evaluate the effect of LLNL operations on human health and the environment at both the Livermore site and Site 300.

Three organizations within ORAD have specific responsibilities for the activities described in this environmental monitoring plan.

- The Terrestrial and Atmospheric Monitoring and Modeling (TAMM) Group is responsible for planning, sampling, data analysis, regulatory compliance, dose assessments, and reporting for all radiological air effluent and non-water environmental surveillance monitoring, including soils and sediments, vegetation and foodstuffs, ambient air, meteorology and climatology, and ambient radiation, both on and off LLNL property.
- The Water Guidance and Monitoring Group (WGMG) is responsible for planning, sampling, data analysis, regulatory compliance, and reporting for all nonhazardous wastewater, storm water, non-CERCLA groundwater, and surface water monitoring.
- The ORAD Data Management Team (DMT) provides data-management support for the WGMG and TAMM groups.

1.4 Setting

1.4.1 Location

LLNL consists of two main facilities (Figure 1-1)—the main laboratory site located in Livermore, California (Livermore site), and the Experimental Test Facility (Site 300) located near Tracy, California. Each site is unique, requiring a different approach for environmental monitoring and protection.

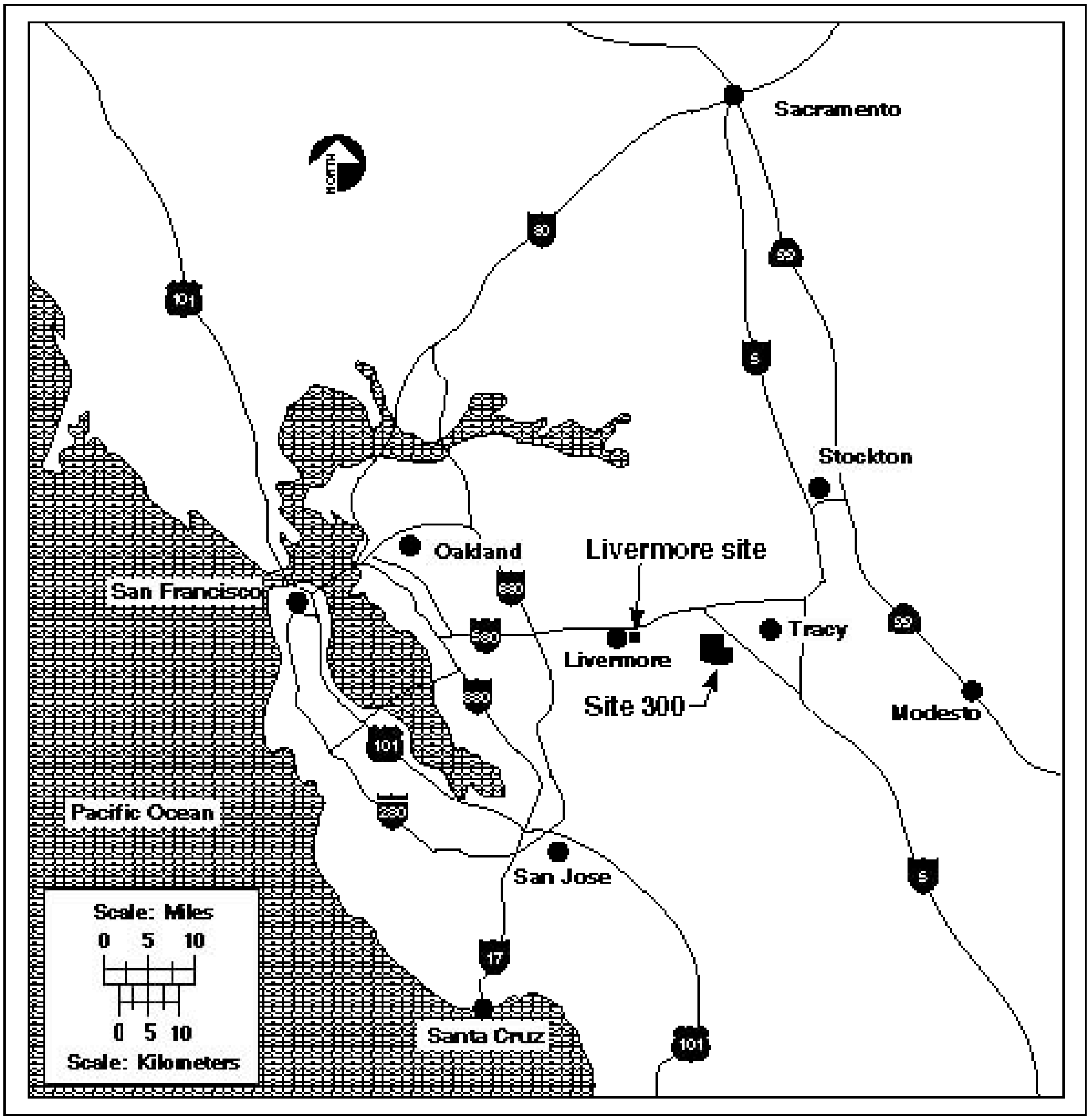


Figure 1-1. Location of LLNL Livermore site and Site 300

1.4.1.1 Livermore Site

LLNL was founded at the Livermore site in 1952 at the site of a former U.S. Navy air station. At that time, the location was relatively isolated, being approximately 1.6 km from the Livermore city limits. Over the years, Livermore evolved from a small town of fewer than 7,000 people to its present population of approximately 78,600. The area's economy diversified from primarily agricultural to include light industrial and business parks. Within the last few years, low-density, single-family residential developments have begun to fill formerly vacant fields, bringing the city limits of Livermore up to LLNL's western boundary.

LLNL's Livermore site occupies an area of 3.28 km^2. Onsite land uses include offices, laboratory buildings, support facilities such as cafeterias, storage areas, maintenance yards, and a fire station; roadways, parking areas, buffer zones, and landscaping. The site also includes internal utility and communication networks. A 150-meter wide security buffer zone lies along the northern and western borders of the Livermore site.

The Livermore site is bordered on the east by Greenville Road. The property east of Greenville Road is agricultural with a few scattered rural residences and is used primarily for grazing. A Western Area Power Administration (WAPA) electrical substation is on the southeast corner of Greenville Road and Patterson Pass Road. The South Bay Aqueduct, a branch of the California Aqueduct, traverses the land east of the Livermore site in a north-south direction. The Patterson Reservoir and filtration plant for the South Bay Aqueduct are northeast of the Livermore site along Patterson Pass Road.

Patterson Pass Road runs along the northern boundary of the Livermore site. A light industrial park lies across Patterson Pass Road to the north. Several complexes have been completed within that park in recent years. A Union Pacific Railroad line runs in an east-west direction along the northern boundary of the industrial park. Land uses farther north include vacant land, industrial, and Interstate 580 (I-580). Land northeast of the site is agricultural and used primarily for grazing. Wind turbines are installed on the hills of the Altamont Pass, northeast of the site.

Vasco Road borders the Livermore site to the west. A low-density, single-family residential subdivision begins at the southwest corner of Patterson Pass Road and Vasco Road, and extends south and west. A housing development of attached single-family residences is directly west of the site (north of East Avenue). Medium-density residential areas, mainly apartment complexes, exist on the west side of this development approximately 600 meters west of Vasco Road.

East Avenue borders the Livermore site to the south. Sandia National Laboratories, California (Sandia/California), which has land uses very similar to those at LLNL, is south of East Avenue. The primary land uses to the east and west of Sandia/California are rural residential and agricultural (mainly grazing). The Stivers Academy, a Kindergarten through 8th grade school, is located southwest of Sandia/California on the east side of Vasco Road, between East Avenue and Tesla Road. Public access to the section of East Avenue common to the Livermore site is administratively controlled. There is a small light-industrial park on the southwest corner of East Avenue and Vasco Road. Single-family housing is being built south of this industrial park, on both sides of South Vasco Road.

1.4.1.2 Site 300

Site 300, LLNL's Experimental Test Site, is located 20 km east of the Livermore site in San Joaquin and Alameda counties in the Altamont Hills of the Diablo Range. The site occupies an area of 30.3 km^2, of which approximately 28 km^2 is undeveloped land. Site 300 is primarily a component test facility for non-nuclear explosives and other non-nuclear weapons. The site has three remote explosive testing facilities supported by a chemistry processing area, a weapons test area, maintenance facilities, and a General Services Area (GSA) at the site entrance. About 0.65 km^2 at Site 300 have been set aside as the "*Amsinckia grandiflora* Reserve" to protect the natural habitat of this plant species.

The majority of the existing land uses surrounding Site 300 are agricultural, primarily for grazing cattle and sheep. Two small, privately operated research and testing facilities are located near Site 300. The property east of and adjacent to Site 300 is now owned by Fireworks America and is currently being used to store pyrotechnics. A portion of the property is leased to Reynolds Initiator Systems, Inc., and is used to manufacture initiators, which are agents that cause a chemical reaction to commence. A facility operated by SRI International, that conducts explosives tests, is located approximately 1 km south of Site 300.

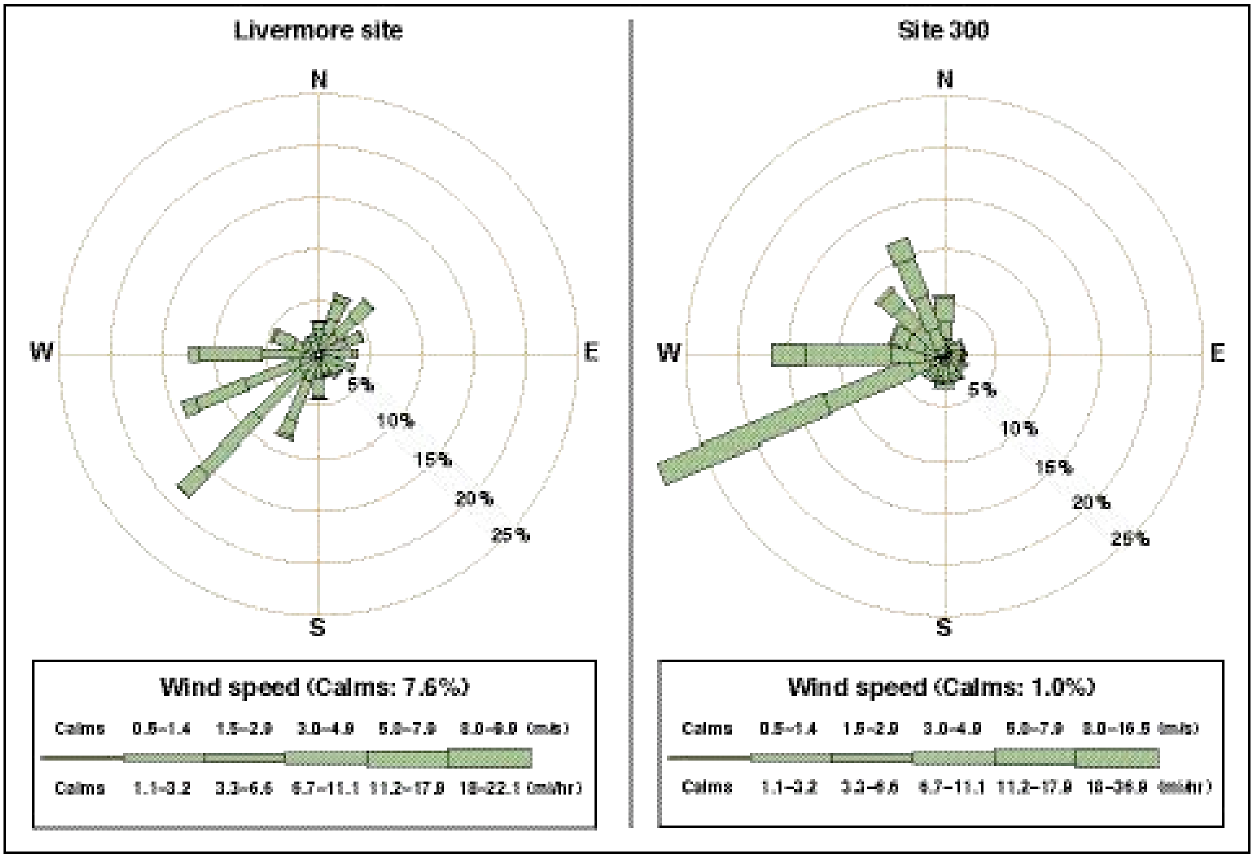
Corral Hollow Road borders Site 300 on the south. The Carnegie State Vehicular Recreation Area is south of the western portion of Site 300, across Corral Hollow Road. It covers approximately 5,000 acres and is operated by the California Department of Parks and Recreation, Off-Highway Motor Vehicle Recreation Division, for the exclusive use of off-highway vehicles. The nearest urban area is the city of Tracy, approximately 3 km northeast of Site 300. Rural residences are located along Corral Hollow Road, west of Site 300 and the Carnegie State Vehicular Recreation Area. Power-generating wind turbines occupy the land northwest of the site.

1.5 Meteorology

1.5.1 Livermore Site

Mild, rainy winters and warm, dry summers characterize the climate of the Livermore Valley. The mean annual temperature is 15 °C (59 °F). Temperatures range from –4 °C (25 °F) during the coldest predawn winter mornings to 40 °C (104 °F) during the hottest summer afternoons.

Prevailing winds from the west and southwest occur about 50% of the time. These winds are especially prevalent in the summer, as the thermal draw caused by rising air in the warm Central Valley of California results in wind blowing from the cool ocean toward the warm valley, increasing in intensity as the valley heats up. Winds from the northeast become more frequent during the winter. The annual wind pattern for 2003 is depicted by the Livermore site wind rose included in Figure 1-2.



Note: The length of each spoke is proportional to the frequency at which the wind blows from the indicated direction. Different line widths of each spoke represent wind speed classes. The average wind speed in 2003 at the Livermore site was 2.4 m/s (5.3 mph); at Site 300, it was 5.5 m/s (12.4 mph).

Figure 1-2. Wind roses showing wind direction and speed frequency at the Livermore site and Site 300 during 2003

Precipitation also exhibits a strong seasonal pattern, with most of it occurring between October and April, but very little during the warmer months. Snow is uncommon in the Livermore Valley. Based on a 46-year record, the highest and lowest annual rainfalls were 85.2 and 16.7 cm (33.57 and 6.57 in.). The 30-year normal annual rainfall is 34.6 cm (13.62 in.).

1.5.2 Site 300

The climate at Site 300, while generally similar to that at the Livermore site, is modified by the higher elevation and more pronounced topographical relief, which significantly influences local wind and temperature patterns. The nighttime temperatures are typically higher (and diurnal temperature range smaller) at Site 300 compared to the Livermore site; stronger winds at a higher elevation prevent formation of strong radiational inversions near the ground. At Site 300, the prevailing winds blow more consistently from the west-southwest and reach greater speeds than at the Livermore site. The wind rose at Site 300 for the year 2003 is included in Figure 1-2.

The annual 30-year normal rainfall for Site 300 is 26.8 cm (10.55 in.). The highest and lowest annual rainfalls over a 44-year period were 59.9 and 14.2 cm (23.58 and 5.61 in.).

1.6 Topography

1.6.1 Livermore Site

The Livermore site is located in the southeastern portion of the Livermore Valley, a topographic and structural depression oriented east–west within the Diablo Range of the California Coast Range Province. The Livermore Valley, the most prominent valley within the Diablo Range, is an east-west trending structural and topographic trough that is 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 covered by alluvial, lake, and swamp deposits consisting of gravels, sands, silts, and clays, with an average thickness of about 100 m. The valley floor is at its highest elevation of 220 m above sea level along the eastern margin and gradually dips to 92 m at the southwest corner. The valley's major streams, Arroyo del Valle and Arroyo Mocho, drain the southern highlands and flow mostly during the rainy season.

1.6.2 Site 300

The topography of Site 300 is much more irregular than that of the Livermore site. It consists of a series of steep hills and ridges oriented along a generally northwest-southeast trend and separated by intervening ravines. The Altamont Hills, where Site 300 is located, are part of the California Coast Range Province and separate the Livermore Valley to the west from the San Joaquin Valley to the east. The elevation ranges from approximately 150 m above sea level at the southeast corner of the site to approximately 540 m in the northwestern portion.

1.7 Hydrogeology

1.7.1 Livermore Site

The hydrogeology and the movement of groundwater near the Livermore site have been the subjects of several recent and continuing investigations (Stone and Ruggieri 1983; Carpenter et al. 1984; Webster-Scholten and Hall 1988; Thorpe et al. 1990). This section has been summarized from these reports and from data supplied by Alameda County Flood Control and Water Conservation District, Zone 7, which is the agency responsible for groundwater management in the Livermore Valley basin (CRWQCB 1995).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley groundwater basin and is an important water-bearing formation. Natural recharge occurs primarily along the fringes of the basin and through the arroyos during periods of winter flow. Artificial recharge, if needed to maintain groundwater levels, is accomplished by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the east. Groundwater flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Groundwater flow in the basin is assumed to be primarily horizontal although a significant vertical component probably exists in fringe areas, under localized sources of recharge, and near heavily used extraction (production) wells.

Beneath the Livermore site, the depth to the water table varies from about 10 to 40 m. Figure 1-3 shows a contour map of water table elevations (meters above mean sea level) for the Livermore site area. Although water table elevations vary slightly with seasonal and year-to-year differences in both natural and artificial recharge, the qualitative patterns shown in Figure 1-3 are generally maintained. At the eastern edge of the Livermore site, groundwater gradients (change in vertical elevation per unit of horizontal distance) are relatively steep; but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003. Groundwater flow under most of the site is southwesterly. This flow direction diverges from the generally westward regional flow and from flow patterns demonstrated for the site in the 1980s. This shift in flow direction is a consequence of groundwater recovery and remediation in the southwest portion of the site and agricultural pumping. Aquifer tests on monitoring wells near the Livermore site indicate that the hydraulic conductivity of the permeable sediments ranges from 1 to 16 m per day (Isherwood et al. 1991). This, in combination with the observed water table

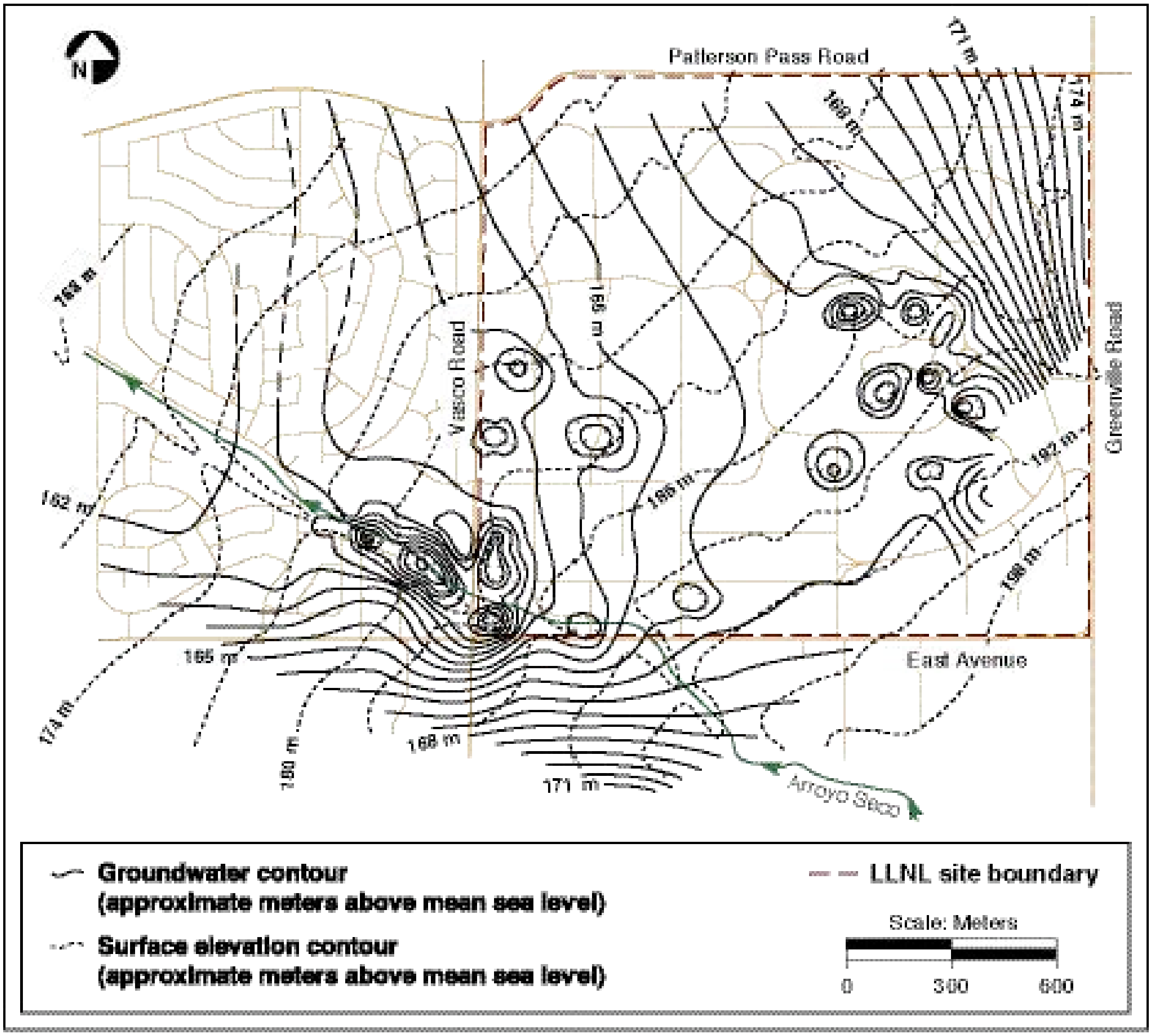


Figure 1-3. Approximate groundwater and surface elevation contours, Livermore site and vicinity

gradients, yields an average groundwater velocity estimate of 20 m/y (Thorpe et al. 1990). The range in these values reflects the heterogeneity typical of the more permeable of the alluvial sediments that underlie the area.

1.7.2 Site 300

Site 300 is generally underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock consists primarily of interbedded sandstone, siltstone, and claystone. Most groundwater occurs in the Neroly Formation upper and lower blue sandstone aquifers. Significant groundwater is also locally present in permeable, quaternary alluvium valley fill. Much less groundwater is present within perched aquifers in the unnamed Pliocene non-marine unit.

Perched aquifers contain unconfined water separated from an underlying main body of water by impermeable and permeable layers; normally, they are discontinuous and highly localized. Because water quality is generally poor and yields are low, these perched water-bearing zones do not meet criteria of the state of California for aquifers that are potential drinking water sources.

Fine-grained siltstone and claystone interbeds may confine the groundwater and act as aquitards, or perching horizons. Groundwater is present under confined conditions in parts of the deeper bedrock aquifers but is generally unconfined elsewhere.

Groundwater flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300, groundwater in bedrock generally flows northeast except where it is locally influenced by the geometry of alluvium-filled ravines. In the southern half of Site 300, groundwater in bedrock flows roughly south–southeast, approximately coincident with the attitude of bedrock strata. The thick Neroly lower blue sandstone, stratigraphically near the base of the formation, generally contains confined water. Wells located in the western part of the General Services Area, near the southeast border of Site 300, are completed in this aquifer and are used to supply drinking and process water.

Figure 1-4 shows the elevation contours for water in the regional aquifer at Site 300. This map of the piezometric surface (the elevation to which water rises in a well that penetrates a confined or unconfined aquifer) is based primarily on water levels in the Neroly lower blue sandstone aquifer.

Recharge occurs predominantly in locations where saturated alluvial valley fill is in contact with underlying permeable bedrock, or where permeable bedrock strata crop out because of structure or topography. Local recharge also occurs on hilltops, creating some perched water-bearing zones. Low rainfall, high evapotranspiration, steep topography, and intervening aquitards generally preclude direct vertical recharge of the bedrock aquifers.

1.8 Environmental Monitoring Activities at LLNL

The current LLNL environmental monitoring program has two major components:

- Monitoring effluents such as stack emissions, wastewater, and storm and sanitary sewer discharges.

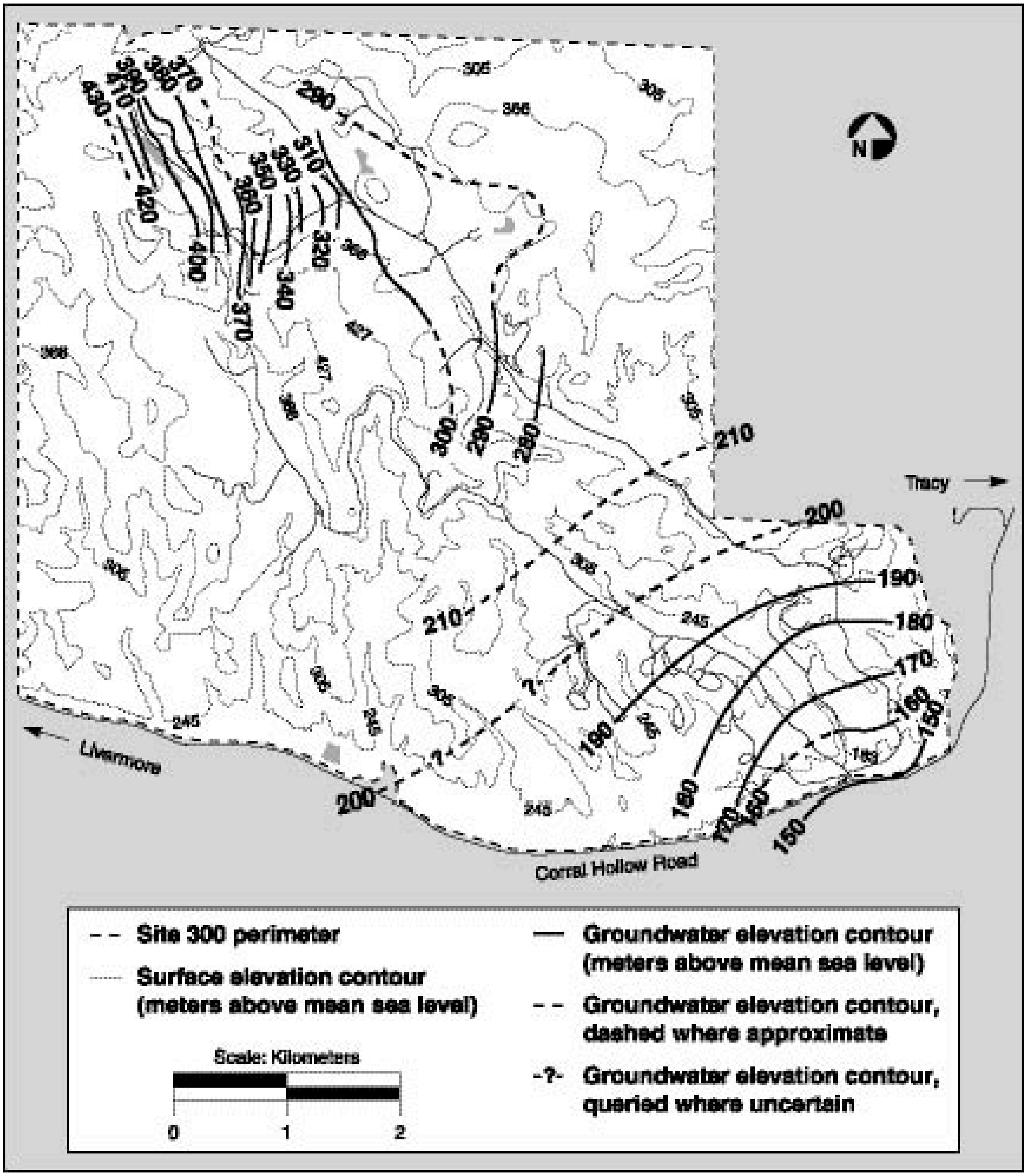


Figure 1-4. **Approximate groundwater elevations in principal continuous water-bearing zone aquifer at Site 300**

- Conducting surveillance monitoring of environmental media that could be impacted by LLNL, including air, surface water, groundwater, rainwater, surface runoff, vegetation and foodstuffs, soils and sediments, and ambient radiation.

The existing monitoring program involves a staff of Laboratory scientists and technologists as well as contractors. The environmental monitoring program collects more than 24,000 samples from a variety of environmental media and performs more than 260,000 analyses each year.

Funding for environmental monitoring is provided by general and administrative funds collected from scientific research programs in operation at LLNL.

1.9 Document Organization

The LLNL *Environmental Monitoring Plan* is structured to provide the environmental professional with an understanding of how LLNL fulfills its monitoring obligations. The EMP describes and explains LLNL's environmental monitoring networks; sampling methods, locations, and frequencies; and measured parameters as well as methods and procedures for data collection, analysis, maintenance, reporting, and archiving. It addresses quality assurance for monitoring data and the specifics of sampling and data collection.

The mission of LLNL and EPD and the organizational framework of the Laboratory's environmental monitoring program as well as the setting of environmental monitoring at the Livermore site, Site 300, and the surrounding environs are described in this chapter.

The group responsible for monitoring each specific environmental medium has prepared a chapter in this EMP that contains a discussion of the rationale and design criteria, the extent and frequency of monitoring and measurements, data quality requirements, procedures for laboratory analysis, data quality assurance, program implementation procedures, action levels, preparation and disposition of reports, and future plans for that medium. All future plans described are contingent on the allocation of funding and the approval of LLNL management. Short-term plans have a high likelihood of implementation; long-term plans are more likely to be subject to revision. The TAMM Group is responsible for the Air Effluent chapter, the Ambient Air Particulate chapter, the Ambient Air Tritium chapter, the Ambient Radiation chapter, the Meteorology chapter, the Soil and Sediment chapter, and the Vegetation and Foodstuff chapter. The WGMG Group is responsible for the Categorical Pretreatment chapter, the Construction Storm Water chapter, the Drainage Retention Basin Release chapter, the Ground Water chapter, the Other Waters chapter, the Rainwater chapter, the Retention Tanks chapter, the Sanitary Sewer chapter, the Site 300 Drinking Water Discharges chapter, and the Storm Water chapter.

The monitoring, quality assurance, and data and records management procedures referenced in this EMP are available upon request.

1.10 Laboratory Analysis

All laboratory analyses are conducted by either an LLNL analytical laboratory or an off-site analytical laboratory under contract to LLNL. All analytical laboratories used must be accredited by the California Department of Health Services Environmental Laboratory Accreditation Program (ELAP). Conditions and methodology for analyses performed by contract analytical laboratories are specified in an approved Statement of Work (SOW) that is prepared and managed by the LLNL Procurement Department.

1.11 Sample and Data Management

Sample and data management requirements are defined in EMP-QA-DM*, Sample and Data Management*. Sampling plans are documented and revised quarterly and as needed by the ORAD DMT. Field tracking forms (FTFs) are forms used to document sample collection information in the field. A unique FTF containing sample identifiers, sampling locations, requested analyses, QC sample identifiers, special instructions, and field notes is prepared for each environmental medium. FTFs are prepared and revised as described in EMP-QA-DM*, Sample and Data Management.* The responsible environmental analyst must approve all changes to the sampling plan and associated FTFs.

Samples and data are identified and controlled using chain-of-custody (COC) forms and protocol described in EMP-QA-DM, *Sample and Data Management*. Samples that are submitted to analytical laboratories for analysis are accompanied by COC forms to track custody of the samples as they move from the sampler to the analytical lab and the data as it moves from the lab to the analytical laboratory and finally to the ORAD DMT for archival. Collection and analysis of method blanks, matrix spikes, matrix spike duplicate, and laboratory control samples are described in the Statement of Work for analytical laboratories.

Processes to ensure that environmental monitoring samples are handled, stored, and shipped to prevent damage, loss, or deterioration are also described in EMP-QA-DM*, Sample and Data Management.* Samples are shipped in sealed coolers using either a laboratory courier or a common carrier such as Federal Express.

1.12 Quality Assurance

1.12.1 Quality Assurance Program

The goal of the EPD Quality Assurance (QA) program is to ensure that adequate and effective QA and ES&H controls are developed and implemented within EPD. The *EPD Quality Assurance Management Plan (QAMP*) (Merrigan 2002) defines the QA program requirements that must be integrated into EPD activities. The EPD QA program is designed to emphasize administrative and oversight functions at the department level and operational functions at the division, project, and group levels. The EPD QA program also incorporates applicable elements of the LLNL Integrated Safety Management System (ISMS) to address the needs of EPD's activities and personnel.

1.12.2 Quality Assurance Documents

All environmental monitoring and sampling is conducted by LLNL technical staff according to documented standard operating procedures (SOPs), SOP supplements, and instructions. Samples are tracked and submitted for analyses according to SOP EMP-QA-DM, *Sample and Data Management*. Supplements to EMP-QA-DM specify procedures used for completing field tracking forms and chain-of-custody forms. Hazards and controls for each environmental monitoring activity are described in an Integration Work Sheet (IWS). Nonconformances are tracked and resolved according to procedure ORAD-QA-NCR*, Nonconformance Reporting and Tracking*. Monitoring activities are subject to periodic informal self-assessments as described in procedure ORAD-QA-SA*, Self Assessments*.

1.12.3 Nonconformance Reporting and Tracking

Nonconformances are managed in a graded manner, depending on their type and severity according to ORAD-QA-NCR*, Nonconformance Reporting and Tracking*. When samples are planned but not collected, the sampling technologist notifies the ORAD QA Coordinator and the responsible environmental analyst in writing.

EPD uses the deficiency tracking system described in Document 4.2, *Environmental, Safety, and Health Deficiency Tracking System*, in the *LLNL ES&H Manual*, and the occurrence reporting process described in Document 4.4*, Identification, Reporting, and Tracking of Noncompliances with Nuclear Safety Requirements*, to identify and track deficiencies to resolution when appropriate.

1.12.4 Audits and Assessments

1.12.4.1 Management Assessments

EPD uses management assessments (i.e., walkabouts, self assessments, and prestart reviews) to ensure that work activities are conducted in a safe manner and that quality is achieved.

EPD line managers perform walkabouts of activities they are responsible for during each year. The majority of walkabouts must be related to field and laboratory activities. Identified issues that require follow-up must be agreed upon by personnel involved in the walkabout and tracked to closure. Walkabouts are intended to evaluate the effectiveness of processes and controls (e.g., procedures), observe work conditions and the work environment, identify workplace issues that could potentially have a negative impact on a deliverable, and obtain feedback from activity personnel concerning potential improvements to an activity or its product.

1.12.4.2 Informal Self Assessments

The ORAD self-assessment program includes an informal self-assessment of each environmental monitoring activity approximately once every three years. These self-assessments are performed by Quality Assurance or technical personnel with an understanding of the activity being assessed. Self-assessments include an evaluation of the adequacy of hazards and controls specified in the IWS as well as the adequacy of and conformance with procedures and other documents that govern the activity. ORAD self-assessments are documented and observations requiring a response are tracked to closure by QA staff.

1.12.4.3 Independent Assessments

External organizations frequently perform independent external assessments to evaluate environmental monitoring activities. These organizations include the LLNL Assurance Review Office (ARO), the LLNL Office of Audit and Oversight, the Safety & Environmental Protection SEP Directorate Assurance Office, and regulatory agencies.

Independent assessments generally result in a formal assessment report and any deficiencies requiring corrective action are entered into the LLNL DefTrack application and tracked to closure.

1.13 Integrated Safety Management

LLNL implements an Integrated Safety Management System (ISMS) designed to ensure the systematic integration of ES&H considerations into management and work practices so that missions are accomplished safely. “Safety,” used in this context, is synonymous with environment, safety, and health to encompass protection of the public, workers, and the environment, including pollution prevention and waste minimization. LLNL regards protection of the environment an essential component in its overall safety management system. LLNL’s ISMS is detailed in the *Integrated Safety Management System Description.*

1.14 Emergency Response

Emergency response activities at LLNL are performed according to Document 22.1, *Emergency Preparedness and Response*, in the LLNL *ES&H Manual*. The objectives of emergency response are to respond to and mitigate potential consequence of onsite emergencies and significant nearby emergencies that could threaten Laboratory workers, the public, national security, or the environment. The Emergency Response Plan further specifies methods to be employed for emergency response including the organizational structure, response procedures, and functional roles of responding personnel.

The Laboratory organization responsible for the initial and ongoing response to an actual operational emergency, and for the mitigation of it, is the Emergency Management Team (EMT). During an emergency, the EMT may be supported by several Operation Support Centers (OSCs), including one within the Environmental Protection Department.

In the event of a large emergency requiring the involvement of EPD, it will support emergency response efforts by sending a senior member of EPD management to serve as a member of the EMT. For smaller incidents, an EPD Environmental Duty Officer (EDO), on call 24 hours a day to support environmental emergency response needs, may report directly to the scene of the emergency.

EPD provides necessary expertise and equipment to ensure that releases of radiological or hazardous materials are assessed for possible environmental impacts. EPD is responsible for identification and implementation of environmental mitigation and corrective actions, containment, cleanup, disposal, environmental monitoring and modeling, notification of regulatory agencies, and preparation of required reports.

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2 Air Effluent

Kent Wilson

2.1 Introduction

A key monitoring method for evaluation of environmental impacts from facilities having discharges to the atmosphere is the measurement of pollutants at their point of emission. This type of monitoring is part of a comprehensive and continuous environmental program at Lawrence Livermore National Laboratory (LLNL) (see Chapter 1). LLNL performs continuous air effluent sampling of atmospheric discharge points at several facilities that complies with federal laws and industry standards. DOE monitoring guidance specifies that emissions from facilities with radionuclides should be monitored. The LLNL air effluent monitoring program complements the environmental air surveillance monitoring effort (see Chapters 4 and 5); it can confirm or discount specific source locations as being contributors to any release that environmental surveillance monitoring might detect. It can also provide source term information for regulatory compliance or emergency response and dispersion and dose assessment modeling.

2.2 Rationale and Design Criteria

2.2.1 Regulatory Drivers

The applicable portions of 40 CFR 61 Subpart H, a regulation promulgated under the Clean Air Act, set requirements for continuous monitoring of radiological discharges and the estimation of radiological dose to the public resulting from operations at DOE facilities. Guidance on dose assessment is provided in EMP-R-DA*, Radiological Dose Assessment Guidance Document*.

Historically, monitoring of radionuclide air effluents at LLNL has been implemented according to the DOE as low as reasonably achievable (ALARA) policy. The more recent 40 CFR 61 Subpart H National Emission Standards for Hazardous Air Pollutants (NESHAPs) regulations require that monitoring of radionuclide air effluents must be performed if the potential off-site effective dose equivalent (EDE) from a specific emission point is greater than 1 µSv/y (0.1 mrem/y), as calculated using the air dispersion dose models mandated by the U.S. Environmental Protection Agency (EPA) and assuming no emission control devices. Where air monitoring is not required, periodic measurements are to be performed to confirm that alternative methods used to evaluate emissions and calculate resultant doses are conservative.

All LLNL operations having the potential for radiological air emissions are evaluated to determine the need for continuous monitoring. At discharge points having air effluent monitoring, the monitoring results provide the actual source term for determining that the radiological NESHAPs standard, 100 μSv/y (10 mrem/y) effective dose equivalent (EDE) from all site operations, is not exceeded.

2.2.2 Monitoring Objectives

The primary purpose of LLNL's air effluent sampling program is to measure radiological emissions at the point of release. In doing so, LLNL can demonstrate compliance with regulatory requirements and ensure protection of the public and the environment. In addition, sampling provides confirmation of the performance of emission control systems in place at facilities.

2.2.3 Sources and Analytes

Researchers at LLNL use a wide variety of radioisotopes for experimental purposes, including uranium and transuranic elements, biomedical tracers, tritium, mixed fission products, and others. The radionuclide with the greatest dose consequence released to the atmosphere from the Livermore site is tritium. In addition to effluent sampling for tritium, a number of facilities at the Livermore site have air effluent samplers to detect the release of uranium and transuranic aerosols. The air effluent sampling systems described in this chapter apply to stationary point-source discharges. Sampling methods to evaluate LLNL diffuse sources are described in Chapter 5.

To assess the need for monitoring air effluent discharge points, LLNL conducts evaluations of all operations having the potential to release radionuclides to the atmosphere. The evaluation is intended to demonstrate that LLNL is in compliance with 40 CFR 61 Subpart H section (b)(4) for the regulation of radionuclide emissions from DOE-owned or -operated facilities. Internal to LLNL, the Terrestrial and Atmospheric Monitoring and Modeling (TAMM) group in the Environmental Protection Department (EPD) is responsible for radiological NESHAPs evaluations and reporting. Results for the evaluation are contained in the current version of the *LLNL NESHAPs Annual Report*.

As a result of annual NESHAPs evaluations and the DOE ALARA policy, LLNL as of September 2004 operates 74 continuous samplers in 8 facilities at the Livermore site. Site 300 was also evaluated as part of this process and LLNL now operates a continuous sampler at a Site 300 facility. Implementation guidance on air effluent sampling is provided in the NESHAPs-cited American National Standards Institute (ANSI) N13.1-1969 and the revision ANSI/HPS N13.1-1999 and in the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991).

LLNL operations that have the potential to release non-radiological pollutants are currently not required to be monitored. Moreover, LLNL is not considered a major source of non-radiological pollutant emissions. However, permits for certain operations must be obtained from the local air districts responsible for enforcement, which are the Bay Area Air Quality Management District (BAAQMD) for the Livermore site and the San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD) for Site 300. The TAMM group of EPD is responsible for obtaining necessary permits and exemptions, maintaining permit records, and coordinating inspections.

2.2.4 Collection Methods

Elements of the radiological air effluent sampling systems that may affect the representativeness of sampling include the following.

- Sampling location and probe placement
- Extraction probe design
- Sample transport line
- Sample collector
- Degree of isokinetic sampling

Air effluent sampling locations must meet the requirements of 40 CFR 60, Appendix A, Reference Method 1 and is required by Subpart H (b)(2)(i) for particle sampling traverses. Because LLNL facilities were in place before the NESHAPs regulations became effective, meeting the requirement for a minimum of eight duct diameters downstream and two duct diameters upstream from any flow disturbance is not usually feasible. The alternative configuration of two duct diameters downstream and one-half diameter upstream from any disturbance, as allowed in Method 1 section 2.1, is required to be met for sampling systems that are compliant with NESHAPs.

To achieve representative samples, an extraction probe continuously removes a volume of air from the air effluent discharge duct. For those exhaust points where continuous sampling for aerosols is required, sample extraction probes have been designed, fabricated and installed to meet the (ANSI 1999) guidelines called for by Subpart H (b)(ii)(2). For continuous sampling systems in place prior to 2003, the extraction probes have been designed, fabricated and installed as grandfathered under the (ANSI 1969) guidelines. The ANSI 1969 extraction probes are sometimes multi-nozzled (i.e., air is withdrawn through nozzles at more than one point across the exhaust duct and joined into a collection manifold). For circular ducts, nozzles are located in equal concentric annular areas as per the guidelines. For rectangular ducts, more than one multi-nozzle probe may be used to provide adequate sampling coverage across the cross section of the duct. The extraction at multiple points helps ensure that representative sampling is attained even if particles are not evenly distributed across the cross section of the duct. For smaller circular ducts (less than 8 inches in diameter), only a single point nozzle extraction probe is used. Probes are positioned isoaxially in the exhaust duct and the probe nozzles have tapered edges. The extraction probes meeting the ANSI 1999 are single-point shrouded probes. Both ANSI 1969 and 1999 probes and nozzles are made of stainless steel so that no degradation is expected to occur under normal facility operations. Sampling is performed at temperature and humidity conditions similar to that in the facility.

The extracted air passes though a sample transport line and is delivered to the air samplers. In the particle sampling systems, particles in the extracted air are collected on 47-mm diameter membrane filters. Where feasible, the filter collectors are connected to the extraction probe immediately outside the duct to minimize the length of the sample transport line, and therefore, minimize particle loss in the transport line. Bends are also avoided or minimized because of associated particle losses in the transport line. Where bends cannot be avoided, they are made gradually to minimize particle deposition. The membrane filters are at least 98% efficient for the collection of particles at the sample flow rates used (Hoover and Newton 1991). For tritium sampling, tritium gas and tritiated water vapor are collected in molecular sieves (Ostlund and Mason 1974).

The ANSI 1969 guidelines for sampling radioactive aerosols also require that sampling be isokinetic. The ANSI 1999 allows for the option of either isokinetic or fixed-rate sampling. If sampling at fixed-rate, each probe is rated to sample at a specific flow up to a maximum stack velocity (e.g., a 2 CFM probe is compliant to stack velocities that do not exceed 15 m/s). Isokinetic sampling occurs when the sampler flow rate and extraction nozzle size are such that the velocity through the inlet nozzle is equivalent to the gas velocity in the duct being sampled. This ensures that a representative size distribution of the aerosol is being sampled. For the locations required to have continuous sampling, sample flow rate and extraction probe inlet nozzles have been designed and operate in a range from less than isokinetic to 100% isokinetic. Less than isokinetic sampling guarantees that sampling is conservative in the case where the aerosol distribution being sampled contains particles micron-sized or greater. LLNL has received approval from US EPA Region IX (US EPA 1994) to conduct less than isokinetic sampling.

2.3 Extent and Frequency of Monitoring and Measurement

2.3.1 Evaluation of the Need for Air Effluent Sampling

LLNL complies with radiological NESHAPs requirements by performing assessments on the need for new sampling locations. The assessments are performed by the TAMM group in EPD. Each assessment addresses LLNL air emission points and diffuse sources that have the potential to discharge radionuclides to the atmosphere. The potential EDEs to members of the public from these discharge points are calculated and used to determine if any additional monitoring is required.

2.3.2 Air Effluent Sampling Locations

The locations of facilities or buildings at the Livermore site and Site 300 that have air monitoring systems for radiological emissions are listed and updated regularly in EMP-AE-ESS, *Exhaust Stack Samplers.* EMP-AE-ESS also lists the number and type of samplers; identifies the type of EPA-required sampling or sampling for best management practice; includes requirements for quarterly checks, calibration, and maintenance; and includes procedural and applicable ANSI guidelines.

Since the last revision of the *Environmental Monitoring Plan*, sampling has been discontinued at two facilities, Buildings 175 and 177, because there no longer is active work with or inventory of radionuclides at those buildings. Two air monitoring systems have been added at the Decontamination and Waste Treatment Facility (Building 695), which has begun operations with radionuclides.

2.3.3 Low-Volume Ambient Air Samplers

Two special low-volume ambient air sampling systems support the air effluent sampling network. These samplers are co-located with high-volume environmental surveillance air samplers at the FCC and HOSP sampling locations shown in Figure 4-2. These locations are generally upwind of the Livermore site and are used to establish background levels of gross alpha and gross beta activity for comparison to results from the air effluent samplers monitoring facility discharge points. These special sampling systems are very similar to the air effluent samplers, including sampling system design, sampler operation, sample tracking, sample analysis, and results processing.

2.3.4 Periodic Confirmatory Measurements

In addition to continuous air effluent monitoring, LLNL conducts periodic sampling measurements at selected potential radiological effluent locations where continuous sampling is not specifically required by the radiological NESHAPs regulations. This periodic sampling is required by the NESHAPs regulations to confirm that alternative methods used to evaluate emissions and calculate resultant doses are conservative. The extent and frequency of these measurements are not specified in those regulations. The TAMM group in EPD annually reviews candidate operations for this type of sampling, makes arrangements with LLNL program personnel, and samples exhausts during active operations on a case-by-case basis. The method for determining which discharge points will be measured and the techniques used to carry out the measurements can be found in EMP-AE-PCM, *Air Effluent Periodic Confirmatory Measurements*. Resulting data are reported in the annual NESHAPs report.

2.3.5 Effluent Flow Rate Measurement

To determine the annual emissions, both the concentration of radiological constituents in the discharge as determined by the continuous sampling systems and the effluent volume from a discharge point must be known. The effluent flow rate from all discharge points having continuous sampling systems is determined by EPA-approved methods (40 CFR 60). At most facilities, periodic measurements of stack flow velocity are made using hot-wire anemometers or pitot tubes. Effluent volume is then calculated from the periodic flow rate measurements. At the other facilities, continuous measurements of stack flow rates are made using permanent electronic velocity, or mass flow, probes. These locations are listed in EMP-AE-ESS*, Exhaust Stack Samplers*. Stack flow rate is measured every few seconds and the average rate is calculated and recorded every two hours. Effluent volume is calculated by integration of these data over time.

2.4 Procedures for Laboratory Analysis

Air effluent samples are processed and analyzed by the Hazards Control Department (HCD) Radiation Measurements Laboratory (RML) and Hazards Control Analytical Laboratory (HCAL).

2.4.1 Sample Preservation and Handling

Filter samples taken from field locations are first stored in glassine bags before being routed to the HCD HCAL or RML. No special preservation techniques are necessary for air effluent samples. The molecular sieve samplers are sealed. Prior to submission of samples to the HCD laboratories (HCAL and RML), they are logged into the HCD sample tracking and receiving (STAR) computer system by EPD environmental monitoring technologists or by HCD health & safety technicians. Information provided at login includes field identification number, origin, sample type, the start and stop date/times, and the required analyses. Samples received by HCAL and RML are stored in a specially designated area that includes separate storage for incompatible samples and for volatile or unstable compounds. All personnel delivering samples to the HCD laboratories are trained in contamination control and taught to segregate any samples with potentially unusual activity.

2.4.2 Analytical Methods

Methods used for the analysis of air effluent samples conform to the requirements of 40 CFR 61, Appendix B Method 114, specifically:

- Method A-4 for gross alpha determination
- Method B-4 for gross beta determination
- Section 3.5.1 for alpha counting using gas flow proportional counters
- Method B-5 for beta counting by scintillation counters

Gross alpha and gross beta activity from particles collected on air filters is detected with gas flow proportional counters. Samples are not analyzed until at least four days after sampling to allow for the decay of naturally occurring radon daughters. To verify the operation of the counting system, calibration sources as well as background samples are intermixed with the sample filters for analysis. Laboratory blanks constitute at least 10 % of analyses and serve as indicators of cross-contamination within the counters. Sample handling, equipment operation, and calibration are performed according to RML procedures documented in the *Radiological Measurements Laboratory Gross Alpha-Beta Procedures Manual* (HCD 2000a).

Molecular sieves for tritium collection are prepared for counting by the HCAL. The sieves are installed in a recovery system where tritiated water is baked out and collected in cold traps according to a written procedure, *Recovery of Tritiated Water from Molecular Sieve Stack Samples* (HCD 2000c). The water collected is forwarded to the RML, where the samples are counted by liquid scintillation techniques (*Liquid Scintillation Counting Procedures Manual)* (HCD 2000b).

2.5 Data Quality Assurance

The quality assurance parameters that are applicable to the NESHAPs program at LLNL are accuracy, precision, and completeness as defined in paragraph 4.4 of Appendix B 40 CFR 61 Subpart H.

2.5.1 Precision

Precision is typically evaluated by assessing the degree of similarity of analytical results from replicate and/or co-located samples. Continuous stack sampling does not readily lend itself to either type of sample, and a direct measurement of the precision of air effluent samples is not available. However, limited indirect data indicate that reasonable precision of air effluent samples is achieved. One of the eight facilities monitored has a co-located continuous filter sampler, and results are regularly reviewed. Further, specific consideration is given to the number of samples above the limit of sensitivity (LOS) for each sampling period and measurement method.

2.5.2 Accuracy

Accuracy can be affected by the degree of representative sampling, maintenance and calibration of samplers, calibration of analytical equipment, and agreement of analytical results with data from standards. Air effluent sampling system design conforms to specifications for continuous sampling systems given in ANSI (1969, 1999) and in 40 CFR 61 Subpart H. Specifically, all required air effluent sampling systems in monitored facilities meet the design specifications, location and sample probe placement criteria, and degree of isokinetic sampling as applicable to the appropriate ANSI. Operating parameters of the samplers are checked weekly or biweekly, and samplers are calibrated annually and samplers with electronic mass flow meters have a quarterly calibration check as stated in EMP-AE-ESS*, Exhaust Stack Samplers*.

The accuracy of sample analytical results is determined by comparison of samples to known concentrations of analytes. Matrix spikes (i.e., samples prepared in the matrix of interest with NIST-traceable standards) are used by the RML in their analyses of tritium. Sample batches of tritiated water, and filters analyzed for gross alpha and gross beta activity include numerous other analytical standards. Custom data reduction and report generation software automatically compares pre-determined control limits for analytical standards against the sample values obtained in each analytical run. Procedures are in place to prevent the release of analytical data that do not meet QC standards.

2.5.3 Completeness

Within the context of NESHAPs compliance, completeness applies both to sampling systems and to laboratory analyses of environmental samples. For the continuous stack samplers, TAMM requires 80 percent completeness of sample collection. That is, over all monitored facilities, samplers must be operational for at least 80 percent of the sampling period. With respect to laboratory analyses, TAMM requires that 90 percent of the samples submitted to, and analyzed by, the HCD laboratories yield valid data. If these completeness criteria are not met, non conformance reports are prepared according to the procedure ORAD-QA-NCR*, Nonconformance Reporting and Tracking*, and the issue(s) resolved with the Facility, program, and/or analytical laboratory.

2.5.4 Calibration

Equipment in the HCAL and the RML is calibrated with sources that are traceable to National Institute for Standards and Technology (NIST). Calibration follows a variety of methods from calibration by a certified third party (as is done for laboratory balances), to calibration with known standards that are made from traceable materials (as is done for metals and most radiological analyses). Calibration practices are in accordance with standard procedures and are evaluated during audits required for maintenance of certifications.

The HCD Radiological Materials Laboratories are part of LLNL's calibration program. Calibration records are maintained for each piece of calibrated equipment.

2.6 Program Implementation Procedures

EPD is responsible for the LLNL air effluent monitoring program; however, implementation of the program relies strongly on participation by facilities, programs, and HCD.

2.6.1 Air Effluent Sampling

Instructions for the collection and replacement of air effluent samples for radionuclides performed by the ES&H Team health & safety technician assigned to the facility are described in the environmental discipline action plan (DAP) for the facility. The DAP specifies the frequency of sample exchange, bar coding of the sample, delivery to the HCD laboratory for analysis, and the analytes for assay. The TAMM environmental analyst is responsible for the drafting and revision of the ES&H field support instructions for air effluent sampling and ensuring that the instructions are implemented by the ES&H Team health and safety technician.

The operation and maintenance of the two special low-volume ambient air samplers is performed by the TAMM environmental monitoring technicians. The procedure that describes this activity is EMP-AP-LV, *Low-Volume Radiological Air Particulate Sampling*.

Analytical results of the air effluent samples and low-volume samples are reported to the responsible environmental analyst in TAMM. Air effluent results are also retained in the air effluent database in ORAD. The procedure EMP-AE-DAM, *Air Effluent Data Analysis and Management*, describes the methods used to manage and analyze the data.

2.6.2 Effluent Flow Measurement, Calibration, and Maintenance

Effluent flow is determined by measurement of the velocity of the effluent exiting a discharge point and its cross-sectional area. The procedure EMP-AE-SF*, Air Effluent Stack Flow Measurement,* describes the methods used to measure gas velocity and the calculation of flow rate from a discharge point. At exhaust points having permanent mass flow probes, calibration of the probes is performed in accordance with the procedure EMP-AE-MFC*, Air Effluent Stack Mass Flow Probe Calibration*. Data from the mass flow probes are recorded on electronic data cards in the field. The procedure EMP-AE-SFDR*, Air Effluent Stack Flow Data Retrieval,* provides detailed instructions for downloading data from the electronic data cards. Quarterly flow checks of the mass flow calibration are described in EMP-AE-QFC*, Air Effluent Quarterly Flow Check.* Stack sampling systems equipped with electronic mass flow samplers have quarterly flow checks as described in EMP-AE-QSC, *Quarterly Sampler Check.* The annual maintenance with inspection of stack sampling systems is described in EMP-AE-AMI, *Annual Maintenance and Inspection.* Effluent flow measurement, probe calibration, and data retrieval from the mass flow probes is the responsibility of EPD’s TAMM group.

2.7 Action Levels

For particulate monitoring, the HCD health physicist for the affected facility is notified immediately by RML in cases where gross alpha activity concentration in the air effluent from a discharge point exceeds 3.7×10^{-3} Bq/m^3 (1×10^{-13} µCi/mL) or the gross beta activity exceeds 3.7×10^{-1} Bq/m^3 (1×10^{-11} µCi/mL). Such cases may warrant further investigation of the sample, such as verification of location, sample volume, comparison with past data, reanalysis, and identification of the specific radionuclides present.

In addition, the EPD TAMM group has established a notification level for the gross alpha and beta activity concentration as measured by the air filter samplers. The level is based on a dose to a member of the public receiving 1 mrem/y, or 10 % of the NESHAPs regulatory standard, assuming that the level was released throughout the entire year. Since the estimation of dose is dependent on many parameters, not the least of which is the radiological material having the potential for emission, conservative assumptions were made and resulted in a notification levels for gross alpha and beta activity of 3.7×10^{-3} Bq/m^3 (1×10^{-11} µCi/mL) and 3.7×10^{-1} Bq/m^3 (1×10^{-9} µCi/mL), respectively. For air filter samples having confirmed results greater than these concentrations, the analyst and the facility management are notified. If consecutive results continue to be above the notification level, the analyst works with the facility and the health physicist to determine the source and possibly implement better controls.

In addition to the action levels in place at the facility, the EPD TAMM group notifies EPD and Building 331 management if stack emissions exceed 3.7×10^5 Bq/m^3 (1×10^{-5} µCi/mL) as measured by the molecular sieve samplers. This action level is based on a dose to a member of the public receiving 1 mrem/y or more, assuming emissions at or above the notification level continued for the entire year. As with particulate emissions, if results continue to be above the action level, EPD works with the facility to determine the source.

2.8 Preparation and Disposition of Reports

The TAMM group is responsible for the reporting of air effluent radionuclide emissions. Radionuclide emissions are reported in the annual *Environmental Report* and in the *LLNL NESHAPs Annual Report* to DOE and EPA, respectively. Additionally, the *LLNL NESHAPs Annual Report* includes the estimated potential emissions from all facilities whose operations have the potential to release radionuclides to the atmosphere; and hence, it documents if there is need for additional effluent sampling systems. Because tritium emissions from the Tritium Facility are the major source of atmospheric radionuclide releases, a summary report of emissions is provided to the Tritium Facility manager quarterly from the TAMM environmental analyst.

2.9 Future Plans

In the near future, the EPD TAMM group will continue to monitor the air effluent in the manner described in this chapter.

Air samplers in some locations at Building 251 are scheduled for deactivation and are currently sampling from ventilation systems that are no longer in use or that exhaust work areas where radiological materials are no longer used or stored. In fact, Building 251 is scheduled for future demolition when decontamination and decommissioning activities are completed. This is currently scheduled for 2007.

TAMM will continue to review the need for air effluent sampling from all facilities including new facilities and existing facilities having new and/or modified operations.

2.10 References

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3 Meteorology

Brent M. Bowen

3.1 Introduction

The Lawrence Livermore National Laboratory (LLNL) uses meteorological data to demonstrate compliance with federal, state, and local laws, regulations, and orders. U.S. Department of Energy (DOE) directives require LLNL to collect sufficient meteorological data to assess the potential or actual impact from toxicological or radiological material releases on the environment and the public. Onsite meteorological monitoring is required to accurately assess the transport and diffusion of airborne materials and the impacts of such planned and unplanned airborne releases on public health.

Meteorological monitoring is part of a comprehensive and continuous environmental program at Lawrence Livermore National Laboratory (see Chapter 1).

3.2 Rationale and Design Criteria

3.2.1 Regulatory Drivers

The regulatory drivers for meteorological monitoring are the applicable portions of DOE Orders 450.1 and 151.1B. DOE Order 450.1 requires that environmental monitoring programs be able to ensure compliance with all applicable regulations and to confirm adherence to DOE environmental protection policies. DOE Order 151.1B provides the framework for maintenance and development of all emergency planning, preparedness, readiness assurance, and response and recovery for the DOE Emergency Management System. The requirements for meteorological monitoring are discussed in Volume IV, Program Elements (2) of DOE Order 151.1B. These orders and the associated regulatory guide, EH-0173T (DOE 1991) require that each DOE site have a meteorological program that should provide the data used in atmospheric transport and diffusion calculations appropriate to the site’s activities, topography, and distance to critical receptors. Furthermore DOE Guide 151.1-1 indicates that real-time meteorological data must be available to assess adequately the actual or potential onsite and offsite consequences of an emergency.

Meteorological monitoring data are also required to demonstrate compliance with the *National Emissions Standards for Hazardous Air Pollutants (NESHAPs*), 40 Code of Federal Regulations (CFR) 61 Subpart H. Subpart H requires DOE sites to have onsite programs that can provide the data (including meteorological data) used to model the required radiological dose calculations.

Off-site meteorological data, such as the data collected at National Weather Service (NWS) stations, may be used if the meteorological conditions at the NWS station are similar to on-site conditions. However, meteorological conditions at the observing station closest to the Livermore site (i.e., the Livermore Airport) do not always accurately represent dispersion conditions at the Livermore site and especially at Site 300. Moreover, the Livermore airport typically reports data only once an hour and occasionally reports are missing. For these reasons LLNL employs meteorological monitoring systems at both the Livermore site and Site 300.

3.2.2 Monitoring Objectives

The primary purpose of LLNL's meteorological monitoring is to assess the potential consequences of projected airborne releases of contaminants from new or modified facilities as well as the consequences of actual accidental releases. In doing so, LLNL can demonstrate compliance with regulatory requirements, provide onsite data for the most accurate atmospheric transport and dispersion modeling, and ensure protection of the public and the environment. In addition, the monitoring provides supports facility design, worker safety, and general LLNL operations.

DOE Guides 420.1-1 and 420.1-2 describe the use of meteorological data to aid in identifying conditions that may influence the design and operation of a facility and in mitigating natural phenomena hazards, such as strong winds, hurricanes, tornados, hail, lightning, and snow. Temperature and humidity data can be used to plan efficient air conditioning and space heating of proposed facilities.

Various projects require meteorological monitoring and they should not be expected to re-create the monitoring systems currently in place at LLNL. Therefore, it is good business practice for LLNL to centralize ambient meteorological monitoring and make the data available to all. Several DOE orders and guides suggest some of the possible uses for meteorological data. DOE Order 4320.1B encourages facility personnel to utilize onsite meteorological data in site development planning.

Examples of other data used in laboratory operations include temperature, humidity and wind to support fire-fighting operations; wind speed data to curtail many operations during windy periods including use of cranes, construction activity, etc.; calculation of predominant wind directions to strategically site monitors downwind of potential releases; daily and seasonal temperatures to estimate the electrical load of individual buildings and the site as a whole; discomfort indexes based on measured temperature and humidity to manage or limit physical work outside during the summer season; relative humidity to assist in determining the amount of evaporation from a chemical pool; rainfall data are used to support hydrological monitoring and studies, environmental sampling, and in atmospheric dispersion models to estimate washout from toxic plumes; and atmospheric pressure is used as an input for experiments and instrumentation. LLNL's meteorological database includes expected annual ranges and distributions of wind direction and wind speed, temperature, humidity, solar and infrared radiation, stability, rainfall and other variables.

3.2.3 Sources and Analytes

3.2.3.1 General Pattern of Wind

The wind at both the Livermore site and Site 300 is strongly influenced by the sea breeze (Gouveia and Chapman 1989). The wind comes from the southwest and west quadrants more than 50 percent of the time. This surface flow pattern can be enhanced or weakened by large-scale, upper-air circulation. The meteorology at Site 300, while generally similar to the Livermore site, is modified by the higher elevation, the greater distance from the ocean, and the greater topographical relief. At the higher Site 300, winds are stronger with less directional variation: winds blow from west-southwest through west and northwest through north-northwest for nearly 45% and 25% of the time, respectively.

During the summer, differential heating between the ocean and land produces afternoon winds that generally are stronger than morning and nighttime winds at both sites. A strong, upper-air, high-pressure circulation frequently occurs, suppressing convection and formation of clouds. The result is warm, dry weather during the summers with a persistent diurnal cycle of winds.

Because differential heating is less in winter than in summer, the sea breeze in winter is less pronounced. The winters commonly feature long periods of weak winds separated by short episodes of strong winds that are associated with winter storms. The winds are generally from the south to southwest during storms and from the northwest to north after storms pass. During the periods of weak, synoptic-scale winds, cold air drainage may occur during the night. The cold air that reaches the Livermore site is drained from the slightly higher elevation toward the southeast.

3.2.3.2 Measured Variables

Dataloggers using accurate time continuously measure wind direction and speed, temperature, relative humidity, precipitation, solar radiation, atmospheric pressure, and vertical wind speed at both tower sites (one each at the Livermore site and Site 300). The wind direction, wind speed, and vertical velocity are measured at one level at Site 300 and at two levels at the Livermore site, offering redundancy. Temperatures are also measured at the same levels as the winds and at the 2-m level along with relative humidity. Additional measurements at the main site include reflected solar radiation and net infrared radiation (allowing net radiation calculation), soil temperature, moisture, and heat flux.

All meteorological instruments must be capable of continuous operation in the expected range of atmospheric conditions at the Livermore site and Site 300. Because of the relatively mild weather conditions in the Livermore area, most meteorological instruments that are designed for routine measurement meet this requirement. Sensors installed at Site 300, especially anemometers, must be checked frequently because of more frequent strong winds at the site.

3.2.3.3 On-site Dispersion Modeling

LLNL uses EPA-approved dispersion models for compliance with NESHAPs Subpart H. The meteorological input to the regulatory model CAP88-PC, developed by EPA's Office of Radiation Programs (Parks 1992), includes joint-frequency tables of wind direction, wind speed, and stability, average wind speed for each combination of wind direction and stability class, mixing layer depth, average annual air temperature, and annual rainfall. LLNL has computer programs that transform a year of data from the archive into the tables that are used as meteorological input to the CAP88-PC code. An average mixing depth is estimated for both the main site and Site 300.

The real-time availability of the meteorological data is critical in estimating the transport and dispersion of toxic material released into the atmosphere. In the case of accidental air releases, the LLNL Emergency Operations Center (EOC) and the Hazards Control Department (HCD) and the Environmental Protection Department (EPD) Operations Support Centers (OSCs) are equipped to apply simple straight-line Gaussian models such as HotSpot (Homann 1994) or EPICode (Homann 1988) for releases of radionuclides or toxic chemicals, respectively. For more sophisticated modeling, the National Atmospheric Release Advisory Center (NARAC) dispersion models (ARAC; Sullivan et al. 1993) can be executed in order to account for the varying terrain, time- and space-varying meteorological data, and more detailed plots. The Livermore site and Site 300 towers are incorporated automatically in the NARAC models along with the nearby Sandia tower and other regional observations.

In addition to using simple straight-line Gaussian models using annual winds or frequency distributions, NARAC models (Nasstrom et al. 2000) are now being used by LLNL to calculate annual depleted uranium exposures at Site 300 from several annual explosive tests in order to determine monitor locations. Archived data from only one tower is used as input to the Gaussian models while the NARAC modeling system automatically acquires and incorporates the Site 300 tower data and other regional meteorological data as well.

3.2.4 Collection Methods

Meteorological instruments in use at LLNL are specified in procedure EMP-M-MCA, *Meteorological System Maintenance and Sensor Calibration.* The horizontal wind sensors currently used are cup-and-vane style, the vertical wind sensors are propeller anemometers, the temperature sensors are precision thermistors, the relative humidity instruments use variable capacitance thin film technology, the solar and infrared radiometers are thermopile detectors, and the rain gauges are tipping buckets. A 3-D sonic anemometer with no moving parts makes precision wind and turbulence readings at the 10-m level of the Livermore site. The temperature sensors are housed in fan-aspirated radiation shields. These shields are adequate for measuring absolute temperature and vertical temperature differences, provided a sufficiently accurate sensor is used. At the Livermore site, wind measurements are made at the standard height of 10 m and additional measurements are made at a height of 40 m to evaluate releases from stacks. At Site 300 wind measurements are made close to an 8-m height. Temperatures are measured at the 2-, 10-, and 40-m levels and at a depth of 4 cm in the soil at the Livermore site and at the 2- and 8-m heights at Site 300. Relative humidity is measured at the 2- and 10-m levels at the Livermore site and at the 2-m level at Site 300. Other humidity variables (dew point, absolute humidity, etc.) can be calculated using simultaneous temperature measurements. The use of two humidity sensors at the Livermore site together with the measured temperatures can be used to estimate evaporation.

Incoming solar radiation is measured at both tower sites, with reflected solar radiation and incoming and outgoing infrared radiation also measured at the Livermore site, allowing estimation of net radiation. Net radiation is important in estimating stability and turbulence in the lower atmosphere. All radiation sensors are in locations free of any obstruction to the measurement and away from light-colored walls or artificial sources of radiation.

Both the Livermore site and Site 300 systems include rain gauges. These gauges are mounted on stable platforms and are adjusted so that their openings are horizontal. They are at least 30 cm above the ground to prevent surface water splash into the gauges and are shielded from the wind.

Barometers are deployed at both sites. The inlet port of the barometer is protected from wind effects. The barometer measures actual pressure to allow the most accurate calibration. Actual pressure is preferred to allow LLNL personnel to directly use pressure data without conversion. A pressure reading reduced to sea level (RSL) is also estimated in the datalogger to allow comparison with regional RSL reports.

Other instruments at the Livermore site include vertical propeller anemometers at the 10- and 40-m levels to estimate vertical wind fluctuations (turbulence); a sonic anemometer that can estimate vertical heat flux and more accurate estimates of wind speeds and wind fluctuations at low wind speeds; a reflectometer that estimates soil moisture; and a heat flux plate that estimates vertical heat transfer in the soil.

Based on guidance in meteorological data collection, processing, and archiving (Crutcher 1984; EPA 1990), LLNL's meteorological system provides 15-minute averages of all measured quantities to dispersion models used in emergency response capability, environmental regulations, and safety analysis. Instruments are polled at least 450 times over the 15-minute averaging-period to provide adequate statistical representation of conditions.

Meteorological data are available in real-time on the LLNL Weather Pages web site. Real-time meteorological data is collected and can also be viewed on the personal computers in the HCD OSC and the TAMM Group of EPD. An emergency power backup system at the HCD OSC allows data collection and viewing in case of a temporary power outage or a problem with the web pages or the LAN.

A Laboratory meteorologist or environmental analyst reviews the data every working day. Files of 15-minute averages are saved in the two personal computers that receive the data, the web page database, and on the meteorologist's computer. In addition, the dataloggers can store 15-minute data for a year. Each line of 15-minute averages is uniquely identified with the site code, year, month, date, and time. Each month, meteorological data are transferred from the personal computer that downloads the data to the meteorologist's computer and further data inspection, reduction, and analyses are performed.

The 15-minute averages are combined into hourly averages, following guidelines in Section 6 of *Meteorological Monitoring Guidance* (EPA 2000). The hourly averages are used to summarize local climatology data and provide hourly frequency of occurrence tables of dispersion parameters or actual hourly values input to dose models. One-hour averages of all measured quantities are generally considered adequate to assess the consequences of potential releases and to demonstrate compliance with regulatory requirements.

A 48-hour battery backup ensures continuous operation of the NARAC site system computer so that it will receive data from the meteorological towers even if power is lost. Although lightning storms are infrequent at both sites, the meteorological tower and associated systems at the Livermore site are protected from lightning strikes with grounding spikes. Other phenomena that could deteriorate performance, such as icing and sea spray, are not problems at either the Livermore site or Site 300.

Every 15 minutes, LLNL meteorological data received by the personal computers are accessed and transferred to a parallel database on a fileserver. An HTML script developed by LLNL makes the information available to end users on the World Wide Web at the address *http://www-metdat.llnl.gov/*. Data from towers at the Livermore site, Site 300, and Sandia/California are continuously available via the Weather Pages web site (*http://www-metdat.llnl.gov/*) at the EOC and OSCs for input to local and the LLNL's NARAC transport and dispersion models.

3.3 Extent and Frequency of Monitoring and Measurement

3.3.1 Locations of Monitoring Sites

Important considerations in choosing a meteorological monitoring site include siting and exposure of meteorological instruments and towers (EPA 2000), local conditions, and obstructions. Meteorological monitoring sites should be located in areas that have atmospheric conditions similar to those into which any material potentially would be released. The monitoring location should be away from the influence of manmade and natural obstructions, such as buildings and trees. The onsite meteorological towers at the Livermore site and at Site 300 have been located with these considerations in mind. The locations of the Livermore site and Site 300 meteorological towers are shown in Figure 3-1 and Figure 3-2, respectively.

To minimize the tower's influence on wind measurements, wind and temperature instruments have been mounted on booms extending more than two tower widths from the side of the meteorological tower. They are mounted on the west side of the tower, facing the prevailing wind.

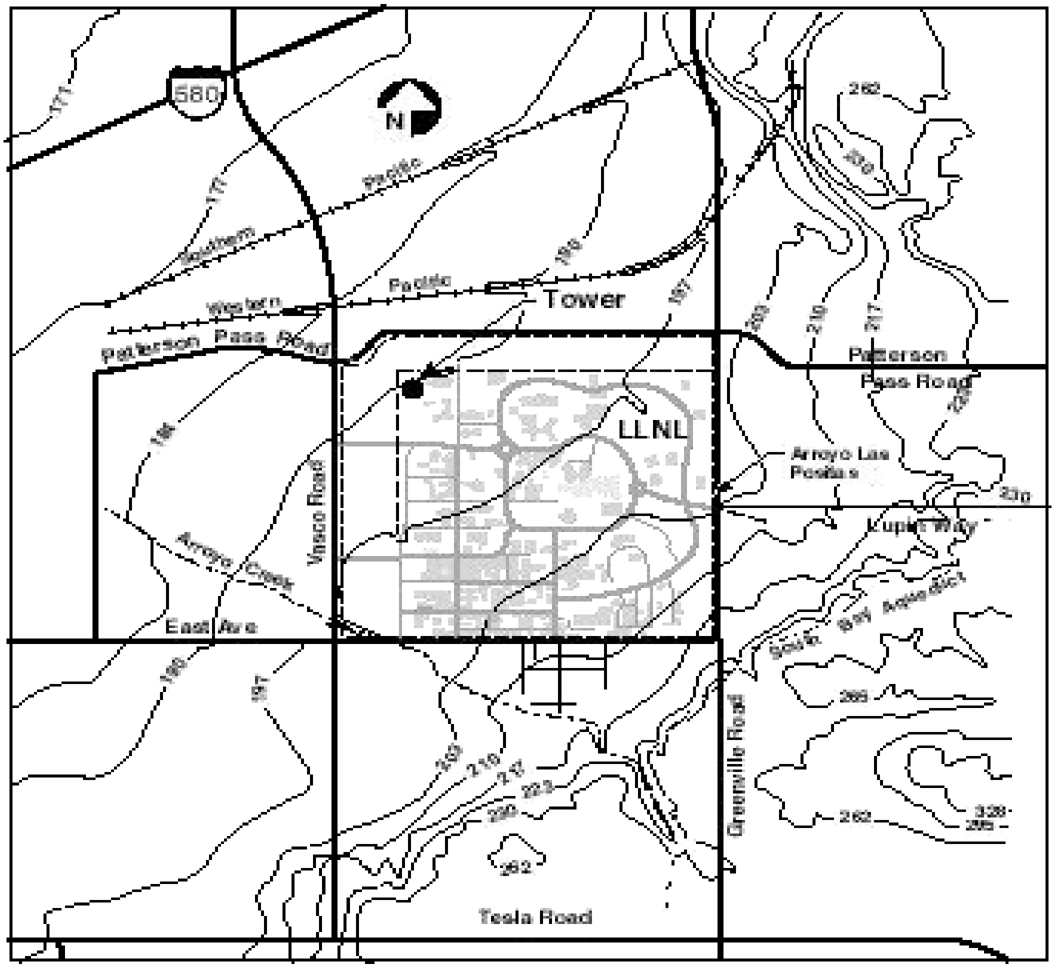

Figure 3-1. Location of the Livermore site meteorological tower

3.3.2 Frequency of Sampling

The data loggers at the meteorological towers sample all instrumentation at the shortest, practical time interval. This interval is 2 seconds at the Livermore site and 1 second at Site 300 for all instruments. This rate results in 15-minute sample sizes of 450 and 900 at the Livermore site and Site 300, respectively, which are large enough to estimate means to within at least ± 5%. The sampling rate does not apply to rainfall that is measured by total number of tipping events in the gauges.

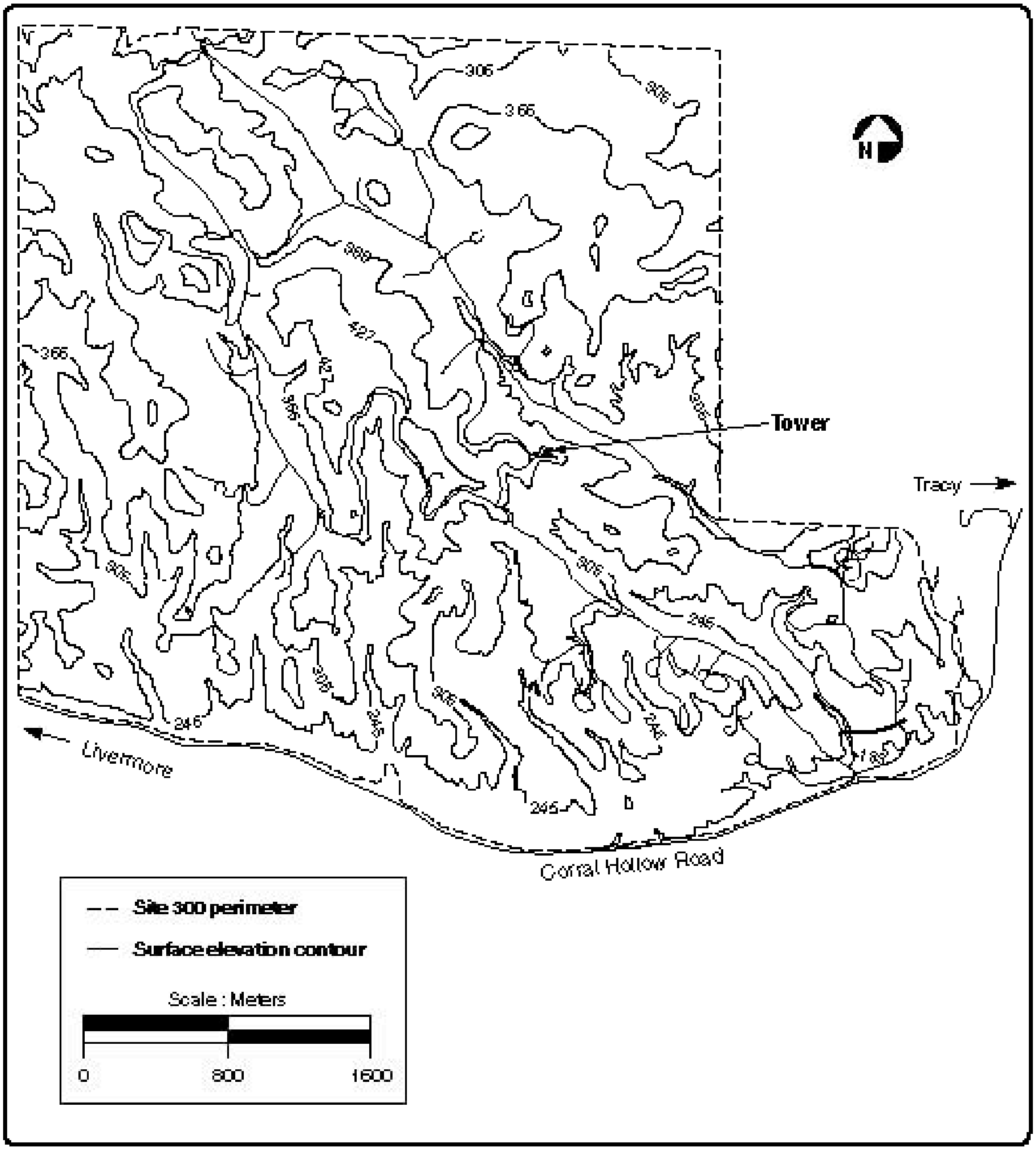

Figure 3-2. Location of the Site 300 meteorological tower

The time period represented by the averages should not be less than 10 minutes (EPA 2000); the LLNL data loggers collect 15-minute averages of all meteorological parameters as recommended by DOE (1991). This period is long enough to give good estimates of both mean and turbulence quantities during fairly steady conditions, yet it is short enough to provide adequate frequency during periods of changing conditions for emergency response dispersion modeling. The time associated with each 15-minute average is the ending time in PST. The loggers' averaged values are saved for automatic retrieval, which is conducted within minutes after the sampling period.

3.4 Data Analysis Discussion

3.4.1 Computed Parameters

Several useful parameters can be computed from the meteorological data, including stability, diffusion coefficients and boundary layer parameters. Atmospheric stability is important in order to characterize the horizontal and vertical spread of the plume that in turn determines plume concentrations or exposure. LLNL uses the solar radiation-delta T (SRDT) method recommended by the EPA (2000) to estimate stability at both the Livermore site and Site 300 towers. Daytime stability is estimated based on incoming solar radiation (measured by a pyranometer) and wind speed at the 10-m level. Nighttime stability is estimated from 10-m level wind speed and the difference in temperature between the 2-and 10-m levels (□T).

Other derived parameters from measurements include $\square_{\square}$ and $\square_{\square}$, the standard deviations of horizontal and vertical wind fluctuations. These turbulence coefficients indicate the amount of horizontal and vertical turbulence and are directly related to the expected downwind plume spreading. The turbulence coefficients can be used to estimate the dispersion coefficients ($\square_y$ and $\square_z$), used to quantify the spread of plumes in Gaussian and trajectory models. Alternatively, the dispersion coefficients can be estimated from the atmospheric stability class and from the time that has elapsed since a release. Gifford (1976) and Hanna et al. (1977) discuss various methods for determining dispersion coefficients and Draxler (1976) discusses the direct use of measured $\square_{\square}$ and $\square_{\square}$ to more accurately estimate $\square_y$ and $\square_z$.

Calculating boundary-layer parameters, such as sensible and latent heat flux, requires accurate temperature and wind speed measurements taken at multiple levels. These parameters are related to atmospheric stability, temperature tendency, soil moisture flux, and mixing depth among others. The sonic anemometer and two levels of accurate hygrometers at the Livermore site output data to estimate sensible and latent heat flux, respectively. In addition, a ground heat flux plate and soil moisture sensor just under the soil surface output data at the Livermore site to estimate ground heat flux.

Other hygrometric parameters, such as dew point temperature and absolute humidity, are calculated from LLNL meteorological data based on air temperature and relative humidity. These parameters are useful when planning efficient air conditioning and space heating of proposed facilities, monitoring heat stress on workers, and as input to atmospheric dispersion models.

3.4.2 Wind-Rose Diagram

The wind-rose diagram displays the frequency of winds coming from 16 compass directions and also retains information on the frequency of wind speed in each sector. Often at low winds, especially at night, wind direction becomes highly variable. At wind speeds lower than the starting threshold of the wind vane, the wind direction value is meaningless. At that time, the wind is considered to be calm, and the wind direction is undefined. Wind speeds below the 0.22 m/s (0.5 mph) starting threshold of wind vanes and anemometers occur during nighttime periods at the Livermore site but they rarely occur at the windier Site 300. Even when light winds exceed the instrument starting threshold, wind directions detected at speeds below 0.5 m/s (~ 1 mph) or so are associated with large spatial and temporal changes in wind direction, thereby limiting their significance in transport and dispersion.

3.5 Data Quality Assurance

LLNL maintains a quality assurance (QA) program for its meteorological stations that meets the performance requirements set by DOE and EPA. Regulatory drivers for quality assurance of LLNL's monitoring programs come from DOE Order 414.1B. The primary guidance for quality assurance of LLNL's meteorological monitoring program is contained in the comprehensive EPA document prepared by Thomas Lockhart (EPA 1990). LLNL's meteorological monitoring also reflects the guidance for assessing the validity of meteorological data and the accuracy of meteorological measurement systems contained in Volume IV of EPA's *Quality Assurance Handbook for Air Pollution Measurements* (EPA 1990).

Regular and frequent routine operational checks of the monitoring system are performed to ensure high data-retrieval rates. These include visual inspections of the instruments for signs of damage or wear, inspections of the recording devices to ensure correct operation and reasonableness of data, and periodic preventive maintenance measures. The latter includes periodic checks of wind speed and direction bearing assemblies, cleaning of aspirated shield screen in temperature systems, clearing the precipitation-gauge funnel of any obstructing debris, and frequent cleaning of the optical surface of the radiometers.

A meteorologist reviews the meteorological data at least once every working day. Periods of missing data are noted and investigated. The EPD database automatically checks the reported values for reasonableness and proper format, and compares captured values with expected values or a range of values. The limits used in the screening test are based upon historical data or physically realistic values. Another screening test, called the rate of change test, compares the difference between data of adjacent time periods. Table 3-1 lists meteorological data screening criteria.

Table 3-1. Meteorological data screening criteria

Meteorological variable	Screening criteria: flag the data if the value
Wind speed	• is less than zero or greater than 20 m/s • does not vary by more than 0.1 m/s for 3 consecutive hours • does not vary by more than 0.5 m/s for 12 consecutive hours
Wind direction	• is less than zero or greater than 360° • does not vary by more than 1° for more than 3 consecutive hours • does not vary by more than 10° for more than 18 consecutive hours
Temperature	• is greater than the record high • is less than the record low • is greater than a 5°C change from the previous hour • does not vary by more than 0.5°C for more than 12 consecutive hours
Vertical temperature difference	• is greater than 0.1°C/m during the daytime • is less than –0.1°C/m during the nighttime
Precipitation	• is greater than 0.1 in. (2.5 mm) in 15 minutes • is greater than 1 in. (25 mm) in 1 hour • is greater than 4 in. (100 mm) • is less than 2 in. (50 mm) per month during the rainy months
Solar radiation	• is greater than zero at night • is less than zero at any time • is greater than the maximum possible for the date and latitude

Selected data are compared to other available, reliable data. Data and averages are thoroughly scanned for quality and consistency at the end of each month. Variables measured at more than one level are compared within the month and with the same month in years past. Monthly averages and diurnal variations during the month are examined.

Major problems with the meteorological instruments or data are noted in nonconformance reports (NCRs). Appropriate procedures are followed to alleviate the problem, and the NCR is concluded with an explanation of the corrective action taken. Brief periods of questionable data are deleted from the record. Replacement of questionable data is done carefully and only when large blocks of contiguous data are involved. When available, data from another level of the same tower may be used with the proper adjustments for the magnitude of the wind speed or temperature.

All uses of the meteorological database comply with EPA guidance established in *Guideline for Fluid Modeling of Atmospheric Diffusion* (EPA 1981), *Ambient Air*

Monitoring Guidelines for Prevention of Significant Deterioration (EPA 1987), and *Meteorological Monitoring Guidance for Regulatory Modeling Applications* (EPA 2000).

3.5.1 Accuracy

The accuracies of the monitoring measurements should be consistent with the specifications set forth in either:

- Guidance provided by EPA
- American National Standard for Determining Meteorological Information at Nuclear Power Sites, ANSI/ANS-3.11-2000, published by the American National Standards Institute (ANSI 2000).

The standards in the EPA guidance are usually similar to or stricter than those found in ANS-3.11. Because of EPA guidance and the large frequency of wind speeds below 0.5 m/s at the Livermore site, a more stringent anemometer specification for starting speed of less than 0.22m/s is used. Low wind speed threshold wind instruments (vane and anemometer) are also used at Site 300. The instruments in use at both the Livermore site and Site 300 meteorological towers meet or exceed the performance standards of accuracy identified in Table 3-2.

Table 3-2. Standards of accuracy of meteorological parameters

Parameter	Standard of accuracy
Wind direction	±5° azimuth with a starting threshold of 0.5 m/s. The delay distance[a] must not exceed 2 m, and the damping ratio must be between 0.4 and 0.6.
Wind speed	±0.2 m/s for speeds less than 2.2 m/s; within 5 percent for speeds of 2.2 m/s or greater; the starting speed must be 0.5 m/s or less.
Temperature	±0.5°C
Delta temperature	±0.1°C
Relative humidity	±10 percent
Dew point temperature	±1.5°C
Solar radiation	±5 percent of observed
Precipitation	±10 percent of observed
Pressure	±3 mb
Time	±5 min

a The delay distance is the length of air, at any wind speed, that must pass through a wind vane during the time it takes the vane to return to 50% of the initial displacement.

3.5.2 Completeness

LLNL's meteorological system is designed to provide data recovery of at least 90% on an annual basis. An even higher annual recovery rate of 95% or higher is strived for. When data from a tower are not available or reliable, representative offsite meteorological data from a nearby tower may be used occasionally. This approach works best for temperature, relative humidity, and solar radiation. Wind speed and direction can vary greatly with increasing distance, so offsite data may not be suitable as a replacement.

3.5.3 Calibration and Audits

Routine inspection, scheduled maintenance, and calibration of the meteorological instrumentation and data acquisition system meet the manufacturer's recommendations and are conducted in accordance with LLNL procedure EMP-M-MCA, *Meteorological System Maintenance and Sensor Calibration*. External audits are performed by an outside, independent contractor at least annually. Calibrations are also performed between the annual audits and when problems are found or instruments switched out. The logs of inspections, maintenance, and calibrations are maintained as permanent records, allowing routine inspection of current data.

3.6 Program Implementation Procedures

The following procedures are used to support and ensure meteorological data collection and analyses:

- EMP-M-MCA, *Meteorological System Maintenance and Sensor Calibration*
- EMP-M-D, *Meteorological Data Management and Analysis*
- EMP-M-D Instruction #1, *Preparation of Monthly Records of Meteorological Observations for LLNL and Site 300*
- EMP-M-D Instruction #2, *Preparation of Annual Records of Meteorological Observations for LLNL and Site 300*
- EMP-M-D Instruction #3, *Preparation of Graphical Wind Rose*

3.7 Action Levels

When a serious problem is discovered with an instrument that provides critical data (wind direction, wind speed, etc.), an NCR is prepared and the problem is addressed immediately. In addition, the meteorologist will notify personnel using the data, such as those supporting emergency preparedness, that the data are invalid. If the problem persists for more than a few hours, a message is placed on Weather Pages website informing users of the problem.

3.8 Preparation and Disposition of Reports

A wind rose is generated for the Livermore site and Site 300. Reports requiring the annual wind rose include the annual *Environmental Report* and the *LLNL NESHAPs Annual Report.*

The regulatory model, CAP88-PC, requires joint-frequency tables of wind direction, wind speed, and stability. LLNL has computer programs that transform a year of data from the archive into the tables that are used as meteorological input to the CAP88-PC code. These programs are described in procedure EMP-M-D, *Meteorological Data Management and Analysis*.

3.9 Future Plans

The EPA is currently in the process of approving two models to replace CAP88-PC Versions 1.0 and 2.0, which are the same model, unchanged since 1992, with different user interfaces. Version 3.0 of CAP88-PC with updated transfer and dose factors, but the same dispersion model, should be approved in early 2005. Another model, GENII/NESHAPS (Napier et al. 2002) should be approved later in 2005. It is likely that both approvals will occur later than planned. Hourly data including wind direction, speed, and stability will be input to the GENII model; a joint frequency distribution, based on the same underlying 15-minute meteorological data that go into the GENII hourly files, is used in CAP88-PC.

Some of the new instruments installed in late 2003 and their data will be analyzed and improved if possible. For example, the current sampling frequency at the Livermore site may need to be increased to better estimate heat flux values estimated by the sonic anemometer. Comparison of the sonic and mechanical wind sensors will also be made to determine if the sonic anemometer shows a significant improvement in measuring winds and turbulence in low wind speed conditions and if the sonic is reliable enough to eventually replace the mechanical wind sensors. A fast-response hygrometer has been identified for installation at the main site tower to allow real-time evaporation (and evaporative heat flux) monitoring.

Replacement of the two existing meteorological towers will be investigated and pursued. The current 8-m tower at Site 300 is lower than recommended by the EPA, has only one wind level, and is reaching the end of its service life. A 25-m tower with redundant monitoring levels with an electronic instrument elevator will be proposed at a location farther north at Site 300 than the current tower location. The current 40-m tower at the Livermore site has useful service left; however, the current manual lift system prevents servicing during moderate northerly or southerly winds. A 50-m tower with an electric instrument elevator will be proposed to replace the current tower.

The Weather Pages website file server currently accesses data every 15 minutes from the TAMM personal computer. Software will be added to the HCD OSC computer to allow data access for redundancy. There are also plans for the data to be sent to a computer at the EOC. A beta and modified version of NARAC's Metview program was installed on the computers in late 2004 to allow user-friendly viewing of the latest 15-minute data and a graphical display of a potential plume (or wind sock) overlain on Livermore site and Site 300 maps. The software will be improved and updated in 2005.

Mixing height is another common parameter used in many dispersion models and is often measured with an acoustic sounder. Adding an acoustic sounder to the monitoring system would provide data for comparison of mixing height to measured meteorological parameters, such as wind speed and vertical temperature difference. Evaluations of this technology for potential use at LLNL will be conducted.

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4 Ambient Air Particulate

Paris E. Althouse

4.1 Introduction

Ambient air particulate monitoring is part of a comprehensive and ongoing environmental monitoring program (see Chapter 1) for Lawrence Livermore National Laboratory (LLNL). Data collected from air monitoring are used to demonstrate compliance with regulatory requirements, calculate the dose to public from LLNL activities, and monitor any changes in the activity detected in the airborne particulate levels in and around LLNL.

At a research facility like LLNL, there is a potential for emissions to the atmosphere. If released in significant amounts, various types of emissions are considered air pollutants. Currently, the EPA has identified nearly 200 hazardous air pollutants. Typically, air pollutants can be categorized as either particulate matter or gases. Potential air particulate pollutants that can contribute to radiological dose or inhalation hazard from LLNL operations include radioactive particulate and beryllium metals. Air can be a primary exposure pathway for human and ecological impact.

To reduce, control, and eliminate air pollutants from its operations, LLNL employs an array of engineering and administrative controls. LLNL conducts air surveillance monitoring in the environment to assess the adequacy of these controls and to determine the impact, if any, of its air pollutant releases on the environment. Using data obtained from air effluent monitoring (see Chapter 3) and air surveillance monitoring, LLNL-induced human-health and environmental impacts can be assessed accurately.

LLNL is not considered a major source of non-radiological pollutants as defined under the Clean Air Act. These pollutants, known as criteria air pollutants, include carbon monoxide, sulfur dioxide, nitrogen dioxide, volatile organic compounds, particulate matter (particles with a diameter less than or equal to 10 µm; PM_{10}), and lead.

The sources of criteria pollutants from the Livermore site and Site 300 are surface coating operations, internal combustion engines, solvent operations, soil vapor extraction, gasoline dispensing operations, boilers, and open burning (only at Site 300). Operations at both sites also use a variety of chemicals that are considered air toxics. In accordance with the regulatory authority of the local air districts, monitoring for both criteria pollutants and air toxics is managed through permits issued by the air districts.

4.2 Rationale and Design Criteria

4.2.1 Regulatory Drivers

Air monitoring regulations are driven by the applicable portions of Department of Energy (DOE) Orders 5400.1[1] and 5400.5. DOE Order 5400.1 states that environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on environmental and natural resources both onsite and offsite. It is the objective of DOE Order 5400.5 to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within the limits established the order. It is also a DOE objective that potential exposure to members of the public be as far below limits as is reasonably achievable (ALARA) and that DOE facilities have the capabilities to monitor for such releases.

LLNL is also subject to the National Emission Standards for Hazardous Air Pollutants (NESHAPs) of the Clean Air Act, (40 CFR 61, Subpart H). As part of its compliance with this regulation, LLNL has authorization to use ambient air surveillance monitoring for public dose assessment for minor and diffuse sources. (Harrach et al. 2003 [Attachment 3]).

The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991), provides the guidance for ambient air particulate monitoring. In addition to routine monitoring, environmental monitoring during an emergency situation should be considered. LLNL's surveillance air monitoring network is part of the EPD emergency response program.

Sampling for beryllium in ambient air is performed to comply with the Bay Area Air Quality Management District (BAAQMD) Regulation 11, Rule 3. This rule establishes an air concentration limit for beryllium metals of 0.01 $\mu g/m^3$, averaged over a 30-day period.

4.2.2 Monitoring Objectives

The primary objective of ambient air particulate monitoring is to assess radiological dose to the public and the environmental impact of routine and non-routine radiological and

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

beryllium metal airborne releases. The sample results may be used to validate dispersion models and calculations, determine offsite effects, and determine future courses of action.

There are several goals for analyzing surveillance data:

- Estimation of concentrations at each sampling point,
- Comparison of current concentrations to previous concentrations in order to identify changes or inconsistencies,
- Comparison of concentrations to established regulatory limits,
- Comparison of concentrations at a single location, or a group of locations, to control or background locations and evaluation of the reliability of the comparisons, and
- Review of quality assurance data to ensure validity.

4.2.3 Sources and Analytes

The air monitoring program at LLNL is designed to identify a problem at the lowest possible level; therefore, all total suspended particles (TSP) are analyzed. Particle-size distributions (PM2.5 or PM10 analysis) are not determined because the dose to the public is well below the threshold limits required by the regulations. Since the TSP method includes the collection of all particle sizes, LLNL takes a conservative approach assuming all particles are respirable when in fact only the smaller (less than 10 microns) are considered respirable particulate matter.

Plutonium and uranium are the primary particulate radionuclides of concern at the Livermore site. The major potential source for plutonium is Building 332, the Plutonium Facility. The potential source of uranium is the Building 321 Complex, where milling, shaping, and machining of depleted uranium as well as other related operations occur. Other sources include Chemistry and Material Sciences Directorate facilities, Radiological and Hazardous Waste Management operations, and the southeast quadrant of the Livermore site.

LLNL also analyzes the air samples for gamma-emitting radionuclides, and in doing so verifies that there is no evidence of release of the small inventories of mixed fission products and radiochemical tracers used by LLNL.

At Site 300, depleted uranium, used in explosive tests, is the primary particulate of concern. Historically explosive tests were conducted on open-air firing tables located at Bunkers 801, 850, and 851. Presently these explosive tests are conducted on Bunker 851 and inside Building 801, the Contained Firing Facility (CFF). Components of depleted uranium include the isotopes uranium-234, uranium-234, and uranium-283.

Beryllium, the primary non-radiological particulate of concern, is used in several facilities at the Livermore site, including Buildings 231, 235, 241, and 321. Site 300 explosive tests may also include beryllium.

4.2.4 Collection Methods

Air samples are collected on high volume air particulate sampling units (hi-vol) which run continuously at a flow rate of 15 cubic feet per minute (cfm). Sampling units have self-adjusting flow controllers that maintain a constant flow. This automatic system adjusts the motor speed to compensate for changes in temperature, barometric pressure, and mass loading that effect flow rate. The exposed cellulose filters are collected weekly.

For emergency response air monitoring, battery operated portable emergency air samplers are available for deployment. The surveillance and portable air sampling units do not provide data in real-time, but they are available if emergency sampling is needed.

4.3 Extent and Frequency of Monitoring and Measurement

Air samplers are located to ensure reasonable probability that any significant concentration of particulate effluents of concern from LLNL operations will be detected. Locations for all of the air monitoring sites are provided in Figures 4-1, 4-2, and 4-3. Sampling units are placed in all directions from sources and each station was specifically selected to represent a particular region. These include on site, off site (upwind and downwind), diffuse or areas of known contamination, and areas within populated city limits. A detailed description of past and present sampling locations is maintained in procedure supplement EMP-QAS-LOC, *Locations Database SOP Supplement*. The supplement also describes the process to be used for defining, documenting, and approving sampling locations.

The siting configuration of the network involves several elements: proximity to potential sources, their geographical location, historical wind patterns, effects of topography, and access logistics. Through air dispersion modeling, specific locations have been identified as those having the maximum dose to the public, while other sites represent onsite, downwind, upwind and background locations.

Sampling on the Livermore site occurs at the following locations: MESQ, MET, COW, VIS, CRED, SALV, and CAFÉ (Figure 4-1). CRED and VIS represent the primary and secondary site-wide maximally exposed individual (SW-MEI) locations. Location SALV is situated in the southeast quadrant of LLNL and in an area of known historical plutonium soil contamination (Sims 1991) for details of a special study perform in this area. As shown if Figure 4-2, off site upwind stations are HOSP, FCC, CHUR, and FIRE, while downwind stations are TANK, PATT, ZON7, and ALTA. A special interest station is located at LWRP where historical plutonium contamination exists from plutonium released by LLNL to the sanitary sewer during the late 1960s.

Site 300 has eight stations located onsite: GOLF, WCP, WOBS, NPS, EOBS, 801E, ECP, and COHO (Figure 4-3). WOBS and 801E are very close to test bunkers and COHO serves as the SW-MEI. TCDF is a background location, offsite and upwind station for Site 300.

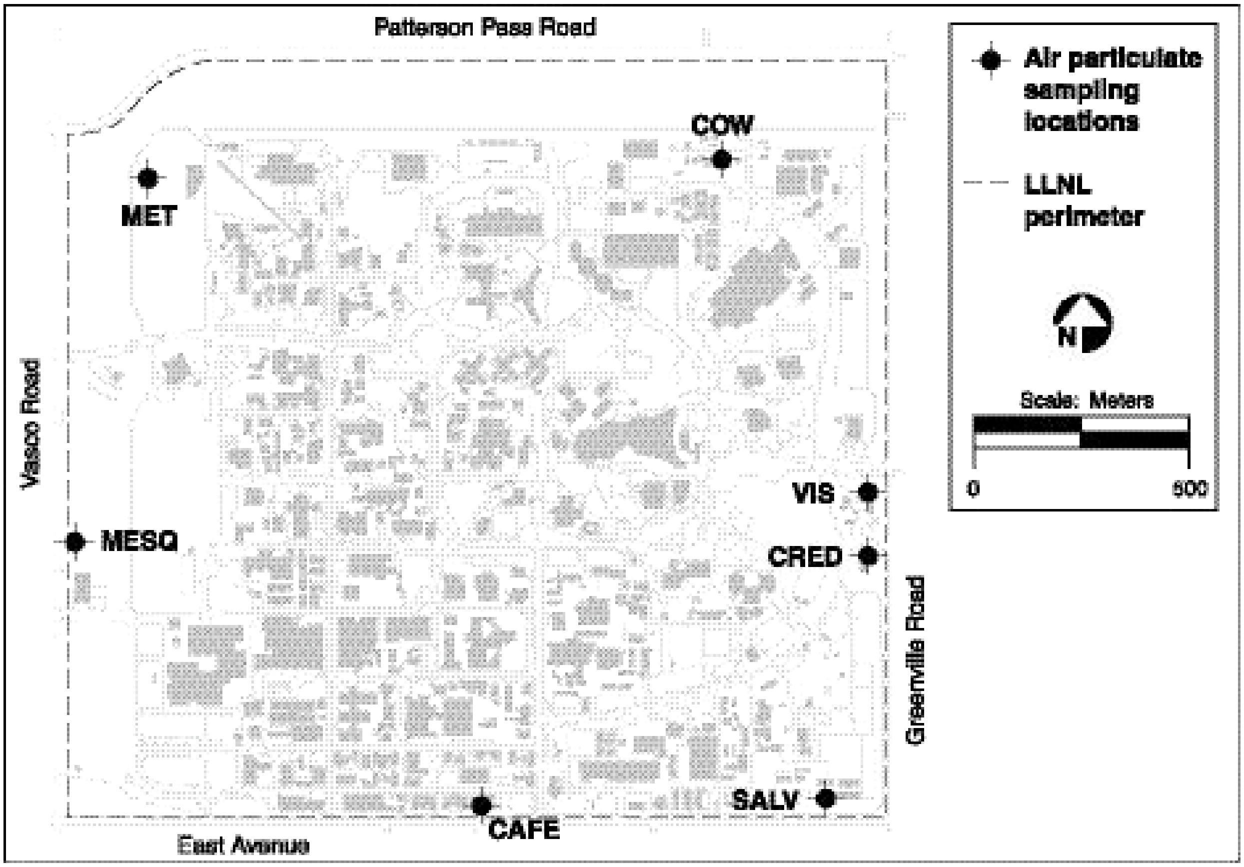

Figure 4-1. Air particulate sampling locations, Livermore site

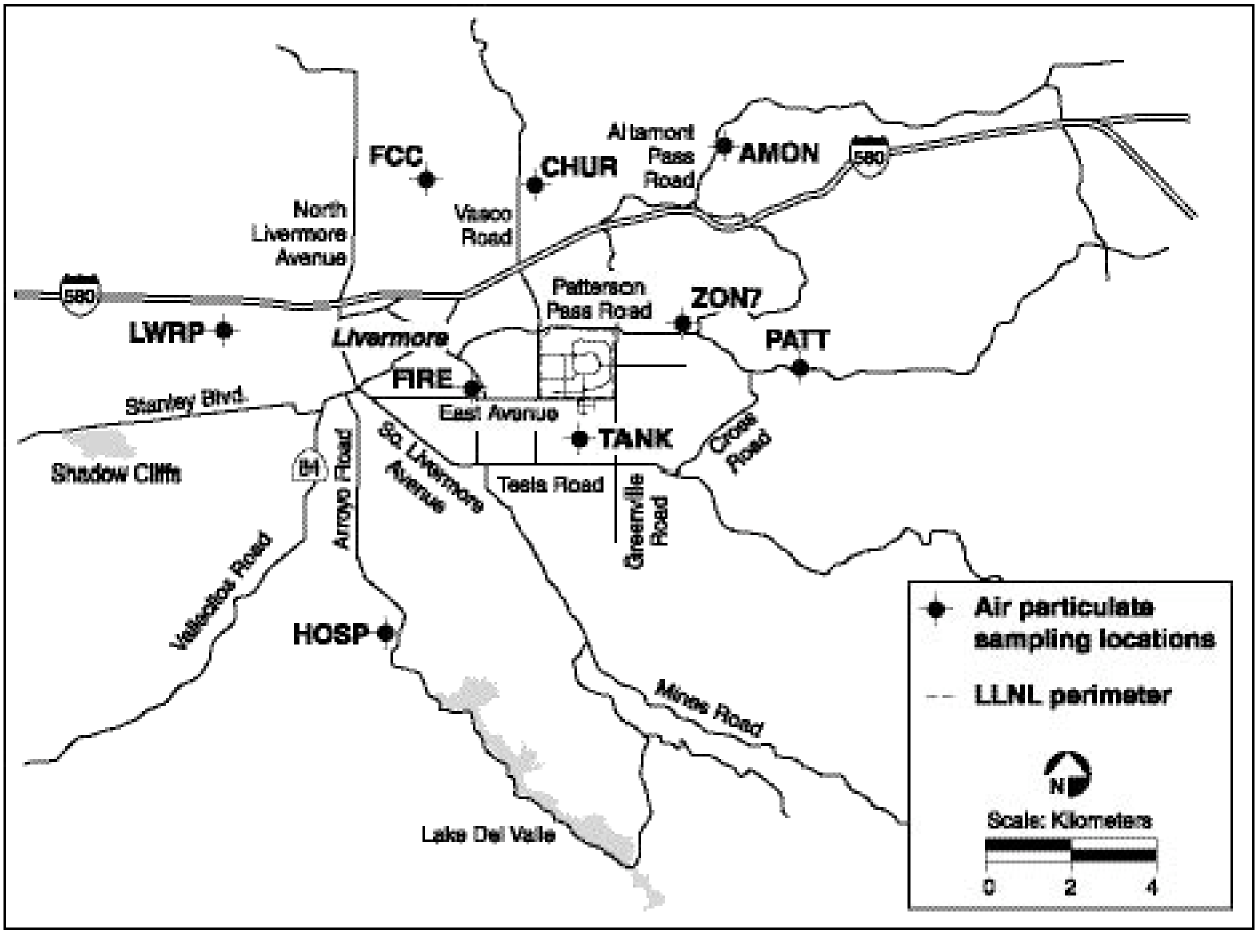

Figure 4-2. Air particulate sampling locations, Livermore Valley

Surveillance of potential emissions from beryllium operations is performed at six locations along the perimeter fence line of the Livermore site (MET, COW, VIS, SALV, CAFE, MESQ). Although under no regulatory requirement to monitor for beryllium at Site 300, as a best management practice, LLNL monitors for beryllium at three locations within Site 300 (801E, EOBS, GOLF) and at the background location (TCDF).

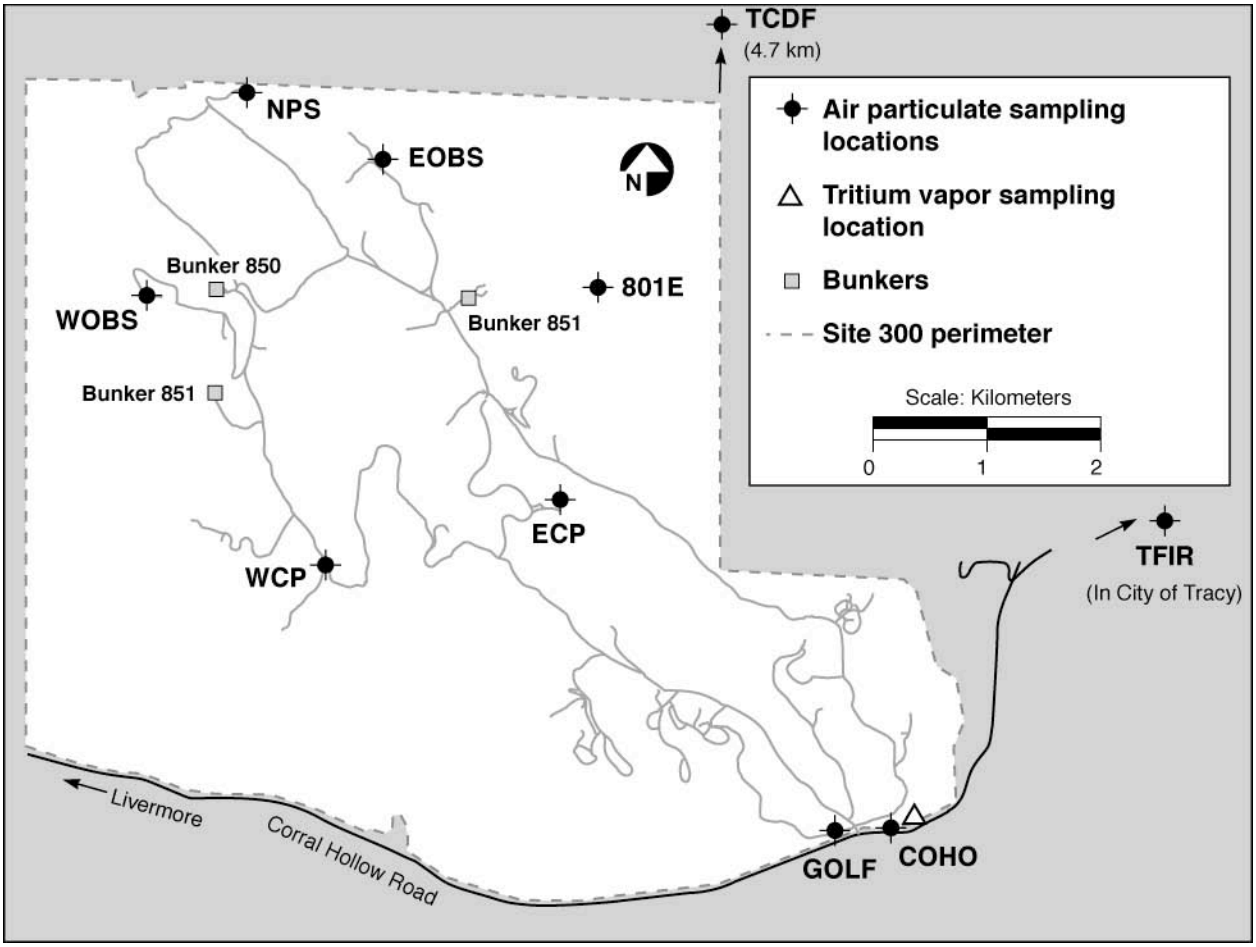

Figure 4-3. Air particulate and tritium sampling locations, Site 300

In January 2004 the particulate sampling location called TFIR located in downtown Tracy was removed due to demolition of the facility. A replacement location was determined by modeling explosive test data from Site 300. A new location, identified as TCDF, was deemed a satisfactory replacement background location for Site 300 and a hi-vol air sampler was deployed in March 2004.

4.4 Procedures for Laboratory Analysis

All samples are submitted to the analytical laboratory weekly where they are analyzed after a 4-day delay to allow for decay of the radon and thoron daughters. Samples are submitted to the laboratory with a chain-of–custody along with a spreadsheet with the flow data for each sample.

Portions of all weekly air particulate samples (including those from Site 300) are screened for gross alpha and non-volatile beta-emitting isotopes by a gas-flow proportional counting system. Two composite samples are created by the laboratory from portions of LLNL and Site 300 weekly air filters (for the entire month), then analyzed for gamma emitting isotopes. Isotopic plutonium analysis is then performed on samples collected from the Livermore site locations; isotopic uranium analysis is performed on samples collected from the Site 300 locations. Beryllium analysis is performed on selected on-site locations at both the Livermore site and Site 300.

Data results from field samples are analyzed based on the area of the filter (per square centimeter) then divided by the flow rate so that the activity provided to the analyst in the data reports is activity per unit of flow (cubic meter). Method blanks, laboratory control sample (LCS), and field trip blanks have no flow associated with them; therefore, they are reported in activity per area.

A certified on-site analytical laboratory performs all of the air particulate analysis. Table 4-1 describes the required analysis, method of analysis, and the minimum detection limit.

Table 4-1. Air particulate analysis methodology and detection limits

Requested Analysis	Method	Detection Limit
Gross alpha & gross beta	Gas-flow proportional counting	5.0 X 10^{-15} Ci/m^3
Beryllium metal	Inductively Coupled Plasma- Mass Spectrometry	5.0 X 10^{-12} g/m^3
Plutonium 239+240	Alpha Spectrometry	5.0 X 10^{-19} Ci/m^3
Uranium-235	Inductively Coupled Plasma- Mass Spectrometry	7.0 X 10^{-16} g/m^3
Uranium-238		1.0 X 10^{-13} g/m^3
Gamma emitters	Gamma Spectroscopy	Depends on isotope

Sample analysis and data reporting are conducted using methodology as detailed in the following Chemistry Materials and Sciences SOPS: SOP- EM-P557, *Preparation of Air Filters for Determination of Pu, U and Gamma Radioisotopes*; SOP- EM- P554, *Operation of Canberra Alpha Spectrometry Systems*; SOP-CES-P512, *Reporting CES Analytical Results*; SOP-EM-P565, *Beryllium Analysis by ICP/MS*; and SOP-EM-P545, *Gross Alpha and Gross Beta Method 7100B.*

4.5 Data Quality Assurance

4.5.1 Precision

One duplicate air particulate sampling unit operates at each site. The sampling locations of field duplicate samples are not identified on the filters, so the analytical laboratory does not know where the samples originated (procedure EMP-QA-DM, *Sample and Data Management*). This information is recorded on field tracking forms (FTFs) that are filled out in the field by the sampling technologist. The hi-vol sampling units for duplicate QA/QC samples are rotated among the locations at bimonthly intervals.

After the analyst obtains the laboratory results, the concentrations of duplicates are compared. Different concentrations can be explained by analytical error and natural variability. In most cases historically, the difference between duplicates can be explained exclusively by analytical error. This is invariably true when concentrations are near the detection limits, which is the case with a majority of the air particulate radiological data. When one of the results in a pair is a nondetection, then the other result should be less than two times the detection limit (Sanchez et al. 2004, Chapter 8). Natural variability becomes important at higher concentrations. Nevertheless, if all parts of the sampling system are working properly and no human error is involved, the mean ratio should be between 0.7 and 1.3 (Sanchez et al. 2004, Chapter 8). If a larger difference is detected, the reason should be investigated by checking the information contained on the FTF. Specifically, the total flow rates and run times should be compared. If the total flow rates are similar, the counts per minute should also be similar during a sampling period. If the magnitude of the differences cannot be explained, the analytical laboratory is contacted to discuss any problems that may have occurred during analysis.

Laboratory batch duplicates (or splits) are created from the field samples collected each sampling period and are introduced blind into sample processing. The relative error ratio is calculated and reported for each split sample. If the control limit of 3.0 is exceeded, the source of the problem is investigated and corrected (EMRL procedures, SOP-CES-P810, Data Validation and SOP-CES-P811, Data Verification).

4.5.2 Accuracy

As an additional component of the QA program to ensure data accuracy, the radiological laboratory runs blank and control samples traceable to standards of the National Institute of Standards and Technology (NIST). The laboratory runs clean unexposed blank filters (BLM) just as it would the routine filters. The laboratory also performs laboratory control spikes (LCS) in which blank filters are exposed to known quantities of tracers. Tracer recovery evaluates the effectiveness of sample preparation process which is used to isolate the radioisotope.

In addition to the lab review process required for data release, the analyst also reviews all quality assurance data (laboratory blanks and control samples). Data released that falls outside the lower control limit of 75% and above the upper control limit of 125% are "rejected". In this case the laboratory must rerun or reanalyze the samples before delivering the data report.

After receipt of data, the environmental analyst compares the data to the action levels provided in this document. If data is outside the action limits or the analyst has reason to question the value, the analyst may ask for reanalysis.

Triennial self-assessments of all monitoring networks are also performed (LLNL procedure ORAD-QA-SA, *Self Assessments*). Informal field audits are also performed periodically by the air particulate analyst at their discretion.

4.5.3 Completeness

Over the last 5 years (1999–2003) air particulate samples were tested for over 10,000 different analytes; this represent a completeness of over 99% from what was expected. Problems causing loss of field samples include pump or flow controller failure and power outages. At Site 300, access to the sampling unit is often denied due to explosive testing and area closure. In such cases the sample is allowed to run for an extended period of time (2 weeks compared to the normal 1 week sampling interval). Periodic sample loss occurs in the laboratory; however, there is typically extra filter material available to rerun the sample.

With respect to laboratory analyses, TAMM requires that 90% of the samples submitted to and analyzed by EMRL yield valid data. If these completeness criteria are not met, nonconformance reports are prepared according ORAD-QA-NCR, *Nonconformance Reporting and Tracking*).

4.6 Program Implementation Procedures

The primary responsibility for activities related to the air particulate monitoring networks is assigned to a TAMM environmental analyst. The analyst is responsible for the network design, implementation, and correct operation of the network; the analysis and evaluation of all monitoring results; data trending; documentation; and reporting. The following is a list of the procedures associated with the sampling network:

- EMP-AP-S, *Air Particulate Sampling*: Details of sampling, processing, and documentation for radiological and beryllium air particulates.
- EMP-AP-CA*, Air Particulate Sampler Calibration:* Details of calibration protocol are described.
- EMP-QA-DM*, Sample and Data Management*: Details how samples are handled, stored, and delivered.
- ORAD-QA-NCR*, Nonconformance Reporting and Tracking*: Details how to complete a report when a sample is deemed unacceptable.

In conjunction with the sampling procedures, the handling and validity of air samples is documented using FTFs, chain of custodies, and nonconformance reports.

4.7 Action Levels

The action levels for air particulate were determined from data collected in 2002–2003. Action levels for gross alpha, gross beta, plutonium, and beryllium metals are provided in Table 4-2. Action levels for isotopic uranium-235 and uranium-238 are based on the uranium-235/uranium-238 ratios. This ratio should be between 0.002 for depleted uranium and 0.00725 for natural uranium. Positive isotopic ratios (those with both uranium-235 and uranium-238 positively detected) which are over 0.008 are investigated as described below. Gamma activity is screened every month and those isotopes which do not occur naturally are investigated.

Table 4-2. Action levels for gross alpha, gross beta, isotopic plutonium-239, and beryllium metals

Analyte Area	Geometric Mean	Geometric Standard Deviation	Warning Level (upper)	Action Limit (upper)
Gross Alpha	(mBq/m^3)			
Perimeter	31	2.7	249	702
Downwind	33	2.5	206	519
Upwind	29	2.5	199	518
LWRP	39	2.2	207	477
Site 300	35	2.4	193	480
Gross Beta	(mBq/m^3)			
Perimeter	320	1.6	876	1448
Downwind	308	1.7	876	1479
Upwind	285	1.8	931	1681
LWRP	329	1.7	932	1570
Site 300	319	1.6	830	1338
Plutonium	(nBq/m^3)			
Perimeter	4.0×10^{-9}	3.4	5.0×10^{-8}	1.8×10^{-7}
LWRP	9.7×10^{-9}	4.2	1.8×10^{-7}	2.2×10^{-5}
Valley	3.0×10^{-9}	2.6	2.2×10^{-8}	8.0×10^{-7}
Site 300	5.1×10^{-8}	2.5	1.3×10^{-8}	3.3×10^{-8}
Beryllium metals	(pg/m^3)			
Livermore	8.8	1.9	33	64
Site 300	7.6	2.2	38	85

As a screening tool, air samples are analyzed weekly for gross alpha and gross beta measurements. If the gross measurements are at the warning or action level for 2 weeks in a row, isotopic analysis is performed on those samples. Typically isotopic analysis is only performed on monthly composite samples created from weekly filters from specific locations.

When a warning or action level is exceeded, the analyst must investigate and determine the cause. This investigation begins by checking sampling operations performed by the technologist. This is done by meeting with the technologist and reviewing the appropriate field tracking forms. Field operations can greatly impact the data; for example, excessive particulate buildup on air filters (caused by soil resuspension) from construction activities may result in higher sample results. If a sample results that exceeded warning levels are not the result of sampling or field activities the data are checked for transcription errors, flow rates are confirmed, and the analytical lab is contacted to determine if any problems occurred during analysis. In some cases, reanalysis may be performed. If the activity is high and no transcription, analytical or other problems are found, the TAMM analyst notifies EPD management, and further action is taken with EPD management concurrence. EPD management is notified when any DCG (radiological limit) or ACG (ambient concentration limit for beryllium) is exceeded.

Ambient beryllium concentrations that exceed the ACG of 10,000 pg/m^3 also require immediate notification (within 24 hours) to the BAAQMD.

4.8 Preparation and Disposition of Reports

Ambient air monitoring results are reported in the annual *Environmental Report* and the *LLNL NESHAPs Annual Report*.

The requirement for quarterly beryllium reporting to the BAAQMD was lifted in January 2002. Instead, LLNL provides the BAAQMD with the *Environmental Report* each year. LLNL has an agreement with BAAQMD to notify them should any location exceed the limit and reporting for this requirement is done in the *Environmental Report*.

4.9 Future Plans

In the near future we will investigate what effect mass particulate loading has on the activity collected on the air filters. It has been noted that during late summer and early fall, the particulate loading on filters increases concurrently with increases of activity on the filters. We would like to substantiate that the increase in activity is the result of an increase in particle concentration of naturally occurring soil resuspension.

The environmental analyst will continue to investigate the suitability of new filters that possess low background activity and beryllium content yet have a high particle collection efficiency.

We will also continue to make improvements to our emergency response air monitoring capabilities. For example, in a situation where filters might be collected and analyzed immediately, correction factors to account for the short-lived radon daughter products will be developed.

In the long-term we will continue to review sampling locations and make changes and/or additions, as appropriate, to adapt to changes in Laboratory operations.

4.10 References

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5 Ambient Air Tritium

Jennifer M. Larson • S. Ring Peterson

5.1 Introduction

At a research facility like Lawrence Livermore National Laboratory (LLNL), there is a potential for emissions to the atmosphere. Potential air pollutants that can contribute to radiological dose or inhalation hazard from LLNL operations include tritium, a non-particulate radioactive isotope of hydrogen. Air can be a primary exposure pathway for human and ecological impact.

To reduce, control, and eliminate air pollutants from its operations, LLNL employs an array of engineering and administrative controls. LLNL conducts air surveillance monitoring in the environment to assess the adequacy of these controls and to determine the impact, if any, of its air pollutant releases on the environment.

Tritiated water and water vapor (HTO) can be incorporated into all biological systems and is readily mobile. It can enter the human body through respiration, ingestion, and absorption through the skin (Okada and Momoshima 1993). If air concentrations of HTO are measured, conservative doses from inhalation and skin absorption of HTO and ingestion of HTO and OBT[1] can be calculated quite accurately by means of the specific activity model (see Biermann et al. 2001, Appendix A). The specific activity model assumes that the tritium to hydrogen ratio in every environmental compartment is the same as the tritium to hydrogen ratio in air.

Ambient air tritium monitoring is part of a comprehensive and ongoing environmental monitoring program (see Chapter 1) for LLNL. Data collected from air monitoring are used to demonstrate compliance with regulatory requirements and U.S. Department of Energy (DOE) orders, calculate the dose to public from LLNL activities, and monitor any changes in the activity detected in the airborne tritium levels in and around LLNL.

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[1] Organically bound tritium (OBT) is formed during plant photosynthesis from HTO. It is tritium bound to the organic matter of plants. When animals eat these plants, OBT is transferred to the organic matter of the animal.

5.2 Rationale and Design Criteria

5.2.1 Regulatory Drivers

LLNL is subject to the National Emission Standards for Hazardous Air Pollutants (NESHAPs) of the Clean Air Act (40 CFR 61, Subpart H). As part of its compliance with this regulation, LLNL has authorization to use ambient air surveillance monitoring for public dose assessment for minor and diffuse sources.

The regulatory drivers for air tritium monitoring are the applicable portions of Department of Energy (DOE) Order 5400.1[2] and 5400.5. (The applicable portions are called out explicitly in Work Smart Standards B93 and B94.) DOE Order 5400.1 states that environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on environmental and natural resources both onsite and offsite. It is the objective of DOE Order 5400.5 to operate DOE facilities and conduct DOE activities so that radiation exposures to members of the public are maintained within the limits established by the order. It is also a DOE objective that potential exposure to members of the public be as far below limits as is reasonably achievable (ALARA) and that DOE facilities have the capabilities to monitor for such releases.

Guidance for monitoring tritium in air is provided in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, DOE/EH-0173T (DOE 1991). This document advises that air sampling techniques should employ methods that extract moisture from the air. It also states that, for facilities that release tritium to the air, air sampling is an important medium, but not the only one (see Chapter 2). Guidance on choice of sampling method and precautions associated with sampling is provided. In addition to routine monitoring, environmental monitoring during an emergency situation should be considered. LLNL's surveillance air monitoring network is part of the EPD emergency response program.

5.2.2 Monitoring Objectives

Data collected from the surveillance program should characterize the radiological conditions of the environment and should be used to estimate inhalation doses to the public and provide compliance data for all applicable environmental regulations. To do

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[2] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

this, estimations of concentrations at each sampling point are needed. To identify changes or inconsistencies, current concentrations must be compared to historical concentrations. Furthermore, concentrations at a single location or group of locations must be compared with control or background locations to evaluate the effect of LLNL operations on the environment.

Tritium in air monitoring data may be used to test predictions by dispersion/dose models of concentrations in air to assess whether the model predictions are sufficiently higher than the measurements to be health-protective. Measured air concentrations of tritium from monitors located near diffuse sources (e.g., B331 outside) are used to estimate the tritium released from these areas of waste storage to estimate dose (Harrach et al. 2004), which otherwise would go unreported.

According to DOE/EH-0173T, environmental monitoring during an emergency situation should be considered (DOE 1991). LLNL's routine air monitoring network is part of EPD's emergency response program (see Chapter 1). The air sampling units do not provide data in real-time, but they are available if sampling is needed to confirm elevated concentrations due to an accidental release.

5.2.3 Sources and Analytes

Tritium is the only non-particulate radionuclide from LLNL operations present in the environment at concentrations that warrant monitoring. The majority of tritium is released as tritiated water (HTO) and tritiated hydrogen gas (HT) from the Tritium Facility (Building 331). In recent years, the important contributors to estimated dose have been the Tritium Facility (Building 331 and its associated operations) and the Building 612 Radioactive and Hazardous Waste Management Yard. Operations at the Decontamination and Waste Treatment Facility (DWTF, B695) may potentially release tritium.

Environmental monitoring is conducted routinely by LLNL for HTO only. Monitoring for HT in the environment is unnecessary because the potential inhalation dose from HT is approximately 10,000 times lower than an inhalation dose from a comparable air concentration of HTO and because monitoring for HTO accounts for tritium released both as HTO and as HT that has been converted to HTO in the environment.

Tritiated organics (e.g., tritiated methane) may also be released to the environment. The operations at LLNL are such that the likelihood of such releases is minimal, and the potential dose to the public would be far below any level of concern.

At Site 300, both past and current activities influence emissions and environmental impacts. Historically, tritium-contaminated material from explosive tests at Site 300 was disposed of in the site's landfills. The groundwater at Site 300 has locally elevated levels of tritium (see Chapter 15), which can be evapotranspired by plants under the right conditions. Tritium purge water from routine monitoring of groundwater wells in areas where elevated tritium levels occur also represents a usually insignificant diffuse source of tritium emissions at Site 300. These sources of tritium may cause slightly elevated air concentrations locally. One air tritium sampler at the location (COHO) that represents the site-wide maximally exposed individual (SW-MEI) fulfills NESHAP's compliance requirements.

5.2.4 Collection Methods

A suitable collection technique for tritium must remove moisture from the air. This is done by pumping a known volume of air through a desiccant that absorbs all the moisture from the air. The length of the sampling period depends on the amount of desiccant used, average absolute humidity, and airflow rate. DOE/EH-0173T (DOE 1991) recommends the use of silica gel as a desiccant, as is done by LLNL.

The LLNL tritium samplers, operating at a flow rate of 500 mL/min, use about 700 g of silica gel in a cylindrical flask to trap the tritiated water vapor. The silica-gel flasks are changed every two weeks. Data collected includes location, date on, date off, elapsed sampling time, instantaneous and total flow rates, empty flask weight, flask weight with dry silica gel, and flask weight with wet silica gel. All weights are captured electronically (EMP-AT-S Instruction 1, *Air Tritium Pre-Sampling Activities*). Each sample has a sample identifier that accompanies it through the analysis.

The sample collection for tritium is a simple exchange process (EMP-AT-S Instruction 2, *Air Tritium Sampling Activities*). The sampling technologist determines the existing flow rate, removes the exposed flask, and places it in the special transport carrier. Then, a replacement flask containing fresh silica gel is placed on the sampling unit. The flow rate is checked, and if necessary, adjusted. The technologist then completes the field tracking form (FTF) in the logbook. About 70 g of moisture is extracted from the air during the sampling period, but the exact quantity will depend upon the average absolute humidity and the volume of air passed through the sample. No break-through occurs, indicating that all moisture is removed from the air as it passes through the silica gel. A complete, detailed procedure for tritium sample collection is found in procedure EMP-AT-S, *Air Tritium Sampling* and its four sets of instructions (#1 *Air Tritium Pre-Sampling Activities*, #2 *Air Tritium Sampling Activities*, #3 *Annual Rotameter Calibration Check*, and #4 *Air Tritium Electronic Flow Meter Calibration*).

There are very few cross-contamination concerns with air tritium samples because the field technologists never come in physical contact with the silica gel samples. Special care is taken to minimize the possibility of breaking a flask containing an air tritium sample. Each flask is wrapped in plastic mesh to reduce the chance of breakage. The sample flasks are transported in a Plexiglas transport carrier specifically designed to hold them.

5.3 Extent and Frequency of Monitoring and Measurement

5.3.1 Sampling Locations

The configuration of LLNL's air tritium monitoring network is based on the guidance provided by DOE/EH-0173T (DOE 1991). Using the EPA- and DOE-approved Gaussian plume dispersion model CAP88-PC, dose at the perimeter fence and in the vicinity of the Livermore site were last modeled using 1995 source terms from the Tritium Facility and the B612 Yard. Concentration contours were created from the CAP88-PC output. Given that the two largest sources of tritium were accounted for in the analysis, results confirm that current perimeter sampling locations adequately monitor locations of potentially elevated tritium concentrations. In addition to perimeter locations, off-site tritium monitors are situated in the areas with the potential for the highest air concentrations, background locations, and other locations of interest.

Currently, tritium air samplers operate continuously at eleven locations on the Livermore site (Figure 5-1), at six locations in the Livermore Valley (Figure 5-2), and at one location near the southeast boundary of Site 300 (Figure 5-3). In accordance with DOE/EH-0173T (DOE 1991), the air tritium sampling network includes:

1. HOSP (Figure 5-2), the background or control location about 7 or 8 km from the site in an upwind direction. Although 10-15 km distant is recommended for a background location, concentrations of tritium at HOSP are expected to be below detection limits.

2. CRED (Figure 5-1), the location where the maximum, predicted ground-level concentrations at the perimeter from all releases coincides with the location of a given publicly accessible facility.

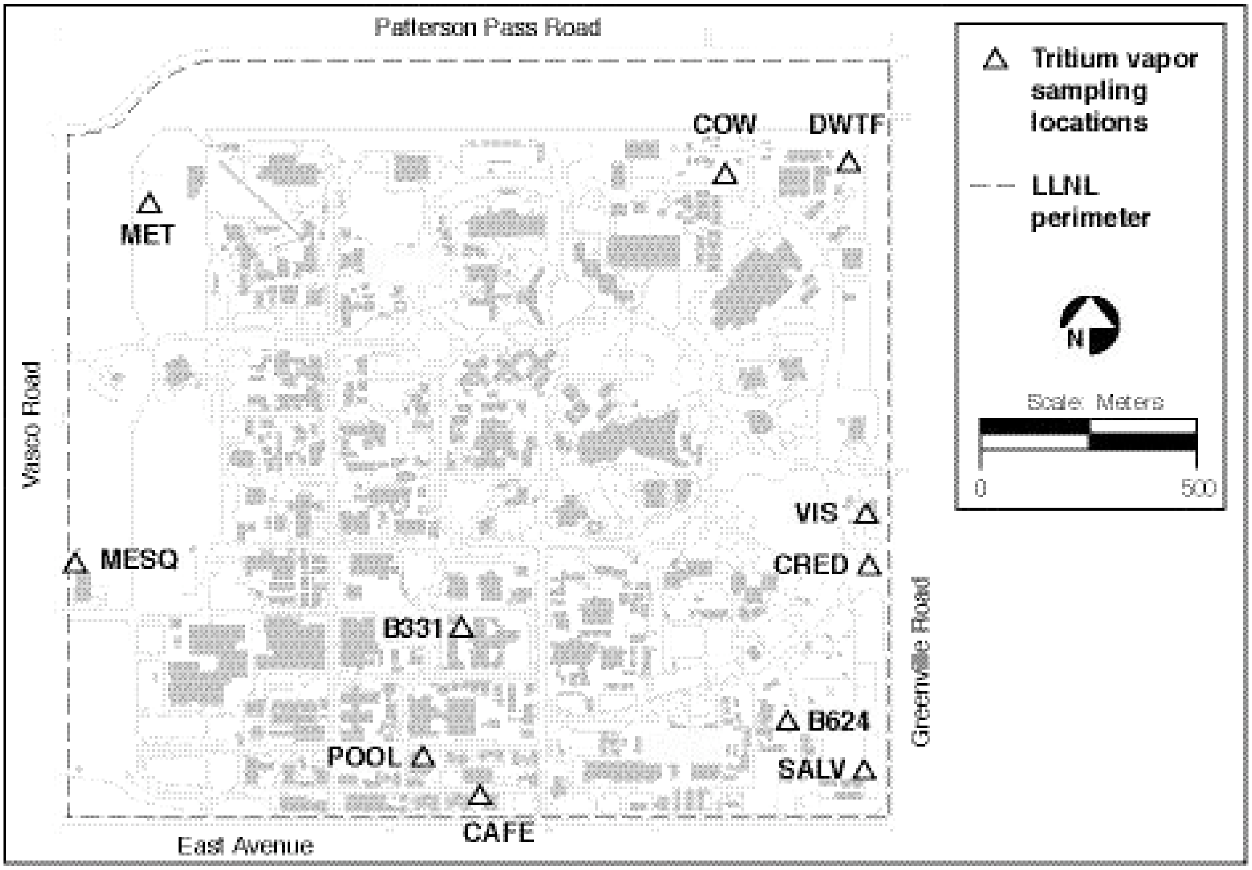

Figure 5-1. Air tritium sampling locations, Livermore site

3. FIRE (Figure 5-2), the location in the nearest community (Livermore) within a 15 km radius.

Resources, manpower, and logistics (such as the availability of electrical power, access and security) are also considered when selecting a sampling location.

Offsite samplers are placed both upwind (VET) and downwind (ZON7, also the site of a water treatment plant) from LLNL. The tritium sampling network provides a comprehensive assessment of tritium concentrations in the Livermore Valley. Three of the Livermore site locations (B331, B624, and DWTF) monitor specific diffuse sources of tritium emissions. A few changes in sampling locations have occurred since the last *Environmental Monitoring Plan* was issued in February 2002 (UCRL-ID-106132). The locations B292 and B514 were discontinued, CRED was added, and SALV relocated (Figure 5-1).

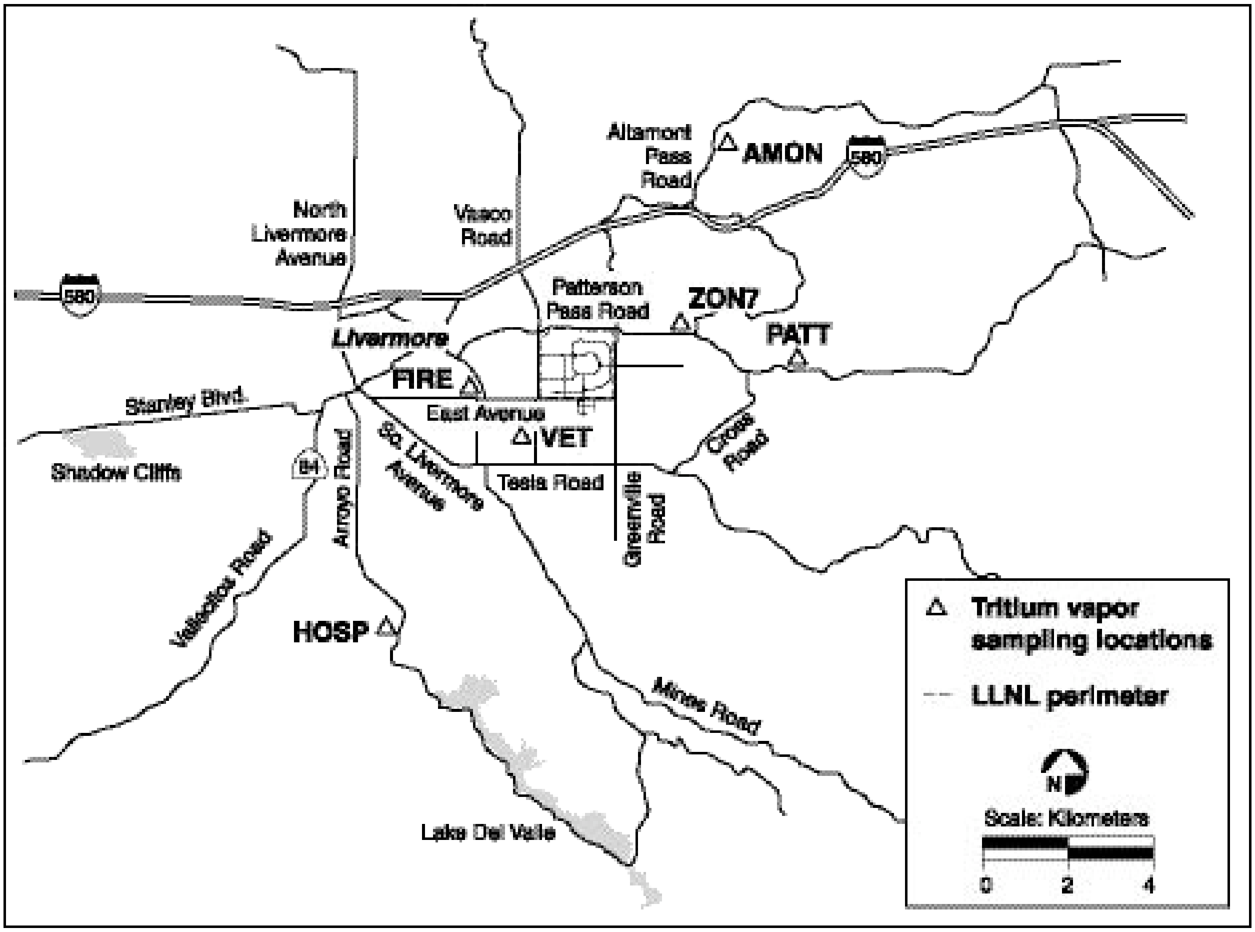

Figure 5-2. Air tritium sampling locations, Livermore Valley

A detailed description of all past and present sampling locations is maintained in a database, the Locations Database. The Locations Database includes directions to the sampling location, the environmental medium sampled at the location, safety concerns and other pertinent information. EMP-QAS LOC, *Locations Database SOP Supplement*, describes the process to be used for defining, documenting and approving sampling locations. In addition, the Technical Supervisor in TAMM maintains a hardcopy of all current sampling locations.

5.3.2 Sampling Frequency

Many factors must be considered to determine sampling frequency. These factors include limitations of the sampling units themselves, amounts of moisture required for analysis, flow rates, and sample retrieval time. Typical sampling frequency for tritium is biweekly at LLNL. All routine air tritium sampling, regardless of location, is conducted according to the LLNL procedure EMP-AT-S, *Air Tritium Sampling*.

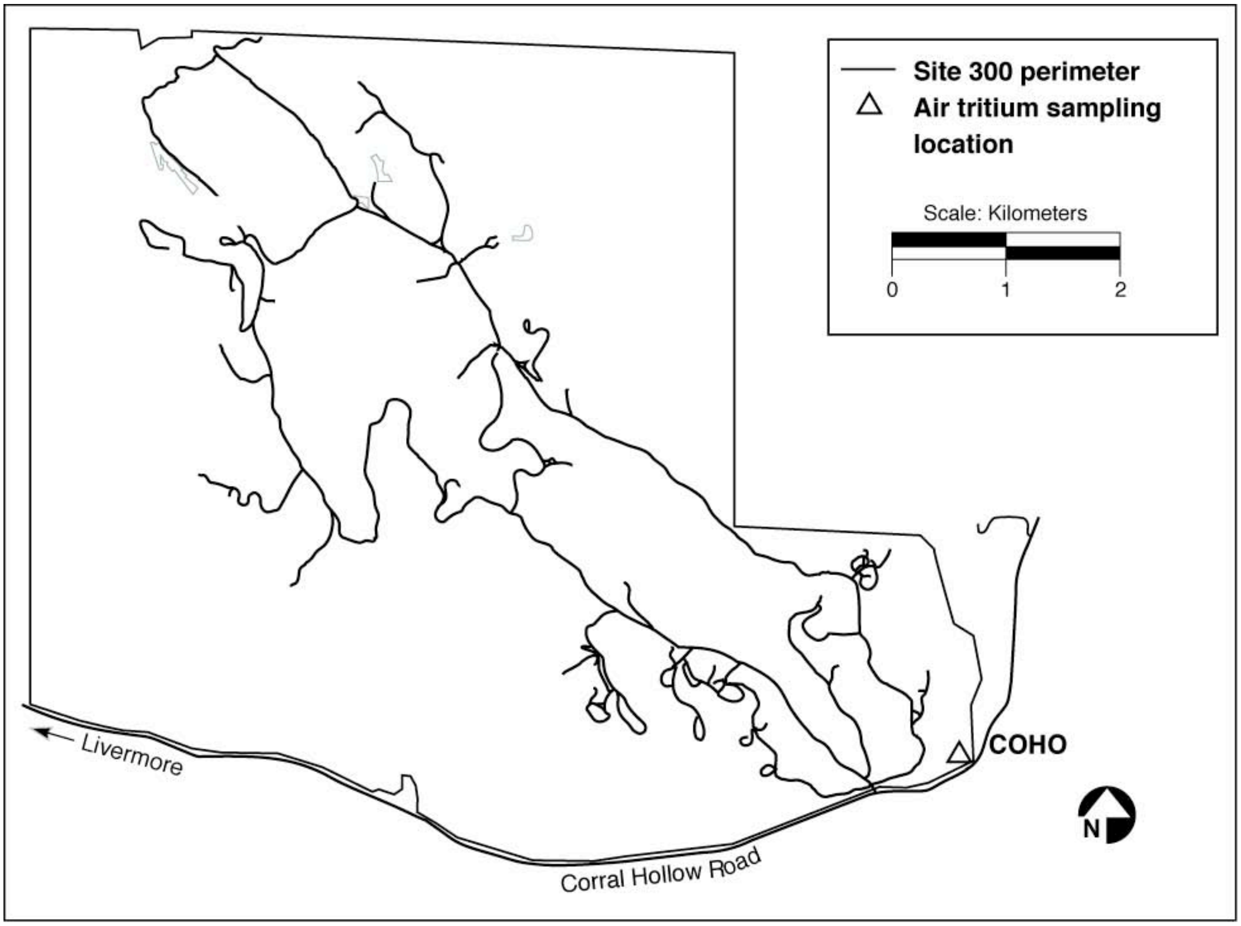

Figure 5-3. Air tritium sampling location, Site 300

As circumstances may dictate, special studies are occasionally instituted in addition to the routine sampling. Two such studies have recently reached closure. For the first of these studies, requested by the National Tritium Labeling Facility (NTLF) at Lawrence Berkeley National Laboratory (LBNL), LLNL operated, for approximately two years, an air tritium sampler co-located at an LBNL sampling location. LBNL was interested in finding out whether two different sampling set-ups and two different analytical methods would yield the same tritium concentrations. LLNL personnel compared the data from the two samplers and provided the results of their analysis to LBNL in 2003.

The other special study was established at LLNL at T5475 at the request of the Environmental Restoration Division, as part of the Livermore Site Ground Water Project (Biermann et al. 2001, Chapter 2). A groundwater treatment facility that extracts groundwater and removes volatile organic compounds operates next to T5475. Because levels of tritium are known to be elevated in the groundwater, the Livermore site local air district required ERD to monitor the ground level air concentrations of tritium. Data from this sampler demonstrated no impact on local air tritium concentrations from the groundwater facility operations. After two and one-half years of sample collection from this location, sampling was discontinued.

Started in the final quarter of 2003, an ongoing special study is investigating if, after applying different correction factors, measured air concentrations at a given location will be the same whether the silica gel used has been dried or not just prior to deployment in the field. According to current and historical practice, the Environmental Monitoring Radiological Laboratory (EMRL) at LLNL, dries the silica just before use; if this step can be eliminated, money and time will be saved.

5.4 Procedures for Laboratory Analysis

Flasks of silica gel that have been in the field for two weeks with an indicated total flow greater than half that expected for the sampling period are taken to the Chemistry and Materials Science Directorate. After the sampling technician weighs a flask on properly maintained and calibrated balances (SOP-CES-P542, *CES Balances*) the flask is then placed in the fume hood of the EMRL, and EMRL assumes responsibility for the air tritium samples. All silica gel from each flask is emptied into a jar for freeze-drying. The water extracted by freeze-drying (CES-EM-P542, *Low-Level Tritium Analysis- Freeze Dry*) is counted for HTO by liquid scintillation (SOP-EM-P552, *Operation of Packard Tri-Carb LSC for Environmental Sample*s). About 5 mL of extract is needed for each liquid scintillation sample. The following equation is used for silica gel that has been dried just prior to deployment to correct the measured concentration (Guthrie et al. 2002):

$$C = 1.0309\ C_m'\ [(0.0512 + W)/W]$$

where

C = corrected concentration (to equal the HTO in sampled air moisture)

C_m' = HTO measured in the extracted water

W = fraction adsorbed water in silica gel = (wet weight of silica gel – dry weight of silica gel)/dry weight of silica gel

This correction is necessary because about 5% of the “dry” silica gel is water that cannot be removed unless the silica gel is destroyed. When the tritiated air moisture comes in contact with this residual water in the silica gel, exchange occurs. As a result, the tritium concentration of the ambient air moisture will be diluted by the water in the silica gel. This effect is greater when less water is extracted from the air relative to the mass of dry silica gel. A new equation will be developed for each new batch of silica gel. Concentrations are reported for the extracted water as the measured value in pCi/L and as a calculated value of pCi/m^3 based on the volume of air that has passed through the sample.

5.5 Data Quality Assurance

5.5.1 Precision

The reporting limits for tritium in extracted air moisture are usually about 2.0 to 3.0 Bq/L (50 to 80 pCi/L). Typically this means that the reporting limits per cubic meter (a derived value) are usually between 0.011 and 0.019 Bq/m^3 (0.3 to 0.5 pCi/m^3).

Two air tritium duplicate samples are taken during each sampling period. The sampling locations of field duplicate samples are not identified on the silica gel flasks, so the analytical laboratory does not know where the samples originated (procedure EMP-QA-DM, *Sample and Data Management*). This information is recorded on FTFs that are filled out in the field by the sampling technologist. The tritium air samplers for duplicate QA/QC samples are rotated among the locations at bimonthly intervals.

After the analyst obtains the laboratory results, the concentrations of duplicates are compared. Different concentrations can be explained by analytical error and natural variability. In most cases historically, the difference between duplicates can be explained exclusively by analytical error. This is invariably true when concentrations are near the detection limits, which occur much of the time in the air tritium network. When one of the results in a pair is a non-detection, then the other result should be less than two times the detection limit (Sanchez et al. 2004, Chapter 8). Natural variability becomes important at higher concentrations. Nevertheless, if all parts of the sampling system are working properly and no human error is involved, the mean ratio should be between 0.7 and 1.3 (Sanchez et al. 2004, Chapter 8). If a larger difference is detected, the reason should be investigated by checking the information contained on the FTF. Specifically, the total flow rates and grams of water extracted should be compared. If the total flow rates are similar, the quantity of water extracted should also be similar for all locations during a sampling period. If it is not, the reason for the inconsistency in the duplicate concentrations has been found. If the magnitude of the differences cannot be explained, the analytical laboratory is contacted to discuss any problems that may have occurred during analysis and to recount the samples.

Two laboratory duplicates (or splits) are created from the field samples collected each sampling period and are introduced blind into sample processing. The relative error ratio is calculated and reported for each split sample. If the control limit of 3.0 is exceeded, the source of the problem is investigated and corrected (EMRL procedures, SOP-CES-P810, *Data Validation* and SOP-CES-P811, *Data Verification*).

5.5.2 Accuracy

As an additional component of its program to ensure data accuracy, the radiological laboratory runs blank and control samples traceable to standards of the National Institute of Standards and Technology (NIST). Currently, no field blanks are collected. The laboratory blank is obtained by bubbling argon gas through 250 mL of water known to be free of tritium. The 250 mL of water is trapped on silica gel and extracted by freeze-drying (CES-EM-P542, *Low Level Tritium Analysis – Freeze Dry*). A laboratory standard of known tritium concentration is prepared similarly to assess percent recovery. The efficiency of recovery is reported for each sampling period and must fall within the EMRL's arbitrarily set internal acceptance criterion of 75% ≤ recovery ≤ 125%.

Until 2004, the radiological laboratory participated twice yearly in the DOE Environmental Measurements Laboratory Quality Assurance Program (SOP-CES-P820, *CES Performance Evaluation Program*), which ran from 1976 to 2004. For tritium, the DOE sent water[3] samples containing known concentrations to the participating laboratories, compared the analytical results (thereby determining the accuracy of the various participating laboratories), and published reports so that analytical laboratory personnel and their customers could evaluate their analytical laboratory's relative performance. The results of the study were published on the EML web site (http://www.eml.doe.gov/QAP/).

Triennial self-assessments of all monitoring networks are also performed (procedure ORAD-QA-SA, *Self Assessments*).

5.5.3 Completeness

For the last five years (1999–2003), just over 95% of all air tritium samples were collected. Problems causing loss of field samples include pump failure, power outages, flow meter malfunction, and flask breakage. With respect to laboratory analyses, TAMM requires that ninety percent of the samples submitted to and analyzed by EMRL yield valid data. If these completeness criteria are not met, nonconformance reports are prepared according to ORAD-QA-NCR (*Nonconformance Reporting and Tracking*).

5.5.4 Calibration

Equipment in the EMRL is calibrated with sources that are traceable to NIST. Calibration follows a variety of methods, from calibration by a certified third party, to calibration with known standards that are made from traceable materials. Calibration

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[3] Air-moisture silica-gel reference samples were not available through NIST or any of the intercomparison laboratory study programs.

practices are in accordance with standard procedures, and records are maintained for each piece of calibrated equipment.

5.6 Program Implementation Procedures

The primary responsibility for activities related to the air tritium monitoring network is assigned to a TAMM environmental analyst in ORAD. The analyst is responsible for the network design, implementation, and correct operation of the network; the analysis and evaluation of all monitoring results; data trending; documentation; and results reporting.

The laboratory preparation of the silica gel flasks is carried out by TAMM technologists following EMP-AT-S, Instruction #1, *Air Tritium Pre-Sampling Activities*. Technologists follow EMP-AT-S, Instruction #2, *Air Tritium Sampling Activities*, for the work in the field, when silica gel flasks are replaced. These instructions also cover final treatment of the samples before delivery to EMRL. Air tritium samples are submitted for analyses using sample control, chain-of-custody, and documentation procedures (EMP-QA-DM, *Sample and Data Management*). The written procedures include requirements for sample collection and submittal for chemical analysis, keeping a log, and filling out FTFs and chain-of-custody forms. The procedures also require the sampling technologist to alert the environmental analyst about difficulties encountered during any sampling event and complete a report for unacceptable samples (ORAD-QA-NCR*, Nonconformance Reporting and Tracking).*

Because the DOE/EH-0173T (DOE 1991) states that the "air sampling rate should not vary by more than ±20 percent, and the total air flow or total running time should be indicated", LLNL uses flowmeters at the air tritium sampling locations. These flowmeters provide the instantaneous flow rate, and the minimum, maximum, and total flow during a sampling period. Electronic flowmeters are removed from the field and calibrated either biannually or when the percent difference between the flow off as measured by rotameter (see below) and the flow off measured by flowmeter is greater than 15% for two consecutive sampling periods. Flow calibrations of the electronic flowmeters are done according to EMP-AT-S, Instruction #4, *Electronic Flowmeter Calibration*.

Gilmont rotameters are used to set the flow rate of the flowmeter at the start of the sampling period to 500 cc/min and to measure the instantaneous flow when the sample flask is changed, which is compared with the indicated flow of the flowmeter. Rotameter readings are also used to determine the total flow when a flowmeter has failed or the location does not have a flowmeter. The rotameters used for tritium air sampling flow adjustments are serviced and calibrated to NIST standards annually by the LLNL Hazards Control Instrument Calibration Laboratory. Technologists visually inspect the rotameter for damage prior to use. Additionally, they ensure that the rotameter has been serviced within the past year. The TAMM sampling technologist delivers the rotameter to Hazards Control and picks it up, along with a new calibration curve, when the instrument has been calibrated (EMP-AT-S Instruction #3, *Annual Rotameter Calibration Check*).

5.7 Action Levels

Table 5-1 shows the upper warning limits and upper action limits for each of five sampling groups in the air tritium monitoring networks (perimeter sampling locations and diffuse sources on the Livermore site, offsite sampling locations in the Livermore Valley, Site 300 perimeter sampling locations, and POOL); concentrations are expressed both in Bq/m^3 and Bq/L. The warning and action limits, two times and three times the geometric standard deviation respectively, were calculated using five years of historical data (1997 – 2001; *Environmental Monitoring Plan 2002*) and will be reassessed using more recent historical data if increases in LLNL operations cause tritium concentrations to approach the warning limits.

Table 5-1. Upper warning and action limits for air tritium sampling groups in Bq/m^3 and Bq/L

Location	Bq/m^3 [(a)]		Bq/L[(a)]	
	Warning Limit	Action Limit	Warning Limit	Action Limit
Livermore Perimeter	0.35	0.96	51	150
Livermore Offsite	0.11	0.31	14	43
Site 300	0.029	0.066	4.1	9.5
POOL	0.92	2.3	120	320
B331	43	240	5,700	32,000
B624	15	36	2,000	4,900

a Bq/m^3 is derived from Bq/L based on the total flow that has passed through the silica gel. Bq/L is the fundamental measured value; Bq/ m^3 is the reporting unit.

Each sampling period, the air tritium sample results for each location are checked to see if they fall within the warning limit. Any data results that are greater than the warning limit must be investigated. The investigation involves checking sampling operations by contacting the technologist who performed the sampling and by reviewing the appropriate FTFs. If the sample results that exceeded warning limits are not the result of sampling or field activities, further investigation is required. The data are checked for transcription errors, and the analytical lab is contacted to determine if any problems occurred during analysis. In some case, re-analysis may be performed. Atmospheric dispersion modeling may be used to assess the possibility that the number is real. Any results outside the action level are also subject to the same investigation as warning levels, but the environmental analyst must notify EPD management. Further action will be taken with EPD management concurrence.

5.8 Preparation and Disposition of Reports

Data are analyzed based on ORAD-QA-D, *Data Analysis*. The air monitoring results and inhalation dose assessments based on these data are reported in the annual *Environmental Report*. A comparison between mean annual tritium concentrations in air and air concentrations predicted by CAP88-PC is reported in the *LLNL Annual NESHAPs Report*.

5.9 Future Plans

As locations and release rates of tritium sources at LLNL change over time, the need to add, remove, or relocate air tritium samplers will be assessed through dispersion modeling. The output from the dispersion model will serve as input to an easy-to-use program, now being developed, that will determine the tritium dose from all sources at any particular location.

5.10 References

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6 Sanitary Sewer

Henry E. Jones • Bob Williams • Allen Grayson • Michael J. Revelli

6.1 Introduction

The Livermore site of Lawrence Livermore National Laboratory (LLNL) is the largest single source of the sanitary sewage processed by the Livermore Water Reclamation Plant (LWRP). LLNL and Sandia National Laboratories, California (Sandia/California) together produce an average of 1-million liters of sewage each day, approximately 4 percent of the volume treated at the LWRP. The combined volume, consisting primarily of sanitary wastewater and cooling tower blowdown water, is discharged to the city of Livermore sewer system from the northwest corner of the Livermore site (Figure 6-1).

After treatment at the LWRP, the wastewater is pumped out of the Livermore Valley through a pipeline shared with four other publicly owned treatment works (POTWs) and discharged into the San Francisco Bay. The sludge produced in the treatment process is disposed of in landfills.

The research and development activities at LLNL require the use of hazardous and radioactive materials; if significant concentrations of these materials were inadvertently discharged to the sanitary sewer, they could seriously impact LWRP operations and potentially degrade the quality of water resources. Programs to control these materials are mandated in federal and state law, U.S. Department of Energy (DOE) orders, and local regulations. In some cases, these requirements impose specific engineering standards for discharge control measures. Generally, though, they impose numerical limits on the presence of pollutants.

6.2 Sewer Compliance Monitoring Program

6.2.1 Rationale and Design Criteria

6.2.1.1 Regulatory Drivers

Nonradiological pollutants generated at the Livermore site are covered under the wastewater discharge permit issued by the LWRP (City of Livermore 2004). The permit is issued following review of an application that provides a comprehensive overview of

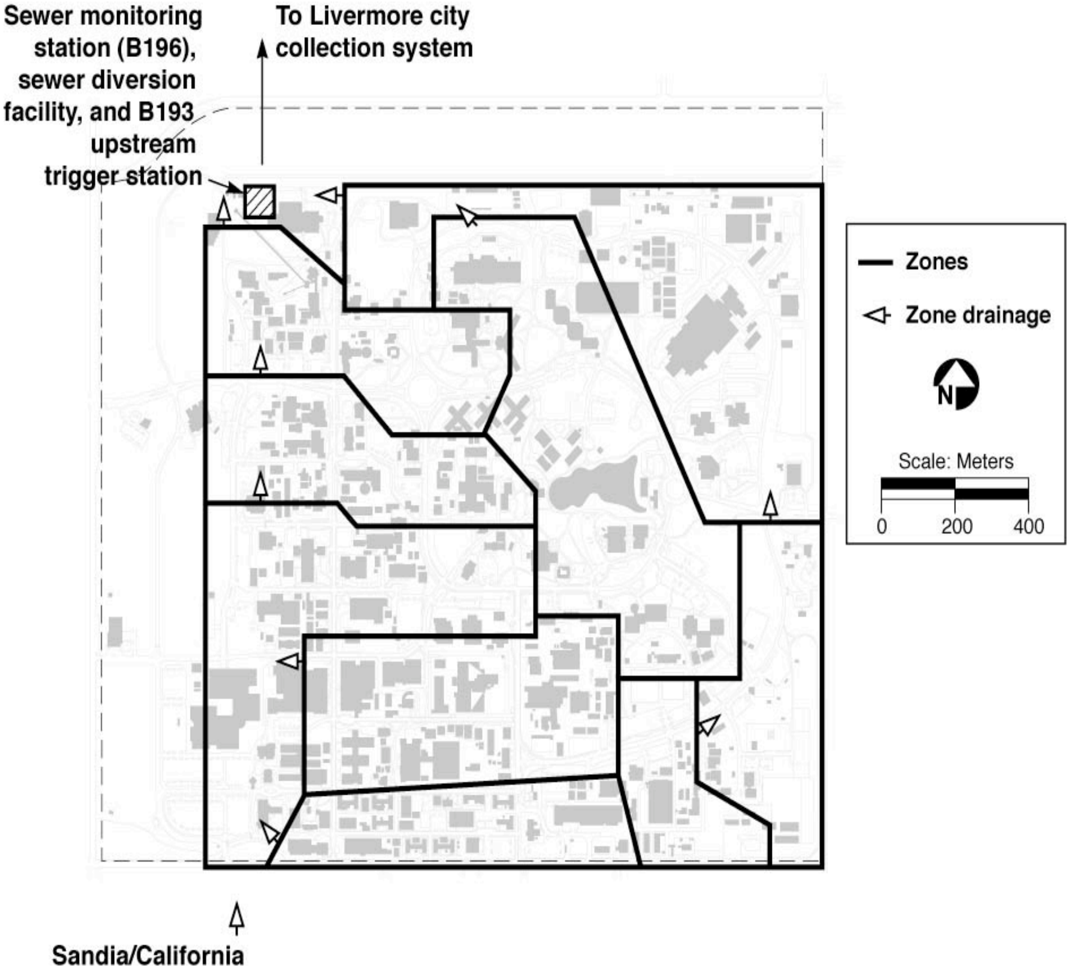

Figure 6-1. Livermore site sewer monitoring network

LLNL wastewater discharges (Grayson 2004). Documentation includes a complete listing of chemicals used at the site, process diagrams for specific waste treatment and materials processing operations, a description of retention tank systems, and an overview of the sewer monitoring program. The permit covers reporting and monitoring requirements, as well as specific outfall discharge limits (Table 6-1) and point-source discharge limits as prescribed by the federal Categorical Standards. These standards are discussed in Chapter 8.

General discharge prohibitions are also stated for:

- Explosive or pyrophoric solids, gases, or liquids
- Solids or viscous substances
- Toxic pollutants

Table 6-1. Nonradiological pollutant outfall limits specified in the LLNL wastewater discharge permit

Parameter	Limit (mg/L)
Arsenic	0.06
Cadmium	0.14
Chromium	0.62
Copper	1.0
Lead	0.2
Mercury	0.01
Nickel	0.61
Silver	0.20
Zinc	3.0
Cyanide	0.04
pH	5-10
Total toxic organics (TTO)	1.0

Source: City of Livermore 2004

- Substances that would cause the LWRP to be in noncompliance with sludge use or disposal criteria
- Noxious or malodorous liquids, gases, or solids that would create a public nuisance or hazard to life
- Substances that would cause the LWRP to violate its National Pollutant Discharge Elimination System (NPDES) permit or receiving water quality standards
- Wastewater with objectionable color
- Heated waters that may inhibit biological activity
- Pollutants that may cause interference to the LWRP
- Wastewater that would cause hazard to human life or would create a public nuisance
- Radioactive wastes or isotopes that exceed limits established by a state or federal regulatory agency

Discharge criteria for radiological pollutants are specified in DOE Order 5400.5, Chg. 2, Chapter II, paragraph 1 (except 1.a.3.c. and 1.c.); Code of Federal Regulations (CFR), Title 10, Part 20.2003 (a)4, Subpart K; and the general discharge prohibitions of the wastewater discharge permit issued by the LWRP (City of Livermore 2004). Because DOE facilities are not licensed by the Nuclear Regulatory Commission, they are, in principle, exempt from the requirements of 10 CFR 20. However, LLNL has adopted parts of California Code of Regulations (CCR), Title 17, Section 30253, which incorporates by reference 10 CFR 20 requirements. Both DOE Order 5400.5 and 10 CFR 20 contain concentration-based discharge limits for specific radioisotopes. Also 10 CFR 20.2003 (a)4, Subpart K, contains total annual radioactivity discharge limits. The concentration-based discharge limits from DOE Order 5400.5 and the total annual radioactivity discharge limits from 10 CFR 20 are summarized in Table 6-2.

Table 6-2. Discharge limits applicable to LLNL for radionuclides in sewage

Source	Radionuclide	Limit
10 CFR 20.2003 (a)4, Subpart K,	Tritium	185 GBq/y
	Carbon-14	37 GBq/y
	All others	37 GBq total/y
DOE Order 5400.5, Chg. 2, Chapter II, Paragraph 1 (except 1.a.3.c, and 1.c)	Tritium	370 Bq/mL
	Potassium-40	1.3 Bq/mL
	Uranium-238	0.11 Bq/mL
	Plutonium-239	0.0056 Bq/mL
	Americium-241	0.0056 Bq/mL

After specifying the discharge limitations, the regulations generally leave to the discharger the development of administrative and engineering control systems that will ensure that the discharge meets established limits. At LLNL, administrative measures include implementation of internal discharge limits, training of materials handlers, control and tracking of certain materials, drain labeling, and inspection and review of facilities and operations. Engineering controls include isolating specific operations from sanitary connections and collecting industrial wastewater from entire facilities in retention tanks.

The program also seeks to aid in evaluating the control program that prevents violation of sewer discharge requirements imposed by local, state, and federal regulations, and by DOE Order 5400.1[1], Chapter IV, Paragraph 1.a. LLNL's compliance in the monitoring of nonradioactive contaminants is defined by the terms of the discharge permit granted by the LWRP (City of Livermore 2004). Components of the radiation monitoring program also are keyed to demonstrating compliance with regulatory requirements (10 CFR 20, Subpart 2003(a)4, Subpart K, and DOE Order 5400.5, Chg. 2, Chapter I,

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

Paragraph 7). However, demonstrating the effectiveness of a control program also requires measures that track certain contaminants at levels far below regulatory limits. An example of these measures is tracking plutonium at levels 1 million times lower than the most restrictive discharge standard.

6.2.1.2 Monitoring Objectives

The primary goal of the sewer compliance monitoring program is to evaluate LLNL's compliance with regulatory requirements. The wastewater discharge permit issued to LLNL by the LWRP requires continuous outfall pH and flow monitoring and analysis of weekly flow-proportional composite samples for nine specific metals (Table 6-1). Once each month, the permit also requires analysis of 24-hour flow-proportional composite sample and grab samples.

6.2.1.3 Sources and Analytes

The composite sample must be analyzed for water quality parameters (biochemical oxygen demand, total dissolved solids, and total suspended solids) and toxic substances (tributyltin in January and July). The grab samples must be analyzed for an additional suite of toxic substances (cyanide in January and July, and volatile and semivolatile organic compounds monthly).

Requirements for the radiation monitoring program are less prescriptive. Gross alpha and gross beta analyses of daily flow-proportional composite samples are good screening measures for the presence of radioactivity, but do not give the specific radioisotopic concentrations necessary for comparison with limits contained in 10 CFR 20.2003(a)4, Subpart K and Order 5400.5, Chg. 2, Chapter III. Gross radiation screening is also not sensitive to very low-energy beta radiation, such as that produced by tritium. For these reasons, the general screening program must include some isotope-specific analysis.

6.2.1.4 Collection Methods

Once contaminants are introduced to the sewer system, they travel along a well-defined route until they arrive at the LWRP for treatment. The primary monitoring location, as required by logic and regulation, is located at LLNL's point of discharge to the city collection system. Sampling at this location allows assessment of LLNL's compliance with discharge requirements. Assessment of the impacts of LLNL discharges requires sampling of process waste streams at the LWRP. On-site sampling requirements are discussed below.

The constituents in sewage are constantly varying. The most representative characterization of the overall quality of wastewater is, therefore, obtained by compositing (that is, small aliquots of the discharge are combined into a large container, which at the end of the sampling period is mixed and decanted into sample bottles). There are two methods of compositing:

- In the time-proportional method, which can be used for waste streams with relatively constant flow, aliquots are taken at fixed time intervals. This method is not used at LLNL because flow rates vary from 200 to 2400 L/min during the course of a normal day.
- In the flow-proportional method, an integrating flow meter monitors the total volume of wastewater discharged and activates a sampler each time a fixed volume of wastewater is discharged (e.g., once every 3785 L). This method, which is used at LLNL, provides an accurate daily average pollutant concentration when the flow rate varies widely.

The frequency of composite sampling should correspond with what is known about facility discharges and the hydrodynamics of the sewer flow. LLNL facility discharges generally are of two classes: brief releases of small (approximately 4 L) quantities through sinks or other plumbing fixtures, occurring at almost any hour of the day; and discharges on the 4,000 L scale, lasting from 10 to 30 minutes (as constrained by the capacity of most facility connections), and occurring mostly during normal working hours. The primary sources of these discharges are planned releases from boilers, cooling towers, and retention tanks.

pH fluctuations at LLNL are most frequently observed for the first, smaller-volume class of discharge. Monitoring data show that these releases usually last two to 10 minutes, so adequate samples should be obtained using flow-proportional compositing with an aliquot acquired every 2 to 5 minutes. At this frequency, the second class of discharges (larger volume, longer duration) will also be adequately sampled.

Compositing is most applicable for analysis of pollutants, such as heavy metals or minerals, that are stable over time. Compositing cannot be used for less stable analytes. For example, volatile organic compounds (VOCs) may dissipate during collection and prior to analysis of a composite sample. Certain wastewater-quality parameters may be affected by the biological activity of the sewage, which also precludes the use of composite sampling. Grab sampling is used to collect samples for these types of analysis.

6.2.2 Extent and Frequency of Monitoring and Measurements

6.2.2.1 Sampling Locations and Methodology

6.2.2.1.1 On-Site

The sewer monitoring station (Building 196), as shown in Figure 6-1, is the location for outfall compliance monitoring. As required by the terms of the sanitary sewer permit, the LLNL outfall compliance sampling point is located at the northwest corner of the site, where LLNL sewage is discharged to the city collection system. The flow-proportional composite and grab samples acquired here are used to determine the combined contribution of LLNL and Sandia/California discharges to the LWRP. The samples described here are all collected at the LLNL outfall. Three distinct sampling locations are used at the outfall:

- The Sewer Monitoring Station, or Building 196, which serves as the main monitoring station.
- C196, a composite sampling system located in a shelter to the east of Building 196.
- The flume, located in the vault to the east of Building 196. (The vault contains the flow-monitoring equipment used to trigger the composite sampling systems.)

The Building 196 sampler is activated once every 3785 L of flow (approximately once every two minutes at normal on-shift flow rates, and once every 10 minutes during the off shift). The C196 sampler is activated once every 30,000 L of flow.

6.2.2.1.2 Off Site

As described in procedure EMP-SW-LWRP*, Sewage Sampling at LWRP*, LWRP personnel collect two types of samples for LLNL. Samples of LWRP effluent are used to monitor the release of soluble contaminants to the San Francisco Bay, while samples of the liquid in the aerated digesters are used to track levels of heavy metals and radionuclides that concentrate in the dried sludge. LWRP personnel collect these samples according to their own procedures. LLNL personnel pick up these samples and deliver them to the analytical laboratory for analysis.

6.2.2.2 Sampling Frequency and Analytes Measured

Compliance sampling and analysis follow regular schedules and are subdivided into two types—radiological and nonradiological.

6.2.2.2.1 Sampling and Analysis for Radiological Parameters

Each day, a flow-proportional composite of LLNL effluent is acquired, as described in sampling procedure EMP-SW-B196*, Sewage Sampling at B196*. Each daily sample is analyzed for alpha, beta, and tritium activity. Monthly composites of the LLNL daily samples are analyzed for plutonium and cesium-137. A monthly composite of LLNL effluent from the C196 sampling location is also analyzed for tritium and gross alpha and beta activities (see procedure EMP-SW-C196*, Sewage Sampling at C196*). The results of these analyses are used to assess compliance with gross radiation and isotope-specific discharge limitations imposed by 10 CFR 20.2003(a)4, Subpart K, and with the isotope-specific limitations of Order 5400.5, Chg. 2, Chapter III.

As described in procedure EMP-SW-LWRP*, Sewage Sampling at LWRP*, daily composite samples of LWRP effluent are combined to create a monthly composite sample. These monthly composites are analyzed for alpha, beta, and tritium activity as well as for plutonium and cesium-137. Samples of LWRP's microbially-activated liquid sludge are collected monthly and analyzed for gross alpha and beta activity. Quarterly composites of these monthly samples are analyzed for plutonium and gamma activity.

6.2.2.2.2 Sampling and Analysis for Nonradiological Parameters

The wastewater discharge permit issued to LLNL by the LWRP prescribes the requirements for monitoring nonradiological parameters. As described in sampling procedure EMP-SW-C196*, Sewage Sampling at C196*, a weekly composite of LLNL effluent is acquired from the C196 sampling location and analyzed for metals content. In addition, 24-hour composite samples and grab samples of LLNL effluent are collected from the flume once each month. These samples are submitted to be analyzed for water-quality parameters and toxic chemicals. Table 6-3 shows the complete list of parameters that are checked at C196. Rationale, scheduling, and sampling protocols are detailed in EMP-SW-C196.

A pH probe and circular chart recorder operate continuously inside the Building 196 Sewer Monitoring Station to record the pH levels of the effluent. The rationale and scheduling of routine operations for this equipment are discussed in two procedures: EMP-SW-M*, Sewer Equipment Maintenance*, and EMP-SW-CA*, Sewer Equipment Calibrations*.

Some additional sampling and analysis for nonradiological analytes (not required by the discharge permit) is performed. Portions of the daily samples from Building 196 are combined and analyzed weekly for metals content, and LWRP sludge samples are analyzed monthly for metals.

Table 6-3. Analytical methods used by off-site contract analytical laboratories

Analyte	Method
Total settleable solids	EPA Method 160.5
Total suspended solids	EPA Method 160.2
Total dissolved solids	EPA Method 160.1
Alkalinity	EPA Method 310.1
Total phosphorus	EPA Method 365.4
Anion analysis	EPA Method 300.0
Chemical oxygen demand	EPA Method 410.4
Total organic carbon	EPA Method 415.1
Nutrients	EPA Methods 353.2, 351.2 and 350.1
Volatile solids	EPA Method 160.4
Aluminum, cadmium, calcium, chromium, copper, iron, magnesium, potassium, silver, sodium, and zinc	EPA Method 200.7
Beryllium	EPA Method 210.2
Nickel	EPA Method 249.2
Arsenic	EPA Method 206.2
Lead	EPA Method 239.2
Mercury	EPA Method 245.1
Selenium	EPA Method 270.2
Tributyltin	Gas Chromatography/Flame Photometric Detector
Total cyanide	EPA Method 335.3
Volatile organics	EPA Method 624
Semivolatile organic compounds	EPA Method 625
Total oil and grease(a)	EPA Method 1664
Biochemical oxygen demand	SM17-5210B

Source: Blanket service agreements between the Regents of the University of California and off-site contract analytical laboratories.

a The requirement to sample for oil and grease has been suspended until the Livermore Municipal Code can be modified to remove references to “Freon-extractable” oil and grease (LWRP letter dated 4/1/99).

6.2.3 Procedures for Laboratory Analysis

Radiological analyses of B196 daily samples are performed by the LLNL Hazards Control Analytical Laboratory (HCAL). The LLNL Environmental Monitoring Radiation Laboratory performs high-sensitivity analyses for plutonium and cesium as well as for gross alpha, gross beta, and tritium.

Nonradiological analyses are performed by HCAL or by an outside contract laboratory. The portions of the LLNL daily samples that are combined weekly and the LWRP monthly sludge samples are analyzed for metals content by LLNL HCAL using EPA methods. Off-site contract analytical laboratories perform all other nonradiological analyses. The standard analytical methods used by off-site contract analytical laboratories are listed in Table 6-3.

6.2.4 Data Quality Assurance

6.2.4.1 Precision

Quality control duplicate samples are collected and analyzed to verify the quality of analytical results. Under the quality assurance program for these monitoring networks, duplicate samples are collected according to procedures EMP-SW-C196*, Sewage Sampling at C196;* EMP-SW-B196*, Sewage Sampling at Building 196;* and EMP-SW-LWRP*, Sewage Sampling at LWRP* . These duplicate samples are submitted to the laboratory for analysis. The results for the duplicate samples are compared by the network analyst upon the receipt of the analytical results from the laboratory. Trip blanks are not necessary for these networks.

6.2.4.2 Accuracy

All quality check information provided by the analytical laboratories, including matrix spikes, matrix duplicates, and calibration standards, are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation.

6.2.4.3 Completeness

Sanitary sewage samples are collected from B196, C196 and LWRP. Given the potential for sample loss due to mechanical failure and laboratory mishaps, our target completeness is 90%.

6.2.5 Program Implementation Procedures

The primary responsibility for activities related to the sanitary sewer monitoring networks is assigned to a Water Guidance and Monitoring Group (WGMG) environmental analyst. The analyst is responsible for the network design, implementation, and correct operation of the network; the analysis and evaluation of all monitoring results; data trending; documentation; and reporting. The following procedures are associated with the sanitary sewer monitoring networks:

- EMP-SW-B196*, Sewage Sampling at B196*: Details of sampling, processing, and documentation for sampling at the B196 Sewer Monitoring Station.
- EMP-SW-C196, *Sewage Sampling at C196*: Details of sampling, processing, and documentation for sampling at the C196 Sewer Monitoring Station behind Building 196.
- EMP-SW-CA, *Sewer Equipment Calibrations*: Details of calibration protocol for sewer monitoring equipment.

- EMP-SW-LWRP, *Sewage Sampling at LWRP*: Details of sampling, processing, and documentation for sampling at the LWRP.
- EMP-SW-M, *Sewer Equipment Maintenance*: Details of maintenance protocol for sewer monitoring equipment at B196.
- EMP-QA-DM, *Sample and Data Management*: Details how samples are handled, stored, and delivered.

6.2.6 Action Levels

A WGMG analyst routinely checks data against action levels. For gross alpha, gross beta, and tritium analytical results, the informal, internally developed action levels are 3.7×10^{-4} Bq/L (0.01 pCi/mL), 0.02 Bq/L (0.5 pCi/mL), and 0.19 Bq/L (5 pCi/mL), respectively. The concentration-based discharge limits of DOE Order 5400.5 and annual totals of 10 CFR 20 are considered formal action levels for the radiological.

For nonradiological analytes regulated by LLNL's wastewater discharge permit, the action levels for pH, cyanide, and total toxic organics (TTO) are the discharge limits specified in the permit. Action levels for regulated metals (arsenic, cadmium, copper, chromium, lead, mercury, nickel, silver, and zinc) are 50 percent of the limits specified in the permit for weekly samples and 100 percent of the limits specified in the permit for 24-hour composite samples (see Table 6-1).

If the concentration of an analyte exceeds an action level and the QC data are acceptable, the WGMG analyst looks for a correlation between a retention tank discharge and the analyte concentration. Depending upon the outcome, further investigation may be initiated by the WGMG analyst. The investigation may include, but is not limited to, the analysis of archived samples and the collection of non-routine samples using strategically located portable samplers. In cases where the concentration of a regulated metal in a weekly sample exceeds the 50-percent action level, archived 24-hour composite samples (corresponding to the weekly sampling period) must be submitted for analysis to provide direct comparison with LLNL's 24-hour discharge limit. If, in any case, the wastewater discharge permit limit is exceeded, the investigation must include resampling for the analyte in question in order to establish the time that LLNL returned to a state of compliance with the permit; the event is reported to the LWRP and DOE.

6.2.7 Preparation and Disposition of Reports

LLNL's wastewater discharge permit requires that outfall data be reported monthly. The report includes both the radiological and the nonradiological monitoring data received during the month. It discusses any unusual data or data that indicate exceedance of permitted levels, summarizes changes in the monitoring program, and reports on activity in the continuous monitoring program. Data tables present (1) monthly radiation monitoring results for the year to date (tritium, cesium, and plutonium), (2) monitoring results for tritium in LLNL daily sewage samples for the previous month, (3) weekly LLNL effluent metals concentrations for the last three months, and (4) results for water quality parameters and toxic substances of regulatory concern for the year to date.

If any analytical results exceed the LWRP-issued outfall discharge limits, the wastewater discharge permit requires LLNL to issue a Five-Day Report that details the incident. A copy of this report is sent to DOE. If LLNL receives enforcement action for the event, specifically a Notice of Violation, from the LWRP, then LLNL prepares an Occurrence Report, as required by Order 232.1A.

The annual *Environmental Report* includes a summary and analysis of the radiological and nonradiological monitoring results for sewer.

6.2.8 Future Plans

New sampling and measurement equipment will be evaluated. If improvements to the current system are possible then the process of acquiring and installing the upgraded equipment will begin.

6.3 Sewer Spill Monitoring Program

6.3.1 Rationale and Design Criteria

6.3.1.1 Regulatory Drivers

As a research and development facility, LLNL's discharges of non-domestic wastewater are almost universally batch discharges, as opposed to the continuous discharges typical of many industrial facilities. Sources at LLNL can be as small as 1-liter discharges of dilute chemical solutions by individual experimenters, lasting a few seconds or minutes. At facilities with retention tanks, these small-quantity discharges are consolidated in 1,000- to 20,000-L batches and released to the sanitary sewer following chemical and radiological analysis (Chapter 7). Emptying a retention tank typically requires 30 minutes. For batches of this size, an inadvertent release of contaminants to the sewer can cause a violation of LLNL's discharge limitations (which are averaged over weekly flows of 7 million liters) if the contaminant concentration in the batch is much higher than the permit limitation. Because LLNL has historically contributed a maximum of 10 percent and, more recently, 3.8 percent of the influent received at the LWRP, for a release to disrupt LWRP operations the contaminant concentration would need to be 10 to 20 times higher than if LLNL were the sole contributor to the LWRP. Although

LLNL cannot monitor continuously for the presence of all contaminants at concentrations near LWRP permit levels, it is possible to monitor for critical contaminants at concentrations that could pose an immediate threat to LWRP operations. Should a release of those contaminants occur, LLNL could then notify LWRP personnel to initiate mitigating measures (i.e., diversion of the contaminated influent into a holding pond for special treatment) and provide timely feedback to LLNL personnel so that corrective action (either further training or modification of wastewater handling procedures) could be implemented.

In the late 1980s, it became apparent that, in the context of rapidly tightening regulations and the operational flexibility required by LLNL's research and development missions, the Laboratory's wastewater infrastructure was insufficient to guarantee continuous compliance with sewer discharge requirements. LLNL consequently initiated a comprehensive upgrade of that infrastructure. The Sewer Monitoring Complex (SMC) was redesigned to maximize sensitivity to the contaminants of most concern, an 880,000-L sewage diversion and retention facility was constructed at the point of discharge to the city sewerage, and sampling stations were installed at a number of locations around the LLNL site (see EMP 1999, Section 6.4.8.1, Satellite Station Network).

With the addition of these capabilities, the SMC system became an integral part of LLNL's environmental control program. There is little formal guidance and few formal requirements for the system. DOE/EH-0173T (DOE 1991) suggests, "Continuous radionuclide monitoring [at] those release points that could exceed 1 DCG [derived concentration guide] equivalent averaged over 1 year." This criterion, however, is far weaker than LLNL's best management practices (BMPs), which maintain radionuclide concentrations at levels thousands to millions of times lower than their DCGs. The remaining EH-0173T guidance applies only to the calibration of equipment, spill response, and spill notification. Specific capabilities of the system are not identified. The other relevant standard—the self-monitoring program defined in the permit awarded by the LWRP—specifies only that pH and flow must be recorded continuously.

6.3.1.2 Monitoring Objectives

The most important monitoring goal is the detection and containment of releases of radioactive materials that exceed discharge limitations or LLNL BMPs. Specific monitoring goals are based principally upon an institutional evaluation of the probability and potential impact of releases of specific contaminants. Currently, those goals have emphasized the real-time continuous monitoring of pH, flow, metals, and radioactivity. An evaluation of the compliance monitoring data establishes that other parameters of potential concern, such as organic chemicals and cyanide, are generally well within discharge limits and so do not merit the expense and effort of installing and maintaining real-time continuous monitoring capabilities.

6.3.1.3 Sources and Analytes

6.3.1.3.1 Radioactivity

The hazards posed by LLNL's inventory of radioactive materials are mitigated by administrative and engineering controls upstream of the monitoring system. Early in the life of the Laboratory, LLNL invested in these controls, and they have been successful in preventing releases that posed a serious threat (as defined in EPA and DOE public-protection standards) to the public welfare.

Most discharge limitations are specified as bounds on the average monthly concentration for a specific radionuclide. See Section 6.2.1.1 for details about regulatory guidance for the average monthly concentration. Evidence that releases have exceeded the discharge concentration limits (DCGs) of DOE Order 5400.5 would require that LLNL implement best available technology to reduce discharges (DOE 1993). LLNL policy is to detect, as soon as possible, any release above the DCGs so that control measures may be implemented prior to violation of the DCG for the month as a whole.

6.3.1.3.2 Metals

In the case of nonradioactive industrial pollutants, the development of upstream controls was less methodical than it was for radioactive materials. Standards prior to the implementation of the Clean Water Act in 1972 allowed the proliferation of small metal-finishing operations. This trend was encouraged by the nature of Laboratory operations. For sensitive operations, access to materials and information is limited to those with a "need to know," which is best managed when each project controls all of the resources necessary to accomplish its work. Additionally, research at the forefront of technical development is fostered when there is close contact among scientists and technicians. In this context, no concerted effort was made to consolidate metal-finishing operations until after 1986, when tightening pretreatment standards brought direct regulatory attention to the problem of the occasional release of metal-finishing solutions.

In setting its metals discharge limits, the LWRP considers three issues. First, the LWRP has discharge limitations of its own, established in its National Pollutant Discharge Elimination System (NPDES) permit. Compliance with these limits is evaluated through analysis of 24-hour composite samples of treated water. After accounting for the efficiency of the treatment process in removing metals, the NPDES limits translate to maximum concentration values allowed for metals in the influent wastewater. Second, those metals that are removed from the sewage are concentrated in sludge that is shipped to a sanitary landfill. Each shipment is generally a consolidation of sludge accumulated over weeks or months. When metals concentrations in the sludge are too high, it must be shipped to a hazardous waste landfill at significantly greater cost. Finally, bacteria in the activated digesters (the holding time in the digesters is only 6 hours) are suppressed when the concentrations of certain heavy metals become too high.

The primary purpose of the discharge limitations is to prevent disruption of LWRP operations. That purpose is the appropriate context for establishing the goals of LLNL's continuous metals monitoring program. From the details of the LWRP operations schedule, it appears that 6 hours is the shortest timeframe over which a violation might result in serious disruption of plant operations. If the typical release at LLNL leaves the site over a 30-minute period, the target sensitivity for the monitoring system would be 12 times the discharge limit for the specific metal (resulting in a violation in the average concentration for the entire 6 hours). If the reduction in potency is accounted for by the addition of household wastewater prior to arrival at the treatment plant, a target sensitivity of 100 to 200 times the discharge limit could be acceptable.

For metals that do not strongly suppress bacteria, 24 hours is the appropriate timeframe for comparison with the discharge limitation; and that is, in fact, generally the enforcement standard that has been applied by the LWRP in the recent past. Target monitoring sensitivities for these metals might be as much as 50 times the discharge limit. In this case, because the limit has been enforced at LLNL's outfall, any additional adjustments to account for reduction in potency are not appropriate for calculating target sensitivities.

The metals concentration limits imposed in the permit issued by the LWRP are presented in Table 6-1.

6.3.1.4 Collection Methods

A continuous monitoring system requires a complex balance between the desired capabilities and the limitations of the currently available technology. The following sections discuss the issues raised in implementing the available technology.

6.3.1.4.1 System Response Time

Having established the general goals for monitoring sensitivity, the next step is to determine acceptable bounds for the system response time. For the technologies chosen for metals and radioactivity monitoring in the current system, rapid response and high sensitivity are actually competing criteria. Maximizing sensitivity would be unacceptable if response times were so long that a spill would arrive at the LWRP prior to annunciation of an alarm. Even with the Sewer Diversion Facility fully functional, an alarm will occur well before the bulk of a release leaves the LLNL site.

Response time criteria can be developed in several ways. If analysis could establish a maximum credible concentration for a contaminant, the response time could be calculated as some fraction of the length of time necessary for the discharged mass to disrupt LWRP operations. A survey of historical retention tank records might provide a suitable basis for such an analysis. In general, though, contaminant discharges disperse and spread as they flow through the plumbing and pipes connecting the point of discharge to the monitoring station. Rather than a sharp increase, the concentration of the pollutant generally rises smoothly before the arrival of the main slug and falls slowly afterwards. The front-loading of the slug provides the possibility of detecting and containing a release when contaminants are still at moderate concentrations. An analysis of the dynamics of contaminant transport through the sewer system might show that more time was available to detect the leading edge of the spill than to contain the spill itself. As a benchmark, the shortest pH excursions observed are a full 2 minutes in duration, with rise-times of approximately 30 seconds.

Finally, the system responsiveness is limited by the mechanical characteristics of the monitoring and sampling equipment itself. Pumping a sample from the pipe to the monitoring station requires roughly 75 seconds (to ensure the representativeness of the sample, the delivery speed is constrained to the velocities typically observed in sewer systems, or roughly 61 cm/s [2 ft/s]). Phase separation equipment retains the liquid for roughly 30 seconds. The pneumatic valves of the Sewer Diversion Facility close approximately 6 seconds following activation. From this information, it can be concluded that performing analyses more frequently than once every 30 seconds would have no practical impact on spill control at the Sewer Diversion Facility. Because of these mechanical limitations to system response time, LLNL installed an Upstream pH Trigger Station in 1998.

6.3.1.4.2 Technologies

The factor that most complicates the continuous monitoring of sewage is the medium itself. Sewage is a mixed-phase and highly variable mixture of biologically and chemically active waste. Most sensors, when directly exposed to such sewage, suffer either interference or destruction as a result of the contact. PH sensors are the only common tools that have been shown to withstand extended contact with sewage. Flow monitoring, metals monitoring, and radiation analysis have all been implemented using noncontact methods. Unfortunately, to provide reliable analytical results, noncontact methods generally require that the effluent be constrained to a stable geometry. The required mechanical preparation and channeling usually result in restricted orifices and flow volumes that collect gravel, silt, grease, and/or biological growth. To manage these problems, two stages of phase separation remove gravel and grit: chlorine is injected to control bacteria, and a macerator reduces impassable solids to a manageable size.

The technologies implemented for metals monitoring and radiation analysis are x-ray fluorescence spectroscopy (XRFS) and gamma spectroscopy, respectively. The ultrasonic sensing technology implemented for flow rate measurement is typical for use in flow-through systems, but XRFS and gamma spectroscopy are usually used in a laboratory setting. The tendency of sewage to foul and clog the monitoring equipment complicates the design of an unattended system. Successful operation requires fouling-resistant flow cells and comprehensive maintenance procedures. Furthermore, diagnostic sensors (pressure and voltage gauges, for example) must be used to test for anomalous conditions in the monitoring and flow systems. When equipment is not operating properly, sewage release alarms must be disabled and personnel notified so that normal operation can be restored.

Finally, wear and age can change the performance of the monitoring equipment. Calibration checks generally must be conducted once each month, except as existing engineering standards allow otherwise (DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* requires annual calibration and weekly checks [DOE 1991]). When a piece of equipment does fail completely, it should be possible to reconfigure the system rapidly for continued operation. For the mechanical equipment, duplication is appropriate, as is the case for the pH- and flow-monitoring equipment required by permit. For the rest of the monitoring equipment—which is susceptible to failure when not operated continuously, and, therefore, cannot be kept in duplicate—simple flow bypasses and flexibly configurable computer software allow normal operation of the unaffected sensors while the broken component is repaired or replaced.

The final issue to be considered is computer hardware and software. XRFS and gamma spectroscopy are complex techniques that require sophisticated signal analysis to generate reliable results. Acquisition of both the monitoring and status information requires complex data acquisition hardware and software. Much of this can be provided by third-party vendors, but LLNL-designed and -implemented software is necessary to control analysis of the data and annunciate alarms that initiate response activities. To ensure the reliability and accuracy of the software, a subset of the Institute of Electrical and Electronics Engineers (IEEE) software QA procedures must be met (ANSI 1983, 1998a, 1998b). These documents must also be approved under the EPD QA procedures.

6.3.1.4.3 Alarm Response

When a possible contaminant release or system malfunction is identified, sewer-monitoring personnel must be notified to control and/or correct the condition. DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991) requires that the alarm be in a location that is continuously occupied by operations or security personnel.

The alarm response process includes three steps:

1. The system annunciates either a contaminant release or a system malfunction. Automatic diversion occurs in when the possibility of a contaminant release exists.

2. Alarm response personnel evaluate the condition causing the alarm and contact WGMG personnel for assistance in determining corrective action (Step 3). The monitoring system must provide access to archive data to aid in the evaluation of the alarm.

3. WGMG personnel determine appropriate action to correct the conditions causing the alarm. At this point, alarm response personnel must be able to adjust monitoring parameters and correct any hardware conditions that may have occurred. If a spill actually appears to have occurred, WGMG personnel develop an action plan for identifying and correcting the cause of the release (pre-established action plans are required by DOE [1991]).

All sewer alarm response activities must be thoroughly documented.

6.3.1.4.4 Upstream pH Trigger Station

The Upstream pH Trigger Station (Building 193), which is upstream of the Sewer Monitoring Station and the Sewer Diversion Facility [SDF] retention tanks, includes pH monitoring equipment capable of triggering a diversion at the SDF should the pH of LLNL effluent go above or below the limits specified in the permit. A sewer vault was installed 32 meters upstream of the diversion valve for the SDF retention tanks in the SDF yard (with pH monitoring and communications equipment to identify and signal the need for diversion). New grinder vaults were installed on each of the major sewer trunk lines approximately 30 meters upstream of the pH-monitoring vault. Each grinder vault contains a grinder for sewage homogenization. The intent of this upstream trigger is to capture the entirety of a pH spill before it is released to the Livermore collection system. The leading edge of such a spill could not be contained using the Building 196 real-time continuous monitoring system in the Sewer Monitoring Station because of limitations in the system response time.

On the basis of this analysis, it appears that practical response times should be in the range between 30 seconds and 10 minutes. The upper range is simply a reasonable fraction of the 30-minute period expected for most retention-tank releases and guarantees that a substantial fraction of the volume is retained prior to discharge.

6.3.2 Extent and Frequency of Monitoring and Measurements

6.3.2.1 Continuous Sampling

Continuous sampling for metals, pH, flow, and radioactivity occurs at the B196 sewer monitoring station. Continuous sampling for pH occurs at the B193 Upstream pH Trigger Station.

6.3.2.2 Alarm Annunciation

Although sampling is performed continuously, actual alarm analysis is performed by a computer in discrete intervals. The frequency of analysis and the duration of an excursion prior to annunciation of an alarm are based upon four considerations:

- Potential severity of the impact on the LWRP
- Impact of alarm response activities on monitoring program resources
- Accuracy of the methods
- Susceptibility of the equipment to false positives caused by fouling or instability of the monitoring equipment

Because each sensor system has different design parameters, each contaminant has a different alarm algorithm.

6.3.2.2.1 pH Alarm

The terms of LLNL’s discharge permit require that the pH effluent at the LLNL sewer outfall is no less than 5 and no greater than 10. Between the bounds of 2 and 12.5 (nonhazardous waste lower and upper bounds), the primary goal of the permitted pH values is to minimize damage to the sewer infrastructure. Alarm response is instantaneous below 5 or above 10 pH units.

“Instantaneous,” in this case, is as frequent as monitoring readings are taken. Although it is possible to monitor pH continuously, the shortest pH releases appear to be at least 2 minutes in length, with rise times on the order of 30 seconds. Once-a-minute readings are capable of detecting extreme pH excursions and guarantee that all but the first couple of minutes of a serious spill will be captured by the diversion facility. (Upstream pH monitoring equipment installed in 1998 captures the first few minutes of low- and high-pH spills. See Section 6.3.1.4.4.) This is, therefore, the measurement frequency used for pH monitoring.

6.3.2.2.2 Metals Alarm

As summarized in Table 6-1, the discharge limitations for metals are in the parts-per-million (ppm) or sub-ppm range. LLNL's goals for metals spill monitoring sensitivity are roughly 50 times the values shown, with measurements made no less than once every 10 minutes. In the current system, analysis is performed once every five minutes, with alarm levels set in the 5- to 12-ppm range (see Table 6-4, where the discharge limits are reproduced to facilitate comparison). To justify this choice, Figures 6-2 and 6-3 show typical metals monitoring results over the course of a seven-day period. The cadmium concentration plot of Figure 6-2 shows primarily the effect of the fundamental uncertainty in the measurement method. The measurement results fall in a Gaussian distribution, and the alarm levels are set at some multiple of the width of the distribution.

Table 6-4. Metals alarm levels

Metal	Permit limit (mg/L)	Alarm level (mg/L)
Arsenic	0.06	5
Cadmium	0.2	5
Chromium	0.62	10
Copper	1.0	11
Lead	0.2	7
Mercury	0.01	7
Nickel	0.62	12
Silver	0.2	5
Zinc	3.0	10

In Figure 6-3, the statistical distribution of the zinc measurements is systematically skewed by an upward trend. Such trends result from two effects: the accumulation of grit and the deformation of the flow cell itself. (The flow cells are thin, pancake-shaped volumes, one side of which is defined by 0.1-mm-plastic films. These films stretch over time, resulting in the flow-cell deformation.) The conclusion that must be drawn from the data is that increasing the analysis time to improve sensitivity will not lead to a corresponding reduction in alarm settings, which are driven by systemic effects. Decreasing the analysis time to one minute, however, more than doubles the alarm level for metals (the alarm level is inversely proportional to the square root of the analysis time). The five-minute analysis time and individual alarm levels are reasonable compromises among response time, sensitivity, and resources expended on management of spurious alarms.

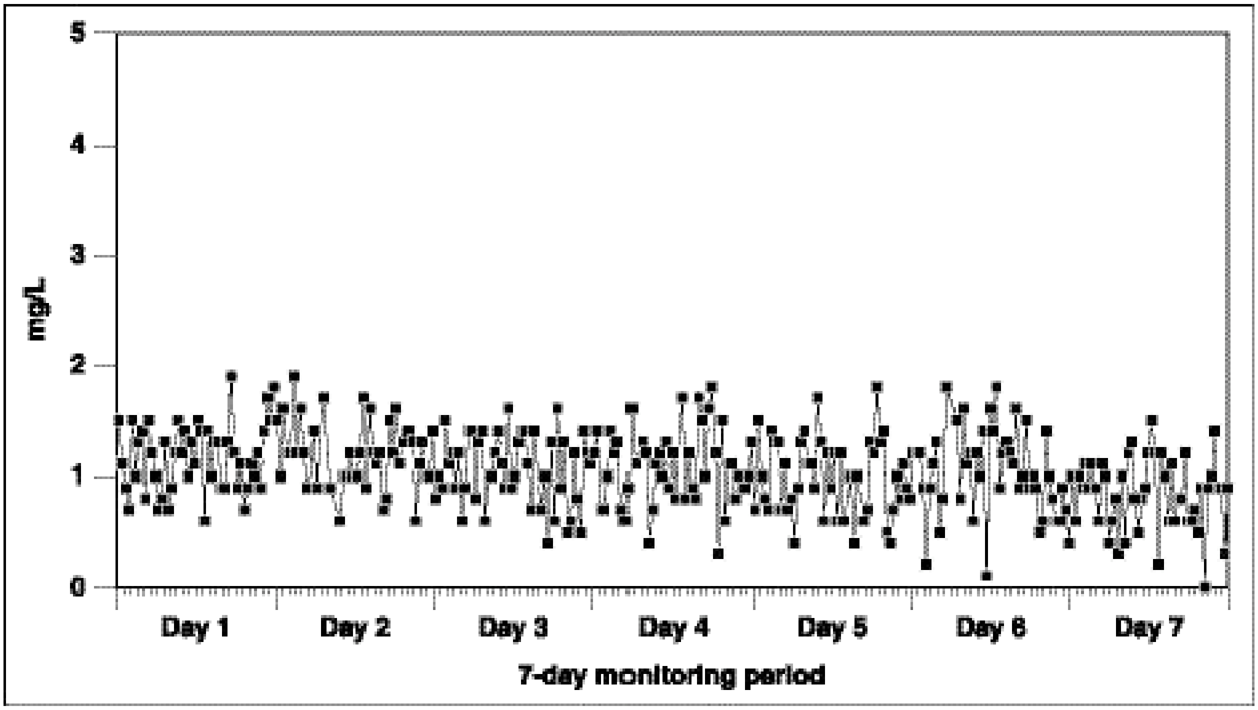

Figure 6-2. Cadmium concentration in LLNL sewage over 7-day period as measured by the continuous monitoring system

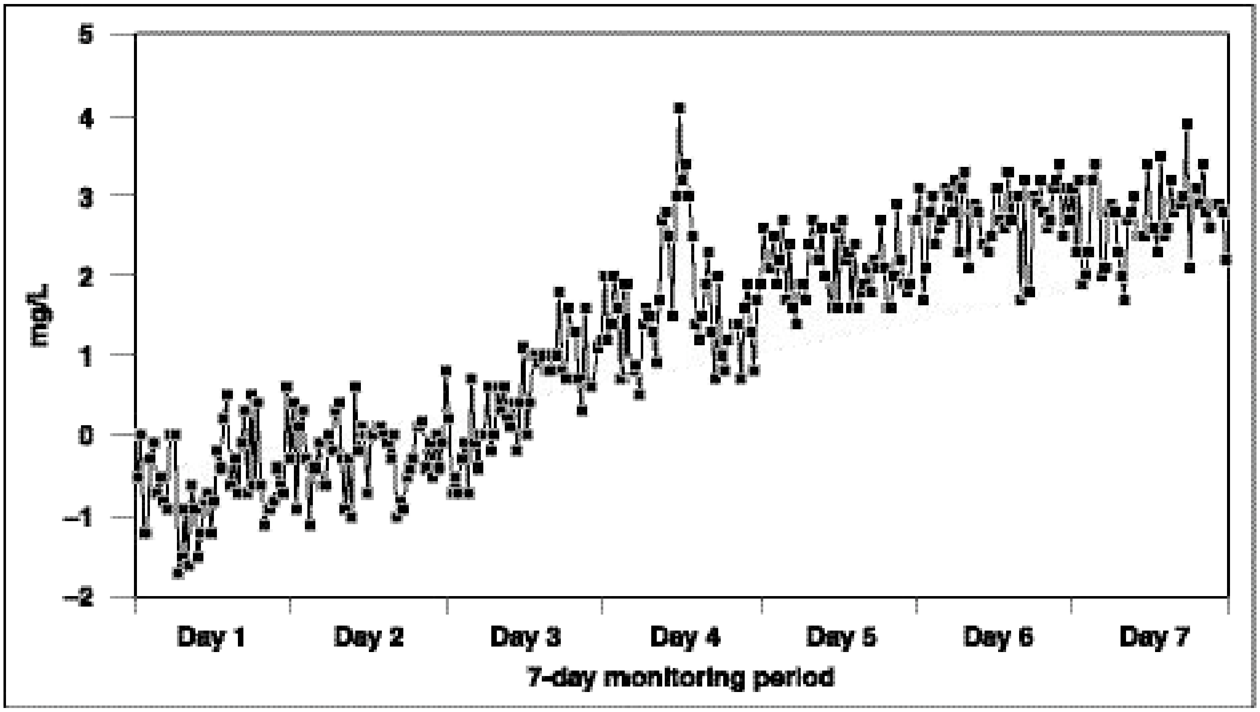

Figure 6-3. Zinc concentration in LLNL sewage over 7-day period

6.3.2.2.3 Radioactivity Alarms

As well as flow-cell fouling, the alarm conditions for radiation monitoring are further complicated by interference among the various decay signals. Radiation monitoring is actually the analysis of three distinct phenomena: gamma emission, beta decay, and alpha decay. Non-contact analyzers are rarely capable of analyzing beta and alpha emission directly, and certainly cannot do so in the case of sewage. The system installed at LLNL instead detects the emission of gamma radiation emitted as an after-effect of alpha and beta decay. Unfortunately, these "follow-on" signals (x-ray emission and bremsstrahlung radiation, respectively) are not as distinctive as the monoenergetic lines from direct gamma decay. In fact, direct gamma decay generally masks both beta and alpha decay, while beta decay masks alpha decay. For this reason, radiation alarms for beta decay are only enabled when no gamma lines are identified in the spectrum, and alpha-decay alarms are only enabled when neither gamma lines nor bremsstrahlung are evident.

While the alpha- and beta-radiation algorithms (described Section 6.3.3.1) are fairly straightforward, the gamma emission algorithm is complex. The algorithm begins with a search for any peaks in the analyzer energy spectrum. Often this analysis is performed against a low-statistics background, and occasionally the algorithm identifies random fluctuations in the background as a peak. When peaks are found, they are typically from medical radioisotopes such as technetium-99, thallium-201, iodine-131, or natural radioisotopes such as bismuth-214 and lead-214. The identified peaks are scanned against a peak library to identify radioisotopes that emit at a given energy. To make this algorithm feasible on a workstation computer, this library contains only those radioisotopes most commonly used at LLNL. If an emitted isotope is not in the library, the algorithm attempts to assign its peak lines to other radioisotopes in the library, potentially causing a false alarm. Finally, Compton scattering of gamma radiation can obscure decay lines at lower energies or generate small peaks when fluctuations in the Compton signal occur.

In the alpha and beta analysis, as well as interference from gamma decay, it has been observed that numerous transient phenomena give rise to spurious signals. These transient phenomena include intense sound and poor electrical connections.

To suppress false positives and interferences, the alarm algorithm requires that the signal be reproduced over two-count intervals. For convenience, the interval is chosen to be the same as the metals analysis interval. This provides a 10-minute alarm cycle, compatible with the requirements outlined in the previous Section.

6.3.2.3 Off-Line Sample Analysis

Given the incidence of false alarms caused by flow-cell fouling and signal interferences, the evaluation of an alarm cannot rest solely on the results of the real-time analysis. To support the evaluation, a grab sample is automatically collected each time an alarm is annunciated. For immediate substantiation of a release, a desktop radiation counter (swipe counter) and pH probe are kept in the sewer monitoring station. Use of these instruments by alarm responders is documented in procedure EMP-SW-SWAR*, Sewer Alarm Response*. For metals alarms, no immediate means of independently validating the alarm are available.

Even if an alarm can be initially substantiated, the interference and fouling problems described above make it impossible to evaluate the compliance implications of a release with data provided by the continuous monitoring system. For that purpose, portions of the grab sample are submitted for analysis by analytical chemistry laboratories. The preparation and submission of the grab sample are described in monitoring procedures EMP-SW-SWAR*, Sewer Alarm Response,* and EMP-SW-B196*, Sewage Sampling at B196*. Off-line analysis is also performed for alarms that cannot be definitively determined to have been false, based on the information preserved in the monitoring records.

Finally, if a release is confirmed, the daily composite sample acquired by the compliance-monitoring program (Section 6.2) is analyzed to assess the impact of the release on LLNL’s compliance with the discharge limits for the day as a whole. Because these results are reported to the LWRP, EPA-approved methods must be used.

Analysis and disposition of material held in the Sewer Diversion Facility are discussed in EMP-SW-DS*, Diversion Facility Tank Sampling*.

6.3.3 Analysis Procedures

Although x-ray fluorescence and gamma spectroscopy are standard analytical methods, their application to continuous sewage monitoring is unique to LLNL. Equipment has to be designed to prepare and position sewage for analysis, and new spectral-analysis algorithms are required to correct for interference and fouling problems not commonly encountered in benchtop analysis. The monitoring program is actively developing solutions to these problems discussed below.

The monitoring program uses standard, EPA-approved analytical methods for the analysis of grab samples. For these samples, analysis performed under extreme urgency (2 to 3 days) is required to support the timely confirmation of a spill.

6.3.3.1 Radiation Monitoring

Only minor mechanical modifications were necessary to modify a commercial radiation monitoring system for flow-through sewage analysis (Figure 6-4). The sewage is injected into the bottom of a 1-L Marinelli beaker, which surrounds the detector vacuum shield. The analysis flow rate, roughly 4 L/min, is sufficient to prevent stagnation of the liquid at the bottom of the beaker but does not prevent sediment settling on horizontal surfaces. The detector itself is a high-purity, liquid-nitrogen-cooled germanium crystal, 5.5 cm in diameter and 6.2 cm high. To maximize acceptance for low-energy photons (down to 12 keV), magnesium is used for the vacuum shield wall, while the top is 0.5-mm-thick beryllium. To shield the detector from external radiation, it is seated in a cylindrical container lined with 10 cm of pre-World War II lead (such lead has low lead-210 activity).

A typical 5-minute radiation analysis spectrum is shown in Figure 6-5. The region from 40 keV to 2.4 MeV is scanned for gamma peaks, which are then matched against a library of peaks from radioisotopes commonly used at LLNL. The detector efficiency is calibrated annually using a mixed fission product source, and the isotopic activity is determined from the results of the calibration and the total count rate in the highest branching ratio decay line. This industry standard algorithm has two significant deficiencies: it does not use multiline analysis to properly resolve interferences between isotopes with shared lines, and it does not use the activity information available in the side peaks and the Compton scattering edge (from partial conversion of gammas in the

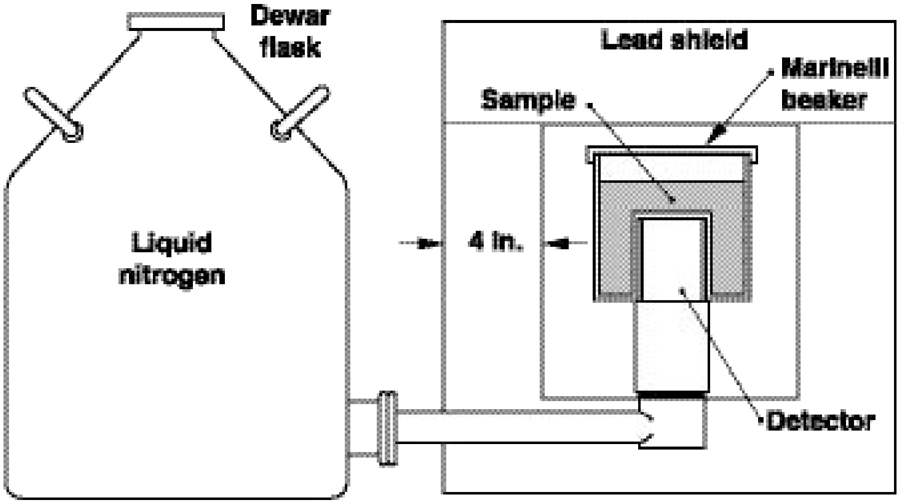

Figure 6-4. Flow-through monitoring system for radioactivity in sewage

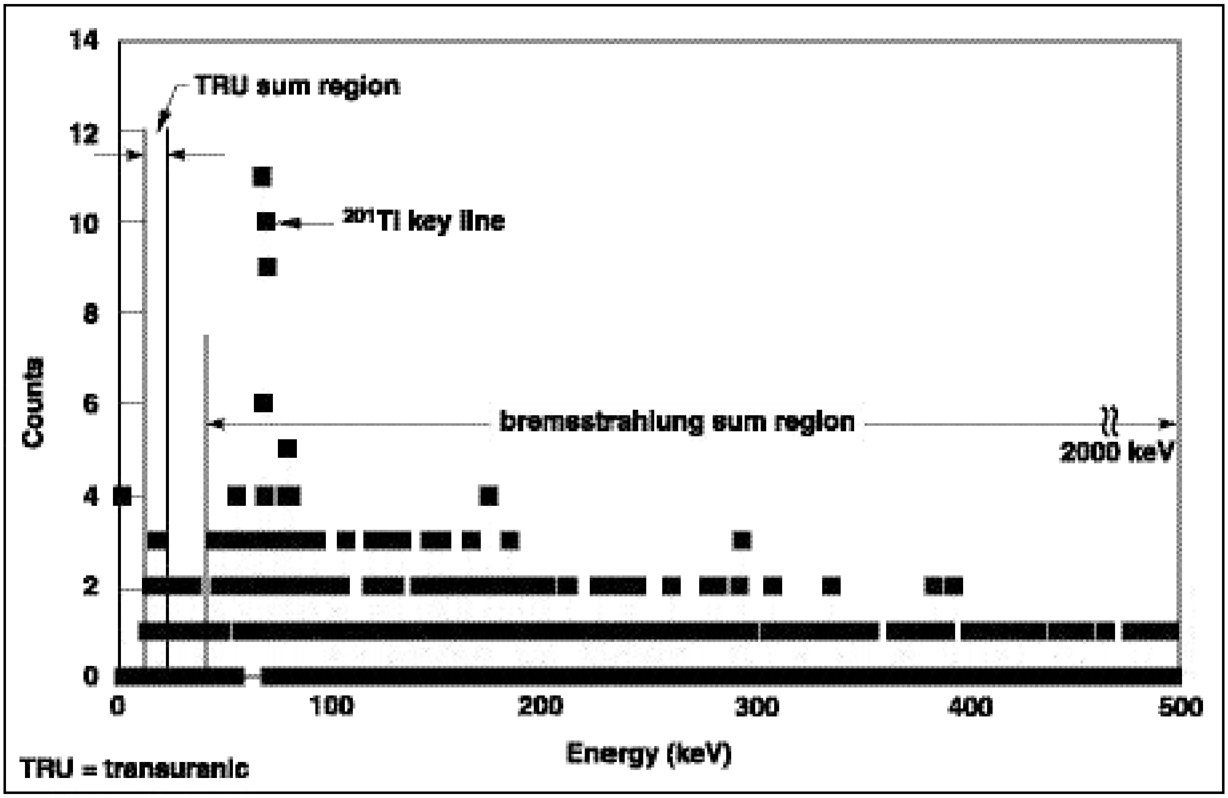

Figure 6-5. Typical gamma spectroscopy data

germanium detector). The most commonly detected gamma-emitting isotopes are medical isotopes and the radon daughters, bismuth-214 and lead-214.

Pure beta-emitting radioisotopes can be detected through the bremsstrahlung photons emitted by the high-energy electrons as they thermalize through collisions with the sewage itself. Neither the decay electrons nor the bremsstrahlung photons are monoenergetic. The observable impact on the gamma spectrum is an elevated count rate at all gamma energies below the maximum decay energy of the electron, with the greatest relative effect appearing at the lowest energies. The most sensitive measure for beta activity is the total count rate in the spectrum, which shows a significant deviation from background readings well before an alteration to the spectral shape can be discerned.

Analytical deficiencies with this algorithm are a susceptibility to electronic noise with a characteristic shape, and interference from the Compton photons generated by gamma-emitting radioisotopes. In principle, spectral analysis could help to eliminate the electronics background, while an accurate determination of spectral peak heights should allow an accurate subtraction of the Compton background. This has not been attempted. The primary failing of this method is a lack of specificity and, therefore, an inability to perform a meaningful calibration of the detector; true quantification of detector readings must occur through off-line analysis.

Analysis for alpha-emitting radioisotopes is very similar to the x-ray fluorescence technique used for metals monitoring. Alpha emitters are generally heavy atoms, and the departing helium nucleus usually ejects several inner-shell electrons. As the inner-shell electronic states of the daughter atom are filled, X rays are emitted in the 12- to 20-keV energy range. Although these should in principle be resolvable as pure spectral lines, in the normal operating configuration the low-energy resolution and efficiency of the detector do not allow elemental identification. Thus, the analysis algorithm is again a simple comparison of the total count rate with the normal background, although this analysis is limited to the 12- to 20-keV range. The lack of spectral information makes the analysis susceptible to interference from electronics noise, bremsstrahlung, and partial conversion (Compton scattering in the detector). Calibration is also problematic, although a check source of dilute plutonium solution has been used to establish the sensitivity of the method to alpha activities near the DCGs of Order 5400.5 (DOE 1993).

6.3.3.2 Metals Monitoring

Adaptation of the x-ray fluorescence technique for flow-through analysis required significant technical innovation. A cross-section of the flow cell, with the attached x-ray generator and the detector, is shown in Figure 6-6. The base geometry is standard for x-ray fluorescence (XRF) analysis, with the generator positioned at right angles to the detector to minimize backgrounds from elastic scattering of the exciting x rays. The detector is a Si (Li) crystal, with a 30-mm^2 active area and 3-mm thickness. The flow cell is a three-piece construction with an aluminum base plate, an aluminum body plate, and a plastic cover. The x-ray generator illuminates a 4-cm hole in the center of the flow cell. A heavy Kapton sheet, glued to the cover, defines the rear of the analysis volume, while the front surface is bounded by spectroscopy-quality plastic films: a 0.04-cm Mylar film on the sample side provides water resistance, and a 0.04-cm Kapton film provides tensile strength. The thickness of the analysis volume is considerably less than that of the body plate itself. Finally, a 1-cm, leaded plastic shield provides radiation shielding in the forward beam direction. Shielding in the reverse direction is provided by the material of the x-ray tube, the flow cell, the detector, and the mounting block that orients the system components.

Sewage is injected perpendicular to the plate. The body plate serves to blunt the force of the flow, which develops into a laminar stream prior to entering the restricted area of the analysis volume. In the system as currently configured, sewage flows from the bottom to top of the cell; in the reverse configuration, a large air pocket remains trapped in the cell when flow is introduced. Unfortunately, the current configuration encourages the accumulation of heavy phases, including silt and sand, in the flow cell.

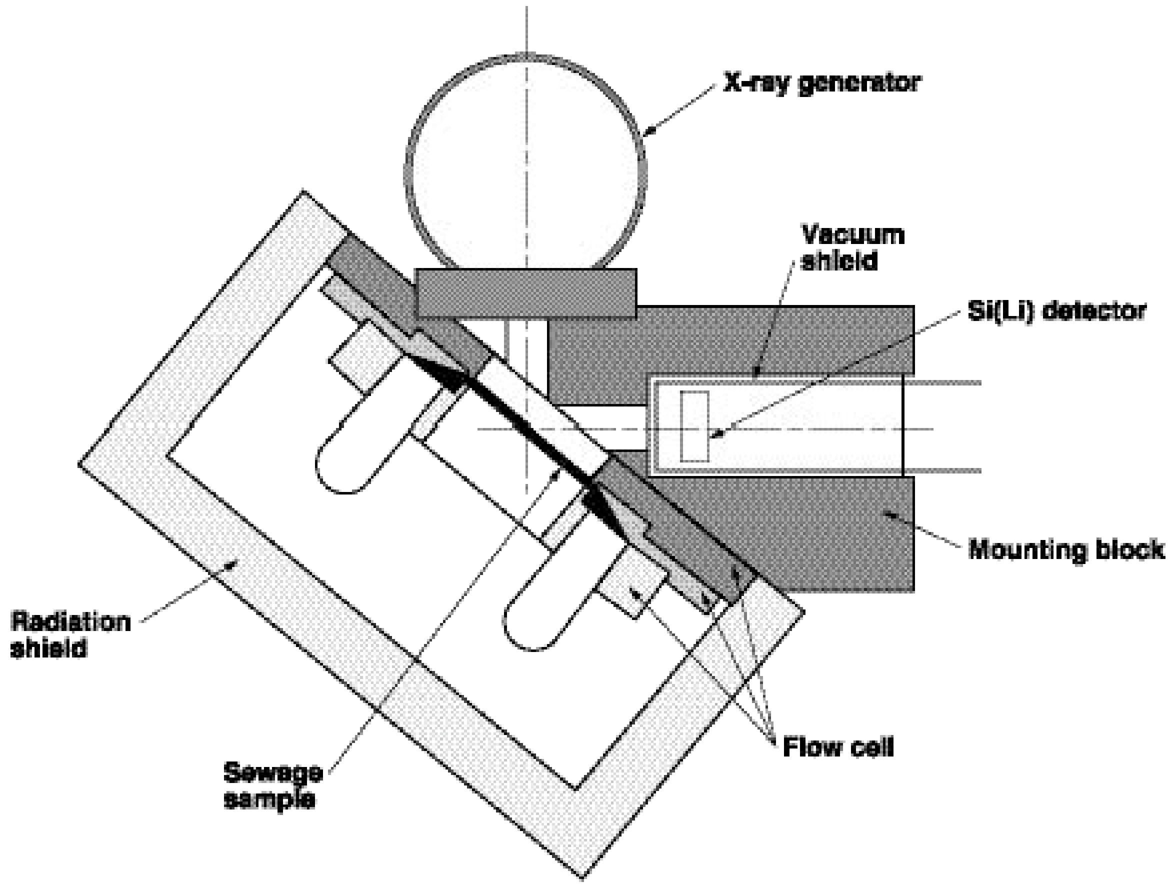

Figure 6-6. **X-ray fluorescence analysis configuration for flow-through monitoring of metals in sewage**

Designing an analysis system for a specific metal begins with selection of a target fluorescence line. Table 6-5 lists the target lines for the metals regulated by LLNL's discharge permit. Given a target line, then the x-ray tube voltage and target material are chosen, and a metal filter is selected to remove source X rays that could interfere with the fluorescence line. The tube current is based upon the maximum throughput of the acquisition electronics; higher currents imply higher count rates in the detector, which eventually saturate the electronics.

Given the tube voltage and target-line energy, the thickness of the flow-cell volume is determined through an optimization analysis of the signal-to-noise ratio in the detector. The higher energy source X rays penetrate to a greater depth than the fluorescence lines. Therefore, at any given depth the intensity of elastically scattered source x rays is greater than the intensity of the fluorescence lines, which undergo stronger attenuation. The ideal thickness is one that maximizes the intensity of the fluorescence lines relative to the background curve. The thicknesses of the three flow cells are shown in Table 6-6.

Table 6-5. Metals fluorescence line

Metal	Fluorescence line			XRF unit
	Transition	Energy (keV)	Attenuation length (mm)	
Silver	K□	22.1	19	3
Arsenic	K□	10.5	2	2
Cadmium	K□	23.1	23	3
Chromium	K□	5.4	0.3	1
Copper	K□	8.0	0.9	2
Mercury	L□	10.0	1.8	2
Nickel	K□	7.5	0.7	2
Lead	L□	10.5	2	2
Zinc	K□	8.6	1	2

Table 6-6. X-ray fluorescence-unit design parameters

XRF unit	Generator		Target	Filters	Thickness (mm)
	Voltage (kV)	Current (μA)			
1	25	75	Nickel	Nickel	3
2	45	90	Rhodium	Molybdenum	5
3	50	67	Tungsten	Tantalum, copper	21

In a perfectly stable system, the concentration of a particular metal is proportional simply to the excess counts (over background) in the energy range of the fluorescence x rays (Table 6-6). In practice, the intensity of the excitation beam, the electronics dead-time, and the volume of the flow cell are not perfectly stable. To account for these effects, the counts in the fluorescence range are normalized by the counts in the energy range populated by elastically scattered excitation photons. This algorithm suffices for the first and third configuration of Figure 6-7.

XRF 1 is opaque to both the excitation and fluorescence X rays, and thus a change in analysis volume (caused by the stretching of the thin-film windows) do not result in a change in the volume that contributes to the signal in the detector. XRF 3 is thick compared with typical volume fluctuations and relatively transparent to the source and

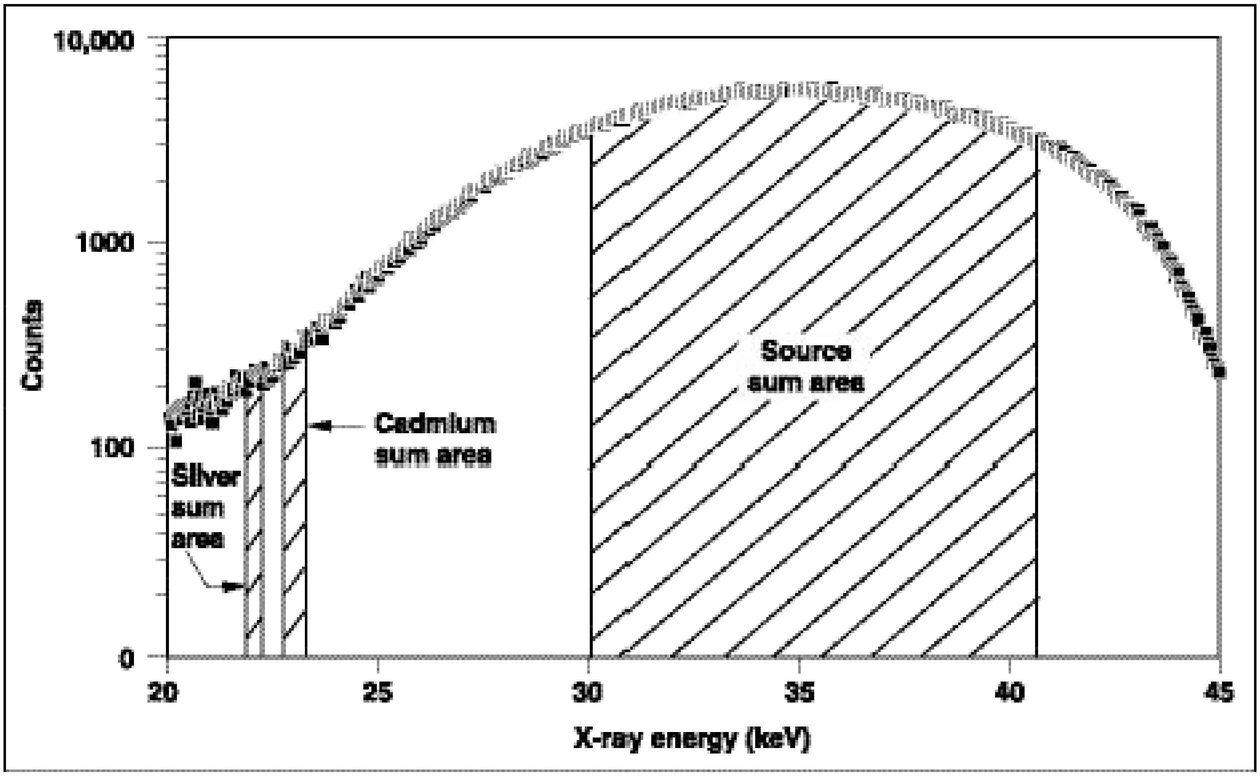

Figure 6-7. Typical x-ray fluorescence spectrum

fluorescence x-rays, so that a slight change in volume does not cause a large change in the relative count rate in the source and fluorescence energy ranges.

In the case of XRF 2, however, film stretching causes a change in the thickness of the flow cell, which is an appreciable fraction of the design thickness. Additionally, the x-ray attenuation lengths are comparable to the design thickness, with a strong increase in attenuation at lower energies. For these reasons, an increase in analysis volume thickness results in an appreciable change in the shape of the fluorescence spectrum, as the x rays scattered elastically from the additional volume at the back of the flow cell are more likely to be observed in the detector than fluorescence x rays from the same location. This effect can bias, by several milligrams per liter, the simple ratio analysis algorithm for the metals concentration.

This effect also complicates the metals calibration of the analysis systems. Calibration involves sequential loading of the flow cell with laboratory-standard metals solutions of known concentrations. Several spectra are acquired at each concentration. The ratio of the fluorescence counts to the elastic scattering counts is computed for each metal at each concentration; then the calibration constants (slope and background) are determined by a least squares fit of the ratio to the known metals concentrations. The background constants, however, are usually biased low because the static loading of the flow cell results in a different analysis volume, as compared with the normal operating state. Under the assumption (supported by the compliance monitoring data) that the actual metals concentrations in sewage are small compared with the alarm levels, the background constants are adjusted manually during routine system operation to achieve zero mean concentrations.

Currently, no routine check of the system calibration has been developed; the calibration procedure outlined above takes several days. Gross stability can be assessed by monitoring the total detector count rate, and the energy calibration is readily assessed by monitoring the position of fluorescence lines from common sewage constituents and the x-ray filters. The metals calibration coefficients are assumed to be stable on the basis of the stability of these other parameters.

Finally, because of the phase separation in the preparation of the sample stream for analysis, the metals monitoring results do not include a true proportional contribution from the heaviest solids, which encompass everything from gravel to bolts. Reviews of the summary of operational impacts at the LWRP indicate that these settleable, nonleachable solids do not pose an operational concern.

6.3.4 Data Quality Assurance

6.3.4.1 Precision

Monitoring results are compared to analytical results from grab samples collected during an alarm event. Monitoring equipment is calibrated with certified standards.

6.3.4.2 Accuracy

All quality check information provided by the analytical laboratories, including matrix spikes, matrix duplicates, and calibration standards are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation.

6.3.4.3 Completeness

The sanitary sewer is monitored continuously. Given the potential for system downtime due to mechanical failure, our target completeness is to maintain monitoring capability 90% of the time.

6.3.5 Program Implementation Procedures

The primary responsibility for activities related to the sewer monitoring networks is assigned to a WGMG environmental analyst. The analyst is responsible for the network design, implementation, and correct operation of the network; the analysis and evaluation of all monitoring results; data trending; documentation; and reporting. The following procedures are associated with the sewer monitoring networks:

- EMP-SW-B196, *Sewage Sampling at B196*: Details of sampling, processing, and documentation for sampling at the B196 Sewer Monitoring Station.
- EMP-SW-CA, *Sewer Equipment Calibrations*: Details of calibration protocol for sewer monitoring equipment.
- EMP-SW-DS, *Diversion Facility Tank Sampling:* Details of sampling, processing, and documentation for sampling sewage diverted by the B196 Monitoring Station.
- EMP-SW-M, *Sewer Equipment Maintenance*: Details of maintenance protocol for sewer monitoring equipment at B196.
- EMP-SW-SWAR, *Sewer Alarm Response:* Details of activities to be performed when responding to alarms at the B196 Sewer Monitoring Station.
- WGMG-UT-M, *UB193A, pH Monitoring Station Maintenance:* Details of sampling and maintenance protocols for the UB 193 upstream pH monitoring station.
- EMP-QA-DM, *Sample and Data Management:* Details how samples are handled, stored, and delivered.

6.3.6 Action Levels

Action levels for the sewer spill monitoring program are described in Section 6.2.6.

6.3.7 Preparation and Disposition of Reports

LLNL’s wastewater discharge permit requires that outfall data be reported monthly. The report summarizes activity for both the compliance and spill monitoring programs. Five-Day Reports are also required under the terms of the permit (see Section 6.2.7). The annual *Environmental Report* includes a summary and analysis of the spill monitoring results.

6.3.8 Future Plans

6.3.8.1 Satellite Station Network

Although the theoretical concept of using a satellite station network as a discharge control aid is excellent, adequate resources for maintaining such a network are not available. Consequently, there are no plans to reinstate satellite station monitoring at this time. Individual locations may be considered for satellite sampling if a problem is identified. For more detail on the history of the satellite station network, see Tate et al. (1999).

6.3.8.2 Real-Time Continuous Monitoring System

Future improvements in the continuous sewage monitoring system will focus on the performance of the XRF metals monitoring equipment and the radiation monitoring equipment. As the need for additional improvements is identified, they will be scheduled for implementation.

6.4 References

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17 CCR 30253, California Code of Regulation*s,* Title 17, Section 30253, *Standards for Protecting Against Radiation,* Health and Welfare Agency, State of California, Sacramento, CA.

33 USC 1251 et seq., Federal Water Pollution Control Act Amendments: Clean Water Act, 1972.

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7 Retention Tank Sampling

Allen Grayson

7.1 Introduction

Retention tank sampling is part of a comprehensive and ongoing environmental monitoring program for Lawrence Livermore National Laboratory (see Chapter 1). Data from retention tank sampling are used to determine disposition for tank contents and demonstrate compliance with regulatory requirements.

7.2 Rationale and Design Criteria

LLNL's wastewater retention systems consist of on-ground tanks, underground tanks, aboveground tanks, piping, pumps, and ancillary equipment for collecting dilute rinse water and wastewater generated by LLNL research activities. These wastewaters can be hazardous, nonhazardous, radioactive, or mixed (i.e., hazardous and radioactive) wastes. Most systems collect and temporarily store dilute, nonhazardous rinse water from materials fabrication or finishing operations, or semiconductor research. The retention systems ensure that discharges to the LLNL sanitary sewer system are within internal discharge parameters designed to meet permit limits at the point of compliance. This policy ensures nonsewerable wastewater is properly stored until appropriate disposal or treatment can take place. This program provides the main component of a Slug Discharge Plan.

Installation of a retention tank system is based upon the potential for chemical and radiological inventories and operations at a facility to impact the Livermore Water Reclamation Plant (LWRP) operations. During normal operation, a retention tank collects small-quantity discharges that, given measures implemented at the source, usually comply with internal discharge limits. When the tank becomes full, the contents are sampled and analyzed to validate their suitability for discharge. If the content concentrations are below internal discharge limits, the contents are released to the sanitary sewer (see Section 7.2.1 for information about internal discharge limits). When pollutant concentrations are above internal discharge limits, the collected wastewater is transferred to the on-site Department of Toxic Substances Control (DTSC)-permitted Radioactive and Hazardous Waste Management (RHWM) facility.

By LLNL policy, all wastewater retention tank systems are required to have secondary containment capacity. This capacity is usually provided by a berm around the retention tank and all aboveground piping. During the rainy season, storm water that falls into the berm presents maintenance and operational problems. Most serious is the reduction of the available secondary containment capacity. Consequently, LLNL's tank engineering guidelines (*ES&H Manual,* Document 32.2) suggest covering bermed areas or providing separate retention capacity for collected water.

Many systems in place do not have features to control berm water and so must be drained rapidly following any significant rainfall. By agreement with the Central Valley and San Francisco Bay Regional Water Quality Control Boards (Fisher 1995; SFBRWQCB 1995), and the LWRP (City of Livermore), as stated in LLNL's permit application to the LWRP (Grayson 2004), LLNL discharges uncontaminated berm water to the storm drain system or if not suitable for release to the storm drain system, sent to the sanitary sewer provided specific administrative controls are met. These controls include screening the wastewater to determine whether the pH is within an acceptable range; reviewing maintenance records and spill logs; and visually inspecting the tank system and the contained liquid.

7.2.1 Regulatory Drivers

Except for waste streams that are federally regulated under the Categorical Pretreatment Standards (see Chapter 8), the criteria for discharge authorization into the LLNL sanitary sewer are established by internal policy; LLNL internal policy is designed to ensure that wastewater leaving the site meets the outfall limits specified in LLNL's wastewater discharge permit (City of Livermore). As enforced by the LWRP, the site outfall limits apply to the combined volume released to the city sewerage, rather than to individual processes. The outfall limits apply to both radiological and nonradiological contaminants. Discharge limits on radioactivity in sewage specified by Order 5400.5, Chg. 2, Chapter I, Paragraph 7 and Chapter III are also applied at the LLNL site outfall, rather than on wastewater released from individual processes. This allows LLNL some flexibility in developing criteria for releases from retention tanks that are upstream of the point of discharge to the city sewerage. For these reasons, LLNL developed uniform release criteria for most of its retention tank systems. (The one notable exception, the Sewer Diversion Facility, is discussed below.)

Although preferable in principle, uniform release criteria cannot completely encompass the complexity of actual operations and in-place facilities. Predicting the impact of a tank discharge on pollutant concentrations at the site outfall requires some assumptions concerning the rate of release from the tank and the flow rate at the outfall. To derive its internal discharge limits, EPD's Water Guidance and Monitoring Group (WGMG) conducted a study in 2002 using data from 1995–2001 tank releases coupled with time-proportional flow data. The internal limits were derived using conservative assumptions concerning release capabilities and discharge conditions.

For radioactivity, additional criteria follows from DOE Order 5400.5, Chg. 2, Chapter II, Paragraph 3d(2) and 10 CFR 20.2003 (a) 4, Subpart K limits the total activity released during any one year to 1 curie (excluding tritium and carbon-14). For most radionuclides, this activity divided by LLNL's average daily flow is far less than the isotope-specific concentration limits. Order 5400.5, Chg. 2, Chapter II, Paragraph 3d(2) contains narrative requirements limiting the total activity to levels that prevent "long-term buildup of radionuclides in solids" and exposures to members of the public (principally publicly owned treatment works operators) "exceeding a small fraction of the basic annual dose limit". Concentrations of radionuclides in wastewater shall be controlled so that long-term buildup of radionuclides in solids will not present a handling and disposal problem at the LWRP (DOE 1993). To address these requirements, as well as concentration limits, the internal release criteria constrain the total radioactivity that can be released from all retention tanks during a single day.

7.2.2 Monitoring Objectives

It is the objective of this Program to ensure that wastewater leaving the site meets the outfall limits specified in LLNL's wastewater discharge permit (City of Livermore). Additional objectives include the protection of workers, both LLNL and City of Livermore personnel, who may be exposed to excessive contaminants as a function of their job responsibilities and the protection of LLNL property from the effects of chemical or radiological contaminates above preset limits.

7.2.3 Sources and Analytes

The criteria derived from these considerations are presented to the LLNL work force in the *ES&H Manual*, Document 32.4. The criteria, reproduced here in Tables 7-1 and 7-2, indicate the potential scope and sensitivity of LLNL's retention tank sampling program.

Absent from Table 7-2 are release limits for specific radioisotopes other than tritium. Instead, limits are imposed on gross alpha and gross beta activities. This simplification reflects the practical aspect of managing a retention tank program: when retention tanks are at full capacity, the time between sampling and the return of analytical results imposes costs on the facility, either in the form of reduced storage capacity, the need to pay for additional storage capacity, or operational delays. Secondly, the cost of the analysis must be reasonable.

Table 7-1. LLNL's internal discharge limits for nonradioactive parameters in noncategorical wastewater

Parameter	Limit (mg/L)
Beryllium	0.20
Cadmium	1.4
Chromium	6.2
Copper	10
Mercury	0.10
Nickel	6.1
Lead	2.0
Silver	2.0
Zinc	30
Cyanide	0.4
Arsenic	0.6
pH	5-10
Total toxic organics (TTO)	4.57

Source: *ES&H Manual*, Document 32.4

Table 7-2. LLNL's internal discharge limits for radioactive parameters in wastewater

Parameter	Individual discharges	Total daily limit for site
Gross alpha	300 pCi/L	5.0 µCi
Gross beta	3000 pCi/L	50.0 µCi
Tritium	10 mCi/L	20 mCi
Gamma	—[a]	—[a]

Source: *ES&H Manual*, Document 32.4

a There is no gross gamma limit; isotope-specific limits apply.

Radioisotopic analysis, unfortunately, is both time-consuming and expensive. As a practical compromise, retention tank samples are analyzed for gross alpha and gross beta activity, and the release criteria are based upon the permissible release concentrations of the commonly available alpha- or beta-emitting isotope with the lowest discharge limits. The values of Table 7-2 assume uranium-238 as the alpha emitter and strontium-90 as the beta emitter.

7.2.4 Collection Methods

The retention tank sampling protocols must guarantee that a representative sample of the wastewater is collected for analysis. The analysis protocols must ensure that, without imposing needless cost, a meaningful assessment can be made of wastewater against the established discharge criteria. Both protocols must be structured to minimize the time between when the tank has been filled and the final disposition of its contents.

The pollutants that can be found in a specific tank are dependent only on the types of processes that discharge to the tank. Operations in a specific LLNL facility may change routinely as research and development activities progress, and so the potential contaminants can change over time. As a result, the Retention Tank Analysis List (RTAL) displays the sampling requirements for each Facility retention system. This list is reviewed periodically, (at least semiannually).

Just as each retention tank system has its own analytical requirements, the number and type of sample bottles and the preservation and holding time requirements for analysis also vary from location to location. Changing analytical requirements are communicated through the distribution of the RTAL each time an update occurs. Additionally these analytical requirements and any subsequent changes are made available to the RHWM field sampling and support teams electronically via the on-line Wastewater Discharge Authorization Record (WDAR) process.

To obtain analytical results quickly, the tank should be sampled as soon as possible when it becomes full. Achieving this goal requires routine inspection of the tank, timely availability of sample bottles, and timely preparation of necessary paperwork.

Procedures for obtaining a representative sample from a retention tank vary from location to location, depending on the system design. For tank systems with recirculation capability, the waste should be recirculated for a minimum of three tank volumes. For tank systems without recirculation capability, appropriate sampling equipment should be used.

Retention tanks fill at differing rates, depending on operations that generate the wastewater. Unusual or special circumstances can reduce fill times to a few days. Turnaround time (that span of time from initial sampling to final disposition of the wastewater) varies, and turnaround times of three weeks or more are not uncommon. However, for retention tanks with short fill times, the turnaround time must also be shortened. For example, the Sewer Diversion Facility requires rapid turnaround to minimize the cost of operations while sewage is in the tanks. In addition, operations of the RHWM Division can be impacted when tardy analytical results delay discharge of wastewater from the treatment tanks. Ideally, turnaround times of five to seven days would be provided for these operations.

Given the relative infrequency and time constraints of the sampling activities, the individuality of the tank systems, and the variability of the sampling requirements, quality assurance (QA) and quality control (QC) sampling is an important consideration in this program. Field and trip blanks should be utilized, along with equipment blanks when samples are not transferred directly from the tank to the sample containers (e.g., coliwasas or pumps are used). Additionally, consideration should be given to a comprehensive analysis of a few samples each year to validate the process by which the RTAL is developed.

7.3 Extent and Frequency of Monitoring and Measurement

There are currently 45 in-service wastewater retention tank systems at LLNL, including those at Site 300. Sampling frequency for retention tanks is determined by operations:

- Nonhazardous waste tanks and radioactive waste tanks are sampled whenever the tank is full.
- Hazardous waste and mixed waste tanks are sampled and emptied within 90 days of the time they begin receiving waste.

Samples are collected by the RHWM Sampling Team, RHWM field technicians, technicians from the Water Guidance and Monitoring Group (WGMG) of the Operations and Regulatory Affairs Division (ORAD), or, in isolated circumstances, Hazards Control or LLNL program representatives. Sampling technicians use the RTAL to determine which analyses are required and to sample accordingly.

The list of required analytes for an individual retention tank is based upon process knowledge. Considerations include any specific regulatory requirements for operations discharging to the tank, the type of operations generating the waste, and the contaminants that could potentially be present. For example, a retention tank that receives waste from a full-service analytical chemistry laboratory would need a full suite of analyses that includes pH, metals, total toxic organics, and possibly radiological analysis if the facility has a Radioactive Materials Management Area (RMMA). Other analyses such as cyanide or oil and grease can be added if those constituents are used in the facility or are required by specific regulation. However, a tank that receives only photo processing rinse water and is not connected to an RMMA may require only pH and metals analyses.

Special protocols are followed for sampling sewage diverted into the Sewer Diversion Facility. The tank contents are analyzed only for pH, normality, and the specific pollutant detected by the continuous monitoring system (see Chapter 6). Samples are taken by WGMG technicians who follow procedure EMP-SW-DS, *Diversion Facility Tank Sampling*. Analysis is performed by either an off-site State-certified analytical laboratory under contract to LLNL or LLNL's Chemistry & Materials Science-Environmental Services (CES) Laboratory.

7.4 Procedures for Laboratory Analysis

Most retention tank sample analyses are performed according to standard EPA procedures. For screening purposes, a few analyses of non-regulated wastewater (e.g., field pH measurements) are done using non-certified methods. Samples are generally analyzed by onsite state-certified laboratories; however, these laboratories may choose to contract the analysis of particular samples to certified off-site analytical laboratories.

When the data package is received from the laboratory, results are reviewed to determine whether the contents meet discharge requirements specified in LLNL guidance documents (see *ES&H Manual*, Documents 32.1, 32.2 and 32.4), which are based upon LWRP permit limitations and categorical pretreatment requirements in federal law (see Chapter 8). The evaluation of the analytical results is the responsibility of WGMG, which issues a WDAR authorizing disposal of the tank contents.

7.5 Data Quality Assurance

Although most sampling and analysis of retention tank volumes are not under the direct control or authority of WGMG personnel, protocols exist to ensure that quality objectives for these functions are met. Currently, WGMG uses the procedures and quality control manuals of the RHWM Sampling Team and the CES analytical laboratory to ensure the dependability of the results used in determining the deposition of the waste volumes from retention tanks.

7.5.1 Precision

Quality control samples including field blanks, duplicate samples, and trip blanks are collected according to RHWM Procedure AP 158, *Waste Sampling Quality Assurance and Control Plan*. According to this procedure, equipment blanks are collected for each decontamination event or for every 20 pieces of equipment decontaminated, whichever is lowest. One trip blank is collected for each day that volatile organics are sampled, and field blanks are collected if called for in the sampling and analysis plan or by the Sampling Team Leader. Replicate samples are required 5 percent of the time, or every 20th time. Sample results are compared with historical data maintained on each retention tank system by WGMG staff. Unusual results are followed up by discussions with the analytical laboratory, sampling technician, responsible Environmental Operations Group (EOG) analyst, and/or the facility tank operator. If an error in sampling or analysis is determined, or an improper discharge to the retention system occurred, a Nonconformance Report (NCR) is filed with the ORAD QA coordinator. The NCR is processed according to procedure ORAD-QA-NCR, *Nonconformance Reporting and Tracking*, to determine whether further action is necessary.

7.5.2 Bias

All quality check information provided by the analytical laboratory (CES), including laboratory control standards, matrix spikes, matrix duplicates, and calibration standards are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact CES for an explanation.

7.5.3 Completeness

Retention system samples used for content characterization are collected from each discrete tank volume from each system. Profiling is not performed due to the variability of operations and LLNL research needs. The overall tank characterization process will be considered a success, or complete, only when each tank volume is sampled and analyzed (or evaluated using other means). Post-discharge sampling and characterization is allowed only in isolated cases when program needs would be negatively impacted if usual sampling procedures were followed.

7.6 Program Implementation Procedures

The primary responsibility for determining disposition of retention tank contents is assigned to a WGMG environmental scientist. This position has been given the title Discharge Authorization Manager or DAM. The DAM oversees the design, implementation, and maintenance of the retention tank-sampling program. The environmental analyst determines analytes, collection methods, and analytical methods; reviews and analyzes the data; follows trends in data; and reports results.

Although the facility users at LLNL are responsible for the operation and maintenance of the retention tank systems that service the facility, EPD is responsible for sampling; determining appropriate analytes (with input from facility users and knowledge of operations that discharge to the tank), collection methods, and analytical methods; evaluating the subsequent data and their quality; communicating and coordinating network activities among sampling technicians and analytical personnel; and reporting the results. The EPD RHWM Division personnel manage removal of the waste volume, followed by any required treatment and off-site shipment. In a small number of cases, tank contents may be treated at the facility rather than removed, using a state-licensed transportable treatment unit (TTU). Following this treatment, the waste volume is sampled, analyzed, and reviewed following the same procedures as non-TTU treated volumes.

Retention tank samples are collected by RHWM technicians following RHWM Procedure 411, *Sampling Containerized Liquids*. Sampling locations are at the point of discharge from the retention tank and are permanently marked with location and tank-specific identification. The written procedures include requirements for collecting samples and submitting them for chemical analysis, keeping a field log, and filling out a chain of custody (CoC) form. The procedures also require the technicians to alert the Waste Generation Services Technical Lead if any difficulties or anomalies are encountered during the sampling event.

7.7 Action Levels

When the data package is received from the CES laboratory, the WGMG staff member responsible for discharge authorizations begins the processes of evaluation against the internal discharge criteria shown in Tables 7-1 and 7-2. Release authorization is granted as described in the WGMG procedure, WGMG-WD-AR, Wastewater Discharge Authorization. This procedure states that sample data are reviewed and, for the majority of tank systems, compared with the internal discharge limits. For the small number of tank systems dedicated to accepting waste streams from categorical processes, predetermined federal limits apply (for a more thorough discussion of categorical processes, see Chapter 8). Prior to completion of the WDAR, the data package sample numbers from the sample strategy form, the waste analysis request form, and the laboratory data report are reviewed to ensure that the results correspond to the waste volume intended. If the data indicate that contaminant loads are below numerical discharge limits, authorization for discharge to sewer is given via a WDAR. If they are above numerical limits, the waste volume is handled for treatment by the on-site RHWM facility or shipped to an off-site permitted treatment, storage, and disposal facility.

7.8 Preparation and Disposition of Reports

A WDAR is generated for each tank sampling event and is kept on file for a minimum of five years. The form includes the final disposition alternative determined by WGMG discharge control personnel (following procedure WGMG-WD-AR, *Wastewater Discharge Authorization*) and records the date, time, and circumstances under which the tank was drained.

A Retention Tank Analysis List (RTAL) is generated at least annually to keep sampling technicians apprised of any changes in retention tank analytical requirements

General engineering information about retention tanks and the Sewer Diversion Facility is included in LLNL's annual wastewater discharge permit application (Grayson), which is submitted annually to the LWRP.

7.9 Future Plans

Because the retention tank sampling program is a mature program that functions well, no significant changes are anticipated. The program does change as needed, to adapt to process changes, and to ensure compliance with any changes to regulatory requirements. Efforts to improve the efficiency of the retention tank sampling program and the associated data management are continual.

7.10 References

10 CFR 20, Subpart 2003. Code of Federal Regulation*s,* Title 10, Part 20, Subpart 2003*, Disposal by Release into Sanitary Sewerage,* Office of the Federal Register, Washington, D. C.

City of Livermore (current version), *Wastewater Discharge Permit/Chemical Storage Permit #1250 (current version)*, City of Livermore, Livermore, CA.

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ES&H Manual, Volume III, Part 32, Document 32.1, "Managing Discharges to Water and Land," Lawrence Livermore National Laboratory, Livermore, CA. Available at: http://www-r.llnl.gov/es_and_h/esh-manual.html

ES&H Manual, Volume III, Part 32, Document 32.2, "Management of Retention Tank Systems," Lawrence Livermore National Laboratory, Livermore, CA. Available at: http://www-r.llnl.gov/es_and_h/esh-manual.html

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Grayson, A. R. (2004), *Wastewater Discharge Permit Application*, Lawrence Livermore National Laboratory, Livermore, CA (UCRL-AR-106905-04).

SFBRWQCB (1995), *Waste Discharge Requirements for U. S. Department of Energy and Lawrence Livermore National Laboratory, Order No. 95-174, National Pollutant Discharge Elimination System No. CA0030023,* San Francisco Bay Regional Water Quality Control Board, Alameda County, August 23, Oakland, CA.

8 Categorical Pretreatment

Allen Grayson

8.1 Introduction

Categorical pretreatment monitoring is part of a comprehensive and ongoing environmental monitoring program for Lawrence Livermore National Laboratory (see Chapter 1). Data from categorical pretreatment monitoring are used to demonstrate compliance with regulatory requirement.

8.2 Rationale and Design Criteria

8.2.1 Regulatory Drivers

The Federal Water Pollution Control Act of 1972, as amended, grants authority to the U.S. Environmental Protection Agency (EPA) to establish and enforce National Pretreatment Standards for the indirect discharge of industrial wastewater. The intent of these regulations is to prohibit the discharge of wastes that are incompatible with wastewater treatment plant processes.

Categorical standards are a component of the National Pretreatment Standards. These are codified (40 CFR 405 through 471) standards specifying quantities or concentrations of pollutants that may be discharged to a sanitary sewer from specific industrial categories of wastewater-generating processes. Separate standards are established for specific industrial processes, in addition to the general prohibitions established in the National Pretreatment Standards. The intent of the requirements is to ensure that industrial wastewater effluent does not disrupt the ability of a treatment plant to treat wastewater. (Disrupting Livermore Water Reclamation Plant [LWRP] operations could cause contamination of the receiving waters of San Francisco Bay.) The LLNL categorical pretreatment, self-monitoring program accomplishes this intent by maintaining compliance with all applicable regulations.

Because there are a number of these regulated processes in use at the Livermore site, LLNL is required by our Wastewater Discharge Permit (City of Livermore) to maintain a categorical pretreatment program (40 CFR 403). This program consists of administrative and engineering controls and procedures, coupled with process monitoring of nondomestic, industrial wastewater sources with specific discharge standards identified in 40 CFR 403, Subpart 5.

The LLNL categorical, pretreatment, self-monitoring program is also mandated under the terms of the *Wastewater Discharge Permit/Chemical Storage Permit No. 1250* issued by the City of Livermore to LLNL governing the discharge of all wastewater from the Livermore site to the city's sewer system. Authority to enforce federal, state, and local limits on waste streams discharged to the Livermore sanitary sewer system lies with the LWRP under the authority of the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB).

8.2.2 Monitoring Objectives

Pretreatment sampling is required by 40 CFR 403.2 "(a) to prevent the introduction of pollutants into publicly owned treatment works (POTWs) which will interfere with the operation of a POTW, including interference with its use or disposal of municipal sludge; (b) to prevent the introduction of pollutants into POTWs which will pass through the treatment works or otherwise be incompatible with such works; and (c) to improve opportunities to recycle and reclaim municipal and industrial wastewaters and sludges."

8.2.3 Sources and Analytes

LLNL processes regulated under the categorical standards of the National Pretreatment Standards include metal finishing processes (40 CFR 433, Subpart A*)*, such as metal-plating and bright dipping located in the Building 322 Plating Shop, and certain semiconductor (40 CFR 469, Subpart A) processes, such as the microfabrication for developing semiconductor and micromechanical devices that occurs in Building 153.

The Code of Federal Regulations (40 CFR 405 - 471) contains 55 industrial categories. Three operations that fall within these categories are performed at LLNL: plastics molding and forming, metal-finishing operations, and electrical and electronic component (semiconductor) production. However, only metal finishing and semiconductor production are included in the pretreatment monitoring program permit requirements; LLNL received an exemption from the standard for plastics processing from LWRP. There are 46 specific operations defined within the metal finishing category. The first six processes are considered primary operations and define the applicability of the standard. These defining processes are: electroplating, electroless plating, anodizing, conversion coating (e.g., chromating, phosphating, and coloring), chemical etching and milling (e.g., bright dip, electropolish), and printed circuit board production. A number of the subsequent 40 metal-finishing processes are also likely to be conducted at LLNL. If these processes do not support one of the six primary operations, the requirements of 40 CFR 433 may not apply.

Metal finishing processes are usually sampled for pH, metals, cyanide, and total toxic organics (TTO). Semiconductor processes are usually sampled for pH, TTO, and arsenic. Table 8-1 shows typical sampling frequencies and analytes. The current Permit (City of Livermore) lists specific analytes and sampling frequencies for each regulated process.

Analytes for regulated processes that discharge to a dedicated retention tank system are specified in the current retention tank analysis list (RTAL).

Table 8-1: Typical sampling frequencies and analytes

Sample Type	Sample Frequency	Typical Analysis
Baseline	3 samples within a two week period at process start-up	Process dependent
Compliance—Electrical/ Electronic Component (semiconductor)	semiannual	Arsenic pH TTO
Compliance—metal finishing	semiannual	Cyanide Metals (Cd, Cr, Cu, Pb, Ni, Ag, Zn) pH TTO
Categorical retention tanks	Each tank volume	See RTAL

8.2.4 Collection Methods

A grab sample is collected over a period of time not exceeding 15 minutes for categorical process monitoring (40 CFR 136). Composite sampling is not appropriate because volumes from these processes are extremely small and flows are not continuous. Also, samples containing some constituents, such as cyanide, cannot be held for an extended period of time because of biological, chemical, or physical interactions after sampling that affect the results. A more detailed description of grab sampling for categorical process monitoring is available in WGMG-PT-S, *Pretreatment Sampling of Rinsewater*.

8.3 Extent and Frequency of Monitoring and Measurement

In its December 1996 written Inspection Summary of the June 1995 EPA/LWRP Facility Audit of LLNL, the EPA determined that LLNL wastewater generating processes that meet the following defining criteria must comply with the applicable Categorical Standards:

- The process must discharge to the sanitary sewer, either directly or indirectly. (Processes that have their waste removed by means other than discharge to the sanitary sewer are not regulated under the Categorical Standards.)
- The process must not use radioactive materials. (Those processes are regulated under separate LWRP Permit conditions and DOE orders.)
- The process must generate sufficient volumes of wastewater to potentially impact the environment, which is currently considered to be 100 gallons per day or per batch discharge.
- The process must support other programmatic or institutional needs. If the process under evaluation exists solely for an R&D project, that process is not defined as a regulated categorical process. However, if that process discharges to sewer and supports widespread programmatic work or has other institutional customers, then that process is considered regulated under the applicable categorical standard.

As a result of this EPA decision, in July 1997 LLNL renewed its compliance with all of the administrative and monitoring requirements for the Categorical Standards contained in 40 CFR 403, Subpart 6; 40 CFR 433, Subpart A; and 40 CFR 469, Subpart A for those processes identified by the newly implemented defining criteria. These administrative and monitoring requirements are specified in LLNL's Wastewater Discharge Permit, #1250, issued by the LWRP (City of Livermore). LLNL samples, reports, and inspects three discharging processes: the Building 321 water-jet, the Building 153 wafer saw-cut, and the Building 153 microfabrication shop.

All LLNL wastewater-generating processes are evaluated to determine if they meet the definitions of specific industrial categories as set forth in the federal regulations. Currently, processes at LLNL fall into two such categories:

- Metal-finishing as defined in 40 CFR 433, Subpart A
- Semiconductor processes as defined under 40 CFR 469, Subpart A

Routine process review and evaluation occurs at least semiannually.

Monitoring for all categorical processes occurs at the point of discharge to the sanitary sewer. For instance, if the identified process discharges to a sink connected to the sewer, compliance samples are taken at the sink. If the process discharges to a retention tank dedicated to that process waste, the tank is sampled prior to discharge. The number of sampling locations is determined by the number of categorical processes that discharge to the sanitary sewer. Currently 15 metal finishing and 2 semiconductor processes are identified at LLNL. Of those, only three discharge to the sanitary sewer. These three (the Building 321 abrasive jet machining, Building 153 wafer saw-cut, and Building 153 microfabrication unit) are the only three that are inspected and sampled, with results reported to the LWRP in semiannual wastewater reports. The number of categorical processes at LLNL can change as existing processes are dismantled or new ones are installed.

The LWRP permit requires that both metal-finishing and semiconductor processes be sampled semiannually. Specific analysis requirements are mandated in the LWRP permit and federal regulations. Each Categorical Standard has its own defined sampling requirement. For instance, metal-finishing processes are sampled for pH, metals, total toxic organics (TTO), and cyanide. Semiconductor processes are sampled for pH, arsenic, and TTO.

The LWRP establishes sampling frequency and analytes for pretreatment sampling in the annual Wastewater Discharge/Chemical Storage Permit (City of Livermore). Sampling requirements are specified in 40 CFR, Parts 433 and 469.

Pretreatment samples are collected and analyzed for one of three purposes:

1) As a baseline when a new regulated process begins. Baseline sampling consists of three consecutive samples taken within a period of two weeks.

2) To demonstrate compliance for existing regulated processes according to the frequency defined in the LLNL Wastewater Discharge/Chemical Storage Permit (generally semiannually, except when regulated processes discharge to a dedicated retention tank system. Those retention tanks must be sampled prior to each discharge).

3) The LWRP conducts annual inspections and sampling of each regulated process that discharges to sanitary sewer, whether it discharges to a dedicated retention tank, or directly to the sewer. Whenever the LWRP collects samples, the Water Guidance and Monitoring Group (WGMG) must collect split samples. Where split samples are not possible, duplicate samples may be used.

Table 8-1 summarizes categorical pretreatment sampling frequencies and analytes.

8.4 Procedures for Laboratory Analysis

Categorical pretreatment samples are delivered to offsite, state-certified analytical laboratories for analysis as described in EMP-QA-DM, *Sample and Data Management*. Samples are analyzed using approved, standard EPA methodology.

8.5 Data Quality Assurance

8.5.1 Precision

LLNL collects duplicate samples for quality control of sampling technique and analysis. When determining whether to collect a duplicate, the sampler must consider the amount of sample material required and the total volume available. Overall, the total number of duplicates should be at least 10% of the cumulative total of sample locations (processes). The sampler submits QC samples as “blind”—the sample location identifier on the chain of custody (CoC) form is coded in such a way that the analytical laboratory cannot tell that the sample is a duplicate. During data review, the WGMG environmental analyst (EA) compares the results of duplicate and routine samples to ensure they are within approximately ±10%. Trip blanks, sampling bottles pre-filled with deionized water, are not necessary for this network.

8.5.2 Accuracy

The duplicate samples are collected for every analyte at that location and submitted to the lab for analysis, each with a unique sample identifier. The results for the duplicate location sample and actual location sample are compared by the network analyst upon the delivery of the analytical results from the laboratory. Trip blanks, sampling bottles pre-filled with deionized water, are not necessary for this network.

All quality check information provided by the analytical laboratories, including lab control standards, matrix spikes, matrix duplicates, and calibration standards are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation.

8.5.3 Completeness

Samples from identified categorical processes are collected twice per year as dictated by permit. Samples are only collected when the processes are operational. No mock-up sampling is performed. Collection of all required samples at each identified process location plus an annual QA sample would be considered 100% compete.

8.6 Program Implementation Procedures

The primary responsibility for activities related to categorical pretreatment monitoring is assigned to a WGMG EA. The EA designs, implements, and maintains the sampling network. The EA determines analytes, collection methods, and analytical methods; coordinates network activities with sampling technologists and analytical laboratory personnel; reviews and analyzes the data; performs dose assessments; follows trends in data; and reports results.

Pretreatment samples are collected and managed according to procedure WGMG-PT-S, *Pretreatment Sampling of Rinsewater,* which is reviewed annually, and revised at least once every three years. The handheld pH meter is calibrated as described in EMP-W-S, *Water Sampling*. Samples are submitted for analyses using sample control, chain-of-custody, and documentation procedures (EMP-QA-DM, *Sample and Data Management*). The written procedures include requirements for sample collection and submittal for chemical analysis, keeping a log, and filling out field tracking forms (FTFs) and CoC forms. The procedures also require the sampling technologist to alert the EA about difficulties encountered during any sampling event that may result in an NCR (ORAD-QA-NCR, *Nonconformance Reporting and Tracking*).

8.7 Action Levels

Sample analyses results are checked against the federal Categorical Discharge Standards by a WGMG EA. The concentration-based discharge limits in 40 CFR 433, Subpart A, and 40 CFR 469, Subpart A, are considered formal action levels for the regulated pollutants. The discharge limits specified in the federal standards and implemented via the permit are provided in Table 8-2.

If the concentration of any regulated pollutant exceeds a discharge limit and the QC data are acceptable, the WGMG EA contacts the Program representative responsible for that specific wastewater generating process. This inquiry will determine if the process was operated in any unusual manner or used in a different configuration than normal. Depending upon the outcome of that inquiry, further investigation may be initiated by the WGMG EA. The investigation may include, but is not limited to, inspection of the usage logs, base material used, and any chemicals or reagents used in the process. Additional samples will be taken to determine if the process is still out of compliance or to establish a time that marks the return to a state of compliance with the Categorical limit. After the issue of noncompliance is confirmed, it is reported to the LWRP and DOE within 24 hours. This verbal report is followed by a Five-Day Report to the LWRP and the information in the Five-Day Report is included in the applicable semiannual wastewater report.

Table 8-2. LLNL's self-monitoring program for nonradioactive parameters in wastewaters from categorical processes

Parameter	Categorical Discharge Standards(a) (mg/L)	
	Metal finishing	Semiconductor
Metals		
Cadmium	0.07	—
Chromium (total)	1.71	—
Copper	2.07	—
Cyanide[b]	0.65	—
Lead	0.43	—
Nickel	2.38	—
Silver	0.24	—
Zinc	1.48	—
Organics		
Total toxic organics	2.13	1.37
Physical		
pH (units)	5–10	5–10

[a] These standards are specified in 40 CFR 433, Subpart 13 and 40 CFR 469, Subpart 17. Noncategorical discharge limits apply when no other standard is specified.

[b] Limits apply to CN discharges other than CN salts. CN salts are classified by the State of California as "extremely hazardous waste" and cannot be discharged to the sewer.

8.8 Preparation and Disposition of Reports

All monitoring results, as well as the current status of the identified wastewater generating processes, are reported in Semiannual Wastewater Point-Source Monitoring Reports. These reports are submitted to the LWRP every January and July (e.g., Grayson 2004), as required in Attachment A-2 of the *LLNL Wastewater Discharge Permit #1250* (City of Livermore). As indicated in Section 8.7, Five-Day Reports are also required as necessary.

8.9 Future Plans

The most important goal for the categorical pretreatment monitoring program is to maintain an effective level of effluent discharge control ensuring full compliance under the appropriately applied regulatory standards. Due to the criteria for defining regulated processes, future resources will be best focused on those wastewater-generating activities that have the greatest potential to adversely affect water quality and cause interference or pass-though to the LWRP.

8.10 References

City of Livermore, *Wastewater Discharge Permit/Chemical Storage Permit #1250 (current version)*, City of Livermore, Livermore, CA.

40 CFR 136, Code of Federal Regulations, Title 40, Part 136, *Guidelines Establishing Test Procedures for the Analysis of Pollutants,* Office of the Federal Register, Washington, D. C.

40 CFR 403, Code of Federal Regulations, Title 40, Part 403, *General Pretreatment Regulations for Existing and New Sources of Pollution,* Office of the Federal Register, Washington, D. C.

40 CFR 403, Subpart 5, Code of Federal Regulations, Title 40, Part 403, Subpart 5, *National Pretreatment Standards: Prohibited Discharges,* Office of the Federal Register, Washington, D. C.

40 CFR 403, Subpart 6, Code of Federal Regulations, Title 40, Part 403, Subpart 6, *National Pretreatment Standards: Categorical Standards,* Office of the Federal Register, Washington, D. C.

40 CFR 433, Subpart 13, Code of Federal Regulations, Title 40, Part 433, Subpart 13, *Effluent Limitations Representing the Degree of Effluent Reduction Attainable by Applying the Best Practicable Control Technology Currently Available (BPT)* Office of the Federal Register, Washington, D. C.

40 CFR 433, Subpart A, Code of Federal Regulations, Title 40, Part 433, Subpart A, *Metal Finishing Subcategory,* Office of the Federal Register, Washington, D. C.

40 CFR 469, Subpart 17, Code of Federal Regulations, Title 40, Part 469, Subpart 17, *New Source Performance Standards (NSPS),* Office of the Federal Register, Washington, D. C.

40 CFR 469, Subpart A, Code of Federal Regulations, Title 40, Part 469, Subpart A, *Semiconductor Subcategory,* Office of the Federal Register, Washington, D. C.

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9 Storm Water

Richard A. Brown • Chris G. Campbell • Sandra Mathews

9.1 Introduction

Lawrence Livermore National Laboratory (LLNL) monitors storm water runoff at its Livermore site, as well as at Site 300. Water samples are analyzed for certain radionuclides, explosive compounds, total organic carbon (TOC), total organic halides (TOX), total suspended solids (TSS), electrical conductivity, pH, chemical oxygen demand (COD), total dissolved solids (TDS), oil and grease, metals, minerals, anions, nutrients, physical parameters, and a wide range of organic compounds. In addition, fish bioassays and other toxicity tests are performed on storm water entering and leaving the Livermore site via Arroyo Las Positas.

9.2 Rationale and Design Criteria

9.2.1 Regulatory Drivers

U.S. Department of Energy (DOE) Order 5400.1[1] is the primary regulation driving the monitoring of storm water runoff at LLNL. The order states, "Environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on on-site and off-site environmental and natural resources . . . ".

In addition, the Federal Water Pollution Control Act (Clean Water Act, 1972, 33 USC 1251) was enacted to restore and maintain the chemical, physical, and biological integrity of waters of the United States. To this end, Section 402 established the National Pollutant Discharge Elimination System (NPDES) to set the conditions under which pollutants could be discharged to navigable waters. NPDES requires industries to obtain permits before discharging storm water associated with industrial activities from their facilities. Specific U.S. Environmental Protection Agency (EPA) requirements applicable to LLNL's NPDES permits are contained in Title 40 of the Code of Federal Regulations (CFR), Part 122, *EPA Administered Permit Programs: The National Pollutant Discharge Elimination System*. NPDES permits requiring storm water runoff monitoring at the

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

Livermore site and Site 300 are issued in California as Waste Discharge Requirements (WDRs). These permits regulate storm water discharges associated with industrial

activities and low-threat, non-storm water discharges, such as air-conditioner condensate. The following WDR permits are the regulatory drivers for LLNL's storm water runoff monitoring:

- Order No. 95-174, Waste Discharge Requirements and National Pollutant Discharge Elimination System (NPDES) for U.S. Department of Energy and Lawrence Livermore National Laboratory, issued by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB 1995) for the Livermore site.
- Order No. 97-03-DWQ, Statewide General National Pollutant Discharge Elimination System (NPDES) Permit for Storm Water Discharges Associated with Industrial Activities, issued by the State Water Resources Control Board (SWRCB 1997) for Site 300 in August 2000.

Waters of the state of California are also regulated by the California Porter-Cologne Water Quality Control Act (California Water Code 13000). Under this act, the jurisdictional regional water quality control board (RWQCB) must evaluate waste discharges and issue a WDR if it determines that the waste could adversely affect water quality. This act also requires the state to develop several statewide water quality plans and individual regional water quality control plans. Any WDR must be consistent with these plans and must protect the beneficial uses and the water quality objectives these plans identify. In addition, Site 300 storm water monitoring meets the requirements of the *Post-Closure Plan for the Pit 6 Landfill Operable Unit* (Ferry et al. 1998).

9.2.2 Monitoring Objectives

The California SWRCB and its associated RWQCBs administer LLNL's site-specific NPDES permits. The LLNL NPDES storm water monitoring programs meet permit requirements by:

- Aiding in the implementation of Storm Water Pollution Prevention Plans (SWPPPs).
- Measuring the effectiveness of Best Management Practices (BMPs) in reducing or eliminating specific pollutants in storm water discharges.
- Ensuring that storm water discharges comply with discharge prohibitions and receiving water limitations as specified in LLNL's storm water discharge permits.
- Determining that facility practices to control storm water pollution are evaluated and modified to meet changing conditions.

In addition to the NPDES requirements already stated, DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991) describes the environmental monitoring objectives applicable to runoff:

"The purpose of the surveillance program is to characterize the radiological conditions of the off-site environs and, if appropriate, estimate public doses related to these conditions, confirm predictions of public doses based on effluent monitoring data, and, where appropriate, to provide compliance data for all applicable regulations. The results of this evaluation should[*] be documented in the site Environmental Monitoring Plan."

"The environmental surveillance program for DOE-controlled sites should be conducted in accordance with the requirements of DOE Order 5400.5. . . ."

Ambient water quality monitoring should be conducted through a network of fixed stations from which data will establish well-defined histories of the physical, biological, and chemical conditions of local bodies of water and sediments.

Analysis of data collected from a fixed station monitoring network should support:

- Characterizing and defining trends in the physical, chemical, and biological conditions of surface waters;
- Establishing baselines of water quality;
- A continuing assessment of water pollution control programs;
- Identifying new water quality problems; and
- Detecting, characterizing, and reporting unplanned releases and their effects on water quality.

9.2.3 Sources and Analytes

Storm water runoff at the Livermore site flows through the LLNL storm drainage system to either Arroyo Las Positas or Arroyo Seco. These two arroyos merge and flow into Arroyo Mocho west of the Livermore site (Figure 9-1). Arroyo Mocho flows toward the west where it merges with other arroyos in the west end of the Livermore Valley. There they form the southward-flowing Arroyo de la Laguna, a tributary to the Alameda Creek drainage system, which eventually flows to San Francisco Bay. At Site 300, storm water flows south and southeasterly through the LLNL storm drainage system and on-site surface waters into Corral Hollow Creek, which flows eastward into the San Joaquin Valley west of Tracy where it dies out and infiltrates into valley alluvial sediments and

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[*] The term *should* in this quotation identifies a DOE "high-priority element."

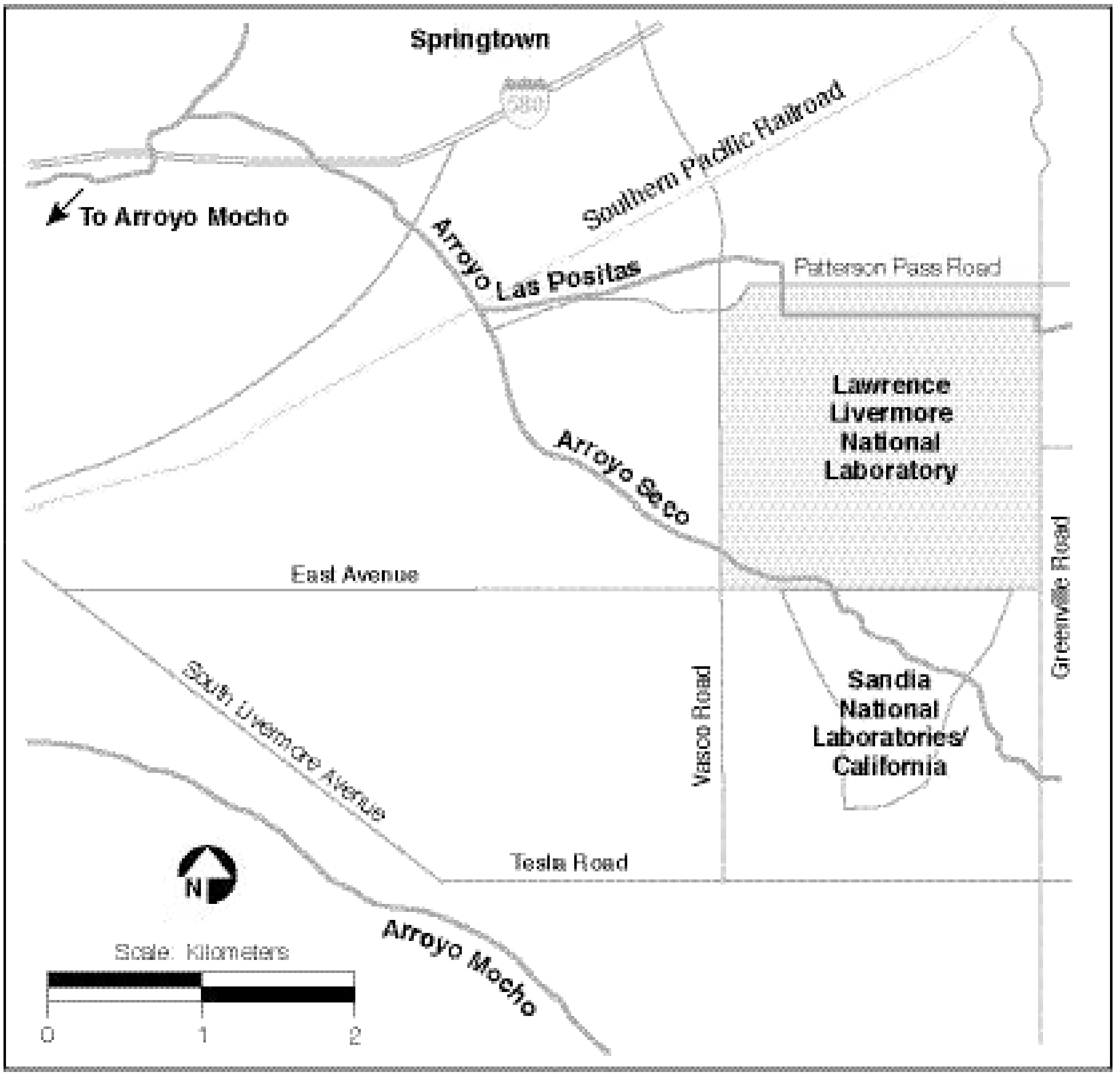

Figure 9-1. Surface waterways in the vicinity of the Livermore site

never reaches the San Joaquin River. A small number of unnamed drainages at Site 300 flow northerly toward Tracy (Figure 9-2).

The LLNL storm water program meets specific permit requirements and, in support of the DOE orders described above, exceeds permit requirements for both the number of samples collected and the analyses conducted on the samples. In 1995, the SFBRWQCB issued NPDES No. CA0030023, WDR 95-174 for the Livermore site. This site-specific permit replaced coverage under the Statewide General Permit for Storm Water Discharges Associated with Industrial Activities. Required analyses and additional analyses conducted on Livermore site and Site 300 storm water samples are summarized in Table 9-1. Analyses are conducted for constituents that may be present in storm water discharges in significant quantities. Storm water on the Livermore site can acquire contaminants from a variety of sources, such as neighboring agricultural land, parking

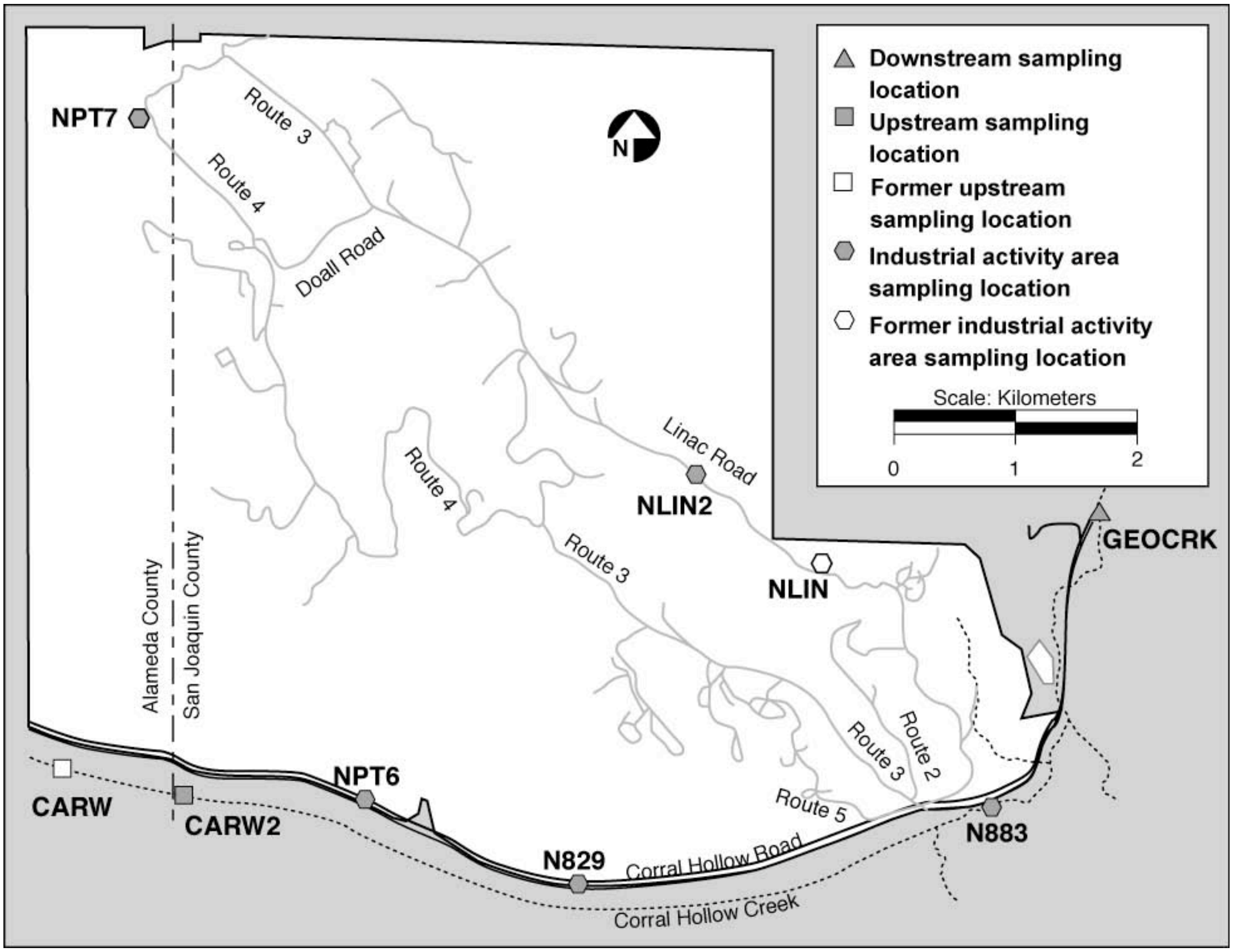

Figure 9-2. Storm water runoff sampling locations at Site 300 and Corral Hollow Creek

lots, and landscaped areas. Possible off-site sources and the wide range of activities conducted at the Livermore site make it necessary to analyze this runoff for a wide range of constituents. In contrast, storm water runoff at Site 300 is sampled at locations targeting specific industrial activities and potential contaminants (see Section 9.3.2).

9.2.4 Collection Methods

Samples are collected by grab sampling from the runoff flow at specified locations. Portable parastoltic pumps are used for sampling. If the water to be sampled is accessible to the technician, grab samples are collected by partially submerging triple-rinsed sample bottles directly into the water and allowing them to fill with the sample water. Sampling is conducted away from the edge of the water, when possible, to minimize the collection of sediment with the sample matrix. Sample vials for volatile organics analyses are filled

Table 9-1. Summary of analyses conducted and EPA methods used on storm water samples

Livermore site	Site 300
Chemical oxygen demand (EPA 410.4)	Chemical oxygen demand (EPA 410.4)
Dissolved oxygen (EPA 360.1)	Cyanide (EPA 335.2)
Oil and grease (EPA 1664)	Oil and grease (EPA 1664)
pH (EPA 150.1 or 9040)	pH (EPA 150.1 or 9040)
Specific conductance (EPA 120.1 or 9050)	Specific conductance (EPA 120.1 or 9050)
Total dissolved solids (EPA 160.1)	Total dissolved solids (EPA 160.1)
Total suspended solids (EPA 160.2)	Total suspended solids (EPA 160.2)
Anions (EPA 300.0, 365.1, or 365.2)	Ammonia (EPA 350.2)
General minerals (EPA 200.7, 300.0, 310.1, 353.2, 365.1, 365.4, 425.1, or SM2340B)	Potassium (EPA 200.7)
Metals (EPA 200.7 or 200.8)	Metals (EPA 200.7, 210.2, 245.1, or 200.8)
Total organic carbon (EPA 9060)	Explosives (EPA 8330)
Fish bioassay (fathead minnow) (EPA 1000 and 2000)	Total organic carbon (EPA 415.1 or 9060)
Diuron (EPA 632)	Volatile organic compounds (EPA 624)
Glyphosphate (EPA 547)	Semivolatile organic compounds (EPA 625)
Polychlorinated biphenyls (PCBs) (EPA 8082)	Polychlorinated biphenyls (PCBs) (EPA 8082) and dioxins (EPA 8290)
Gross alpha and gross beta radioactivity (EPA 900)	Chlorinated pesticides and polychlorinated biphenyls (EPA 608)
Tritium (EPA 906)	Total organic halides (EPA 9020)
Plutonium (alpha spectroscopy)	Gross alpha and gross beta radioactivity (EPA 900)
Radioisotopes by gamma ray spectroscopy (EPA 901.1)	Tritium (EPA 906)
	Depleted uranium (alpha spectroscopy)
	Radioisotopes by gamma ray spectroscopy (EPA 901.1)

first, before sample vials for all other constituents and parameters. After the bottles are filled, they are dried, labeled, packaged, and placed in an ice chest.

Sample bottle requirements, special sampling techniques, and preservation requirements for each analyte are specified in procedures EMP-W-S, *Water Sampling*; EMP-WSS-RO, *Storm Water Runoff Sampling*; and EMP-QA-BOT, *Aqueous Sample Bottle Requirements*.

9.3 Extent and Frequency of Monitoring and Measurement

9.3.1 Monitoring Requirements for Livermore Site

NPDES permits specifically require visual observations at storm water discharge points during the dry and wet seasons. In general, the wet season occurs between October 1 and April 1; however, this is a regulatory definition and is defined differently in different cases. NPDES permits for storm water require LLNL to visually inspect the storm drainage system monthly during the wet season (if significant storm events occur). The regulations require analysis of storm water from two storm events during which runoff occurs. Additionally, LLNL must visually inspect the storm drainage system twice (once each quarter) during the dry season to identify any dry weather flows.

The storm water surveillance monitoring network consists of nine sampling locations, each with a unique identifier (Figure 9-3). A complete description of the sampling locations is entered in the Locations database maintained by the Data Management Team in LLNL's Operations and Regulatory Affairs Division (ORAD).

NPDES monitoring points required by permit are ALPE, ALPO, ASW, ASS2, GRNE, and WPDC, a subset of the overall surveillance monitoring network. Of the nine locations in the Livermore site storm water sampling network (Figure 9-3), six characterize storm water either entering (influent—ALPE, ALPO, GRNE, and ASS2) or exiting (effluent—WPDC and ASW) the site, as required by the NPDES permit. Three

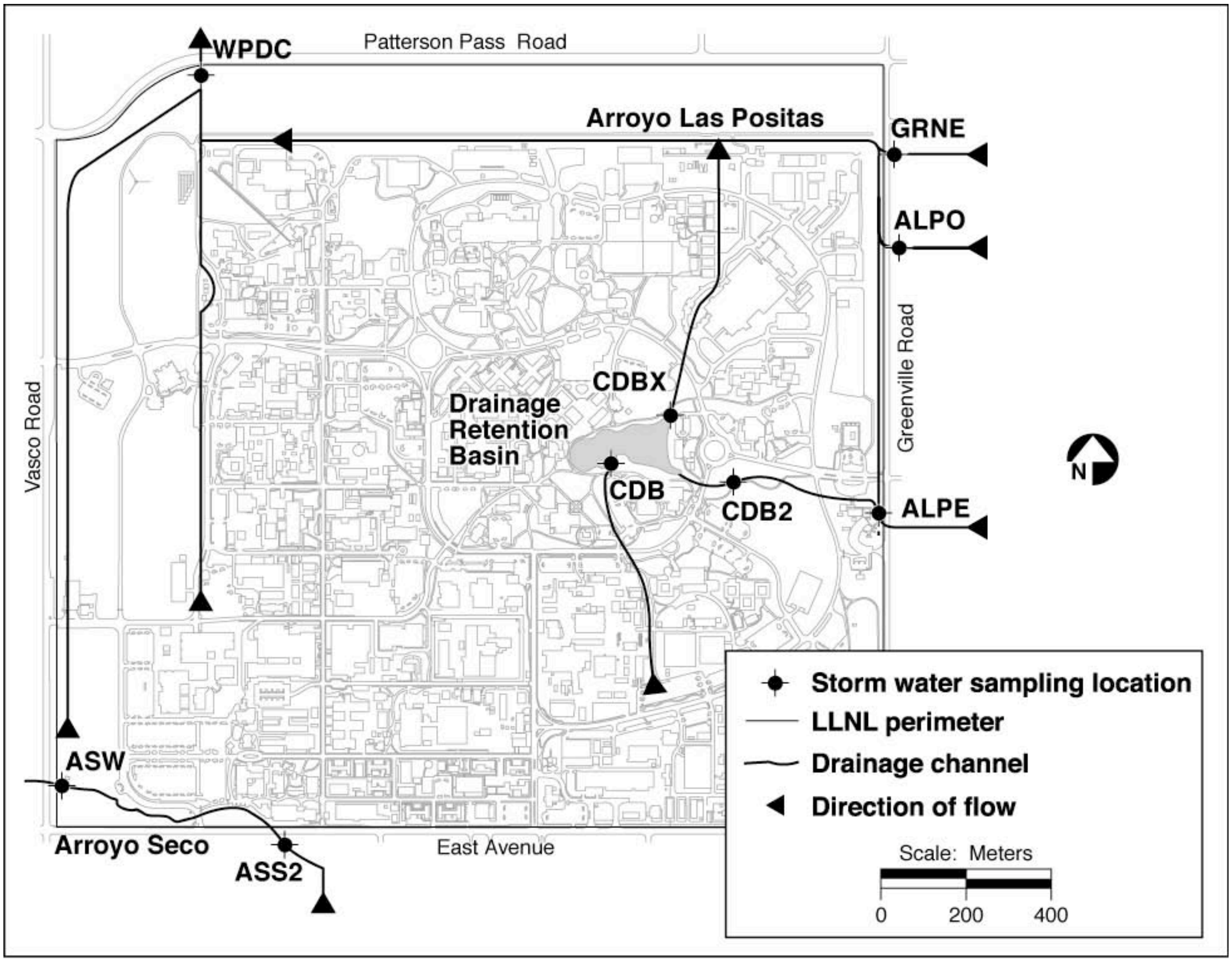

Figure 9-3. Storm water runoff sampling locations, Livermore site and vicinity

additional locations (CDB, CDB2, and CDBX) serve the monitoring of influent and effluent locations of the DRB. Although the DRB locations are not required in the storm water NPDES permits, they are sampled as part of the storm water network in order to improve the efficiency of administration and sample collection.

9.3.2 Monitoring Requirements for Site 300

Based on field examinations of Site 300 drainage (performed during storm events), communications with Central Valley RWQCB, and a review of the "industrial activity" criteria in the NPDES General Permit for discharges of storm water associated with industrial activities (SWRCB 1997), seven monitoring locations are used at Site 300 (shown in Figure 9-2). Five locations (NPT7, NPT6, N829, N883, NLIN2) monitor runoff related to specific industrial activities, one location (CARW2) monitors water quality upstream of Site 300 in Corral Hollow Creek, and one location (GEOCRK) monitors water quality downstream of Site 300 in Corral Hollow Creek. (The original NLIN location was moved 1200 meters upstream to NLIN2 for better access.)

Rifle Canyon in the southern portion of Site 300 is a natural drainage for the Explosives Burn Pits at the Building 829 Complex. Monitoring location N829 sits where Rifle Canyon exits the Site 300 perimeter, east of Pit 6. The Building 829 Treatment Facility, located in the Explosives Process Area in the south-central sector of Site 300, operates as a permitted Resource Conservation and Recovery Act (RCRA) facility, under "Sector K" in the NPDES WDR 97-03-DWQ, from California EPA's Department of Toxic Substances Control (DTSC). The complex consists of three separate burn pits and an explosives combustion unit known as the "iron horse." It is used to burn explosive wastes generated by Explosives Process Area operations. LLNL continues to sample the Building 829 Complex at N829 after its closure.

The Building 883 Facility (also a "Sector K" facility), a hazardous waste container storage area, is located in the General Services Area (GSA) in the southeast corner of Site 300. This RCRA-permitted facility stores containerized wastes awaiting off-site disposal by the Radioactive and Hazardous Waste Management (RHWM) Division of EPD. The facility design includes engineered controls that catch storm water in a sump, where it is pumped into barrels or drums, pending analysis and disposal. Roof runoff from this facility flows through storm drains in the GSA and exits Site 300 along Corral Hollow Road at monitoring location N883.

Location NLIN2 is used to monitor runoff from several closed landfills at Site 300 that fall under both "Sector K" and "Sector L" for landfills. Pits 1 and 2 are landfills (Sector L) located south of the East Observation Post in the upper central portion of Site 300. Pits 3, 4, 5, and 7 lie directly above the West Observation Post in the northwest quadrant. Pit 8 is located in the northeastern portion of the site, just east of the 801 Facility, and Pit 9 is located near Building 845. These landfills hold debris from past experiments conducted at Site 300. A history of each pit's contents can be found in the *Final Site-Wide Remedial Investigation Report* (Webster-Scholten 1994). Although these landfills are capped, so that the contents do not come in contact with storm water runoff, the RWQCB requires sampling of associated runoff.

NLIN2 is used to monitor drainage from the closed landfills (except Pit 6 and some drainage from Pit 7), which flows southeasterly until it passes through a culvert off Linac Road, and then it exits Site 300 via Elk Ravine to the east. Elk Ravine has no safe or accessible sampling point at the Site 300 boundary. No industrial activity occurs between the Linac Road culvert and the final Elk Ravine exit point; therefore, LLNL collects samples at the Linac Road culvert (NLIN). This sampling point was approved in personal communication with Central Valley RWQCB staff on December 8, 1992 (and documented in a January 22, 1993, letter to Central Valley RWQCB [Isherwood, 1993]). Because of past activity at the Building 850 Area, storm water could become contaminated with polychlorinated biphenyls (PCBs) and dioxins. Therefore, samples collected at NLIN, which is downgradient from B850, are also analyzed for PCBs and dioxins.

Location NPT6 is used to monitor Pit 6 runoff. Drainage from the region surrounding the Pit 6 cap is diverted by a ditch and culvert north of the pit to prevent intermittent sheet flow over the landfill. Runoff is sampled at the culvert on the southern end of Pit 6 (NPT6). Post-closure monitoring at Pit 6 requires (Ferry et al., 1998) analysis for potassium, beryllium, mercury, total dissolved solids, and a wide range of organic constituents (EPA Methods 608, 624, and 625).

The Pit 7 cap includes a graded concrete drainage system that directs flow away from the pit. Consequently, a portion of this storm water runoff now flows north and is monitored at location NPT7.

Slightly south of Site 300 near its western border is location CARW, where technical staff collect samples from Corral Hollow Creek. Because this location is upstream of any discharge from Site 300 and the water contains constituents and parameters considered typical of the region, CARW samples aid LLNL in determining the water quality of storm water not impacted by Site 300 operations.

Sampling location GEOCRK lies downstream of Site 300 in Corral Hollow Creek. This location helps LLNL assess the potential influence of Site 300 on water quality in Corral Hollow Creek.

9.4 Procedures for Laboratory Analysis

All water quality chemical and radioactivity analyses, including fish toxicity testing, are performed by California-certified off-site contract laboratories using appropriate EPA standard methods according to ORAD procedure EMP-QA-BOT, *Aqueous Sample Bottle Requirements*. Analyses for specific alpha particle-emitting radionuclides, such as plutonium-239 or uranium-238, use methods specific to each laboratory for detecting radiation from alpha particles (see Table 9-1). A standard chain of custody form is used to track samples, double-check bottle labels, and exchange information with contract laboratories.

9.5 Data Quality Assurance

Field activities are recorded on field tracking forms and/or in logbooks, and sample tracking is maintained through the chain-of-custody process. Additionally, temperature blanks are included in each shipping container of samples to verify that the temperature is maintained at $4 \pm 2\ ^{\circ}C$ until receipt at the analytical laboratories. ORAD data management procedure EMP-QA-DM ensures that all laboratory measurements are received, accurately recorded, and properly stored in a computer database for easy and fast retrieval. Hard copies of the data are also archived by the ORAD Data Management Team.

9.5.1 Precision

Under the quality assurance program for this monitoring network, a duplicate sample is collected from a single location from each site (Livermore site and Site 300) for each storm water runoff event. The duplicate location is randomly chosen from the available locations, excluding locations around the drainage retention basin and location WPDC for the first storm. This last exclusion is due to difficulties in duplication of fish toxicity analyses.

The duplicate samples are collected for every analyte at that location and submitted to the lab for analysis, each with a unique sample identifier. The results for the duplicate location sample and actual location sample are compared by the network analyst upon the delivery of the analytical results from the laboratory. Trip blanks, sampling bottles pre-filled with deionized water, are not necessary for this network.

9.5.2 Bias

All quality check information provided by the analytical laboratories, including lab control standards, matrix spikes, matrix duplicates, and calibration standards are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation.

9.5.3 Completeness

Storm water runoff samples are collected for two storm events per year as dictated by permit. Samples are only collected when water is flowing at all locations so that sampling of all locations during the two storms sampled at each site (Livermore site and Site 300) would be considered 100% compete. Given the potential for sample loss due to broken bottles our target completeness is 90% for the Livermore site. At Site 300, there may not be sufficient storms to collect samples for two runoff events within working hours during a year. Often only one storm per water year produces significant runoff and some locations (NPT6 and N829) have not produced runoff samples for several years. Therefore, target completeness for Site 300 is 90% of all sampling locations where with storm water runoff was flowing during working hours.

9.6 Program Implementation Procedures

Storm water runoff sampling is conducted by LLNL technical staff according to procedure EMP-W-S, *Water Sampling*, and EMP-WSS-RO, *Storm Water Runoff Sampling*. Methods used to prevent cross-contamination are similar throughout all sampling events. They include wearing disposable gloves when collecting samples, discarding gloves between sampling locations, keeping the work area clean, not placing open sample bottles or caps on any surface (sample bottles should be kept closed until used), and not touching the insides of the sample bottles.

Sample preservation and handling practices are performed according to the analytical method requirements, and are specified in ORAD procedure EMP-QA-BOT, *Aqueous Sample Bottle Requirements*. Conditions identified during each sampling event are recorded on a Field Tracking Form (FTF). This information, in conjunction with sampling results, provides a complete summary for each representative sampling location. The FTF may also provide information in the form of comments and in situ measurements that may be useful to the analyst. Chain of custody forms document the sample from collection in the field through receipt of the data results from the analytical laboratories. Samples are submitted for analyses and resulting analytical results are managed using sample control and documentation procedure EMP-QA-DM, *Sample and Data Management*.

9.7 Action Levels

No numeric water quality criteria for storm water discharges from LLNL currently exist, other than derived concentration guidelines (DCGs) for specific radionuclides according to DOE Order 5400.5. In order to provide stringent criteria relevant to the environment around both LLNL sites, site-specific comparison criteria have been calculated for a select group of parameters based on historical concentrations in runoff samples. A storm water concentration exceeds the threshold if it is greater than the 95 percent confidence limit computed for the historical mean concentration for a specific analyte (Table 9-2).

In addition, LLNL storm water analysis results are compared with other water quality criteria. The U.S. EPA established benchmark values for 41 parameters in the multisector permit (EPA 2000), but stressed that these concentrations should not be interpreted as effluent limitations. Rather, they are the levels that EPA uses to determine whether storm water discharges from specific categories of industrial facilities merit further monitoring. LLNL storm water analysis results are compared with water quality criteria listed in *Water Quality Control Plan, San Francisco Bay Basin* (CRWQCB 1995) and *Central Valley Water Quality Control Plan: the Sacramento River Basin and the San Joaquin River Basin* (CVRWQCB 1998). Criteria in the Water Quality Control Plans include surface water quality objectives for the protection of aquatic life, and water quality objectives for waters designated as domestic, municipal, or agricultural supply. Water Quality Control Plan criteria also list the California drinking water Maximum Contaminant Levels (MCLs) for drinking water. LLNL storm water analysis results are

Table 9-2. LLNL site-specific threshold comparison criteria for storm water constituents of concern. Values were estimated based on historical runoff data.

Parameter	Livermore site	Site 300
Total suspended solids (TSS)	750 mg/L(a)	1,700 mg/L(a)
Chemical oxygen demand (COD)	200 mg/L(a)	200 mg/L(a)
pH	<6.0, >8.5(a)	<6.0, >9.0(b)
Nitrate (as NO_3)	10 mg/L(a)	not monitored
Orthophosphate	2.5 mg/L(a)	not monitored
Mercury	above RL(c)	above RL(c)
Beryllium	0.0016 mg/L(a)	0.0016 mg/L(a)
Chromium (VI)	0.015 mg/L(a)	not monitored
Copper	0.013 mg/L(d)	not monitored
Lead	0.015 mg/L(e)	0.015 mg/L(e)
Zinc	0.35 mg/L(a)	not monitored
Diuron	0.014 mg/L(a)	not monitored
Oil and grease	9 mg/L(a)	9 mg/L(a)
Tritium	36 Bq/L(a)	3.17 Bq/L(a)
Gross alpha radioactivity	0.34 Bq/L(a)	0.90 Bq/L(a)
Gross beta radioactivity	0.48 Bq/L(a)	1.73 Bq/L(a)

a Site-specific value calculated from historical data and studies. These values are lower than the MCLs and EPA benchmarks except for zinc, TSS, and COD.

b EPA benchmark

c RL = reporting limit (normally) = 0.2 µg/L for mercury

d Ambient water quality criteria (AWQC)

e EPA/CA action level

also compared with EPA's MCLs and Ambient Water Quality Criteria (AWQC) for the protection of freshwater organisms, as well as California's AWQC.

To evaluate LLNL storm water effluent, analysts carry out the following ordered sequence (see also Campbell et al. 2004):

1. Compare storm water effluent concentrations with the above criteria.
2. If an effluent concentration exceeds any criterion, compare effluent value with corresponding influent concentration.
3. If an effluent concentration is lower than the influent concentration, assume that the source is off site or naturally occurring, and take no further action.
4. If data for a given calendar year or wet season indicate that more than 25 percent of effluent concentrations for a particular constituent on a particular flow path (i.e., Arroyo Seco or Arroyo Las Positas) exceed both a criterion and the corresponding influent concentration, develop a historical trend plot.
5. If (a) the historical trend indicates that concentrations are consistently increasing, or if (b) data for a given calendar year or wet season indicate that more than 50 percent of effluent concentrations for a particular constituent on a particular flow path exceed both a criterion and the corresponding influent concentrations, initiate a detailed investigation.
6. A single, unusually high concentration may, by itself, trigger a detailed investigation.

   Detailed investigations may include elements such as:

   - Management notification.
   - Re-analysis of the samples.
   - Analysis of archived samples. (Because it is not possible to resample a storm event, procedures dictate collecting archival samples.)
   - Analysis of subsequent storm events. (Routinely, four storm events are sampled each year. During a detailed investigation, the storm event immediately following a finding may also be sampled for further evaluation.)

- Source investigation. (Results are compared with findings from other monitoring networks [e.g. air, rain, or sediments], and LLNL activities that may have contributed to the result are investigated.)
- Expanded monitoring (more locations).
- Increased monitoring frequency (i.e., more storm events sampled per wet season).

9.8 Preparation and Disposition of Reports

Storm water monitoring findings are presented in the surface water monitoring section of the annual LLNL *Environmental Report*. In addition, storm water sampling results are transmitted annually in two reports to regulatory agencies. Livermore site findings are reported to the San Francisco RWQCB, and Site 300 results are reported to the Central Valley RWQCB (e.g., Sanchez 2003a, 2003b). Both reports follow the *Storm Water Annual Report* format stipulated by the California SWRCB in the General Permit and are due on July 1 (Site 300) and August 1 (Livermore site) of each year. All storm water data are reported and summarized, trends are discussed, and efforts to reduce constituent loadings in storm water are evaluated.

9.9 Future Plans

Future plans for storm water monitoring include two NPDES permit renewals and additions to the Livermore site and Site 300 storm water monitoring programs. Future plans are still in the formative stages until the SFBRWQCB and the SWRCB act on the respective permit renewals. Therefore, only very preliminary plans can be provided in the sections below.

Order 95-174, which regulates storm water discharges at the Livermore site, expired in 2000. LLNL initiated the permit renewal process by submitting a Report of Waste Discharge in February 2000 (Mathews 2000), the required 180 days in advance of the expiration date. In April 2000, the SFBRWQCB issued a written administrative continuance for WDR 95-174, until a new permit is adopted. Additionally, the federal Phase II storm water regulations went into effect in March 2003. The SFBRWQCB is currently in the process of designating institutional facilities that operate storm drainage systems, such as the LLNL Livermore site, as requiring a municipal storm water permit. These upcoming changes in the regulatory permits and programs that govern the Livermore site storm water discharges are expected to have a significant affect on the storm water monitoring program.

Order 97-03-DWQ, a general permit issued by the SWRCB, expired in 2002. The State initiated the public process to revise Order 97-03-DWQ. Once the revised permit is adopted by the State, the Site 300 storm water monitoring program will be revised to meet it requirements. Based upon the draft permit released by the State for public comment significant changes are expected to be required for the Site 300 storm water monitoring program

9.10 References

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10 Construction Storm Water

Sandra Mathews

10.1 Introduction

This chapter describes the program to monitor the Construction Storm Water network. General information on the Environmental Monitoring Plan and the facilities at Lawrence Livermore National Laboratory (LLNL) can be found in the Chapter 1.

Storm water runoff at the Livermore site flows through the LLNL storm drainage system to either Arroyo Las Positas or Arroyo Seco. These westward-flowing arroyos merge in the west end of the Livermore Valley. There they form the southward-flowing Arroyo de la Laguna, a tributary to the Alameda Creek drainage system, which eventually flows to San Francisco Bay. At Site 300, storm water flows south and southeasterly through the LLNL storm drainage system and on-site surface waters into Corral Hollow Creek, which flows eastward toward the San Joaquin River basin in the Central Valley. Corral Hollow Creek, as well as a small number of unnamed drainages at Site 300, flows northerly toward Tracy (and generally cease to flow as they dissipate into alluvial sediments and never reach the San Joaquin River system). At both sites, LLNL undertakes construction activities. LLNL monitors construction storm water runoff at the Livermore site and Site 300.

10.2 Rationale and Design Criteria

10.2.1 Regulatory Drivers

The regulatory drivers for monitoring the construction storm water network are the applicable portions of DOE Order 5400.1[1]; the Federal Water Pollution Control Act, (Clean Water Act, 1972, USC 1251); and the California Porter-Cologne Water Quality Control Act. The requirements of these federal and state laws are implemented through a general National Pollutant Discharge Elimination System permit issued by the State of California, NPDES Permit No. CAS000002, (also known as WDR 99-08-DWQ, State

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

General Permit for Discharges of Storm Water Runoff Associated with Construction Activity) .

10.2.2 Monitoring Objectives

The purpose of the sampling and analysis is to evaluate the best management practices (BMPs) and help determine if storm water runoff is being contaminated by construction activities. The applicable portions of DOE Order 5400.1 and the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991) direct LLNL to characterize the impact, if any, of LLNL operations on the receiving waters.

10.2.3 Sources and Analytes

The NPDES permit requires LLNL to characterize the runoff from construction sites that meet the following specific ground disturbance thresholds.

- When construction site storm water is directly discharged into a water body that is on the 303d list (list of waters declared to be “impaired” under section 303d of the Clean Water Act) as being impaired for sediment, silt, or turbidity.
- When nonvisible pollutants might contaminate construction site runoff.

The first condition does not currently apply to LLNL construction projects because runoff from projects located at both Site 300 and the Livermore site is not directly discharged into a water body listed as impaired. LLNL must evaluate each of its permitted construction projects to determine if sampling and analysis are required under the second condition. This evaluation is documented in each individual construction project’s Storm Water Pollution Prevention Plan (SWPPP).

Nonvisible pollutants are materials that could contaminate storm water runoff that is discharged from the construction site, but which are not visually detectable in the runoff. The source of these pollutants include:

- Previously existing contaminants that may be mobilized by construction operations
- Construction phase materials including:
  - Materials used on the construction site in a manner that exposes them to storm water (e.g., soil amendments, such as gypsum, that are widely applied on the site)

  - Materials stored on the construction site in a manner that exposes them to storm water

As required by WDR 99-08-DWQ, each individual construction SWPPP must identify known previously existing contamination and materials used and stored on a construction site that have the potential to pollute storm water. The SWPPPs are also required to identify the BMPs that will be employed on the project to prevent pollution of storm water. Potential sources of construction storm water pollution are those materials or previously existing contaminants that are not isolated from exposure to storm water runoff.

10.2.3.1 Evaluation of Previously Existing Contaminated Sources at LLNL Construction Projects

The United States Environmental Protection Agency (EPA) placed the two LLNL sites on the National Priorities List under the Comprehensive Environmental Response Compensation and Liability Act (CERCLA). Because of this status as Superfund sites, there is a potential that construction activities may disturb contaminated soil. Therefore, preconstruction soil evaluations are conducted to provide advance information on whether or not soil from the project areas contains contaminants. These preconstruction soil evaluations form the basis of the determination of whether there are previously existing contaminants at permitted construction projects that will trigger storm water sampling and analysis.

Data from preconstruction soil sampling are compared with previously established background concentrations for both LLNL sites. The soil reuse criteria for the Livermore site are also used. Soil reuse criteria were established for constituents that either do not occur naturally or are slightly elevated above the background concentrations. Reuse criteria currently in use at Livermore site were developed using the Designated Level Methodology (Marshack 2000) and were approved by the San Francisco Bay Regional Water Quality Control Board (RWQCB) (SFBRWQCB 1994).

The following steps identify the process LLNL uses to evaluate preconstruction soil information to determine whether construction runoff sampling and analysis is required.

- If the preconstruction evaluations determine that soil constituent concentrations on the construction site are consistent with background, then the soil constituents are not considered potential sources of storm water pollutants.

- If preconstruction evaluations determine that soil constituent concentrations on the construction site are above background but below approved reuse concentrations, or if there is no background value, then the soil will be further evaluated to determine whether the concentrations exceed established appropriate water quality objectives for aquatic life protection. If soil constituent concentrations exceed the appropriate water quality objectives for aquatic life protection, then the soil constituent(s) are considered potential sources of storm water pollutants. If soil constituent concentrations do not exceed the appropriate water quality objectives for aquatic life protection, then the soil constituent(s) are not considered potential sources of storm water pollutants.

- If preconstruction evaluations determine that soil constituent concentrations on the construction site are above reuse concentrations, then the soil constituent(s) are considered potential sources of storm water pollutants. This source evaluation takes into account the location of the potentially contaminated soil (e.g., depth), and its potential for exposure to storm water runoff by the construction activity.

The results of the evaluation to determine whether pre-existing contaminants are present on any specific LLNL construction project are documented in the project SWPPP.

10.2.3.2 Evaluation of Construction Phase Contaminate Sources at LLNL Construction Projects

Each specific construction SWPPP identifies the materials and activities planned, the potential pollutants (including whether this pollutant will be visually detectable), and the BMPs planned to prevent exposure of the potential pollutants to storm water runoff. If evaluations determine that a material or activity has the potential to pollute storm water and cannot be isolated, then the contaminant(s) generated by that material or activity are considered potential sources of storm water pollutants. In general, LLNL construction specifications and standards require that all materials that have the potential to pollute storm water be isolated from storm water either by BMPs that cover the material storage or activity or by BMPs that contain the runoff from the material storage or activity.

10.2.4 Collection Methods

Grab sampling or field measurements (e.g., pH with meters) are used for all construction storm water compliance monitoring. Sample handling and collection techniques used are similar to those for other environmental water sampling, as noted in procedure EMP-W-S, *Water Sampling*. Standard chain of custody and field tracking form (FTF) procedures (EMP-QA-DM, *Sample and Data Management*) are employed to track samples and to document field conditions that may affect the samples.

10.3 Extent and Frequency of Monitoring and Measurement

The frequency of sampling for nonvisible pollutants is determined based on the exposure of pollutant sources. Runoff needs to be sampled only when there is exposure of a pollutant source to storm water when the runoff enters a storm drain or surface water. Sampling and analysis schedules for each construction project vary and are established in the individual project SWPPP.

Factors that influence the collection of samples include rain events that produce runoff, exposure of materials that could result in the discharge of nonvisible pollutants to runoff, or the failure of a BMP designed to prevent exposure, such as the overflow of secondary containment. Sampling for nonvisibly detectable pollutants is required under two conditions:

- Visual inspections indicate that there has been a breach, malfunction, leakage, or spill from a BMP that could result in the discharge of pollutants that are not visually detectable and is discharged off the construction site into the storm drainage system or surface waters.
- Storm water comes into contact with soil amendments, or other exposed materials, or pre-existing contamination that is not visually detectable and is discharged off the construction site into the storm drainage system or surface waters.

Routine inspections of the construction site are required by WDR 99-08-DWQ before a predicted rain event, during rain events lasting more than 24 hours, and following rain events. Observations of failed BMPs during these inspections trigger the collection of storm water samples for analysis. In cases where a known pre-existing contaminant is present in the construction site soil, or where a material, such as a soil amendment, will be used and exposure cannot be prevented, sampling frequencies can be established at the outset of a project to screen for the contaminant in runoff.

Sampling locations must be identified that provide information on both the runoff quality that is affected by the construction activity and the background runoff quality (i.e., an uncontaminated sample). Depending on the nature of the exposure, the affected runoff may be confined to a small area of the project (such as a BMP failure in a material storage area) or may be widely spread throughout the construction site (such as pre-existing contamination or use of soil amendments). Therefore, sample locations may be identified in the SWPPP in advance or may be identified in the field when visual inspections identify a BMP failure or breach. The SWPPP must describe the sampling procedure, the location, and the rationale for selecting the sampling locations.

10.4 Procedures for Laboratory Analysis

All analyses are conducted by off site contract analytical laboratories with the exception of field measurements, such as pH and specific conductance.

10.5 Data Quality Assurance

10.5.1 Precision

A duplicate sample is collected from a single location for each storm water runoff event, when there is adequate volume for a duplicate. The duplicate location is randomly chosen from the available locations.

The duplicate samples are collected for every analyte at that location and submitted to the laboratory for analysis, each with a unique sample identifier. The results for the duplicate location sample and actual location sample are compared by the network analyst upon the delivery of the analytical results from the laboratory. Trip blanks, sampling bottles pre-filled with deionized water, are not necessary for this network.

10.5.2 Bias

All quality check information provided by the analytical laboratories, including matrix spikes, matrix duplicates, and calibration standards are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation.

10.5.3 Completeness

Construction storm water runoff samples are collected as needed based upon the project SWPPP or contact of construction materials with storm water (see Section 10.3). Sampling would be considered complete if all the samples identified in the project specific SWPPP are collected. For inspection triggered sampling, sampling would be considered complete if the required samples were collected within the first two hours of runoff of the first storm following a determination of the need to sample.

10.6 Program Implementation Procedures

Each specific construction SWPPP identifies the sampling and analysis strategy for each construction project.

All construction storm water sampling is conducted by LLNL technical staff according to procedure EMP-W-S, *Water Sampling*, and samples are submitted for analyses using sample documentation and data management procedure EMP-QA-DM, *Sample and Data Management*. Supplements to EMP-QA-DM, *Sample and Data Management*, specify procedures for completing field tracking forms (EMP-QAS-FTF, *Completing Field Tracking Forms*), and chain-of-custody forms (EMP-QAS-COC, *Completing Chain of Custody Forms*). Sample bottle requirements and preservation requirements for each analyte are specified in EMP-QA-BOT, *Aqueous Sample Bottle Requirements*.

10.7 Action Levels

Construction storm water sampling and analysis evaluates the BMPs and helps determine if storm water runoff is being contaminated by construction activities. These determinations are specific to each construction site, and regulatory agencies have not established specific numeric criteria for construction storm water effluent. When sample results indicate that the construction site's storm water discharges significantly exceed the background concentrations, two actions are required:

- Report the results to the appropriate RWQCB in accordance with section B.3 (Receiving Water Limitations) of WDR 99-08-DWQ.
- Evaluate the BMPs to determine what is causing the difference between the runoff and background concentrations.

The BMP evaluation needs to identify the source of the pollutant and possible solutions to correct the problem. These solutions may include revising the existing BMPs, evaluating alternative BMPs that could be implemented, and/or implementing additional BMPs (such as, cover and/or containment) that further limit or eliminate contact between storm water and nonvisible pollutant sources at the construction site. Where contact cannot be reduced or eliminated, storm water that has come in contact with the nonvisible pollutant source must be retained on the construction site and not allowed to be discharged to the storm drainage system or a water body.

After corrective actions are implemented, additional samples will be taken during the next runoff event to demonstrate and document that the problem has been corrected.

If sampling and analysis during subsequent storm events show that there is still a problem, the steps above are repeated until the analytical results of upstream and downstream samples are relatively comparable.

10.8 Preparation and Disposition of Reports

Construction storm water monitoring results must be filed in the SWPPP, which must be kept on the project site until the Notice of Termination is filed and approved by the appropriate RWQCB. Waste Discharge Requirement 99-08-DWQ requires that the records of all inspections, compliance certifications, and noncompliance reporting must be retained for a period of at least three years from the date generated or after project completion.

Each year LLNL prepares an annual certification of compliance for each permitted construction project. The sampling and analysis data are included in this report. The data are also included in the annual *Environmental Report*.

10.9 Future Plans

No changes in construction storm water monitoring are planned at this time. However, LLNL will track the following regulatory actions for potential changes in the monitoring objectives that might occur as the result of regulatory actions.

- The 303d list of impaired water bodies is updated by the SWRCB every two years. These updates are monitored to determine if sediment monitoring described in Section 10.2.3 is required in the future.
- The SWRCB plans to reissue the NPDES permit requiring this monitoring. This reissuance may change the monitoring requirements.

10.10 References

33 USC 1251 *et seq*., *Federal Water Pollution Control Act Amendments: Clean Water Act*, 1972.

California Water Code 13000 *et seq*., *California, Porter-Cologne Water Quality Control Act of 1969*, State of California, Sacramento, CA.

DOE (1991), *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance,* U. S. Department of Energy, Washington, D. C. (DOE/EH-0173T).

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Environmental Report (annual), Lawrence Livermore National Laboratory, Livermore, CA. (UCRL-50027). Available at http://cmg.llnl.gov/saer/

Marshack, J. B. (2000), *A Compilation of Water Quality Goals,* Central Valley Regional Water Quality Control Board, Sacramento, CA.

SFBRWQCB (1994), "Using soils containing trace levels of contaminant as fill." San Francisco Bay Regional Water Quality Control Board, letter from Vincent Christian to W.F. Isherwood.

SWRCB (1999, 2001, 2002, 2004), National Pollutant Discharge Elimination System (NPDES) General Permit for Storm Water Discharges Associated with Construction Activity, Order 99-08-DWQ, NPDES Permit N. CAS000002.

11 Rainwater

Eric Christofferson • Chris G. Campbell

11.1 Introduction

This chapter describes the program for monitoring tritium activity in rainwater at the Livermore site, in the surrounding Livermore Valley, and at Site 300 in the Altamont Hills. Rainwater monitoring is part of a comprehensive and ongoing environmental monitoring program for LLNL (see Chapter 1).

11.2 Rationale and Design Criteria

11.2.1 Regulatory Drivers

Although no state or federal laws require rainwater monitoring, U.S. Department of Energy (DOE) Order 5400.1[1] objectives for environmental monitoring apply for monitoring tritium activity in rainwater at LLNL. The Order states, "Representative meteorological data are required at DOE facilities to support environmental monitoring activities. This information is essential to characterize atmospheric transport and diffusion conditions in the vicinity of the DOE facility and to represent other meteorological conditions (e.g., precipitation, temperature, and atmospheric moisture) that are important to environmental surveillance activities such as air quality and radiation monitoring."

DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991) describes the environmental surveillance monitoring objectives applicable to tritium activity in rainwater:

"The purpose of the surveillance program is to characterize the radiological conditions of the off-site environs and, if appropriate, estimate public doses related to these conditions…."

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

11.2.2 Monitoring Objectives

The specific purpose of monitoring rainwater at LLNL is to determine the impact, if any, of tritium emissions from LLNL on levels of tritium in rainfall at and in the vicinity of LLNL.

11.2.3 Sources and Analytes

Livermore Site. Tritium activity in air-moisture and, thence, in rainwater at the Livermore site and in the Livermore Valley, results primarily from atmospheric emissions of tritiated water vapor (HTO) from operations at LLNL's Tritium Facility (Building 331) and hazardous and radioactive decontamination and treatment facilities at Buildings 612, 693, 695, and 696.

Site 300. Minute quantities of tritium are occasionally used in open-air explosive experiments on firing tables at Site 300. Tritium is present in groundwater at Site 300 and groundwater release at the surface during treatment activities or natural spring discharges are possible.

11.2.4 Collection Methods

Rainwater is collected in stainless-steel buckets mounted at fixed locations about one meter above ground within the Livermore site, in the surrounding Livermore Valley, and at Site 300. Rainwater samples for tritium analysis are decanted directly from the collecting buckets following procedures EMP-W-S, *Water Sampling*, and supplement EMP-WSS-RA, *Livermore and Site 300 Rain*. Field measurements and observations are documented on Field Tracking Forms according to procedure EMP-QA-DM, *Sample and Data Management*, and supplement EMP-QAS-FTF, *Completing Field Tracking Forms*.

11.3 Extent and Frequency of Monitoring and Measurement

Livermore Site. Rainwater sampling locations at the Livermore Site and in the surrounding Livermore Valley are shown in Figure 11-1. Rainwater samples are collected whenever storm water runoff samples are collected, typically for two events per calendar year. Rainwater sampling is conducted adjacent to air-moisture tritium sampling locations wherever possible. Air-moisture containing HTO is rapidly entrained and precipitated locally during rainwater events. Co-location of rainwater and air-moisture tritium sampling allows for comparison of results for these media. Air-moisture sampling locations have been sited based on knowledge of local HTO source locations and wind directions. Winds are typically southwesterly during rainwater events, but are occasionally northeasterly. Northwesterly or southeasterly winds are rare during rainwater events.

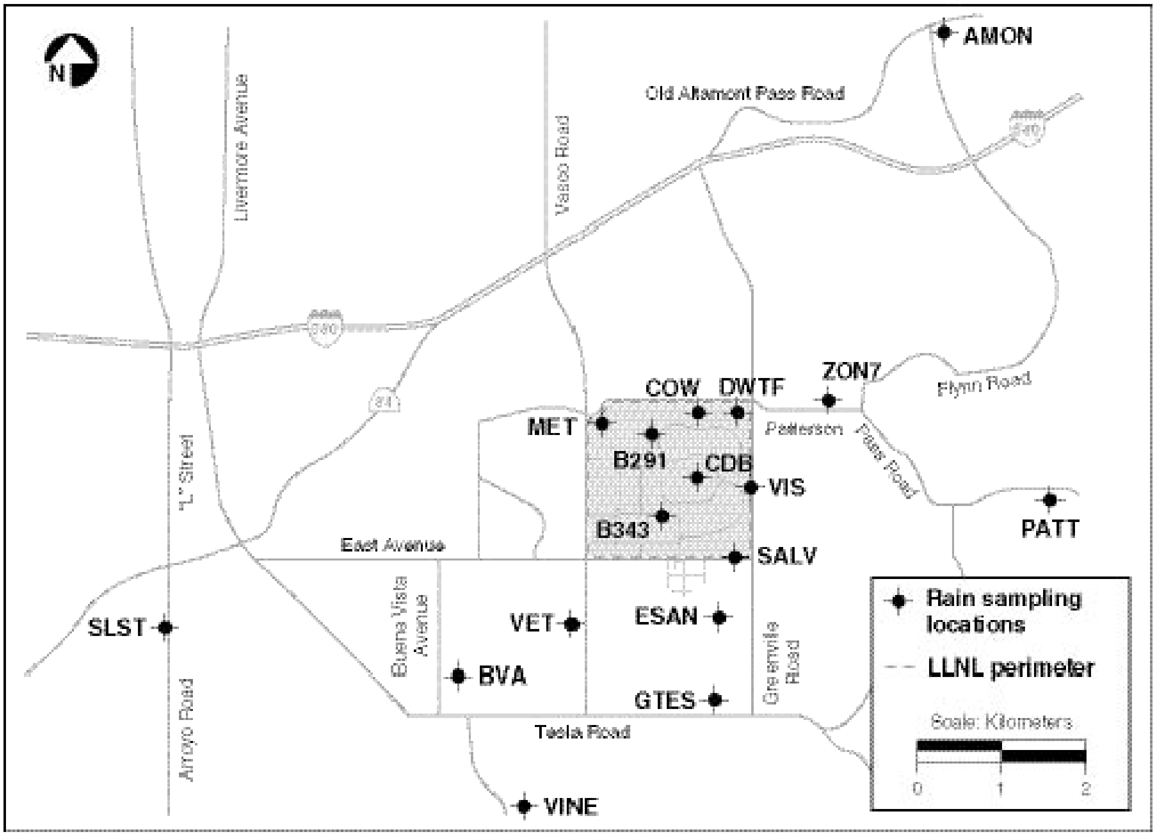

Figure 11-1. Rainwater sampling locations, Livermore site and Livermore Valley

Although total HTO emissions have declined significantly since 1988, emissions continue from Building 331 operations. Historical tritium activity measurements demonstrate that tritium activity in rainwater decreases exponentially with distance from Building 331. Two of the more distant rainwater sampling locations, PARK to the west and FCC to the north, were discontinued, because they were no longer needed to determine background tritium activity in Livermore Valley rainwater.

Monitoring tritium in rainwater at location DWTF, in the northeastern corner of the Livermore site, adjacent to air-moisture tritium sampling location DWTF, began in 2003. This location is used to monitor the effect on rainfall of low-level HTO emissions from the new DWTF facility.

Site 300. Figure 11-2 shows the locations of the three rainwater monitoring stations at Site 300. Winds are stronger and show less directional distribution than at the Livermore site, with winds most often from the west-southwest through west. Site 300 is semi-arid with an average rainfall of about 10.5 inches a year. Because of reduced rainfall there, it is not always possible to sample two rain events each year.

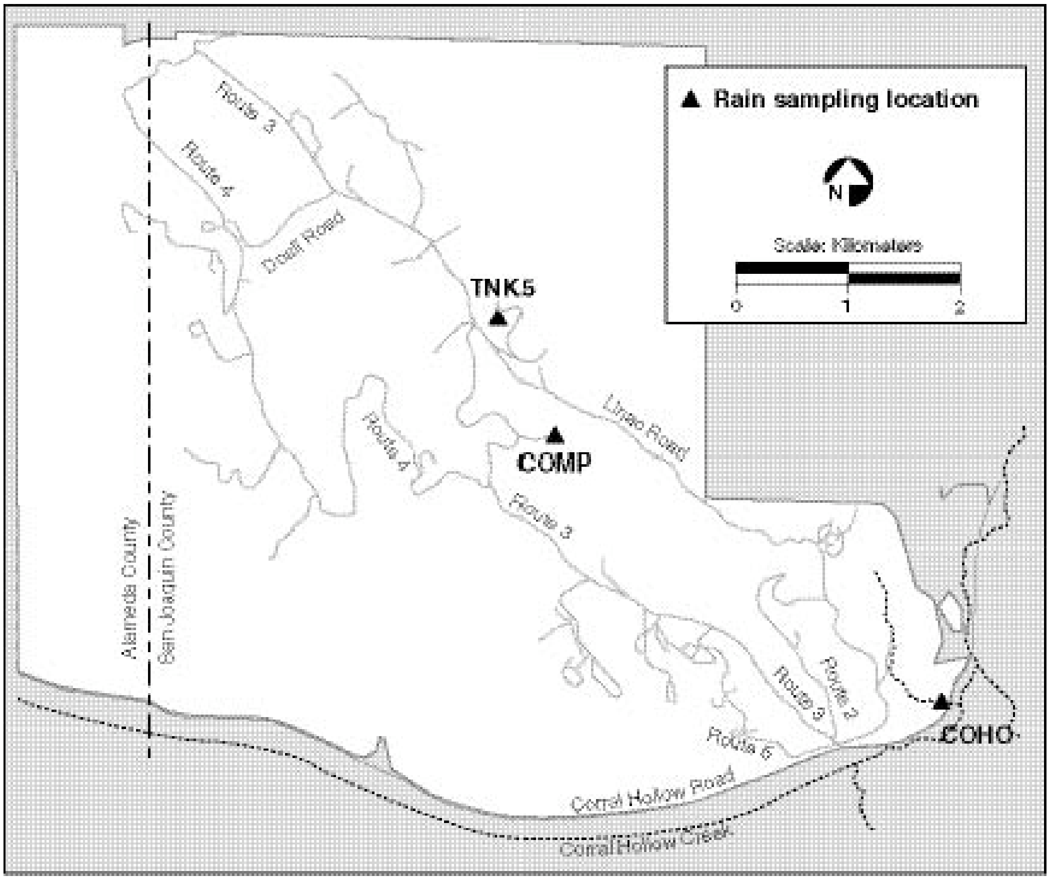

Figure 11-2. Rainwater sampling locations, Site 300

Historically, rainwater samples were collected from a single central location (COMP) within Site 300 adjacent to the meteorological tower (Figure 11-2). The tritium activity in the rainwater samples obtained historically from location COMP has all been below the reporting level (RL) of about 4 Bq/L (100 pCi/L). To determine if tritium activity in rainwater at Site 300 was being adequately monitored, two additional rainwater sampling locations were added in 1999; one on the site to the north of location COMP (TNK5, Figure 11-2) and one off the site to the east of location COMP (PRIM, not shown in Figure 11-2. However, location PRIM was abandoned in 2002 because of continued disappearance (theft) of the rainwater collection bucket. To replace PRIM, location COHO (Figure 11-2) was established in 2002 in the southeastern corner of Site 300, adjacent to the air-moisture tritium sampler there. Since 1999, no tritium activity in rainwater above the RL has been measured at any of the three Site 300 locations.

11.4 Procedures for Laboratory Analysis

Radioactivity and radioisotope measurements are currently performed off site by contract analytical laboratories according to conditions and methodology specified in an approved Statement of Work (SOW). The EPA-approved method of scintillation counting (EPA

Method 906) is employed to measure tritium activity in rainwater samples. This method is cost-effective and it provides accurate measurements down to approximately 3.8 Bq/L (100 pCi/L), equal to 1/200 of the state and federal MCL of 740 Bq/L (20,000 pCi/L) for tritium activity in drinking water.

11.5 Data Quality Assurance

11.5.1 Precision

Under the quality assurance program for this monitoring network, a duplicate sample is collected from a single location for each rain event. The duplicate location is randomly chosen from the available locations, if rain sample volume is sufficient. If the rain sample volume is insufficient at the pre-selected location, an alternative location may be used. This duplicate sample is submitted to the laboratory for analysis with a unique sample identifier. The results for the duplicate location sample and actual location sample are compared by the network analyst upon the delivery of the analytical results from the laboratory. Trip blanks (sampling bottles prefilled with deionized water) are not necessary for this network.

11.5.2 Bias

All quality check information provided by the analytical laboratories, including matrix spikes, matrix duplicates, and calibration standards, are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation.

11.5.3 Completeness

Rain water is collected from a given site if storm water samples are collected or if the analyst specifically requests samples. Therefore, planned rain sampling includes two sampled storm water events and any additional sampling deemed necessary by the analyst. Sampling of all locations during the two storms sampled at each site (Livermore site and Site 300) would be considered 100% completeness. Given the potential for sample loss due to broken bottles, target completeness is 90% for each site (Livermore site and Site 300).

11.6 Program Implementation Procedures

Rainwater sampling is conducted by LLNL technical staff according to procedure EMP-W-S, *Water Sampling*, and supplement EMP-WSS-RA, *Livermore and Site 300 Rain*. Sample bottle requirements for tritium analysis are specified in supplement EMP-QA-BOT, *Aqueous Sample Bottle Requirements*. Sample and data management requirements, including documentation and the process used for submitting samples to analytical laboratories, are defined in EMP-QA-DM, *Sample and Data Management*. Supplements to EMP-QA-DM define processes that must be used for completing field tracking forms (EMP-QAS-FTF, *Completing Field Tracking Forms*) and chain-of-custody forms (EMP-QAS-COC, *Completing Chain of Custody Forms*), and for controlling sample locations (EMP-QAS-LOC, *Locations Database*). Sample locations are tracked in a database.

11.7 Action Levels

Tritium activities in rainwater samples are compared with the drinking water MCL and with historical activity data trends for each sampling location. If any sample result exceeds the drinking water MCL of 740 Bq/L (20,000 pCi/L) or shows an increase that is significantly above the historical trend, the responsible environmental analyst would notify LLNL Environmental Protection Department (EPD) management of the event. An investigation of the cause for the increase(s) could ensue and may include elements such as:

- Re-analysis of the samples.
- Source investigation. (Rainwater tritium results are compared with tritium data from other monitoring networks such as air-moisture and storm water run-off. LLNL tritium-handling activities that may have contributed to any marked increase are investigated and documented.)
- Expanded monitoring (more locations).
- Increased monitoring frequency.

11.8 Preparation and Disposition of Reports

Rainwater monitoring results are described in the water monitoring section of the annual LLNL *Environmental Report*. The *Environmental Report* summarizes the rainwater tritium activity data, discusses trends, and includes a brief statement regarding the impact, if any, of LLNL tritium-handling operations on the local environment.

11.9 Future Plans

The sufficiency of rainwater sampling (frequency and locations) is reviewed annually by the responsible analyst. Should LLNL HTO emissions increase significantly in the future, more distant sampling locations could be added to better encompass the impacted area.

New sources of HTO vapor will be considered and appropriate changes to the rainwater monitoring program will be made as they occur.

11.10 References

DOE Order 5400.1, *General Environmental Protection Program*, U. S. Department of Energy, Washington, D.C.

DOE (1991), *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance,* U. S. Department of Energy, Washington, D. C. (DOE/EH-0173T).

Environmental Report (annual), Lawrence Livermore National Laboratory, Livermore, CA. (UCRL-50027). Available at http://cmg.llnl.gov/saer/

12 Drainage Retention Basin Release

Duane Rueppel

12.1 Introduction

This chapter describes the program for monitoring releases of water from the Drainage Retention Basin (DRB). General information regarding the Environmental Monitoring Plan and the facilities at Lawrence Livermore National Laboratory (LLNL) can be found in Chapter 1.

The DRB lies in the central area of the LLNL main site. It covers 1.6 hectares and contains up to 45.6 mega-liters (37 acre-feet) of water. Remediation action studies indicated that infiltration of collected storm water from the unlined basin caused increased dispersal of groundwater contaminants beneath the DRB. The basin was lined as part of Livermore site remediation activities and to halt infiltration. Lining was completed in March 1992 and LLNL adopted the *Drainage Retention Basin Management Plan* (Limnion Corporation 1991) as the protocol to maintain high water quality in the DRB. Monitoring of releases from the DRB began in 1992. The DRB discharges into LLNL's storm drainage system and eventually to Arroyo Las Positas, a navigable water of the United States (see Figure 12-1).

12.2 Rationale and Design Criteria for DRB Release Monitoring

12.2.1 Regulatory Drivers

Releases from the DRB are governed by the applicable, relevant, and appropriate requirements (ARARs) derived from the federal Clean Water Act (EPA 1977), federal and state Safe Drinking Water Acts (CHSC 1974; EPA 1974), and the Porter-Cologne Water Quality Control Act (State of California 1969) The San Francisco Bay Regional Water Quality Control Board (RWQCB) prescribes DRB discharge monitoring requirements.

Because the DRB was constructed as a Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)-directed remediation, its discharges are regulated like those of treated groundwater from other LLNL CERCLA cleanup activities. A Federal Facility Agreement (FFA) among the San Francisco Bay RWQCB, the California Department of Toxic Substances Control (DTSC), the U.S. Environmental Protection Agency (EPA), and the Department of Energy (DOE) is in place, requiring

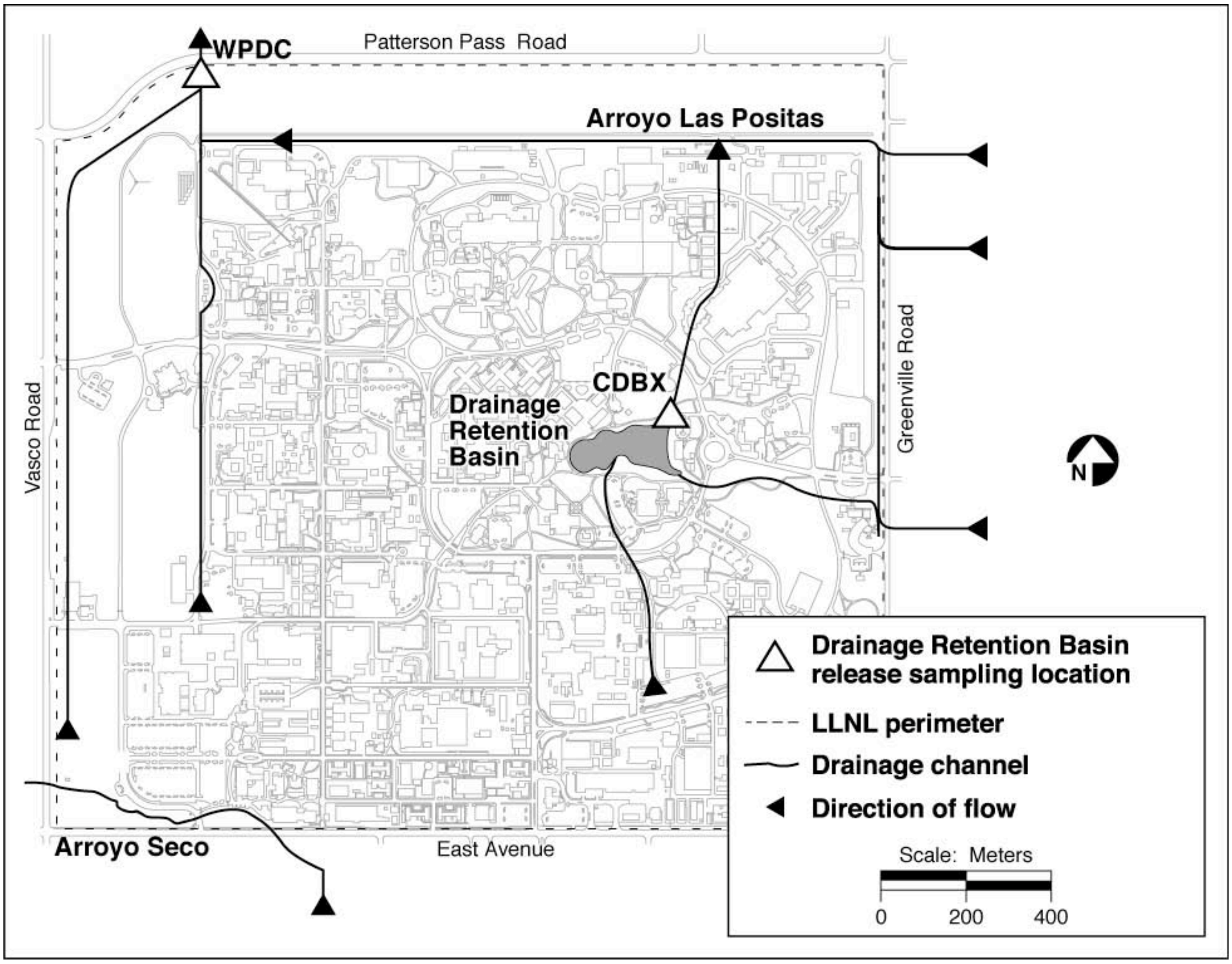

Figure 12-1. Drainage Retention Basin Release sampling locations, Livermore site and vicinity

that all ARARs specified in the (CERCLA) *Record of Decision (ROD) of the Lawrence Livermore National Laboratory, Livermore Site* (LLNL 1992) be observed.

12.2.2 Monitoring Objectives

The primary objective of monitoring DRB releases is to ensure that concentrations of metals, organics, physical properties, and toxicity remain within the discharge limits identified in the amended CERCLA ROD.

12.2.3 Sources and Analytes

The *DRB Management Plan* identifies two sources of water for filling and maintaining the DRB:

- Water generated from groundwater treatment units that discharge to the DRB through the existing storm water drainage system or pipelines

- Storm water runoff (drainage from approximately one-fourth of the Livermore site)

From 1993 through 1997, storm water runoff was the primary source of water to the DRB, and the treated groundwater contribution was only minor in both the wet and dry season. Since 1997, dry season discharges to the DRB have become dominated by treated groundwater discharges as more treatment facilities began discharging to the DRB. However, storm water continues to be the major source water during the wet season.

Potential pollutant sources discharging to the DRB in addition to the two main water sources include:

- Storm water runoff from parking
- Excess landscape irrigation (a potential source of nutrients and pesticides)
- Pesticides washed in from applications upstream of the DRB
- Sediments from multiple upstream sources
- Unplanned releases of materials to the ground

For compliance monitoring, the constituents of concern for the DRB and their action levels, as defined in the *CERCLA ROD* and the *Explanation of Significant Differences for Metal*s, are listed in Table 12-1 (in the section, “Action Levels”).

For surveillance monitoring, the 96-hour acute toxicity test using fathead minnow (*Pimephales promelas)* was added to test for general toxicity. Three chronic toxicity tests are performed using fathead minnow, the daphnid (*Ceriodaphnia dubia)*, and green alga (*Selenastrum capricornutum)*. Sampling for PCBs was added when PCBs were found in soil and cleaned up just east of the DRB. A special study for the pesticides/herbicides bromicil, glyphosate and diuron was added after one brief toxic event traced to either tanbark or weed spraying inside the berm surrounding the DRB. The use of tanbark and weed spraying have been discontinued.

Table 12-1. Treated groundwater and DRB discharge analytes for sampling locations CDBX and WPDC, and discharge limits in the amended CERCLA ROD applied at CDBX

Constituent	Location	Frequency[a]	Discharge limits	
			Dry season[b]	Wet season[c]
Metals (µg/L)				
Antimony	CDBX, WPDC	W & D	6	(d)
Arsenic	CDBX, WPDC	W & D	50	10
Beryllium	CDBX, WPDC	W & D	4	(d)
Boron	CDBX, WPDC	W & D	(d)	(d)
Cadmium	CDBX, WPDC	W & D	5	2.2
Chromium (total)	CDBX, WPDC	W & D	50	(d)
Chromium (VI)	CDBX, WPDC	W & D	(d)	22
Copper	CDBX, WPDC	W & D	1300	23.6
Iron	CDBX, WPDC	W & D	(d)	(d)
Lead	CDBX, WPDC	W & D	15	6.4
Manganese	CDBX, WPDC	W & D	(d)	(d)
Mercury	CDBX, WPDC	W & D	2	2
Nickel	CDBX, WPDC	W & D	100	320
Selenium	CDBX, WPDC	W & D	50	10
Silver	CDBX, WPDC	W & D	100	8.2
Thallium	CDBX, WPDC	W & D	2	(d)
Zinc	CDBX, WPDC	W & D	(d)	220
Physical				
pH (units)	CDBX, WPDC	W & D	6.5–8.5	6.5–8.5
Toxicity				
Aquatic survival bioassay (96 hours)	CDBX, WPDC	W & D	90% survival median, 90 percentile value of not less than 70% survival	
E1000	CDBX	W	(d)	(d)
E1002	CDBX	W	(d)	(d)
E1003	CDBX	W	(d)	(d)
Organics (µg/L)				
Volatile organic compounds (EPA Method 601 only)	CDBX	W	5	5
1,1-dichloroethane (1,1-DCA)	CDBX	W	5	5
1,1-dichloroethylene (1,1-DCE)	CDBX	W	5	5
1,2-dichloroethylene (1,2-DCE)	CDBX	W	(d)	(d)
cis-1,2-dichloroethylene (cis-1,2-DCE)	CDBX	W	5	5

(continued)

Table 12-1. Treated groundwater and DRB discharge analytes for sampling locations CDBX and WPDC, and discharge limits in the amended CERCLA ROD applied at CDBX (cont.)

Constituent	Location	Frequency[a]	Discharge limits	
			Dry season[b]	Wet season[c]
trans-1,2-dichloroethylene (trans-1,2-DCE)	CDBX	W	5	5
1,2-dichloroethane (1,2-DCA)	CDBX	W	5	5
Carbon tetrachloride	CDBX	W	5	5
Total THM (chloroform, bromoform, chlorodibromomethane, bromodichloromethane)	CDBX	W	5	5
Tetrachloroethene/Perchloroethylene (PCE)	CDBX	W	4	4
Trichloroethylene (TCE)	CDBX	W	5	5
Vinyl chloride	CDBX	W	2	2
Radiological (Bq/L)				
Tritium	CDBX	W	740	740

Source: LLNL 1992

[a] W= Monitoring occurs at the first DRB discharge of the wet season and at one or more additional discharges associated with storm water runoff monitoring. Toxicity testing is required only on the first release.

D = Monitoring occurs at each dry season release. For purposes of discharge sampling, the dry season is defined to occur from June 1 through September 30.

[b] Dry season limits apply to CDBX from April 1 to November 30.

[c] Wet season limits apply to CDBX from December 1 to March 31.

[d] No limit specified

12.2.4 Collection Methods

During release sampling, grab samples are collected according to procedure EMP-W-S, *Water Sampling*, and supplement EMP-WSS-RE, *Drainage Retention Basin Release Sampling*. Sample bottle and preservation requirements for each analyte are specified in procedure EMP-QA-BOT, *Aqueous Sample Bottle Requirements*. All instruments used for field measurements (e.g., pH, temperature, and turbidity) are calibrated prior to use following manufacturer instructions. Field measurements and observations are documented on field tracking forms (FTF) according to procedure EMP-QA-DM, *Sample and Data Management*, and supplement EMP-QAS-FTF, *Completing Field Tracking Forms*.

Table 12-2. Analytes and action levels for DRB discharge studies for sampling locations CDBX and WPDC

Constituent	Location	Frequency[(a)]	Investigation level
Organics (µg/L)			
Polychlorinated biphenyls	CDBX, WPDC	W & D	NA
Chemical oxygen demand	CDBX	W	20
Herbicides (E507-Bromicil, E547-Glyphosate, E632-Diuron)	CDBX	W	NA
Total organic carbon	CDBX	W	NA
Physical			
Turbidity (NTU)[(b)]	CDBX, WPDC	W & D	15
Total suspended solids	CDBX, WPDC	W & D	NA
Conductivity (µS/cm)	CDBX, WPDC	W	900
Total dissolved solids (mg/L)	CDBX, WPDC	W	360
General minerals			
Total alkalinity (mg/L)	CDBX	W	<50
Nitrate (as N) (mg/L)	CDBX	W	0.2
Nitrite (as N) (mg/L)	CDBX	W	0.2
Radiological (Bq/L)			
Alpha	CDBX	W	0.56
Beta	CDBX	W	1.85

Source: LLNL 1992

a W= Monitoring occurs at the first DRB discharge of the wet season and at one or more additional discharges associated with storm water runoff monitoring. Toxicity testing is required only on the first release.

D = Monitoring occurs at each dry season release. For purposes of discharge sampling, the dry season is defined to occur from June 1 through September 30.

b Nephelometric turbidity units

12.3 Extent and Frequency of Monitoring and Measurement

The sampling frequency for releases from the DRB was determined in agreement with the San Francisco Bay RWQCB (Isherwood 1993; Galles 1997; Jackson 2002). Samples are collected from the first wet season release and from at least one subsequent wet season release. The second wet season release is sampled in conjunction with storm water runoff (see Chapter 9). During the dry season, samples are collected during each release or monthly if the release is continuous. For the purpose of DRB releases, the dry season is defined as June 1 through September 30. Flow from the DRB is typically continuous except for brief periods when maintenance is performed.

Releases from the DRB are sampled at two locations: the DRB outfall (CDBX) and the Livermore site storm drain outfall (WPDC) as shown in Figure 12-1.

Special studies are occasionally implemented to address specific issues that may arise in managing the DRB. They may include increased monitoring frequencies for specific analytes, additional toxicological testing, adding constituents or field measurements, and supplemental biological or microbiological monitoring.

12.4 Procedures for Laboratory Analysis

Analysis of DRB release samples is currently performed off site by contract analytical laboratories according to conditions and methodology specified in an approved Statement of Work (SOW). In some cases, the analytical method is prescribed by the RWQCB. When a specific method is not prescribed, a method is selected based on the WGMG environmental analyst's ability to provide detection limits below release limits.

12.5 Data Quality Assurance

12.5.1 Precision

Random duplicate samples are collected at either of the two sampling locations to meet the minimum 10% QA sample requirement. These duplicate sample are submitted to the lab for analysis with a unique sample identifier. The results for the duplicate samples and routine sample are compared by the network analyst upon the delivery of the analytical results from the laboratory. Trip blanks, sampling bottles prefilled with deionized water, are not necessary for this network.

12.5.2 Bias

All quality control sample information provided by the analytical laboratories, including matrix spikes, matrix duplicates, and calibration standards are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation.

12.5.3 Completeness

DRB release samples are collected during the first wet season release from the DRB, and at least once more in conjunction with storm water runoff monitoring. Samples are collected at each dry season release or monthly if the release is continuous. Samples collected at all these times would be considered 100% compete. Given the potential for sample loss due to broken bottles our target completeness is 90%.

12.6 Program Implementing Procedures

DRB release sampling is conducted by LLNL technical staff according to procedure EMP-W-S, *Water Sampling,* and supplement EMP-WSS-RE, *Drainage Retention Basin Release Sampling*. Sample bottle requirements for tritium analysis are specified in supplement EMP-QA-BOT, *Aqueous Sample Bottle Requirements.* Sample and data management requirements, including documentation and the process used for submitting samples to analytical laboratories, are defined in EMP-QA-DM, *Sample and Data Management*. Supplements to EMP-QA-DM define processes that must be used for completing field tracking forms (EMP-QAS-FTF) and chain-of-custody forms (EMP-QAS-COC), and for controlling sample locations (EMP-QAS-LOC). Sample locations are tracked in a database.

12.7 Action Levels

Limits for discharging treated groundwater into the storm drainage system, including the DRB, were established by the *CERCLA ROD* and amended by the *Explanation of Significant Differences for Metals Discharge Limits at the Lawrence Livermore National Laboratory, Livermore Site* (Berg et al. 1997). These constituents of concern and their discharge limits are listed in Table 12-1. Additional parameters for surveillance monitoring and their action levels are listed in Table 12-2.

Discharges from the DRB exceeding these limits constitute CERCLA noncompliance. LLNL responses to DRB release water above release limits may include some or all of the steps listed below. A single, unusually high concentration may, by itself, trigger a detailed investigation. Detailed investigations may include elements such as

- Management notification.
- Re-analysis of the samples.
- Additional sampling and analysis of water contained within the DRB or analysis of subsequent releases. During a detailed investigation, a release occurring immediately following a finding may be sampled to confirm or negate the concentration being investigated or to determine whether the finding was a single or chronic occurrence.
- Source investigation. Results are compared with findings from other monitoring networks [e.g., air, rain, and storm water], and LLNL activities that may have contributed to the result are investigated.
- Expanded monitoring to additional locations.
- Increased monitoring frequency.

In addition, findings of concentration levels not meeting release limits are evaluated to determine if an occurrence report is also required.

12.8 Preparation and Disposition of Reports

Since September 1993, results from DRB release monitoring have been reported to the San Francisco Bay RWQCB regulatory agencies in quarterly and annual groundwater project reports submitted under the *CERCLA ROD*. Monitoring results are also reported in the annual *Environmental Report*. These reports note any releases exceeding limits and contain information on the nature, time, duration, cause of the finding, and a description of any measures taken to remedy it and to prevent its recurrence.

12.9 Future Plans

No changes in the DRB release monitoring are planned at this time.

12.10 References

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

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EPA (1977), Clean Water Act (CWA) as amended; 33 U.S.C. ss/1251 et seq., Environmental Protection Agency.

Galles, H. L. (1997), letter to Joseph Chow of the San Francisco Bay Regional Water Quality Control Board, *Lawrence Livermore National Laboratory Drainage Retention Basin Monitoring Plan Amendments*, *(*WGMG97:439, December 9, 1997).

Isherwood, W. F. (1993), letter to Elizabeth Adams of the San Francisco Bay Regional Water Quality Control Board, *Discharge Release From Lawrence Livermore National Laboratory Central Drainage Retention Basin (NPDES No. CA0029289*), (PRA92-572, January 5, 1993).

Jackson, C. S. (2002), *Drainage Retention Basin Monitoring Plan*, letter to Naomi Feger, San Francisco Bay Regional Water Quality Control Board, December 6, 2002.

LLNL (1992), *Record of Decision for the Lawrence Livermore National Laboratory, Livermore Site*, Lawrence Livermore National Laboratory, Livermore, CA. (UCRL-AR-109105).

Limnion Corporation (1991), *Drainage Retention Basin Management Plan,* Draft Final, December 1991.

State of California (1969), California Water Code 13000 *et seq*., *California, Porter-Cologne Water Quality Control Act of 1969*, State of California, Sacramento, CA.

13 Site 300 Drinking Water Discharges

Michael A. Revelli

13.1 Introduction

This chapter describes the program for monitoring Drinking Water System Discharges at the Lawrence Livermore National Laboratory (LLNL) Experimental Test Site (Site 300). General information regarding the Environmental Monitoring Plan and the facilities at LLNL can be found in Chapter 1.

LLNL Site 300 operates a nontransient, noncommunity water system. Water is pumped from the regional aquifer by two on-site supply wells (Wells W-18 and W-20) into the distribution and storage system. Groundwater is chlorinated at the wellheads and may also be chlorinated, as needed, at the booster/transfer stations. Occasionally, discharges that may enter waters of the United States must be made from the drinking water system.

13.2 Rationale and Design Criteria

13.2.1 Regulatory Drivers

The Federal Water Pollution Control Act (Clean Water Act, 1972, 33 USC 1251) was enacted to restore and maintain the chemical, physical, and biological integrity of waters of the United States. To this end, Section 402 established the National Pollutant Discharge Elimination System (NPDES) to set the conditions under which pollutants could be discharged to navigable waters. The Central Valley Regional Water Quality Control Board (CVRWQCB) chose to regulate low-threat discharges to surface waters under a general NPDES permit (CAG995001, WDR 5-00-175). These low-threat discharges are defined to include discharges of potable water from drinking water systems.

WDR 5-00-175 establishes monitoring requirements to verify compliance with established effluent limitations and to test for adverse impacts to the receiving waters. Effluent limits are established by the CVRWQCB for constituents of concern that could adversely affect waters of the state of California and of the United States.

13.2.2 Monitoring Objectives

The objective of the Site 300 Drinking Water Discharges monitoring program is to demonstrate compliance with the effluent limitations of WDR 5-00-175 and to provide timely information to stop discharges if effluent limitations are not met. WDR 5-00-175 establishes monitoring requirements to verify compliance with established effluent limitations and to test for adverse impacts to the receiving waters. Effluent limits are established by the Central Valley RWQCB for constituents of concern that could adversely affect waters of the state of California and of the United States.

13.2.3 Sources and Analytes

Anticipated pollutants from the drinking water system are residual chlorine and pH. The residual chlorine in the drinking water system is maintained between 0.2 and 3.0 parts per million (ppm). The pH of the drinking water is 7.84 to 8.4. Locations of drinking water sources and monitoring locations at Site 300 are shown in Figure 13-1.

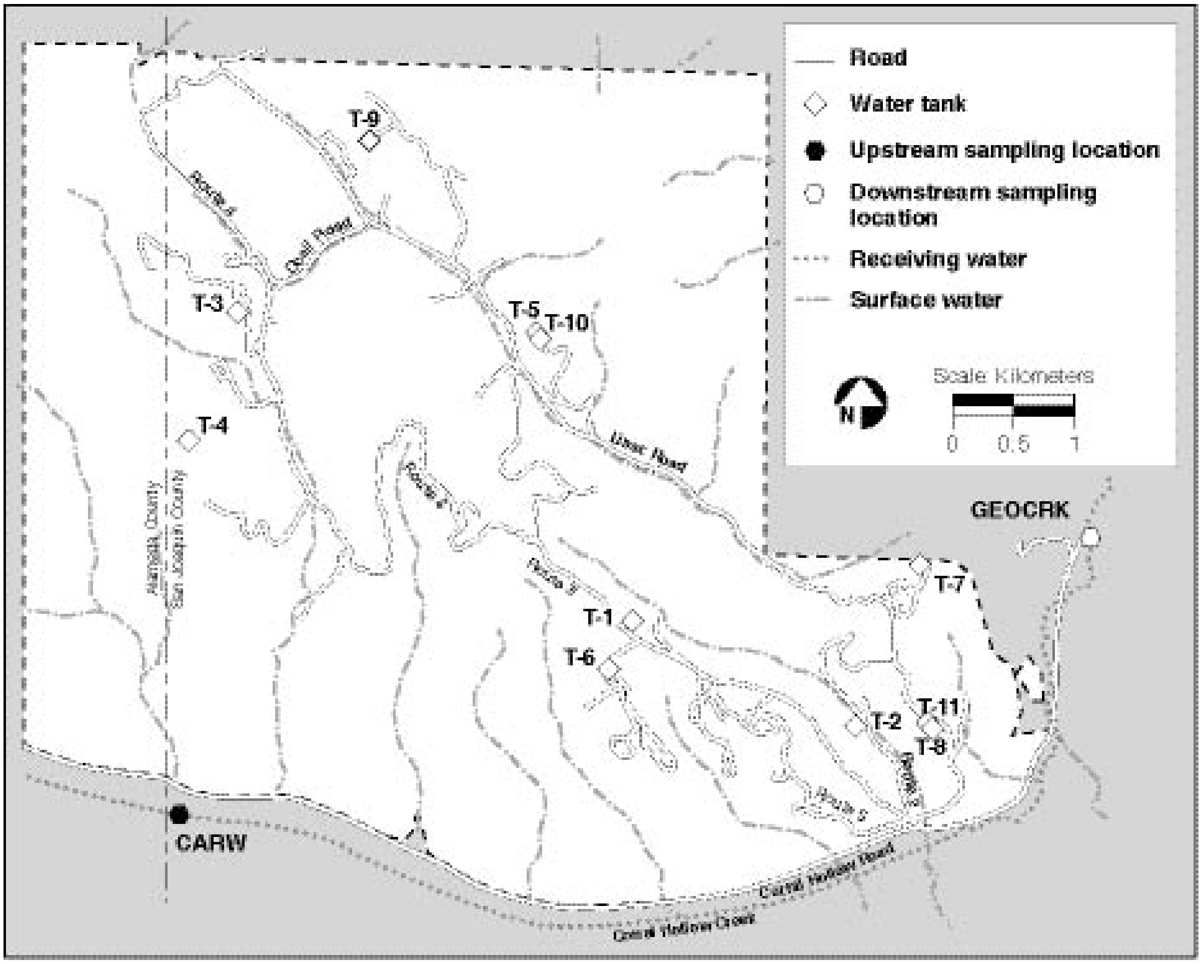

Figure 13-1. Site 300 surface waters, drinking water tanks, and receiving water monitoring locations

13.2.4 Collection Methods

Compliance monitoring of Site 300 drinking water discharges is done by field measurements on grab samples because immediate measurements provide more representative information than laboratory analysis for pH and residual chlorine. Sample handling and collection techniques used are similar to those for other environmental water sampling, as noted in procedure EMP-W-S, *Water Sampling*, and supplement EMP-WSS-WSD, *Site 300 Water System Discharges Monitoring and Sampling*. Standard field tracking procedures as described in EMP-QA-DM, *Sample and Data Management*, are employed to document field conditions that may affect the samples.

13.3 Extent and Frequency of Monitoring and Measurement

The *Pollution Prevention and Monitoring and Reporting Program* (PPMRP) (Mathews 2000) prepared by LLNL and approved by the CVRWQCB establishes the following specific monitoring requirements for discharges:

- Drinking water storage tanks—monitor all discharges that have the potential to reach surface waters.
- System flushes—monitor one flush per pressure zone per year.
- Deadend flushes—monitor all flushes that have the potential to reach surface waters and, for any discharge that continues for more than four months, monitor semiannually.

Each release is monitored at up to three points, depending upon how far the water flows from the source of discharge. Residual chlorine and pH measurements are taken at the point of discharge, at the point the discharge enters the surface water, and, if it reaches the receiving water, at the established downstream monitoring location in Corral Hollow Creek (GEOCRK). When a discharge reaches Corral Hollow Creek, the established upstream monitoring location in Corral Hollow Creek (CARW) is also sampled in order to evaluate the impact of the discharge on the receiving water. See Figure 13-1 for the locations of the drinking water tanks, surface waters, and receiving water monitoring locations.

Observations of the discharges are also made. At the discharge point, the effluent is observed for evidence of other pollutants being carried with the discharge (such as oil and sediment), discoloration of water, and estimate of flow rate from the source. At the point that the effluent discharges into surface waters, observations are made for the same parameters.

If the effluent reaches the receiving water, Corral Hollow Creek, observations are made at upstream and downstream locations for evidence of:

- Floating or suspended matter
- Discoloration
- Bottom deposits
- Aquatic life
- Visible films, sheens, or coatings
- Potential nuisance conditions
- Fungi, slimes, or objectionable growth

13.4 Procedures for Laboratory Analysis

All analysis of Site 300 drinking water discharge samples is done in the field as described in EMP-WSS-WSD and EMP-W-S; no samples are submitted for laboratory analysis.

13.5 Data Quality Assurance

To ensure that all quality assurance (QA) and quality control (QC) objectives are met, all samples are collected in accordance with written procedures by trained sampling technologists. All required permit documentation, such as calibration and monitoring records, is recorded on FTFs archived by DMT per procedure EMP-QA-DM, *Sample and Data Management*.

13.5.1 Completeness

The monitoring program, specified in the PPMRP, defines the sampling locations and frequency for the Site 300 Drinking Water Discharges Network. Completeness requires the successful collection of these PPMRP-specified samples. Controllable factors, such as time of day and planned entry restrictions, will be considered when scheduling routine discharges from the drinking water system to ensure that required samples are collected. If these completeness criteria are not met, nonconformance reports are prepared according to the procedure ORAD-QA-NCR, *Nonconformance Reporting and Tracking*.

13.5.2 Equipment Calibration

All samples collected in support of the Site 300 Drinking Water Discharges Network Monitoring Program are analyzed in the field at the time of collection, by trained individuals using calibrated equipment. All instruments used for field measurements (e.g., pH, temperature, and turbidity) are calibrated prior to use following manufacturer instructions. The supplement EMP-WSS-WSD, *Site 300 Water System Discharges Monitoring and Sampling*, describes the calibration and field analysis requirements for chlorine and pH measurements.

13.6 Program Implementation Procedures

The PPMRP identifies the approved monitoring and reporting program for WDR 5-00-175. Field sampling is conducted by LLNL technical staff according to procedure EMP-W-S, *Water Sampling*, and supplement EMP-WSS-WSD, *Site 300 Water System Discharges Monitoring and Sampling*. Sample and data management requirements, including documentation, are defined in EMP-QA-DM, *Sample and Data Management*. Supplements to EMP-QA-DM define processes that must be used for completing field tracking forms (FTFs) (EMP-QAS-FTF) and for controlling sample locations (EMP-QAS-LOC). Sample locations are tracked in a database.

13.7 Action Levels

Action levels for this network are the permitted effluent limits for the two pollutants of concern: a residual chlorine concentration above 0.02 mg/L and a pH level outside the range of 6.5 to 8.5.

If a field measurement indicates a discharge above the allowed residual chlorine concentration or outside the allowed pH range, the measurement is immediately repeated in the field. If the out-of-range measurement is confirmed, immediate corrective actions may include ceasing the discharge or redirecting effluents away from the surface water. Afterward, the procedures for discharges may be reviewed and modified, if necessary, to prevent future occurrences.

If observations indicate that other pollutants, such as eroded sediment, are carried in the effluent, immediate corrective actions may include:

- Ceasing the discharge
- Reducing the flow rate of the discharge
- Redirecting the effluent away from the surface water

- Redirecting the effluent away from the area where the pollutants are being picked up by the effluent flow

If noncompliance with any prohibition, daily maximum effluent limit, or receiving water limitation contained in WDR 5-00-175 is identified, it must be reported to the CVRWQCB by phone within 24 hours, followed by a written report within 5 days (unless this requirement is waived by the CVRWQCB). The written confirmation must include the nature, time, duration, cause of the noncompliance, and a description of measures taken to remedy it and to prevent its recurrence.

13.8 Preparation and Disposition of Reports

Drinking water system discharge monitoring reports are prepared and submitted quarterly to the CVRWQCB. These reports are due on the first day of the second month following the end of the calendar quarter. Drinking water system discharge monitoring results are also summarized and discussed in the annual *Environmental Report*.

13.9 Future Plans

In the future, LLNL anticipates the delivery of drinking water from the Hetch Hetchy system. The drinking water system discharge monitoring plan will be reevaluated at that time.

13.10 References

33 USC 1251 *et seq*., *Federal Water Pollution Control Act Amendments: Clean Water Act*, 1972.

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14 Other Waters

Daniel Laycak • Sandra Mathews

14.1 Introduction

This chapter describes the program to monitor the Other Waters network of the environmental monitoring program at the Lawrence Livermore National Laboratory (LLNL). The Other Waters network comprises several on-site and off-site surface waters and drinking water sources in the Livermore Valley. The purpose of the Other Waters network is to determine the impact, if any, of airborne tritium or radionuclide particulates on surface water bodies and on drinking water derived from local groundwater sources in the Livermore Valley. Locations far from LLNL are sampled to serve as background values for comparison with sampling locations near and at LLNL. On-site and off-site locations are sampled to provide information on tritium, gross alpha, and gross beta levels. General information on the Environmental Monitoring Plan and the facilities at LLNL can be found in Chapter 1.

14.2 Rationale and Design Criteria for Other Waters Monitoring

14.2.1 Regulatory Drivers

The regulatory drivers for monitoring the Other Waters network are the applicable portions of DOE Orders 5400.1[1] and 5400.5.

14.2.2 Monitoring Objectives

The primary purpose of monitoring surface water locations and drinking water sources in the Livermore valley is to characterize the impact, if any, of LLNL operations on these waters (DOE Order 5400.1) and to ensure that effluents from DOE activities not cause

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

private or public drinking waters downstream of the facility discharges to exceed the drinking water radiological limits in 40 CFR Part 141 (DOE Order 5400.5).

DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991) describes the environmental monitoring objectives:

> The purpose of the surveillance program is to characterize the radiological conditions of the off-site environs and, if appropriate, estimate public doses related to these conditions, confirm predictions of public doses based on effluent monitoring data, and, where appropriate, to provide compliance data for all applicable regulations. The results of this evaluation should* be documented in the site Environmental Monitoring Plan.
>
> The environmental surveillance program for DOE-controlled sites should be conducted in accordance with the requirements of DOE 5400.1 and DOE 5400.5.

14.2.3 Sources and Analytes

Samples are analyzed for tritium, gross alpha, and gross beta radiation. Surface water locations are positioned to monitor either tritium that is washed out of the air by rainfall or direct runoff of tritium. In addition, three locations upwind and not directly connected to LLNL runoff are used to determine background concentrations. Drinking water locations are selected to sample drinking water derived from local groundwater sources.

14.2.4 Collection Methods

Samples are collected by grab sampling from the surface waters or drinking water taps. If the water to be sampled is accessible to the technician, grab samples are collected by partially submerging triple-rinsed sample bottles directly into the water and allowing them to fill with the sample water. Sampling is conducted away from the edge of the water, when possible, to minimize the collection of sediment with the sample matrix. If the water is not directly accessible, the sample may be collected in a large container and then transferred to sample bottles. After the bottles are filled, they are dried, labeled, packaged, and placed in an ice chest.

Sample bottle requirements, special sampling techniques, and preservation requirements for each analyte are specified in procedure EMP-W-S, *Water Sampling,* and supplements

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* The term *should* in this quotation identifies a DOE "high-priority element."

EMP-QA-BOT, *Aqueous Sample Bottle Requirements,* and EMP-WSS-VOW*, Valley Other Waters Sampling*.

14.3 Extent and Frequency of Monitoring and Measurement

14.3.1 Livermore Site

Surface and drinking waters are sampled on the Livermore site and at various locations in the Livermore Valley (Figure 14-1). On-site samples provide information about potential radioactive constituents in the LLNL drinking water supply; off-site samples provide information about potential radioactive constituents in the local supplies that could be related to LLNL activities.

At the Livermore site, sampling location TAP provides samples of on-site drinking water. (LLNL's primary on-site drinking water is Hetch Hetchy water; Zone 7 is the backup water supplier). Of the ten sampling locations in the Livermore Valley, four (BELL, GAS, ORCH, and PALM) provide samples of domestic drinking water, and the other six provide samples from surface water bodies, some of which are potential drinking water sources.

Surface water bodies near the Livermore site include the treatment tanks and the reservoir at the Patterson Pass drinking water treatment facility (ZON7) 1.2 km east of the Livermore site, and the Springtown pond (DUCK), an artificial decorative pond maintained in a community recreation area 2.6 km northwest of the Livermore site. Sampling location ALAG is in the Arroyo de la Laguna, 13 km southwest of LLNL. Arroyo Seco and Arroyo Las Positas, to which LLNL discharges runoff, merge into Arroyo de la Laguna.

Lake Del Valle (DEL) and the Calaveras Reservoir (CAL) are drinking water storage reservoirs 9 km south of the Livermore site and 21 km southwest of the Livermore site, respectively. Lake Del Valle is also used for aquatic recreation (swimming, boating, and fishing), as is the Shadow Cliffs Regional Park (SHAD), a water storage reservoir 11 km west of the Livermore site. Locations DEL, CAL, and SHAD are used to evaluate background concentrations for environmental surface water monitoring. All three sites are generally upwind of LLNL and are not directly connected to LLNL runoff.

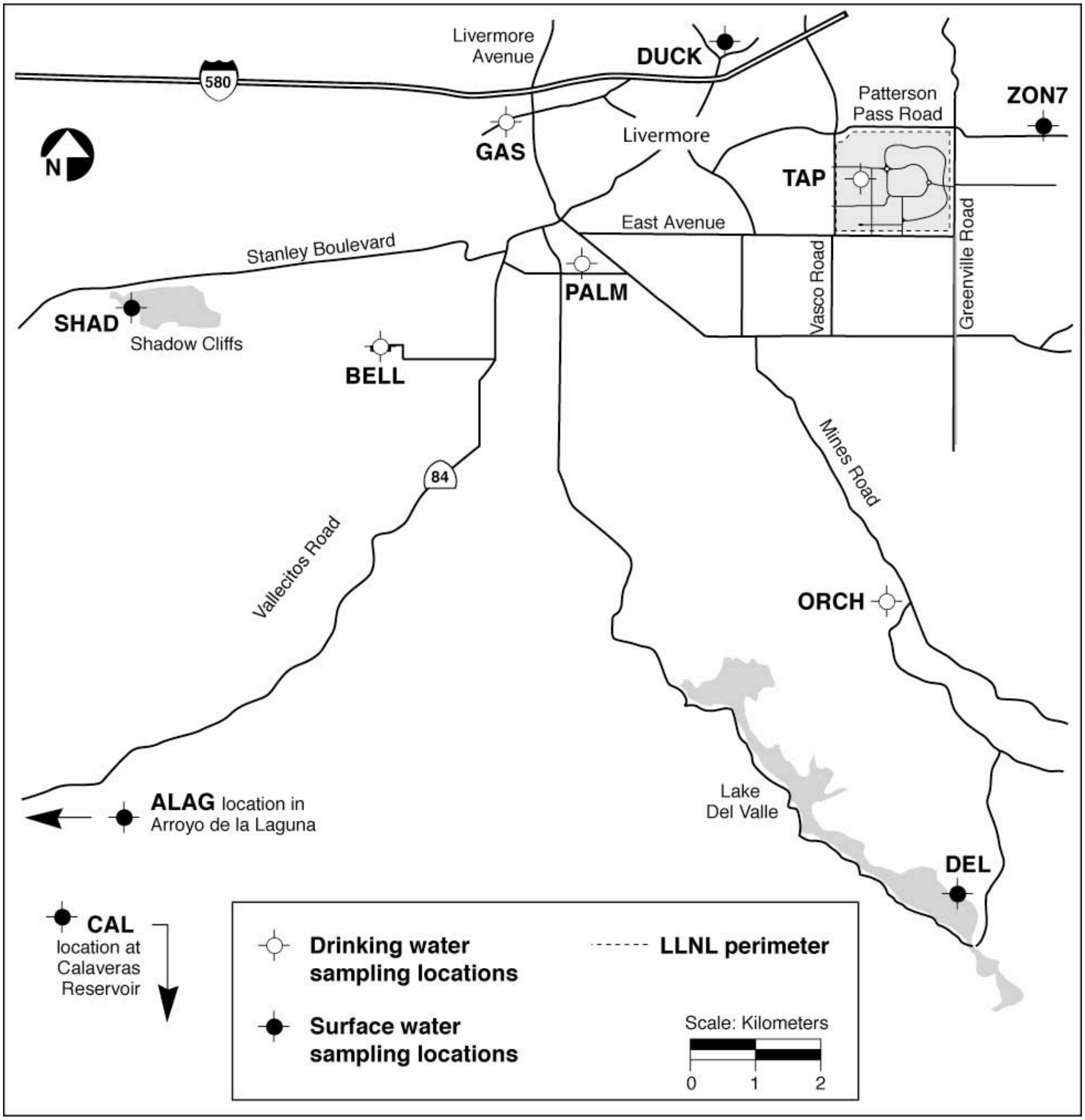

Figure 14-1. Surface and drinking water sampling locations, Livermore Valley

Drinking water and surface water bodies are sampled semiannually based on the demonstrated history of minimal impact from LLNL.

14.3.2 Site 300

The requirements of DOE Orders 5400.1 and 5400.5 are fully integrated in to storm water monitoring network discussed in Chapter 9 and the ground water monitoring networks discussed in Chapter 15.

14.4 Procedures for Laboratory Analysis

Laboratory analyses are conducted by a laboratory currently under contract with LLNL that is accredited by the California Department of Health Services Environmental Laboratory Accreditation Program (ELAP). LLNL samples are analyzed according to conditions and methodology specified in an approved Statement of Work (SOW). A standard chain of custody form is used to track samples, double-check bottle labels, and exchange information with contract laboratories.

14.5 Data Quality Assurance

Field activities are recorded on field tracking forms, and sample tracking is maintained through the chain-of-custody process. Additionally, temperature blanks are included in each shipping container of samples to verify that the temperature is maintained at 4 ± 2 °C until receipt at the analytical laboratories. Procedure EMP-QA-DM, *Sample and Data Management,* ensures that all laboratory measurements are received, accurately recorded, and properly stored in a computer database for easy and fast retrieval. Hard copies of the data are also archived by the ORAD Data Management Team.

14.5.1 Precision

Under the quality assurance program for this monitoring network, a duplicate sample is collected from a single location during each sampling event. The duplicate location is randomly chosen from the available locations.

The duplicate samples are collected for every analyte at that location and submitted to the lab for analysis, each with a unique sample identifier. The results for the duplicate location sample and actual location sample are compared by the network analyst upon the delivery of the analytical results from the laboratory.

14.5.2 Bias

All quality check information provided by the analytical laboratories, including lab control standards, matrix spikes, matrix duplicates, and calibration standards are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation. Field blanks, samples filled in the field to help assess contamination from ambient conditions, the sample containers, and transit process and in the laboratory. One field blank is collected per sampling event. Trip blanks, sampling bottles pre-filled with deionized water, are not necessary for this network.

14.5.3 Completeness

Samples from the Other Waters network are collected semiannually. Sampling would be considered 100 percent compete when all semiannual samples are collected in the Livermore Valley. Sample loss due to broken bottles is minimal and these locations can be readily resampled. The completeness target for this network is 100 percent.

14.6 Program Implementation Procedures

Sampling for the Other Waters network is conducted by LLNL technical staff according to procedure EMP-W-S, *Water Sampling*, and instruction EMP-WSS-VOW, *Valley Other Waters Sampling*. Methods used to prevent cross-contamination are similar throughout all sampling events. They include wearing disposable gloves when collecting samples, discarding gloves between sampling locations, keeping the work area clean, not placing open sample bottles or caps on any surface (sample bottles should be kept closed until used), and not touching the insides of the sample bottles.

Sample preservation and handling practices are performed according to the analytical method requirements and are specified in the SOW. Conditions identified during each sampling event are recorded on a field tracking form (FTF). This information, in conjunction with sampling results, provides a complete summary for each representative sampling location. The FTF may also provide information in the form of comments that may be useful to the analyst. Chain of custody forms document the sample from collection in the field through receipt of the data results from the analytical laboratories. Samples are submitted for analyses and resulting analytical results are managed using sample control and documentation procedure EMP-QA-DM, *Sample and Data Management*.

14.7 Action Levels

To evaluate the data from the Other Waters network, analysts compare the concentrations of tritium, gross alpha, and gross beta with their respective drinking water maximum contaminant levels (MCLs) of 740, 0.56, and 1.85 Bq/L, respectively, and to historical data. If concentrations were to increase dramatically or exceed an MCL, the cause of the result or results would be investigated. A detailed investigation may include elements such as:

- Management notification.
- Re-analysis of the samples.

- Additional sampling and analysis.
- Source investigation. (Results are compared with findings from other monitoring networks [e.g., air or rain], and LLNL activities that may have contributed to the result are investigated.)
- Expanded monitoring (more locations).
- Increased monitoring frequency.

14.8 Preparation and Disposition of Reports

Drinking water and surface water body monitoring results are summarized and discussed in the Water Monitoring Programs chapter of the annual *Environmental Report*. All data are summarized and trends are discussed. Each report includes a brief interpretation of the data.

14.9 Future Plans

In 2004, sampling location POOL was removed from the network when the LLNL swimming pool was closed for repair and later permanently closed. LLNL currently has no plans to build a new swimming pool. There are no other plans to change the Other Waters network.

14.10 References

DOE (1991), *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance,* U. S. Department of Energy, Washington, D. C. (DOE/EH-0173T).

DOE Order 5400.1, *General Environmental Protection Program*, U. S. Department of Energy, Washington, D.C.

DOE Order 5400.5, *Radiation Protection of the Public and the Environment*, U. S. Department of Energy, Washington, D.C.

Environmental Report (annual), Lawrence Livermore National Laboratory, Livermore, CA. (UCRL-50027). Available at http://cmg.llnl.gov/saer/

15 Ground Water

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15.1 Introduction

This chapter describes environmental ground water monitoring programs conducted both at the LLNL main site and in the surrounding Livermore Valley, and at the LLNL Experimental Test Site (Site 300) in the Altamont Hills that border the Livermore Valley on the east. The chapter is divided into surveillance monitoring (Section 15.2), which comprises four separate networks of ground water monitoring wells, and compliance monitoring (Section 15.3), which comprises six separate networks of ground water monitoring wells. The ten well networks are:

1. Livermore site surveillance wells
2. Livermore valley surveillance wells
3. Site 300 surveillance wells
4. Off-Site 300 surveillance wells
5. Site 300 Pit 1 compliance wells
6. Site 300 Pit 6 compliance wells
7. Site 300 Pit 7 compliance wells
8. Site 300 high explosives (HE) burn pit compliance wells
9. Site 300 process water impoundments compliance wells
10. Site 300 sewage ponds compliance wells

Common to all ten monitoring well networks are the standard procedures used to obtain representative ground water samples, the standard methods used to analyze the samples, the management of the resulting data, and the data quality assurance methods.

Data and data analyses for the four surveillance well networks (1-4 above) are published only in the LLNL annual *Environmental Report*. Data and data analyses for the Pit 1 and Pit 7 compliance well networks (5 and 7 above) are combined in a quarterly publication (e.g., Christofferson and MacQueen 2004). Data and data analyses for the Pit 6 compliance well network (6 above) are published quarterly (e.g., Christofferson and Blake 2004). Data and data analyses for the HE burn pit compliance well network (8 above) are published annually (e.g., Revelli 2004). Data and data analyses for the process water and sewage compliance well networks (9 and 10 above) are combined in a quarterly monitoring report (e.g., Brown 2004). Compliance monitoring summaries (networks 5-10 above) are also published annually in the *Environmental Report*.

Section 15.2 describes in detail the environmental ground water surveillance monitoring that is conducted. Section 15-3 describes the six ground water compliance monitoring programs only briefly, because they are fully described in other readily available LLNL publications to which references are given.

15.2 Rationale and Design Criteria for Surveillance Ground Water Monitoring

15.2.1 Regulatory Drivers

Environmental ground water surveillance monitoring is driven by U.S. Department of Energy (DOE) Orders 5400.1[1] and 5400.5.

15.2.2 Monitoring Objectives

The primary objective of surveillance ground water monitoring is to determine the impact, if any, of continuing LLNL operations on local ground water resources. Surveillance monitoring is not a first-line defense against any inappropriate LLNL operation that might release hazardous material to the environment, because lag times of years are likely before such releases could be detected in the underlying ground water. Stringent administrative and operational controls of all hazardous materials are now in place at LLNL. These controls are designed either to prevent entirely or to minimize any release of hazardous material to the environment. The absence of such controls in the past caused some local contamination of ground water. Ground water contamination resulting from historical operations that have ceased is addressed by compliance monitoring and other LLNL ground water remediation programs that are conducted under Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) auspices.

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

Ground water that is or could be affected by DOE activities shall be monitored to determine and document the effects of those activities on ground water quality and quantity. LLNL's surveillance ground water monitoring program is designed to meet the following objectives:

1. Obtain data for the purpose of determining baseline conditions of ground water quality and quantity,
2. Demonstrate compliance with and implementation of all applicable regulations and DOE orders,
3. Provide data to permit the early detection of ground water pollution or contamination,
4. Furnish a reporting mechanism for detected ground water pollution or contamination,
5. Identify existing and potential ground water contamination sources and maintain surveillance of these sources, and
6. Supply data to inform the decisions that should be made concerning land disposal practices and the management and protection of ground water resources.

15.2.3 Sources and Analytes

Site-specific characteristics determine surveillance monitoring requirements. These include areas where surficial materials, including soil, sediment, and shallow bedrock, that are contaminated from past operations, but are at levels below the concern of CERCLA ground water remediation programs. LLNL CERCLA restoration programs extensively monitor ground water contamination that resulted from historical operations by LLNL and previous site owners, before stringent controls were implemented. Current surveillance monitoring includes those constituents of concern (COCs) addressed by the CERCLA restoration programs and many additional COCs that are not of concern to CERCLA restoration efforts, because they have never, or rarely, been detected, or are detected at concentrations below remedial action levels.

Ground water surveillance monitoring primarily concerns ground water quality beneath and adjacent to the LLNL Livermore site and Site 300. In total, it covers a wide range of elements, radioisotopes, inorganic and organic compounds, and general contaminant indicators.

15.2.3.1 Site-specific Characteristics—Livermore Site and Livermore Valley

For specifics of geology, see *CERCLA Remedial Investigation Report for the LLNL Livermore Site* (Thorpe et al. 1990).

Beneath the Livermore site, depth to the water table varies from about 8 to 40 m. At the eastern edge of the Livermore site, ground water gradients are quite steep, but under most of the site and farther to the west, the contours flatten to a gradient of approximately 0.003. Ground water flow under the northern and western portions of the site is generally westward. Aquifer tests on monitoring wells in the vicinity of the Livermore site indicate that the hydraulic conductivity of the permeable sediments ranges from 1 to 16 m/day. This, in combination with observed water-table gradients, yields ground water velocity estimates of 5 to 90 m/year. The range in these values reflects the heterogeneity typical of the alluvial sediments that underlie the area (Thorpe et al. 1990).

Figure 15-1 is an east-west cross-section along East Avenue showing the hydrostratigraphic units (HSUs) underlying the Livermore site. This cross section extends slightly past the western edge of LLNL at Vasco Road. The water table cuts across HSUs so that the shallowest water-saturated HSU (the uppermost aquifer) is HSU-6 at the southeastern corner of the site at Greenville Road and HSU-1B and HSU-2 along and toward the western site boundary (Vasco Road). Ground water from this area flows offsite toward the southwest (Hoffman et al. 1993; Macdonald et al. 1994).

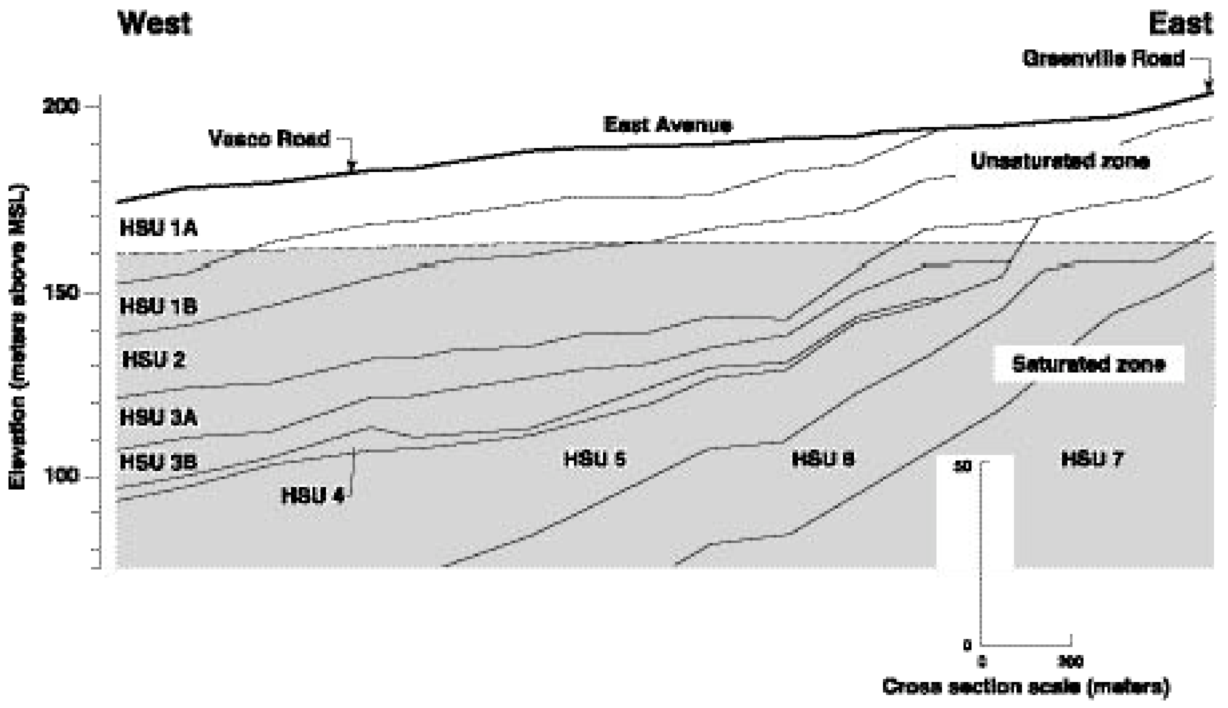

Figure 15-1. Livermore site hydrostratigraphic east-west cross section along East Avenue

Ground water surveillance monitoring includes many potential COCs. The list of potential sources is long and includes those described in the *CERCLA Remedial Investigations Report for the LLNL Livermore Site* (Thorpe et al. 1990). Wastes at the Livermore site that could potentially become pollutants to the ground water include metals, VOCs, petroleum hydrocarbons, pesticides and herbicides, and radioactive wastes. Tritium is present in ground water near the East Taxi Strip Area, mostly in HSU-3A and HSU-3B (Figure 15-1). Tables 15-1 and 15-2 (at the end of this chapter) contain a comprehensive list of the elements, isotopes, and chemical compounds that are analyzed for by the environmental ground water surveillance monitoring programs. Importantly, not all of the constituents shown in Tables 15-1 and 15-2 are monitored at each ground water sampling location. Rather, cost-effectiveness is achieved by limiting both the number of different analyses employed and the frequency of sampling. These decisions are made by the LLNL water analysts responsible for each surveillance monitoring network.

Two potential sources of ground water contamination that were initially evaluated prior to the LLNL sitewide remedial investigation—the Taxi Strip Area and the East Traffic Circle Landfill (Figure 15-2)—were further assessed for surveillance purposes through ground water monitoring during 1997 and 1998. Radioactively contaminated liquid wastes had been deposited in four disposal pits in the Taxi Strip Area from 1953 through about 1976, according to the remedial investigation (Thorpe et al. 1990). Contaminants detected in the soil were VOCs, metals, and various radionuclides. The radionuclides initially detected in the soils and other materials were transuranics (unspecified), americium-241, uranium-235, and cesium-137 (Buerer 1983). An earlier remedial action removed about 3000 cubic meters of contaminated soil and sediments.

At the East Traffic Circle Landfill, polychlorinated biphenyls (PCBs), metals, and various radionuclide contaminants were initially detected in the soil. The radionuclides detected in the soils and other materials were, in order of abundance: cesium-137, depleted uranium, radium-226, thorium-232, uranium-238, americium-241, and some cobalt-60 (McConachie et al. 1986). Remediation there involved the excavation and removal of 11,000 cubic meters of debris and soil with metal shavings, broken bottles, and capacitors. About 6 cubic meters of the total material excavated contained radioactive material (Thorpe et al. 1990; McConachie et al. 1986).

Although contaminated sediments were removed from both of these waste management units (WMUs), and the depth to ground water is greater than 20 m, LLNL continues surveillance monitoring to determine whether any hazardous materials have reached the ground water. Monitoring wells downgradient from these two areas (already used for restoration monitoring for VOCs and tritium) were added to the surveillance monitoring network during 1997.

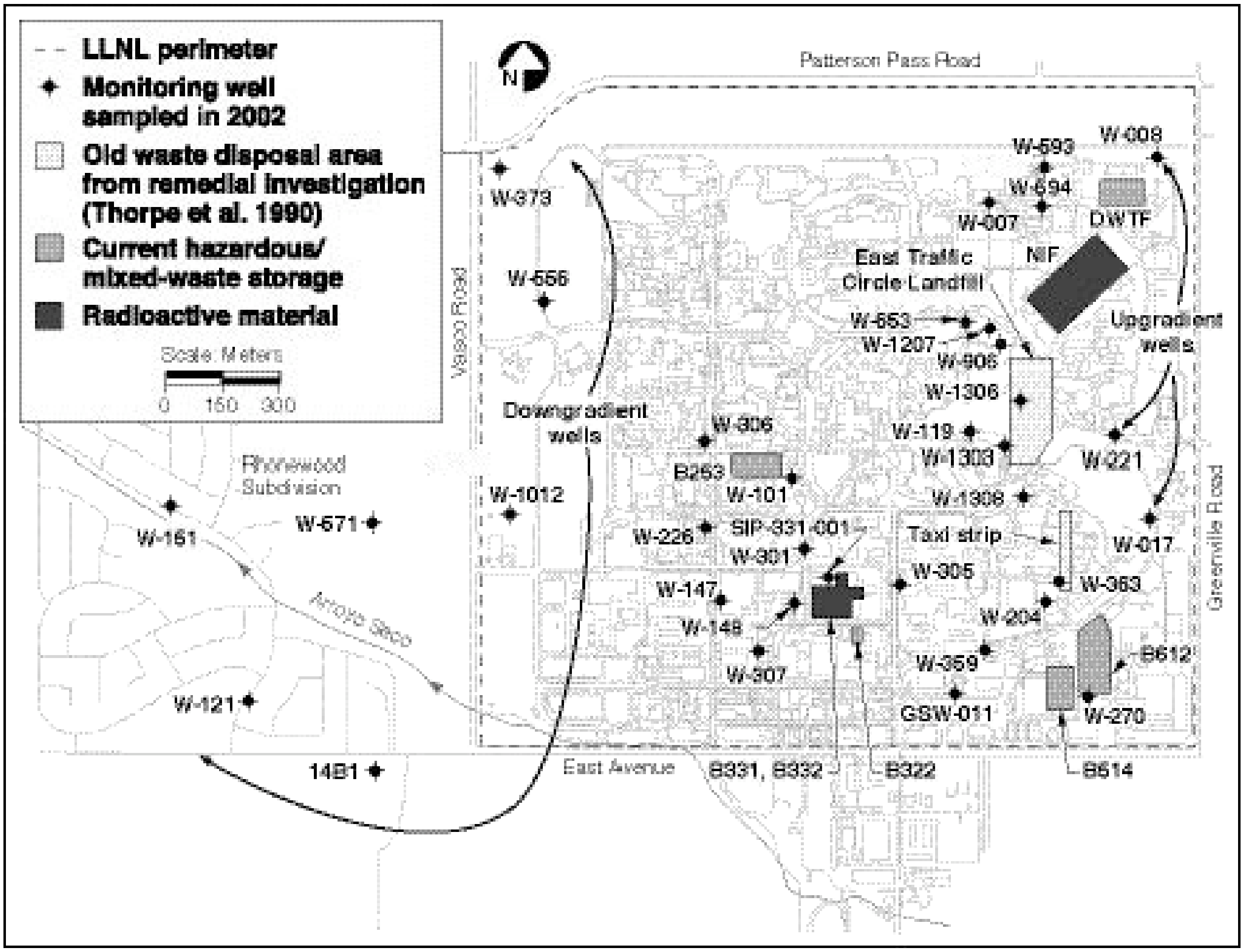

Figure 15-2. Livermore site and ground water surveillance monitoring well locations

During 1999, surveillance monitoring of the uppermost saturated aquifers (HSU-1B and HSU-2) began, in monitoring wells both hydrologically upgradient and downgradient from the Tritium and Plutonium Facilities (Buildings 331 and 332, respectively). This monitoring provides a baseline for any contamination that may be present, prior to expected increases in processing activities in both facilities and monitoring during those increased activities.

The old hazardous waste/mixed waste storage facilities around Area 514 and Building 612 are potential sources of contamination. (At the time of this writing in 2004, Area 514 and Building 419 are undergoing closure under the Resource Conservation and Recovery Act [RCRA].) This area is monitored by wells W-270 and W-359 (screened in HSU 5), and well GSW-011 (screened in HSU 3A). Ground water from these wells is sampled and analyzed for selected trace metals, general minerals, americium-241, plutonium-238, plutonium-239, radium-226, and tritium.

Ground water samples are obtained downgradient from areas where past releases of metals to the ground have occurred. Samples are obtained from monitoring well W-307 (screened in HSU 1B), downgradient from a fume hood vent on the roof of Building 322, a metal plating shop. Soil samples obtained from the area show elevated concentrations (in comparison with Livermore site background levels) of total chromium, copper, lead, nickel, zinc, and occasionally other metals. LLNL removed contaminated soils near Building 322 in 1999 and replaced them with clean fill. The area was then paved over, making it less likely that metals will migrate from the site.

A newer potential source of ground water contamination is the Decontamination and Waste Treatment Facility (DWTF) in the northeastern portion of the Livermore site. Ground water samples are obtained downgradient from this facility from wells W-007, W-593 (screened in HSU 3A), and W-594 and are analyzed for minerals, selected metals, americium-241, plutonium-238, plutonium-239, radium-226, and tritium. Monitoring wells W-007 and W-594 (screened in HSUs 2/3A and 2, respectively) were added to this monitoring network in 2003.

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

At the Livermore site, many utility vaults receive storm water runoff. These collected wastewaters are sampled and analyzed on a representative basis by other LLNL monitoring programs to determine proper disposal. The utility vaults may have contributed some amount of contaminants from surface runoff to the underlying sediments. Other potential sources of ground water contamination are investigated on a case-by-case basis as they are discovered, to determine if additional ground water monitoring is needed.

15.2.3.1.1 Extent and Frequency of Monitoring and Measurements—Livermore Site and Livermore Valley

LLNL has constructed more than 500 ground water monitoring wells on and in the vicinity of the Livermore site. Although the primary function of these wells is environmental restoration monitoring, data from a subset of these wells also fulfill the surveillance monitoring mandates of DOE Order 5400.5.

Subpart F of 40 CFR 265, details requirements for RCRA Interim Status facilities, including locating at least one monitoring well upgradient of the facility to represent background ground water quality in the uppermost aquifer. LLNL's program employs three upgradient monitoring wells (W-008, W-017, and W-221) in the eastern and northeastern portions of the site, and seven downgradient monitoring wells located near the western boundary of the site as shown in Figure 15-2. These wells are located downgradient from Treatment Facility B (W-571 and W-1012) and Treatment Facility C (W-373 and W-556); three of the downgradient wells (W-121, W-151, and W-14B1) are located downgradient from, but near the zone of influence of, Treatment Facility A. This configuration of monitoring wells was implemented in 1996 to monitor the uppermost aquifers (HSUs 1B and 2 [Figure 15-1]) for COCs that could be transported off site beneath Vasco Road by the predominant westward direction of ground water flow.

In 1997, the ground water surveillance network was expanded to incorporate on-site monitoring wells downgradient from the Taxi Strip Area and the East Traffic Circle Landfill. Figure 15-2 shows the locations of the seven downgradient monitoring wells (W-119, W-204, W-363, W-906, W-1303, W-1306, and W-1308) that form the monitoring network for the Taxi Strip and the East Traffic Circle WMUs.

The network of 33 wells established for Livermore site surveillance (Figure 15-2) is sampled quarterly at the three upgradient wells and at least annually at the 30 remaining surveillance wells. An additional 7 wells surrounding well W-1012 are monitored for nitrate only. Generally, the downgradient wells are sampled after the heaviest winter rains. Heavy winter rains tend to wash some metals out of the vadose zone and into the ground water. Retest samples are obtained subsequent to analytical results that are

elevated above background concentrations or above concentrations of concern for human health. All ground water sampling at the Livermore site is conducted by EPD's Environmental Restoration Division (ERD) technical staff or contract staff. Radioisotopes and general water quality parameters (general minerals) are monitored at wells GSW-11, W-359, and W-270 downgradient from the hazardous waste and mixed-waste storage area near Building 514. Ground water samples from these wells are collected and analyzed annually.

Ground water samples are collected annually and analyzed for metals from monitoring well W-307, downgradient from where a fume hood on Building 322 released metals to ground. Ground water samples are also collected annually and analyzed for metals from monitoring wells W-226 and W-306. These wells are downgradient from sediments containing elevated metals that accumulated in a storm water catch basin (Figure 15-2).

In 1999, LLNL began monitoring well W-305 upgradient from Building 332 and well W-148 hydrologically downgradient from Buildings 331 and 332 (Figure 15-2). Well W-305 is screened in HSU-2, and well W-148 is screened in HSU-1B.

COCs are reviewed annually by the responsible LLNL water analysts to determine whether they satisfy present surveillance needs. The COCs chosen for the surveillance sampling program are determined largely by knowledge of materials used at the Livermore site. All surveillance wells are now analyzed for general minerals. All surveillance monitoring wells are analyzed for metals and general minerals, gross alpha and beta, tritium, strontium-90, radium and uranium radioisotopes, and herbicides currently used on site. Livermore site perimeter surveillance monitoring wells are sampled and analyzed at least annually for plutonium-238 and plutonium-239+240. Additional radioisotopes (thorium-228, thorium-230, thorium-232, plutonium-238, plutonium-239+240, and americium-241) are measured in the ground water in the vicinity of the Taxi Strip and the East Traffic Circle Landfill areas. PCBs are monitored annually at surveillance wells downgradient from the Taxi Strip Area and the East Traffic Circle Landfill.

LLNL measures the tritium activity in ground water samples obtained annually from a network of 25 wells in the Livermore Valley. These Livermore Valley wells are located hydraulically downgradient (westward) of the LLNL site at distances ranging from 3.5 to 16 km. The well locations and their identification codes are shown in Figure 15-3. Ground water samples are obtained in LLNL-supplied bottles by personnel employed at the following four facilities:

- California Water Service (six wells)
- City of Livermore (nine wells)
- City of Pleasanton (three wells)
- Zone 7 Water Agency (seven wells)

Wells occasionally go out of service and other wells may be substituted by the facilities. Changes are made to the annual *Environmental Report* as this occurs.

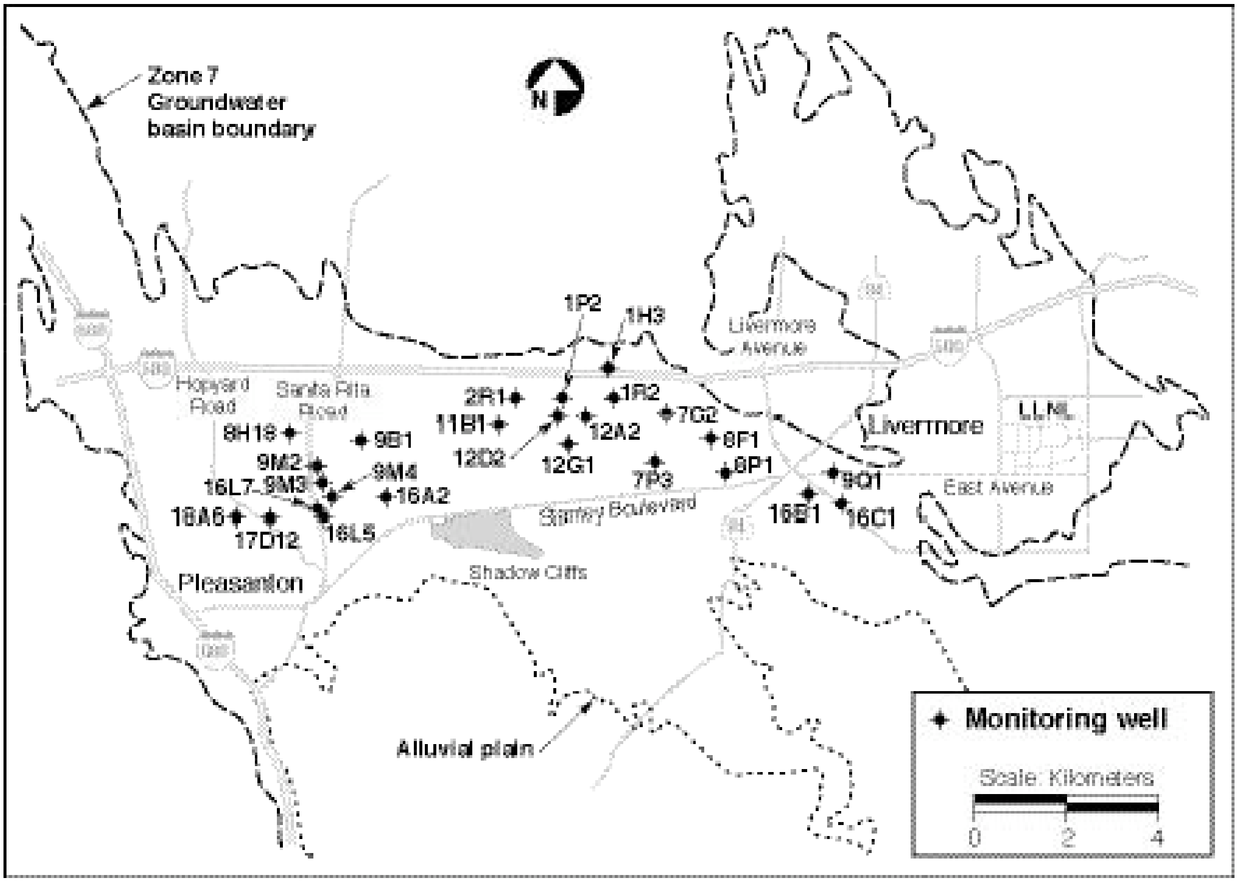

Figure 15-3. Livermore Valley ground water surveillance monitoring well locations

15.2.3.2 Site-specific Characteristics—Site 300

Details of Site 300 geology and hydrogeology may be found in early studies edited by Raber and Carpenter (1983), and in subsequent CERCLA remedial investigations edited by Webster-Scholten (1994) and in Taffet et al. (1996). Site 300 is generally underlain by gently dipping sedimentary bedrock dissected by steep ravines. Topographic relief at the site is about 300 m. Elevations range from about 200 m in the southeast to more than 500 m in the northwest. The bedrock is formed primarily of interbedded sandstone, siltstone, and claystone. The Neroly Formation is the principal hydrologic unit. The Neroly Formation is about 150 m thick and consists of distinctive blue-gray to brown weathering volcaniclastic sandstone and sandy siltstone, interbedded with light gray weathering tuffaceous claystone and conglomerate. It is exposed extensively within the northern half of Site 300. The Neroly Formation is also present in the subsurface underlying the southeastern portion of the Site. Figure 15-4 is a generalized stratigraphic diagram of Site 300 near-surface rocks and sediments.

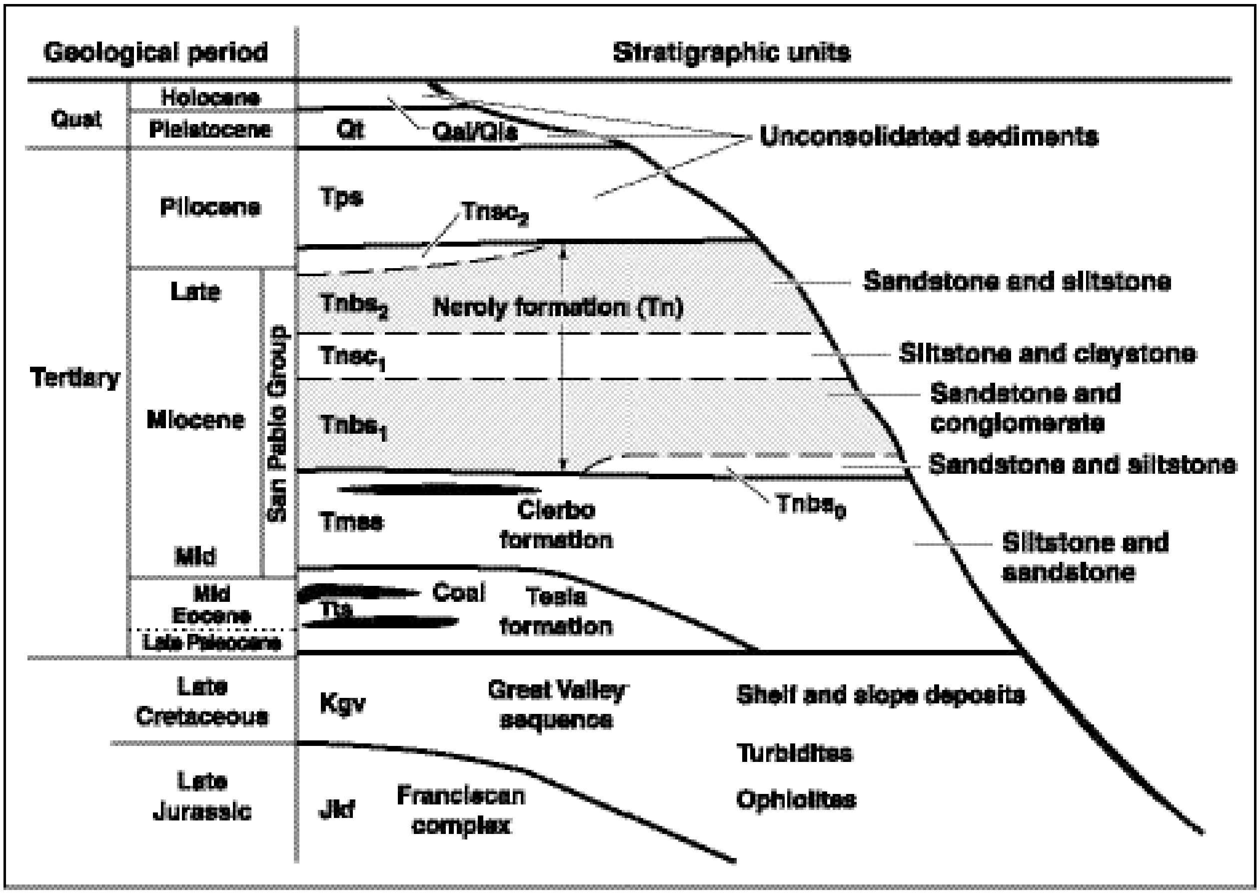

Figure 15-4. Site 300 generalized stratigraphy

Hydraulic conductivities in the water-bearing strata at Site 300 vary over three orders of magnitude, from 10^{-3} to 10^{-6} cm/s. Ground water flow ranges from less than 1 to 40 m/year. Maximum flow rates occur in valley-fill deposits.

The uppermost, generally unconfined water-bearing zone is the primary target for ground water monitoring at Site 300 because it contains most of the existing contamination, and it would be the first zone to be influenced by any new release of contaminants at or near the ground surface.

15.2.3.2.1 Extent and Frequency of Surveillance Monitoring and Measurements—Site 300

Present LLNL operations at Site 300 are designed and managed to minimize contamination of soil and bedrock. Some soil and bedrock has been contaminated by historical LLNL operations at the site and some of the contaminants have reached to the ground water beneath the site. Much of the contaminated soil remains in place or is buried in closed landfills at the site. Removal actions, including the capping of landfill pits, have significantly reduced the rates of contaminant migration to ground water in those areas. However, under the unusual circumstance of excessive rainfall, rain infiltration, and water table rises, additional contaminants may be released to the underlying ground water.

Surveillance monitoring at Site 300 analyzes ground water samples from on-site DOE CERCLA wells and from private off-site production wells and springs. Although surveillance monitoring uses on-site wells that were placed for the purpose of site characterization under CERCLA, it is conducted independently of other monitoring. COCs of many types are monitored in ground water samples to accomplish several important goals. Surveillance monitoring provides independent checks of findings from site characterization studies and remediation efforts. It detects (down to detection limits) any slow-to-develop releases of COCs to ground water at the site. This program also detects any increases in existing contamination that could indicate accelerated COC releases from remaining buried sources. Chemical and radiological data from ground water monitoring at Site 300 are added continually to LLNL's database.

For surveillance monitoring purposes, the number and locations of sampling wells, the COCs, and frequency of sampling are prerogatives of LLNL, allowing the Laboratory to devise a comprehensive, cost-effective monitoring program. Because the flow rates of ground water beneath Site 300 rarely exceed 40 m/year, quarterly, semiannual, and annual sampling frequencies are deemed appropriate for data trending and to meet annual reporting requirements.

Ground water flow directions beneath Site 300 are known from area-wide measurements of water table elevations in the CERCLA wells and piezometers. Figure 15-5 shows the locations of closed landfills (formerly open pits), surface impoundments (process water), sewage ponds, and ground water surveillance wells and springs

The selected wells are typically screened in the uppermost water-bearing zone beneath the units in order to provide the earliest warning of COC releases to ground water. Other wells are screened in the regional aquifer and are used to detect any degradation of drinking water supplies. Some wells within Site 300 (Figure 15-5) were selected to follow surface water courses, such as Elk Ravine, where contaminant plumes caused by past operations have been detected by exhaustive remedial investigation studies (Webster-Scholten 1994; Taffet et al. 1996). These wells were installed to monitor the concentrations of COCs within contaminant plumes and to monitor the fate and transport of contaminant plumes. The surveyed locations and engineering specifications of the Site 300 ground water monitoring installations are maintained in the LLNL computer databases.

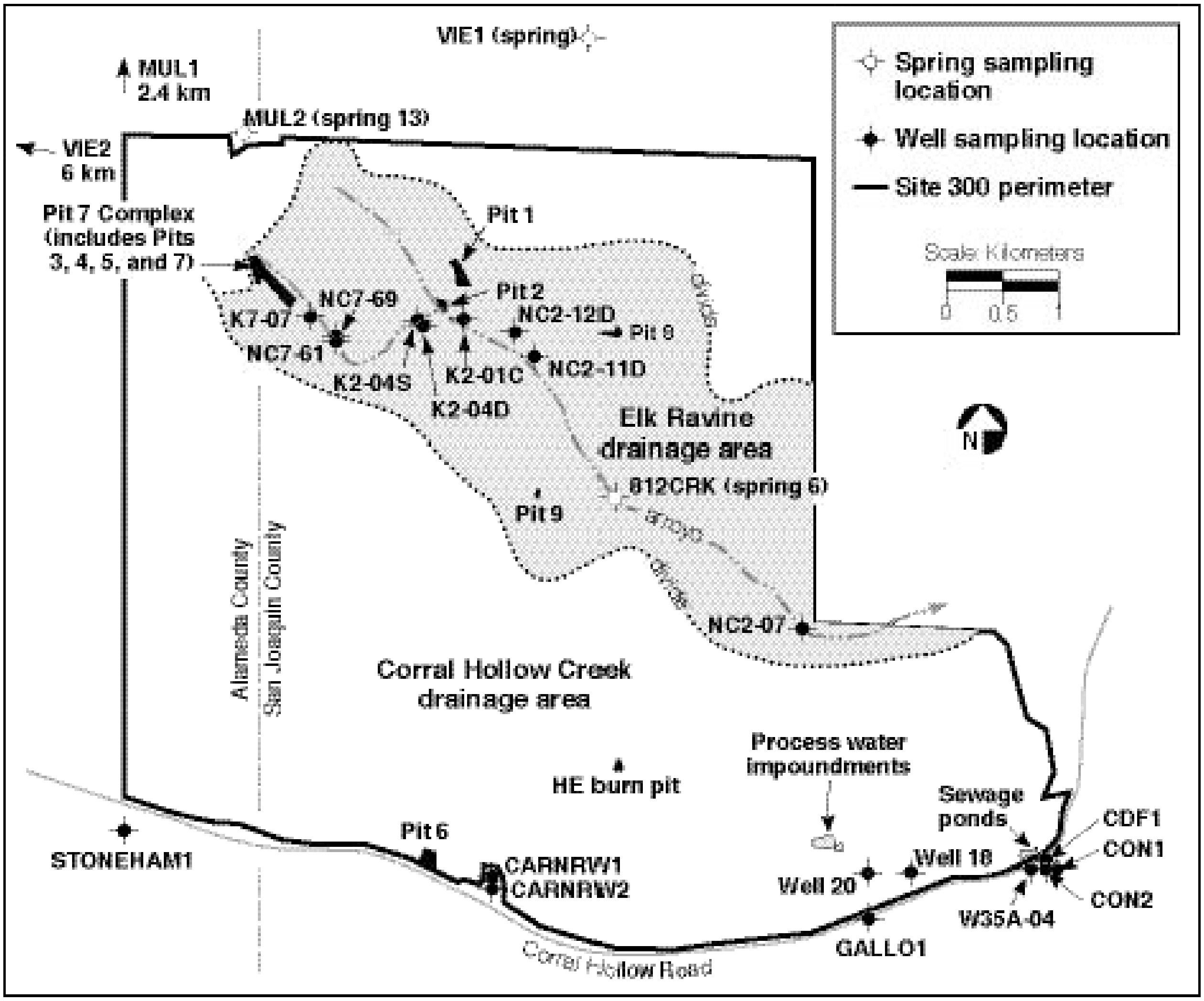

Figure 15-5. Site 300 locations of pits (closed landfills), former HE burn pit, surface impoundments (process water), sewage ponds, and ground water surveillance wells and springs.

Twelve surveillance locations for ground water monitoring are off site. Four are to the north, and eight are to the south of Site 300 (Figure 15-5). Three locations, the MUL2 and VIE1 springs, and the cattle watering well, MUL1, are adjacent to Site 300 on the north, where the Altamont Hills slope down to the San Joaquin Valley. VIE2 represents a background well, typical of drinking water supplies in the Altamont Hills. It lies 6 km northwest of Site 300 in the upper reaches of the Livermore Valley watershed. Eight off-site surveillance locations are located immediately south of Site 300 in the Corral Hollow Creek drainage area. These are wells CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1, STONEHAM1, and W35A-04. Of these southern wells, STONEHAM1 is monitored primarily to provide upgradient background data for water supply wells in Corral Hollow Creek. The remaining off-site surveillance wells, which are used to water cattle or suppress fires, monitor for VOCs beyond the southern boundary of Site 300.

Of the 12 off-site ground water surveillance wells sampled, water samples are obtained quarterly from CARNRW1 and CON2 and are analyzed for VOCs only. Samples from the remaining ten wells are obtained either quarterly (CARNRW2, CON1, CDF1, and GALLO1), or annually (MUL1, MUL2, VIE1, VIE2, STONEHAM1, and W35A-04). Those samples are analyzed for 17 elements (mostly metals), HE compounds, VOCs, extractable organic compounds, nitrate, perchlorate, general radioactivity (gross alpha and gross beta), tritium, and uranium isotopes.

Nine on-site surveillance wells and one spring (812CRK) are located along the system of fault-marked ravines and arroyos that constitute the Elk Ravine drainage area. Surveillance monitoring also includes two on-site water production wells, Well 18 and Well 20 (Figure 15-5). Well 20 provides potable water for use at Site 300. Well 18 is a standby supply well.

Elk Ravine drains most of northern Site 300 in the area between the drainage divides shown in Figure 15-5. Surface runoff from firing tables and closed WMUs within the drainage area (Pits 1, 2, 3, 4, 5, 7, 8, and 9) is collected in arroyos. With sufficient seasonal rainfall, unconfined ground water can flow southeast on and within the valley-fill deposits that floor the Pit 7 Complex valley. Surface runoff from the Pit 7 Complex valley (containing the most elevated landfills) can flow southeast to Doall Road, where it is deflected northeastward into Doall Ravine by a landslide deposit. At the northeastern end of Doall Ravine, this runoff combines with channeled runoff from the 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, that may provide pathways to the underlying ground water. Thus, ground waters from wells that lie within the Elk Ravine drainage area are monitored. 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 identified as Spring 6), 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 that is screened in both $Tnbs_1$ and Qal. It is downgradient from Pits 3, 4, 5, and 7 with respect to unconfined flow in the valley-fill deposits 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 join between Elk Ravine and Doall Ravine. They are all screened in $Tnbs_1$.

Wells NC2-12D and NC2-11D are located in Elk Ravine below its join with Doall Ravine. Well NC2-11D is screened at the contact between $Tnbs_1$ and Tmss. Well NC2-07 is the farthest downstream surveillance well in the Elk Ravine drainage area and is screened in $Tnbs_1$.

Ground water samples are obtained semiannually from the nine wells and one spring in Elk Ravine and are analyzed for 17 elements (mostly metals), HE compounds, VOCs, nitrate, perchlorate, general radioactivity (gross alpha and gross beta), tritium, and uranium isotopes.

Well 20 supplies potable water for Site 300, and Well 18 serves as a standby water supply well. Both are located in the southeastern part of Site 300 (Figure 15-5). They are deep, high-production water wells screened in $Tnbs_1$. The Well 18 screen extends upward into a fine-grained aquitard ($Tnsc_1$) in the Neroly Formation that separates $Tnbs_1$ from the overlying $Tnbs_2$. Each well can produce up to 1500 L/min.

Ground water samples are obtained monthly from supply Well 20 and are analyzed for VOCs. Well 20 samples are analyzed quarterly for 17 elements (mostly metals), HE compounds, nitrate, general radioactivity (gross alpha and gross beta), tritium, and uranium isotopes. Since monitoring of Well 20 began in the 1980s, no contamination has appeared in ground water samples obtained from this production well. Ground water samples are obtained quarterly from the backup supply Well 18 and are analyzed for VOCs. For many years TCE was detected occasionally at Well 18 at very low concentrations (<1.0 µg/L). The long-term trend is less frequent TCE detections at lower concentrations. Well 18 monitoring is conducted by the LLNL Environmental Restoration Division (ERD).

15.3 Rationale and Design Criteria for Compliance Ground Water Monitoring

15.3.1 Regulatory Drivers

Environmental ground water compliance monitoring is conducted at Site 300 only and is driven by WMU post-closure plans and/or state-issued permits, such as:

- Permits and written agreements with the California Environmental Protection Agency (Cal EPA) Department of Toxic Substances Control (DTSC) issued under RCRA and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)

- Permits and other controlling documents issued under the Porter-Cologne Water Quality Control Act (California 1969) by the California Central Valley Regional Water Quality Control Board (CVRWQCB).

The specific documents governing ground water compliance monitoring at Site 300 are:

- For Pit 1 and Pit 7:

  Order No. 93-100, Waste Discharge Requirements for University of California Lawrence Livermore National Laboratory Site 300 and U.S. Department of Energy, Landfill Pits 1 and 7, San Joaquin County (CVRWQCB 1993).

  Revised Monitoring and Reporting Programs No. 93-100 and 96-248, Lawrence Livermore National Laboratory Site 300, San Joaquin County (CVRWQCB 1998).

  Lawrence Livermore National Laboratory Site 300 Resource Conservation and Recovery Act Closure and Post-Closure Plans, Landfill Pits 1 and 7, Volumes I and II, (Cal EPA No. CA2890090002) (Rogers/Pacific Corporation 1990).

- For Pit 6:

  Post-Closure Plan for the Pit 6 Landfill Operable Unit, Lawrence Livermore National Laboratory Site 300 (Ferry et al. 1998).

  Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300 (Ferry et al. 2002).

- For the HE burn pit:

  Hazardous Waste Facility Post-Closure Permit (Permit Number: 02-BRK-04) (DTSC 2003).

  Final Closure Plan for the High-Explosives Open Burn Treatment Facility at Lawrence Livermore National Laboratory Experimental Test Site 300 (Mathews and Taffet 1997).

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

- For the process water impoundments and sewage ponds:

  Order No. 96-248, Waste Discharge Requirements for University of California Lawrence Livermore National Laboratory Experimental Test Site (Site 300) and U.S. Department of Energy Evaporation and Percolation Ponds and Class II Surface Impoundments, San Joaquin and Alameda Counties (CVRWQCB 1996).

  Revised Monitoring and Reporting Programs No. 93-100 and 96-248, Lawrence Livermore National Laboratory Site 300, San Joaquin County (CVRWQCB 1998).

15.3.2 Monitoring Objectives

The primary ground water compliance monitoring objective is to detect any release of COCs to ground water from the monitored facilities. The specific COCs monitored vary by facility.

15.3.3 Sources and Analytes

The sources of the COCs (analytes) typically lie within the monitored facilities themselves. Sources include wastes buried in closed landfills (Pits 1, 6, and 7), residues remaining in soil beneath a covered former high explosives (HE) burn pit (Building 829 area) and active process and sewage water impoundments (HE area and General Services Area [GSA], respectively). Updated (2004) maps of facility (COC source) locations at Site 300, including the locations of their compliance monitoring wells are shown in Figures 15-6 through 15-11.

15.3.3.1 RCRA-closed Pit 1 Landfill

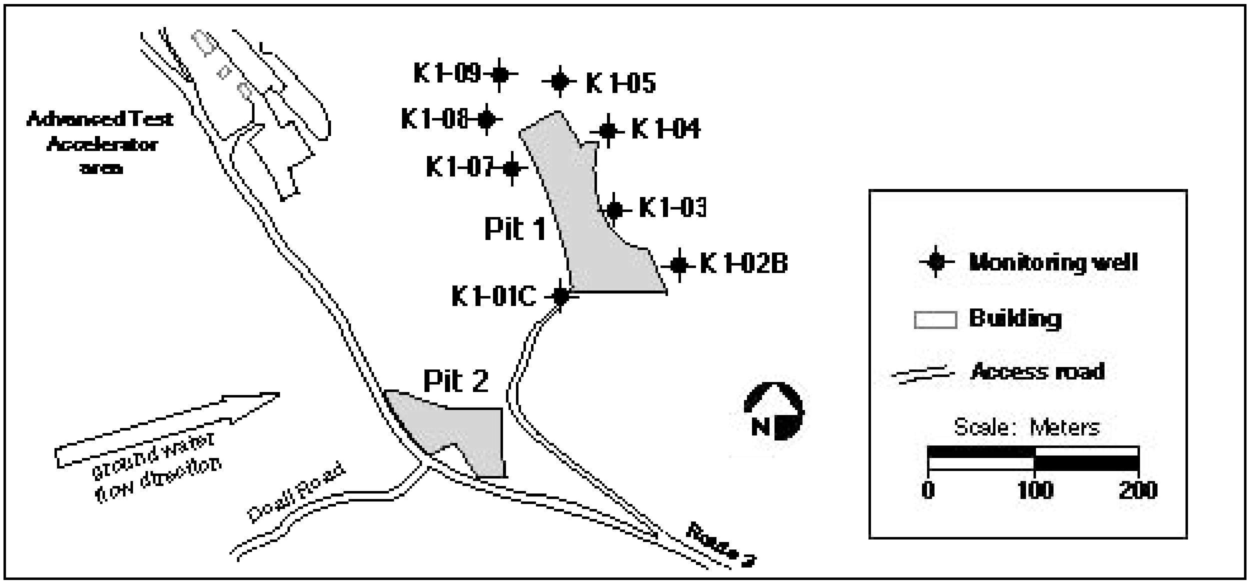

Figure 15-6. Location of Pit 1 and its eight compliance detection monitoring wells.

For specific details regarding the Pit 1 compliance monitoring program, including COCs and their permitted limits of concentration in ground water at each of the monitoring wells, see the regulatory documents listed for this monitoring network in Section 15.3.1. Ground water samples are obtained quarterly from the wells in this network.

15.3.3.2 CERCLA-closed Pit 6 Landfill

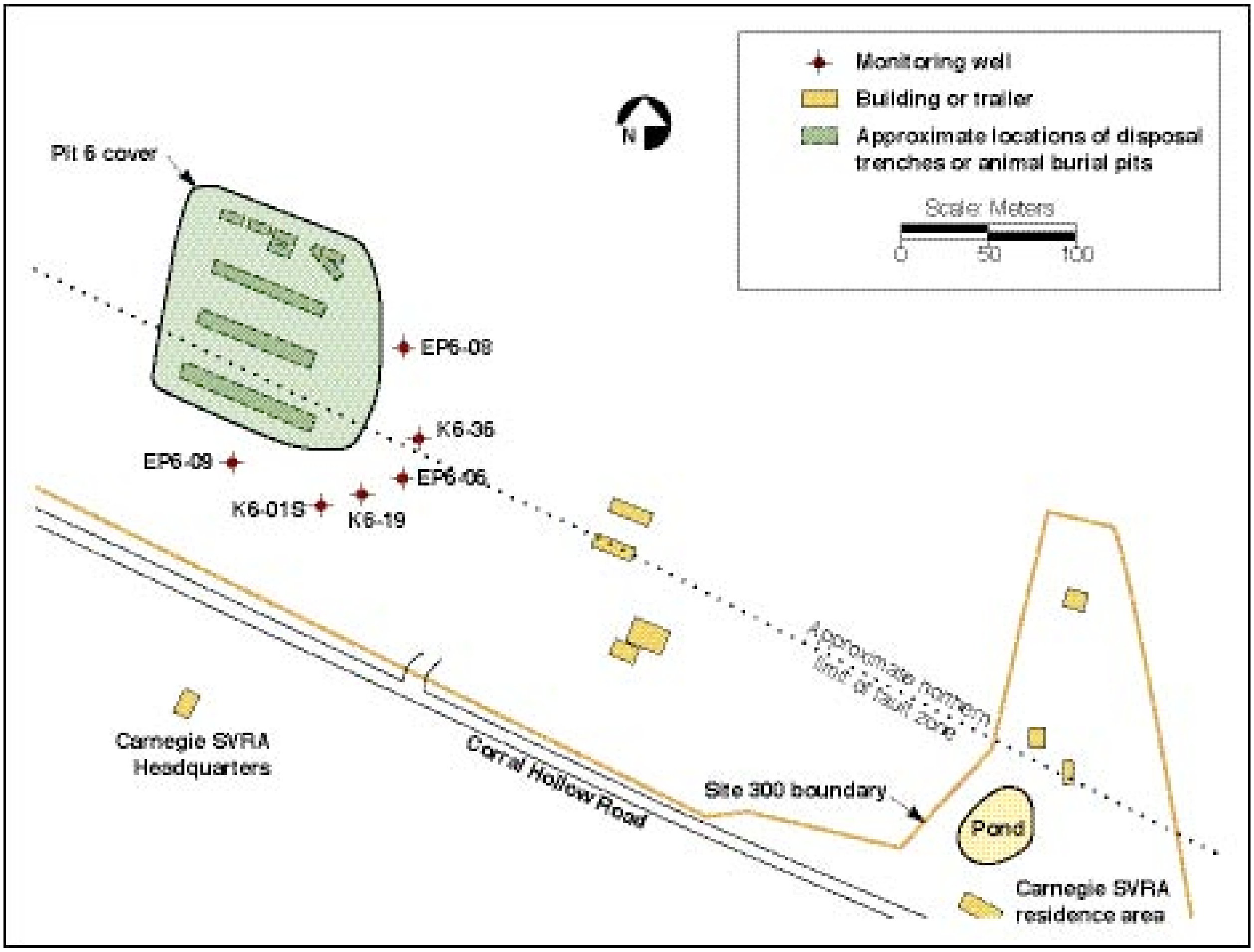

Figure 15-7. Location of Pit 6 and its six compliance detection monitoring wells

For specific details regarding the Pit 6 compliance monitoring program, including COCs and their permitted limits of concentration in ground water at each of the monitoring wells, see the regulatory documents listed for this monitoring network in Section 15.3.1. Ground water samples are obtained quarterly from the wells in this network.

15.3.3.3 RCRA-closed Pit 7 landfill

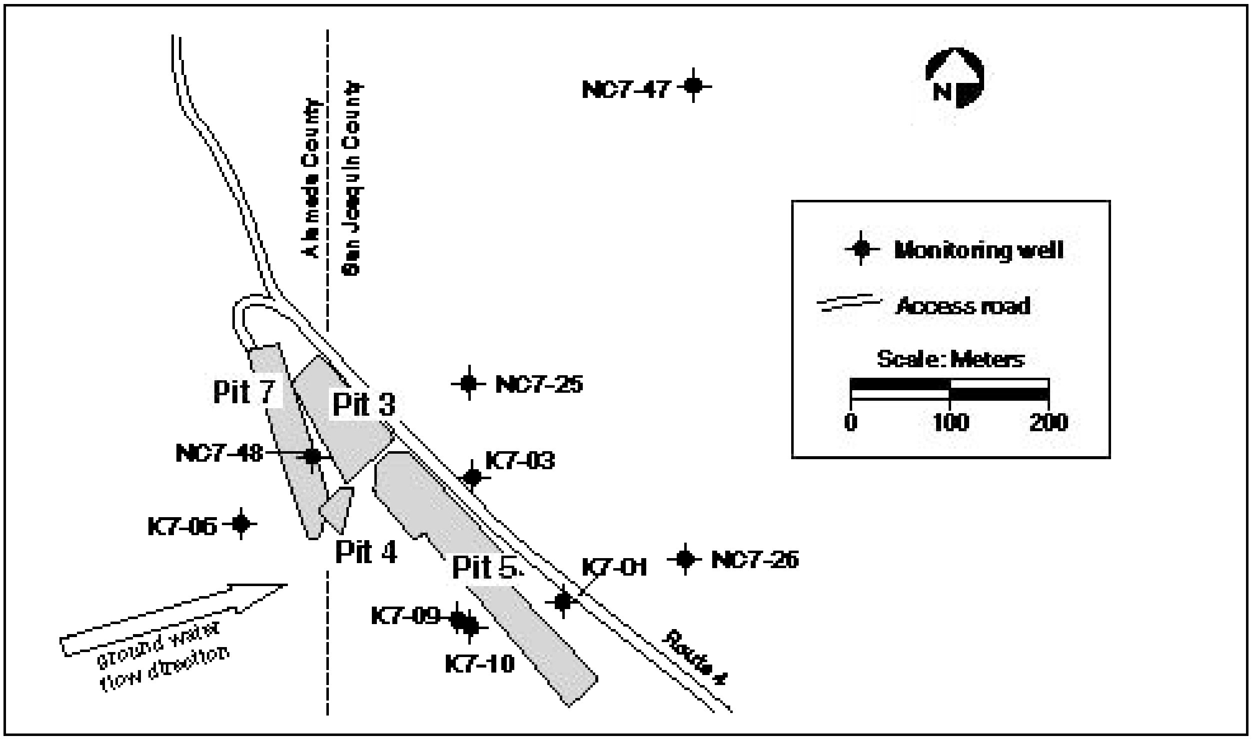

Figure 15-8. Location of Pit 7 and its nine compliance detection monitoring wells.

For specific details regarding the Pit 7 compliance monitoring program, including COCs and their permitted limits of concentration in ground water at each of the monitoring wells, see the regulatory documents listed for this monitoring network in Section 15.3.1. Ground water samples are obtained quarterly from the wells in this network.

15.3.3.4 RCRA-closed Building 829 burn pit

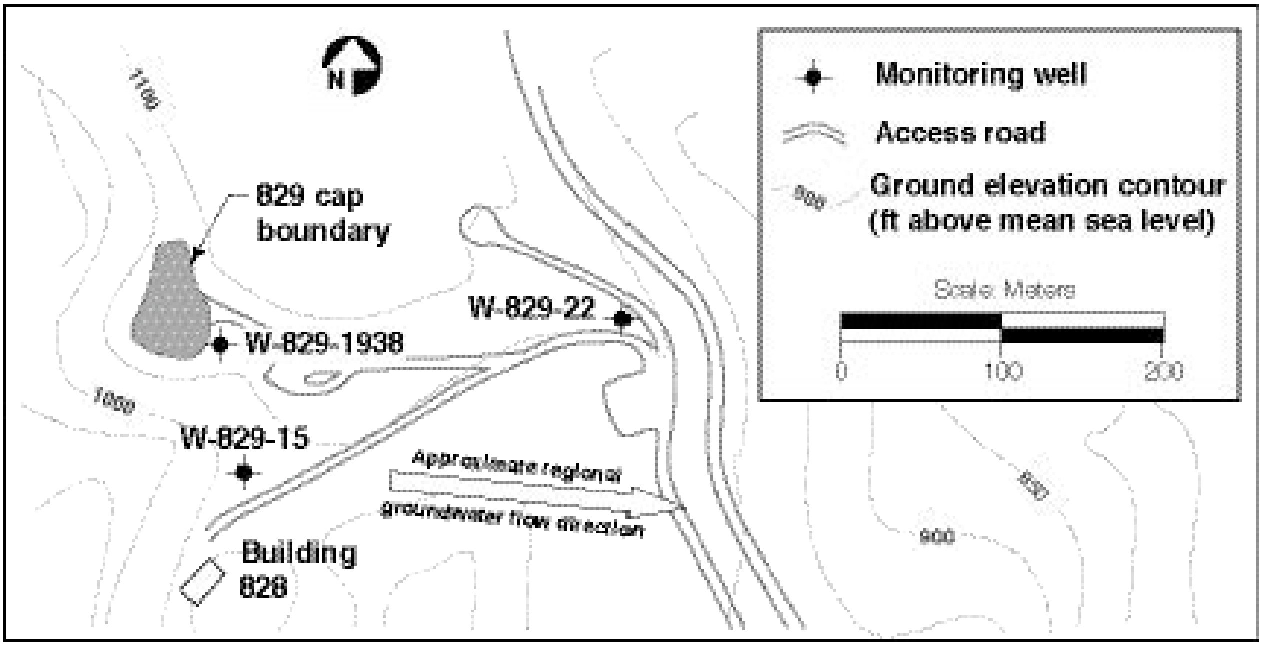

Figure 15-9. Location of the closed Building 829 burn pit at Site 300 and its three compliance detection monitoring wells

For specific details regarding the HE burn pit compliance monitoring program, including COCs and their permitted limits of concentration in ground water at each of the monitoring wells, see the regulatory documents listed for this monitoring network in Section 15.3.1. Ground water samples are obtained quarterly from the wells in this network.

15.3.3.5 Active HE Process Water Impoundments

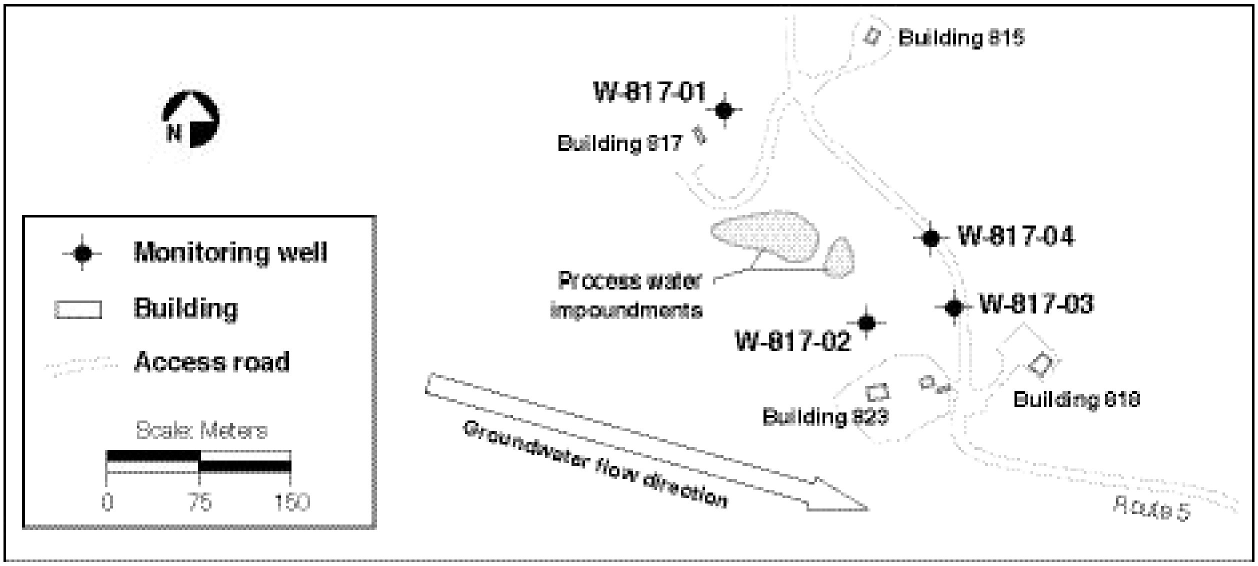

Figure 15-10. Locations of the Explosives Process Area impoundments at Site 300 and their four surface compliance detection monitoring wells.

For specific details regarding the Explosives Process Area Class II surface impoundments compliance monitoring program, including COCs and their permitted limits of concentration in ground water at each of the monitoring wells, see the regulatory documents listed for this monitoring network in Section 15.3.1. Ground water samples are obtained quarterly from the wells in this network.

15.3.3.6 Active Sewage Water Impoundments (Ponds)

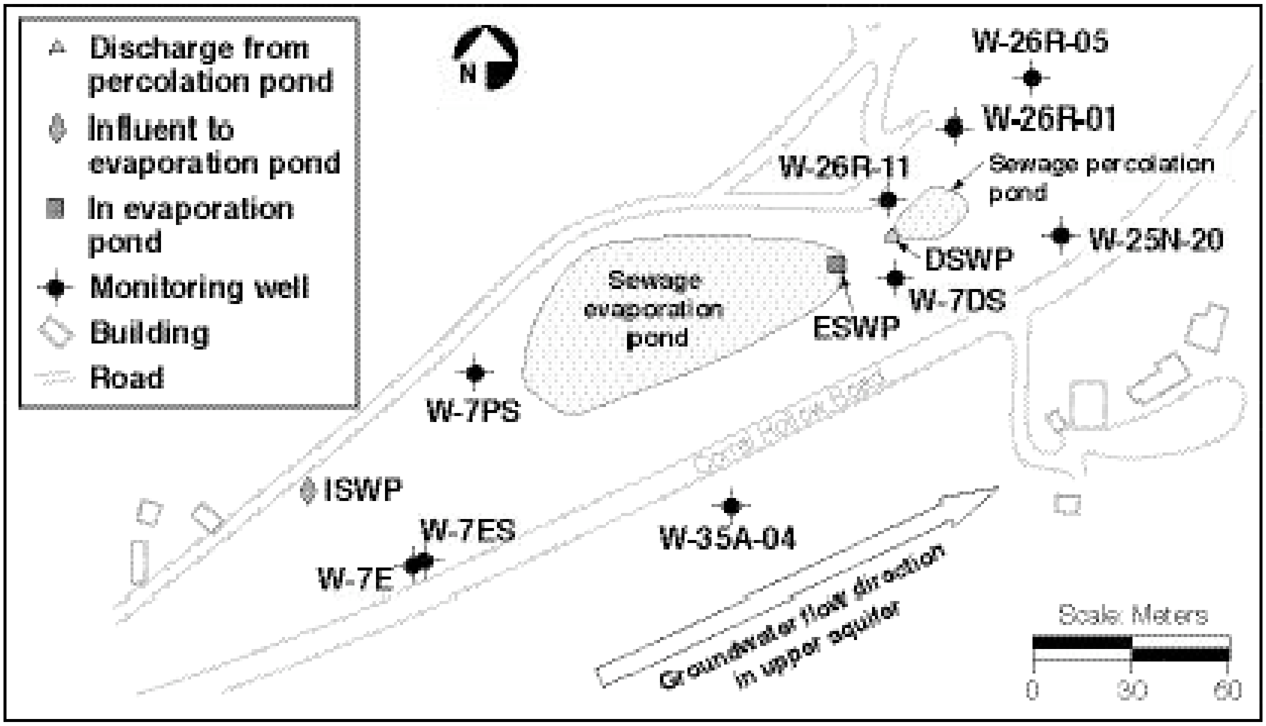

Figure 15-11. Locations of the sewage ponds at Site 300 and their nine compliance detection monitoring wells.

For specific details regarding the sewage ponds compliance monitoring program, including COCs and their permitted limits of concentration in ground water at each of the monitoring wells, see the regulatory documents listed for this monitoring network in Section 15.3.1. Ground water samples are obtained semiannually from the wells in this network.

15.4 Ground Water Sample Collection Methods

The standard operating procedures (SOPs) for ground water sample collection are fully described in the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures* (Goodrich and Depue 2003). Ground water samples are collected by LLNL technicians who are trained in the appropriate SOPs. SOPs are followed to ensure consistent ground water monitoring results that accurately represent the ground water at all the monitoring locations.

15.5 Procedures for Laboratory Analysis

Chemical and radioactivity analyses are conducted by commercial laboratories under contract with LLNL. The analytical laboratories are certified by the California Department of Health Services Environmental Laboratory Accreditation Program (ELAP). Laboratories use EPA approved or other standard methods of analyses in accordance with 40 CFR Part 141. The analytical work is done in accordance with the conditions and methodology specified in an approved statement of work. Typically, COC concentrations in ground water are monitored down to their reporting limits (RLs). Analytical methods are selected to meet LLNL data quality objectives (DQOs). For compliance monitoring, RLs must be at or below permitted statistical limits of concentration (SLs) for the COCs. For surveillance monitoring, analytical methods are chosen whose RLs are at or below EPA or California maximum contaminant levels (MCLs) for the COCs in drinking water. MCLs are used by LLNL water analysts as reference standards. Tables 15-1 and 15-2 at the end of this chapter list LLNL COCs, the EPA or standard method used to measure them, and their contractual RLs.

15.6 Quality Assurance Procedures

15.6.1 Precision

Under the quality assurance program for this monitoring network, a duplicate or collocated sample is collected from at least 10% of sample locations, or at least one location, per sampling event. The duplicate location is randomly chosen from the available locations, if sufficient sample volume is present. An alternative location may be used if the required sample volume is not available at the pre-selected location. This duplicate sample is submitted to the lab for analysis with a unique sample identifier. The results for the duplicate location sample and actual location sample are compared by the network analyst upon the delivery of the analytical results from the laboratory.

15.6.2 Bias

Field blanks may be submitted with some of the networks and analyzed by any compounds desired by the analyst. These analyses give some indication of field contamination, or combined field and laboratory contamination, which can lead to bias in analytical results. All quality check information provided by the analytical laboratories, including matrix spikes, matrix duplicates, and calibration standards are examined by the network analyst to identify any analytical bias. If calibration standards or matrix spikes are consistently high or low, the analyst will contact the laboratory for an explanation. Trip blanks are used with volatile organic compounds only to indicate which of those compounds may be contaminants.

15.6.3 Completeness

Ground water samples may not be collected as planned because of a well being dry, difficult field conditions (that sometimes occur during the rainy season), or for any other reason. For compliance monitoring, sampling of all locations for each compliance parameter is required, therefore, 100% completeness is necessary. Given the potential for sample loss for reasons described above, our target completeness would be 90% for each site (Livermore site and Site 300) for surveillance monitoring.

15.7 Program Implementation Procedures

The requirements for the implementation of the ground water compliance monitoring programs are specified in the post-closure and permit documents listed in Section 15.3.1. Each (new) surveillance or compliance monitoring program is assigned to an Operations and Regulatory Affairs Division (ORAD) water analyst who directs ground water monitoring on a day-to-day basis. The responsible water analyst begins by generating a quarterly sampling plan at least one month in advance of actual sampling. The sampling plan is then carried out by LLNL technicians who are trained in the appropriate SOPs (Goodrich and Depue 2003). Technicians send samples to analytical laboratories where analyses are performed. Analytical data are returned to the responsible water analyst. The analyst apprises LLNL management regarding results from the monitoring program and writes any required reports.

15.8 Action Levels

Environmental action levels are COC concentration levels in ground water above which certain responses are automatic. For compliance ground water monitoring, the action levels are the permitted SLs for the monitored COCs. For surveillance ground water monitoring, the action levels may be the analytical RL for COCs that are not typically detected, or drinking water MCLs. Action level concentrations for ground water COCs at LLNL are listed in Tables 15-1 and 15-2 at the end of this chapter. Some constituents shown in Tables 15-1 and 15-2 do not have action level concentrations established because of a lack of sufficient data, because their concentration varies considerably from location to location, or because they are not actually COCs (that is, they are members of a group of constituents that are routinely measured and reported by a particular analytical method). These are listed as TBD (to be determined) in Tables 15-1 and 15-2.

Automatic responses to exceedances of action level concentrations in routine ground water samples include the following actions:

1. Assess the accompanying QA/QC data from the reporting analytical laboratory.

2. Notify LLNL management of the off-normal result.
3. Resample the monitoring location twice, with samples obtained at least one week apart to ensure independence. The samples are analyzed for the suspect COC using the same method as was used for the initial routine sample.
4. If either "retest" sample shows an exceedance of the COC, then the initial routine sample result is judged to be confirmed. If neither sample shows an exceedence, then the initial result is judged to be invalid. LLNL management is notified of the retest results.
5. For compliance monitoring (only), if retesting confirms the exceedance, a letter report regarding "statistical evidence of a release of (the COC) from (the monitored facility)" is made to the Site 300 Remedial Program Managers (RPMs) within seven days of the finding.

15.9 Preparation and Disposition of Reports

The following reports document monitoring results from both the compliance and the surveillance networks.

- The annual *Environmental Report*. Ground water surveillance monitoring data and significant results for a calendar year are summarized in the water chapter of the annual *Environmental Report* that is widely distributed to state and federal agencies and to the public. Summaries of the compliance monitoring at Site 300 are also included in the report. The report is recorded on a compact disk (CD). Surveillance ground water monitoring data are included in tables on the *Environmental Report* CD.

- *LLNL Experimental Test Site 300 Compliance Monitoring Program for RCRA-Closed Landfill Pits 1 & 7* (e.g., Christofferson and MacQueen 2004). This report is submitted quarterly to the CVRWQCB. Required contents are tables of measurements made during a quarter or year, a summary of the measurement data with regard to compliance, and a short discussion of monitoring results, including any water quality violations. The fourth-quarter report (annual report) is included on the *Environmental Report* CD for that year.

- *LLNL Experimental Test Site 300 Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill* (e.g., Christofferson and Blake 2004). This report is submitted quarterly to the Site 300 RPMs. Required contents are tables of measurements made during a quarter or year, a summary of the measurement data with regard to compliance, and a short discussion of monitoring results, including any water quality violations. The fourth-quarter report (annual report) is included on the *Environmental Report* CD for that year.

- *LLNL Experimental Test Site 300 Compliance Monitoring Report for Waste Discharge Requirements 96-248* (e.g., Laycak 2004). This reports is submitted quarterly to the CVRWQCB. Contents of the reports are similar to the reports outlined above for closed landfills. The fourth-quarter report (annual report) is included on the *Environmental Report* CD for that year.
- *LLNL Experimental Test Site 300 Compliance Monitoring Program for the Closed Building 829 Facility Annual Report* (e.g., Revelli 2004). This report is submitted annually to DTSC. Report contents are similar to the reports outlined above for closed landfills. The report is included on the *Environmental Report* CD for that year.

- Occurrence Reports. An occurrence report may be required when a permitted COC concentration is exceeded, if it entails nonroutine reporting to a regulatory agency.

15.10 Plans for the Future

15.10.1 Livermore Site and Livermore Valley Surveillance Monitoring

Immediate short-term plans include sampling and analyzing the 25 monitoring wells on and adjacent to the Livermore site and the 23 off-site tritium wells described in this plan for the next few years. These analyses will confirm present baseline conditions and detect any possible additional contamination (particularly radiological) that may leach into ground water and migrate off site.

Ongoing analyses will determine the need for long-term additions to the ground water surveillance monitoring program and will determine sampling frequencies.

No changes to the off-site tritium monitoring program are planned for the immediate future.

15.10.2 Site 300 Surveillance Monitoring

Surveillance monitoring at Site 300 requires revision, because of a greatly expanded program of ground water monitoring begun there in 2003 by ERD. Much of the sampling and analytical work previously done under ORAD surveillance monitoring is now part of ERD's *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at LLNL*

Site 300 (Ferry et al. 2002), including the monitoring of the closed landfill pits 2, 8, and 9. Alternative surveillance plans are proposed. Alternative one is to discontinue the monitoring of all but two surveillance locations in Elk Ravine, 812CRK (spring 6) and well K2-07 (Figure 15-5), which are currently beyond, but will be reached eventually by existing contaminant plumes in Elk Ravine. This alternative would result in a cost savings to the ORAD surveillance program. Alternative two is to conduct random surveillance sampling of the more than 400 CERCLA wells at Site 300 at a rate of up to ten wells per quarter. This alternative could be adjusted to be in line with current surveillance costs.

15.10.3 Off-Site 300 Surveillance Monitoring

No changes to this off-site surveillance monitoring program are planned for the immediate future. However, some cost savings to ORAD will be achieved by eliminating those analyses called for in ERD’s expanded monitoring plan (Ferry et al. 2002).

15.10.4 Pit 1 Compliance Monitoring

Future expectations for compliance ground water monitoring at Site 300 include further consolidation of the separate, but overlapping, monitoring plans for Pits 1 and 7 currently being followed (Rogers/Pacific Corporation 1990; CVRWQCB 1993).

15.10.5 Pit 6 Compliance Monitoring

No changes to ground water detection monitoring (ORAD’s part) are planned for the immediate future. Future changes may occur in corrective action monitoring program (ERD’s part, Ferry et al. 2002).

15.10.6 Pit 7 Compliance Monitoring

Future expectations for compliance ground water monitoring at Site 300 include further consolidation of the separate, but overlapping, monitoring plans for Pits 1 and 7 currently being followed (Rogers/Pacific Corporation 1990; CVRWQCB 1993).

15.10.7 Building 829 Compliance Monitoring

The sampling frequency for this monitoring network may be reduced in 2006, if approved by the DTSC.

15.10.8 Explosives Process Area Class II Surface Impoundments Compliance Monitoring

These impoundments may be closed in the near future (in 2005 at the earliest). If so, then the ground water monitoring requirements will likely be eliminated. In the interim, a letter has been sent to the CVRWQCB requesting approval for several changes to the analytical methods and SLs used in the monitoring program (Raber 2004).

15.10.9 Sewage Ponds Compliance Monitoring

No changes to this monitoring can be made without the approval of the CVRWQCB. The CVRWQCB is in the process of revising this portion of the WDR 96-248 permit. This could involve changes to the monitoring schedule.

15.10.10 Long-Term Ground Water Monitoring

Long-term monitoring at both the Livermore site and Site 300 is presented in the LLNL *Ground water Protection Management Program* (Brown 2002). Long-term monitoring evaluates the potential for ground water contamination and projects the migration of contaminants during a 50-year timeframe, in conjunction with existing land use development plans in the vicinity of both sites. Long-term monitoring seeks to detect ground water contamination at an early stage so that appropriate remedial steps can be considered in time to be effective. The monitoring plans will be assessed annually by the responsible analyst to determine whether the existing ground water networks are adequate for detecting current releases that, although not necessarily of concern today, could be of concern within the 50-year timeframe.

For Site 300, the process is much the same. Community growth expectations for Tracy and unincorporated areas of San Joaquin and Alameda Counties will be examined. These expected population and developmental pressures will be studied as they relate to LLNL's continuing remediation and monitoring activities in adjacent areas.

15.11 References

40 CFR Part 141. Code of Federal Regulations, Title 40, Part 141, *National Primary Drinking Water Regulations,* Office of the Federal Register, Washington, D. C.

40 CFR 265, Subpart F. Code of Federal Regulations, Title 40, Part 265, Subpart F, *Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities,* Office of the Federal Register, Washington, D .C.

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Table 15-1. Ground water monitoring, inorganic COCs, analytical methods, reporting limits, and action level concentrations

Constituent of concern (COC)	Analytical method	Reporting limit[(a)]	Action level concentration
Metals and minerals (mg/L)			
All alkalinities	EPA 310.1	1	TBD[(b)]
Aluminum	EPA 200.7 or 200.8	0.05	MCL[(c)]
Ammonia nitrogen (as N)	EPA 350.1, 350.2, or 350.3	0.025	RL[(d)]
Antimony	EPA 204.2 or 200.8	0.005	MCL
Arsenic	EPA 206.2 or 200.8	0.002	MCL
Barium	EPA 200.7 or 200.8	0.025	MCL
Beryllium	EPA 210.2 or 200.8	0.0002	MCL
Boron	EPA 200.7	0.05	TBD
Bromide	EPA 300.0	0.5	TBD
Cadmium	EPA 213.2 or 200.8	0.0005	MCL
Calcium	EPA 200.7	0.5	TBD
Chloride	EPA 300.0	0.5	TBD
Chromium	EPA 218.2, 200.7, or 200.8	0.001	MCL
Chromium(VI)	EPA 218.4 or 7196	0.002	MCL
Cobalt	EPA 200.7 or 200.8	0.025	TBD
Copper	EPA 200.7, 220.2, or 200.8	0.001	MCL
Fluoride	EPA 300.0, 340.1 or 340.2	0.05	MCL
Hardness, total (as $CaCO_3$)	SM2320B[(e)]	1	TBD
Iron	EPA 200.7 or 200.8	0.1	TBD
Lead	EPA 239.2 or 200.8	0.002	MCL
Magnesium	EPA 200.7 or 200.8	0.5	TBD
Manganese	EPA 200.7 or 200.8	0.03	RL
Mercury	EPA 245.1, 245.2, or 200.8	0.0002	MCL
Molybdenum	EPA 200.7 or 200.8	0.025	TBD
Nickel	EPA 249.2, 200.7, 200.8	0.002	MCL
Nitrate (as NO_3)	EPA 353.2, 354.1, or 300.0	0.5	MCL
Orthophosphate	EPA 300.0, 365.1, or 365.2	0.05	TBD
Perchlorate	EPA 314.0	0.004	TBD
Potassium	EPA 200.7 or 200.8	1	TBD
Selenium	EPA 270.2 or 200.8	0.002	MCL
Silver	EPA 272.2 or 200.8	0.0005 or 0.001	TBD
Sodium	EPA 200.7	1	TBD
Sulfate	EPA 300.0	1	TBD
Surfactants	EPA 425.1	0.5	TBD
Thallium	EPA 279.2 or 200.8	0.001	MCL
Total dissolved solids	EPA 160.1	1	TBD
Total Kjeldahl nitrogen	EPA 351.2 or 351.3	0.2	TBD
Total suspended solids	EPA 160.2	1	TBD
Vanadium	EPA 200.7 or 200.8	0.02	TBD
Zinc	EPA 200.7 or 200.8	0.02	TBD

(continued)

Table 15-1. Ground water monitoring, inorganic COCs, analytical methods, reporting limits, and action level concentrations (concluded)

Constituent of concern (COC)	Analytical method	Reporting limit[(a)]	Action level concentration
Phenolics (mg/L)			
Phenolics	EPA 420.1	0.005	TBD
General indicator parameters			
pH	EPA 150.1	none	TBD
Specific conductance (µS/cm)	EPA 120.1	none	TBD
Total organic carbon (mg/L)	EPA 9060 or 415.1	1.0	TBD
Total organic halides (mg/L)	EPA 9020	0.01	TBD
Explosive compounds (*µ*g/L)			
HMX(f)	EPA 8330	1 or 5	TBD
RDX(g)	EPA 8330	1 or 5	TBD
TNT(h)	EPA 8330	5	TBD
Radioactivity (Bq/L)			
Gross alpha	EPA 900.0	0.074	MCL
Gross beta	EPA 900.0	0.111	MCL
Radioisotopes (Bq/L)			
Americium 241	HASL-300(i)	0.0037	RL
Plutonium 238	HASL-300	0.0037	RL
Plutonium 239 + 240	HASL-300	0.0037	RL
Radon-222	EPA 913.0	3.7	TBD
Radium-226	EPA 903.1	0.009	MCL
Radium-228	EPA 904.0	0.037	MCL
Thorium-228	HASL-300	0.009	TBD
Thorium-232	HASL-300	0.006	TBD
Tritium	EPA 906.0	3.7	MCL
Uranium-234	HASL-300	0.0037	MCL
Uranium-235	HASL-300	0.0037	MCL
Uranium-238	HASL-300	0.0037	MCL

a The significant figures displayed in this table vary by COC. These variations reflect regulatory agency permit stipulations, or the applicable analytical laboratory contract under which the work was performed, or both. Reporting limits listed are lowest possible limits as of November 2001.

b TBD = To be determined

c MCL = Maximum contaminant level

d RL = Reporting limit

e SM = Standard Methods, rather than EPA Methods

f HMX = octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine

g RDX = hexahydro-1,3,5-trinitro-1,3,5-triazine

h TNT = 2,4,6-trinitrotoluene

i HASL = Health and Safety Laboratory of DOE's Environmental Monitoring Laboratory. HASL-300 is a procedures manual for radiochemical and other analytical procedures (EML 1990).

Table 15-2. Ground water monitoring, organic COCs by EPA analytical method

Constituent of concern (COC)	Action level concentration[a,b] (µg/L)
EPA Method 502.2	
1,1,1,2-Tetrachloroethane	0.5
1,1,1-Trichloroethane	0.5
1,1,2,2-Tetrachloroethane	0.5
1,1,2-Trichloroethane	0.5
1,1-Dichloroethane	0.5
1,1-Dichloroethene	0.5
1,1-Dichloropropene	0.5
1,2,3-Trichlorobenzene	0.5
1,2,3-Trichloropropane	0.5
1,2,4-Trichlorobenzene	0.5
1,2,4-Trimethylbenzene	0.5
1,2-Dichlorobenzene	0.5
1,2-Dichloroethane	0.5
1,2-Dichloropropane	0.5
1,3,5-Trimethylbenzene	0.5
1,3-Dichlorobenzene	0.5
1,3-Dichloropropane	0.5
1,4-Dichlorobenzene	0.5
2,2-Dichloropropane	0.5
2-Chlorotoluene	0.5
4-Chlorotoluene	0.5
Benzene	0.5
Bromobenzene	0.5
Bromochloromethane	0.5
Bromodichloromethane	0.5
Bromoform	0.5
Bromomethane	0.5
Carbon tetrachloride	0.5
Chlorobenzene	0.5
Chloroethane	0.5
Chloroform	0.5
Chloromethane	0.5
cis-1,2-Dichloroethene	0.5
cis-1,3-Dichloropropene	0.5
Dibromochloromethane	0.5
Dibromomethane	0.2
Dichlorodifluoromethane	0.5
Ethylbenzene	0.5
Freon 113	0.5
Hexachlorobutadiene	0.5
Isopropylbenzene	0.5
m- and p-Xylene isomers	0.5
Methylene chloride	0.5
n-Butylbenzene	0.5
n-Propylbenzene	0.5
Naphthalene	0.5
o-Xylene	0.5
Isopropyl toluene	0.5
sec-Butylbenzene	0.5
Styrene	0.5
tert-Butylbenzene	0.5
Tetrachloroethene	0.5
Toluene	0.5
trans-1,2-Dichloroethene	0.5
trans-1,3-Dichloropropene	0.5
Trichloroethene	0.5
Trichlorofluoromethane	0.5
Vinyl chloride	0.5
EPA Method 507 or 525.2	
Alachlor	0.5
Atraton	0.6
Atrazine	0.5
Bromacil	1

(continued)

Table 15-2. Ground water monitoring, organic COCs by EPA analytical method (continued)

Constituent of concern (COC)	Action level concentration(a,b) (µg/L)
EPA Method 507 or 525.2 (cont'd)	
Butachlor	0.5
Diazinon	0.5
Dichlorvos	0.5
Dimethoate	0.5
Ethoprop	0.5
Merphos	0.5
Metolachlor	0.7
Metribuzin	0.5
Mevinphos	0.5
Molinate	0.5
Prometon	0.5
Prometryn	0.5
Simazine	0.5
Terbutryn	0.5
EPA Method 524.2	
1,1,1,2-Tetrachloroethane	1
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1-Dichloroethane	1
1,1-Dichloroethene	1
1,1-Dichloropropene	1
1,2,3-Trichlorobenzene	1
1,2,3-Trichloropropane	1
1,2,4-Trichlorobenzene	1
1,2,4-Trimethylbenzene	1
1,2-Dibromo-3-chloropropane	2
1,2-Dichlorobenzene	1
1,2-Dichloroethane	1
1,2-Dichloropropane	1
1,3,5-Trimethylbenzene	1
1,3-Dichlorobenzene	1
1,3-Dichloropropane	1
1,4-Dichlorobenzene	1
2-Chlorotoluene	1
4-Chlorotoluene	1
Benzene	1
Bromobenzene	1
Bromodichloromethane	1
Bromoform	1
Bromomethane	2
Carbon tetrachloride	1
Chlorobenzene	1
Chloroethane	2
Chloroform	1
Chloromethane	2
cis-1,2-Dichloroethene	1
cis-1,3-Dichloropropene	1
Dibromochloromethane	1
Dibromomethane	1
Dichlorodifluoromethane	2
Ethylbenzene	1
Ethylene dibromide	1
Freon 113	1
Hexachlorobutadiene	1
Isopropylbenzene	1
m- and p-Xylene isomers	1
Methylene chloride	1
n-Butylbenzene	1
n-Propylbenzene	1
Naphthalene	1
o-Xylene	1
Isopropyl toluene	1
sec-Butylbenzene	1
Styrene	1
tert-Butylbenzene	1

(continued)

Table 15-2. Ground water monitoring, organic COCs by EPA analytical method (continued)

Constituent of concern (COC)	Action level concentration$^{(a,b)}$ (µg/L)
EPA Method 524.2 (cont'd)	
Tetrachloroethene	1
Toluene	1
trans-1,2-Dichloroethene	1
trans-1,3-Dichloropropene	1
Trichloroethene	0.5
Trichlorofluoromethane	1
Vinyl chloride	2
EPA Method 547	
Glyphosate	20
EPA Method 601	
1,1,1-Trichloroethane	0.5
1,1,2,2-Tetrachloroethane	0.5
1,1,2-Trichloroethane	0.5
1,1-Dichloroethane	0.5
1,1-Dichloroethene	0.5
1,2-Dichlorobenzene	0.5
1,2-Dichloroethane	0.5
cis-1,2-Dichloroethene	0.5
trans-1,2-Dichloroethene	0.5
1,2-Dichloroethene (total)	1.0
1,2-Dichloropropane	0.5
1,3-Dichlorobenzene	0.5
1,4-Dichlorobenzene	0.5
2-Chloroethylvinylether	0.5
Bromodichloromethane	1.0
Bromoform	0.5
Bromomethane	0.5
Carbon tetrachloride	0.5
Chlorobenzene	0.5
Chloroethane	0.5
Chloroform	0.5
Chloromethane	1.0
cis-1,3-Dichloropropene	0.5
Dibromochloromethane	0.5
Dichlorodifluoromethane	0.5
Freon 113	0.5
Methylene chloride	1.0
Tetrachloroethene (PCE)	0.5
trans-1,3-Dichloropropene	0.5
Trichloroethene (TCE)	0.5
Trichlorofluoromethane	0.5
Vinyl chloride	0.5
EPA Method 602	
1,2-Dichlorobenzene	0.3
1,3-Dichlorobenzene	0.3
1,4-Dichlorobenzene	0.3
Benzene	0.4
Chlorobenzene	0.3
Ethylbenzene	0.3
m- and p-Xylene isomers	0.4
o-Xylene	0.4
Toluene	0.3
Total xylene isomers	0.4
EPA Method 608	
Aldrin	0.05
BHC, alpha isomer	0.05
BHC, beta isomer	0.05
BHC, delta isomer	0.05
BHC, gamma isomer (Lindane)	0.05
Chlordane	0.5
Dieldrin	0.1
Endosulfan I	0.05
Endosulfan II	0.1

(continued)

Table 15-2. Ground water monitoring, organic COCs by EPA analytical method (continued)

Constituent of concern (COC)	Action level concentration$^{(a,b)}$ (µg/L)
EPA Method 608 (cont'd)	
Endosulfan sulfate	0.1
Endrin	0.1
Endrin aldehyde	0.1
Heptachlor	0.05
Heptachlor epoxide	0.05
Methoxychlor	0.5
4,4'-DDD	0.1
4,4'-DDE	0.1
4,4'-DDT	0.1
Toxaphene	2
EPA Method 615	
2,4,5-T	0.5
2,4,5-TP (Silvex)	0.2
2,4-D	1
2,4-Dichlorophenoxy acetic acid	2
Dalapon	10
Dicamba	1
Dichloroprop	2
Dinoseb	1
MCPA	250
MCPP	250
EPA Method 624	
1,1,1-Trichloroethane	1
1,1,2,2-Tetrachloroethane	1
1,1,2-Trichloroethane	1
1,1-Dichloroethane	1
1,1-Dichloroethene	1
1,2-Dichlorobenzene	1
1,2-Dichloroethane	1
cis-1,2-Dichloroethene	1
trans-1,2-Dichloroethene	1
1,2 Dichloroethene (total)	1
1,2-Dichloropropane	1
1,3-Dichlorobenzene	1
1,4-Dichlorobenzene	1
2-Butanone	20
2-Chloroethylvinylether	20
2-Hexanone	20
4-Methyl-2-pentanone	20
Acetone	10
Benzene	1
Bromodichloromethane	1
Bromoform	1
Bromomethane	2
Carbon disulfide	1
Carbon tetrachloride	1
Chlorobenzene	1
Chloroethane	2
Chloroform	1
Chloromethane	2
cis-1,3-Dichloropropene	1
trans-1,3-Dichloropropene	1
Dibromochloromethane	1
Dibromomethane	1
Dichlorodifluoromethane	2
Ethylbenzene	1
Freon 113	1
Methylene chloride	1
Styrene	1
Tetrachloroethene (PCE)	1
Toluene	1
Total xylene isomers	2
Trichloroethene (TCE)	0.5

(continued)

Table 15-2. Ground water monitoring, organic COCs by EPA analytical method (continued)

Constituent of concern (COC)	Action level concentration(a,b) (µg/L)
EPA Method 624 (cont'd)	
Trichlorofluoromethane	1
Vinyl acetate	1
Vinyl chloride	1
EPA Method 625	
1,2,4-Trichlorobenzene	5
1,2-Dichlorobenzene	5
1,3-Dichlorobenzene	5
1,4-Dichlorobenzene	5
2,4,5-Trichlorophenol	5
2,4,6-Trichlorophenol	5
2,4-Dichlorophenol	5
2,4-Dimethylphenol	5
2,4-Dinitrophenol	25
2,4-Dinitrotoluene	5
2,6-Dinitrotoluene	5
2-Chloronaphthalene	5
2-Chlorophenol	5
2-Methylphenol	5
2-Methyl-4,6-dinitrophenol	25
2-Methylnaphthalene	5
2-Nitroaniline	25
3,3'-Dichlorobenzidine	10
3-Nitroaniline	25
4-Bromophenylphenylether	5
4-Chloro-3-methylphenol	10
4-Chloroaniline	10
4-Chlorophenylphenylether	5
4-Nitroaniline	25
4-Nitrophenol	25
Acenaphthene	25
Acenaphthylene	5
Anthracene	5
Benzo(a)anthracene	5
Benzo(a)pyrene	5
Benzo(b)fluoranthene	5
Benzo(g,h,i)perylene	5
Benzo(k)fluoranthene	5
Benzoic acid	50
Benzyl alcohol	10
Bis(2-chloroethoxy)methane	5
Bis(2-chloroisopropyl)ether	5
Bis(2-ethylhexyl)phthalate	5
Butylbenzylphthalate	5
Chrysene	5
Di-n-butylphthalate	5
Di-n-octylphthalate	5
Dibenzo(a,h)anthracene	5
Dibenzofuran	5
Diethylphthalate	5
Dimethylphthalate	5
Fluoranthene	5
Fluorene	5
Hexachlorobenzene	5
Hexachlorobutadiene	5
Hexachlorocyclopentadiene	5
Hexachloroethane	5
Indeno[1,2,3-c,d] pyrene	5
Isophorone	5
m- and p-Cresol	5
N-Nitroso-di-n-propylamine	5
Naphthalene	5
Nitrobenzene	5
Pentachlorophenol	5
Phenanthrene	5
Phenol	5
Pyrene	5
EPA Method 632	
Diuron	0.1
EPA Method 8082A	
Aroclor-1016	0.5
Aroclor-1221	0.5

(continued)

Table 15-2. Ground water monitoring, organic COCs by EPA analytical method (concluded)

Constituent of concern (COC)	Action level concentration[(a,b)] (µg/L)
EPA Method 8082A (cont'd)	
Aroclor-1232	0.5
Aroclor-1242	0.5
Aroclor-1248	0.5
Aroclor-1254	0.5
Aroclor-1260	0.5
EPA Method 8140	
Bolstar	1.0
Chlorpyrifos	1.0
Coumaphos	1.0
Demeton	1.0
Diazinon	1.0
Dichlorvos	1.0
Disulfoton	1.0
Ethoprop	1.0
Fensulfothion	1.0
Fenthion	1.0
Merphos	1.0
Methyl parathion	1.0
Mevinphos	1.0
Naled	1.0
Phorate	1.0
Prothiophos	1.0
Ronnel	1.0
Stirophos	1.0
Trichloronate	1.0

a The significant figures displayed in this table vary by COC. These variations reflect regulatory agency permit stipulations, or the applicable analytical laboratory contract under which the work was performed, or both. Action level concentrations listed correspond with the lowest possible reporting limits as of November 2001.

b For each COC, the action level concentration is the reporting limit.

16 Soil and Sediment

Gretchen M. Gallegos • Richard A. Brown

16.1 Introduction

Soil is an integrating medium that can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. For the purpose of surveillance monitoring, “soil” is defined as the top layer of earth, suitable for the growth of plants; and “sediment” is defined as recently deposited, finely divided solid material that has settled out of a liquid stream in an arroyo or other storm water drainage. In a geologic sense, all Livermore site soils are sediment.

Sedimentary materials in active streambeds can accumulate contaminants. Sampling and analysis of these sediments can provide a measure of waterborne radionuclides not available from direct water sampling because of the potential accumulation of contaminants in sediment.

16.2 Rationale And Design Criteria

16.2.1 Regulatory Drivers

Soil and sediment monitoring efforts are driven by the applicable portions of Department of Energy (DOE) Order 5400.1[1] and 5400.5. DOE Order 5400.1 states that environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on environmental and natural resources both onsite and offsite. The objective of DOE Order 5400.5 is for DOE to operate its facilities and conduct its activities so that radiation exposures to members of the public are maintained within the limits established by the order. It is also a DOE objective that potential exposure to members of the public be as far below limits as is reasonably achievable (ALARA) and that DOE facilities have the capabilities to monitor for such releases.

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

Soil and sediment are specifically mentioned in the DOE guidance for environmental monitoring, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991), as environmental media that should be analyzed to determine the impacts of facility operations. DOE states that “periodic sampling and analysis of indicator materials, such as soil . . . should be performed to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment. . . . Soil sampling and analysis should be used to evaluate the long-term accumulation trends and to estimate environmental radionuclide inventories” (DOE 1991).

In addition, “the sampling of sedimentary material from streams or ponds can provide an indication of the accumulation of undissolved radionuclides in the aquatic environment. The accumulation of radioactive materials in sediment can lead to exposure of humans through ingestion of aquatic species, through sediment resuspension into drinking water supplies, or as an external radiation source. . . .” (DOE 1991). The cleanup of contaminated sedimentary materials is regulated by a number of federal laws, including the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA); Resource Conservation and Recovery Act (RCRA); Clean Water Act; Toxic Substances Control Act; and Oil Pollution Act; however, these laws do not address the routine surveillance monitoring of sediment.

No specific guidance or regulations requiring or recommending soil monitoring for surveillance of the nonradiological environmental effects of ongoing operations have been identified. However, explicit regulatory requirements are not the sole basis for monitoring. Monitoring is carried out where there is a high level of public interest or concern, or where best management practices indicate monitoring is appropriate. Best management practice evaluations have indicated that sediment samples should be evaluated for metals and known contaminants, and that soil samples at Site 300 should be evaluated for beryllium.

16.2.2 Monitoring Objectives

LLNL conducts soil and sediment surveillance monitoring to evaluate long-term accumulation trends and to estimate environmental radionuclide inventories. DOE monitoring guidance specifies that nuclides in use at a facility, as well as naturally occurring nuclides, should be monitored. In particular, the guidance states: “it is desirable to assess, document, and periodically reassess the distribution and fate of radionuclides in the environment, especially plutonium in soil samples” (DOE 1991).

The most significant pathway of soil contamination, barring direct contamination by dumping (which is prevented by LLNL administrative and management controls) is the deposition of materials from the air, whereas the pathway for sediment contamination is a combination of deposition from the air and from water. Consequently, the surveillance soils monitoring program addresses the surface of the soil on which materials can be deposited or from which materials can be resuspended. However, when air monitoring is carried out routinely, as at LLNL, soil sampling plays a supplementary role in the monitoring program (Hardy and Krey 1971). Similarly, the sediment monitoring plays a supplementary role to both the air monitoring and the water monitoring programs.

The two primary objectives of the soil and sediment monitoring program are (1) to establish background levels of radioactive fallout radionuclides, naturally occurring radionuclides, and naturally occurring metals and (2) to assess the effects, if any, of LLNL operations on soils and sediments.

16.2.3 Sources and Analytes

Soil and sediment contaminants can be solids, liquids, or gases. All types of materials can settle out of the atmosphere or can be scoured from the atmosphere and transported by rainfall.

At the LLNL Livermore site, the major potential sources of radionuclides are the Building 332 Plutonium Facility; the Building 331 Tritium Facility; the southeast quadrant, from which low levels of plutonium can be resuspended; and the Decontamination and Waste Treatment Facility (DWTF) and other waste management treatment and storage areas, from which materials can be emitted or resuspended. All soil and sediment samples are analyzed for plutonium and gamma-emitting nuclides; sediment samples are also analyzed for tritium because these samples are taken in locations that channel water on the site. In addition, the tritium results are used in dose to biota calculations set forth by DOE in the guidance document, “DOE Standard: A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota” (DOE 2002), and the RAD-BCG (Biota Concentration Guides) Calculator (Version 2). DOE sites are requested to calculate dose to biota based upon this guidance, and tritium measured in sediment is one of the primary contributors to dose by this calculation. In addition, sediment is analyzed for gross alpha and gross beta to provide a comparison point for the data obtained from these measurements in surface water.

The radiological analytes of interest at Site 300 are the isotopes of uranium, especially uranium-238 and uranium-235, and the ratio of these values in a given sample. Depleted uranium (i.e., natural uranium depleted of much of the uranium-235) has historically been and is currently used in experimental tests at Site 300. The variation of the sample ratio of uranium-235/uranium-238 from the natural ratio of 0.726 percent gives an indication of the impact of LLNL operations on the site.

Beryllium is also used in explosive tests at Site 300. Preliminary results of dispersion measurements and modeling of beryllium from high explosive tests at Site 300 during 1991 show that these tests have a very small "footprint" and that soils testing would only show elevated levels of beryllium if the soil samples are obtained in that footprint. In addition, not all beryllium in the test shot becomes part of the explosive cloud (Baskett 1994). However, in view of the fact that some samples at locations near firing tables show increased beryllium levels, samples representing background and soils near firing table operations at Site 300 continue to be analyzed for beryllium.

Sediment contaminants of concern are the same radionuclides as soils, but additionally include metals and PCBs. Metals and PCBs in sediments are of interest because of the possibility of transport of these materials from storm water channels to groundwater through the vadose zone at the site. PCBs are of particular interest at a known site of contamination. (For information about PCBs see the EPA web page *http://www.epa.gov/OGWDW/dwh/t-soc/pcbs.html*.) The metals analyses for sediments include both total and soluble concentrations of metals. The current Livermore site sediment monitoring program is conducted as part of the groundwater protection management effort (discussed in Chapter 15).

16.2.4 Collection Methods

There are three generally accepted methods for collecting soils samples: coring, template, and trench. The coring method uses a coring tool to take samples of a standard volume and depth; it usually involves taking a number of samples to a depth of 5 cm to represent one sampling location. The template method is used in locations where the presence of rocks makes it impossible to collect samples using the coring method. The template method employs a square, cold-rolled steel template, 20 or 30 cm on the inner edge, to mark an area; the area is then excavated to the appropriate depth using chisels and scoops. The trench method is used to establish a depth profile. It requires digging a trench about 60 cm wide by 90 cm long by 60 cm deep and taking samples by pressing a flat-bottomed, three-sided pan with cutting edges on the open side into the face of the trench.

The coring method is preferred for collecting surface samples from soil. LLNL follows the coring method set out by the American Society for Testing and Materials, *Standard Practice for Sampling Surface Soils for Radionuclides* (ASTM 1990). The sampling technologist chooses two 1-m^2 areas from which to collect the sample. Surface vegetation is cleared away from the sampling area, and an LLNL-designed, stainless steel core sampler (8.25 cm in diameter) is driven into the ground to a depth of 5 cm for each subsample. The sample is a composite consisting of ten subsamples collected individually at the four corners and the center of each square (procedure EMP-S-S, *Soil and Arroyo*

Sediment Sampling). As previously determined by soil profiles to 30 cm deep, a surface sample from a depth of 5 cm is sufficiently deep to obtain 90 to 95 percent of airborne material, and the results are reproducible (EML 1997).

The coring method is also used to collect sediment samples. As previously determined by a comparison of samples taken 30–45 cm deep and 0–5 cm deep, a sediment sample taken 0–5 cm deep is sufficient to obtain materials deposited in the sediment sampling locations (Gallegos et al. 1993). For particulate radionuclide and metals analysis, the sediment coring samples are collected the same way as soil samples, except the ten subsamples are taken at 1-m intervals along a linear transect that approximates the center line of the arroyo or channel. The transect is plotted to get a sample that is representative of the flow of water and resultant deposition from what is known to be a spatially heterogeneous deposition process. For tritium analysis, a sample is taken 5–15 cm deep from one core of the transect. Because the concern being addressed by sampling for PCBs is the potential effect of sediment contamination on groundwater, and because PCBs are not present in as great a concentration at the surface as at depth, these samples are collected at 45–65 cm deep.

16.3 Extent and Frequency of Monitoring and Measurement

16.3.1 Sampling Locations

No set number of soil sampling locations is required. Soil sampling locations are selected based on the following criteria:

- Proximity to LLNL and the potential for being affected by LLNL operations from wind deposition of contaminants,
- Background locations with geologically similar substrates as those near LLNL, but unlikely to be affected by LLNL operations,
- Areas of known or suspected LLNL-induced contamination, and
- Proximity to an air sampling location to enable analysis of resuspension.

Specific sampling locations should represent the geographical areas in which they are located. Some areas—such as frequently tilled or disturbed areas, locations near buildings or other obstructions, or areas with unusual wind or precipitation influences—are avoided because samples are intended to be representative of the geographical area. Practical considerations also influence the selection of sampling locations. The use of private property is discouraged because private ownership may change, and attitudes toward sampling may also change. Also, private property may be developed, rendering the location no longer useful. If a location on private property is chosen, a written access agreement is required. Government installations (federal, state, city, or regional) can be good sources of sampling locations as long as appropriate arrangements are made and development does not occur on the property. Other considerations for sampling locations include locations of underground utilities, access during inclement weather, and the safety of personnel in vehicle operation or sample collection.

Consistent sampling locations enable evaluation of long-term trends. The LLNL environmental monitoring program soil sampling locations are shown in Figure 16-1 and Figure 16-2. Specific location descriptions are maintained in the Sampling Locations Database (EMP-QAS-LOC, *Locations Database SOP Supplement*). The supplement also describes the process to be used for defining, documenting, and approving sampling locations.

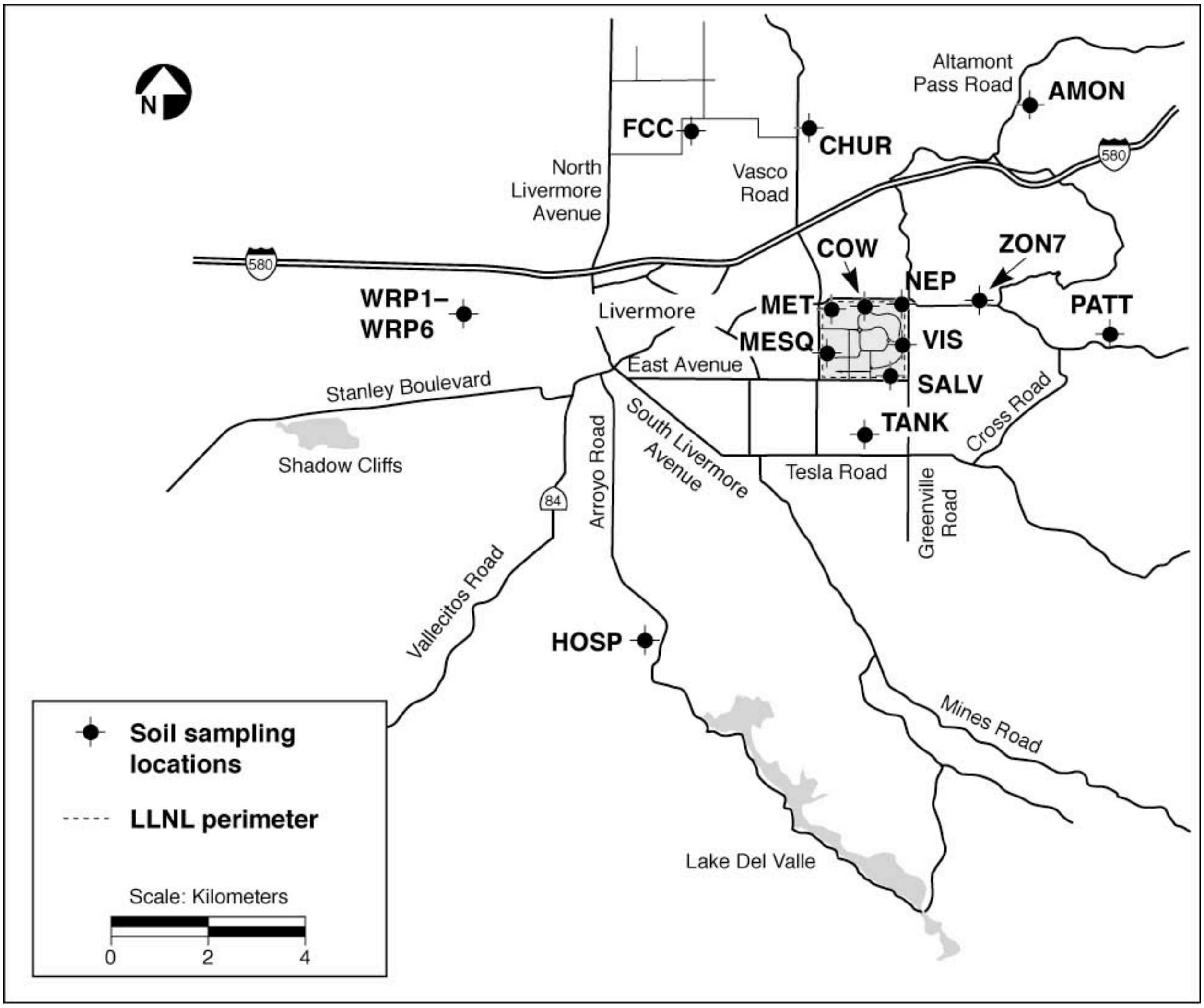

Figure 16-1. Soil sampling locations, Livermore Valley

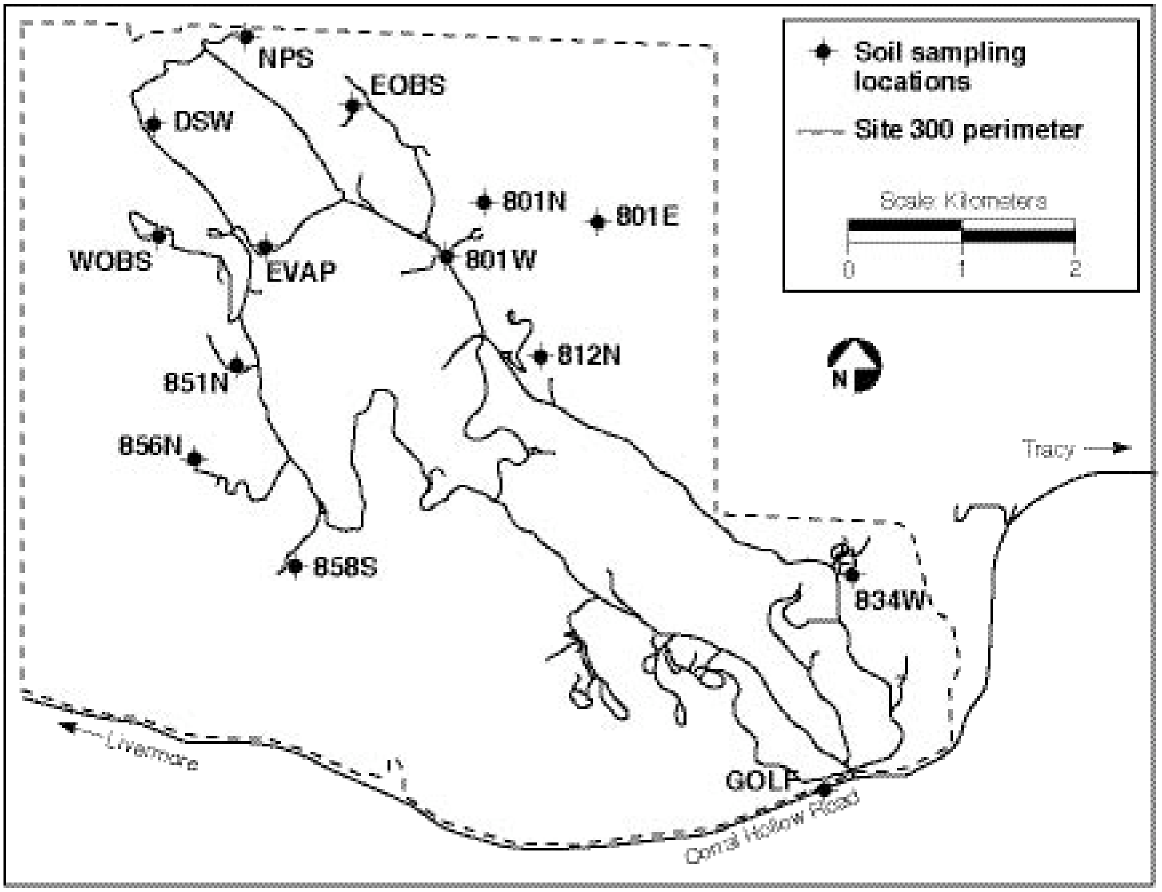

Figure 16-2. Site 300 soil sampling locations

Six soil sampling locations are positioned around the Livermore site perimeter; four sampling locations are offsite in generally downwind directions; and three sampling locations are offsite in generally upwind directions, representing background locations. Two of the generally upwind perimeter locations, MET and MESQ (Figure 16-1), may not both be necessary, but both are air particulate monitoring locations, and both are near offsite areas that have been developed for residential use. In addition, samples are collected at the Livermore Water Reclamation Plant (LWRP); historic releases, including an estimated 32-mCi plutonium release to the sewer in 1967, resulted in local contamination of soils in the area around the LWRP. Six locations are sampled at the LWRP to monitor the area. Construction at the LWRP site in recent years has reduced the surface area of concern; continued construction or paving the surface may remove some of these locations. Another 14 sampling locations are at Site 300 near active or historic experimental test sites and at background locations.

Sediment sampling locations are selected based on the following criteria:

- An influent or effluent point of an arroyo or storm drainage channel to represent sediment conditions as water flows onto or away from the Livermore site,
- A location where sediment collects in large volume,
- Areas of known or suspected LLNL-induced contamination, and
- A location that drains an area potentially affected by ongoing LLNL operations.

Other considerations include access to the location, location of underground utilities, the use of the location as a storm water sampling point so that data comparisons can be made, and safety of personnel during vehicle operation or sample collection.

Sediment samples are collected at three locations around the Livermore site: two in the Arroyo Las Positas and one in a settling basin that precedes drainage into the Drainage Retention Basin (Figure 16-3). Sediment sampling locations have been removed from the Arroyo Seco. Upstream modifications have caused the stream channel to be scoured and no sediment is deposited. Similarly, sediment sampling locations have not been established at Site 300. The drainage courses at Site 300 are steep, causing the flowing water to scour the drainages, so that sediment is not deposited. The need for sediment sampling in these locations will continue to be evaluated as modifications to surface flow are implemented.

Specific location descriptions are maintained in the Sampling Locations Database (EMP-QAS-LOC, *Locations Database SOP Supplement*).

16.3.2 Sampling Frequency

Soil and sediment sampling is conducted annually, as recommended by DOE/EH-0173T (DOE 1991) for sampling that is conducted to determine trends. Soil and sediment sampling is generally conducted in the second or third quarter of each year. In these quarters, the soils and sediments are no longer extremely wet from the rainy season and new sediment has been deposited. An important constraint on soil and sediment sampling is that it should no be conducted when the ambient air temperature is so high that sampling technologists will suffer heat-related stress due the physically demanding effort required to collect the samples. A further constraint on sediment sampling in the Arroyo Las Positas is the presence of water due to releases from the Drainage Retention Basin. The sediment sampling must be coordinated with the Wildlife Biologist who arranges for flow to cease, if possible, in late August or early September.

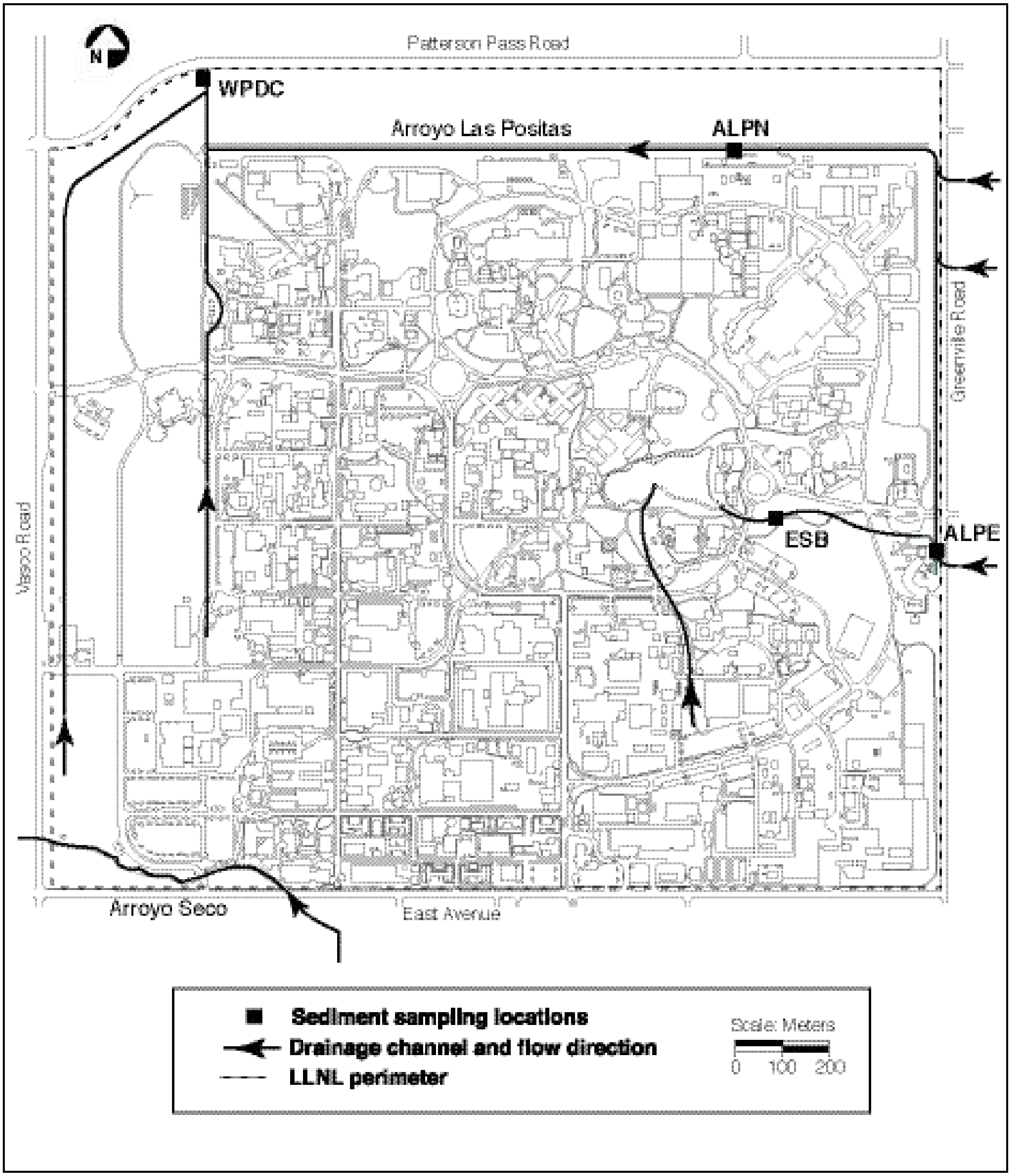

Figure 16-3. Arroyo and drainage basin sediment sampling locations

16.4 Procedures for Laboratory Analysis

Preservation is not required for soils and sediment samples that are analyzed for particulate radionuclides. Sediment samples that are analyzed for tritium are chilled in the field and frozen until analyzed. Sediment samples collected for metals and PCB analysis are kept cool until analysis; they are kept on dry ice while in the field; samples for Total Threshold Limit Concentration (TTLC) and Soluble Threshold Limit Concentration (STLC) metals analyses are stored in a refrigerator and samples for PCB analysis are kept in a freezer. The samples are still refrigerated or frozen when delivered to analytical laboratories.

Soil samples to be analyzed for plutonium and gamma-emitting radionuclides have defined sample preparation requirements. These samples are dried at 100°C for at least two days, pulverized in a grinding mill, sieved through a 32-mesh sieve, and blended. Samples for gamma analysis are packed in a tared, steel can and allowed to equilibrate for at least 30 days before counting.

Radiological analyses for soil and sediment samples are completed by LLNL's Chemistry and Materials Sciences Environmental Monitoring Radiological Laboratory (EMRL). EMRL follows verified analytical methods in its radiological analyses. The methods used include the following:

- plutonium-238 and plutonium-239+240 by alpha spectroscopy following acid leaching.
- tritium by liquid scintillation following freeze-dry extraction of the soil moisture.
- gamma scan by EPA Method 901.1 using a high purity germanium detector. The library for the gamma scan includes 47 radionuclides and over 350 gamma rays. The radionuclides include fission products (Zr-95, Nb-95, Sb-125, I-131, Cs-137, Cs-134, Ce-141, Ce-144, Eu-152, Eu-154, and Eu-155), activation products from neutron interactions on steel (Mn-54, Co-57, Co-60, Zn-65, Ag-108m, and Ag-110m), actinides (Pu-239, Pu-241, and Am-24), and naturally occurring radionuclides (Be-7, K-40, U-235, U-238, Th-232, Ra-226, and Ra-228). In addition, any peaks not identified in the standard library are manually identified from other references. So effectively all radioisotopes that emit gammas above minimum detectable limits are being scanned, regardless of the gamma library used.

Nonradiological analyses are performed by off-site laboratories. Standard EPA methods are used, including EPA Methods 200.7, 245.2, 7471A and 6010B for total metals. Soluble extraction and metals analyses are carried out by California's Waste Extraction

Test (WET), followed by the same analyses used for total metals on that extract. Analysis of polychlorinated biphenyls by EPA Method 8082. Beryllium content is determined by atomic emission spectrometry (EPA Method 200.7). Chain-of-custody procedures are followed throughout the sampling, delivery, and analytical processes.

16.5 Data Quality Assurance

16.5.1 Precision

The detection limits for radionuclides in soils are shown in Table 16-1.

Table 16-1. Detection limits for radionuclides in soil

Radionuclide	Detection Limit (Bq/g)
$^{239+240}$Pu	1.0×10^{-6}
^{137}Cs	1.0×10^{-4}
^{238}U	2.0×10^{-2}
^{235}U	2.0×10^{-4}
^{232}Th	1.0×10^{-3}
^{40}K	1.0×10^{-2}
^{3}H	1.7 (Bq/L of extracted moisture)

A lower detection limit for uranium-238 would be advantageous because it would be useful to have well-characterized background values. However, the current detection limit is sufficient to determine impacts on areas affected by LLNL operations, and the expense of analytical methods with more sensitive detection limits is not justified.

The detection limit for beryllium in soils is 0.5 mg/kg.

The analytes, analytical methods, and reporting limits for total metals, soluble metals, and organic compounds are shown in Table 16-2.

In accordance with LLNL procedure EMP-S-S, *Soil and Arroyo Sediment Sampling*, field duplicate samples are submitted with each batch of soil samples. At locations chosen for duplicate samples, two identical samples are collected. Adjacent cores are collected from the corners and the center of the sampling square. Separate composites of ten cores each are made, and the two samples are identified with unique sample identifier codes. Similarly, duplicate 10-g aliquots for beryllium analyses are produced. The sampling locations of field duplicate samples are not identified on the sample bags, the sample identification tags, or vial labels, so that the analytical laboratory does not know where the samples originated (procedure EMP-QA-DM, *Sample and Data Management*). However, this information is recorded on field tracking forms (FTFs), which are filled

Table 16-2. Analytes, analytical methods, and reporting limits for subsurface sediment samples

Analyte	Method	Reporting limit (mg/kg)
Total metals		
Antimony	EPA 6010 or 6020	1
Arsenic	EPA 6010 or 6020	0.5
Barium	EPA 6010 or 6020	5
Beryllium	EPA 6010 or 6020	0.5
Cadmium	EPA 6010 or 6020	0.1
Chromium	EPA 6010 or 6020	5
Cobalt	EPA 6010 or 6020	5
Copper	EPA 6010 or 6020	5
Lead	EPA 6010 or 6020	10
Mercury	EPA 7471	0.05
Molybdenum	EPA 6010 or 6020	5
Nickel	EPA 6010 or 6020	10
Potassium	EPA 6010 or 6020	100
Selenium	EPA 6010 or 6020	2.5
Silver	EPA 6010 or 6020	2.5
Thallium	EPA 6010 or 6020	1
Vanadium	EPA 6010 or 6020	5
Zinc	EPA 6010 or 6020	5
Soluble metals	**CA WET followed by:**	**Reporting limit (mg/L)**
Antimony	EPA 6010 or 7041	0.06
Arsenic	EPA 6010 or 7060	0.05
Barium	EPA 6010 or 7041	0.5
Beryllium	EPA 6010 or 7091	0.04
Boron	EPA 6010 or 6020	0.5
Cadmium	EPA 6010 or 7130	0.05
Chromium	EPA 6010 or 6020	0.5
Cobalt	EPA 6010 or 6020	0.5
Copper	EPA 6010 or 6020	0.5
Iron	EPA 6010 or 6020	0.5
Lead	EPA 6010 or 7420	0.5
Manganese	EPA 6010 or 6020	0.15
Mercury	EPA 245.2 or 7471	0.005
Molybdenum	EPA 6010 or 6020	0.5
Nickel	EPA 6010 or 6020	0.5
Potassium	EPA 6010 or 6020	10
Selenium	EPA 6010 or 7740	0.05
Silver	EPA 6010 or 7760	0.5

(continued)

Table 16-2. Analytes, analytical methods, and reporting limits for subsurface sediment samples (cont'd)

Analyte	Method	Reporting limit (mg/L)
Soluble metals (cont.)	**CA WET followed by:**	
Thallium	EPA 6010 or 7841	0.02
Vanadium	EPA 6010 or 6020	0.5
Zinc	EPA 6010 or 6020	0.5
Organic compounds		**Reporting limit (mg/kg)**
PCBs	EPA 8082	0.1

out in the field by the sampling technologist and which contain detailed information about actual sampling locations and other conditions affecting sampling. Approximately 10 percent of samples are field duplicates. After the results are obtained, the ratios of the individual sample pairs (of greater-than-detection-limit results) are averaged; the average ratio should be between 0.7 and 1.3. If the average is not within this range, the data are first examined for transcription errors; and then the analytical laboratory is contacted to discuss any problems that may have occurred during analysis. Continued ratios outside the range may indicate problems with the analytical method and require further investigation, including preparation of a nonconformance report (NCR) to document the actions taken.

The analytical laboratory creates laboratory duplicates (also called splits) in accordance with the laboratory standard operating procedures. Laboratory duplicates are introduced blind into the sample processing at a rate of about 10 percent of samples. Results from duplicate samples are compared according to CES procedure CES-SOP-P500, *CES Control Charts*.

16.5.2 Accuracy

Soil is not very amenable to the creation of field blank and spike samples. It is virtually impossible to create a blind field blank that would not be immediately obvious to the analytical staff. In addition, blank soil samples from the National Institute for Standards and Technology (NIST) are very expensive (on the order of $10 per gram). Because about 300 g per sample are needed, the use of blank soil samples gets very expensive and, furthermore, is of little value because the blank soil is physically different from the soils collected in the Livermore Valley and Site 300.

Field spikes are also very difficult to prepare due to the heterogeneity of soils and the difficulty of evenly dispersing any known amount of material in soil.

The radiological laboratory does run blank and standard reference NIST-traceable samples, as do the nonradiological laboratories. For example, NIST "Environmental Radioactivity River Sand" is used as a primary standard for gamma soils analysis.

The radiological laboratory also participates in the DOE Environmental Measurements Laboratory Quality Assurance Program. In these studies, the DOE sends samples with known amounts of radionuclides to the participating laboratories, compares the analytical results (thereby determining the accuracy of the various participating laboratories), and publishes reports of the results so that analytical laboratory personnel, and their customers, can evaluate the analytical laboratory's relative performance.

16.5.3 Completeness

In general, all soil samples that are planned to be collected are actually collected. Exceptions can occur where the location has been developed (and is no longer undisturbed) or is inundated with water. With respect to laboratory analyses, TAMM requires that 90 percent of the samples submitted to, and analyzed by, EMRL yield valid data. If these completeness criteria are not met, nonconformance reports are prepared according to the procedure ORAD-QA-NCR, *Nonconformance Reporting and Tracking*.

16.5.4 Calibration

Equipment in the EMRL is calibrated with sources that are traceable to NIST. Calibration follows a variety of methods, from calibration by a certified third party, to calibration with known standards that are made from traceable materials. Calibration practices are in accordance with standard procedures, and records are maintained for each piece of calibrated equipment.

16.6 Program Implementation Procedures

The primary responsibility for activities related to the soil and sediment monitoring network is assigned to a TAMM environmental analyst. The analyst is responsible for the design, implementation, and correct operation of the network; the analysis and evaluation of all monitoring results; data trending; documentation; and reporting. The following is a list of the procedures associated with the sampling network:

- EMP-S-S, *Soil and Sediment Sampling*: Details of sampling, processing, and documentation for radiological and beryllium air particulates.
- EMP-QA-DM*, Sample and Data Management*: Details how samples are handled, stored, and delivered.

- ORAD-QA-NCR, *Nonconformance Reporting and Tracking*: Details how to complete a report when a sample is deemed unacceptable.

In conjunction with the sampling procedures, the handling and validity of soil and sediment samples is documented using field tracking forms, chain of custody forms, and nonconformance reports.

16.7 Action Levels

Sample results are compared to the running historic geometric means for the Livermore and Site 300 locations for lognormally distributed materials such as plutonium-239, cesium-137, uranium-235, thorium-232, and beryllium. Separate uranium and thorium values are stated for the Livermore site and Site 300 because the underlying geology is different and these differences are reflected in the amounts of naturally occurring uranium and thorium that are present. The 5-year running mean and standard deviation for radionuclides in soils are shown in Table 16-3. (Results for naturally occurring and fallout materials are consistent from year to year and can be used as an indicator of sampling or analytical problems.)

The 5-year running historic geometric mean and standard deviation for beryllium at most Site 300 sampling locations are 0.56 and 1.6, respectively, and for the Building 812 area (an area of known contamination) are 4.2 and 9.2, respectively.

Table 16-3. Mean and standard deviation for radionuclides

Radionuclide	Mean (Bq/g)[(a)]	Standard deviation
$^{239+240}$Pu	5.95×10^{-5}	3.8
$^{239+240}$Pu (LWRP)[(b)]	1.72×10^{-3}	3.1
^{137}Cs	1.10×10^{-3}	3.1
^{238}U (Livermore site)	2.02×10^{-2}	1.4
^{238}U (Site 300)	3.19×10^{-2}	1.7
^{238}U (B812)	5.60×10^{-1}	2.3
^{235}U (Livermore site)	1.34×10^{-3}	1.3
^{235}U (Site 300)	1.99×10^{-3}	1.5
^{235}U (B812)	8.01×10^{-2}	2.2
^{232}Th (Livermore site)	2.55×10^{-2}	1.3
^{232}Th (Site 300)	3.88×10^{-2}	1.2
^{40}K	4.27×10^{-1}	0.077
^{3}H	5.90×10^{0} (Bq/L)	2.7

a The arithmetic mean is shown for ^{40}K; geometric mean is shown for other radionuclides.

b Livermore Water Reclamation Plant

Any results for lognormally distributed analytes outside two geometric standard deviations of the mean (a warning level) are examined for data transcription errors, and the analytical lab is contacted to discuss any problems that may have occurred during analysis. Any results outside three geometric standard deviations (the action level) are also subject to examination for transcription errors and analytical problems. In addition, the location is resampled, perhaps in duplicate or triplicate, depending on the nature of the problem. For normally distributed materials, such as potassium-40, the results are compared to a running arithmetic mean and standard deviation, with the same warning and action levels. If no transcription, analytical, or other error is found to explain an out-of-limit value, the environmental analyst notifies EPD management in writing following procedure ORAD-QA-NCR, *Nonconformance Reporting and Tracking*, and further action, such as a special study in the area of the problematic sample, may be taken with EPD management concurrence.

For metals, results for total concentrations in sediment samples are first compared to background values for total metals developed for LLNL soils and sediments. If the results for total concentrations are less than background, then no further comparisons are necessary. If the results for total concentrations are greater than background, then the soluble results are compared to the soluble background value. Again, if the soluble result value is less than background, no further comparisons are necessary. If the soluble result value is greater than background, then that soil is concluded to be not representative of background. The current values representing total background and soluble background, as well as the five-year average results, are shown in Table 16-4.

16.8 Preparation and Disposition of Reports

The environmental analyst analyzes the monitoring results after all the results for the calendar year are obtained. The results are reported in annual *Environmental Report*. No other reporting for soil and sediment data is required.

16.9 Future Plans

The short-term plan for soil and sediment sampling is to continue monitoring soil and sediment in the manner described in this chapter.

Long-term plans include following the development of federal and regional soil and sediment policies to ensure that soil and sediment monitoring is conducted in an appropriate manner. An additional long-term plan is to keep up-to-date with changes in LLNL operations and to add and remove sampling locations as indicated by operational impacts or changes in sampling conditions.

Table 16-4. Background screening concentration values and five-year average results for total and soluble metals in sediment, Livermore site

Metal	Background screening value	5-year average
Total (mg/kg)		
Antimony	1.12	ND
Arsenic	8.51	2.7
Barium	308	136
Beryllium	0.62	0.62
Cadmium	1.59	0.29
Chromium	72.4	21.8
Cobalt	14.6	7.3
Copper	62.5	14.3
Lead	43.7	12.3
Mercury	0.14	0.056
Molybdenum	any detection	ND
Nickel	82.8	30.4
Selenium	any detection	ND
Silver	any detection	ND
Thallium	any detection	ND
Vanadium	65.2	20.9
Zinc	75.3	35.8

Metal	Background screening value	5-year average
Soluble (mg/L)		
Antimony	any detection	1 detection[b]
Arsenic	0.237	0.073
Barium	16.7	6.3
Beryllium	any detection	ND
Boron	not determined [a]	0.65
Cadmium	any detection	2 detections[b]
Chromium	0.727	ND
Cobalt	0.985	ND
Copper	2.6	0.57
Iron	not determined [a]	27.5
Lead	0.987	1.5
Manganese	not determined [a]	20.7
Mercury	0.0063	ND
Molybdenum	any detection	ND
Nickel	1.68	0.57
Selenium	any detection	ND
Silver	any detection	ND
Thallium	any detection	1 detection[b]
Vanadium	1.22	0.5
Zinc	4.52	1.38

Source: Jackson 1995

a Background screening values were only developed for those metals having limits stated in 22 CCR 66261.24; boron, iron and manganese do not have such limits.

b Detection not significant because TTLC was not above background.

16.10 References

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17 Vegetation and Foodstuff

S. Ring Peterson

17.1 Introduction

Vegetation and foodstuff monitoring is part of a comprehensive and ongoing environmental monitoring program for Lawrence Livermore National Laboratory (see Chapter 1*).* Data from the vegetation and foodstuff network are used to demonstrate compliance with regulatory requirements and to calculate doses that evaluate the effect of LLNL operations on human health and the environment.

Sampling and analysis of vegetation and foodstuff can provide information about the presence and movement of radionuclides released to the environment. At LLNL, vegetation and wine are part of the environmental pathway from atmospheric releases of radionuclides to ingestion dose. Concentrations of radionuclides in vegetation can be used to estimate concentrations in edible plant and animal products and consequent dose to humans from ingestion of a normal diet. Although the ingestion of wine may be just a small fraction of the total diet, wine is the most important agricultural product in the Livermore Valley, representing an industry in excess of $140-million annually. Since monitoring of wine began in 1977, data have indicated that, although tritium concentrations in all wines are low, Livermore Valley wines contain statistically more tritium than do their California counterparts. Therefore, local wines are monitored to demonstrate the small but measurable effect of LLNL operations on wine.

In the past, other foodstuffs (cow milk, goat milk, and honey) leading to potential dose were also monitored for tritium. At present, however, honey and milk are no longer produced in the vicinity of LLNL, so only tritium concentrations in vegetation and wine are used to assess potential ingestion dose from tritium emitted during LLNL operations.

17.2 Vegetation Monitoring Program

17.2.1 Rationale and Design Criteria for Vegetation Monitoring

17.2.1.1 Regulatory Drivers

The regulatory driver for vegetation and foodstuff monitoring is the applicable portions of Department of Energy (DOE) Order 5400.1[1]. Guidance for monitoring specific terrestrial foods appropriate for surveillance sampling and analysis is provided in the DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991). The DOE guidance calls for pathway analyses of important agricultural products grown within 16 km of the site. Although milk is considered the most important pathway-significant agricultural product, it is no longer included in the LLNL monitoring program because no dairy cows are found within 16 km of the Livermore site. LLNL thus samples vegetation, the second most important agricultural product within 16 km. When locally grown vegetables, grains or fruit do not contribute significantly to diet, as is the case with LLNL, DOE guidance states that native (or, more correctly, non-cultivated) vegetation can be used as an indicator species.

17.2.1.2 Monitoring Objectives

The primary purpose of vegetation monitoring is to evaluate the ingestion dose to people from radionuclides that enter the food chain through vegetation. Secondary purposes are to determine if the radionuclide is behaving as expected in the environment, to evaluate long-term accumulation trends, and to estimate environmental radionuclide inventories.

17.2.1.3 Sources and Analytes

Tritium is the only nuclide released from LLNL that can be detected in vegetation. Most uptake is from tritium released to the atmosphere from LLNL's ongoing operations, but in a few locations uptake is from tritium-contaminated groundwater. Tritium moves through the environment as tritiated water (HTO). As such, it is easily assimilated into plant water. Through photosynthesis, tritium is incorporated into the organic matter of plants. Tritiated water and organically bound tritium (OBT) are readily transferred to animals that eat vegetation exposed to tritium in air or soil water. A fraction of the

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

radiation dose to human beings results from ingestion of contaminated plant or animal products.

Organically bound tritium in vegetation is not measured by LLNL. Analyzing for OBT is more time-consuming and labor-intensive than analyzing for HTO, and, given the minimal risk to the public from LLNL's low levels of tritium, models can be used to estimate OBT concentrations. Although the dose per unit intake of OBT is about 2.3 times higher than dose per unit intake of HTO (ICRP 1996), the OBT contribution from the diet is unlikely to increase the tritium dose to the public by more than a factor of two (ATSDR 2002).

At LLNL's Livermore site, the major contributors to airborne tritium emissions are routine emissions from the Tritium Facility (Building 331 and its associated operations) and the Building 612 Radioactive and Hazardous Waste Management Yard. Tritium is also present at Site 300.

There are no longer any particulate radionuclide emissions from LLNL operations at the Livermore site, but there is some resuspension of plutonium-contaminated soils in the southeast quadrant. At Site 300, the primary radionuclide of concern for surveillance of ongoing activities is uranium, which is used in tests at the site. Plutonium and uranium are not of concern in vegetation surveillance monitoring because they are only slightly soluble, leading to minimal plant uptake. In addition, their low solubility also results in a low ingestion dose. For dose calculations, the fractional uptake from the small intestine to blood for common chemical forms ranges from 0.002 to 0.05 for uranium and 0.00005 to 0.003 for plutonium (EPA 1988). Inhalation of these radionuclides is a much more significant environmental pathway, and the air is monitored for these radionuclides. (See Chapters 2, 4, and 5)

Emission levels of nonradiological materials at LLNL do not warrant routine monitoring. An evaluation of air deposition to vegetation for a variety of volatile organic compounds was conducted for the *Health Risk Assessment for Hazardous and Mixed Waste Management Units at Lawrence Livermore National Laboratory* (McDowell-Boyer et al. 1995). The evaluation, based on an assumed 1 mg/m^3 concentration in air, showed that the ingestion pathway accounts for less than 1 percent of the overall risk calculated for these compounds. Furthermore, the *AB2588 Air Toxics Risk Screening Document for Lawrence Livermore Laboratory, Plant 255* (LLNL 1991) indicates that LLNL's actual concentrations of volatile organic chemicals in air at the point of maximum impact would be three orders of magnitude to several times lower than 1 mg/m^3.

17.2.1.4 Collection Methods

Preferentially, the green, leafy material of grass and other vegetation is collected. Leaves of different types of plants will exhibit similar tritium concentrations in their plant water, so the vegetation sampled does not have to be edible. Since water is easily extracted from plants, it is the tritium in the free water of plants that is measured. Tritium concentrations in plant water rapidly reach equilibrium with tritium in air moisture. Therefore, collection methods used by the sampling technologists are designed to avoid contamination of the sample and ensure that the sample is sealed in a plastic bag so that no exchange can occur between the tritium in the plant water (at time of sampling) and air after leaving the sampling location. The sample is also placed on dry ice in the field to freeze it as quickly as possible to prevent the loss of tritiated water to the sample container.

Because the concentrations of HTO found in leaves are normally higher than those observed in fruits, vegetables, root crops and grain for the same tritium concentration in air moisture (Peterson and Davis 2002), dose estimates based on HTO concentrations in leaves will be more health protective than those based on measured HTO in other edible plant parts.

17.2.2 Extent and Frequency of Vegetation Monitoring and Measurement

To assess doses from ingestion of tritium in vegetation, LLNL primarily monitors annual grasses, the occasional forb, and a few leafy vegetables. Noxious plants (e.g., poison oak, stinging nettles) are not sampled to avoid injury to the sampling technologists. The potential for seasonal variability for vegetation is addressed through quarterly sampling. Only plants that are green (i.e., living) are sampled. In dry summer months, mostly deep-rooted plants are sampled, because most grasses are dried. Duplicate samples are collected from each location. In addition, sets of QA duplicates are collected each quarter from one on-site, one Livermore Valley, and one Site 300 location.

The vegetation locations for the area in and around the Livermore site comprise three groups (see Figure 17-1). The first group, “Near,” includes locations onsite or within 1 km of the Livermore-site perimeter (AQUE, GARD, NPER, MESQ, MET, and VIS). The “Intermediate” group consists of locations in the Livermore Valley that are removed from the site (1 to less than 5 km from the Livermore site perimeter), but close enough and often downwind so that they are still potentially under the influence of tritium releases at the site. The “Intermediate” locations are I580, TESW, ZON7, and PATT. The third group, “Far,” represents locations highly unlikely to be affected by LLNL operations. One background location (CAL) is more than 25 km away, while the other (FCC) is about 5 km upwind of the Livermore site perimeter.

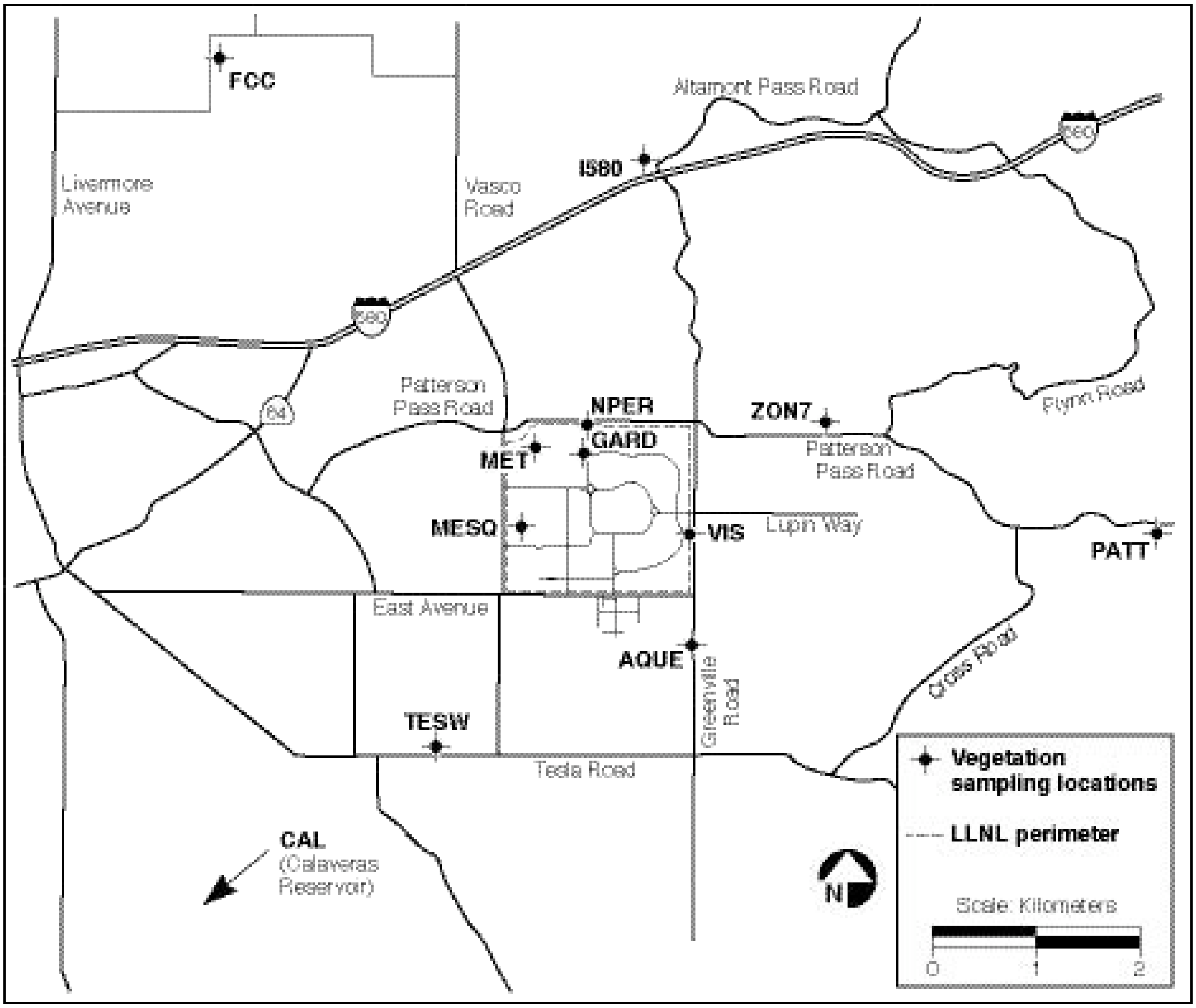

Figure 17-1. Vegetation sampling locations, Livermore site and surroundings

From December 1996 through the last quarter of 2004, two pine trees on the Livermore site were monitored for tritium. PIN1 is rooted in a location of known elevated tritium concentrations in soil and groundwater near Building 292 and is a small diffuse source of tritium; PIN2, at the VIS location, was sampled for direct comparison. Through 2002, miniscule doses at the perimeter fence were estimated based on potential ingestion of hypothetical foodstuffs contaminated by tritium released from PIN1. In 2003, dose calculations using PIN1 as a source were discontinued because LLNL obtained permission from the Environmental Protection Agency to demonstrate compliance by using air monitoring data in place of modeling dose from releases from small sources. Sampling of both pine trees was discontinued accordingly.

At Site 300, most sampling locations historically have exhibited natural background tritium levels in vegetation. At present, background tritium concentrations are monitored at locations 801E and COHO (Figure 17-2), and any changes in operations should be detected at these locations. The vegetation at locations DSW and EVAP (Figure 17-2) may have elevated tritium concentrations due to root uptake from contaminated groundwater. From 1971 until 1994, vegetation samples from location DSW consistently exhibited much higher than background concentrations of tritium. DSW is adjacent to a landfill that contains debris contaminated with tritium from past experiments and is included in the investigation for contaminated groundwater under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (see annual *Environmental Report*, Compliance Summary chapter). More recently, vegetation samples from DSW have exhibited variable concentrations, ranging from relatively high to not detectable. Similarly, since sampling began in 1993, samples from the location EVAP have shown both higher-than-background tritium values as well as non-detects. The highest concentrations apparently occur when plants with roots that reach the water table are sampled randomly.

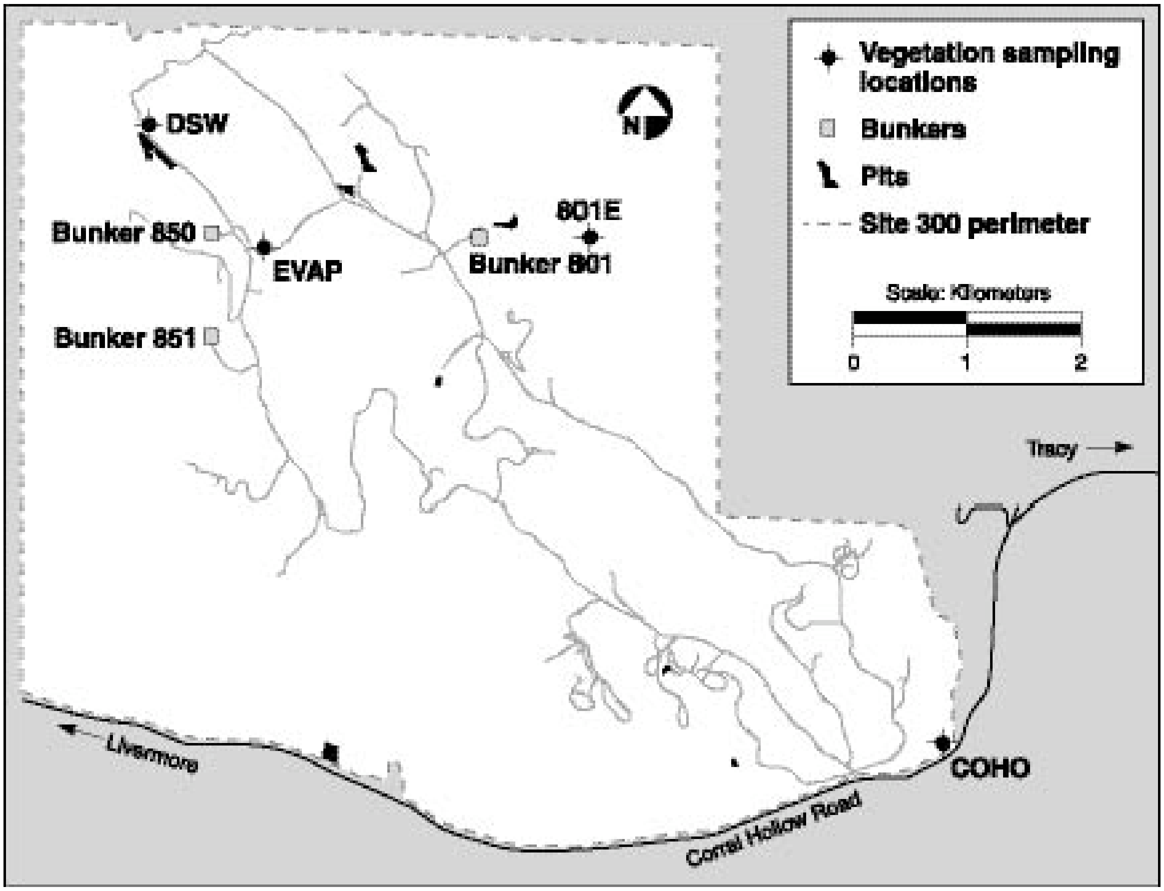

Figure 17-2. Site 300 vegetation sampling locations

Consistent use of the same sampling locations allows for better trending of data and closer monitoring of areas of concern. A detailed description of all past and present sampling locations is maintained in a database. The EMP-QAS-LOC, *Locations Database SOP Supplement*, describes the process to be used for defining, documenting, and approving sampling locations. All vegetation sampling locations are marked with permanent location markers. The requirements for a good sampling location are described in the procedure EMP-VG-S, *Vegetation and Foodstuff Sampling.*

17.2.3 Procedures for Laboratory Analysis

Two bags of frozen, labeled samples of vegetation from each sampling location are delivered to the onsite laboratory. The vegetation is stored in a non-frost-free freezer until analysis. One bag of vegetation is analyzed, and the other is archived by the analytical laboratory. Vegetation samples are weighed on properly maintained and calibrated balances (SOP-CES-P542, *CES Balances*). Tritiated water is extracted from the samples by freeze-drying samples (CES-EM-P542, *Low Level Tritium Analysis – Freeze Dry*) in the laboratory. The samples are then analyzed for tritium by liquid scintillation counting (SOP-EM-P552, *Operation of Packard Tri-Carb LSC for Environmental Sample*s). Concentrations are reported in pCi/L extracted plant water and in pCi/g dry weight vegetation both in hard copy and electronically to the ORAD Data Management Team (DMT).

17.2.4 Data Quality Assurance

17.2.4.1 Precision

The reporting limit for tritium in vegetation is about 2.2 Bq/L (59 pCi/L). In accordance with LLNL procedure EMP-VG-S, *Vegetation and Foodstuff Sampling*, field duplicate samples are submitted with each batch of vegetation samples. Approximately 10 percent of samples are field duplicates. Two “identical” samples are collected at locations chosen for duplicate samples. The sampling locations of field duplicate samples are not identified so the analytical laboratory does not know where the samples originated (EMP-QA-DM*, Sample and Data Management*). However, this information is recorded on field tracking forms (FTFs), which are filled out in the field by the sampling technologist and which contain detailed information about actual sampling locations and other conditions affecting sampling. After the results are obtained, the concentrations of duplicates are compared. Either analytical error or natural variability is the most likely cause of different concentrations, because sampling vegetation is quite simple and straightforward. When the source of the tritium is atmospheric, the difference between duplicate samples usually can be explained by analytical error. This is invariably true when concentrations are near the detection limits, which occurs much of the time in the vegetation network. When one of the results in a pair is a nondetection, the other result should be less than two times the detection limit (annual *Environmental Report*, Quality Assurance chapter). When the source of the tritium is soil water, as at locations DSW and EVAP, natural variability will be the cause of any large differences in the concentrations of the duplicates (up to a factor of three, historically, although usually less than a factor of two). These differences are to be expected because the roots of even adjacent plants may reach water of different concentrations. Given the variability in the field from a groundwater source and the rapid exchange of HTO between air and vegetation when the tritium source is atmospheric, re-sampling cannot resolve any differences. If the magnitude of the differences cannot be explained, the analytical laboratory is contacted to discuss any problems that may have occurred during analysis.

The analytical laboratory creates laboratory duplicates (also called splits) in accordance with SOP-EM-P542, *Low Level Tritium Analysis – Freeze Dry*. Laboratory duplicates are introduced blind into sample processing at a rate of about 10 percent of samples. The relative error ratio is calculated and reported for each split sample. If the control limit of 3.0 for the Relative Error Ratio is exceeded, the source of the problem is investigated and corrected (SOP-CES-P810, *Data Validation* and SOP-CES-P811, *Data Verification*).

17.2.4.2 Accuracy

The radiological laboratory runs blank and control samples traceable to standards of the National Institute of Standards and Technology (NIST). There are no field or laboratory blanks for vegetation, but, to compensate for this, the laboratory analyzes vegetation samples concurrently with air monitoring samples, with a silica gel blank serving as the laboratory blank for both media (see Chapter 5). Currently, no field spikes are prepared due to the difficulty of evenly dispersing any known amount of tritium in vegetation, but laboratory spikes made from blanks with standards added are counted.

The radiological laboratory also participated in the DOE Environmental Measurements Laboratory (EML) Quality Assurance Program (SOP-CES-P820, *CES Performance Evaluation Program*), which ran from 1976 to 2004. For tritium, the DOE sent water samples with known concentrations to the participating laboratories, compared the analytical results (thereby determining the accuracy of the various participating laboratories), and published reports of the results so that analytical laboratory personnel and their customers could evaluate their analytical laboratory’s relative performance. The results of the study were published on the EML web site http://www.eml.doe.gov/QAP/.

17.2.4.3 Completeness

100% of all vegetation samples are collected routinely. However, it may be time-consuming to sample during the driest periods of the year when a large area must be covered to collect an adequate mass of growing vegetation. With respect to laboratory analyses, the Terrestrial & Atmospheric Monitoring & Modeling (TAMM) Group of ORAD requires that ninety percent of the samples submitted to and analyzed by EMRL yield valid data. If these completeness criteria are not met, nonconformance reports are prepared according ORAD-QA-NCR, *Nonconformance Reporting and Tracking*.

17.2.4.4 Calibration

Equipment in the EMRL is calibrated with sources that are traceable to NIST. Calibration follows a variety of methods, from calibration by a certified third party, to calibration with known standards that are made from traceable materials. Calibration practices are in accordance with standard procedures, and records are maintained for each piece of calibrated equipment.

17.2.5 Program Implementation Procedures

The primary responsibility for activities related to vegetation monitoring is assigned to an environmental analyst in TAMM. The analyst is responsible for the following:

- designing, implementing, and maintaining the sampling network
- determining analytes, collection methods, and analytical methods
- coordinating network activities with sampling technologists and analytical laboratory personnel
- reviewing and analyzing the data
- performing dose assessments
- following trends in data
- reporting results

Vegetation is collected according to LLNL procedure EMP-VG-S, *Vegetation and Foodstuff Sampling,* which is reviewed annually, and revised at least once every three years. Vegetation is submitted for analyses using sample control, chain-of-custody, and documentation procedures (EMP-QA-DM*, Sample and Data Management*). The written procedures include requirements for sample collection and submittal for chemical analysis, keeping a log, and filling out FTFs and chain-of-custody (COC) forms. The procedures also require the sampling technologist to alert the environmental analyst about difficulties encountered during any sampling event that may result in a nonconformance report (NCR) (ORAD-QA-NCR*, Nonconformance Reporting and Tracking*).

17.2.6 Action Levels

Sample results are compared to the 5-year running historic geometric mean for each sampling group in the vegetation monitoring networks ("Near," "Intermediate," or "Far" for Livermore site vegetation; "General," EVAP, or DSW for Site 300 vegetation). As discussed in Section 17.2.2, plants at DSW and EVAP are growing in locations of known groundwater contamination. Thus their action levels need to be calculated separately. Geometric means, standard deviations, warning limits, and action levels for 1999 through 2003 are provided in Table 17-1**.**

Table 17-1. Geometric means, geometric standard deviations, and upper warning and action limits for vegetation sampling groups (1999–2003)

Group	Geometric Mean (Bq/L)	Geometric Standard Deviation	Warning Limit (upper)	Action Limit (upper)
LLNL vegetation				
Near	2.6	3.5	34	120
Intermediate	1.6	2.8	14	41
Far	0.66	5.5	22	130
Site 300 vegetation				
General	0.86	4.0	15	63
DSW	26	15	6,700	110,000
EVAP	24	9.2	2,300	23,000

Any results outside two geometric standard deviations (a warning level) are examined for data transcription errors, and the analytical lab is contacted to discuss any problems that may have occurred during analysis. In addition, an attempt is made to determine if the result could have been caused by an unusual release or wind patterns. If a release occurred, other locations may have been affected to some degree; as well, the release will probably have been detected by another sampling network (e.g., air tritium). No further action need be taken unless the warning limit is exceeded at the next quarterly sampling. In this case, a special study to determine the source of the tritium is warranted. Any results outside three geometric standard deviations (the action level) are also subject to examination for transcription errors, analytical problems, and unusual releases and/or wind patterns. In addition, the location is resampled, perhaps in duplicate or triplicate depending on the nature of the problem. If no explanation is found for the out-of-limit value, the environmental analyst notifies EPD management, and further action, such as a special sampling study, may be taken.

17.2.7 Preparation and Disposition of Reports

The environmental analyst conducts ingestion dose assessments, based on the monitoring data and using methods detailed in guidance document ORAD-R-DA*, Radiological Dose Assessment Guidance Document*, for vegetation once all data for a calendar year are obtained. Data are analyzed based on ORAD-QA-D*, Data Analysis*. The monitoring and dose assessment results are reported in the SAER

No other reporting is required for vegetation.

17.2.8 Future Plans

The short-term plan for vegetation sampling is to continue monitoring in the manner described in this document. Sampling may be initiated at the location of the site-wide maximally exposed individual at Site 300.

The long-term plan for vegetation sampling may be to sample more frequently from locations DSW and EVAP to better understand the soil water/vegetation dynamics in those locations. In addition, if a change in operations results in releases of nuclides not significant in the past (e.g., radioiodine), the use of vegetation as a monitor will be considered.

17.3 Wine Monitoring Program

17.3.1 Rationale and Design Criteria for Wine Monitoring

17.3.1.1 Regulatory Drivers

The regulatory driver for foodstuff monitoring is the applicable sections of DOE Order 5400.1[2]. Guidance in monitoring specific terrestrial foods appropriate for surveillance sampling and analysis is provided in the DOE's *Environmental Regulatory*

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[2] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE 1991).

It is not necessary to monitor fruit unless pathway analysis indicates that unusual circumstances are present (DOE 1991); therefore, there is no regulatory requirement to monitor wine, which is made from fruit (grapes). Explicit regulatory requirements are not the sole basis for monitoring, however. Monitoring is also carried out when there is a high level of public interest or concern, or where best management practices indicate monitoring is appropriate. In the past, tritium concentrations in Livermore Valley wines have attracted much public interest, as evidenced by newspaper and television coverage. Because of that interest, and because wines can contribute to radiological doses, however small, LLNL has analyzed more wine samples at more sensitive detection levels than might otherwise be required.

17.3.1.2 Monitoring Objectives for Wine

The primary purpose of wine monitoring is to evaluate the dose to the public from tritium found in wines purchased during the reporting (calendar) year. Secondarily, because wine samples integrate their tritium exposure over the growing season, the tiny impact of LLNL operations on tritium concentrations in Livermore Valley wines can be tracked based on concentrations decay-corrected to vintage year. Furthermore, measuring concentrations in California wines (other than Livermore Valley) provides the background concentrations against which to compare the low concentrations found in local wines; measuring concentrations in wines from Europe demonstrates that wines other than those from the Livermore Valley may have slightly elevated tritium concentrations that may exceed those of Livermore wines.

17.3.1.3 Sources and Analytes

Tritium is the only nuclide released from LLNL that can be detected in wine. At LLNL's Livermore site, the major contributors to airborne tritium emissions are routine emissions from the Tritium Facility (Building 331 and its associated operations) and the Radioactive and Hazardous Waste Management Yard of Building 612. Tritium is released from the Building 331 stacks as either tritiated gas (HT) or as tritiated water vapor (HTO). Tritium moves through the environment as tritiated water. As such, it is easily assimilated into plant water and incorporated into developing grapes. Through photosynthesis, tritium also is incorporated into the organic matter of grapes. The HTO and OBT in grapes made into wine can contribute to a radiation dose to human beings from drinking wine.

17.3.1.4 Collection Methods

Wine for annual analysis is purchased at local retail stores in 750 mL or 1 L bottles. The wine represents what a customer might purchase and take home to drink during the calendar year. It represents more than one vintage year.

17.3.2 Extent and Frequency of Wine Monitoring and Measurements

Wine is sampled annually at the end of the calendar year. The annual wine sampling is an extremely sensitive issue because of the potential economic, political, and public relations impacts of the data, and because it involves the purchase of alcoholic beverages and their possession onsite at LLNL. As a controlled item, the purchase of wine samples requires special approval by DOE and both the LLNL Procurement and Materiel Department and the Safeguards and Security Department (see EMP-VG-S, *Vegetation and Foodstuff Sampling*).

Each year since 1993, twelve bottles (plus two duplicates) from the Livermore Valley, six bottles (plus one duplicate) from California (outside the Livermore Valley), and four bottles from Europe (France, Germany, and Italy) have been sampled. In 2004, the sampling effort was reduced to six bottles (plus two duplicates) from the Livermore Valley, two bottles from California, and two bottles from the Rhone Valley in France. Wine sampling locations are listed in the locations electronic database (EMP-QAS-LOC*, Locations Database SOP Supplement*). Since 1996, an equal number of red and white wines from each geographic area have been sampled. Any wine from a designated area is considered representative of that area, and the selection is random. Every effort is made to purchase estate wines (27 CFR 4.26), especially for the Livermore Valley sample. If an appropriate estate wine cannot be found, then the California wine must at least be labeled as being from an American Viticultural Areas (27 CFR 9 Subpart C).

European wines were initially chosen for evaluation because Europe is a significant wine-growing region with historically or potentially high tritium content in wine from locations, such as the Rhone Valley, near nuclear power plants. California wines from regions other than the Livermore Valley serve as natural background samples for comparative purposes.

17.3.3 Procedures for Laboratory Analysis

To avoid airborne tritium contamination, wine samples are submitted unopened to the onsite Noble Gas Mass Spectrometry Laboratory (NGMSL). Samples are analyzed for tritium content (both HTO and OBT) by helium-3 mass spectrometry (Surano et al*.* 1992) and reports are issued to the environmental analyst.

17.3.4 Data Quality Assurance

17.3.4.1 Precision

The detection limit for wine using helium-3 mass spectrometry is 5.6×10^{-2} Bq/L (1.5 pCi/L). In accordance with LLNL procedure EMP-VG-S, *Vegetation and Foodstuff Sampling,* two QA duplicates, both from the Livermore Valley, are purchased each year. The identity of each wine is listed on the FTF, but, on the COC, each is referred to only as a QA sample. The labels are removed from the bottles before submission to the laboratory to disguise the identities of the vineyards. The bottles are relabeled as QA samples. Once the identity of the QA duplicates has been revealed, the likelihood that the samples are identical is calculated by the laboratory.

Laboratory duplicates (also called splits) are analyzed each year. Results are expected to be very close because wines are well-mixed. Paired duplicates are compared, and the magnitude and distribution of deviations relative to stated errors are examined. In general, the duplicate analyses agree slightly better than those predicted by their stated uncertainties.

17.3.4.2 Accuracy

For wine, an empty sample bottle serves as a blank. A controlled 18 L cask of wine, purchased in 1990, serves as a secondary standard. Samples of this cask wine have been measured yearly, and the measurements serve as a good test of long-term reproducibility. The primary standard is produced by mixing a low-level NIST standard with either "dead" water or the cask wine. A number of years ago, there was a laboratory intercomparison (unpublished) for low-level tritium concentrations in water. Five laboratories participated, analyzing 45 blind samples over a two-year period. All laboratories measured the samples accurately. Based on these results, the LLNL helium-3 mass spectrometry laboratory adopted an uncertainty relation of 10% + 0.185 Bq/L (quadratic sum). In 2003, the laboratory ran approximately 50 samples in duplicate with the United States Geological Survey and had excellent agreement (unpublished).

17.3.4.3 Completeness

100% of all wine samples are collected routinely. When twelve bottles of Livermore Valley wine had to be collected, it was sometimes difficult to select estate bottled wines exclusively, but this criterion is much more easily met when just six bottles are required. With respect to laboratory analyses, TAMM requires that ninety percent of the samples submitted to and analyzed by the laboratory yield valid data. If these completeness criteria are not met, nonconformance reports are prepared according ORAD-QA-NCR, *Nonconformance Reporting and Tracking*.

17.3.4.4 Calibration

Equipment in the NGMSL is calibrated with sources that are traceable to NIST. Calibration follows a variety of methods, from calibration by a certified third party, to calibration with known standards that are made from traceable materials. Calibration practices are in accordance with standard procedures, and records are maintained for each piece of calibrated equipment.

17.3.5 Program Implementation Procedures

The primary responsibility for activities related to wine monitoring is assigned to an environmental analyst in the TAMM Group of ORAD. The analyst is responsible for the following:

- designing, implementing, and maintaining the sampling network
- determining analytes, collection methods, and analytical methods
- coordinating network activities with sampling technologists and analytical laboratory personnel
- reviewing and analyzing the data
- performing dose assessments
- following trends in data
- reporting results

Wine samples are collected according to LLNL procedure EMP-VG-S*, Vegetation and Foodstuff Sampling,* and are submitted for analyses using sample control, chain-of-custody, and documentation procedures (EMP-QA-DM*, Sample and Data Management*). The written procedures include requirements for sample collection and submittal for chemical analysis, keeping a log, and filling out FTFs and COC forms.

17.3.6 Action Levels

Sample results are compared to the 5-year running historic geometric mean for each sampling group in the wine monitoring networks (Livermore, California, and Europe). These geometric means and standard deviations are provided in Table 17-2.

Table 17-2. Geometric means, geometric standard deviations, and upper warning and action limits for wine sampling groups (1999-2003).

Group	Geometric Mean (Bq/L)	Geometric Standard Deviation	Warning Limit (upper)	Action Limit (upper)
Livermore	1.7	1.6	4.6	7.6
California	0.44	1.2	0.69	0.86
Europe	1.2	1.7	3.6	6.1

Any results outside two geometric standard deviations (a warning level) are examined for data transcription errors, and the analytical lab is contacted to discuss any problems that may have occurred during analysis. Any results outside three geometric standard deviations (the action level) are also subject to examination for transcription errors and analytical problems. In addition, an attempt will be made to purchase the same wine, perhaps in duplicate or triplicate, for reanalysis. If no transcription, analytical, or other error is found to explain an out-of-limit value, the environmental analyst notifies EPD management, and further action, such as a special study, may be taken with EPD management concurrence.

17.3.7 Preparation and Disposition of Reports

The environmental analyst conducts dose assessments, based on the monitoring data and using methods detailed in guidance document EMP-R-DA, *Radiological Dose Assessment Guidance Document*, for wine once all data for a calendar year are obtained. The monitoring and dose assessment results are reported in the annual *Environmental Report*. In addition, tritium concentrations in wine decay-corrected to the harvest year are reported for all wines sampled. No other reporting is required for wine.

17.3.8 Future Plans

The short-term plan for wine sampling is to continue monitoring in the manner described in this chapter.

17.4 References

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18 Ambient Radiation

Nicholas A. Bertoldo

18.1 Introduction

At a facility such as LLNL, where a wide variety of radiological operations take place, the potential exists for radiological impacts to the public and environment. Dose assessment based on a comprehensive environmental surveillance and effluent monitoring program (see Chapter 1) is one method to determine LLNL-induced radiological impacts. But for completeness, direct radiation impacts must also be evaluated. At LLNL this means evaluating direct gamma radiation doses.

18.2 Rationale and Design Criteria

18.2.1 Regulatory Drivers

In accordance with applicable portions of DOE Orders 5400.1[1] and 5400.5, as well as the California Code of Regulations Title 17, LLNL must monitor direct radiation to establish background levels and to determine public doses resulting from its operations. To measure potential doses from DOE operations, the *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE 1991) recommends using thermoluminescent dosimeters (TLDs) to monitor direct gamma radiation at the site perimeter. Furthermore, DOE Order 5400.1 requires that specific TLD-related activities (e.g., annealing, calibration, readout, storage, and exposure periods) be consistent with the recommendations of the American National Standards Institute (ANSI 1975). LLNL's use of TLDs meets the specifications of the above-mentioned orders, regulations, and guidance.

Public dose as defined in DOE 5400.5, does not include dose received from occupational exposures, naturally occurring "background" radiation, doses received as a patient from medical practices, or doses received from consumer products.

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[1] DOE Order 5400.1 was cancelled by DOE Order 450.1 in 2003 and formally removed from the LLNL Work Smart Standards (WSS) in January 2005. LLNL will not be adopting DOE Order 450.1 as a WSS. LLNL is in the process of developing an implementation strategy for integration of ISO 14001 (International Organization for Standardization's Environmental Management Standard—adopted as an LLNL WSS in 2004) into LLNL's Integrated Safety Management System (ISMS). It is anticipated that existing sampling and monitoring programs required by DOE Order 5400.1 will continue to be required under ISO 14001 so no major changes to those programs are anticipated at this time.

18.2.2 Monitoring Objectives

The primary purpose of direct radiation monitoring is to measure radiation doses and evaluate the dose received by the public, if any, from direct gamma radiation originating at LLNL. This is accomplished by deploying a sufficient number of TLDs around the Laboratory to ensure that any measurable direct radiation dose from LLNL operations would be detected by the monitoring network and to make direct measurements in areas where members of the public may potentially be exposed.

A second objective is to establish the natural background radiation levels so that the contribution of dose to the public from LLNL operation, if any, can be properly assessed.

18.2.3 Sources and Analytes

There are many radiological operations throughout LLNL in a variety of research and development programs that employ direct gamma radiation sources. There are various sources of gamma radiation at the Livermore site: for example, waste management activities, and laser and biomedical research.

Documentation and notification of changes in LLNL operations affecting the storage and use of gamma and neutron radiation sources is obtained through the following actions:

- participation in Environmental Support Teams by the Terrestrial & Atmospheric Monitoring & Modeling (TAMM) Group
- consultation with the Hazards Control Department about classification of radioactive materials management areas
- notification when new operations or facilities are planned through the review process of National Environmental Policy Act documentation for all new and modified operations
- review of radioactive materials usage inventory forms collected as part of the National Emissions Standards for Hazardous Air Pollutants (40 CFR 61 Subpart H) dose evaluation process

18.2.4 Collection Methods

Penetrating radiation, which cannot be measured by collection of material on filters nor chemically trapped, is collected by trapping the penetrating gamma radiation in the crystal lattice of solid state devices known as TLDs. These dosimeters absorb the direct gamma radiation energy that is imparted to the dosimeter as a result of its exposure to the natural background radiation environment and anthropogenic radiation sources at the deployed location.

When certain crystals in the physical matrix of the TLD are exposed to gamma radiation, impurities in the crystals form low temperature trapping sites for electrons excited to higher energy states. The electrons remain in a high energy state at normal ambient temperatures. In the analytical laboratory, the TLD is processed in a three-phase process. First, the TLD is heated, causing the electrons to be released from the trapping sites; when they drop to a lower energy state, photons are emitted. Second, the photons are measured with a photomultiplier tube with the light intensity being proportional to the original absorbed dose of radiation; the light intensity measurement is recorded. Third, after the TLD is read, it is heated and read again. The second reading should be near zero, indicating that all of the gamma-radiation-induced stored energy has been released (and therefore measured). This second heat treatment is referred to as annealing and verifies that the TLD is ready for reuse in the field.

TLDs measure exposure as absorbed dose (in milliroentgen; mR). The absorbed dose is the quantity of energy deposited by radiation in a given amount of material. This is converted to radiation dose (mrem or mSv) by calibrating the dosimeter reader to read the absorbed dose and then applying a quality factor for a beta/gamma radiation field (Graham and Trombino 1997). The accuracy of radiation measurements made with TLDs is evaluated by charting the performance of dosimeters exposed to known radiation exposures. These quality-control TLDs are irradiated for TAMM by the LLNL Hazards Control Calibration and Standards Laboratory with National Institute of Standards and Technology (NIST)-traceable cesium-137 standards.

LLNL uses the Panasonic Model UD-814AS1 TLD, which contains three components of activated calcium sulfate ($CaSO_4$) and one element of lithium borate ($Li_2B_4O_7$). Only the $CaSO_4$ components are used to measure LLNL direct environmental gamma radiation because of the crystal's sensitivity to environmental radiation levels. The luminescence of the $CaSO_4$ element is 30 times greater than other TLD crystals considered for use. This makes the UD-814AS1 TLD an obvious choice for measurements in the milliroentgen absorbed dose range (converted to the single-digit millirem range).

18.3 Extent and Frequency of Monitoring and Measurement

TLDs are deployed at locations around the Laboratory perimeter and off-site at both the Livermore site and Site 300 to ensure that any measurable direct radiation dose from LLNL operations would be detected and to characterize the ambient average level from terrestrial and cosmic background radiation.

The Livermore site perimeter locations have been chosen based on proximity to LLNL gamma emitting operations, potential public exposure, and accessibility of the monitoring location. The off-site dosimeters are located to provide information about background radiation and LLNL impact on radiation levels in nearby residential areas. All radiation monitoring locations are chosen to ensure that the exposures measured will be representative of those that could potentially result from LLNL operations.

In addition, the following network design criteria were considered before deciding on permanent TLD sampling locations:

- The assurance that the TLDs are placed as far as possible from large or dense objects and that proximity of a structure will not alter the measurement
- The assurance that sampling areas will not be temporarily obstructed to minimize distortion of the radiation field
- Suitable TLD hanging location including consistency in TLD height from the ground (approximately one meter)
- Population distributions
- Representative local geology

Sampling is done quarterly as directed in the guidance document DOE/EH-0173T (DOE 1991) to establish a detectable background dose.

Evaluations of the monitoring network are continually performed by the TAMM environmental analyst to ensure that monitoring locations are suitable and comply with applicable regulations. TLD sampling locations have undergone recent adjustments as a result of geographical changes, safety concerns, and overall reduction in sampling locations. A detailed description of past and present sampling locations is maintained in procedure supplement EMP-QAS-LOC, *Locations Database*. The supplement also describes the process to be used for defining, documenting, and approving sampling locations.

18.3.1 Livermore Site and Livermore Valley

External exposures from gamma radiation are measured quarterly, using TLDs, at 14 Livermore-site perimeter locations and 22 off-site locations in the Livermore Valley (Figures 18-1 and 18-2). Quarterly sampling periods produce a readily detectable dose, following guidance in DOE/EH-0173T (DOE 1991). For TLDs in the LLNL vicinity, this nominally represents a quarterly background direct radiation dose on the order of 0.1 to 0.2 mSv (10 to 20 mrem). Furthermore, quarterly sampling allows evaluation of seasonal variation and increases the probability that data are obtained from all locations for at least a portion of the year. That is, if a TLD is lost or damaged at a given location, data from only a single quarter are lost, thus allowing an estimate of annual exposure to be made from data acquired during the other three quarters.

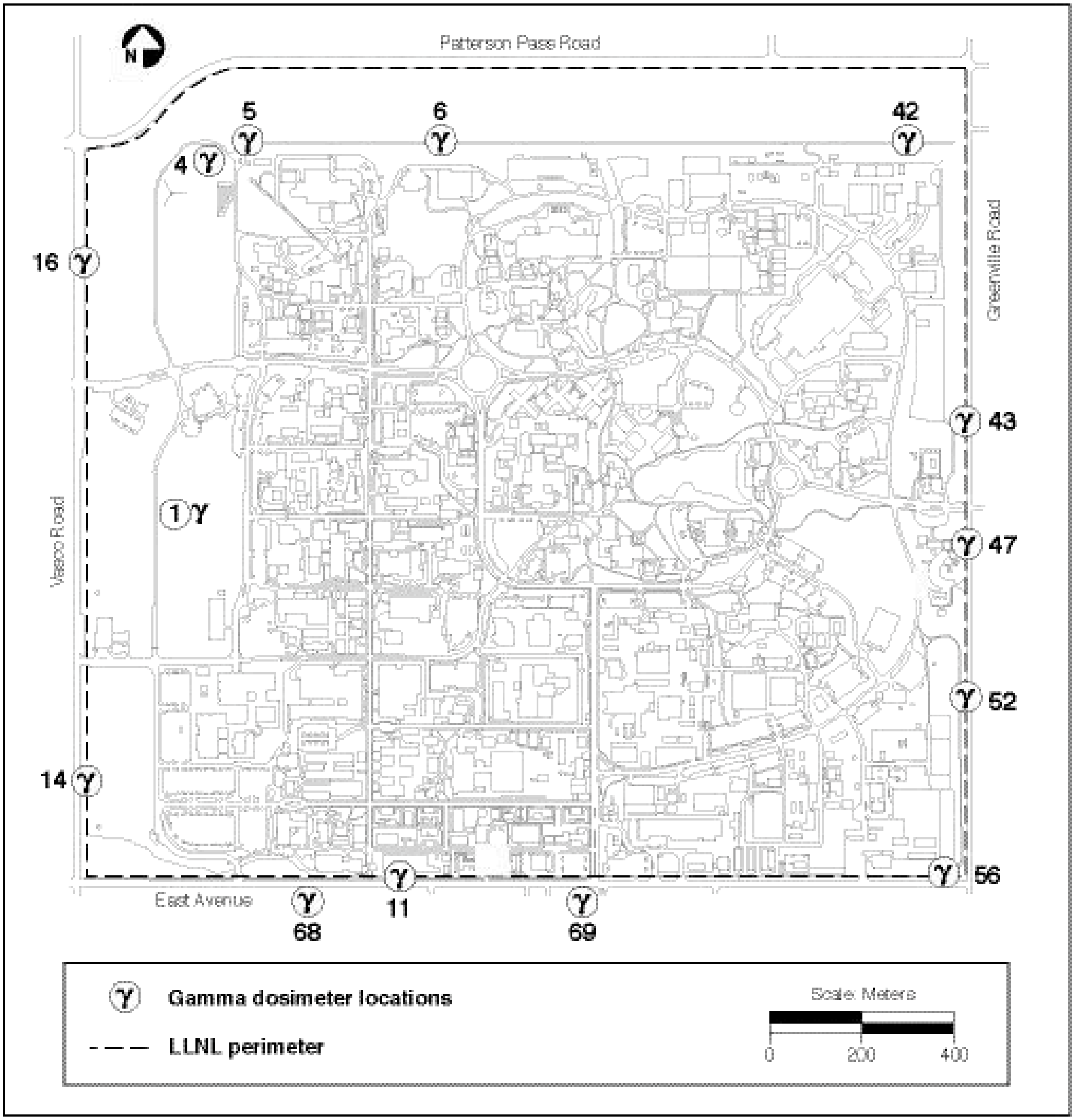

Figure 18-1. Gamma dosimeter locations, Livermore site

Contributions to direct radiation doses from LLNL operations have neither been historically above the natural background radiation environment levels at or beyond the Livermore-site perimeter, nor have they changed significantly over the last twenty years. Exposures measured at the LLNL perimeter typically are statistically identical to the off-site doses, which are considered to be natural direct radiation background levels. This indicates that LLNL operations do not contribute to the external dose at or beyond the Livermore-site perimeter.

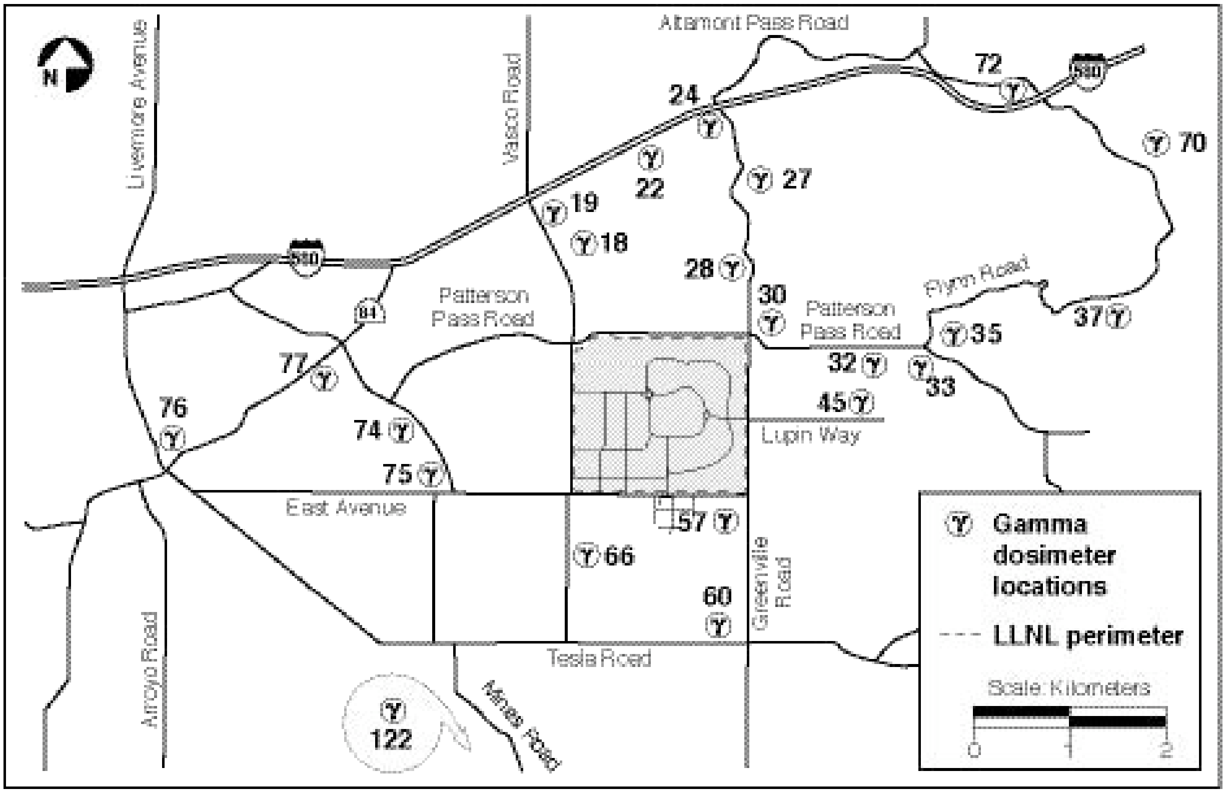

Figure 18-2. Gamma dosimeter locations, Livermore Valley

18.3.2 Site 300

There are nine on-site perimeter and two off-site TLD monitoring locations at Site 300 plus two locations in Tracy, California. These locations are illustrated in Figure 18-3. Off-site dosimeters are located in areas accessible to the public, including locations on Corral Hollow Road, and in the city of Tracy.

The initial TLD network design for Site 300 limited monitoring to the site perimeter and three locations in the San Joaquin Valley near the city of Tracy. These original off-site locations were chosen to provide exposure information about nearby population centers, as well as background radiation levels, and they continue to serve those purposes. However, the terrain and geological composition of Site 300 is different from that of the city of Tracy and the surrounding San Joaquin Valley; Site 300 has outcroppings of igneous rocks, whereas the city of Tracy and the surrounding area is located on sedimentary soils. The region around Site 300 has elevated levels of naturally occurring uranium, and this accounts for the difference between historically measured external gamma radiation between Site 300 and the city of Tracy. The more recently selected off-site monitoring locations, found on a geological substrate more comparable to that at Site 300, are used to evaluate the potential for local, LLNL-induced exposures.

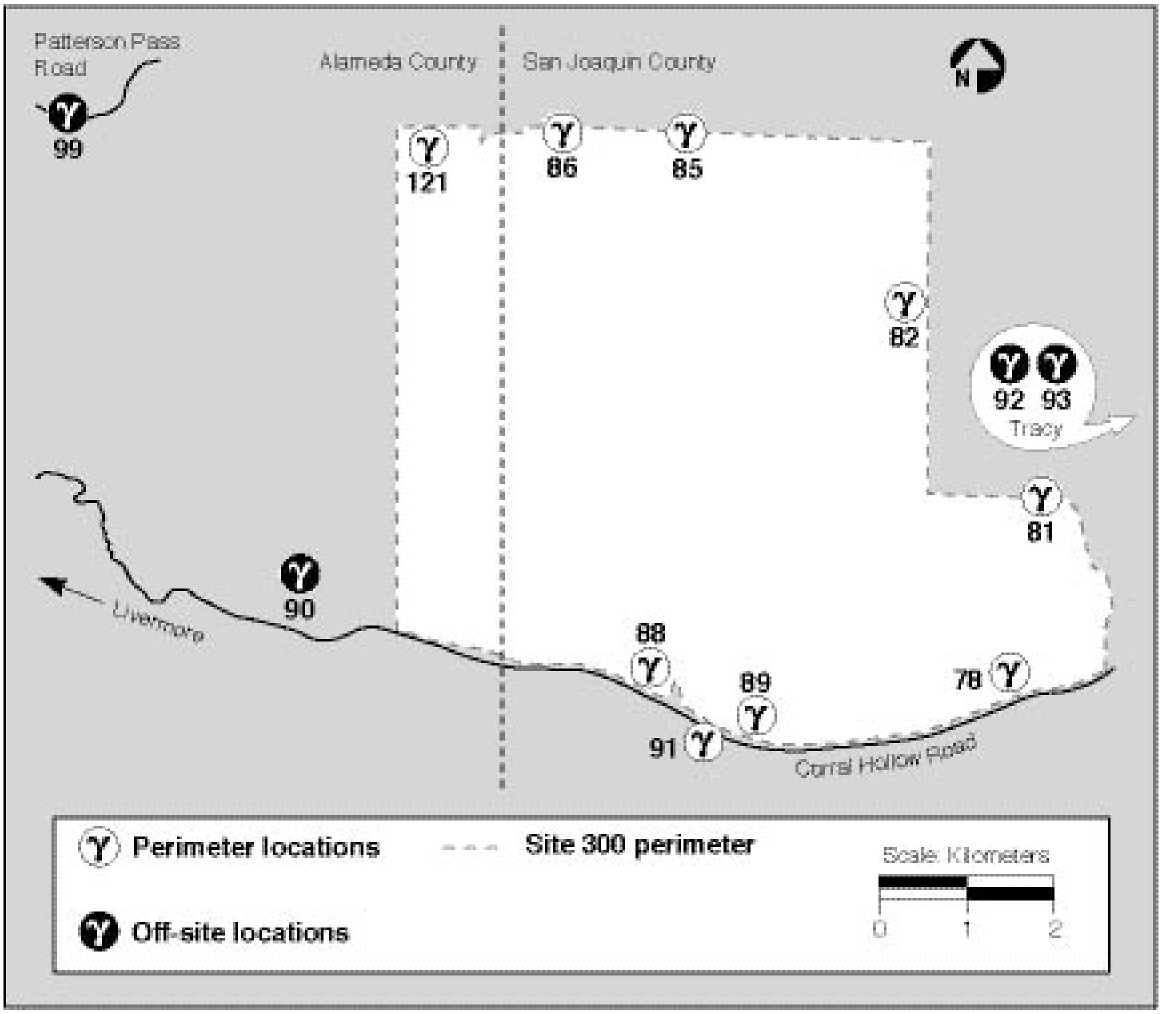

Figure 18-3. Gamma dosimeter locations, Site 300 and vicinity

18.3.3 State of California Co-Monitoring

Currently, the California Department of Health Services (DHS), Radiological Health Branch, co-monitors direct gamma radiation using their own TLDs at nine LLNL monitoring locations; this co-monitoring effort began in 1987. These radiation dosimeters are also collected and read on a quarterly basis. Historically, data from the State dosimeters have been in good agreement with data from LLNL TLDs.

18.4 Procedures for Laboratory Analysis

TLDs are read and annealed by the LLNL Hazards Control Department, Personnel Dosimetry Group. Calibration of the TLD reader is performed by the Hazards Control Standards and Calibration Laboratory using standards traceable to National Institute of Standards and Technology (NIST). Data are electronically reported to the TAMM environmental analyst. The environmental analyst is responsible for calculating the gamma exposure on the TLDs, ensuring that the data are corrected to a 90-day standard quarter, performing quality control checks, and reporting the data in the annual *Environmental Report*.

18.4.1 Calibration

Each quarter, when environmental TLDs are read, the Panasonic TLD reader used by the Personnel Dosimetry Group is calibrated. A batch of annealed TLDs slated for calibration usage is stored for the first half of the quarter in a zip-locked plastic bag in a lead container, on-site and outdoors. The lead container protects the calibration TLDs from natural terrestrial and cosmic background radiation while allowing them to be subjected to the same environmental conditions as those being used for monitoring. At mid-quarter, of the 12 calibration TLDs, 6 are irradiated to 100 mR exposures while 6 of the “zero” or “background” TLDs are exposed only to “natural” dose. The calibration TLDs are then returned to the lead container until the quarter’s end when all TLDs recovered from the field plus the calibration TLDs in the lead shielded container are returned to LLNL’s Personnel Dosimetry group for reading. See procedure EMP-R-SCA, *External Environmental Radiation Monitoring and Calibration*, for details on the calibration of the Panasonic reader and the reading of the TLDs.

18.4.2 TLD Data Analysis

The TLDs measure environmental gamma radiation exposure in milliroentgens. The measured exposure is converted to dose by using a correction factor to determine the absorbed dose and by applying a quality factor to determine the dose equivalent. A quality factor of one (1) is applied for gamma radiation, and the dose equivalent in rem (or mrem) is obtained from the absorbed dose in rads.

All measured doses at the Livermore site boundary are compared to both recent and historical background measurements to determine the contribution, if any, from LLNL operations. All data are reported as total doses (EDE in mrem), including those from both background and LLNL sources.

When a TLD is missing, the annual dose is calculated as four times the average quarterly dose determined from available data. TLDs that are wet, damaged, or found on the ground are not accepted for use in monitoring. The analyst indicates which TLDs were reported as missing or damaged in the data tables for the annual *Environmental Report*.

18.5 Data Quality Assurance

Summary statistics, accuracy and precision of analytical results are reported using means, range, variance, standard deviation and/or confidence intervals as stated in guidance document ORAD-QA-D, *Data Analysis*.

18.5.1 Precision and Accuracy

In an effort to maintain the highest quality standards, TLD results are rigorously examined and statistically compared to long-term background averages, and the procedures for calibration, sample preparation, and field deployment are strictly adhered to. This effort ensures that appropriate analytical methods and TLD holding times are being used to attain the level of precision and accuracy sought in measuring the ambient radiation field at LLNL and the nearby community.

The TAMM analyst examines results from blanks and spikes of known exposures by comparing the reported data to the known exposures. Each quarter, a set of quality control (QC) TLDs are irradiated with known exposures ("spikes"); some of the QC TLDs remain unexposed and therefore serve as "blanks." Although handled in a similar manner, these QC TLDs should not be confused with the calibration TLDs described in Section 18.4.1. Like the calibration TLDs, the QC TLDs are stored in a lead container, subjected at mid-quarter to known exposures, returned to the lead container, and submitted for analysis at the end of quarter along with the environmental monitoring and calibration TLDs. However, unlike the calibration TLDs, members of the Personnel Dosimetry Group do not know which of the submitted TLDs are the QC TLDs nor do they know the exposures. The average value of the QC TLD readings must fall within ±20% of the "true" TLD exposure value (Graham and Trombino 1997).

The Personnel Dosimetry Group participates in the DOE Laboratory Accreditation Program (DOELAP) every two years and must meet specified interlaboratory comparison performance goals and pass a two-day on-site audit. TAMM participates in the DOE Environmental Measurements Laboratory (EML) Intercomparison Study Program whenever intercomparison tests are offered; TLDs with known exposures are sent to TAMM and are then forwarded on to the Personnel Dosimetry Group for analysis. The analytical results are published, allowing TAMM to evaluate the performance of the Personnel Dosimetry Group in an independent quality check.

When deviations from procedures occur, nonconformance reports are completed in accordance with ORAD-QA-NCR, *Nonconformance Reporting and Tracking*. Sampling and analysis procedures are reviewed annually to determine whether the procedures are up-to-date and being performed correctly.

As stated in Section 18.3.3, LLNL maintains a significantly diverse number of , the California Department of Health Services (DHS) co-monitors at nine of the LLNL monitoring locations. According to the DHS personnel, the DHS dosimeters consist of four individual elements of calcium sulfate dysprosium-doped powder, wrapped with a cadmium foil to provide linear energy response, and assembled into a single package. The material is annealed together and subsequently read simultaneously. Control packets are used to determine transit exposure. Selected packages are exposed within the NIST calibration range in Sacramento, California, for quality control purposes. The gross exposures received by the dosimeters are determined by the Radiation Detection Company, Sunnyvale, California, and are reported to DHS Radiological Health Branch. LLNL is in contact with DHS regarding the co-monitoring program and its data.

18.5.2 Completeness

In addition to the comparison of co-located TLD data as stated in Section 18.5.1, LLNL deploys a significant number of TLDs to obtain a reasonable representation of the natural background in the surrounding areas of the Livermore site and Site 300. Although some samples may be lost due to either uncontrollable damage or vandalism, every effort is made to ensure the media completeness is maintained to the highest quality objective by the frequency of sampling and number of locations used for sampling. Missing samples are reported on the field tracking forms at the time of collection on a quarterly basis. Summary statistics that represent these data losses are generated and reviewed as needed in order to take action (such as moving a particular sample location to ensure sample survivability) should any trend develop. On average, the statistical number of data lost each year is less than 10% for Site 300, Livermore site, and the Livermore Valley sample locations.

18.6 Program Implementation Procedures

The primary responsibility for activities related to the radiation monitoring network is assigned to a TAMM environmental analyst. The analyst is responsible for the network design, implementation, and correct operation of the network; the analysis and evaluation of all monitoring results; data trending; documentation; and reporting. The following is a list of the procedures associated with the sampling network:

- EMP-R-SCA*, External Environmental Radiation Monitoring and Calibration*: Details of sampling, processing, and calibration for the TLDs.
- EMP-TLD-CALC*, TLD Calculation*: Methodology used to calculate the gamma radiation dose from the TLDs.
- EMP-QA-D*, Data Analysis*: Guidance on the statistical analyses of monitoring results.
- EMP-QA-DM, *Sample and Data Management:* Details methods used for sample and data management and the documentation required for environmental samples.
- ORAD-QA-NCR*, Nonconformance Reporting and Tracking*: Details how to complete a report when a sample is deemed unacceptable.

18.7 Action Levels

Action levels for environmental TLDs are now derived by calculating a four-year average with the error limited to plus or minus three standard deviations of all combined locations on a quarterly basis. Measurements that fall outside the action level range are investigated. LLNL management is notified if the unusual measurement cannot be attributed to sampling variability or errors in analytical methodology. The quarterly action level for all TLD locations is set to the quarterly 4-yr mean ± 3 σ. These calculated quarterly ranges are as follows:

- 1st Quarter: 0.145 ± 0.061 (mSv)
- 2nd Quarter: 0.152 ± 0.070 (mSv)
- 3rd Quarter: 0.155 ± 0.070 (mSv)
- 4th Quarter: 0.154 ± 0.077 (mSv)

Due to seasonal effects, the measured data tends to be higher in dry quarters. The annual mean of the Livermore Valley is approximately 0.60 mSv. Although the data may be seen to vary terrestrially by soil moisture content and geological constituents that produce higher natural background at some locations, the mean + 3 sigma upper bound tends to account for both terrestrial and cosmic variability. As the overall mean background is represented by the Livermore Valley data at a dose level of 0.60 mSv annual average, a reasonable investigative action level set to 0.23 mSv/quarter/location would remain conservative based upon the public dose limit of 1 mSv/yr above background. The lower bound of 0.08 mSv addresses measurement attributable errors and missing data.

18.8 Preparation and Disposition of Reports

The data from the environmental gamma radiation network are processed, analyzed, and reported in the annual *Environmental Report* . No other reporting is required for the direct radiation data. Sampling location maps, descriptions of collection and analytical methods, all data from all monitoring locations, summary statistics, statistical evaluations, comparisons with background radiation levels, trending of data, and discussion of overall environmental impacts are included in the annual *Environmental Report*.

18.9 Future Plans

Ambient radiation monitoring as described here will continue to be a part of LLNL's environmental monitoring effort. The monitoring locations will continue to be evaluated to ensure that suitable coverage and compliance with regulations are sustained.

18.10 References

ANSI (1975), *N545: Performance, Testing, and Procedural Specifications for Thermoluminescent Dosimetry: Environmental Applications*, American National Standards Institute, Philadelphia, PA.

California Code of Regulations, Title 17, Chapter 1, Section 30250, Public Health, Group 3 *Standards for Protection Against Radiation*, State of California, Sacramento, CA.

DOE (1991), *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*, U. S. Department of Energy, Washington, D. C. (DOE/EH-0173T).

Environmental Report (annual), Lawrence Livermore National Laboratory, Livermore, CA. (UCRL-50027). Available at http://cmg.llnl.gov/saer

Graham, C. L., and D. G. Trombino (1997) *Personnel Dosimetry Procedures: Chapter 6, Environmental Dosimetry,* Hazards Control Department, Lawrence Livermore National Laboratory, Livermore, CA, internal document.

Appendix A. Acronyms

1,1,1-TCA	1,1,1-trichloroethane
1,1-DCA	1,1-dichloroethane
1,1-DCE	1,1-dichloroethene
1,2-DCA	1,2-dichloroethane
1,2-DCE	1,2-dichloroethene
ACG	Ambient concentration guide
ACMT	Analytical contract management team
ALARA	As low as reasonably achievable
ANSI	American National Standards Institute
ARAC	Atmospheric Release Advisory Capability
ARAR	Appropriate, relevant, and applicable requirement
ARO	Assurance Review Office
ATA	Advanced Test Accelerator
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	Ambient Water Quality Criteria
BAAQMD	Bay Area Air Quality Management District
BMP	Best management practice
Cal EPA	California Environmental Protection Agency
CCR	California Code of Regulations
CD	Compact disk
CEQA	California Environmental Quality Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CES	Chemistry & Materials Science Environmental Services Laboratory
CFF	Contained Firing Facility
CFR	Code of Federal Regulations
cis-1,2-DCE	*cis*-1,2-dichloroethane
COC	Constituent of concern

CoC	Chain of custody
COD	Chemical oxygen demand
CRWQCB	California Regional Water Quality Control Board
CVRWQCB	Central Valley Regional Water Quality Control Board
DAM	Discharge Authorization Manager
DAP	Discipline action plan
DCG	Derived concentration guide
DHS	(California) Department of Health Services
DMT	Data Management Team
DOE	U.S. Department of Energy
DOELAP	Department of Energy Laboratory Accreditation Program
DQO	Data quality objective
DRB	Drainage retention basin
DTSC	Department of Toxic Substances Control
DWTF	Decontamination and Waste Treatment Facility
EA	Environmental analyst
EDE	Effective dose equivalent
EDO	Environmental Duty Officer
ELAP	Environmental Laboratory Accreditation Program
EML	Environmental Monitoring Laboratory
EMP	Environmental Monitoring Plan
EMRL	Environmental Monitoring Radiation Laboratory
EMT	Emergency Management Team
EOC	Emergency Operations Center
EPA	(U.S.) Environmental Protection Agency
EPD	Environmental Protection Department
ERD	Environmental Restoration Division
ES&H	Environment, Safety, and Health
EST	Environmental Support Team

FFA	Federal Facility Agreement
FTF	Field tracking form
GSA	General Services Area (Site 300)
HCAL	Hazards Control Analytical Laboratory
HCD	Hazards Control Department
HE	High explosive
HSU	Hydrostratrigraphic units
HT	Tritiated hydrogen gas
HTO	Tritiated water
IEEE	Institute of Electrical and Electronics Engineers
ISM	Integrated Safety Management
ISMS	Integrated Safety Management System
IWS	Integration work sheet
LBNL	Lawrence Berkeley National Laboratory
LCS	Laboratory control sample
LLNL	Lawrence Livermore National Laboratory
LWRP	Livermore Water Reclamation Plant
MCL	Maximum contaminant level
NARAC	National Atmospheric Release Advisory Center
NCR	Nonconformance report
NEPA	National Environmental Policy Act
NESHAPs	National Emission Standards for Hazardous Air Pollutants
NGMSL	Noble Gas Mass Spectrometry Laboratory
NIF	National Ignition Facility
NIST	National Institute for Standards and Technology
NPDES	National Pollutant Discharge Elimination System
NTLF	National Tritium Labeling Facility
NWS	National Weather Service
OBT	Organically bound tritium

ORAD	Operations and Regulatory Affairs Division
OSC	Operation Support Center
PCB	Polychlorinated biphenyl
POTW	Publicly owned treatment works
PPMRP	Pollution Prevention and Monitoring and Reporting Plan
QA	Quality assurance
QAMP	Quality Assurance Management Plan
QC	Quality control
RCRA	Resource Conservation and Recovery Act
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RHWM	Radioactive and Hazardous Waste Management (Division)
RL	Reporting limit
RML	Radiation Measurements Laboratory
RMMA	Radioactive Materials Management Area
ROD	Record of decision
RPM	Remedial Program Manager
RSL	Reduced to sea level
RTAL	Retention Tank Analysis List
RWQCB	Regional water quality control board
Sandia/California	Sandia National Laboratories, California
SDF	Sewer Diversion Facility
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SJVUAPCD	San Joaquin Valley Unified Air Pollution Control District
SL	Statistical limit of concentration
SMC	Sewer Monitoring Complex
SOP	Standard operating procedure
SOW	Statement of Work
SRDT	Solar radiation-delta T
STAR	Sample Tracking and Receiving system (Hazards Control)

STLC	Soluble Threshold Limit Concentration
SW-MEI	Sitewide maximally exposed individual
SWPPP	Storm Water Pollution Prevention Plan
SWRCB	State Water Resources Control Board
TAMM	Terrestrial and Atmospheric Monitoring and Modeling (Group)
TDS	Total dissolved solids
TLD	Thermoluminescent dosimeter
TOC	Total organic carbon
TOX	Total organic halides
TSP	Total suspended particles
TSS	Total suspended solids
TTLC	Total Threshold Limit concentration
TTU	Transportable treatment unit
VOC	Volatile organic compound
WAPA	Western Area Power Administration
WDAR	Wastewater Discharge Authorization Record
WDR	Waste Discharge Requirement
WGMG	Water Guidance and Monitoring Group
WMU	Waste management unit
WSS	Work smart standards
XRF	x-ray fluorescence
XRFS	x-ray fluorescence spectroscopy