ENVIRONMENTAL MONITORING PLAN

Environmental Monitoring Section

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Authors

Paula J. Tate
Shari L. Brigdon
Gretchen M. Gallegos
Brian K. Balke
Arthur H. Biermann
Frank J. Gouveia
Lucinda M. Garcia
Donald H. MacQueen
Nina L. Hankla
Sandra Mathews
Eric Christofferson
Richard Brown
Erich Brandstetter
Robert J. Harrach
Allen Grayson
Barbara C. Fields
Jennifer Larson
Robert J. Vellinger
Rebecca A. Failor
Kris A. Surano
William G. Hoppes
Paris E. Althouse
Becky Ward

Editor

Gloria C. Wilt

Environmental Monitoring
and Analysis Division

Environmental Protection
Department

Lawrence Livermore
National Laboratory
University of California,
Livermore, California 94551

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1

Introduction

This document meets the requirements of DOE Order 5400.1, which requires a written Environmental Monitoring Plan (EMP) for each DOE site, facility, or process that uses, generates, releases, or manages significant pollutants or hazardous materials. This is the first revision of the Lawrence Livermore National Laboratory (LLNL) EMP prepared in 1991–92 and is consistent with the triennial revision schedule called for by the Order.

1.1 MISSION

The mission of LLNL is to serve as a national resource in science and engineering, focused on national security, energy, the environment, biomedicine, economic competitiveness, and science and mathematics education, with a special responsibility for nuclear weapons. Our mission is dynamic and over the years has been broadened to meet new national needs.

The environmental policy of LLNL is to conduct its operations in a manner that preserves the quality of the environment. This includes compliance with the letter and the spirit of governmental regulations and orders, effective internal and external oversight of activities, and open and honest interactions with the general public. Safety, health, and environment have top priority.

In keeping with this policy, LLNL carries out its mission in compliance with local, state, and federal environmental regulatory requirements and takes measures to ensure that its operations do not adversely affect the environment or public health. It does so with the support of the Environmental Protection Department (EPD), the organization responsible for environmental monitoring, environmental restoration, hazardous waste management, and ensuring environmental compliance.

The role of the EPD is to help implement LLNL's environmental policy by providing Laboratory organizations with the guidance and necessary expertise to meet the environmental requirements of all relevant federal, state, and local regulations and DOE Orders. More specifically, EPD's mission is to:

- Be the Laboratory gatekeeper for environmental issues.
- Help the programs carry out their missions in an environmentally acceptable manner.

- Help ensure environmental compliance.
- Conduct environmental monitoring and reporting.
- Provide environmental training, assistance, and guidance.
- Perform environmental restoration.
- Provide hazardous waste management and waste minimization guidance and services.
- Maintain an environmental emergency response and reporting capability for the Laboratory.
- Prepare and maintain environmental permits.

Throughout this document the importance of environmental monitoring in an overall environmental protection program will be emphasized. Monitoring of effluents and of the environment through surveillance efforts confirm whether pollution prevention activities are working and provide an understanding of the impact of LLNL's activities on its surroundings.

1.2 ORGANIZATIONAL RESPONSIBILITIES

All LLNL staff have responsibilities that include environmental protection and environmental compliance. The level of responsibility is dependent upon the position held by the individual. The document *Roles, Responsibilities and Authorities for Environment, Safety, and Health at LLNL* clearly lists these responsibilities for all levels of staff.

The Environmental Protection Department has a special role with respect to environmental monitoring. All environmental surveillance monitoring, CERCLA-related monitoring, and liquid effluent monitoring is performed by EPD. In addition, EPD oversees and reports on all air effluent monitoring.

The Environmental Protection Implementation Plan (EPIP; LLNL 1994) provides detailed information on the operational responsibilities of EPD. A brief description will be provided here, with emphasis on the responsibilities for environmental monitoring.

The Department is divided into four divisions:

- Operations and Regulatory Affairs Division (ORAD)
- Hazardous Waste Management Division (HWM)

- Environmental Restoration Division (ERD)
- Environmental Monitoring and Analysis Division (EMAD).

Figure 1-1 identifies the organizational structure of EPD by function and depicts the responsibilities, activities, and inter-relationships of the organizational units.

The Operations and Regulatory Affairs Division helps Laboratory programs and facilities operate in an environmentally sound manner and meet environmental compliance requirements. The ORAD staff works with Laboratory personnel on regulatory compliance, permitting issues, waste minimization, pollution abatement, and inspections to help identify and mitigate potential environmental concerns in existing and planned projects.

The Hazardous Waste Management Division manages all hazardous, radioactive, and mixed wastes generated at all Laboratory facilities. Operationally, HWM staff process these wastes for temporary storage, treatment, or transportation for recycling or off-site disposal.

Figure 1-1. Environmental Protection Department organizational structure.

The Environmental Restoration Division manages and operates the CERCLA remediation program at LLNL. These efforts focus on correcting problems resulting from past hazardous material handling and disposal practices and from leaks that have occurred. ERD staff plan, direct, and conduct assessments to determine both the impact of these problems and work to restore the environment to acceptable levels. ERD maintains CERCLA-related monitoring, primarily focused on ground water, but also including the unsaturated zone.

The Environmental Monitoring and Analysis Division is responsible for monitoring air and liquid effluent and environmental surveillance monitoring. EMAD also provides chemical and radiological analytical services for monitoring samples, for waste generators, and HWM. EMAD is responsible for all wastewater regulatory interactions and provides support to programs for wastewater issues. EMAD also performs public dose assessments, impact modeling and analysis, and provides emergency response support.

The Environmental Monitoring Section (EMS) within EMAD has the primary responsibility for conducting environmental monitoring and reporting, especially that required under DOE Orders 5400.1 and 5400.5. The mission of EMS is to protect the environment by verifying the effectiveness of operational controls and compliance with regulations. EMS accomplishes this mission by performing independent surveillance and effluent monitoring; assessing the impacts of LLNL's operations on the public and the environment; communicating findings to DOE, regulatory agencies, and the public; and advancing the science and technology of monitoring. This Environmental Monitoring Plan provides a detailed look at the monitoring provided by EMS.

Figure 1-2 is an organizational chart for EMS. The Technical Support Group provides the foundation for EMS' monitoring efforts by performing all sample collection, sample management, and data management functions. The Terrestrial and Atmospheric Monitoring and Modeling Group is responsible for the planning, data analysis, regulatory compliance, dose assessments and reporting for all air effluent and nonwater environmental surveillance monitoring. Surveillance monitoring includes soil, arroyo sediment, vegetation, air particulate, nonparticulate air, meteorological, direct radiation, and foodstuffs, both on and off LLNL property. The Water Guidance and Monitoring Group is responsible for planning, data analysis, regulatory compliance, and reporting for all nonhazardous wastewater, storm water, non-CERCLA ground water and surface water monitoring. The quality assurance and training coordinator reports

to the section leader and also reports to EPD's assurance manager and training manager, providing the needed independence in this function.

Certain aspects of the air effluent monitoring effort are handled by non-EMS staff in the facilities being monitored. These functions typically are calibration and maintenance of the equipment. Hazards Control technicians are responsible for air effluent sample collection. The Hazards Control Analytical Laboratory provides some analyses of the samples. Hazards Control is the LLNL department responsible for worker and public health and safety; it provided air effluent monitoring services prior to the creation of EPD and has retained many of these functions. However, EPD is responsible for reporting and regulatory compliance in air effluent monitoring; it accomplishes these through EMS.

Sample analyses associated with monitoring efforts are provided by five external contract analytical laboratories and three in-house analytical laboratories. The choice of which laboratory to use is dependent on the analysis needed, detection limits needed, laboratory certification requirements, turnaround time requirements, cost, and historical precedent. Individual chapters will document which laboratory provides analysis for the medium under discussion.

Funding for air and liquid effluent and environmental surveillance monitoring is provided from overhead funds collected from programs in operation at LLNL.

Monitoring efforts associated with CERCLA compliance are conducted by the Environmental Restoration Division. ERD monitors more than 600 wells and conducts soils sampling at the well sites in conjunction with remedial activities performed at both of LLNL's sites. Funding for these activities is provided by DOE's Office of Environmental Restoration and Waste Management (EM). The planning activities for remedial sampling are identified in the ERD Work Plans (e.g., Webster-Scholten and Hall 1988), the *Quality Assurance Project Plan* (Rice 1988), and other CERCLA planning documents.

1.3 DOCUMENT ORGANIZATION

This LLNL Environmental Monitoring Plan is structured to provide the environmental professional who is familiar with environmental monitoring at DOE facilities with an understanding of how LLNL fulfills its monitoring obligations. The mission of LLNL and the historical background of environmental monitoring is described in Chapter 1. Setting of the Livermore site and Site 300 are given in Chapter 2. Chapter 3 describes the philosophy and the technical assessment approach taken to determine the optimal monitoring networks, EMS emergency response activities and EMS reporting. Chapters 4 through 15 address subjects that encompass all environmental media (air effluent, meteorology, air surveillance, sewage, rain, surface water, storm water, ground water, categorical processes, cooling towers, building drains, soil, vegetation, foodstuffs, direct radiation and noise). Each chapter specific to a medium contains a discussion of the rationale and design criteria, the extent and frequency of monitoring and measurements, quality assurance requirements, program implementation procedures, preparation and disposition of reports, and short- and long-term plans. All future plans are contingent on the acquisition of funding and the approval of LLNL management. Short-term plans have a high likelihood of implementation, while long-term plans are more likely to be subject to revision.

Chapter 16 is dedicated to describing procedures for laboratory analysis. It provides a description of sample identification systems, cross-contamination prevention, sample preservation and handling, standard analytical methods, modified analytical methods, and analytical equipment calibration for each analytical laboratory that processes LLNL samples. The information is general with some specifics, especially when samples for certain media are treated differently. Chapter 17 addresses the EMS Quality Assurance Plan, including discussions of the QA program, personnel training and qualification, quality improvement, documents and records, work processes, design control, procurement, inspection and acceptance testing, management assessment, independent assessment, field and laboratory quality control, and laboratory intercomparison studies. Chapter 18 describes data management of routine monitoring data, wastewater data, and data storage and Chapter 19 describes radiation dose and risk assessment activities.

The actual procedures for conducting monitoring are contained in the EMS procedures, which are attached to this EMP as Appendix A.

2 Setting

Climate and geography play primary roles in how the environment is affected by human actions. Dispersal of particles in the air, for example, is influenced by wind patterns, surface heating and cooling, and rainfall, which in turn are influenced by geographical characteristics. Similarly, the flow and hydrodynamic dispersion of ground water is constrained by the particular geology of the site. Thus, data on wind, rainfall, and geological and geographical characteristics are used to calculate the effects that operations at LLNL might have on the surrounding environment. Some history and a description of these data help us understand the relationship of the Laboratory to its climatic and geographic setting.

2.1 LOCATION

LLNL consists of two main facilities—the main laboratory site located in Livermore, California (Livermore site), and the Experimental Test Facility (Site 300) located near Tracy, California (Fig. 2-1). Each site is unique, requiring a different approach for environmental monitoring and protection.

Over forty years ago, LLNL was founded on the site of a former U.S. Naval air station. At that time the location was relatively isolated, being approximately 1.6 kilometers from the Livermore city limits. Over the years, Livermore evolved from a small town of fewer than 7000 people to its present population of nearly 55,000. The economy diversified from primarily agricultural to include light industry and business parks. Within the last few years, low-density, single-family residential development has begun to fill the formerly agricultural fields, bringing the city limits of Livermore to LLNL's western boundary.

LLNL's Livermore site occupies an area of 3.28 square kilometers, including the land that serves as a buffer zone around the site. Immediately to the south is Sandia National Laboratories, California (SNL/CA), operated by Martin-Marietta under DOE contract. SNL/CA provides research and development associated with nuclear weapons systems engineering, as well as related national security tasks. Although their primary missions are similar, LLNL and SNL/CA are separate facilities, each with its own management and each reporting to a different DOE operations office. Sandia National Laboratory maintains its own on-site monitoring but relies on LLNL for off-site surveillance monitoring.

Setting

Potential off-site environmental impacts of SNL/CA operations are considered in LLNL's monitoring plans.

To the south of LLNL and SNL/CA are agricultural areas devoted to grazing, orchards, and vineyards; some low-density residential areas; and a business park is found to the southwest. Farther south, property is primarily open space or rural ranchettes, with some agricultural use. A very small amount of low-density residential development lies to the east of the Livermore site, and agricultural land extends to the foothills of the intercoastal range that defines the eastern margin of the Livermore Valley. A business park is located to the north, and a 2-2199.6-hectare parcel of open space to the northeast has been rezoned to allow development of a center for heavy industry.

Site 300, LLNL's Experimental Test Site, is located 24 kilometers east of the Livermore site in the Altamont Hills of the Diablo Range; it occupies an area of 30.3 square kilometers. It is in close proximity to two other testing facilities: Physics International operates a testing facility that is adjacent and to the east of Site 300, and SRI International operates another facility, located approximately 1 kilometer south of Site 300. The Carnegie State Vehicular Recreation Area is located south of the western portion of Site 300, and wind turbine generators line the hills northwest of the site. The remainder of the surrounding area is in agricultural use, primarily as grazing land for cattle and sheep. The nearest residential area is the town of Tracy (population 25,000), located 10 kilometers to the northeast.

2.2 METEOROLOGY

Mild, rainy winters and warm, dry summers characterize the climate of the Livermore Valley. The mean annual temperature is 15°C. Temperatures range from -5°C during pre-dawn winter mornings to 40°C during summer afternoons. Prevailing winds for approximately 45% of the year are from the west and southwest. These wind patterns are controlled by the thermal draw caused by rising air in the warm Central Valley of California, which results in wind blowing from the cool ocean toward the warm valley, increasing in intensity as the valley heats up. This is the predominant wind direction during the summer. The wind blows from the northeast, primarily during the winter storm season.

Rainfall also exhibits a strong seasonal pattern. Most of the precipitation occurs between October and April, with very little rainfall during the warmer months. Snow in the Livermore Valley is uncommon. The highest and lowest annual rainfalls on record (1870 to 1977, City of Livermore) are 728 mm and 122 mm. The average and median annual rainfall for Livermore are 364 mm and 345 mm, respectively.

The climate at Site 300, while generally similar to the Livermore site, is modified by higher elevation and more pronounced relief. The complex topography of the site significantly influences local wind and temperature patterns. At Site 300 the prevailing winds for approximately 33% of the year are from the west-southwest and reach greater speeds than at the Livermore site. The temperature range is slightly more extreme than the Livermore site, and surface winds are generally greater. For the 20-year period from 1973 through 1993, the average rainfall was 269 mm.

2.3 GEOLOGY

2.3.1 Topography

2.3.1.1 *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 kilometers long and averages 11 kilometers 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 meters. The valley floor is at its highest elevation of 220 meters along the eastern margin and gradually dips to 92 meters at the southwest corner. The major streams passing through the Livermore Valley are Arroyo del Valle and Arroyo Mocho, which drain the southern highlands and flow only during the rainy season.

2.3.1.2 *Site 300*

The topography of Site 300 is much more irregular than that of the Livermore site; a series of steep hills and ridges is oriented along a generally northwest-southeast trend and is separated by intervening ravines. The Altamont Hills, in which 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 meters at the southeast corner of the site to approximately 538 meters in the northwestern portion.

2.3.2 Hydrogeology

2.3.2.1 *Livermore Site*

The hydrogeology and movement of ground water in the vicinity of the Livermore site have been the subjects of several recent and continuing investigations. Detailed discussions of these investigations can be found in Stone and Ruggieri (1983); Carpenter et al. (1984); Webster-Scholten and Hall (1988); Dresen et al. (1989a-f); and Thorpe et al. (1990). This section has been summarized from the reports of these investigations and from data supplied by Alameda County Flood Control and Water Conservation District, Zone 7, the agency responsible for ground water management in the Livermore Valley basin (California RWQCB 1982).

The Livermore Formation (and overlying alluvial deposits) contains the aquifers of the Livermore Valley ground water basin and is an important water-bearing formation. The Livermore Formation is also comprised of unconsolidated alluvial and lacustrine deposits. 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 ground water levels, is accomplished by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the east. Ground water flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Ground water flow in the basin is assumed to be primarily horizontal, although a significant vertical component probably exists in fringe areas and also under localized sources of recharge and in the vicinity of heavily used extraction (production) wells.

Beneath the Livermore site, the depth to the water table varies from about 8 to 40 meters. **Figure 2-2** 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 2-2** are generally maintained. At the eastern edge of the Livermore site, ground water 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.

Figure 2-2. Approximate ground water and surface elevation contours, Livermore site and vicinity.

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 meters per day (Isherwood et al. 1991). This, in combination with the observed water table gradients, yields an average ground water velocity estimate of 20 meters per year (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.

2.3.2.2 Site 300

Site 300 is generally underlain by gently dipping sedimentary bedrock dissected by steep ravines. The bedrock is made up primarily of interbedded sandstone,

siltstone, and claystone. Most ground water occurs in the Neroly Formation upper and lower blue sandstone aquifers. Significant ground water is also locally present in permeable Quaternary alluvium valley fill. Much less ground water is present within perched aquifers in the unnamed Pliocene nonmarine 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 generally is poor and yields are low, these perched water-bearing zones do not meet the State of California criteria for aquifers that are potential water supplies.

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

Ground water flow in most aquifers follows the attitude of the bedrock. In the northwest part of Site 300, ground water 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, ground water 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 Miocene Neroly formation, contains confined water. Wells located in the western part of the General Services Area are completed in this aquifer and have been used to supply drinking and process water.

Figure 2-3 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.

2.4 CONCLUSION

LLNL recognizes the importance of our geology, hydrogeology, climate, and geographical relationship with our neighbors in assessing potential impacts of operations at the Livermore site and Site 300. Each year additional information is gained to allow us to better predict, interpret, and avoid potential impacts. Each environmental medium that is discussed within this document—air, soil, ground water, and vegetation—may be affected differently. The environmental scientists at LLNL take into account the unique locations of the Livermore site and Site 300 to tailor sampling and analysis programs for each medium used to monitor the environment.

3

General Topics

3.1 PHILOSOPHY AND TECHNICAL ASSESSMENT APPROACH

DOE Order 5400.1 states that a written Environmental Monitoring Plan must be prepared for each site, facility, or process that uses, generates, releases, or manages significant pollutants or hazardous materials. The plan must be reviewed annually and updated every three years. According to DOE 5400.1, the monitoring plan must contain the rationale and design criteria for the monitoring program, extent and frequency of monitoring measurements, procedures for laboratory analysis, quality assurance requirements, program implementation procedures, and direction for the preparation and disposition of reports.

Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance (DOE/EH-0173T) requires that the environmental surveillance program be based on the applicable regulations, the hazard potential of the effluents, the quantities and concentrations of effluents, the specific public interest, and the nature of potential or actual impact on air, land, biota, and water. LLNL evaluates each of these requirements as they apply to both present and future LLNL environmental monitoring activities.

The current environmental monitoring networks have evolved over time. However, a formal evaluation of them has not previously been completed. We have now developed assessment criteria to formally evaluate monitoring requirements, compare the requirements to the existing networks, and make any needed adjustments. These evaluations, which are termed technical assessments, are being performed on all monitoring networks and are ongoing. Some assessments are in progress and have not been completed. This Environmental Monitoring Plan is a "snapshot" of the process in time. Furthermore, as the mission of LLNL changes, environmental surveillance and effluent monitoring activities are modified to keep pace with programmatic and regulatory changes.

LLNL environmental monitoring technical assessment begins with examining five basic design criteria. These include identification of all regulatory drivers and the monitoring objectives, identifying all potential sources of pollution so that decisions about analytes that should be measured can be made, examining all potential sample collection methods and selecting the method that is most appropriate for the specific sampling needs, and identifying any best management practices that should be incorporated into the monitoring network.

The technical assessment then proceeds to determining the extent and frequency of monitoring. The appropriate number of sampling locations, the appropriate sampling locations and rationale for each, and the appropriate sampling frequency all are identified.

Good laboratory analysis procedures and practices are important to obtaining quality results from environmental surveillance and effluent monitoring programs. As part of a technical assessment, laboratory sample identification systems, cross-contamination prevention measures, sample preservation and handling practices, analytical methods, equipment calibration procedures and other quality assurance procedures are identified.

The environmental analysts assure the quality of collected data by developing data quality objectives for precision and accuracy. For precision, an evaluation of detection limits for specific analytes is undertaken, and the number and frequency of field duplicates, interlaboratory samples, and laboratory QC samples are determined. For accuracy, an evaluation of the number and frequency of field blanks, field spikes, laboratory control standards, and matrix spikes is determined. Also, any interlaboratory cross-check programs are evaluated. Acceptance criteria and actions to be taken if the results are questionable are evaluated.

Finally, program implementation procedures are developed. The implementation procedures include sample identification systems, cross-contamination prevention measures, sample preservation and handling practices, sample collection procedures, and calibration procedures. Action levels and actions to be taken if the results are not acceptable are also finalized.

The process for completing technical assessments includes a presentation for peer review and a written report of the assessment. The monitoring changes that need to be implemented are incorporated into the procedures and the Environmental Monitoring Plan.

3.2 SITE-WIDE EMERGENCY RESPONSE

3.2.1 Rationale and Design Criteria

All LLNL emergency response activities, including those for environmental monitoring, are part of the LLNL Emergency Management System and fall under the auspices of the LLNL Emergency Preparedness and Response Program. Regulatory drivers for all emergency response can be traced to common

documents (federal regulations, DOE Orders, associated guidance) that require LLNL to develop site-wide emergency response capabilities.

3.2.1.1 *LLNL Site-Wide Emergency Management System*

The objectives of the LLNL Emergency Management System are "to respond to and mitigate potential consequences of credible onsite and significant nearby emergencies that could threaten Laboratory workers, the public, national security, or the environment" according to the LLNL Draft Emergency Plan 1993 (LLNL 1993a). This plan fulfills the requirements of federal regulations including 40 CFR 355 (*SARA Title III Emergency Planning and Notification*), 40 CFR 265 (*Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities*), 40 CFR 302.6 (*Release Reporting*), and 29 CFR 1910.120 (*Hazardous Waste Operations and Emergency Response*). The plan also meets the requirements of DOE Order 5500.3A (*Planning and Preparedness for Operational Emergencies*), and incorporates requirements from other DOE Orders and associated management guides. These other regulatory drivers for site-wide emergency preparedness and response include DOE Orders 5000.3B (*Occurrence Reporting and Processing of Operations Information*), 5480.10 (*Contractor Industrial Hygiene Program*), 5480.11 (*Radiation Protection for Occupational Workers*), 5500.2B (*Emergency Categories, Classes, and Notification and Reporting*), 5500.4A (*Public Affairs Policy and Planning Requirements for Emergencies*), 5500.10 (*Emergency Readiness Assurance Program*), and 5633.33 (*Control and Accountability of Nuclear Materials*). Applicable Emergency Management Guides listed in LLNL 1993a include those for Program Administration, Emergency Exercise Evaluation Criteria, Guidance for Emergency Response Drills and Exercises, Standard Format and Content for Emergency Plans, Guidance for Hazards Assessment, Event Classification and Emergency Action Levels, Consequence Assessment, and interim guidance for Emergency Medical Support, Notification, Offsite Response Interfaces, Emergency Management Training, Protective Actions, and Reentry and Recovery.

Furthermore, the federal government has established a *Federal Radiological Emergency Response Plan* (50 Fed. Reg. 46, 542, 1985) under the management of the Federal Emergency Management Agency (FEMA) for responding to incidents involving radiological materials. For incidents involving other hazardous material, the EPA planning requirements of 40 CFR 355 provide for National Response Teams to assist if needed. LLNL participates with the California State

Office of Emergency Services, the City of Livermore, and the County of Alameda in the development of plans and designated resources for emergency incidents.

The LLNL Emergency Preparedness Program coordinates and integrates all aspects of emergency response, including notification, protective actions, and mutual assistance. The program also specifies the methods employed and provides the framework and support for ongoing maintenance of the emergency response programs; it includes the organizational structure, response procedures, and functional roles of responding personnel. Specifically, the LLNL Emergency Plan (LLNL 1993a) incorporates the 14 essential elements for such a plan as set forth in DOE Order 5500.3A: Consequence Assessment, Drills and Exercises, Emergency Facilities and Equipment, Emergency Response Organization, Medical Support, Notification, Offsite Response Interfaces, Operational Emergency Event Classes, Program Administration, Protective Actions, Public Information, Recovery and Reentry, Training, and the Emergency Operations Center.

The types of emergencies on which the plan is based include bomb threats, civil disturbances, declared state of national alert, explosions, fires, natural disasters (such as earthquakes), radiation incidents, terrorism, and toxic materials incidents. The degree of emergency planning for any particular LLNL facility corresponds to the scope of the potential hazards and consequences of potential harm associated with activities and materials at that facility.

A variety of assessment and planning tools and documents are used to guide emergency preparedness. Facility Hazards Analyses (FHA) are completed for each facility classified as a Category 1, 2, or 3 nonreactor nuclear facility or a High-, Moderate-, or Low-hazard non-nuclear facility. FHAs are based on assessments of the hazards and hazardous materials within a facility and the potential for accidents with consequences extending beyond the boundary of the facility. Safety Analysis Reports (SARs) describe credible accidents for each facility. All buildings at both the Livermore site and Site 300 are classified on a Building Hazards Classification List (LLNL 1993a, Appendix C). Assessments take into consideration the nature and magnitude of potential accidents, geography, seismicity and hydrogeology, site meteorology and storm event history, land use and population distribution, transportation, and utility and communications systems, as well as the special hazards from work performed in that facility.

Although LLNL's Emergency Preparedness and Response Program is designed to prepare for, respond to, and mitigate all potential incidents at LLNL, both large and small, it is useful to determine upper bounds for incidents to ensure

that response organizations could perform adequately in "worst-case" scenarios. Hazards analyses for eight LLNL buildings have identified accident scenarios that might require the declaration of DOE-defined General Emergency in the event of a credible accident. These various bounding accident scenarios involve the potential release of ammonia, hydrogen cyanide gas, chlorine, and transuranic waste following an earthquake, a criticality accident resulting in the release of radioactive materials, and the ignition/burning of transuranic waste following the rupture of a waste drum during an industrial accident. Details on these bounding accident scenarios are found in the LLNL Environmental Impact Statement and Environmental Impact Report (U.S. Department of Energy and University of California 1992).

The LLNL Emergency Preparedness and Response Program has established formal and informal agreements with federal, state, and local agencies and organizations responsible for off-site emergency response, and for the protection of the environment and the health and safety of the public, to ensure appropriate levels and integration of emergency responses. These include DOE, the Federal Bureau of Investigation, the National Response Center, The State of California's Office of Emergency Services, the California Highway Patrol, the Alameda County Office of Emergency Services and Sheriff's Department, the Livermore Fire and Police Departments, and the Atmospheric Release Advisory Capability (ARAC). Where possible, these relationships are prearranged and documented in formal plans, agreements, and understandings for mutual assistance (both mutual- and automatic-aid).

The Emergency Preparedness Plan and its Implementing Procedures are reviewed annually, changes are coordinated, revisions published, approvals acquired, and appropriate controlled distribution is carried out (U.S. Department of Energy and University of California 1992).

3.2.1.2 LLNL On-Site Emergency Response Organization

Although the Emergency Preparedness and Response Program is responsible for strategic emergency planning, preparedness, response, recovery, resource management, readiness assurance, and associated maintenance, the Laboratory organization responsible for initial and ongoing response to, and mitigation of, an actual operational emergency is the On-Site Emergency Response Organization (OERO). The OERO assembles and becomes operational at the direction of the on-duty Laboratory emergency duty officer (LEDO), a senior management representative who is always on call. The OERO is headed by the

Emergency Management Team led by an emergency manager and includes a deputy emergency manager, as well as emergency response and support management representatives from the following departments: Environmental Protection, Hazards Control, Health Services, Plant Engineering, Public Affairs, Safeguards and Security, and Site 300. This team is supported by a staff and operates from the LLNL Emergency Management Center (LLNL 1993a). All additional Laboratory resources respond to incidents at the direction of this management team.

The following sections describe the specific emergency response organizations and obligations of the Environmental Protection Department and the Environmental Monitoring Section.

3.2.1.3 *Environmental Protection Department (EPD)*

EPD is one of the Laboratory's important resources during certain emergencies and follows established LLNL reporting and dispatching protocols used for all emergencies. An environmental duty officer (EDO) is on call 24 hours per day to support environmental emergency response needs, especially during off-hours. In the event of an emergency requiring the involvement of EPD, the department will support LLNL emergency response efforts by sending a senior member of EPD management to serve as an Emergency Management Team member at the Emergency Management Center. In addition, the coordination and direction of EPD operations during operational emergencies is generally controlled through the EPD Satellite Operations Center (EPD-SOC). The EPD-SOC is staffed by a commander (usually the on-duty EDO), communicators, an information manager, runners, and representatives from three divisions of EPD—Hazardous Waste Management, Environmental Monitoring and Analysis, and Operations and Regulatory Affairs (LLNL 1994a).

These three divisions of EPD may also support the OERO directly. The Environmental Operations Group of the Operations and Regulatory Affairs Division is the primary EPD emergency-environmental support arm to all LLNL programs and departments. Environmental analysts from this group serve as members of Environmental, Safety and Health Teams that support groups of Laboratory programs. During an on-hours emergency, these analysts usually report to the scene of the incident and help identify the character, exact source, amount and extent of released material, assess the threat to the environment, report to regulatory agencies if required, and may direct actions to clean up spills. During off-hours, these responsibilities are usually performed by the on-

duty EDO. Hazardous Waste Management provides equipment and personnel for spill containment and cleanup. Environmental Monitoring and Analysis supports the emergency response system by providing environmental monitoring support (see Section 3.2.1.4 below) and analytical services for environmental samples (through the Radiation Analytical Sciences laboratory and Environmental Analytical Sciences laboratory). These analytical laboratories can analyze samples to help determine the nature of spills and to determine when cleanup is complete.

3.2.1.4 *Environmental Monitoring Section (EMS)*

In the event of an emergency involving release of materials to the environment, EMS will provide environmental sampling resources in support of LLNL as requested, using an Emergency Environmental Monitoring procedure and associated command/staffing structure (EMP-EM-S). EMS personnel are ready to respond to emergencies at all times. Responding to the emergency may include determining the nature and extent of contamination and evaluating the hazard to humans and the environment. Releases of hazardous or radioactive materials to the air or sanitary sewer are of primary importance. EMS follows the established LLNL reporting and dispatching protocols used for all emergencies. Emergency response sampling procedures generally follow those established for surveillance monitoring, but can be adjusted depending on the nature of the emergency incident. A detailed discussion can be found below in Section 3.2.5.

3.2.2 *Extent and Frequency of Environmental Monitoring Measurements*

The extent and frequency of environmental monitoring in support of LLNL emergency response will be determined by the nature and scope of the environmental incident. As requested, environmental monitoring staff will give monitoring/sampling advice, participate in formulating environmental sampling plans, and conduct environmental sampling operations. EMS personnel also are available for interpretation of the emergency sampling data when data are received from analytical laboratories.

3.2.3 *Procedures for Laboratory Analysis*

The potential need for analytical laboratory support for emergency environmental monitoring is evaluated as soon as EMS is requested to respond to an emergency. If the potential exists, Environmental Analytical Sciences and/or Radiation Analytical Sciences personnel are contacted and asked to stand by to

advise on analytical capabilities and possibly to analyze samples on an extreme rush basis.

Analytical laboratory personnel are also contacted for analytical method advice, sampling container information, and predicted analytical turnaround times when EMS analysts are formulating environmental sampling plans. These personnel are notified of the numbers of samples that will be arriving and the estimated time of arrival. Instructions about disseminating results are also given to them.

In general, samples requiring nonradiological analyses (gas chromatography/mass spectrometry, inductively coupled plasma emission spectroscopy, atomic absorption) are submitted to Environmental Analytical Sciences (Building 226) for analyses using standard methods (LLNL 1993b). Radiological analyses are normally conducted by the Radiation Analytical Sciences laboratory in Building 151 (tritium in Room B136, gamma spectrometry in Room B114, gross alpha, gross beta in Room B130) using standardized procedures (Hall and Edwards 1994). However, Hazards Control laboratories may also be used, depending on the incident and the required analyses. Sampling technicians inform analytical personnel that data should be reported via telephone and/or fax as soon as analyses are completed. Data in original hard copy shall ultimately be accompanied by appropriate documentation (COC forms) and quality assurance/quality control data.

3.2.4 Quality Assurance Requirements

Analysts include quality assurance/quality control samples when developing sampling plans. Duplicate samples are of greatest importance, but trip blanks, which can provide valuable information regarding possible cross contamination of samples, are also used. Method blanks, spikes, and standards are not as important in an emergency situation as they are during routine environmental surveillance monitoring, but are run as part of analytical laboratory quality control programs.

The LLNL Emergency Preparedness Plan requires initial training and annual re-training for key personnel. This training is specific to the tasks of designated emergency response organizations. EMS emergency response personnel are required to take a number of courses as specified in the EMS Training Plan (Garcia 1994). Drills and exercises have been developed and are conducted to train and evaluate emergency response under various scenarios. EMS personnel participate in all LLNL and EPD emergency response exercises and drills when

requested to do so. Periodic exercises, involving only EMS personnel and scheduled at the discretion of the EMS section leader, are also conducted. These exercises result in reports used to evaluate and amend EMS emergency response procedures.

All documentation associated with the EMS emergency response is archived. These documents include field logbooks/FTFs used to record all pertinent information regarding emergency sampling, COCs that have remained with associated samples and sample data at all times, notes and sampling plans prepared by all EMS participants during the emergency incident, and the final incident report. Reports resulting from exercises and drills are also archived.

3.2.5 Program Implementation Procedures

3.2.5.1 LLNL On-Site Emergency Response Organization

Emergency Plan Implementing Procedures prescribe the actions necessary to implement the commitments and responsibilities set forth in the Emergency Plan (LLNL 1993a). Other documents also relate to emergency preparedness and safety program implementation. The LLNL Health and Safety Manual (LLNL 1994b) is written to assist in establishing and maintaining a minimum-risk work environment at LLNL. Facility Safety Procedures (FSP) contain detailed emergency procedures for specific facilities.

LLNL maintains an emergency notification system that includes a continuously operated emergency dispatch center for receiving and relaying emergency information, and reserved telephone lines for reporting emergencies to the emergency dispatcher (911 or ext. 2-7333 at the Livermore site, or 3-5333 at Site 300). Automatic signals at the emergency dispatch center indicate when local warning systems or fire protection systems are activated. In addition, LLNL maintains an emergency public address system to relay vital information and instructions to LLNL personnel. Furthermore, telephones, two-way radios, radio pagers, an AM broadcast station (AM 1610), sirens/klaxons, portable loudspeakers, megaphones, and runners can be used for communicating emergency information.

The emergency dispatcher uses reserved telephone lines to relay emergency calls promptly to the following emergency response departments: Safeguards and Security, Hazards Control (which includes the Fire Department), Plant Engineering, Environmental Protection, and Health Services. Thereafter, the

dispatcher uses the best method available to notify other needed personnel. During off-shift hours, the emergency dispatcher will use regular telephone lines to notify required personnel.

Personnel from the Fire Department, Safeguards and Security Department, and the area Environment, Safety, and Health Team go to the scene of an emergency immediately and establish the Incident Command System. The senior fire officer assumes the role of incident commander (IC) and proceeds with preplanned control actions relevant to the emergency; the IC evaluates the magnitude of the emergency and makes an initial classification, directs appropriate control actions, makes initial notifications, and calls for any additional personnel. The IC is responsible for safety, rescue, fire control and extinguishment, spill control, containment, protection of classified matter, property conservation, and salvage operations. On-scene operational control is retained by the IC throughout the duration of the incident. Safeguards and Security Department personnel control traffic, guard the scene, or perform other tasks requested by the IC. The Environment, Safety, and Health (ES&H) Team provides guidance on the hazards and control methods and proceeds with control activities as directed; the ES&H Team includes the appropriate Operations and Regulatory Affairs Division environmental analyst.

The Emergency Management Team, operating from the Emergency Management Center, categorizes all emergencies based on a standardized scheme of escalating severity levels (Alert, Site Area Emergency, General Emergency). In close communication with the IC, additional resources are called upon as needed. Ultimate responsibility for LLNL emergency response actions lies with the Director of the Laboratory, who delegates this authority to the Emergency Management Team.

The Incident Command System ensures a fast and coordinated response to emergencies. The organization of the Incident Command System is the responsibility of the LLNL Fire Department, which is responsible for implementing changes to the system as they become necessary. The effectiveness of this system is tested through emergency exercises, and the results of these exercises are used to improve the system.

3.2.5.2 *Environmental Protection Department Satellite Operations Center*

Environmental Protection Department responsibilities and procedures are documented in LLNL 1993a and 1994a,b. In general, EPD is responsible for

coordinating environmental protection activities both on site and off site in response to environmental threats to the Laboratory, its assets, workers, the public, and/or the environment. EPD is to provide necessary expertise and equipment to ensure that releases are assessed for possible impacts; ensure that mitigation and corrective actions are identified and acted upon; determine and implement containment, clean-up, disposal, monitoring, assessment, and sampling needs; and ensure that appropriate regulatory agencies are notified and provided required reports (1993a). EPD largely conducts these operations for large incidents through the direction of personnel at the EPD Satellite Operations Center (EPD-SOC). For smaller scale incidents, EPD operations can be directed by the environmental duty officer (EDO) and environmental analysts in the field without activation of the EPD-SOC.

The EPD-SOC may be activated at the request of the IC, the EDO, the EPD department head, or the LEDO. It is activated according to prescribed procedures (LLNL 1994a) and normally is established in Room 1145 (Discovery Room) in Trailer 5475.

The role of satellite operations commander is assumed by either the on-duty EDO or a pre-qualified and trained SOC commander designated by the EDO. The commander has overall responsibility for the operation of the satellite operations center and carries out the directives received from the LLNL Emergency Management Team (of which a senior EPD management person is a member). The commander staffs the SOC as necessary, evaluates the situation and estimates the capability of on-site EPD personnel to control the incidents, and makes sure appropriate resources are available. The commander ensures that all members of the SOC conduct their activities accordingly.

Priorities for EPD response are set in the following order, regardless of whether the EPD-SOC is activated or not: (1) evaluate the incident; (2) marshal resources; (3) contain, clean-up, dispose; (4) sample/monitor; (5) determine notification and advise on reporting requirements. Descriptions of the responsibilities and duties of other SOC members, as well as checklists, call-out lists, maps, and detailed procedures can be found in LLNL 1994a.

3.2.5.3 Environmental Monitoring Section

EMS personnel are typically notified as secondary responders to an incident by the emergency dispatcher at the request of the IC, the EDO, the ES&H team leader, or the responsible environmental analyst from the Operations and

Regulatory Affairs Division. EMS personnel report immediately when called (i.e., within 15 minutes during normal working hours and within 45 minutes during off-shift hours) and stand by for assignments through the established chain of command (see Figure 3-1 for emergency chain of command).

All EMS Staff members must respond to support emergency environmental sampling activities when called. Exceptions are if they are unfit for duty, or if responding would result in unattended or potentially endangered minor children. All EMS staff reporting for emergency response must have completed SARA/OSHA 24-hour Hazardous Waste Operations Training and must be current with respect to annual SARA/OSHA Hazardous Waste Operations 8-hour refresher courses. They shall also have completed the EMS training for procedure EMP-EM-S and be current with respect to first aid and CPR training.

3.2.5.4 EMS Emergency Duties

The EMS section leader is responsible for all EMS activities during the incident and determines the extent of EMS involvement in the emergency response. Typically the section leader assumes the role of EMAD representative at the EPD Satellite Operations Center, and functions as the EMS liaison to the incident commander in the emergency chain of command. The EMAD representative provides EMS capability/status information to the incident command staff, takes part in the formulation of sampling plans/strategies, relays EMS data, and provides incident-related information to EMS staff in the EMS Monitoring Headquarters. (EMS Headquarters is located in Room 1242 of Trailer 5475, the Big Sur conference room, unless that area is in the zone of contamination.)

A lead analyst to direct the environmental monitoring effort is selected or designated by management. In consultation with the EMAD representative, the lead analyst assigns duties to all EMS staff present, such as answering phones, updating personnel and incident information on status boards, taking detailed notes and times of all events, preparing sampling plans and evaluating data, collecting samples in the field, and serving as "buddies" for samplers. Some staff members may be asked to stand by and await assignment.

3.2.5.5 Emergency Sampling

Although Hazards Control typically conducts some sampling at the outset of any incident to support immediate health and safety concerns, EMS is called when environmental issues and actions are required.

Using professional judgment in the preparation of emergency sampling plans, analysts must adjust from routine sampling requirements to the emergency situation. In general, the levels of contamination will be much higher than any measured during routine monitoring, so analysts must include appropriate

quality assurance/quality control samples when developing sampling plans (see EMP-QA-S). Emergency monitoring equipment is maintained by the Technical Support Group, under the direction of its group leader, in a state of readiness and is not to be used for other purposes. Analytical techniques might be adjusted, and careful sampling that minimizes the possibility of sample cross contamination may become even more essential than during routine surveillance monitoring activities.

Field sampling personnel are responsible for collecting environmental samples according to established procedures (EMP-EM-S, *Emergency Environmental Sampling*; EMP-W-S, *Water Sampling*; EMP-GW-S, *Groundwater Sampling*; EMP-AP-S, *Air Particulate Sampling*; EMP-AT-S, *Air Tritium Sampling*; EMP-R-S, *External Radiation Monitoring*; EMP-SW-OP, *Sewer Monitoring Operations*; EMP-SW-B196, *Sewage Sampling at B196*; EMP-SW-C196, *Sewage Sampling at C196*; EMP-SW-DS, *Diversion Facility Tank Sampling*; EMP-SW-SAS, *Satellite Alarm Sampling*; EMP-SW-SID, *Sewer Spill Source Identification*; EMP-S-S, *Soil and Arroyo Sampling*; and EMP-VG-S, *Vegetation and Foodstuff Sampling*.) They follow the emergency sampling plan, paying close attention to the location and sequence of sampling and to the established sampling procedures. They take care not to contaminate samples, and fill out all sampling documentation completely. Furthermore, they are responsible for taking detailed notes in the field regarding sampling, and must keep in close contact with EMS headquarters by cellular telephone when in the field.

Although EMS personnel are required to respond to emergencies, they are not responsible for sampling when such activities may place them at risk of loss of life or detrimental health impacts. EMS personnel are not authorized to proceed into contaminated areas requiring greater than OSHA Level D protection (they are not authorized to use respiratory protection in the course of these sampling activities), nor may they be exposed to radiation levels that may result in a dose greater than 5 rem. The industrial hygienist and health physicist on the ES&H Team must determine the safety of the environment in which EMS personnel will be traveling and sampling. Such determinations may be made based on computer dispersion modeling or on monitoring conducted by the Hazards Control health and safety technicians. Hazards Control technicians will accompany EMS staff members to the field, if necessary, and will use radiation survey instruments and other industrial hygiene equipment to ensure that the EMS field sampling personnel are not exposed to unacceptable levels of radiation or toxic agents resulting from the incident. Environmental sampling will

commence *only* after the industrial hygienist/health physicist has determined that the area is safe. Communications regarding the safety of the environment for EMS personnel should be directed from the industrial hygienist/health physicist to the ES&H Team environmental analyst, the EPD-SOC, the EMAD representative, and the lead analyst at the EMS headquarters, in that order.

3.2.6 Preparation and Disposition of Reports

Data from EMS-collected emergency environmental samples are reported to the EMS headquarters and ultimately to the incident commander through the chain of command. EMS analysts interpret results, including evaluation of analytical laboratory QA/QC data, evaluation of duplicate sample results, comparison of data from contaminated areas to data obtained from samples at background locations and to those normally encountered during surveillance monitoring, and comparison of sample data to regulatory limits. If additional sampling is required, additional sampling plans are developed and carried out.

Once the sampling aspects of the emergency response are concluded, a debriefing is conducted for all EMS personnel at the direction of the section leader, with participation by all EMS personnel who responded to the incident. A final report on the EMS response is compiled by the lead analyst and EMAD representative. The debriefing extracts all pertinent information regarding EMS response (e.g., what worked and what did not, what happened, what decisions were made, what assumptions were used, what time things happened, and who made what decisions). The final report relates all information from the debriefing and includes recommendations for future EMS emergency response improvements.

All documentation associated with the EMS emergency response is archived in the Document Retention Center in accordance with procedure EMP-QA-DC. These documents include field logbooks/field tracking forms used to record all pertinent information regarding sampling, chain-of-custody forms that have remained with associated samples and sample data at all times, notes and sampling plans recorded in the EMS headquarters and those compiled by the EMAD representative throughout the course of the emergency incident, and the final incident report.

3.3 REPORTING

Proper reporting and record keeping are essential to the Environmental Monitoring Section (EMS)'s monitoring effort. EMS reports are generally of four types:

- Reports required by regulatory agencies such as the Regional Water Quality Control Boards or the Bay Area Air Quality Control District. These reports are usually required as part of a permit and summarize monitoring data on a monthly, quarterly, or annual basis.
- Reports required, usually by DOE Order, to inform the public about the environmental impacts of LLNL operations on the environment.
- Special reports to DOE, such as Occurrence Reports, needed to explain usual monitoring results or communications with regulatory agencies, and
- Special, one-time reports, usually to regulatory agencies, that detail a specific monitoring effort or compliance activity.

Following is a listing of current EMS reporting in each category.

3.3.1 Reports to Regulatory Agencies

1. *LLNL Site 300 Ground Water Monitoring Program Quarterly Report*, submitted to the California Regional Water Quality Control Board, Central Valley Region (CVRWQCB), fulfills reporting requirements set forth in the Post-Closure Monitoring Plan and Waste Discharge Orders 93-100 and 85-188. This report describes monitoring of 53 wells that provide surveillance information about existing and closed landfill areas at Site 300 and the overall impact of Site 300 operations on regional ground water chemistry. Procedure EMP-GW-QR, *Quarterly Ground Water Report*, provides guidance for preparing this report.
2. *NESHAPs Annual Report*. The National Emissions Standards for Hazardous Air Pollutants (NESHAPs) from 40 CFR Part 61, subpart H, govern radionuclide emissions to air from Department of Energy facilities. Subpart H also outlines NESHAPs reporting requirements, which include the submittal of an LLNL NESHAPs

annual report for each calendar year. The annual report demonstrates LLNL's compliance with the NESHAPs dose standard, lists radioactive materials used at LLNL, describes both point and diffuse sources and effluent controls, states distances to public receptors for each source, includes values for all input parameters used in dose models, and contains certification signatures. Previous quarterly reporting requirements, initiated as part of a Federal Facilities Compliance Agreement (FFCA) signed by EPA and DOE in 1993, were rescinded when EPA notified DOE and LLNL that all requirements of the FFCA have been met.

3. *Radioactive Effluent and On-Site Discharge Data Reports.* DOE 5400.1 requires LLNL to prepare radioactive effluent and on-site discharge data reports annually. The reports are submitted to the Idaho National Engineering Laboratory, DOE Idaho Field Office, Idaho Falls, Idaho, for inclusion in the Effluent Information System/Onsite Discharge Information System (EIS/ODIA) annual report (Meikle 1994). Releases of radioactive materials in effluents from both routine operations and unplanned releases such as spills, leaks, etc., whether on site or off site, are included in these reports.
4. *The Experimental Test Site Cooling Tower Discharge Self-Monitoring Report* satisfies WDR 93-131 issued by the CVRWQCB. The monitoring plan that accompanies WDR 94-131 calls out requirements for quarterly monitoring and reporting for pH and total dissolved solids (TDS) of blowdown water from 17 cooling towers at Site 300; and surface water samples in Corral Hollow Creek. The monitoring plan also requires reporting of visual observation for contaminants at Corral Hollow Creek.
5. *Sewer Monitoring Report.* LLNL submits monthly sewer monitoring reports to the Livermore Water Reclamation Plant (LWRP) in response to Permit number 1250 (93-94). This permit, applied for annually, provides for the continued discharge of LLNL sanitary and industrial effluent to the city sewer system. Under the provisions of this permit, LLNL conducts daily and monthly effluent sampling at its outfall into the LWRP sewer system and reports the results to the LWRP in the *Sewer Monitoring Report*.
6. *Semiannual Wastewater Point Source Monitoring Report.* According to federal pretreatment regulations, quarterly and semiannual

sampling is required of all identified categorical processes. These monitoring results are reported semiannually to the LWRP in the semiannual *Wastewater Point Source Monitoring Reports*.

7. *Self-Monitoring Reports*. Self-monitoring reports to the LWRP verify the performance and effectiveness of several ground water treatment units that discharge at the Livermore Site. In addition, water quality monitoring of the Central Drainage Basin, a lined surface-water impoundment that receives both storm water runoff and treated ground water at the Livermore site, is reported quarterly to the SFRWQCB.
8. *Beryllium Report*. The Bay Area Air Quality Management District's Regulation 11, Rule 3 requires LLNL to monitor and report quarterly on ambient air beryllium concentrations at the Livermore site.

3.3.2 Reports to Inform the Public on LLNL Operations

One of EMS' most important continuing tasks, the Environmental Report (also known as the Site Annual Environmental Report), is required by DOE Order 5400.1. Prepared annually since 1971, the SAER describes the effluent, surveillance, and compliance monitoring performed during the calendar year. The Environmental Report serves as the annual compilation of EMS monitoring activities. Procedure EMP-QA-AER, *Site Annual Environmental Report*, describes guidelines for its production.

3.3.3 Occurrence Reports

Occurrence reporting follows guidelines in DOE Order 5000.3B. The LLNL Occurrence Reporting Office issues detailed instruction on the preparation of Occurrence Reports (ORs) in *LLNL Implementing Procedure for DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information, Revision 1.0 7 July 1994*. ORs provide timely notification of occurrences to DOE and other responsible authorities (see EMP-EM-S, *Emergency Environmental Monitoring*; EMP-SW-AR, *Sewer Alarm Response*; EMP-QA-D, *Data Analysis*). For example, EMS prepares an OR when contaminants exceed sewage discharge standards set by the Livermore Water Reclamation Plant. In compliance with DOE Order 5000.3B, 24-hour written notification, 10-day follow-up reports, and final reports are issued for each occurrence.

3.3.4 Special Reports

1. *Stormwater Pollution Prevention Plans (SWPPP)* In 1994, LLNL developed SWPPPs for both Site 300 and the Livermore site as required by the California General Industrial Activity Storm Water National Pollution Discharge Elimination System (NPDES) Permit. The SWPPPs identify sources of pollution affecting the quality of industrial storm water discharges and describe practices to reduce pollutants in these discharges. Implementation of the SWPPP is documented in annual monitoring reports, one for each site, submitted to the respective RWQCBs. The SWPPPs themselves are not required to be revised and submitted on any regular schedule but amended (1) prior to any planned physical alteration or addition to either site that could significantly change the nature or quantity of pollutants discharged to stormwater, or (2) if a SWPPP is found in violation of any condition of the permit.
2. *Sampling Results: Site 300 Sewage Oxidation Pond Sludge.* In 1994 EMS prepared a report on characterization sampling of sludge from the Site 300 sewage oxidation pond. This report supported permit applications for sludge removal from the pond and aided in evaluating sludge removal options.

3.3.5 Guidance for Report and Document Preparation

Guidance on the preparation of EMS documents exists in several locations. Certain key documents, such as the annual Environmental Report and the LLNL Site 300 Ground Water Monitoring Program quarterly reports, have their own written guidance procedures (EMS-QA-AER and EMS-GW-QR respectively). General guidance on EMS report preparation will be found in EMP-QA-R (*Reporting and Review Requirements*) which is in preparation. Currently, the most detailed instructions appear in Sections 4.1-5 of the EMS Quality Assurance Plan issued 1 October 1993. This section of the QAP establishes the requirements and defines the general methods for the preparation, review, approval, issuance, and use of documents that, among other things, report on quality-affecting activities in EMS.

Department-level guidance on the preparation of documents is present in *Department Office Procedures*, issued 20 October 1992 by Paula Foerschler, and for submitting documents to the ES&H Working Group in *Approval of ES&H Documents*, issued 29 October 1992 by Harry Galles.

Records relating to surveillance and effluent monitoring are maintained by the EMS. Several procedures (e.g., EMP-QA-DP, *Data Packages*, EMP-QA-DM, *Data Management*; EMP-QA-DC, *Document Retention Center*; EMP-QA-SD, *Sample Tracking Documentation*, and EMP-R-DA, *Dose Assessment*) outline steps to preserve specific documents and records. More general guidance is found throughout the EMS Quality Assurance Plan (Garcia and Failor 1993).

4

Air Effluent Monitoring

4.1 RATIONALE AND DESIGN CRITERIA

The ultimate purposes for conducting an air effluent sampling program are to protect the members of the public and the LLNL work force, and to preserve our environment by demonstrating compliance with regulatory requirements and providing information on the performance of emission control systems. The air effluent sampling program must comply with DOE Orders 5400.1, *General Environmental Protection Program*; and 5400.5, *Radiation Protection of the Public and the Environment; Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (EH-0173T, U.S. DOE 1991); National Emission Standards for Hazardous Air Pollutants (NESHAPs) 40 CFR 61; and specified ANSI standards.

Currently, the air effluent sampling program measures only radiological emissions. LLNL has operations with the potential for nonradiological discharges; however, permits for these operations are obtained through local agencies having enforcement authority for the Clean Air Act and monitoring is not required. The agencies governing LLNL compliance are the Bay Area Air Quality Management District for the Livermore site and the San Joaquin Valley Unified Air Pollution Control District for Site 300.

Historically, monitoring of radionuclide air effluents at LLNL has been implemented according to the DOE ALARA (as low as reasonably achievable) policy. The more recent NESHAPs regulations require that monitoring of facility radionuclide air effluents must be performed if the potential off-site dose equivalent is greater than $1 \mu\text{Sv/y}$ (0.1 mrem/y), as calculated using the EPA-mandated air dispersion dose model and assuming no emission control devices. Air effluent monitoring provides the actual source term for modeling to ensure that the NESHAPs standard, $100 \mu\text{Sv/y}$ (10 mrem/y) total site effective dose equivalent, is not exceeded.

A wide variety of radioisotopes is used for research purposes at LLNL, including transuranics, biomedical tracers, tritium, mixed fission products, and others. The major radionuclide 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 transuranic

aerosols. The air effluent sampling systems described in this chapter apply to stationary and point source discharges. Sampling methods to evaluate LLNL diffuse sources are described in Chapter 6.

4.2 EXTENT AND FREQUENCY OF MONITORING AND MEASUREMENTS

4.2.1 Radiological Monitoring

To identify the need for monitoring air effluent discharge points, we have completed an extensive evaluation of all effluent discharge points for their potential to release radionuclides. In addition, we evaluated existing sampling systems for their conformance with regulatory requirements (see Section 4.6).

In April 1991, LLNL was ordered to comply with the requirements of NESHAPs 40 CFR 61, Subparts A and H. The action, Docket 9-91-17, was filed by the U.S. EPA Region IX for LLNL's failure to demonstrate compliance with the regulations. According to NESHAPs 40 CFR 61.93, monitoring of discharge stacks or vents must be performed if a release could result in an effective dose equivalent of greater than $1 \mu\text{Sv/y}$ (0.1 mrem/y) to a member of the public (assuming normal operations, but without emission control systems).

LLNL responded to this action in May 1991 with a work plan to identify all emission sources having a potential to release radionuclides to the air. To assess the need for additional sampling systems, LLNL performed a site-wide engineering survey and a site-wide inventory/source-term evaluation. The engineering survey compiled data that included stack location, stack height, blower description and capacity, emission control equipment, and the hazards in the area being vented. The site-wide inventory identified the quantities of radionuclides stored or used in all facility areas and estimated the potential source-term release, taking into account the type of source and operation. Using these source terms and information from the engineering survey, dispersion modeling was performed with the EPA-mandated codes AIRDOS or CAP88-PC to establish the effective dose equivalents at the nearest fence-line for each discharge point.

The results of this effort, published in eight quarterly reports to EPA Region IX during the period September 1991 through March 1993, identified no discharge points requiring sampling of radionuclide air effluents beyond those already sampled. In fact, some discharge points with existing sampling systems (the ones

located in Buildings 175, 231, 419, 490, and 491) were found not to require them. Sampling at the locations in these facilities will continue as a best management practice. Three buildings already being monitored for air effluents—Building 331, Building 332, and the hardened portion of Building 251—were identified either as requiring monitoring or as locations that, because of classification issues, were difficult to assess, so LLNL agreed to monitor them.

Site 300 was also evaluated in this process and was found to have no locations requiring effluent sampling for radionuclides.

The March 1993 NESHAPs quarterly report reflected our demonstrated compliance with the NESHAPs regulations. EPA concurred with our demonstration of compliance in April 1994.

4.2.2 Nonradiological Monitoring

Operations at LLNL having the potential to release nonradiological pollutants currently are not required to be monitored. LLNL is not considered a major source of nonradiological pollutant emissions. However, permits for such operations must be obtained from the local agencies 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 for Site 300. Internally, the Permits and Regulatory Affairs Group of the Environmental Protection Department is responsible for obtaining necessary permits and exemptions, maintaining permit records, and coordinating inspections. Emissions from LLNL are fewer than 25 tons per year of precursor organic compounds and nitrogen oxides; these emission levels qualify LLNL to be considered a small facility by the BAAQMD.

4.2.3 Air Effluent Sampling Locations

There are currently eight buildings at the LLNL site that have radionuclide air monitoring systems (see **Figure 4-1**). The following descriptions of these sampling systems are organized by building. These buildings are also listed in **Table 4-1**, along with the number of samplers, the types of samplers, the analytes of interest, and the number of monitored discharge points at the building.

Table 4-1. Air effluent sampling locations and systems.

Building	Facility	Analytes	Sample type	Number of samplers	Number of discharge points
175	Mars	Gross α, β on particles	Filters	6	6
231	Vault	Gross α, β on particles	Filter	1	1
251	Heavy Elements				
	Unhardened area	Gross α, β on particles	Filters	44	55 ^a
	Hardened area	Gross α, β on particles	CAM ^b	4	4
331	Tritium	Tritium	Ionization Chamber ^b	4	4
		Gaseous tritium/tritiated water vapor	Molecular sieves	4	2
332	Plutonium	Gross α, β on particles	CAM ^b	12	11
		Gross α, β on particles	Filters	12	11
419	Decontamination	Gross α, β on particles	Filters	2	2
490	Laser Isotope				
	Separation	Gross α, β on particles	Filters	4	4
491	Laser Isotope				
	Separation	Gross α, β on particles	Filters	1	1

Note: "CAM" denotes Eberline continuous air monitors.

^a Alternate blower system measured by the same sampler.

^b Alarmed systems.

4.2.3.1 Building 175—Mars Uranium Facility

Operations performed in the Mars facility support research efforts in uranium laser isotope separation. Discharge points that are monitored from Building 175 have the potential to release uranium aerosols to the atmosphere. The effluent exhausts of four ventilation systems in the building currently are sampled for particles through six sampling probes (the two larger ventilation systems are each driven by two blowers, with each blower having a monitored release point). Samplers are located downstream of high efficiency particulate air (HEPA) filters and immediately before discharge to the atmosphere. The sample filters, 47-mm-diameter mixed cellulose membranes, collect particles continuously and are removed bi-weekly for analysis for gross alpha and gross beta activity. These sampling systems have been upgraded to better meet the specifications of NESHAPs and ANSI N13.1-1969 standards.

4.2.3.2 *Building 231—Vault*

The vault area of Building 231 is used for the receipt and shipment of radionuclides and for storage of sealed radioactive sources that are not immediately needed by programs. Operations in the vault area are limited to shipping, receiving, inspecting, weighing, packaging, transporting, and storing of radioactive and other controlled materials and samples. Radioactive materials include depleted and natural uranium, transuranic wastes, and thorium, among others. The air effluent from the vault area is discharged into the atmosphere after filtration by two stages of HEPA filters. Continuous sampling of the filtered effluent for particulate emissions is performed using a 47-mm-diameter, mixed-cellulose membrane filter sampler. The sample filters are changed and analyzed weekly for gross alpha and gross beta activity.

4.2.3.3 *Building 251—Heavy Element Facility*

The Heavy Element Facility houses laboratories for conducting theoretical and applied research involving transuranics; handling high-specific-activity samples; and characterizing radionuclide materials. The facility has four Eberline continuous air monitoring (CAM) sampling systems on exhausts in the "hardened" area of the building and 44 filter-type continuous sampling systems in the remainder of the building. All samplers are placed downstream of one to three stages of HEPA filtration.

The four CAM Eberline units are on emergency power and monitor common glove box exhausts and common room exhausts of the hardened area. These monitors satisfy the DOE EH-0173T requirement that alarm monitors be in use at discharge points having the potential to give an off-site effective dose equivalent greater than $1 \mu\text{Sv/y}$ (0.1 mrem/y). Alarms for the CAM samplers are sounded in the facility control area and also at the LLNL Sitewide Alarm System Emergency Dispatch Center. Cellulose membrane filters are used in the CAM samplers for particle collection and are analyzed weekly for gross alpha and gross beta activity. In 1990, the sample probes and transport lines to the Eberline continuous air monitors were upgraded to conform to the ANSI N13.1-1969 sampling guidelines.

The filter-type systems in the unhardened area of the facility sample individual emission points, from either glove boxes, fume hoods, or rooms. Glass fiber, 47-mm-diameter filters are used to collect particles and are changed bi-weekly for gross alpha and gross beta analysis. Additional filter-type samplers and air

effluent flow measurement systems are being installed in the Building 251 hardened area (see Section 4.6).

4.2.3.4 *Building 331—Tritium Facility*

The Tritium Facility houses laboratories for conducting experiments involving radioactive gases and their compounds. All air effluent from the facility is exhausted through two stacks with no abatement devices. Total air effluent flow is approximately 1100 m³/min. Each stack is monitored for tritium release by both a continuous monitoring alarm system and continuous molecular sieve samplers; all are on the emergency power system. The alarmed samplers provide real-time tritium concentration release levels (both HT and HTO), while the sieve samplers, which can discriminate between tritiated water (HTO) vapor and molecular tritium (HT), provide the values used for environmental reporting and are exchanged weekly or bi-weekly, depending on what is being requested by the Hazards Control Department or Environmental Protection Department. The continuous-alarmed monitors consist of two Overhoff ion chambers in parallel, one to monitor high tritium concentrations and the other to detect lower levels. The ion chambers have low and high alarm settings of 3.3 TBq (90 Ci) and 33 TBq (900 Ci), respectively, and the alarms sound after a release of 15-minute duration. The high alarm level corresponds to an instantaneous tritium concentration of 0.4 TBq/m³ (10 Ci/m³). High alarm conditions are reported at the facility and the LLNL Sitewide Alarm System Emergency Dispatch Center, while the low alarm is reported only at the facility. Routine inspections of ion chamber operation include a weekly source check for the ion chamber and alarm set points, a quarterly check of the alarmed monitor electronics, and semiannual electronic checks and detector calibration. The ion chambers satisfy the DOE EH-0173T requirement that alarm monitors be in use at discharge points having the potential to give an off-site effective dose equivalent greater than 1 μ Sv/y (0.1 mrem/y).

Each continuous tritium sampler (unalarmed) is placed in parallel with the alarmed monitors and consists of two molecular sieves. The first sieve collects tritiated water vapor; then a palladium-coated catalyst converts molecular tritium to tritiated water and collects the tritiated water on a second sieve.

New continuous air effluent flow measurement systems are planned for installation in the stacks of this facility (see Section 4.6).

4.2.3.5 *Building 332—Plutonium Facility*

The Plutonium Facility has supported research and development in the chemical, metallurgical, and physical properties of plutonium. Currently, the facility supports programs addressing weapon dismantlement and plutonium disposition, research in the metallurgy and chemistry of actinides, and development of pyrochemical processing methods. The facility has 11 air effluent discharge points, including both building and glove box ventilation systems. The discharge points are monitored by alarmed Eberline CAMs and also by simple filter-type aerosol collection systems. The latter are also continuous collection systems but are not alarm systems. The Eberline monitors provide the alarm capability for the facility and meet the DOE EH-0173T requirement of alarm-type samplers as noted above. The filter-type sampling system provides for more representative sampling of the air effluent streams by better placement of the sample extraction probes and minimization of particle losses in the aerosol transport lines. Alarms from the Eberline monitors are automatically routed to the facility's control room and also to the LLNL Sitewide Alarm System Emergency Dispatch Center. Both filter aerosol systems operate from the facility's emergency power system. Sampling locations are downstream of at least two stages of HEPA filtration. The 47-mm-diameter filters from both the CAM and passive systems are changed weekly and analyzed for gross alpha and gross beta activity.

The filter-type air sampling systems in the Plutonium Facility are in the process of being upgraded to include multi-port aerosol extraction probes and air velocity sensors (see Section 4.6 below).

4.2.3.6 *Building 419—Decontamination Facility*

The Decontamination Facility has been used in the past for the decontamination of equipment and parts but is not currently operational. Plans for the eventual decontamination of the facility are being developed. Sampling of the exhausts from the facility will continue until the decontamination process is completed. The facility has two ventilation systems, which are each continuously sampled by a filter sampler. The 100-mm-diameter, glass-fiber filters are changed weekly for analysis of gross alpha and gross beta activity.

4.2.3.7 *Building 490—Laser Isotope Separation Facility*

The Building 490 Facility performs research and development in laser isotope separation; in the past, experiments have been conducted to investigate the

separation of uranium isotopes. The isotope separation facility houses a negative air system to control particulate emissions of uranium from the separator vessel and confinement room. The air system, which has two stages of HEPA filtration, has four air discharge points. The air from each discharge point is sampled for particulate emissions by a 47-mm-diameter cellulose membrane filter through a four-port extraction probe. The samplers operate continuously and are switched to auxiliary power in the event of a power outage. Filters are replaced and analyzed on a weekly basis for gross alpha and gross beta activity.

4.2.3.8 *Building 491—Laser Isotope Separation Facility*

This facility supports the isotope separation experiments performed in the Building 490 separator facility. It has one air effluent discharge stream. The air effluent is sampled for particulate emissions like the Building 490 facility above.

4.2.4 *Sampling Locations - Future NESHAPs Compliance*

LLNL will continue to comply with NESHAPs requirements through annual assessments on the need for new sampling locations. Each assessment will continue to address all LLNL air emission points and diffuse sources with the potential to discharge radionuclides to the atmosphere. To update radionuclide inventories and operations, as well as stack information, inventory forms and appropriate guidance will be sent to Livermore site facilities and Site 300. These forms will be completed by experimenters, certified by facility managers, and returned to the Environmental Protection Department for dispersion modeling with EPA-mandated codes. The potential effective dose equivalents to members of the public will be estimated and will indicate if any additional discharge points require monitoring. More important, the results will serve to confirm that LLNL remains in compliance with the total effective dose equivalent, 100 $\mu\text{Sv}/\text{y}$ (10 mrem/y), for the site. All NESHAPs calculations will be archived with the supporting information used to make the calculations.

In addition to the annual assessment process, the Environmental Protection Department is notified when new operations or facilities are planned. Currently, the Environmental Monitoring Section is notified by the Operations and Regulatory Affairs Division, Environmental Evaluations Group, which conducts reviews for compliance with the National Environmental Policy Act. In addition, the Terrestrial and Atmospheric Monitoring and Modeling (TAMM) Group has representatives on the Environmental Support Teams that routinely discuss environmental issues and are integrated with the Hazards Control Health and

Safety Teams. TAMM continues to refine mechanisms to ensure that it is informed whenever new operations are proposed, significant changes in inventories occur, or existing operations are modified so that NESHAPs evaluation can be performed and appropriate action taken.

In the future, LLNL plans to institute periodic sampling measurements at site effluent locations where continuous sampling is not required by the regulations. Periodic sampling is planned on an annual basis for operations that have the potential to generate effective dose equivalents of between 0.1% and 1% of the NESHAPs emission standard of 100 $\mu\text{Sv}/\text{y}$ (10 mrem/y), that is, between 0.1 and 1.0 $\mu\text{Sv}/\text{y}$ (0.01 and 0.1 mrem/y).

4.2.5 Effluent Flow Rate Measurement

Currently, measurements of effluent flow rate from discharge points having sampling systems are not conducted routinely. With the installation of new sampling probes at discharge points where sampling is required, effluent flow rates will be monitored continuously and calibrated on an annual basis. In the future, the Environmental Monitoring Section will establish and implement procedures to monitor effluent flow rates from all emission points having sampling systems on a routine, preferably annual, basis.

4.3 ANALYTICAL METHODS

Samples requiring radiation counting are analyzed by the Radiological Measurements Laboratory of the Hazards Control Department. Measurement methods conform to the requirements of 40 CFR 61, Method 114, specifically 3.1.4-Method A-4 for gross alpha determination, 3.3.2-Method B-4 for gross beta determination, 3.5.1 for alpha counting using gas flow proportional counters, and 3.5.2 for beta counting by scintillation counters. Radiation measuring equipment is calibrated with standards traceable to the National Institute for Standards and Technology (NIST). Laboratory blanks constitute at least 10% of analyses and serve as indicators of cross contamination within the counters. The Radiological Measurements Laboratory participates in the EPA Environmental Radioactivity Laboratory Intercomparison Studies Program on a quarterly basis, as well as comparison studies with the DOE Environmental Measurements Laboratory and Oak Ridge National Laboratory. For details on analytical procedures, see Chapter 16 on Procedures for Laboratory Analysis.

4.4 QUALITY ASSURANCE

4.4.1 Quality Assurance Program

The NESHAPs regulation (40 CFR 61) specifies a rigorous quality assurance program for the sampling of air effluent radionuclides. The LLNL NESHAPs Quality Assurance Program is a multi-organizational effort that relies on the Quality Assurance/Quality Control programs in place at the LLNL facilities that have continuous air monitoring systems, the Radiological Measurements Laboratory of the Hazards Control Department, and the Environmental Monitoring Section (EMS).

Facility Safety Procedures (FSPs), Safety Analysis Reports (SARs) and QA Manuals for each monitored facility describe its organizational structure, responsibilities for sampling locations used for continuous air monitoring, and the procedures to be followed in the case of unplanned radionuclide releases. For example, the FSP for the Plutonium Facility (Building 332) describes in detail the procedure for responding to detection of radioactive materials in a release from the stacks. These documents also describe the sampling collection systems for both CAM alarm and simple filter-type air monitoring systems, including sampling probes, procedures to be used on measuring flow rates, and sampling and calibration procedures. Similarly, the FSP for the Tritium Facility (Building 331) describes its stack monitoring system, which includes molecular sieve detectors for tritiated water and elemental tritium gas.

The Hazards Control Department's Radiation Measurements Laboratory Quality Assurance Program describes laboratory analysis procedures, precision, accuracy and completeness objectives, sample tracking procedures, quality control sampling, sample handling, and data reporting. For example, its *Gross Alpha-Beta Procedures Manual* (November 1992) describes operational procedures for analyzing the air sample filters for radioactivity (see Section 4.3).

The Environmental Protection Department, under whose auspices NESHAPs modeling and reporting are conducted, also operates under a quality assurance management plan and associated procedures. The TAMM Group, which operates under the Environmental Monitoring Section Quality Assurance Plan (Garcia and Failor 1993), is responsible for modeling and reporting radionuclide emissions for the purpose of NESHAPs compliance. Detailed records are kept of all measurements, model runs, and calculations; and selected model runs are

validated. All NESHAPs calculations are archived with the supporting information used to make the calculations.

LLNL is continuing to upgrade its NESHAPs QA program. A future NESHAPs Quality Assurance Plan will be more comprehensive and specific to NESHAPs requirements. The plan will also include a rigorous assessment of LLNL's compliance with 40 CFR Part 61, Appendix B, Method 114, Section 4. In this regard, we will pull related documents together to form a coherent NESHAPs QA plan. We have collected FSPs, SARs and QA Manuals for the three continuously monitored facilities. In addition, we have collected the *QA Plan, Health and Safety Manual, Laboratory Procedures Manual, Calibration Procedures Manual for the Hazards Control Department Radiological Measurements Laboratory, EMS Quality Assurance Plan* (Garcia and Failor 1993), and *Quality Implementing Procedures* of the Environmental Protection Department.

4.4.2 Data Quality Objectives

No specific data quality objectives have been formally established for radionuclide emission concentrations measured by the air effluent monitoring program. The current radionuclide sampling collection systems and analyses do have sensitivities meeting the requirements of the derived concentration guides (DCG) in DOE Order 5400.5. In the future, data quality objectives will be formulated and will include requirements for data precision, sensitivity, and accuracy.

4.5 PROGRAM IMPLEMENTATION PROCEDURES

The Environmental Monitoring Section is responsible for the LLNL air effluent monitoring program; however, implementation of the program relies strongly on participation by facilities and the Hazards Control Department.

Collection and replacement of air filters for the sampling of particulate radionuclides is performed by the Hazards Control Department's health and safety technician assigned to the facility. Field support instruction HP-46 of the *Health Physics Discipline Action Plan* for the facility specifies the frequency of filter exchange for the CAM and filter-type stack samplers. In some facilities, field instructions HP-47 and HP-48 are implemented and specify monthly sample flow rate adjustment and annual flow rate calibration. After removal from the sample holder, each air sample filter is placed in a glassine bag for subsequent handling and routing to the Radiation Measurements Laboratory. Care is taken to avoid

cross contamination between samples. The health and safety technician labels each sample bag with the sample location, tags the bag with a unique bar code, and logs the sample into the Hazards Control Department sample tracking and receiving (STAR) computer system. The tracking system follows the samples through the submittal, receipt, and analysis processes; in the future, the results will also be available via the tracking system. Air filter samples are submitted to the Radiation Measurements Laboratory and analyzed for gross alpha and gross beta activity.

Collection and replacement of the tritium molecular sieves for the tritium samplers in Building 331 is also performed by the Hazards Control Department health and safety technician. The field support instruction HP-331-002 of the *Health Physics Discipline Action Plan* specifies the change frequency of the samplers. Detailed operating instructions are available for sieve exchange. Field support instruction HP-331-001 calls for the verification of flow rates and operating pressures on a daily basis to ensure proper operation of the HT/HTO sampling system. As with the filter samples, the molecular sieves are labeled, tagged with a bar code, and logged into the STAR system. The molecular sieves are then submitted to the Hazards Control Department analytical laboratory for water extraction and then passed to the Radiation Measurements Laboratory for scintillation counting.

Analytical results of the air samples are reported to the health physicist assigned to the facility and the responsible environmental analyst in EMS. The health physicist is notified immediately in cases where gross alpha activity exceeds 3.7×10^{-9} Bq/mL (1×10^{-13} μ Ci/mL) or the gross beta activity exceeds 3.7×10^{-7} Bq/mL (1×10^{-11} μ Ci/mL). Such cases would warrant further investigation of the sample, such as verification of location, sample volume, comparison with past data, recounting, and identification of the specific radionuclides present, if triggered by gross activity analyses.

4.6 PREPARATION AND DISPOSITION OF REPORTS

The Environmental Monitoring Section is responsible for the reporting of air effluent radionuclide emissions. Radionuclide emissions are reported in the Environmental Report (also known as the Site Annual Environmental Report) and in the NESHAPs annual report to DOE and EPA. Additionally, the NESHAPs annual report includes the estimated potential emissions from all facilities whose operations have the potential to release radionuclides to the atmosphere, and hence, documents if there is need for additional effluent

sampling systems. Actual radionuclide emissions from facilities are also reported to the DOE Effluent Information System/On-Site Discharge Information System annually. Because tritium emissions from the Tritium Facility are the major source of atmospheric radionuclide releases, a summary report of emissions is issued to the Tritium Facility manager quarterly.

Unplanned radionuclide releases have in the past been the subject of occurrence reporting to DOE. Guidelines for the occurrence reporting of radioactive releases to the environment are provided in the *LLNL Implementing Procedures for DOE Order 5000.3B, Occurrence Reporting and Processing of Operations Information*. However, no specific radionuclide emission concentrations have yet been established by EMS which would mandate the submittal of an occurrence report.

4.7 IMPROVEMENTS TO EXISTING SAMPLING SYSTEMS

The existing radionuclide sampling systems have recently been evaluated according to U.S. DOE (1991), the NESHAPs 61.93 regulations, and the ANSI N13.1-1969 guidelines as referenced in the NESHAPs regulations. Physical data on the sampling systems, including location and placement of the sample extraction point in the effluent ventilation system, physical dimensions of the sample extraction probe, dimensions of transport lines, the type of sampler, the sampler air flow, and the type of air moving system were evaluated. Data on the gas stream characteristics, including velocity traverse measurements, temperature, and cyclonic flow (Method 1 of 40 CFR 60, Appendix A) were obtained. As a result, the existing sampling systems that are specified by the NESHAPs regulations are in the process of being upgraded to meet the exact specifications of ANSI N13.1. These facilities are the hardened portion of the Heavy Elements Facility (Building 251), the Tritium Facility (Building 331), and the Plutonium Facility (Building 332).

Requirements that are being addressed in these upgrades are continuous measurement of stack velocity, installation of multi-port aerosol extraction probes, minimization of sample transport line length, and relocation or installation of samplers to meet location requirements for extraction of samples. The probes, which have been designed and fabricated, are currently being installed. Velocity calibrations will be completed in 1995. The upgraded particulate sampling systems will ensure the extraction of representative samples as specified by the ANSI N13.1-1969 guidelines and the continuous measurement of effluent flow.

5

Meteorological Monitoring

5.1 RATIONALE AND DESIGN CRITERIA

Meteorological data are used to demonstrate compliance with federal, state, and local laws, regulations, and orders. DOE directives require LLNL to collect sufficient meteorological data to assess the impact of hazardous material releases on the environment and the public. On-site meteorological monitoring is required to assess accurately the transport and diffusion of airborne materials and the impacts of planned and unplanned airborne releases on public health. In addition, DOE sites are required to have on-site programs that can provide data used to perform the required dose calculations specified in 40 CFR Part 61 subpart H, *National Emission Standards for Hazardous Air Pollutants; Standards for Radionuclides*, which states:

Compliance with this standard will be determined by calculating the dose to members of the public at the point of maximum annual air concentration in an unrestricted area where any member of the public resides or abides.

EPA requires the use of mandated computer models (U.S. Environmental Protection Agency 1979) to demonstrate compliance with 40 CFR Part 61 subpart H. Our primary calculation tool for the estimation of dose and risk is the computer model CAP88-PC, developed by EPA's Office of Radiation Programs (Parks 1992). The meteorological input to CAP88-PC consists of a joint-frequency distribution of wind direction and atmospheric stability, average wind speed for each combination of wind direction and stability, average mixing-layer depth, annual average temperature, and annual rainfall.

DOE Orders 5400.1 and 5400.5 and regulatory guide EH-0173T (U.S. Department of Energy 1991) require each DOE site to have a meteorological program that is appropriate to the site's activities, topography, and distance to critical receptors. DOE requires that meteorological measurements must be representative of the conditions that determine transport and dispersion at the site. Furthermore, real-time meteorological data should be available to assess adequately, in accord with DOE Order 5500.3A, the actual or potential on-site and off-site consequences of an emergency. Meteorological information can also be used to assess potential consequences of radiological releases from projected new or modified facilities, as

well as consequences of actual accidental radiological releases. LLNL and Site 300 are both ARAC (Atmospheric Release Advisory Capability) sites as designated by DOE. ARAC was developed at LLNL to provide real-time assessments of the impact of radiological releases to the atmosphere anywhere in the world.

Off-site meteorological data, such as the data collected at National Weather Services (NWS) stations, may be used if the meteorological conditions at the station are similar to on-site conditions. The closest NWS station is at the Oakland Airport, but meteorological conditions there do not accurately represent dispersion conditions at LLNL and Site 300. Moreover, it may be difficult to retrieve data from off-site meteorological stations in a timely manner during emergencies. For these reasons, among others, an on-site meteorological monitoring system is employed.

DOE Order 6430.1 describes the use of meteorological data to aid in identifying conditions that may influence the design and operation of the facility. Temperature and humidity data can be used to plan efficient air conditioning and space heating of proposed facilities. Hood exhaust re-entrainment and building-wake effects can be modeled using wind-flow data provided by on-site monitoring. Facility designers should use meteorological data when proposing stacks and cooling towers. EPA guidance for stack design can be found in *Guideline for Determination of Good Engineering Practice Stack Height* (U.S. EPA 1985).

On-site programs and off-site groups frequently request meteorological data for various projects. For example, the local air regulatory agency, Bay Area Air Quality Management District, has requested meteorological data from LLNL for use in regional models of air flow. Meteorological data are also used to support fire-fighting operations and to estimate the electrical load of individual buildings and the site as a whole.

The meteorological database includes expected annual ranges and distributions of wind direction and wind speed, temperature, stability, joint frequency of wind speed and stability, water vapor, and joint frequency of temperature and specific humidity (DOE Order 1324.2). LLNL also considers natural hazards including strong winds, hurricane, tornado, hail, lightning, and snow. DOE Order 4320.1 encourages sites to use on-site meteorological data to aid in site development planning, including conditions such as winds, temperature, probabilities and intensities of severe storms, tornadoes, and prolonged rainy and dry seasons.

All uses of the meteorological database must comply with EPA guidance established in *Guideline for Fluid Modeling of Atmospheric Diffusion* (EPA 600/8-81/009), *Ambient Air Monitoring Guidelines for Prevention of Significant Deterioration* (EPA 450/4-80/012), and *On-Site Meteorological Program Guidance for Regulatory Modeling Applications* (U. S. EPA 1987a).

LLNL also maintains a quality assurance program that meets the performance requirements described by EPA and DOE. Volume IV of EPA's *Quality Assurance Handbook for Air Pollution Measurements* (U. S. EPA 1990) provides guidance for making judgments about the validity of meteorological data and accuracy of meteorological measurement systems.

Atmospheric dispersion calculations range in complexity from very simple analytical expressions, requiring little or no meteorological data, to complex super-computer models that can accept extensive data sets. The EPA *Guideline on Air Quality Models* (U. S. EPA 1986) describes its preferred computer models. Another good source is the *Handbook on Atmospheric Diffusion* (Hanna, Briggs, and Hosker 1982). The dispersion model should be appropriate for the site and application. The assumptions upon which a dispersion model is based should be reasonable, completely documented, and scientifically defensible. The dispersion model should be realistic and yet yield conservative predictions. The data used in these models should be based on data from the appropriate time period. For example, if a proposed experiment has the potential for a release during the daytime, then the probability tables and wind roses that are to be used with the model should include meteorological data taken exclusively during the daytime.

5.2 DESCRIPTION OF MEASUREMENTS

The wind at LLNL is strongly influenced by the land/sea breeze and the orientation of the Livermore Valley (Gouveia and Chapman 1989). The wind comes from the southwest quadrant more than 50% of the time. This surface flow pattern can be enhanced or weakened by large-scale upper-air circulation. The climate at Site 300, while generally similar to the Livermore site, is modified by higher elevation, greater distance from the ocean, and greater relief.

During the summer, differential heating between the ocean and land masses accounts for afternoon winds that generally are stronger than morning and nighttime winds. During the summer, a strong, upper-air, high pressure circulation frequently suppresses the advection and formation of clouds. The result is warm, dry weather during the summer with a persistent diurnal cycle of winds.

Differential heating is less during the winter than in summer, so the sea breeze is less pronounced. The winter commonly features long periods of weak winds separated by shorter periods of strong winds from the north that are associated with winter storms. During the periods of weak synoptic scale winds, cold air drainage may occur during the night. The cold air that reaches LLNL is drained from the hills that are east of the Livermore site.

5.2.1 Required Meteorological Measurements

Meteorological data are used as input to dispersion models (e.g., CAP88-PC). Measurements of the local meteorological conditions must include horizontal wind speed and direction, atmospheric stability, air temperature, and rainfall rate. Atmospheric stability can be estimated, following a procedure in Chapter 6 of U.S. EPA (1987), using time of day, wind speed, and sigma theta, the standard deviation of the wind vane position. Another approved stability estimation uses data from the solar radiometer.

Data provided by the wind direction vane are used to determine sigma theta using the algorithm presented in Yamartino (1984). A minimum of 180 samples of the wind vane position are required for estimation of sigma theta. Care is taken to assure the proper computation of the standard deviation in a polar coordinate system.

5.2.2 Accuracy of Monitoring Measurements

The accuracies of the monitoring measurements should be consistent with the specifications set forth in either ANSI-2.5-1984, in the version of ANSI/ANS 2.5 that was current when the monitoring system was designed, or in guidance provided by the EPA if EPA recommends more stringent specifications. Accuracy standards for meteorological systems include the following:

Wind direction	$\pm 5^\circ$ azimuth with a starting threshold of 0.5 m/s. The delay distance 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% for speeds of 2.2 m/s or greater, starting speed of less than 0.5 m/s
Temperature	$\pm 0.5^\circ\text{C}$
Delta Temperature	$\pm 0.1^\circ\text{C}$
Solar Radiation	$\pm 5\%$ of observed

Precipitation	$\pm 10\%$ of observed
Time	± 5 min

Because of the large frequency of wind speeds below 0.5 m/s at LLNL, it is prudent to impose a more stringent anemometer specification of a starting speed of less than 0.25 m/s. This is not required at Site 300 due to the much larger frequency of winds above 0.5 m/s.

All instruments must be capable of continuous operation in the expected range of atmospheric conditions at LLNL and Site 300. Because of the relatively mild weather conditions of the Livermore area, most meteorological instruments designed for routine measurement can meet this requirement. Sensors installed at Site 300, especially the anemometers, are made to withstand the very strong and persistent winds at this site.

5.2.3 Locations of Monitoring Sites

Meteorological monitoring sites should be located in areas that have atmospheric conditions similar to those into which any material potentially will be released. Section 3 of EPA-450/4-87-103 (U. S. EPA 1987b) discusses the concepts of siting and exposure of meteorological instruments and towers. Knowledge of local meteorological conditions is important when siting air monitoring sensors. The site should be away from the influence of man-made and natural obstructions such as buildings and trees. The on-site meteorological towers at the LLNL main site and Site 300 have been located in view of these considerations. The location of the LLNL main site meteorological tower is shown on Figure 4-1 in Chapter 4, Air Effluent Monitoring. The location of the Site 300 meteorological tower is the same as air monitoring location ECP, shown in Figure 6-3 in Chapter 6, Air Surveillance Monitoring.

Wind and temperature instruments are mounted on booms extending from the side of the tower to minimize the tower's influence on the wind. The instruments are away from the tower by more than two tower widths; they are mounted on the west side, facing the prevailing wind. Wind measurements are made at the standard height of 10 meters, and additional measurements are made at 40 meters to accommodate plume rise and help evaluate potential releases from 30-meter stacks at LLNL. Additional temperature sensors are being placed at the standard 2-meter height.

Solar radiation measurements will be taken in a location free from any obstruction to the measurement. The instrument will not be near light-colored walls or artificial sources of radiation.

A rain gauge is mounted on a level platform so that the gauge opening is horizontal. It is at least 30 centimeters above the ground to avoid having surface water splash into the gauge. The gauge should be shielded from the wind and placed in an area where there will not be excessive turbulence from the shield.

5.2.4 Frequency of Sampling

All meteorological instruments are polled by the data logger at the shortest practical time interval. This interval is 10 seconds or less for the anemometers, and 1 minute or less for the thermistors and solar radiometer. The time period represented by the averages should not be less than 10 minutes, and the averaged value should be saved by the logger for retrieval.

5.3 PROGRAM IMPLEMENTATION

5.3.1 System Description

The instruments currently on the LLNL meteorological towers meet or exceed the accuracy standards identified in Section 5.2 except for starting speed and wind vane damping distance. LLNL has purchased and received new sensors that exceed the EPA specifications for delay distance. Because of the high frequency of low winds at LLNL, the starting speed of the wind speed and direction sensors should exceed the above guidelines. This is not required at Site 300 due to the much larger frequency of high winds. A class of anemometers that is capable of routine measurements features a lower starting threshold of 0.22 m/s. Such instruments have been purchased and will be installed in the fall of 1994.

The temperature sensors (thermistors) are currently placed in naturally aspirated radiation shields. These shields are adequate for measuring absolute temperature. To measure vertical temperature difference accurately, EPA suggests the use of fan-aspirated temperature shields. These temperature shields have also been purchased and are being installed in the fall of 1994.

Routine inspection, scheduled maintenance, and calibration of the meteorological instrumentation and data acquisition system meet the manufacturer's factory recommendations and are conducted in accordance with EMS procedure

EMP-M-CA, *Meteorological Equipment Calibrations*. EPA suggests a six-month cycle for calibrations and audits, alternating between calibrations and audits every three months. Calibrations are also performed when problems are found. The logs of the inspections, maintenance, and calibrations are maintained as permanent records, allowing routine inspection of current data.

Regular and frequent routine operational checks of the monitoring system are essential to ensuring 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 radiometer.

A 48-hour battery backup ensures continuous operation of the computer that downloads data even if ac power is lost. Although lightning storms are infrequent at LLNL, the meteorological tower and associated systems are protected from lightning strikes with grounding spikes. Other phenomena that may deteriorate performance, such as icing and sea spray, are not problems at LLNL or Site 300.

5.3.2 Data Inspection and Transfer

Crutcher (1984) and U. S. EPA. (1990) present guidance in meteorological data collection, processing, and archiving. Fifteen-minute averages of all measured quantities are available to dispersion models that are used in response to emergency situations. One-hour averages are adequate to assess the consequences of potential releases and to demonstrate compliance. The instruments are polled more than 30 times over the 15-minute averaging period to provide adequate coverage. The meteorological system is designed to provide data recovery of at least 90% on an annual basis for wind direction, wind speed, and other parameters necessary for classification of atmospheric stability.

The data are reviewed weekly by a meteorologist or environmental analyst. The data reviewer reports questionable data and receives a response by way of special instrument checks. Files of 15-minute averages, also called the raw data files, are saved in the ARAC site system computer. Each file contains an entire day's data. Each file is uniquely identified with the site name, year, month, and date. Each calendar month's daily raw data file is collected on a floppy disk that

is permanently archived. Files from these floppies are copied onto a VAX for electronic transfer to desktop or workstation where further data inspection and reduction are performed.

The 15-minute averages are combined into hourly averages, following guidelines in U.S. EPA (1987), Chapter 6. The hourly averages are used to establish local climatology data, detect problems with the instrumentation and data acquisition, and provide frequency of occurrence tables of dispersion parameters for input to dose models.

5.3.3 Computed Parameters

Diffusion coefficients (σ_y and σ_z) are used to quantify the spread of plumes in Gaussian and trajectory models. These coefficients can be estimated from the atmospheric stability class and from the time that has elapsed since the release. Gifford (1976) and Hanna et al. (1977) discuss various methods for determining diffusion coefficients. Chapter 6 of U.S. EPA (1987) describes the computation of atmospheric stability by EPA's preferred algorithm based on σ_θ , wind speed, and time of day. This algorithm is called the Modified Sigma Theta method and is completely described in Mitchell and Timber (1979) and Mitchell (1982).

EPA is expected to adopt another stability calculation scheme that is based on incoming solar radiation, wind speed, and—at night—wind speed and vertical temperature difference. Data from the new instruments on the LLNL tower will provide a unique opportunity to compare several stability calculation methods.

With accurate temperature and wind speed measurements taken at multiple levels, we have the capability to calculate boundary layer parameters such as sensible and latent heat flux. These parameters are related to atmospheric stability, temperature tendency, soil moisture flux, and mixing depth, among others.

With absolute temperature and relative humidity, other hygrometric parameters can be calculated. These parameters are useful when planning efficient air conditioning and space heating of proposed facilities.

5.3.4 Plans for the Future

Specific quality assurance activities include a program of internal comparisons of measured and computed parameters, and comparisons with LLNL's climatology and other sources of meteorological data. The EMS will examine quality

assurance guidance related to meteorological measurements and meteorological data processing found in U. S. EPA (1990), determine appropriate comparison data and computations, and incorporate these into a meteorological monitoring procedure.

Supplementary locations for additional meteorological instruments should be evaluated at LLNL and Site 300. The distance from a potential source to the site boundary and the topographic setting of the site will be considered when making this determination. The meteorological tower located at Sandia National Laboratories, California, may be included in a information network of local meteorological data. For our purposes, it may be determined that all the towers are duplicates.

Tracer gas studies and dispersion models could be used to determine the meteorological system's ability to predict the transport and dispersion of routine, accidental, or projected releases. The tracer gas can be injected into the atmosphere with the same buoyancy and momentum properties as the source to be imitated. Maximum fence-line concentration, maximum surface concentration, and maximum concentration outside the boundaries of LLNL could be modeled and compared with measured concentrations.

In addition, vertical (or convective) diffusion is not directly measured by the current meteorological system but is implied by the stability typing algorithm using wind speed, sigma theta, and time of day. Instruments to measure vertical turbulence directly, such as vertical temperature difference or vertical angle, should be evaluated for possible inclusion in the LLNL meteorological monitoring system.

All components of the meteorological data retrieval system should be evaluated for resistance to earthquake damage.

Mixing height is a common parameter in many dispersion models and is often measured with an acoustic sounder. If the future monitoring system were to include an acoustic sounder, a comparison could be made between measured mixing height and routinely measured meteorological parameters such as wind speed and vertical temperature difference.

We will also evaluate using a central computer for dissemination of current meteorological data. The new ARAC site system workstation and future updates to the software may facilitate this function. Meteorological data could be uploaded to a networked computer to facilitate distribution of real-time values of

measured and computed quantities. Dispersion models could be installed on the central computer for rapid simulations of accidental releases. The meteorological data on a computer network could also be used by personnel whose work involves potential release of noxious fumes through a stack.

Barometric pressure is commonly required for various programmatic tasks at LLNL. An accurate aneroid barometer installed with the meteorological system, along with the transfer of real-time data to a central computer, would advise experimenters of ambient atmospheric pressure. This addition would eliminate the need to maintain redundant barometers throughout LLNL. Barometric pressure is also used in weather forecasts to aid in predicting changes in wind flow.

5.4 QUALITY ASSURANCE REQUIREMENTS

5.4.1 Data Checks

Soon after the meteorological data have been collected, the values are reviewed by experienced personnel. The data are scanned to determine if the reported values are reasonable and in the proper format. Periods of missing data should be noted and investigated. The data should be compared with expected values or a range of values. The limits used in the range test are based upon historical data or physically realistic values. Another range test, called the rate of change test, compares the difference between data of adjacent time periods. Suggested screening criteria are listed in the following table:

Meteorological Variable	Screening Criterion
	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

...Continued

Meteorological Variable	Screening Criterion
Temperature Difference	— is greater than 0.1°C/m during the daytime
	— is less than -0.1°C/m during the night time
	— is greater than 5.0°C or less than -3.0°C
Precipitation	— is greater than 25 mm in one hour
	— is greater than 100 mm in 24 hours
	— is less than 50 mm in the rainy months
Radiation	— is greater than zero at night
	— is greater than the maximum possible for the date and latitude

Selected data are compared with other available, reliable data. At least one hour out of every month is selected. In addition, monthly averages are compared with climatological norms.

Major problems with the meteorological instruments or data are noted in Non-Conformance Reports (NCRs). Appropriate procedures are followed to alleviate the problem and the report is concluded with explanation of the action taken.

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. It will be necessary to adjust the magnitude of the wind speed or temperature when making this substitution. When data from the same tower are not available or reliable, representative off-site meteorological data from a nearby tower may be used. This approach works best for temperature, solar radiation, and mixing height. Wind speed and direction can vary greatly with increasing distance, so off-site data may not be suitable for replacement.

5.5 REQUIRED REPORTS

A wind rose is a common graphic tool that shows the character of the winds recorded by a weather station. Reports requiring the annual wind rose include the annual Environmental Report (also known as the Site Annual Environmental Report) and the NESHAPs annual report.

The wind rose diagram displays the frequency of winds coming from the 16 compass directions, and also retains information on the frequency of wind speed in each sector. Often at low winds, especially at night, the 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. The upper limit of the calm wind category should be no greater than the starting threshold of the anemometer. The new anemometers at the LLNL main site feature a threshold that is about half that of the previous sensors (0.5 versus 0.25 m/s), so the annual frequency of calm winds should decrease from about 14% to less than 8%. Winds at Site 300 are much greater than at the main site, and there is a very small number of winds less than the starting threshold of even the older, less-responsive anemometer. The wind rose derived from Site 300 data will have a higher upper limit for calm winds, but less than 2% of the data from this site is below this higher threshold.

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 used as meteorological input to the CAP88-PC code.

6

Air Surveillance Monitoring

6.1. RATIONALE AND DESIGN CRITERIA

In any industrial operation like LLNL, air emissions to the atmosphere are inevitable. In sufficient amounts, various types of emissions can be considered air pollutants. In general, over one hundred varieties of air pollutants exist; typically, they can be categorized as either particulate matter or gases. LLNL employs a variety of engineering and administrative controls for air pollutants. Both air surveillance and air effluent monitoring are conducted at LLNL to determine the impact, if any, of air pollutants on the environment. Air effluent monitoring is conducted at the contaminant source (see Chapter 4 for more information on air effluent monitoring) and air surveillance monitoring is conducted in the environment. Air effluent and air surveillance monitoring are intended to be complementary. Since air is a primary exposure pathway for human and ecological impact, many regulations to control, reduce and monitor air pollutants have been developed.

6.1.1 Regulatory Drivers

Air surveillance monitoring is performed to evaluate compliance with local, state, and federal regulations, which ensure that human health and the environment are protected from hazardous air emissions. LLNL complies with all appropriate local, state, and federal environmental air quality laws and DOE regulations, including 40 CFR 61, the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) section of the Clean Air Act; and DOE Orders 5400.1, *General Environmental Protection Program*, and 5400.5, *Radiation Protection of the Public and the Environment*. The *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T; U.S. Department of Energy 1991) is the guidance for implementation of DOE Orders 5400.1 and 5400.5. Other laws governing air quality include 22 CCR 67264.700 and 66265.710, *Environmental and Compliance Monitoring*; and the California Air Toxics "Hot Spots" Information and Assessment Act of 1987 (AB2588).

6.1.2 Monitoring Objectives

LLNL monitors ambient air to determine if airborne radionuclides or hazardous materials are being released by Laboratory operations, and if so, what their

concentrations are, and what the trends are in the LLNL environs. Air monitoring involves measurement of particles collected on filters or of vapor chemically trapped on a collection medium. Concentrations of various airborne radionuclides (including particulates and tritiated water vapor) and beryllium are measured at the Livermore site, Site 300, at off-site locations throughout the Livermore Valley, and at an off-site location in Tracy. Diffuse, or non-point sources, are also monitored to fulfill NESHAPs requirements.

According to DOE 5400.1, environmental surveillance shall be conducted to monitor the effects, if any, of DOE activities on on-site and off-site environmental and natural resources. The following objectives should be satisfied by an air monitoring environmental surveillance program:

- 1) Establish background concentration levels of pertinent chemical species;
- 2) Determine the highest concentrations of the pertinent pollutant species expected to occur in the vicinity of DOE operations;
- 3) Determine representative pollutant concentrations at areas where public health and other concerns should be considered; and
- 4) Evaluate the effects of emissions on ambient levels of pertinent contaminants.

DOE 5400.5 establishes a primary radiation protection standard for members of the public. This standard is 1 mSv/y (100 mrem/y) effective dose equivalent (EDE) for prolonged exposure. For air, Derived Concentration Guides (DCGs) listed in DOE 5400.5 specify the concentrations of radionuclides that could be inhaled continuously 365 days a year without exceeding the DOE primary radiation protection standard for the public. DOE 5400.5 also states that DOE facilities should have the capabilities, consistent with the types of operations conducted, to monitor routine and nonroutine releases and to assess doses to members of the public.

The EPA has established a radiation dose standard for air emissions of 100 μ Sv (10 mrem/y) EDE for members of the public (40 CFR 61). Air effluent monitoring and air surveillance monitoring provide the source terms for modeling to ensure that the 100 μ Sv (10 mrem/y) standard is not exceeded.

DOE/EH-0173T states that it is a DOE objective that all DOE operations properly and accurately measure radionuclides in their effluents and in ambient

environmental media. DOE/EH-0173T also says that the surveillance program should characterize radiological conditions of the off-site environment, estimate public doses, confirm predictions of public dose based on effluent monitoring data and modeling, and provide compliance data for all applicable environmental regulations (see Chapter 19, Dose and Risk Assessment). It also says that surveillance may be necessary for legal reasons, public concerns, and state or local commitments. DOE/EH-0173T states that "provisions *should** be made for the detection and quantification of unplanned releases of radionuclides to the environment" and environmental monitoring during an emergency situation should be considered. The air monitoring network is part of LLNL emergency response program (see the Emergency Response subsection in Chapter 3). The air sampling units are not real-time but they are available if emergency sampling is needed. The sample results may be used to validate dispersion models and calculations, determine off-site effects, and determine the future course of action.

The fundamental objective of the Clean Air Act is to protect human health and the environment from air pollution. The Clean Air Act enables EPA to define and establish standards for several criteria air pollutants that are of major concern to the environment. These pollutants and the National Ambient Air Quality Standards (NAAQS) are defined in 40 CFR 50. In 1990, Section 112 of the Clean Air Act (NESHAPs) was amended by Title III. Title III lists 189 Hazardous Air Pollutants (HAPs), calls for emissions reductions of air toxics, and imposes new standards on both new and existing sources of air toxics. Standards are not yet set for many of these HAPs.

The California Clean Air Act (CCAA), passed in 1988, establishes a mandate for achieving the ambient air quality standards at the earliest practicable date. The CCAA sets criteria pollutant standards that are more restrictive than federal standards.

The California Air Toxics "Hot Spots" legislation requires facilities to prepare an air toxics emissions inventory and risk assessment, which LLNL has completed. Based on these data, the Bay Area Air Quality Management District and the San Joaquin Valley Unified Air Pollution Control District have ranked LLNL as a low risk facility. In compliance with the "Hot Spots" law, LLNL must complete a facility inventory review every two years and submit updated toxics emissions data. Currently, nonradiological emissions (with the exception of beryllium) are permitted through the local air districts and air toxics monitoring is not required.

6.1.3 Potential Sources

6.1.3.1 *Particulates*

There are many radionuclides and nonradiological contaminants with the potential for airborne particulate emissions used at LLNL. Plutonium and uranium are the primary radionuclides of concern. The major potential source for plutonium is Building 332, the Plutonium Facility. Other sources include Building 151, where samples are analyzed for their radionuclide content, and the Heavy Elements Facility (Building 251) where transuranic research is conducted. The major source of uranium is Building 177 where Uranium Atomic Vapor Laser Isotope Separation (U-AVLIS) operations are conducted. Buildings 171 and 179 also contain research and development activities in support of the U-AVLIS program. Other sources at LLNL include Building 131, where a storage vault is housed and where machining is done on classified parts that sometimes contain depleted uranium; Buildings 321, 321A, 321B, and 321C, where operations including milling, shaping and machining of depleted uranium occur; and many buildings in the Chemistry and Material Sciences Directorate that use or store uranium. More detailed information on radionuclide sources is given in Chapter 4, Air Effluent Monitoring. The southeast quadrant of the Livermore site has elevated levels of ^{239}Pu in the surface soil and air (presumably from resuspension). This area is considered a diffuse source of plutonium.

The primary nonradiological particulate of concern is beryllium. Beryllium is used in Buildings 231, 235, and 320 at the Livermore site. An assessment of monitoring requirements for beryllium in air and soil is in process. For more information on this evaluation, see Chapter 12, Soil Monitoring.

Depleted uranium (^{238}U), which is used in explosive tests, is the primary radionuclide of concern at Site 300. Explosive tests are conducted on open-air firing tables located at Bunkers 801, 850 and 851. Small amounts of ^{235}U and ^{234}U are also released during explosive tests. Beryllium is also used in the explosives tests and is therefore a potential hazardous air pollutant of concern at Site 300.

In the future, a review of LLNL operations to identify other nonradiological air particulate contaminants will be conducted. The radionuclide inventory is now regularly updated. Also, as a result of the NEPA review process, the Environmental Monitoring Section (EMS) is notified when new operations or facilities are planned and EMS participates in the Environmental Support Teams

which discuss environmental issues. This enables EMS to evaluate significant changes in operations and take appropriate actions.

6.1.3.2 *Nonparticulates*

Non-particulate radionuclides that should be considered include gases (primarily noble gases), halogens (primarily radioiodines), and tritium. The noble gases of importance at LLNL include xenon, krypton, and radon. Historically, the Nuclear Test Program has been the major source of xenon, krypton, and radioiodines. Since this program is no longer active, measurements for these radionuclides need not be considered. However, monitoring requirements for radon need to be investigated. Two short-lived air activation products, ^{13}N and ^{15}O , are produced by the linear accelerator in Building 194. The accelerator was not active in 1992; however, operations started up again in 1993. Since ^{13}N and ^{15}O have such short half-lives, 9.96 min and 122 s, respectively, measurement of direct exposure, not sampling and analysis, may be the most feasible method to determine the impact. Environmental surveillance monitoring is not required for these short-lived isotopes; however, dose calculations that include ^{13}N and ^{15}O are completed annually.

Based on the evaluation above, tritium is currently the only non-particulate radionuclide that warrants surveillance monitoring. In the over-40-year history of LLNL, approximately 28 PBq (750,000 Ci) have been released from the Tritium Facility (Building 331). Of this, 13 PBq (360,000 Ci) were released in 1965 and 11 PBq (287,000 Ci) were released in 1970 in separate unplanned releases. The tritium released from Building 331 is in the form of tritiated water (HTO) and tritium gas (HT). The potential dose from HT is approximately 25,000 times lower than a dose from a comparable release of HTO. Therefore, the tritiated hydrogen gas does not contribute significantly in calculations of the overall dose. However, it is important to note that HT may be converted to HTO in the environment. Environmental surveillance monitoring is conducted for HTO only. HTO can be incorporated into all biological systems and is readily mobile; it can be incorporated into the human body by three pathways: respiration, ingestion, and absorption through the skin (Okada and Momoshima, 1993).

HTO is released from several facilities and diffuse sources at LLNL and Sandia National Laboratories, California (SNL/CA). In 1993, 4.2×10^{12} Bq (114 Ci) of HTO was released from Building 331 and approximately 4.9×10^{12} Bq (132 Ci) was released from SNL/CA. Other facilities that emit more than 3.7×10^9 Bq/yr (0.1 Ci/yr) include Building 282 (where neutrino mass research is conducted) and Building 391 (laser target research and development). Four diffuse sources of

tritium have been identified at LLNL; near Building 292, outside Building 331, the Building 514 Hazardous Waste Management "Tank Farm", and the Building 612 Yard. Near Building 292 there is an underground tank containing tritium-contaminated water that had previously leaked. Near Building 331, there is a waste accumulation area where tritium-contaminated equipment slated for disposal is temporarily stored and eventually sent to the Hazardous Waste Management facilities. At Building 514, tanks are used to store and treat liquid and solid radioactive and/or mixed wastes that often contain tritium. The Building 612 Yard consists of several areas where containers having radioactive wastes are stacked outdoors. These containers are not airtight and may outgas tritium.

Although tritium is no longer used at Site 300, past activities can influence current emissions and environmental impact. Historically, tritium was used in the explosive tests and tritium-contaminated material was placed in landfills. The ground water at Site 300 has locally elevated levels of tritium and the landfills, specifically the Pit 7 complex, have elevated concentrations of tritium. Tritium incorporated in water molecules in subsurface moisture can evaporate to the atmosphere. Tritium is also found in the subsurface soil near Buildings 802, 850, and 851. At Well 8 Spring, where the ground water flows near the surface, tritium evaporates to the atmosphere. Purge water from ground water surveillance monitoring of wells in areas where elevated tritium levels occur represent a diffuse source at Site 300. Surveillance monitoring requirements for tritium at Site 300 are being evaluated.

6.1.3.3 *Nonradioactive Pollutants*

Section 108 of the Clean Air Act has defined pollutants that are of major concern to the environment. These pollutants, known as criteria air pollutants, include nitrogen oxides, carbon monoxide, photochemical oxidants (such as ozone), sulfur oxides, particulate matter (particles with a diameter less than or equal to 10 micrometers, PM₁₀) and lead. National ambient air quality standards for these pollutants are defined in 40 CFR 50. LLNL currently emits approximately 59 metric tons per year of criteria air pollutants. The major sources of criteria pollutants from the Livermore site are boilers (oil- and natural-gas-fired) and internal combustion engines (approximately 242), solvent operations, and surface coating operations. Major sources at Site 300 include gasoline dispensing operation, open burning, spray booths, and vapor extraction.

LLNL is currently pursuing a Synthetic Minor permit as a more flexible and cost effective alternative to permitting for Title V of the Clean Air Act. Under this permit, LLNL can accept federally enforceable conditions to limit criteria pollutant emissions under 91 metric tons/year (100 tons/year). Surveillance monitoring requirements are not expected as a part of the Synthetic Minor permit.

6.1.4 Collection Methods

6.1.4.1 *Particulates*

Currently, high-volume air particulate samplers are used to monitor particulate radionuclides and beryllium. The samplers consist of a peaked roof inlet, a filter holder, an air mover, an automatic mass flow controller, and a timer. Each air particulate sampler pulls air through a 20.3 cm × 25.4 cm Whatman-41 cellulose filter at a constant rate of 400 liters per minute. An assessment of other potential sampling methods and filter types needs to be completed.

6.1.4.2 *Nonparticulates*

A suitable collection technique for tritium must employ methods that collect moisture from the air. There are several methods available for collection of air moisture. Moisture collection methods such as ethylene glycol bubblers, cold traps, and dehumidifiers are typically used for short sampling periods. The use of desiccants for moisture collection allows for continuous sampling for one- to two-week sampling periods. The sampling period will depend on the amount of desiccant used, humidity, and air flow rate. Commonly used desiccants include silica gel, molecular sieves (alumino-silicates), and anhydrous calcium sulfate. DOE/EH-0173T suggests the use of silica gel for a desiccant. LLNL has investigated different containers for the silica gel. The LLNL containers are shaped such that channeling of air through the silica gel does not occur. The sampling flask currently in use does not show evidence of channeling problems.

6.2 EXTENT AND FREQUENCY OF MONITORING AND MEASUREMENTS

Considered in the LLNL air monitoring network is the guidance given in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T; U.S. Department of Energy 1991), and the Clean Air Act, 40 CFR Parts 53, 58 and 61, which deal with monitoring siting and overall ambient air quality monitoring criteria. DOE/EH-0173T states that an air sampling network should include background or control locations

(10–15 kilometers from the site), locations in the area where the maximum predicted ground level concentration from stack releases, locations in the nearest community within a 15-kilometer radius, and the exact number of sampling locations will be determined by meteorology, demography, and the magnitude of the projected doses. The configuration of an air quality monitoring network involves several elements: the number of sampling/monitoring sites, their geographical location, historical wind patterns, effects of topography, and access logistics. The overall configuration of the LLNL air sampling network is primarily a function of the purpose of the monitoring and the typical spatial distribution of the pollutants being monitored.

The factors (primarily climatological and topographic) that are typically involved in estimating an adequate network size are also involved in designing an optimum network configuration. These siting factors are further discussed by Ludwig (1976). Meteorological factors have the greatest effects on ambient concentrations, and thus LLNL's placement of samplers primarily has been based on the location of main sources, horizontal wind speed and direction, vertical distribution and mixing structure, stability, and mixing heights. Air sampling dilution climatology, the long-term average combination of meteorological conditions that affect the interchange and dispersion of pollutants, can change over relatively large areas and long time intervals. The details of atmospheric dispersion, mixing dilution, and geographical terrain effects are described by Pasquill (1979) and Slade (1968). These factors have required the placement of air samplers both nearby and at facility boundaries; at off-site locations, samplers are placed both upwind and downwind from the facility. Resources, manpower, and logistics (such as availability of ac power, access, and security) must also be considered and often have affected the selection of locations.

Air sampling should also provide adequate temporal and spatial resolution. In addition, DOE/EH-0173T states that air sampling locations should be selected to represent radionuclide concentrations breathed by the population surrounding the facility.

6.2.1 Particulates

LLNL maintains eight continuously operating high-volume air-particulate (hi-vol) samplers on the Livermore site (shown in Figure 6-1), ten in the Livermore Valley (Figure 6-2), eight at Site 300 and one in Tracy (Figure 6-3). One sampling location, LCCY, was removed in 1994 because of vandalism problems. A new sampling location has not been determined. The samplers are

positioned to ensure reasonable probability that any significant concentration of particulate effluents from LLNL operations will be detected.

Geographical details of particulate sampling locations are outlined in Procedure EMP-AP-L, *Air Particulate Locations*.

Two field duplicate samples (one on the Livermore site and one at Site 300) are taken to confirm the results obtained from the samplers. The QA/QC samplers are operated in parallel with a permanent sampler at a given site for two months. The QA/QC samplers are rotated to the other individual locations. The filters are exchanged weekly, and both filter sets are submitted for analysis.

After a four-day delay for decay of the radon-thoron daughters, gross alpha and gross beta activities on the filters are determined. Monthly composites of filters from each of the Livermore-site perimeter locations (SALV, MESQ, CAFE, MET, VIS, and COW) are placed into individual plastic bags. The six bags are then combined and sealed in a 214-cm³ aluminum can and are counted for gamma-emitting radionuclides. The Site 300 filters are sealed and counted in a similar manner. Following gamma counting, the composited filters from each Livermore-site perimeter location are analyzed by LLNL's Radiation Analytical Sciences laboratory for the presence of ²³⁹Pu, ²³⁵U, and ²³⁸U. The off-site samples from the Livermore Valley are analyzed for ²³⁹Pu, and all of the Site 300 samples are composited and analyzed for ²³⁹Pu, ²³⁵U, and ²³⁸U.

Beryllium measurements are made on portions of each of the weekly air filters from the Livermore-site perimeter and Site 300 samplers that are composited by sampling location every month.

Figure 6-2. Air particulate and tritium sampling locations, Livermore Valley.

Particle size distributions are not determined because the estimated effective dose equivalent to the maximally exposed individual is well below the threshold limit set in DOE/EH-0173T.

An assessment of the particulate sampling network to determine the appropriate number and siting of sampling locations, the appropriate sampling frequency, and the appropriate analytes to be measured needs to be completed.

6.2.2 Nonparticulates

Factors considered to determine the tritium sampling locations include source locations, wind roses, CAP88-PC concentration or dose contours, historical data, population, and power and access availability. CAP88-PC is an EPA- and DOE-approved gaussian plume dispersion model that incorporates a dosimetry model man-

dated by EPA for estimating dose and risk from all pathways caused by radionuclide emissions to air. It allows up to six sources (elevated stacks or uniform area types) and utilizes a circular grid with 16 sector directions and up to 20 user-selected distances. The principal inputs for CAP88-PC include radionuclide emissions during the year, a set of source-to-receptor distances, source information, meteorological data, and population data. The principal

outputs include dose and risk as a function of distance and direction and the concentration (pCi/m^3) as a function of distance and direction (see Chapter 19, Dose and Risk Assessment, and EMS procedure EMP-R-DA for more information on CAP88-PC). Concentration contours were created using output data from CAP88-PC modeling runs completed for the LLNL Tritium Facility and the SNL/CA Tritium Research Lab. The modeling results of tritium air effluent emissions agree well with air surveillance measurements. Based on these results and other factors discussed above, it is recommended that one to three background sampling locations, five to seven fence-line locations, and five to six off-site locations be identified, many from the current network.

Currently, tritium air samplers operate continuously at eleven locations on the Livermore site and five in the Livermore valley (**Figures 6-1 and 6-2**). As with the particulates, the sampling location LCCY was removed in 1994 because of vandalism problems, and a new sampling location has not been determined. Site locations are detailed in procedure EMP-AT-L. Four of the Livermore site locations (B331, B292, B514, and B624) monitor diffuse source emissions. Work is in progress to provide more detailed rationale for each sampling location and to determine the adequacy of the current background locations. Also an evaluation to determine the need for monitoring for tritium at Site 300 will be conducted.

Many factors must be considered to determine sampling frequency. These include limitations of the sampling units, required moisture, flow rates, and sample retrieval time. Typical sampling frequency for tritium is weekly or bi-weekly. Experience has shown that sampling bi-weekly meets our monitoring goals. Analytical procedures require two 5-mL aliquots of water. A flow rate of 700 mL/min provides ample air flow through the glass flasks to collect 15 to 30 mL of water.

Two tritium air samplers are rotated among the locations at two-month intervals to provide a duplicate QA/QC sample. Details of the actual tritium sampling are outlined in procedure EMP-AT-S, and a description of tritium sampler calibration can be found in procedure EMP-AT-CA.

6.3 PROCEDURES FOR LABORATORY ANALYSIS

Two analytical laboratories are used to analyze the air samples. The beryllium, gross alpha, and gross beta analyses are completed by an outside contract laboratory, FGL Environmental. All other analyses are performed by the Radiation Analytical Sciences laboratory attached to the Environmental Monitoring and Analysis Division. Details of laboratory procedures are discussed in Chapter 16, Procedures for Laboratory Analysis.

6.4 QUALITY ASSURANCE

For air particulate sampling, two field duplicate samples (one on the Livermore site and one at Site 300) are taken each week. The QA/QC samplers are operated in parallel with a permanent sampler at a given site for two months. The extra QA/QC samplers are rotated randomly to the other individual locations on a bi-monthly basis. Two trip blanks, one for Livermore site and one for Site 300, are also taken each week. Intercomparison samples are supplied to the analytical

laboratory that performs much of the air particulate analysis by the Environmental Protection Agency's Environmental Monitoring Systems Laboratory and the Department of Energy's Environmental Measurements Laboratory.

Two air tritium duplicate samples are taken during each sampling period. The tritium air samplers are rotated among the locations at two-month intervals to provide a duplicate QA/QC sample. Currently, no field blanks are collected. However, laboratory blanks, laboratory duplicates (or splits), and spikes are created at a rate of about 10% of samples and are submitted as blind samples. Air moisture silica gel reference samples are not currently available through NIST or any of the intercomparison laboratory study programs.

The percent relative standard deviation (% RSD; see the EPA Data Quality Objectives for Remedial Response Activities, Section 4.6 [U.S. Environmental Protection Agency 1987]) is a measure of precision. In 1993, the % RSD for the 75th percentile of the distribution of individual precision values for ^{239}Pu in air was 40. This means that approximately 75% of the duplicate samples have a precision better than 40%. This is not particularly good, but the plutonium results are extremely low and close to the detection limit. It is likely that the poor comparison of field duplicates results from a combination of sampling irreproducibility for particles with tiny amounts of plutonium and high uncertainties for analysis at this very low level of plutonium. The % RSD for the 75th percentile of tritium duplicate samples is 27.

An assessment of data quality objectives for precision and accuracy is in progress. The assessment involves the determination of the required number and frequency of field duplicates, laboratory QC samples, interlaboratory samples, field blanks, field spikes, and laboratory control standards. The acceptance criteria and actions to be taken if the results are not acceptable will also be determined.

6.5 PROGRAM IMPLEMENTATION PROCEDURES

The primary responsibility for activities related to the air surveillance monitoring networks is assigned to the environmental analyst within the Environmental Monitoring Section. 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 results.

The air surveillance monitoring samples are collected by EMS technicians following the written procedures, EMP-AP-S, *Air Particulate Sampling*, and EMP-AT-S, *Air Tritium Sampling*.

6.5.1 Sample Identification Systems

The air particulate and nonparticulate samples are identified with a four-field, alphanumeric designator in accordance with EMP-QA-SL. An example air particulate sample identifier for the Livermore site is L-SALV-01-AF.

6.5.2 Cross-Contamination Prevention

There is a risk of cross contamination for air particulate samples. Sampling technicians ensure that neither they nor the sampling equipment are contaminated with any of the analytes of concern. In addition, attempts are made to keep the vehicle used to perform the sampling free of known contaminants.

The sampling technicians wear clean disposable gloves while performing the weekly sample exchange and while preparing the filters for delivery to the analytical laboratories. New gloves are used for each sample location. The filters are placed in glassine bags after removal from the sampling units. Upon completion of the sampling route, the samples are prepared for analytical lab delivery. Samples are cut in half using clean scissors and are placed back into glassine bags. The scissors are decontaminated after every cut. In the event of any suspected contamination, the technician notifies the air analyst.

There are very few cross contamination concerns with air tritium samples because the field technicians never come in physical contact with the silica gel samples. Only during the filling of flasks do technicians come close to the silica gel; therefore, technicians avoid wearing radioactive wristwatches during this portion of the procedure.

6.5.3 Sample Preservation and Handling

All filters awaiting laboratory delivery are stored in locked offices until the end of the month when they are prepared for laboratory analysis. In addition, all sample information (time on, time off, date on, date off, and sampler's initials) is entered into a computer spreadsheet which automatically determines the total air flow. This spreadsheet with the air flow information will follow the samples to the laboratory. The samples are delivered to the appropriate laboratory following proper chain-of-custody procedures (see EMP-QA-SD).

Special care must be taken to minimize the possibility of air tritium sample breakage. The samples are transported in a Lucite transport carrier specifically designed to hold the sample flasks.

6.5.4 Sample Collection

The air particulate network is divided into two "routes". The "Site 300 Route" is composed of Site 300 monitoring locations and one downtown Tracy location. The "Valley Route" encompasses Livermore-site locations and the Livermore Valley locations. Sampling occurs on a weekly basis for each of the two routes.

Each air particulate sampler pulls air continuously at a rate of 400 liters per minute through a 20.3 cm × 25.4 cm Whatman-41 cellulose filter. Particulate filters are changed each week at all locations. Before the filters are removed from the sampling unit, the air flow is determined. New filters are placed on the sampling unit, the air flow is checked again, and if necessary, the flow rate is adjusted.

The air particulate samples are collected according to procedures EMP-AP-S and EMP-AP-CA. All pertinent sample information is recorded on the field tracking form (FTF). Comments regarding the sampling and any unusual, questionable, or noteworthy events that may have occurred during the sampling period are also recorded on the FTF's.

The tritium samplers, operating at a flow rate of 700 mL/minute, use silica gel in flasks to trap the tritiated water vapor. The silica gel flasks are changed every two weeks, and the samples are identified by location, date on, date off, elapsed sampling time, and flow rate. Each sample is given a sample identifier that accompanies it through the analysis.

The sample collection is a simple exchange process. The sampling technician determines the flow rate, removes the exposed flask, and places it in the transport carrier. Then the new flask is placed on the sampling unit. The flow rate is checked and, if necessary, the unit is recalibrated. The technician then fills out the FTF (in the logbook) and a small yellow tag containing the appropriate sample information is placed on each sample. A complete detailed procedure for sample collection is found in EMP-AT-S.

6.5.5 Calibration Procedures

The air particulate sampling units that EMS currently uses have automatic mass flow correction capabilities that allow for automatic self calibration. This system employs "controllers" which increase the motor speed as the filter paper becomes loaded with particles. These "controllers" also correct for changes in the barometric pressure, ambient temperature, and ac line voltage. Generally these controllers maintain a consistent flow rate; however, occasional adjustments are needed.

DOE/EH-0173T states that the "air sampling rate *should** not vary by more than $\pm 20\%$, and the total air flow or total running time *should** be indicated." The air particulate sampling units maintain a constant flow of 400 liters per minute. In an effort to verify this rate, the technician checks the flow at the beginning and end of the sampling period. EMS has several types of calibration units; rate verification is done primarily in the field using the Venturi calibration unit. All calibration units have their own identification number with their own calibration curve, so the technician must ensure that the correct calibration curve for the unit is used. The calibration unit identification number is logged on the FTF. The Venturi is stored in the lead technician's office and spare calibration units are found at the Building 596 repair facility.

The air tritium calibration procedures are handled in a manner similar to air particulate sampling. Each flask flow rate is checked using a Gilmont Rotameter before the sample is removed and after the new flask has been replaced. Any adjustment to the unit is done with the new flask on the unit and is recorded on the FTF in the logbook. The rotameter is visually inspected prior to use and the calibration identification number is logged on the FTF.

Calibration units for air particulate and air tritium sampling are serviced and calibrated to NIST standards annually by the LLNL Hazards Control Industrial Hygiene Instrument Laboratory. Technicians visually inspect the calibration unit for damage prior to use. Additionally, they ensure that the calibration unit has been serviced within the past year. For further detail on types and actual calibration procedures of the air particulate sampling units, see EMP-AP-CA. For air tritium sampling units, see EMP-AT-CA.

6.5.6 Action Levels

The expected values for tritium based on 1992 and 1993 data are as follows:

Off site	$6 \times 10^{-8} \text{ Bq/mL} \pm 4 \times 10^{-8} \text{ Bq/mL}$ $2 \times 10^{-10} \mu\text{Ci/mL} \pm 1 \times 10^{-12} \mu\text{Ci/mL}$
On site (perimeter)	$2 \times 10^{-7} \text{ Bq/mL} \pm 1 \times 10^{-7} \text{ Bq/mL}$ $5 \times 10^{-12} \mu\text{Ci/mL} \pm 3 \times 10^{-12} \mu\text{Ci/mL}$
Background	$<4 \times 10^{-8} \text{ Bq/mL} \pm 3 \times 10^{-8} \text{ Bq/mL}$ $1 \times 10^{-12} \mu\text{Ci/mL} \pm 8 \times 10^{-13} \mu\text{Ci/mL}$

Further investigation is needed to determine the upper limit for an acceptable background location for tritium monitoring.

Although action levels and actions have not been set, an investigation of sample results that are much higher than the expected values is conducted. The data are checked for transcription errors and the analytical lab is contacted to determine if any problems occurred during analysis. If no transcription or analytical problems are found, management is notified.

An assessment of expected values, action levels, and actions will be completed for particulate and non-particulate analytes. The assessment involves the determination of the acceptance criteria and the actions to be taken if the results are not acceptable.

6.5.7 Data Analysis

There are four main goals for analyzing surveillance data: estimate concentrations at each sampling point; compare current concentrations to previous concentrations in order to identify changes or inconsistencies; compare concentrations to established DCGs; and compare concentrations at a single location or a group of locations to control locations and evaluate the reliability of the comparisons.

A measure of central tendency and dispersion are calculated for all sample results. For normally distributed data, the mean and standard deviation are

calculated. For lognormally distributed data, the geometric mean and geometric standard deviation are calculated. If the data set has any nondetects, the median is calculated. The median absolute deviation is calculated if the number of nondetects is less than 50%.

6.6 PREPARATION AND DISPOSITION OF REPORTS

The air surveillance monitoring results and dose assessments based on these data are reported in the annual Environmental Report. Results from diffuse source locations are also reported in the NESHAPs annual report.

The beryllium monitoring results are reported to the Bay Area Air Quality Management District each quarter.

Occurrence reports may be required when sample results are much larger than recent history.

7

Sewer Monitoring

LLNL's Livermore site is the single largest source of the sanitary sewage processed by the Livermore Water Reclamation Plant (LWRP). LLNL and Sandia National Laboratories, California (SNL/CA) together produce an average of 1.3 million liters of sewage each day. The combined volume, consisting primarily of sanitary wastewater and cooling tower blow-down, is discharged to the City of Livermore sewer system from the northwest corner of the Livermore site (Figure 7-1). It represents nearly one-tenth of the volume treated at the LWRP. After treatment at the LWRP, the wastewater is pumped out of the valley through a pipeline shared with three other Publicly Owned Treatment Works (POTW) 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 that, if inadvertently discharged to the sanitary sewer, 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, DOE Orders, and local ordinance. In some cases, these requirements impose specific engineering standards for discharge control measures. More generally, though, they impose numerical limits on the presence of pollutants.

Nonradiological pollutants are covered under the wastewater discharge permit issued by the LWRP (LLNL 1994c). The permit is awarded following review of an application that provides a comprehensive overview of LLNL wastewater discharges (LLNL 1994c). 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 discharge limits (Table 7-1). General prohibitions are also stated for:

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

- Substances that would cause the LWRP to be in noncompliance with sludge use or disposal criteria;
- Odoriferous, colored, or noxious wastewaters;
- Heated waters; and
- Pollutants that may cause interference to the LWRP.

Radiological pollutants are covered under DOE Order 5400.4 and 10 CFR 20. (California Health and Safety Code Title 17 requirements were repealed in 1994.) DOE facilities are, in principle, exempt from the requirements of 10 CFR 20. However, DOE has established a policy that all facilities will comply with "applicable" state and local laws, codes, regulations and ordinances. The limits from these documents are summarized in Table 7-2. Although 10 CFR 20

contains discharge limits on specific radioisotopes similar to those in DOE Order 5400.5, only the DOE limits, which are more restrictive, are presented.

Table 7-1. Nonradiological pollutant limits specified in the LLNL wastewater discharge permit (in mg/L).

Parameter	Limit
Ag	0.2
As	0.06
Cd	0.14
Cr	0.62
Cu	1
Hg	0.01
Ni	0.61
Pb	0.2
Zn	3.0
Cyanide	0.04
pH	5-10
Oil and grease	100
TDS (total dissolved solids)	375
TTO (total toxic organics)	1.0

Table 7-2. LLNL discharge limits for radionuclides in sewage.

Source	Radionuclide	Limit
10 CFR 20	Tritium	185 GBq/year
	¹³ C	37 GBq/year
	All others	37 GBq total/year
DOE 5400.4	³ H	370 Bq/mL
	⁴⁰ K	1.3 Bq/mL
	²³⁸ U	0.11 Bq/mL
	²³⁹ Pu	0.0056 Bq/mL
	²⁴¹ Am	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 prevent violations. At LLNL, administrative measures include development of internal discharge limits, training of materials handlers, control

and tracking of certain materials, and inspection and review of facilities and operations. Engineering controls include isolation of specific operations from sanitary connections, and collection in retention tanks of industrial wastewater from entire facilities.

These upstream controls are supplemented by an automatic sewer diversion and retention facility, the Sewer Diversion Facility (SDF), located adjacent to station B196 at the northwest corner of the site (Figure 7-1). The facility is comprised of a below-grade diversion structure with pumps, 11 completely enclosed, on-ground holding tanks, one large open-top optional treatment tank, one small open-top chemical feed tank, and two large concrete secondary containment structures. In addition, the facility has a paved staging area for vehicles or temporary tank placement. The total permanent capacity is 880,000 liters of wastewater, or roughly six hours of normal flow during peak operating hours. All tanks are equipped with provisions for aeration, pH adjustment, tank wash down, liquid chlorination, and odor control. When a potential release is detected, the facility is automatically activated by the continuous monitoring station, mentioned below and described in Section 7.3.

The sewage monitoring program supports the discharge control effort in three ways. First, it defines criteria for the acquisition and analysis of retention tank samples. Occasionally, monitoring requirements for specific retention tank operations are specified in permits or regulations. More frequently, monitoring is based upon reviews of facility operations and chemical sources. In this area, completeness and representativeness of the monitoring is necessary to allow informed decisions regarding the disposal of collected wastewater.

Second, sampling and analysis of the sewage actually released to the City of Livermore assesses the effectiveness of the control program in maintaining pollutant levels below discharge limits. These monitoring requirements are generally specified in detail by ordinance or DOE Order. The effort covers a broad range of potential contaminants, using sensitive techniques. Trending of the results identifies any increases in pollutant levels that may require further investigation, and potential revision of the control program.

Finally, LLNL has established a continuous monitoring capability for those pollutants with the greatest potential to adversely impact the public welfare. The continuous monitoring effort seeks to detect any rare event in which failure of control measures results in a release that might severely impact LWRP

operations. The system is designed to assure that the bulk of any serious release is captured on site by the Sewer Diversion Facility.

As might be anticipated from the descriptions given above, the three sewage monitoring programs are interrelated, but separate, efforts. We consider each in turn below, starting with the retention tank sampling program.

LLNL also conducts operations at the Experimental Test Facility, or Site 300. Sewage from this location is not handled at the Livermore site. The main complex of buildings at Site 300, the General Services Area, discharges to a sewage oxidation pond. At certain remote facilities, separate septic systems are installed. Since the site does not discharge to a POTW, no routine monitoring of the sanitary sewage is required, and has not been implemented. EMAD has recently completed a special sampling study of sludge and liquid in the oxidation pond, and found only constituents to be expected in domestic wastewater. EMAD also monitors parameters in ground water monitoring wells down-gradient from the pond. These parameters are used to assess the integrity of the pond liner. There are no plans to initiate routine monitoring of the pond itself. A detailed evaluation of the need for additional monitoring will be made during the network assessment. The remainder of the chapter focuses on the Livermore site monitoring programs.

7.1 RETENTION TANK ANALYSIS PROGRAM

7.1.1 Rationale and Design Criteria

LLNL retention systems consist of on-ground tanks, underground tanks, aboveground tanks, piping, pumps and ancillary equipment for collecting dilute rinsewater and wastewater generated by research activities. These wastewaters can be hazardous, nonhazardous, radioactive or mixed (hazardous and radioactive) wastes. Most systems are used to collect and temporarily store dilute, nonhazardous rinsewater from materials fabrication or finishing operations. The systems are used to ensure that discharges to the LLNL sanitary-sewer system are within permit limits, and that non-sewerable wastewater is properly stored until appropriate disposal occurs.

All retention tank systems at LLNL are required to have secondary containment capacity. This 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 (Coleman 1993) 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. As agreed with the Regional Water Quality Control Board, LLNL can discharge berm water to the storm drain if the pH is in an acceptable range and visual inspection of the liquid and tank system does not reveal evidence that the water may be contaminated. When these conditions are not met, the berm water is collected and held in a separate tank and is thereafter handled as retention tank wastewater.

When a retention tank nears capacity, the tank is isolated from the waste stream to prevent further collection of wastewater. A representative sample is taken and analyzed to determine whether the contents meet discharge requirements specified in LLNL guidance documents, which are in turn based upon LWRP permit limitations and categorical pretreatment (this is further explained in Chapter 11 on Categorical Pretreatment) requirements in federal law. The evaluation of the analytical results is the responsibility of the Water Guidance and Monitoring Group, which issues a Retention System Disposition Record(RSDR) giving authorization for disposal for the volume.

7.1.1.1 Retention Tank Release Criteria

Installation of a retention tank system is based upon the potential for inventories and operations at a facility to impact treatment plant operations. During normal operation, a retention tank collects small quantity discharges that, due to measures implemented at the source, usually comply with discharge limitations. When the tank becomes full, the contents are sampled and analyzed to validate their suitability for discharge, and then released. The primary motivation for installing tanks is to prevent inadvertent discharges from reaching sanitary sewer. In those cases, when pollutant concentrations are too high, the collected wastewater is transferred to a licensed Treatment, Storage, and Disposal Facility.

Except for waste streams that are federally regulated (see Chapter 11), the criteria upon which discharge authorization is granted are a matter of internal policy. As enforced by the LWRP, the effluent limits specified in LLNL's wastewater discharge permit (City of Livermore 1993) apply to the combined volume released to the city sewerage, rather than to individual processes. The permit limits apply only to nonradiological contaminants, but similar logic is used in regulations that

impose discharge limits on radioactivity in sewage: DOE Order 5400.5 and 10 CFR 20 both impose limits on the combined effluent released to the POTW (i.e., the LWRP) rather than on wastewater released from individual processes. In this context, LLNL has some flexibility in the development of retention tank release criteria, which are upstream of the point of discharge to the city sewerage.

In principle, this flexibility could be implemented in a process whereby high-concentration wastewater was slowly released to the sanitary sewer in such a way that the contaminant loading was not sufficient to result in a violation of discharge limits. Aside from the practical problems of managing simultaneous releases from many tanks, this approach violates the spirit of cooperation between the LLNL and the LWRP. In fact, DOE Order 5400.5 states that all "discharges [of radioactivity] to the sewers shall be coordinated with the operators of the waste water treatment works." LLNL has also applied this principle to the development of nonradiological release criteria. Variable release criteria also present a problem in that they do not provide consistent guidance to programs designing wastewater control measures, and so interfere with operational planning. For these reasons, LLNL has chosen to develop uniform release criteria for all retention tanks,¹ and has presented those criteria for review by the LWRP.

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 edge of the site requires some assumptions concerning the rate of release from the tank and the flow rate at the outfall. To derive its internal discharge limits, LLNL has imposed a requirement that all discharges occur during peak operating hours, and uses conservative assumptions concerning typical tank pump capacities,

For radioactivity, additional criteria follow from mass loading limits in DOE Order 5400.5, and 10 CFR 20 limits the total activity released during any one year to 37 GBq.² Order 5400.5 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 POTW 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

¹ The one notable exception is the Sewer Diversion Facility, discussed below.

² For most radionuclides, this activity, divided by LLNL's average daily flow, is far less than the isotope-specific concentration limits.

solids will not present a handling and disposal problem at LWRP (DOE 5400.5). To address these requirements, as well as concentration limits, the release criteria constrain the total activity that can be released from all retention tanks during a single day.

The criteria derived from these considerations are presented to the work force in *Guidelines for Discharges to the Sanitary Sewer* (Grandfield 1989). The criteria, reproduced here in Tables 7-3 and 7-4, indicate the potential scope and sensitivity of the retention tank sampling program.

Table 7-3. LLNL's internal discharge limits for nonradioactive parameters in noncategorical wastewater, in mg/L.

Parameter	Limit
Ag	1
Cd	0.9
Cr	4.9
Cu	10
Hg	0.05
Ni	5
Pb	4.9
Zn	15
Cyanide	5
pH	5-10
Oil and grease	500
TTO (total toxic organics)	N/A

Table 7-4. LLNL's internal discharge limits for radioactive parameters in wastewater.

Parameter	Individual discharges [Bq/mL]	Daily limit [MBq]
Gross Alpha	0.01	0.185
Gross Beta	0.1	1.85
Tritium	185	3,700

Conspicuous by their absence in Table 7-4 are release limits for specific radioisotopes other than tritium. Instead, limits are imposed on alpha and 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 return of analytical results imposes cost on the facility, either in the form of extra storage capacity or operational delays. Secondly, the cost of the analysis must be reasonable. 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 7-4 assume ^{238}U as the alpha emitter, and ^{90}Sr as the beta emitter.

7.1.1.2 *Sampling Requirements*

The retention tank sampling protocols must guarantee a representative sampling of wastewater. 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 filling of the tank and ultimate disposition of its contents.

In principle, the pollutants that could be found in a specific tank are dependent only on the types of processes that discharge to the tank. As typical of activities at LLNL, operations in a specific facility change routinely as research and development activities progress, and the potential contaminants will change over time. As a result, the analysis list for each facility must be reviewed periodically.

As each retention tank has its own analytical requirements, the number and type of sample bottles, preservation and holding time requirements for analysis will also vary from location to location. A formal process should exist for communicating changing analytical requirements, and training personnel to modified sampling procedures.

To prevent undue delay in receipt of analytical results, 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.

Obtaining a representative sample from a retention tank requires special procedures, varying from location to location. Recent engineering recommendations for retention tank systems (Coleman 1993) include features that ensure that phase separation in standing wastewater is minimized prior to acquisition of a sample.

Unfortunately, many systems in place do not meet the standards. These deficiencies are being addressed as part of LLNL's comprehensive retention Tank Upgrade Program. In the interim, sampling procedures are often specialized to a particular tank.

Turnaround times for sampling and analysis of tank samples are determined from the usage pattern of a particular tank system. Fill times on most tanks are in the three- to six-month range, and turnaround times of three weeks are acceptable. However, unusual circumstances, such as improperly plumbed flow-through cooling systems for laboratory equipment, can reduce fill times to a few days. The Sewer Diversion Facility requires rapid turnaround to minimize the cost of monitoring operations while sewage is in the tanks. Hazardous Waste Management operations 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 and quality control 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 containers (i.e., using coliwassas or pumps). Additionally, consideration should be given to a comprehensive analysis of a few samples each year to validate the process by which the analytical list is developed.

7.1.2 Extent and Frequency of Monitoring and Measurements

There are currently 35 in-service retention tank systems at LLNL, including 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 Environmental Analytical Sciences (EAS) Sampling Team, Hazardous Waste Management (HWM) field technicians, or in isolated circumstances, LLNL program representatives. HWM field technicians are trained in sampling by EAS personnel. The Sampling Team uses the Retention Tank Analysis List to determine which analyses are required, and samples accordingly.

The list of required analytes for an individual retention tank is based upon process knowledge. The review and distribution process is described in the procedure EMP-RT-AL, *Retention Tank Analysis List Update*. The list is updated once each quarter. 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 lab 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 could be added if those constituents were used in the facility or were required by specific regulation. However, a tank that receives only photoprocessing rinse water and is not connected to an RMMA may require only pH and metals analyses.

Samples are sent for analysis to an approved off-site contract laboratory or the EAS laboratory. All the analytical laboratories use EPA-approved methods and are certified by the State of California. The majority of the sample load generated by the retention systems are handled by the EAS laboratory.

The analytical results are forwarded to the Water Guidance and Monitoring Group (WGMG) for evaluation against the internal discharge criteria of Tables 7-3 and 7-4. Release authorization is granted as described in EMS procedure EMP-RT-RA, *Retention Tank Release Authorization*. This procedure states that sample data are reviewed and for the majority of tank systems, compared to 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, refer to Chapter 11 on Categorical Pretreatment). Next, the contaminant levels are informally compared with historical levels found in that waste stream. Prior to completion of the RSDR, 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. If above numerical limits, the waste volume is handled for treatment or shipment to a certified Treatment, Storage, and Disposal Facility (TSDF).

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 Section 7.3). Samples are taken by EMS technicians from the Technical Support Group who follow procedure EMS-SW-DS. Analysis is performed by LLNL's Hazards Control Analytical Laboratory (HCAL).

7.1.3 Procedures for Laboratory Analysis

All analysis of retention tank samples is performed according to accepted EPA procedures. Except for the Sewer Diversion Facility samples handled by the HCAL, samples are analyzed by LLNL's EAS and Radiological Analytical Sciences (RAS) laboratories, which may also contract samples to IT St. Louis. Please refer to Chapter 16 on Procedures for Laboratory Analysis.

7.1.4 Quality Assurance Objectives

Although the sampling and analysis of retention tank volumes are not under the direct control or authority of EMS personnel, protocols exist to ensure that quality objectives for those functions are met. Currently, the procedures and quality control manuals of the EAS Sampling Team, the EAS Analytical laboratory, and subcontractor analytical laboratories are accepted as controls to ensure dependability of the results used in determining the fate of the waste volumes from retention tanks.

Quality assurance/quality control samples including field blanks, duplicate samples, and trip blanks are collected according to EAS Procedure 300, *Sampling QC*. Only trained personnel who have completed the EP-5200 training course, "Waste Sampling," are allowed to submit samples for analysis. Sample collection follows EAS Procedure 303, *Sampling Containerized Liquids*. EAS laboratory chain-of-custody forms and waste analysis request forms must accompany all samples submitted for analysis. Further details of the sampling protocols are discussed in Section 7.1.1.2 below.

When the data package is received from the EAS laboratory, the person within WGMG responsible for discharge authorizations begins the processes of initiating the RSDR, described in Section 7.1.2 above.

7.1.5 Program Implementation Procedures

Retention tank samples are collected by EAS Sampling Team technicians following procedure EAS-303, *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 sample collection and submittal for chemical analysis, keeping a field log, and filling out the EAS chain-of-custody and waste analysis request forms. The procedures also require the technicians to alert the Sampling Team supervisor if any difficulties or anomalies are encountered during the sampling event.

Samples are taken from the same locations each time, except in the case of pump-outs. A pump-out occurs when a facility has sudden or heavy operational needs and cannot wait for discharge approval. When this occurs, the retention tank volume is pumped from the tank into a portable container to await the sampling and review process leading to eventual discharge. Except for the use of the portable container, the discharge approval process follows all the same procedures.

Although the facility users at LLNL are responsible for the operation and maintenance of the retention tank systems that service the facility, the Environmental Protection Department is responsible for sampling, determination of appropriate analytes (with input from facility users and knowledge of operations that discharge to the tank), collection methods, analytical methods, evaluation of the subsequent data and its quality, communication and coordination of network activities between sampling technicians and analytical personnel, and reporting the results. Removal of the waste volume, followed by any required treatment and shipment, is managed by the EPD's Hazardous Waste Management Division personnel. In a small number of cases, tank contents may be treated at the facility 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.

Sample results are compared to historical data maintained on each retention tank system by WGMG staff. Unusual results are followed up by discussions with the analytical laboratory, sampling technician, the responsible 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 Needs Changing Report

is filed with the EMS QA coordinator. Further action is taken with management concurrence.

7.1.6 Preparation and Disposition of Reports

An RSDR 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 the discharge control personnel (following procedure EMP-RT-RA) and records the date, time, and circumstances under which the tank was drained.

A Tank Status Report is generated monthly to keep program personnel (including other supporting Environmental Protection Department personnel) informed of potential process changes that might lead to a reevaluation of the analytical requirements or the proper hazard classification of a tank system.

General engineering information about retention tanks and the Sewer Diversion Facility is included in LLNL's annual wastewater discharge permit application (LLNL 1994c), which is submitted to the LWRP.

7.2 COMPLIANCE MONITORING PROGRAM

7.2.1 Rationale and Design Criteria

The primary goal of the compliance monitoring program is to evaluate LLNL's compliance with regulatory requirements. The program also seeks to aid in evaluating the control program that prevents violation of sewer discharge guidelines imposed by local, state, and federal regulations, and by DOE orders. 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 1993). Components of the radiation monitoring program also are keyed to demonstrating compliance with regulatory requirements (primarily 10 CFR 20.2003 and DOE Order 5400.5). However, demonstrating the effectiveness of a control program also requires measures that track certain contaminants at levels far below regulatory limits. Examples of these measures include tracking of plutonium at levels one million times lower than the most restrictive discharge standard.

7.2.1.1 General Considerations

Contaminants, once introduced to the sewer system, remain in the sewage until arrival at the LWRP for treatment, traveling along a well-defined route. The

primary monitoring location, as required by logic and regulation, is located at the point of discharge to the city sewerage. Sampling at this location allows assessment of LLNL's compliance with discharge requirements. A complete analysis of the monitoring data also requires knowledge of any contaminants introduced by upstream dischargers (such as SNL/CA). Complete assessment of the impacts of LLNL discharges requires sampling of process waste streams at the LWRP. Sampling and analysis requirements for the off-site monitoring locations will be developed as part of the network technical assessment. We discuss the on-site sampling requirements below.

The constitution of sewage is constantly varying. The most representative characterization of the overall quality of wastewater is therefore obtained by *compositing*: 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: for waste streams that have fairly constant flow, aliquots may be taken at fixed time intervals. This *time-proportional* method is not applicable at LLNL, where 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 is used to monitor the total volume of wastewater discharged. The flow meter activates the sampler once for every fixed volume of wastewater (i.e., every 3785 liters) that is discharged. This method 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. Facility discharges generally are of two classes: brief releases of small (approximately 4 liters) quantities through sinks or other plumbing fixtures, occurring at almost any hour of the day; and discharges on the 4,000-liter scale, lasting from 10 to 30 minutes (as constrained by the capacity of most facility connections), and occurring almost solely during normal working hours. The primary sources in the latter case are planned discharges from boilers, cooling towers, and retention tanks. Of the first class of discharges, pH excursions are the most frequently observed. The monitoring data show that these releases usually last less than 10 minutes and have a minimum duration of 3 minutes. From these considerations, it would appear that compositing with an aliquot acquired every 2 to 5 minutes would be adequate for the types of releases observed at LLNL.

Compositing is not applicable to all analytes. Volatile organics may dissipate prior to collection of the composite. Certain wastewater quality parameters may

be affected by the biological activity of the sewage. Compositing is most applicable for analysis of pollutants that are stable over time, such as heavy metals or minerals. This rule is evident in the monitoring requirements specified by DOE and the LWRP.

7.2.1.2 *Specific Monitoring Requirements*

The wastewater discharge permit issued to LLNL by the LWRP requires continuous pH and flow monitoring and analysis of weekly flow-proportional composite samples for nine specific metals (Table 7-1). Once each month, the permit also requires analysis of a 24-hour composite sample for water quality parameters (biochemical oxygen demand, total dissolved solids and total suspended solids), and analysis of grab samples for toxic substances (cyanide, volatile and semivolatile organic compounds, organochlorine pesticides), and oil and grease.

The regulatory requirements for the radiation monitoring program are less prescriptive. Gross alpha and gross beta analysis 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 to limits contained in 10 CFR 20 and DOE Order 5400.5. 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.

Large quantities of predominantly gamma-emitting isotopes are not produced on site. At one time, LLNL operated a research fission reactor, and ^{90}Sr (a beta emitter) was monitored to track the discharge of fission products. Since the addition of a high-sensitivity gamma monitoring system to the continuous monitoring system (described in Section 7.3), it is clear that the gamma-emitting isotopes discharged with LLNL effluent are predominantly natural (radon and its daughters) and medical (iodine, thallium, and technetium) in origin, and the total activities are typically in millicuries per month. However, until recently EPD has not maintained a detailed inventory of the isotopes identified by the system.

As discussed in the previous section, in order to control daily discharges from the site, LLNL has developed internal retention tank discharge guidelines. The internal guidelines assume that the gross alpha activity detected in retention tanks is due primarily to depleted uranium and apply the discharge standards of

DOE Order 5400.5 to the daily (rather than monthly) effluent concentration. The actual daily discharge guideline developed is 0.2 MBq (5.4 μ Ci) of alpha radiation, while the analytical limit of sensitivity corresponds to 0.1 MBq (2.7 μ Ci), following multiplication by the average daily flow.

7.2.2 Extent and Frequency of Monitoring and Measurements

7.2.2.1 *Sampling Locations*

On-site sampling locations are shown in **Figure 7-1**. The sewer monitoring station (B196) at the northwest corner of the site is the location for compliance monitoring. Location 163A, on the south edge of the LLNL site, is the sampling point for SNL/CA effluent. The remaining locations are satellite sampling points used to trace back spills detected by the spill monitoring equipment at location B196 (see Section 7.3).

The compliance sampling locations are chosen to track the pathway of contaminants released from LLNL and SNL/CA through the LWRP treatment process. As required by the terms of the sanitary sewer permit, the LLNL sampling point is located at the northwest corner of the site, where LLNL sewage is discharged to the city sewerage. The flow-proportional composite samples acquired here are used to determine the combined burden of LLNL and SNL/CA discharges on the LWRP. The acquired samples that are described herein are all collected at the LLNL outfall. However, three distinct sampling locations are used at the outfall: the Sewer Monitoring Station, or B196, serving as the main monitoring station; C196, a composite sampling system located in a shelter to the east of B196; and the flume, located in the vault to the east of B196. The vault contains the flow equipment used to drive the composite sampling systems. The B196 sampler is activated once every 3785 liters of flow (every two minutes at normal on-shift flow rates, and every ten minutes off-shift). The C196 sampler is activated once every 30,000 liters of flow.

Sampling of SNL/CA's effluent occurs at the point of entry to the LLNL sewer system. This sampling location allows separation of the impacts of the two facilities and, as necessary, provides confirmation of SNL/CA monitoring results. As described in EMP-SW-SNLL, *Sewage Sampling at SNLL*, a time-proportional composite sample is collected and archived daily. Because flow measuring equipment has not been installed at this site, the SNL/CA sampling equipment is of the time-proportional type.

As described in procedure EMP-SW-LWRP, sampling at LWRP occurs at two locations. One location samples LWRP effluent to monitor the release of soluble contaminants to the San Francisco Bay, while the other samples liquid from aerated digesters to track levels of heavy metals and radionuclides that concentrate in the dried sludge. Due to extensive mixing and long retention times of liquids in process tanks, grab samples taken by LWRP personnel are sufficient to characterize conditions at the plant.

Compliance sampling and analysis follow regular schedules and are subdividable into two types of programs: radiation and nonradiation monitoring.

7.2.2.2 *Sampling Frequency and Analytes Measured for Radiation Monitoring*

Each day, a composite of LLNL effluent is acquired, as described in the sampling procedure EMP-SW-B196, *Sewage Sampling at B196*. As discussed in the procedure, these daily samples are analyzed individually for alpha, beta, and tritium activity. Monthly composites of the LLNL daily samples are analyzed for plutonium and ^{137}Cs . In addition to analyzing the daily samples for alpha, beta and tritium activity, a weekly 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 this radiation monitoring program are used to assess compliance with gross radiation and isotope-specific discharge limitations imposed by 10 CFR 20, and with the isotope-specific limitations of DOE Order 5400.5.

As described in procedure EMP-SW-LWRP, *Sewage Sampling at LWRP*, the composites of LWRP effluent that are collected each day are combined to create a weekly sample; these weekly samples are analyzed for alpha, beta and tritium activity. Monthly composites of LWRP daily samples are analyzed for plutonium and ^{137}Cs . Lastly, LWRP's microbially activated liquid sludge is analyzed monthly for gross alpha and beta activity, and quarterly composites are analyzed for plutonium and gamma activity.

7.2.2.3 *Sampling Frequency and Analytes Measured for Nonradiation Monitoring*

The nonradiological monitoring program is defined by local ordinance. A pH probe and circular chart recorder operate continuously to record the pH levels of the effluent. As described in the 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, portions of

the LLNL daily samples from the B196 sampling location are combined and analyzed weekly for average metals content. LWRP microbially activated sludge samples are also analyzed monthly for metals content. Finally, once a month, from the C196 sampling location and the flume, respectively, a 24-hour composite and grab samples of LLNL effluent are submitted for analysis of water quality parameters and concentrations of toxic chemicals. Rationale, scheduling and sampling protocols for this work are detailed in EMP-SW-C196.

7.2.2.4 *QA/QC Sampling*

In order to help verify the quality of the compliance monitoring program's analytical results, QC samples are systematically collected and analyzed. The QC samples are obtained by splitting the routine samples and are analyzed by either the primary or the QA laboratory.

7.2.2.4.1 Radiation monitoring program. All the QC samples taken for the radiation monitoring program are analyzed by the laboratories routinely performing the radiological analyses. Once a week, a split of the B196 daily composite sample is analyzed for gross alpha, gross beta and tritium; a total of 12% of all B196 samples analyzed for gross alpha, gross beta and tritium are QC samples. Once a year, a random month's archived splits of the monthly composites of the LLNL daily samples and the monthly composites of the LWRP effluent are submitted for plutonium and ^{137}Cs analysis; these QC samples account for 8% of the samples submitted.

7.2.2.4.2 Nonradiation monitoring program. All the QC samples collected for the nonradiation monitoring program are submitted to LLNL's outside, contract QA/back-up analytical laboratory. Every month, two systematically determined split samples are collected from the monthly 24-hour composite and its associated monthly grab samples. With a total of thirteen different analyses requested on a monthly basis, submittal of two samples for QA purposes equates to a 13% QC sample rate.

7.2.2.5 *Preparation and Transfer of Sample Aliquots*

Preparation of sample aliquots and transfer to the analytical laboratories of the LLNL daily composite, weekly composite, monthly composite samples and grab samples and SNL/CA daily composite is done by EMS environmental technicians. Sampling of LWRP sewage is performed by LWRP personnel and

the transferring of the samples to the analytical laboratories is done by the EMS environmental technicians.

7.2.3 Procedures for Laboratory Analysis

Radiological analyses are performed by LLNL personnel. The daily radiation analyses are provided by LLNL Hazards Control Analytical Laboratory (HCAL), while the RAS laboratory performs high-sensitivity radiation analyses. Using these arrangements, turn-around times of ten days are typical for the analytes of most concern (gross alpha and beta radiation, and tritium activity).

Nonradiological analyses are performed by LLNL personnel and by two outside, contract laboratories, California Laboratory Services (CLS) and GTEL Environmental Laboratories. The LLNL HCAL analyzes for average metals content the portions of the LLNL daily samples that are combined weekly (see Table 7-5 below for the analytical methods used by HCAL).

Table 7-5. Analytical methods used by Hazards Control Analytical Laboratory.

Analyte	Method
Aluminum, Arsenic, Cadmium, Chromium, Iron, Lead, Nickel, Silver, and Zinc	Modified EPA Method 200.7
Mercury	EPA Method 245.1

CLS and GTEL Environmental Laboratories perform all other nonradiological analyses. Specifically, CLS analyzes the weekly composite of LLNL effluent for metals content and the monthly samples for water quality and toxic substances; GTEL Environmental Laboratories serves the role of QA/QC laboratory for monthly sample analyses performed by CLS. The standard analytical methods used by both of these outside, contract analytical laboratories are listed below in Table 7-6.

See Chapter 16 on Procedures for Laboratory Analysis for further details.

Sample preservation is performed by either HCAL personnel or EMS environmental technicians. (For a discussion of those samples preserved by the EMS environmental technicians, see Section 7.2.5.3.) Prior to any analysis, compositing or archival of B196 and SNL/CA daily samples, HCAL personnel preserve the samples with nitric acid (HNO₃). HCAL personnel also preserve

with nitric acid the two splits of the C196 weekly sample; one split is archived and the other used for gross alpha, gross beta and tritium analysis.

Table 7-6. Analytical methods used by California Laboratory Services and GTEL Environmental 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	Standard Method 4500-P D.
Anion Analysis	EPA Method 300.0
Chemical Oxygen Demand	EPA Method 410.4
Total Organic Carbon	EPA Method 415.1
Organochlorine Pesticides	EPA Method 608
Nutrients	EPA Methods 351.2 and 350.2
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 245.2
Selenium	EPA Method 270.2
Polychlorinated Biphenyls	EPA Method 8080
Total Cyanide	EPA Method 335.2
Total Recoverable Phenols	EPA Method 420.1
Volatile Organics	EPA Method 624
Semivolatile Organic Compounds	EPA Method 625
Total Oil and Grease	EPA Method 413.1
Biochemical Oxygen Demand	EPA Method 405.1

7.2.4 Quality Assurance Requirements

The quality of the analytical results is assured by two distinct methods. First, as previously discussed in Section 7.2.2.4, quality control samples are taken in the field and, secondly, laboratory quality control checks are run by the analytical laboratories. Depending on the analysis requested, the laboratory quality control samples may include a method blank, laboratory control standard, laboratory control standard duplicate, matrix spike, and matrix spike duplicate. All quality assurance data are received with the analytic result and subsequently reviewed and evaluated by an EMS environmental analyst.

7.2.5 Program Implementation Procedures

Accurate analytical results are of tantamount importance to the EMS environmental analyst. The data not only determine LLNL's state of compliance with its discharge requirements, but also are trended to assess the effectiveness of the discharge control program. Important factors in achieving accurate analytical results include the existence of sample identification systems, cross-contamination prevention measures, sample preservation and handling practices, and sample collection and calibration procedures. We discuss these factors in the sections below and conclude with a discussion of what takes place when contaminant concentrations exceed predefined action levels.

7.2.5.1 Sample Identification Systems

To ensure that requested analyses are performed for specific samples, the compliance monitoring program follows sample identification systems delineated in the *Sewer Monitoring Sampling Documentation Handbook* (Balke 1994). The details of the sample identification systems vary. Common areas consist of applying labels to all sample bottles, with either EMS environmental technicians or LWRP personnel filling out the labels. All sample bottles are accompanied by a chain-of-custody form completed by LLNL personnel, which reiterates the information contained on the bottle label and specifies the analyses to be performed.

7.2.5.2 Cross-Contamination Prevention Measures

The most likely source of cross-contamination for the compliance monitoring program is between samples taken day to day, week to week, and month to month, or, in other words, between same-type sampling events. This cross-contamination can be minimized in several ways. The permanently installed samplers at the B196, C196, and SNL/CA sampling locations are flow-through

systems, which inherently limits cross-contamination from the sampling equipment itself; the tubing of the portable sampler is cleaned between sampling events. Second, the carboys and stainless steel beakers used for sample collection are also cleaned between sampling events. Disposable gloves worn by the EMS environmental technicians are discarded after each sampling event.

7.2.5.3 *Sample Preservation and Handling Practices*

EPA protocol requires some of the compliance monitoring samples to be preserved. All sample preservation is performed by LLNL personnel; the samples shipped off-site for analytical work are preserved by the EMS technicians (Table 7-7), and those remaining on-site are preserved by HCAL personnel (see Section 7.2.3 for samples preserved by HCAL personnel). EMS technicians change gloves for each different sample preservative.

Table 7-7. Analysis desired and required preservative.

Analysis	Preservative
Chemical oxygen demand, nutrients, total organic carbon, phenols, and oil and grease	Sulfuric acid (H ₂ SO ₄)
Metals	Nitric acid (HNO ₃)
Cyanide	Sodium hydroxide (NaOH)

7.2.5.4 *Sample Collection and Calibration Procedures*

To maintain sampling consistency, EMS technicians follow specific procedures for collecting SNL/CA, LWRP, and LLNL samples. These are EMP-SW-SNLL, EMP-SW-LWRP, and EMP-SW-B196 and EMP-SW-C196, respectively.

The integrity of the flow meter and pH probe readings is confirmed by calibrations performed quarterly on the flow meter by Plant Engineering personnel and monthly on the pH probe by EMS technicians. The calibration procedures followed by LLNL personnel are found in EMP-SW-CA.

7.2.5.5 *Action Levels and Actions for Routine Data*

Routinely received data are checked against action levels by an EMS environmental analyst. For gross alpha, gross beta and tritium analytical results, the informal 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. For nonradiological analytes regulated by LLNL's wastewater discharge permit, the formal action levels are the discharge limits specified in the permit and called out in Table 7-1.

If an analyte concentration exceeds either the informal or the formal action levels and the quality control data are acceptable, the EMS environmental analyst will look for a correlation between a retention tank discharge and the analyte concentration. Depending upon the outcome of the attempted correlation, further investigation may be instigated by the EMS environmental analyst. The investigation may include, but not be limited to, the retrieval of archived samples and the collection of non-routine samples using either the satellite station samplers discussed in Section 7.3 or strategically located portable samplers. However, specifically for cases in which a permit limit is exceeded, the investigation must include a subsequent resampling for the analyte to establish a time that marks LLNL's return to a state of compliance. Additionally, as discussed in Section 7.2.6, reports must be sent to the LWRP and DOE.

7.2.6 Preparation and Disposition of Reports

LLNL's wastewater discharge permit requires a monthly sewer report. The report presents the monitoring data for the previous month, discusses any unusual data or data that indicate deviations from permit levels, summarizes changes to the monitoring program, and reports on activity in the continuous monitoring program (see Section 7.3, Sewer Spill Monitoring Program). Data tables present the radiation monitoring results, metals concentrations, and results for those water quality and toxic substances of regulatory concern.

If any analytical results exceed the LWRP discharge limits, the wastewater discharge permit requires LLNL to issue a Five-Day Report that details the incident. Issuing a Five-Day Report requires LLNL to prepare an Occurrence Report; under DOE Order 5000.3B, Occurrence Reports are required for non-routine reporting of discharges to the sanitary sewer and for unexpected releases to sanitary sewer.

Issued annually, the annual Environmental Report (also commonly known as the Site Annual Environmental Report) includes a comprehensive summary and analysis of the radiological and nonradiological monitoring results.

7.2.7 Comparison to Existing Monitoring

7.2.7.1 Evaluation

The composite samplers at Building 196 are activated once every 3785 liters of flow, or every 2 minutes on-shift, and every 10 to 15 minutes off-shift. Therefore,

in light of the minimum duration of a spill (as discussed in Section 7.2.1), good coverage exists on-shift, but off-shift coverage could be improved.

On the whole, the sensitivity of both the radiological and nonradiological analysis exceeds that required to check LLNL's compliance with the most restrictive discharge regulations. The detection limits for tritium, alpha, and beta analysis (Table 7-8), when multiplied by the total annual discharge volume, correspond to 4.8×10^9 , 1.1×10^8 , and 1.9×10^8 Bq (0.13, 0.003, and 0.005 Ci) activity discharge annually, as compared to the total limit for radiation discharges of 3.7×10^{10} Bq (1 Ci) established by the State of California (10 CFR 20). The limits of sensitivity for ^{239}Pu and ^{137}Cs are 10^{-7} and 10^{-6} of the DOE Order 5400.5 guidelines. The detection limits for the weekly metals compliance analysis are all more than a factor of ten below the discharge standard. Other regulated parameters, such as those for biological oxygen demand, total toxic organic compounds and differential chloride, are all

Table 7.8. Detection limit for compliance monitoring of radiation discharges to the LLNL sanitary sewer.³

Analyte	Detection limit
^3H	0.01 Bq/mL $0.27 \times 10^{-6} \mu\text{Ci/mL}$
Alpha activity	2.0×10^{-4} Bq/mL $5.5 \times 10^{-9} \mu\text{Ci/mL}$
Beta activity	3.5×10^{-4} Bq/mL $9.4 \times 10^{-9} \mu\text{Ci/mL}$
^{137}Cs	3.7×10^{-7} Bq/mL $10 \times 10^{-12} \mu\text{Ci/mL}$
^{239}Pu	7.4×10^{-9} Bq/mL $0.2 \times 10^{-12} \mu\text{Ci/mL}$
Gamma activity	under evaluation

determined with accuracies far beyond those required to verify compliance with discharge guidelines. The only sensitive parameter that is not tabulated by the compliance monitoring program is the one for the total gamma activity in the sanitary sewer effluent released from the site.

³ Because LLNL's sewage effluent is low in chemical contaminants, these numbers are lower than those reported for hazardous waste characterization (LLNL *Draft Criteria and Procedures for the Identification and Management of Mixed Waste*).

Extra sensitivity in the daily gross alpha radiation analysis might also be useful. As shown in the earlier discussion of analytical sensitivities, this is not a compliance issue. However, an improvement by a factor of five in the analytical sensitivity would allow the discharge program to correlate retention tank discharge records with the daily compliance monitoring data, establishing another check on the discharge control program. Currently, the analytical sensitivity is limited by the availability of counting equipment at the Hazards Control Radiological Measurements Laboratory. Because the sewage analysis load is only 4% of the sample volume, the EMS workload does not justify changing laboratory procedures to include longer counting times.

These minor caveats aside, the compliance monitoring program is adequate under the requirements outlined in Section 7.2.2, maintaining a breadth and sensitivity of analysis that exceeds the regulatory requirements. This conclusion will be revisited during the network technical assessment.

7.2.7.2 *Plans for the Future*

During the last three years, the compliance monitoring program has focused significant effort on establishing sampling and maintenance procedures. During the next year, the thrust of the compliance monitoring effort will be on finalizing the procedure EMP-SW-OP and completion of On-the-Job Training Lesson Plans for the sampling and maintenance. Simultaneously, through data trending, informal action levels will be developed for regulated metals. On an ongoing basis, sampling and maintenance procedures will need to be updated and modified as needed, particularly in light of an anticipated technical assessment of the compliance monitoring program.

For two reasons, evaluation of the SNL/CA sampling procedure is necessary. First, the time-proportional sampler at the SNL/CA location does not exclusively sample SNL/CA effluent: the sampler uptake occurs at a junction which is fed by the SNL/CA influent line to LLNL and a branch of the LLNL sewer system. And secondly, LLNL relations with SNL/CA gives LLNL full access to all SNL/CA monitoring results. In light of these circumstances, we are considering transfer of the SNL/CA sampler to the continuous monitoring program (Section 7.3), rather than the compliance monitoring program.

7.3 SEWER SPILL MONITORING PROGRAM

7.3.1 Rationale and Design Criteria

As a research and development facility, LLNL's discharges of nondomestic wastewater are almost universally batch discharges, as opposed to the continuous discharges typical of many industrial facilities. Sources at LLNL could be as small as liter-quantity discharges of dilute chemical solutions by individual experimenters, lasting a few seconds or minutes. At facilities possessing retention tanks, these small-quantity discharges are consolidated in 1000- to 20,000-liter batches, and released to sanitary sewer following chemical and radiological analysis. Voiding a retention tank typically requires 30 minutes. For batches of this size, an inadvertent release of contaminants could only cause a violation of LLNL's discharge limitations (which are averaged over weekly flows of seven million liters) if the contaminant concentration in the batch was much higher than the permit limitation. Since LLNL has historically contributed only 10% of the influent received at the LWRP, for a release to disrupt LWRP operations, the contaminant concentration would need to be 10 times higher than if LLNL were the sole contributor to the LWRP. Therefore, although LLNL cannot monitor continuously for the presence of all contaminants at concentrations near LWRP permit levels, it is possible to monitor for contaminants at concentrations that could pose an immediate threat to LWRP operations. Should a release 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 its research and development missions, LLNL's infrastructure was insufficient to guarantee continuous compliance with sewer discharge requirements. A comprehensive upgrade of the infrastructure was initiated. As part of this program, the monitoring system was completely redesigned to maximize its sensitivity to the contaminants of most concern, an 800,000-liter 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 (samples obtained at the satellite stations may be analyzed after an incident to assist in localization of the source of a release).

With the addition of those capabilities, the spill monitoring system became an integral part of LLNL's environmental control program. However, there are few formal requirements for the system. DOE/EH-0173T (U. S. Department of Energy 1991) does require "continuous radionuclide monitoring [at] those release points that could exceed 1 DCG over 1 year." This criterion, however, is far weaker than LLNL Best Management Practices, which maintain radionuclide concentrations at levels thousands to millions of times less than their DCGs. The remaining EH-0173T requirements apply 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.

Specific monitoring goals are therefore based principally upon an institutional evaluation of the probability and potential impact of releases of specific contaminants. Currently, those goals have emphasized monitoring of pH and 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 continuous monitoring capabilities.

7.3.1.1 *Continuous Monitoring System*

The design criteria for the monitoring system are a complex balance between the desired capabilities and the limitations of the currently available technology. We explore the goals for radiation and metals monitoring, and then explore the issues raised in implementing the available technology.

7.3.1.1.1 Radioactivity. The most important monitoring goal is the detection and containment of releases of radioactive materials that contravene discharge limitations or LLNL Best Management Practices.

Most discharge limitations are specified as bounds on the average monthly concentration for a specific radionuclide. The monthly average concentration limits stated in DOE Order 5400.5 are generally the most restrictive. Evidence that releases have exceeded the concentration limits (the "derived concentration guidelines [DCGs]") of Order 5400.5 would require that LLNL implement "best available technology (BAT)" to reduce discharges. LLNL policy is therefore 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.

As a specific example of LLNL best handling practices for radioactivity, quantities of transuranic materials greater than 3.7×10^5 Bq (10 μ Ci) must be handled in hoods with containers designated for collection of liquid waste; quantities greater than 3.7×10^6 Bq (100 μ Ci) must be handled in glove boxes. Sensitivity in the continuous monitoring system to such quantities would provide immediate feedback (in the form of alarms) to personnel, should such a release occur.

Detailed discharge goals for various radionuclides are presented in Tables 7-3 and 7-4.

7.3.1.1.2 Metals. The hazard posed by LLNL's inventory of radioactive materials is mitigated by administrative and engineering controls upstream of the monitoring system. These investments were made early in the life of the Laboratory and have been successful in preventing releases that posed a serious threat (as defined in EPA and DOE public protection standards) to the public welfare.

In the case of industrial pollutants, the development of upstream controls was less methodical. Loose 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 between scientist and technician. 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 solution.

In developing its metals discharge limits, the LWRP considers three issues. First, the LWRP has discharge limitations of its own, established in its National Pollution Discharge Elimination System (NPDES) permit. Compliance with these limits is evaluated through analysis of 24-hour composites of the treated water. After accounting for the metals removal efficiency of the treatment process, the NPDES limits imply limits on the concentration of metals in the received wastewater. Secondly, 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, the bacteria in the activated digesters are suppressed when the concentrations of certain heavy metals become too high. The holding time in the digesters is only 6 hours.

As may be inferred from the list above, the primary purpose of the discharge limitations is to prevent disruption of the LWRP operations. That is then the appropriate context for establishing the goals of the metals monitoring program. From the details of the plant operations schedule, it appears that 6 hours is the shortest time frame over which a violation might result in serious disruption of plant operations. If the typical release at LLNL leaves the site over 30 minutes, the target sensitivity for the monitoring system would be 12 times the discharge limit for the specific metal (leading to a violation in the average concentration for the whole 6 hours). If we account for the reduction in potency by the addition of household wastewater prior to arrival at the treatment plant, a target sensitivity of 100 times the discharge limit could be acceptable.

For metals that do not strongly suppress bacteria, 24 hours is the appropriate time scale for comparison to 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, since the limit has been enforced at LLNL's outfall, any additional adjustments are not appropriate.

The metals concentration limits imposed in the permit issued by the LWRP are presented in Table 7-1.

7.3.1.1.3. System response time. Having established the general goals for monitoring sensitivity, we need to determine acceptable bounds for the system response time. For the technologies chosen for metals and radioactivity monitoring in the current system (discussed below), 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. With the Sewer Diversion Facility fully functional, we might even desire that an alarm be annunciated well before the bulk of a release leaves the LLNL site.

Response time criteria can be developed in several ways. If some analysis could establish a maximum credible concentration of 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 slugs will 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 will generally rise smoothly before the arrival of the main slug, and fall 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 3 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 30 seconds (to assure representativeness of the sample, the delivery speed is constrained to the velocities typically observed in sewer systems, or roughly 2 feet per second). Phase separation equipment retains the liquid for roughly 30 seconds. The pneumatic valves of the Sewer Diversion Facility close 10 to 20 seconds following activation. From this information, we conclude that performing analysis more frequently than once every 30 seconds would have no practical impact on spill control at the Sewer Diversion Facility.

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 will be retained prior to discharge.

7.3.1.1.4. Technologies. The factor that most complicates 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, suffer either interference or destruction as a result of the contact. pH sensors are the only common tool 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 results in restricted orifices and flow volumes that collect

gravel, silt, grease 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—x-ray fluorescence spectroscopy (XRFS) for metals monitoring, gamma spectroscopy for radiation monitoring, and ultrasonic sensing for flow rate—are discussed in detail in Section 7.3.3. The latter 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 their use in an unattended system. Successful operation requires the design of fouling-resistant flow cells and implementation of comprehensive maintenance procedures. Furthermore, diagnostic sensors (pressure and voltage gauges, for example) can be used to test for anomalous conditions in the monitoring and flow systems. When equipment is not operating properly, alarms should be disabled and personnel notified so that normal operation can be restored.

Finally, due to wear and age, the characteristics of the monitoring equipment can change. Calibration checks generally should be performed once each month, except as existing engineering standards allow otherwise (EH-0173T [U. S. Department of Energy 1991] requires annual calibration and weekly checks). 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 which is 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 would allow normal operation of the unaffected sensors while the broken component is repaired.

This brings us finally to the issue of 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 to initiate response activities. To ensure the reliability and accuracy of the software, a subset of the Institute of Electrical and Electronics Engineers (IEEE)

software quality assurance procedures must be met. These documents must also be approved through the EMS and EPD quality assurance procedures.

7.3.1.1.5. *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. EH-0173T (U. S. Department of Energy 1991) requires that the alarm be in a location that is continuously occupied by operations or security personnel. The response process begins with annunciation of the condition, followed by evaluation, and concluding with corrective action. All alarms and response activities must be documented. In the first stage, the system annunciates either a contaminant release or a system malfunction. In the second stage, the monitoring system must provide access to archive data to aid in the evaluation of the alarm. In the third stage, operators must be able to adjust monitoring parameters to correct any hardware conditions that may have occurred. Alternatively, if a spill actually appears to have occurred, alarm response personnel must work closely with discharge control specialists in the Water Guidance and Monitoring Group to develop an action plan for identification and correction of the cause of the release (pre-established action plans are required by EH-0173T). This plan may encompass collection and analysis of samples held at the satellite monitoring stations.

Because alarms occur infrequently, and releases even more rarely, response activities must be thoroughly documented, so that response personnel can work efficiently to control and correct the cause of the alarm (whether a hardware failure, or an actual release).

7.3.1.2 *Upstream Monitoring*

The network of satellite stations scattered around the LLNL site was installed to support the investigation of releases detected by the continuous monitoring system as the sewage leaves the site. Prior to its installation, the complexity and relative heterogeneity of site operations prohibited identification of a spill source simply on the basis of the type and quantity of the contaminant. Some further information about upstream conditions was required.

The simplest means of obtaining that information was through the installation of passive sampling stations at key points upstream of the monitoring station. Placement of the stations is based primarily upon analysis of the major inventories and operations at the site and the flow patterns through the pipes that service them.

Additionally, spill control scenarios analyzed in the design of the network included long-duration events (lasting many hours) that would be unusual in the context of current operations. If such an event did occur, the satellite samples would speed source identification by facilitating sample collection at the first stage of the traceback.

The ideal sampler would acquire samples as frequently as the monitoring system completes a contaminant measurement. The samples would be composited in small intervals, to allow correlation of acquisition time with the alarm time at the monitoring station (with suitable adjustment for flow transit time). To allow time for responders to acquire samples, and to reduce the frequency of maintenance, the sampler should contain multiple sample bottles that can be filled sequentially through the course of two to three days. Ideally, the sampler would be self-draining, but otherwise should be designed for ease of maintenance.

The choice of sampling method is constrained by cost and site planning requirements. Self-cleaning samplers are not commercially available. Most manholes are located in the middle of streets, and the nearest suitable sites to install a sampler are often 10 to 40 meters from the sewage pickup point. The sampler must be capable of drawing sewage reliably over that distance.

Lastly, special procedures are required for acquisition and analysis of these samples, which must be turned around rapidly if they are to be useful in developing the source identification plan.

7.3.2 Extent and Frequency of Monitoring and Measurements

7.3.2.1 *Continuous Monitoring System*

The Sewer Monitoring Facility is located at the northwest corner of the Livermore site, where the combined effluent from LLNL and SNL/CA is discharged to the city of Livermore sewerage. The facility is shared with the permit-mandated location of the compliance monitoring system.

As described in the previous section, the continuous monitoring methods that have been implemented focus on those analytes that are either permit-mandated or considered to be high-risk contaminants due to the extreme consequences of a spill or an established history of control lapses. In this section, we describe the specific methods and scope of the system.

7.3.2.1.1. Alarm annunciation. Although sampling is performed continuously, actual alarm analysis is performed in discrete intervals. As implied in the discussion of the previous section, the frequency of analysis and duration of an excursion prior to annunciation of an alarm are not strictly based upon compliance requirements. The actual algorithms are based upon four considerations: the potential severity of the impact on the LWRP, the impact of alarm response activities on monitoring program resources, the accuracy of the methods, and the susceptibility of the equipment to false positives due to fouling or instability of the monitoring equipment. Since each sensor system has different design parameters, each contaminant has a different alarm algorithm.

The terms of LLNL's discharge permit require that sewage pH remains between 5 and 10. Between the bounds of 2 and 12.5 (hazardous waste), the primary goal of the requirement is to minimize damage to the sewer system itself; LWRP operations are little affected. Below 2 and above 12.5, the issue is the more serious problem of mishandling of hazardous substances. By agreement with the LWRP, then, the time to alarm follows a sliding scale: "instantaneous" at pH of 2 lengthening to 60 minutes at 5; "instantaneous" at 12.5 lengthening to 30 minutes at 10. "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 3 minutes in length, with rise times on the order of 30 seconds. Once-a-minute readings are therefore capable of detecting extreme pH excursions and guarantee that the bulk of any serious spill will be captured by the Diversion Facility. This is therefore the measurement frequency used for pH monitoring.

As summarized in Table 7-1, the discharge limitations for metals are in the part-per-million (ppm) or sub-ppm range. Our goals for metals monitoring sensitivity are roughly 50 times the values shown, with measurements made no less than once every ten minutes. In the current system, analysis is performed once every 5 minutes, with alarm levels set in the 4 to 12 ppm range (see Table 7-9, where the discharge limits have been reproduced to facilitate comparison). To justify this choice, we present typical metals monitoring results in Figure 7-2. From the cadmium concentration plot of Figure 7-2a, we observe 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

Figure 7-2a. Cadmium concentration in LLNL sewage, January 3–9, 1993.

width of the distribution. In Figure 7-2b, the statistical distribution of the zinc measurements is systematically skewed by an upward trend. Such trends are due to two effects: accumulation of grit and 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 systematic effects. Decreasing the analysis time to one minute, however, will double the alarm level for metals such as cadmium. The 5-minute analysis time and individual alarm levels are reasonable compromises between response time, sensitivity, and resources expended on management of spurious alarms.

Figure 7-2b. Zinc concentration in LLNL sewage, July 17–23, 1992.

Table 7-9. 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	7

As well as flow cell fouling, the alarm conditions for radiation monitoring are further complicated by interferences among the various decay signals. Radiation monitoring is actually analysis of three distinct phenomena: gamma emission, beta decay and alpha decay. Noncontact analyzers are rarely capable of analyzing beta and alpha emission directly, and certainly not 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, 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 in the next section) 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 ^{99}Tc , ^{201}Tl , ^{131}I , or natural radioisotopes such as ^{214}Bi and ^{214}Pb . The identified peaks are scanned against a peak library, which attempts 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 will nonetheless attempt 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 a number of transient phenomena can give rise to spurious signals. These include intense sound and poor electrical connections.

In order to suppress these 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

us with a 10-minute alarm cycle, compatible with the requirements outlined in the previous section.

7.3.2.1.2 Off-line sample analysis. Given the incidence of false alarms due to 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 that an alarm is annunciated. For immediate substantiation of a release, a desk-top radiation counter (swipe counter) and pH probe are kept in the sampling station. Use of these instruments is documented in procedure EMP-SW-HCAR. 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 on the basis of the 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-HCAR and EMP-SW-B196, respectively. This off-line analysis is also performed for alarms that cannot, on the basis of the information preserved in the monitoring records, be definitively determined to have been false.

Finally, if a release is confirmed, the daily composite sample acquired by the compliance monitoring program is analyzed to assess the impact of the release on LLNL's compliance with the discharge limits for the day as a whole. These results are reported to the LWRP, and therefore EPA-approved methods must be utilized.

Analysis and disposition of material held in the Sewer Diversion Facility is discussed in Section 7.1.2.

7.3.2.2 Satellite station network. The satellite station network, shown in **Figure 7-1**, was designed to isolate the different functional areas of the site and the major sewage drainage channels. Experience with different models of sampler has demonstrated that vacuum-pump-based systems, as opposed to peristaltic pump samplers, are the only reliable means of drawing sample over 30-meter or greater lengths. The price paid for this reliability is larger sample volume, and therefore less frequent sampling for any of the standard container configurations.

The sampler in place is the Manning 6900 Stationary Priority Contaminant Sampler, with a carousel containing 24 one-liter bottles. Samples are acquired once every 15 minutes Monday through Thursday, and every 30 minutes Friday through Sunday. Under this schedule, the sample bottles are purged on Monday, Wednesday, and Friday.

The sample frequency is slightly longer than might be desired if the network were to be applied to the control of minor spills, such as the 3-minute pH excursions mentioned earlier. Fortunately, such discharges are unlikely to lead to disruption of LWRP operations or a violation of the concentration limits in LLNL's daily composite sample. Of greater concern would be inadvertent release of the contents of a retention tank or plating bath solution. The duration of these releases would be more typically 30 minutes. In this case, during the course of the release the spill would likely be sampled at every satellite location between the point of discharge and the continuous monitoring station.

The specific locations of the satellite stations, as mentioned above, are chosen to isolate primary sources and distinguish different drainage channels. This analysis would be simpler if flow patterns through the system were unique. However, prior to 1980, the city sewer service tied into LLNL's system at the southwest corner of the site. LLNL maintained a series of lift stations to deliver effluent to that location. The current system drains via gravity to the northwest corner of the site. As might be expected from this history, the drainage patterns on the site are not uniquely determined by the configuration of the lines. This is particularly true in the southwest quadrant of the site, which contains the oldest facilities. The drainage basins shown in **Figure 7-1** are based upon normal flow conditions, as assessed in LLNL's *Mechanical Utilities System Master Plan* (LLNL 1990).

In many cases, the station locations are determined completely by the criteria given above. Where feasible, then, the stations are positioned so as to balance the number of manholes to the terminal end of lines. In the case of an extended spill, this siting principle minimizes the mean time to identification of a spill source.

We now present the specific rationale for each of the sampling locations. Along the west trunk line:

SS 51A: Represents the combined discharge along the west trunk line. Laser programs, Advance Technology Group, LINAC and radioactive tracer analysis projects are located in this area.

SS 53A: Isolates the Biomedical facilities and the Heavy Element Facility.

SS 69A: Isolates Hazards Control and the Nuclear Test Experimental Sciences analysis laboratories.

SS 40B: Isolates the Tritium Facility, the Plutonium Facility, the Main Machine Shop, and the Main Cooling Towers.

SS 231A: Samples LLNL effluent combined with SNL/CA sewage at SS 169A.

SS 169A: With SS 231A, monitors SNL/CA influent.

Along the north trunk line:

Laser programs and the Large Optics Diamond Turning Facility are monitored.

SS 125C: Isolates the Main Laser facilities and the main photo shops.

SS 185F: Serves as an isolation point in the long run from 86B to 177E, and isolates salvage facilities. Prior to installation of 177E, served as primary monitoring point for Hazardous Waste Management operations.

SS 177E: Isolates Hazardous Waste Management facilities and Maintenance and Operations machine shops.

SS 231A: Isolates a series of lines servicing LLNL's Hazardous Waste Management Facility prior to reversal of the drainage system to the north-west corner of the site.

7.3.3 Analytical Methods

Although x-ray fluorescence and gamma spectroscopy are standard analytical methods, their application to continuous sewage monitoring is unique. As well as designing equipment to prepare and position sewage for analysis, new spectral analysis algorithms are required to correct for interference and fouling problems not commonly encountered in bench-top analysis. The monitoring program is actively developing solutions to these problems, as discussed below.

The program uses standard, EPA-approved analytical methods for the analysis of grab samples and satellite station samples. For the latter samples, extreme

rush analysis is required to support the timely development of a spill investigation plan.

7.3.3.1 Radiation Monitoring

Only minor mechanical modifications were necessary to modify a commercial radiation monitoring system for flow-through sewage analysis (**Figure 7-3**). The sewage is injected into the bottom of a 1-liter Marinelli beaker which surrounds the detector vacuum shield. The analysis flow rate, roughly 4 liters per minute, 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 was used for the vacuum shield wall, while the top is 0.5-mm beryllium. To shield the detector from external radiation, it is seated in a cylindrical container lined with 10 cm of pre-WW II lead (such lead has low ^{210}Pb activity).

A typical 5-minute radiation analysis spectrum is shown in **Figure 7-4**. The region from 40 keV to 2.4 MeV is scanned for gamma peaks, which are then matched against a library of lines 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 algorithm has two significant deficiencies: it does not use multi-line analysis to properly resolve interferences between isotopes with shared lines, and it does not use the activity information available in the side peaks and Compton scattering edge (from partial conversion of gammas in the germanium detector). The most commonly detected gamma-emitting isotopes are medical isotopes and the radon daughters, ^{214}Bi and ^{214}Pb .

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

Figure 7-3. Flow-through monitoring system for radioactivity in sewage.

discerned. Analytical deficiencies with this algorithm are a susceptibility to electronic noise with an acharacteristic 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 yet to be attempted. The primary failing of this method is a lack of specificity and therefore an inability to perform a meaningful calibration of the detector.

Analysis for alpha-emitting radioisotopes is actually 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 12–20 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 to the normal background, although this time in the range limited from 12–20 keV. The lack of spectral information makes the analysis susceptible to interference from electronics noise, bremsstrahlung, and

Figure 7-4. Typical gamma spectroscopy data.

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 DOE 5400.5 DCGs.

7.3.3.2 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 attached x-ray generator and detector, is shown in Figure 7-5. The base geometry is standard for XRF analysis, with the generator at right angles to the detector to minimize backgrounds from elastic scattering of the exciting x-rays. The detector is an Si(Li) crystal, with 30-mm² 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

Figure 7-5. X-ray fluorescence analysis configuration for flow-through monitoring of metals in sewage.

of the analysis volume, while the front surface is bounded by spectroscopy-quality plastic films: an 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 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 accumulation of heavy phases, including silt and sand, in the flow cell.

Designing an analysis system for a specific metal begins with selection of a target fluorescence line. Table 7-10 lists the target lines for the metals regulated by LLNL's discharge permit. Given a target line, an x-ray tube voltage and target material are chosen, and a metal filter 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 saturates the electronics.

Table 7-10. Metals fluorescence lines.

Metal	Trans	Fluorescence line		XRF unit
		Energy [keV]	Attenuation length [mm]	
Ag	K α	22.1	19	3
As	K α	10.5	2	2
Cd	K α	23.1	23	3
Cr	K α	5.4	0.3	1
Cu	K α	8.0	0.9	2
Hg	L α	10.0	1.8	2
Ni	K α	7.5	0.7	2
Pb	L α	10.5	2	2
Zn	K α	8.6	1	2

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 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 presented in Table 7-11.

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 (Figure 7-6). 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 Table 7-11: XRF 1 is opaque to both the excitation and fluorescence x-rays, and so a change in analysis volume (due to stretching of the thin film windows) does not result in a change in the volume that contributes to the signal in the detector; XRF 3 is thick compared to typical volume fluctuations, and relatively transparent to the source and fluorescence x-rays, so 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 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.

Table 7-11. XRF unit design parameters.

XRF unit	Generator		Target	Filters	Thickness [mm]
	Voltage [kV]	Current [μ A]			
1	25	70	Ni	Ni	3
2	45	90	Rh	Mo	5
3	50	67	Cu	Ta, Cu	10

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 concentration. 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, and 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 to the normal operating state. Under the assumption (supported by the compliance monitoring data) that the actual metals concentrations in sewage are small compared to the alarm levels, the background

Figure 7-6. Typical x-ray fluorescence spectrum.

constants are adjusted manually during routine system operation to achieve zero mean concentrations.

Currently, no routine check of the system calibration is possible: 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 line 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, we note that due to the phase separation in the preparation of the sample stream for analysis, the metals monitoring results do not include the contribution from large solids, encompassing everything from gravel to bolts. Reviewing our summary of operational impacts at the LWRP, however, we can conclude that these settleable, non-leachable solids do not pose an operational concern.

7.3.4 Quality Assurance Requirements

7.3.4.1 *Continuous Monitoring System*

Quality assurance in the context of a continuous monitoring system means not just the achievement of specific numerical goals for analytical sensitivity, but also reliability in system operation and alarm response activities. Target analytical sensitivities were discussed in detail in Section 7.3.1.2, so here we focus on the other measures of system performance that can be used to guide quality improvement activities.

The primary quality assurance priority is the health and safety of the personnel in the monitoring program. Potential hazards include the medical hazards of handling sewage and equipment in contact with sewage, exposure to x-rays, and the ergonomic hazards of working in a crowded space and lifting heavy containers of sewage samples. These and other hazards are managed through the development and implementation of a formal Operational Safety Procedure, with full participation and review by the Hazards Control Department.

The sewer monitoring system was designed to activate control measures in the case of a materials release that could seriously impact the public welfare.

Although the primary means of preventing these discharges are upstream controls, the monitoring station provides important back-up protection. Operability goals for the station are therefore 100%. Although there are certain unavoidable interruptions to monitoring (such as routine maintenance), other regular causes of interruption are analyzed and, where possible, reduced. Factors that have contributed recently to extended downtimes include deficient plumbing, faulty electronics and computer equipment, and sampling pump failures.

The principal performance goal of the system is to provide stable and accurate measurements of the target contaminants. Specific quality assurance targets in this area are difficult to formulate as the system is still under development to meet the two requirements stated above. However, broad goals for the ideal analysis system can be outlined.

Systematic biases caused by flow cell fouling or artifacts of the equipment design should be minimized. In the metals monitoring equipment, the metals readings should be stable to the statistical level. Over any two-week period, this is only true 25% of the time. In the radiation monitoring system, fouling of the flow cell

by medical isotopes effectively disables alpha and beta monitoring roughly 10% of the time. These numbers are larger than would be desired.

Another potential source of system failure or monitoring error is the software that controls the equipment, interprets the monitoring data and annunciates alarms. Development and validation of the software is covered under the EMS Quality Assurance Plan, and EMAD and EPD Quality Assurance Management Plans (Garcia and Failor 1993; Pendexter 1993). The reference for these documents are the IEEE Software Quality Assurance Standards. The documentation, validation, and verification requirements of these standards are quite extensive and beyond the resources of the monitoring program to implement. The elements that have been chosen for implementation are the Software Validation and Verification Plan (ANSI/IEEE Std 1012-1986 [ANSI 1986]), the Software Requirements Specification (ANSI/IEEE Std 830-1984 [ANSI 1984]), and the Software Test Plan (ANSI/IEEE Std 829-1983 [ANSI 1983]). Other software quality assurance elements may be added following completion of the software development and documentation.

The last equipment performance measure is the frequency of false alarms. Since the system began operation in early 1990, the number of false alarms has fluctuated slowly around four per month. Ideally, a combination of system sensors and software modifications could reduce the number of alarms to less than one.

Although the discussion to this point has focused heavily on the monitoring technology, the limitations of the technology require that personnel maintain a high level of competence in assessing system alarms and conducting source identification efforts in the event of a serious, ongoing release. The relative paucity of events (4 false alarms per month, and 1 release in the last 18 months) necessitates ongoing training and the development of detailed alarm response procedures. Formal documentation of all alarm response activities is required to allow analysis and correction of procedures, should a failure occur. Additionally, ongoing training is required for personnel from all organizations that may participate in an alarm response. Currently, training programs exist only for personnel performing activities described in EMS Procedure EMP-SW-HCAR. Other responders will be trained as the pertinent EMS procedures are completed. (Completion of these procedures has been delayed pending upgrades to the monitoring facility. See Section 7.3.7.)

The ultimate measure of the monitoring system performance is the contribution made to the efforts of the discharge control program to prevent inappropriate release of regulated materials. In this regard, the immediate success of the system is excellent. Detected releases were 10 a year in 1990-1992, 0 in 1993, and 1 to date in 1994. The sharp drop-off in 1992 was primarily the result of the efforts by the discharge control program to identify sources of recurrent releases of zinc and silver.

7.3.4.2 Post-Alarm Sample Analysis

The data quality objective requirements of the compliance monitoring program (Section 7.2.4) apply to the analysis of alarm grab samples, satellite station samples, and daily composite samples. Use of duplicate samples, field blanks, and trip blanks are not appropriate for these samples, which are acquired and analyzed under extreme rush conditions. Quality control of the results is based upon the analysis of control data gathered for the compliance monitoring program.

7.3.5 Implementation Procedures

Continuous sewer monitoring team activities are divided clearly between routine maintenance and calibration activities, and response procedures to a sewer alarm.

7.3.5.1 Maintenance and Calibration

As discussed in earlier sections, the monitoring equipment is subject to the extremity of direct contact with a corrosive and biologically active mixed-phase medium. The plumbing and flow cells contain narrow conduits and dead volumes that can be fouled by silt, grease, hair, and bacterial growth. Continuity of operation requires frequent maintenance. These activities are described in procedure EMP-SW-M. The pH probe is cleaned daily. The x-ray flow cells, Marinelli beaker, phase separators, and plumbing are thoroughly cleaned each week. The flow monitoring stilling well is flushed weekly. Should any of the sophisticated electronics or computer equipment fail, the procedure references contract service personnel who can diagnose system failures and repair and/or replace components as necessary to restore operation. As well as the monitoring equipment itself, procedure EMP-SW-M details the maintenance of ancillary systems such as the uninterruptible power supply, chlorine pump, and composite sample refrigerator.

Calibration of the monitoring equipment is described in procedure EMP-SW-CA. As stipulated in EH-0173T(U. S. Department of Energy 1991), complete calibrations of the gamma and metals equipment are called for yearly. The gamma system is calibrated for energy gain and conversion efficiency using a standard mixed fission product source, with ^{241}Am added to provide a low-energy calibration endpoint at 60 keV. The metals energy calibration is achieved with a ^{57}Co source. The metals calibration coefficients (concentration versus the count rate ratio described in Section 7.3.3.2) are determined by a four-point calibration using metals concentrations of 0, 20, 50, and 100 mg/L. Although alarm levels are generally in the 10 mg/L range, this calibration scheme guarantees accuracy for the releases at higher concentrations that are of greatest concern.

The pH probe is calibrated monthly using standard buffer solutions. As well as the response of the recorder, the procedure verifies that the readings obtained by the computer acquisition system agree with the probe readings. At the same time, the computer and chart recorder flow readings are compared. Flow meter calibration is checked once each quarter and is certified by a registered engineer, as required for equipment that is used to calculate connection fees.

Procedure EMP-SW-CA includes worksheets and detailed computer operator instructions for execution of all of these calibration operations.

Maintenance of the satellite sampling stations includes routine cleaning of the stations, disposal of unneeded samples, and cleaning of the sampler and sewage pick-up tubes. Reliable operation of the samplers requires occasional calibration of pressure switches, and repair and replacement of broken controller cards. These activities are described in procedure EMP-SW-SSM, including detailed notification and computer operator instructions.

7.3.5.2 *Alarm Response*

When the computed pollutant concentrations surpass alarm levels, or equipment parameters deviate from acceptable operating limits, the sewer monitoring computer annunciates an alarm. In the case of a hardware condition, the signal is sent to the LLNL Fire Dispatcher control center, which is staffed continuously. When a spill alarm is annunciated, the signal is received by the Fire Dispatcher, the LWRP, the B511 Main Control Center, and the Sewer Diversion Facility.

When an alarm is annunciated during normal work hours, the Fire Dispatcher notifies EPD response personnel. Off-shift, the Hazards Control off-shift health and safety technician is notified.

7.3.5.2.1 Hardware conditions. Correction of hardware failure conditions is dependent upon the experience of the individual responder. Standing relationships with support personnel are drawn upon in many situations. Mechanical utilities personnel and maintenance machinists typically respond to correct sampling pump failures. Failure of any x-ray fluorescence or gamma spectroscopy equipment is under contract with Canberra Industries. Other systems, such as the pH and flow recorders and the macerators, are installed in duplicate. Personnel who are not intimately familiar with the monitoring system are usually unable to diagnose and correct hardware failures. If monitoring program personnel are not available, the alarm will usually be disabled or left active until they can respond. Correction of hardware conditions is guided by reference to equipment manuals kept in the monitoring station.

7.3.5.2.2. Spill response. If the condition is a spill alarm, the primary responder immediately notifies the LWRP that alarm response has been initiated. During waking hours, sewage transit times from LLNL to the LWRP are roughly 4 hours; at night, transit times can be from 4–6 hours. This provides a buffer during which the alarm assessment can be completed. However, the LWRP expects verbal notification that alarm response has begun within 20 minutes. Otherwise, preparations may be made to initiate a diversion of effluent entering the treatment facility.

The primary role of the off-shift Hazards Control responder is to assess the facility condition and collect alarm data. This includes off-line analysis of the grab sample for pH or radioactivity, as appropriate. These activities are guided by the procedure EMP-SW-HCAR and documented on a sewer response report. Certain simple conditions, such as a false alarm due to loss of flow from the primary sampling pumps, may be corrected independently by the technician. Generally, however, an EPD responder is notified. The information collected by the technician is used by the EPD responder to determine the severity of the alarm condition. Occasionally, the condition can be assessed and/or corrected over the telephone. In all other cases, the EPD responder must travel to the Sewer Monitoring Station to complete the alarm response.

When the EPD responder arrives at the facility, (s)he follows the procedures described in EMP-SW-EAR (in draft). All activities are documented on a spill

response report. A complete alarm response includes evaluation of off-line analysis data and examination of trend data and spectroscopy spectra. If the contaminant concentrations are unusually flat, flow cell contamination may be assessed by running wash water through the analysis system. If the results of this investigation match any of the documented false alarm criteria, the alarm response is terminated. If experienced personnel are available, correction of the condition generating the false alarm, whether flow cell fouling or an electronics failure, may be attempted. In any case, the LWRP, Fire Dispatch and the Plant Operations first line supervisor are notified of the conclusions of the investigation. If the alarm condition cannot be cleared, the alarm signal is disabled in software until monitoring program personnel are available to correct the problem.

If the condition cannot be determined to be a false alarm, the EPD responder must assess the severity of the release, and initiate further spill response activities as necessary. Criteria for this decision are provided in procedure EMP-SW-EAR. In either case, at this point LLNL emergency response managers must be informed of the incident. This contact is managed by the Environmental Duty Officer (EDO), who obtains authorization for the EPD responder to notify the LWRP that a release has possibly occurred.

For a minor release, the responder instructs sampling technicians to collect satellite station samples, along with the alarm grab sample and the daily composite sample. The collection and handling of these samples are described in procedures EMP-SW-SAS, EMP-SW-HCAR and EMP-SW-B196.

In the case of a serious ongoing release, the EPD responder may choose to activate the EPD Satellite Operations Center for assistance in managing the incident. The Sewer Monitoring Station becomes the site of a coordinated spill identification effort involving sampling technicians and LLNL analytical chemists. This effort will be described in procedure EMP-SW-SID (under development).

7.3.6 Preparation and Disposition of Reports

The spill monitoring program generates documentation on all routine activities as well as formal reports.

Maintenance activities are printed out as they occur, interleaved with the spill-monitoring status information generated by the software to aid in alarm analysis.

These records are saved in electronic as well as hard-copy format and can be analyzed to generate tracking information on the frequency of system failures.

Calibration records are defined and maintained by the lead analyst. Special report forms are available for the pH and flow meter calibrations. Longer, computer-generated printouts are saved following metals and gamma calibration.

Spill response activities are generated on the report forms mentioned in the previous section. These reports are kept in the lead analyst's files. When a release is validated through analysis of the alarm grab sample, a formal report is written to the Livermore Water Reclamation Plant, as required in Section 8 of LLNL's Wastewater Discharge Permit (City of Livermore 1993). This permit requires a description of the incident, the duration and extent of noncompliance, and a discussion of the steps taken to prevent future recurrence.

DOE Order 5000.3B also requires reporting of sewer spills. LLNL's Implementing Procedures, Group 2, "Environmental," includes the following off-normal occurrence categories:

- (a) Any release of radionuclide material to the environment that is not part of a normal monitored release and exceeds 50% of a CERCLA RQ specified for such material per 40 CFR 302 within a 24-hour period.
- (b) Any detection of a radionuclide in a sanitary sewer system where the amount exceeds permitted discharge limits.
- (c) Any controlled, uncontrolled or accidental release which is not classified as an Unusual Occurrence but which will be reported in writing to state/local agencies in a format other than routine reports (e.g., monthly and quarterly).

Generation and filing of these reports follows the Implementing Procedures and Environmental Protection Department notification policy.

7.3.7 Future Program Development

The Sewer Monitoring Station was designed and built over a period of 15 years, essentially as an ongoing research and development activity. Although procedures, hardware, and software that have been implemented in the program are adequate, they do not meet the highest engineering standards for safety,

reliability and continued operability of the system. Thus, although the three years following 1990 demonstrated the effectiveness of the system as installed, by 1994 sufficient understanding had been established of the most important deficiencies, and a program of hardware and software upgrades was defined.

The first phase of the upgrades focused on the basic facility infrastructure. A replacement for the main sampling pumps was designed and installed. The new pump is currently under evaluation. Replacement is also underway of the lines that carry wastewater to and from the sewer. These lines were built with fittings that are susceptible to fouling. The next phase of the program will replace all the electrical wiring and mountings in the facility. Planned for the near future is a reworking of the mechanical layout of the facility.

The second phase of the upgrade is a complete replacement of the acquisition electronics and computer system. During FY93, this system began to show serious signs of degradation. Replacement of the computer is accompanied by a complete re-engineering of the software system, including attention to software quality assurance documentation requirements.

Plans for FY95 include a redesign and replacement of the x-ray fluorescence systems. The primary goal is to replace the current equipment with industry-standard components. This will make possible the stocking of duplicate components to allow rapid resumption of operations should a failure occur. The individual components will also be less costly to replace than the current integrated systems.

The net result of these operations will be to significantly streamline and consolidate the facility infrastructure. The workplace will be more accommodating of routine sampling and maintenance activities, as well as alarm response activities.

Following completion of these major modifications, the next improvements will focus on reduction of sensor fouling and improvements to the analysis algorithms. This work, to begin in CY95, should significantly reduce the frequency of false alarms, increase the effective operating time of the system, and aid in alarm analysis and response.

CY95 should also see completion of the remaining sewer monitoring procedures, several of which have been held up pending completion of system modifications. This includes the EPD alarm response procedure, EMP-SW-EAR, and the sewer

spill source identification procedure, EMP-SW-SID. Evaluation of training requirements and initiation of spill response training exercises, will be undertaken at that time.

Finally, the future may hold the need to expand the capabilities of the continuous monitoring system. An immediate possibility would be a continuous organics monitoring system, which is now commercially available. However, in the six years since routine organics monitoring has been performed in the compliance program, only in one instance has the discharge limit been violated. Lacking any evidence of serious discharge control problems, the required capital investment (over \$100K) appears unwarranted. In the recent past, more frequent excursions above discharge limits have been seen in oil and grease and total dissolved solids. The first was traced to correctable equipment problems in the cafeterias, the second is traceable to increased TDS levels in the water supply. These anomalies did not require the extended attention of the discharge control program, and so did not merit the development of monitoring methods. The compliance data also shows that during the decade starting 1973, levels of many other pollutants were frequently higher than today, and often higher than current discharge limits (although below the limits at the time). However, controls were implemented successfully as the compliance requirements were tightened, and it was not necessary to implement continuous monitoring.

As the recent success in controlled metals discharges has shown, the monitoring program remains a well focused and effective component of the discharge control program, as well as a unique technological achievement.

8

Routine Water Monitoring

8.1 RATIONALE AND DESIGN CRITERIA

Routine surveillance water monitoring involves sampling domestic water sources, rainfall, surface waters, ground waters, and storm water runoff at and adjacent to the Livermore site and Site 300. Chapter 10 of this document details ground water monitoring at the two sites. This chapter details current sampling and analysis of domestic water sources, rainfall, surface waters, and storm water runoff at both sites.

8.1.1 Regulatory Drivers

The primary regulatory driver for storm water runoff and surface water monitoring is DOE Order 5400.1, which 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...." The monitoring of storm water runoff at the Livermore site and Site 300 is also required under the State Water Resources Control Board National Pollutant Discharge Elimination System (NPDES) General Permit for Storm Water Discharges Associated with Industrial Activities (General Permit). The Federal Clean Water Act (Section 402[p]) requires industries to obtain NPDES permits to discharge storm water from industrial facilities. These permits include requirements for a comprehensive storm water monitoring and sampling program.

Rain water monitoring is called for in DOE Order 5400.1, which 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."

8.1.2 Monitoring Objectives

DOE/EH-0173T describes monitoring objectives for these networks:

- "...the purpose of the surveillance program is to characterize the radiological conditions of the offsite 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..."

DOE Order 5400.1 further states that:

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

The above-mentioned statements represent the primary DOE drivers for surveillance monitoring of domestic water sources, rainfall, surface water, and storm water runoff at the Livermore site and Site 300.

8.1.2.1 Storm Water

The Environmental Protection Department at LLNL has monitored storm water runoff at the Livermore site since 1975 (Gallegos et al. 1992; Gallegos et al. 1993).

In 1987, amendments to the Clean Water Act (CWA) added Section 402(p), establishing a framework for regulating municipal and industrial storm water

* The term *should* *in this guide refers to a "high-priority element."

discharges under the NPDES program. In 1990, EPA published final regulations establishing application requirements for storm water permits. These regulations require that storm water associated with an industrial activity discharging (either directly or indirectly) to surface waters must be regulated by a NPDES permit. The California State Water Resources Control Board administers this program via a statewide General Permit that applies to all industrial storm water discharges requiring a permit. As stated in the General Permit, goals of storm water monitoring include:

- "demonstrate compliance with the permit,
- aid in the implementation of the SWPPP (Storm Water Pollution Prevention Plan),
- measure the effectiveness of the BMPs (Best Management Practices) in removing pollutants in storm water discharges,
- ensure that storm water discharges are in compliance with the discharge prohibitions, effluent limitations, and receiving water limitations as specified in (the) General Permit, and
- ensure practices at the facility to control pollutants are evaluated and revised to meet changing conditions."

Thus, the monitoring program documents the elimination of specific pollutants resulting from the implementation of the SWPPP, as required by Section A of the General Permit. The General Permit specifically requires visual observations at storm water discharge points during the dry and wet seasons. It also requires analysis of storm water from two qualifying storm events (see Section 8.2.4.1) for "pH, total suspended solids (TSS), total organic carbon (TOC), specific conductance, toxic substances, and other pollutants which are likely to be present in storm water discharges in significant quantities."

8.1.3 Sources and Analytes

8.1.3.1 Storm Water

8.1.3.1.1 Livermore site. The storm water sampling program was initially designed to detect pesticides used at the Livermore site. Over the years, this program expanded to include metals, radioactivity, general water-quality parameters, and other priority pollutants (procedure EMP-RO-S). The analytes now being measured are detailed in Section 8.2.4.1.

8.1.3.1.2 *Site 300*. Storm water samples are analyzed for pH, TSS, specific conductance, and TOC or oil and grease as required by the General Permit. Based on activity at the Site 300 829 complex, an additional analysis, High Explosives (HMX, RDX, TNT), will be added at sample location 3-N829 (Rifle Canyon). Due to existing controls and documentation outlined in the SWPPP (Storm Water Pollution Prevention Plan) and the remedial investigation report, there is no reason to suspect any other pollutants to be present in Site 300 storm water discharge (procedure EMP-RO-S).

8.1.3.2 *Surface and Domestic Waters*

Surface and domestic water locations are sampled for tritium, gross alpha, and gross beta radiation. Surface water locations are positioned to monitor either rainout or direct runoff of tritium from atmospheric discharges from LLNL: the Building 331 Tritium Facility and Sandia National Laboratory's (SNL/CA) former Tritium Research Laboratory. Although gross alpha and gross beta monitoring should identify gross trends in radioactivity, it does not distinguish between radionuclides. It is known that multiple sources of radionuclides either are or have been present at this site. A technical assessment is to be performed to define all possible sources and the optimal choices of analytes and to evaluate all monitoring objectives as stated in Section 8.1.2.

8.1.3.3 *Rain Water*

8.1.3.3.1 *Livermore site*. Historically LLNL has exhibited elevated tritium levels in both rainfall and storm water runoff. The 13 sampling locations for rain water are positioned to monitor precipitation of tritium from the two primary sources of atmospheric tritium activity in the Livermore Valley: the Building 331 Tritium Facility and SNL/CA's former Tritium Research Laboratory. Station locations are based on analysis of approximately 2000 measurements of tritium activity in rain samples; the rain samples were obtained from 19 sampling locations from October 1990 through December 1992, and covered 53 rain events. Locations are further based on analysis of wind direction measurements that were made during rain events over the same period.

8.1.3.3.2 *Site 300*. Minute amounts of tritium were historically used in explosive experiments at Site 300. For the past 22 years, tritium activity has been measured in rain samples taken from a central location within the test site near the meteorological tower (MET). During the period from December 1971 to March 1994, 147 measurements of tritium activity in rain at Site 300 show background levels

of atmospheric tritium, averaging 3.0 Bq/L (81 pCi/L). Based on those measurements, one location is deemed adequate. One rain sampling location is positioned near the MET at a central location within the test site in order to monitor tritium activity in rain at that location.

Sections 8.2.1.3 and 8.2.4.3 have a more complete discussion of the adequacy of sampling locations and of sampling frequencies; see also the *LLNL Environmental Report*, 1993. (Gallegos et al. 1994).

8.1.4 Collection Methods

8.1.4.1 Storm Water

Samples are collected by dip or grab sampling from the runoff flow at the specified locations. Sample bottle requirements, special sampling techniques, and preservation requirements for each analyte are specified in procedure EMP-GW-S. A stainless steel bucket is used for sampling. It is triple rinsed with the water to be sampled, then dipped or submerged into the water and withdrawn in a smooth motion. Sampling is conducted away from the edge of the water to minimize the collection of sediment that may be present in the sample matrix. Sample vials for volatile organics are filled prior to sample vials for all other constituents and parameters. After the bottles are filled, they are dried and placed in an ice chest. If the water to be sampled is accessible to the technician, grab sampling can be used in place of dip sampling. In this case, samples are collected by partially submerging sample bottles directly into the water and allowing them to fill with the sample water.

8.1.4.2 Surface and Domestic Waters

Surface water sampling is performed with a tethered stainless steel pail; domestic drinking water locations are sampled directly from the tap. Sample bottle requirements, special sampling techniques, and preservation requirements for each analyte are specified in procedure EMP-SW-S. Samples for tritium analysis are collected in 500-mL, argon-flushed glass containers; those for other gross alpha and gross beta analyses are collected in acidified 1000-mL polyethylene bottles.

8.1.4.3 Rain Water

Samples for tritium analysis are collected directly from stainless steel buckets in 500-mL, argon-flushed glass bottles supplied by RAS following procedures EMP-RA-S, EMP-QA-SL, and EMP-QA-SD.

8.2 EXTENT AND FREQUENCY OF MONITORING AND MEASUREMENTS

8.2.1 Number of Sampling Locations & Description of Sampling Locations

8.2.1.1 Storm Water

The total surveillance monitoring program consists of twelve sampling locations (Figures 8-1 and 8-2). A complete description of these sampling locations can be found in the EMS procedure, EMP-RO-L, *Storm Water Runoff Locations*.

8.2.1.1.1 Livermore site. Two arroyos cross the Livermore site, Arroyo Las Positas and Arroyo Seco. Of the six storm water sampling locations at the Livermore site, five characterize both storm water entering (influent to) the site or leaving (effluent from) the site via these arroyos (Figure 8-1). Sampling locations near the intersection of East Gate Drive and Greenville Road, on the eastern edge of the site (ALPE), and in the northeast corner of the site (GRNE) are used to characterize influent to the site via the Arroyo Las Positas.

Sampling location (WPDC) in the northwest corner of the site monitors discharges into the Arroyo Las Positas. Drainage channels which converge at this point collect effluent from internal site channels and the Central Drainage Basin. From WPDC, all effluent continues along an existing drainage channel passing through undeveloped land containing no industrial activity until it leaves the Livermore-site perimeter at Patterson Pass Road.

Locations in the southwest region of the site (ASS2 and ASW) characterize the influent and effluent of the Arroyo Seco, respectively.

Sampling location CDB at the Central Drainage Basin characterizes flow into the basin. The basin, located near the center of the Livermore site, collects storm water runoff from a large portion of the site. A complete description of the design, operation, and maintenance of the basin can be found in the *Drainage Retention Basin Management Plan*, prepared for LLNL by Limnion Corporation.

The San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) has requested that LLNL integrate monitoring of industrial discharges from the Central Drainage Basin with the Livermore site's Storm Water Monitoring Program. The storm water locations include monitoring points characterizing areas of industrial activity. The number of locations at the Livermore site was selected based upon the number of storm water effluent and influent locations in addition to one on-site location. (The NPDES monitoring points required by the General Permit are now only WPDC and ASW, a subset of this overall surveillance monitoring).

8.2.1.1.2 Site 300. Effluent from five areas of industrial activity, as defined by the General Permit, is monitored. Based on field examination of the Site 300 drainage (performed during storm events), communications with the Central Valley Regional Water Quality Control Board (CVRWQCB), and review of the "industrial activity" criteria in the General Permit, six monitoring locations have been identified for Site 300 (see Figure 8-2). Five locations monitor runoff related to specific industrial activities. Location NSTN (an upstream location in Corral

Hollow Creek) is used to determine concentrations of constituents and parameters in runoff that may be considered typical of the region, in order to reflect conditions of storm water not influenced by LLNL.

Rifle Canyon, located in the southeastern portion of Site 300, is the natural site drainage for the High Explosives (HE) Burn Pits, Building 829 Complex. Monitoring location N829 is located where Rifle Canyon exits the Site 300 perimeter, just east of Pit 6. The Building 829 Complex currently operates as an interim-status RCRA facility and is located in the HE Process Area in the south-central portion of Site 300. It is used to burn process waste generated by operations in the HE Process Area. The facility consists of three separate burn pits and an HE combustion unit known as the "iron horse." Only two of the three burn pits are currently active.

The Building 883 Facility HWCSA is located in the General Services Area in the southeast corner of Site 300. This RCRA-permitted facility stores containerized wastes prior to disposal by the Hazardous Waste Management Division. The facility has engineered controls that catch storm water in a sump, where it is pumped out and retained in barrels pending analysis and disposal. Storm water runoff from the facility's roof flows through storm drains located in the General Services Area (GSA) and exits Site 300 on the southern slope of the GSA along Corral Hollow Road, where location N883 is used to characterize effluent.

Location NLIN monitors several closed landfill pits at Site 300 (Figure 8-2). Landfill Pits 1 and 2 are south of the East Observation Post in the upper central portion of Site 300. Pits 3, 4, 5, and 7 are located directly above the West Observation Post in the northwest portion, Pit 8 is located in the northeastern portion, just east of the 801 Facility, and Pit 9 is located near Building 845. These landfill pits are all closed. They and Pit 6 (see below) were used for disposal of debris at Site 300. A history of each pit can be found in the *Final Site-Wide Remedial Investigation Report* (Webster-Scholten 1994) of landfill pits at Site 300. Since these landfills are capped, materials in the landfills will not contribute contaminants to storm water runoff. Drainage from all the landfill pits (except Pit 6 and some drainage from Pit 7 flows from the first downgradient point of North Outer Loop Road in a west to east direction through culverts and crests at the East Control Point southeast of the landfills. The runoff then flows through a culvert off Linac Road and exits Site 300 via Elk Ravine to the east. Elk Ravine has no safe or accessible sampling point where it meets the Site 300 boundary. Since there is no industrial activity between the Linac Road culvert and the final

Elk Ravine exit point, LLNL samples the Linac Road culvert (NLIN). This approach received verbal approval by personal communication (December 8, 1992) with the Regional Water Quality Control Board staff.

Drainage from the Pit 6 area is collected by a ditch and culvert north of it to prevent any intermittent sheet flow off the pit. Runoff is sampled from the culvert on the southeast end of Pit 6 (NPT6), near well K6-01, only when the above flow control devices fail to prevent runoff from flowing off the pit.

The closure of Pit 7 included a graded concrete drainage system which directs flow away from the pit. Consequently, a portion of storm water runoff now flows north. This flow is monitored at location NPT7.

Location NSTN is slightly south of Site 300, near the western portion of the site. It is used to monitor runoff that is not related to Site 300, in order to aid EMS in determining representative soil loads.

8.2.1.2 Surface and Domestic Waters

For routine monitoring of the Central Basin, see also Chapter 9, Central Drainage Basin Monitoring.

8.2.1.2.1 Livermore site. Surface and domestic waters are sampled at two locations on the Livermore site and at ten locations in the Livermore Valley (Figure 8-3). Of the two Livermore site locations, POOL provides samples from the swimming pool, and TAP provides samples of on-site drinking water. (LLNL's on-site drinking water is Hetch Hetchy water most

of the time. Zone 7 is a backup supplier.) Of the remaining ten sampling locations in the Livermore Valley, four provide samples of domestic tap water (BELL, GAS, ORCH, and PALM) in the Livermore Valley; the remaining six provide samples of various surface waters. The on-site samples provide information on potential radioactive constituents in the LLNL drinking water supply and in the pool. The off-site drinking water samples provide information on potential radioactive constituents in the local drinking water supplies that could potentially be related to LLNL activities. EMS procedure EMP-W-L documents all surface and domestic water sampling locations.

Surface drainage in the Livermore Valley is by westward-flowing intermittent streams (arroyos) that merge in the west end of the Livermore Valley to form the southward-flowing Arroyo de la Laguna, a tributary to the Alameda Creek drainage system. Six surface water monitoring locations are located within the following water bodies. One sampling location in the Arroyo de la Laguna (ALAG) is 13 kilometers to the southwest of LLNL. Winter flows not captured as ground water recharge flow out the southwestern corner of the valley, eventually entering San Francisco Bay by way of Alameda Creek. Surface water bodies near the Livermore site include the treatment tanks and reservoir of the Patterson Pass water treatment facility (ZON7), about 1.2 kilometers east of the Livermore site; and the Springtown Pond (DUCK), an artificial decorative pond maintained in a community recreation area 2.6 kilometers northwest of the Livermore site. Lake Del Valle (DEL) and the Calaveras Reservoir (CAL), water storage reservoirs 8 kilometers south of the Livermore site and 21 kilometers southwest of the site, respectively, provide aquatic recreation (swimming, boating, and fishing), as does the Shadow Cliffs Regional Park (SHAD), 11 kilometers to the west. The Shadow Cliffs facility is an excavation produced by gravel quarry operations, which continue to mine additional pits in the same general area. These last three surface water locations are considered background for environmental surface water monitoring; all three sites are upwind of LLNL and are not directly connected to LLNL runoff.

8.2.1.2.2 Site 300. Surface and domestic waters are sampled at one location on and one location adjacent to Site 300 (**Figure 8-4**). Location 812CRK provides samples of one of the few spring-fed surface waters at the site. Location GEOCRK provides downstream samples of water in Corral Hollow Creek, which drains most of Site 300.

Figure 8-4. Surface water and rain sampling locations, Site 300.

Sample data from the off-site locations at both the Livermore site and Site 300 provide information on tritium levels in nearby surface water bodies. All of the above locations were selected to characterize long-term trends relating to tritium in water resources. The adequacy of this number of sampling locations will be determined in the technical assessment.

8.2.1.3 Rain Water

8.2.1.3.1 Livermore site. Winds measured during rain events in the semi-arid Livermore Valley are predominantly from the southwest quadrant, but are occasionally recorded from the northeast quadrant. Winds from the northwest and southeast are rare during rain events. Graphical analyses were done using 2000 tritium activity measurements from a special study network of 19 rain sampling locations that covered 53 rain events from October 1990 through

December 1992. The analyses demonstrate that tritium activity decreases exponentially with increasing distance from the LLNL Tritium Facility (Building 331) and from the former Tritium Research Laboratory at SNL/CA nearby. Low (background) levels of tritium activity in rain are reached at about 4 kilometers from these two main sources of atmospheric tritium in the Livermore Valley. The analyses showed that the former special study network of 19 rain sampling stations (described by Christofferson and Hoppes in Chapter 6 of the 1992 Environmental Report [Gallegos et al. 1993]) could be reduced in size by eliminating the stations beyond 4 kilometers from Building 331. These more distant stations, showing background levels of tritium activity, provided little or no additional information to the overall determination of risk to the surrounding population due to tritium released by LLNL and SNL/CA. In the fall of 1993, eight of the most distant locations were eliminated from the network. One station (SLST) more than 4 kilometers to the west remains as a background sampling location. Prior to the onset of rain in the fall of 1994, a new rain sampling station (VET) was established to the southwest of LLNL, adjacent to the air-moisture tritium sampler off Vasco Road. This station was established to fill a directional gap in rainfall sampling based on a study of wind directions during rain events. It will provide a quantitative measure of tritium rained out to the southwest during those few rain events when the wind blows across the site from the northeast.

The rain sampling locations in the Livermore Valley are shown on Figure 8-5. Detailed descriptions of locations are given in EMS Procedure EMP-RA-L. The upwind background station, west-southwest of LLNL, is identified as SLST. The cross-wind background station MET is located on site at the meteorological tower. All 11 additional locations are designed to monitor tritium activity in rainfall close to the main sources at LLNL and SNL/CA where high values have been historically recorded. Stations are placed at various compass directions to provide adequate coverage of variable wind directions expected during rain events. In addition to monitoring stack emissions from Building 331, Station B343 (at Building 343) is very sensitive to any ground level release of tritiated water vapor to rain from the Waste Accumulation Area on the east side of Building 331, about 100 meters (328 feet) southwest of the rain sampling station, where tritium-contaminated materials may be temporarily stored. Likewise, Station B291 (at Building 291), is very sensitive to the ground level release of tritiated water vapor to rain from the Building 292 area, about 150 meters to the southwest of the rain sampling station, where an underground storage tank has leaked tritium-bearing wastewater into the ground.

Figure 8-5. Rain sampling locations, Livermore site and Livermore Valley.

8.2.1.3.2 *Site 300*. Historically, one central location at Site 300 (see Figure 8-4) has been utilized to collect rainfall for tritium activity measurements. Some 147 measurements from this location made over a period of 22 years show a high of 9 Bq/L (246 pCi/L), a mean of 3 Bq/L (81 pCi/L), and a standard deviation of 2 Bq/L (56 pCi/L). The historical tritium activities measured are essentially background for tritium activity in the atmosphere during this time period. The historical data show little evidence of tritium in rain at Site 300 during this 22 year period. Therefore, additional sampling stations would not improve our ability to quantify the amount of tritium in rain at Site 300.

8.2.2 QA and QC Sampling and Quality Assurance Requirements

All routine water monitoring samples are collected and analyzed according to written procedures by trained personnel.

For storm water, surface and domestic water, and rain samples, field duplicates are taken from a randomly selected location. Currently, no field blanks or spikes are taken. The use of QA spikes and blanks is currently being evaluated as part of the technical assessment for these monitoring networks.

For rain samples, the RAS analytical laboratory selects a random sample to create a laboratory split. A set of ten rain samples containing the field duplicate, the split sample, a method blank, and two NIST-traceable standards is then measured as a single batch (RAS procedure 011).

A technical assessment will be conducted to determine appropriate data quality objectives for the storm water, surface and domestic water, and rain monitoring networks.

8.2.3 Sampling Frequency

8.2.3.1 Storm Water

Storm water samples are collected only during the wet season (defined as October through April in the General Permit). Sampling events consist of the first and last storms of the wet season and two storms in between. In addition, Section B of the NPDES General Permit states that samples should be obtained within the first half-hour of flow from a given storm. If the flow ceases within the first hour of discharge, however, the runoff is not considered to be a "significant storm water discharge," and samples are not required. Furthermore, samples are to be taken only from a storm event "that is preceded by at least three working days of dry weather," and are only required "if significant storm water discharges commence during scheduled facility operating hours." Together, these constraints determine whether a runoff event qualifies as a NPDES storm water event. The General Permit requires that two significant storm events be monitored each year. In addition, two storm events are monitored in support of the compliance with DOE Order 5400.1 routine environmental monitoring requirements. A technical assessment will be conducted to determine the adequacy of sampling four runoff events per year.

8.2.3.2 *Surface and Domestic Waters*

Sampling events occur monthly for POOL samples and quarterly for every other sampling location. Quarterly samples for most of the stations ensures that seasonal variations in measurements are taken into account. POOL samples are taken more frequently due to the heavy use of the LLNL pool and the consequent exposures to the public. A technical assessment will address the adequacy of the sampling schedule.

8.2.3.3 *Rain Water*

Four rain events in the Livermore Valley are measured each rain season. The first and last rain events of the rain season are sampled to coincide with storm water runoff sampling. Two intervening rain events are sampled at intervals of at least one month. Rain sampling equipment is in place for the entire year. Rain water from events not needed for surveillance monitoring purposes is discarded. Should a tritium release to the atmosphere occur during a rain event, the equipment is always in place to sample the rain. However, rainfall typically occurs less than 3% of the time in the Livermore Valley.

At Site 300, rain water is sampled once per month during the rain season from the collecting bucket at the MET location. The rain sample may be a composite of several rain events at that location. Some 147 measurements of tritium activity made during the past 22 years show very low (background) levels. These low levels indicate that past experiments at Site 300 did not release significant amounts of tritiated water vapor to rain during this 22-year period. As of 1985, explosive experiments containing tritium ceased at Site 300.

8.2.4 *Analytes Measured*

8.2.4.1 *Storm Water*

8.2.4.1.1 *Livermore site.* Over the years, this monitoring program expanded from just pesticides to include metals, radioactivity, general water quality parameters, and other priority pollutants (see procedure EMP-RO-S). As required by the NPDES General Permit, samples are analyzed for pH, TSS, specific conductance, and TOC or oil and grease. In addition, the NPDES General Permit requires samples to be analyzed for other pollutants that are likely to be present in storm water discharges in significant quantities. A review of storm water runoff data from between 1978 and 1991 was used to select constituents and parameters for ongoing monitoring. Constituents and parameters selected were chemical

oxygen demand (COD), gross beta, tritium, and constituents in the general minerals analysis (which includes total alkalinity, bicarbonate alkalinity, carbonate alkalinity, hydroxide alkalinity, aluminum, calcium, chloride, copper, fluoride, hardness, iron, magnesium, manganese, nickel, nitrate, potassium, sodium, sulfate, surfactant, and zinc). Most of these constituents are naturally occurring and are usually found in LLNL runoff at or near background levels.

Historically, very few of the organic constituents are found above detection limits at the Livermore Site. A technical assessment will be conducted to determine the appropriateness of the existing analytes and the possibility of eliminating many of the organic constituents from the monitoring program.

8.2.4.1.2 Site 300. See Section 8.1.3.1. A technical assessment will be conducted to determine the appropriateness of the existing analytes and the possibility of eliminating many of the constituents from the monitoring program.

8.2.4.2 *Surface and Domestic Waters*

The only radiological contaminants for which analyses are performed at both sites are gross alpha and gross beta radiation and tritium; these are the parameters that have historically been monitored. A technical assessment will determine whether other analytes, such as radium, thorium, or uranium radioisotopes or other constituents should be included in this network.

8.2.4.3 *Rain Water*

Tritium is the single analyte measured in rain water in the Livermore Valley and at Site 300. Determination of other wind-transported radioisotopes is better done by continuous air particulate monitoring (see Chapter 6).

8.3 **PROCEDURES FOR LABORATORY ANALYSIS**

Tritium analyses are performed on site by the LLNL Radiation Analytical Sciences Section, Environmental Monitoring and Analysis Division. All other radioactivity and radioisotope measurements are currently performed off site by IT Corporation, St. Louis, MO, and by Lockheed Analytical Laboratories, Las Vegas, NV.

Nonradioactive water analyses are performed off site by California Laboratory Services, Rancho Cordova, CA, and by GTEL Environmental Laboratories,

Concord, CA. For details on analytical laboratory procedures, see Chapter 16, Procedures for Laboratory Analysis.

8.4 PROGRAM IMPLEMENTATION PROCEDURES

All routine water sampling is conducted by LLNL technical staff. Chain-of-custody procedures (see procedure EMP-QA-SD) are followed when delivering samples to the laboratories for analysis. The following EMS procedures outline the duties and responsibilities involved in sampling for the routine water monitoring program:

- EMP-RO-S, Storm water Runoff Sampling
- EMP-RA-S, Rain water Sampling
- EMP-SW-S, Domestic and Surface Water Sampling

Rain water is measured for tritium activity only, and surface and domestic waters are measured for gross alpha and gross beta radiation and for tritium.

8.4.1 Storm Water

Storm water runoff samples are collected by technicians according to EMP-RO-S and are submitted for analyses using sample control and documentation procedures (EMP-QA-SL and EMP-QA-SD). Samples are collected by dip or grab sampling from the runoff flow at the specified locations. Sample bottle requirements, special sampling techniques, and preservation requirements for each analyte are specified in EMP-GW-S.

8.4.2 Surface and Domestic Waters

Surface and domestic water samples are collected by technicians according to EMP-W-L and EMP-SW-S and are submitted for analyses using sample control and documentation procedures (EMP-QA-SL and EMP-QA-SD). Sampling of the surface water sources is via a tethered stainless steel pail; grab samples at the outfall are taken for other sampling locations. Samples for tritium analysis are collected in 500-mL, argon-flushed glass containers; those for other radiological analyses are collected in 1000-mL polyethylene bottles.

8.4.3 Rain Water

Rain water is collected by sampling technologists in accordance with procedure EMP-RA-S.

8.5 PREPARATION AND DISPOSITION OF REPORTS

Storm water sampling results are reported annually in two reports. Site 300 results are reported to the CVRWQCB and Livermore site results are reported to the SFRWQCB. The reports follow the "Storm Water Annual Report" format specified by the State Water Resources Control Board and are due on July 1 of each year. These reports include summaries of wet and dry season observations, unplanned releases to ground, facility inspections and sampling results, along with a brief interpretation of the data. In these reports, all storm water data are reported and summarized, trends are discussed, and the degree of success of efforts to reduce constituent loadings in storm water are evaluated. Results are also presented in the Environmental Report.

The routine surface water, domestic water, and rain water monitoring results are summarized and discussed in the surveillance monitoring section of the Environmental Report, which is available to the public. All data are summarized and trends are discussed. Each report also includes a brief interpretation of the data.

Occurrence reports may be required when any monitored parameter exceeds local background by a "statistically significant" amount. These results would then be reported to DOE. A recent reportable incident occurred in February 1993, when tritium in rain reached an activity level of 5444 Bq/L (147,000 pCi/L). This tritium in rain water was later found to result from the partial rainout of a small amount of tritium emitted during routine decontamination activities. The impact on the environment, safety, and health of the general public from these emissions was found to be minimal (LLNL-OR-1994-020).

9

Central Drainage Basin Monitoring

The 53-million-liter Central Drainage Basin (CDB; Figure 9-1) was lined as part of the Livermore site remediation activities. Remediation action studies had indicated that infiltration of storm water from the basin caused increased dispersal of ground water contaminants. Basin lining to halt infiltration was completed in March 1992, and LLNL adopted the *Drainage Retention Basin Management Plan* (hereafter referred to as the Management Plan) as the means to maintain high water quality levels in the CDB. Monitoring at the CDB is based on water quality management through the Management Plan and water quality monitoring required by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). Water quality monitoring ensures compliance with the CERCLA Record of Decision and the state-wide NPDES storm water permit.

The focus of the Management Plan is to implement a long-term biological monitoring and maintenance program and to prevent water quality problems such as sedimentation, algal blooms and anaerobic conditions through bioremediation and reduction of nutrient loading. Water quality management objectives are maintained through sediment removal in sediment basins located at the influent points to the CDB; management of upstream watershed activities; use of plants in submersed pods that act as biofilters, and, in the shallow portions of the basin, rooted aquatic plants to remove urban runoff pollutants and control erosion of the basin lining cover; and addition of oxygen by means of recirculating pumps.

9.1 RATIONALE AND DESIGN CRITERIA

The Management Plan identifies two sources of water to fill and maintain water levels in the CDB. The primary water source is water generated from ground water treatment units that may discharge to the basin through the existing storm water collection system or be piped directly to the CDB. The secondary water source is storm water runoff (the CDB drains approximately one-fourth of the Livermore site). During 1993, storm water runoff was the only source of water to the CDB. Treatment Facility D (TFD) began to discharge treated ground water to the basin on September 29, 1994. Pollutant sources include storm water runoff from parking lots, excess landscape irrigation (in particular, a potential source of nutrients), and unplanned releases of materials to ground.

Figure 9-1. Locations of LLNL Livermore site and Site 300.

The CDB discharges wastewater into surface water drainage courses. This discharge of wastewater is governed by the Federal Water Pollution Control Act (FWPCA) and the California Porter-Cologne Water Quality Control Act.

The FWPCA, also known as the Clean Water Act, was enacted to restore and maintain the chemical, physical, and biological integrity of "waters of the Nation." To this end, Section 402 of the FWPCA established the National Pollutant Discharge Elimination System (NPDES) to prescribe conditions under which pollutants can be discharged to "waters of the Nation." The specific requirements of NPDES permits, developed by the EPA, are contained within 40 CFR 122.

The Porter-Cologne Water Quality Control Act protects the quality of "waters of the state" by requiring a Regional Water Quality Control Board to evaluate waste discharges and issue a WDR (Waste Discharge Requirements; 23 CCR, Ch. 9) if it is determined that the waste could adversely affect water quality. The Porter-Cologne Act also requires the development of several state-wide water quality plans and individual regional water quality control plans. Any WDR issued by a Regional Water Quality Control Board must be consistent with these plans.

Discharges of treated groundwater from CERCLA remediation activities at the Livermore site are conducted under a Federal Facility Agreement (FFA) between the San Francisco Regional Water Quality Control Board, the Department of Toxic Substances Control, EPA, and DOE. The FFA requires that all "applicable, relevant and appropriate requirements" (ARARs) be met.

The San Francisco Regional Water Quality Control Board issued WDR No. 91-091 which allows discharges of approximately 1.9 million liters per day from ground water remediation activities to the Livermore-site storm drain system (including the CDB). LLNL has identified these discharge limits as ARARs governing release of treated ground water into the CDB, and they have since been incorporated into the site CERCLA Record of Decision (ROD).

Discharges from the CDB are also regulated under NPDES Permit No. CA0029289. Limits for discharging treated groundwater into the storm drain system, including the CDB, are established by the WDR and ROD (Table 9-1); exceeding these limits constitutes noncompliance with the NPDES permit and the CERCLA ROD.

LLNL agreed (in "Discharge from LLNL CDB," PRA92-572, January 5, 1993) to conduct and report to the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB) the results of routine monitoring at the basin, specified in the Management Plan for water quality management objectives (Table 9-2). The objectives of this monitoring program are to ensure that concentrations of metals, organics, physical properties and toxicity are within the discharge limits identified in WDR No. 91-091 and the ROD and are within the limits set by the Management Plan.

Table 9-1. Treated ground water and Central Drainage Basin discharge limits identified in WDR Order No. 91-091 for outfalls at locations CDBX and WPDC.;^a

Parameter	Discharge limit (µg/L)
Metals	
Antimony	1460
Arsenic	20
Beryllium	0.7
Boron	7000
Cadmium	5
Chromium (total)	50
Chromium (hexavalent)	11
Copper	20
Iron	3000
Lead	5.6
Manganese	500
Mercury	1
Nickel	7.1
Selenium	100
Silver	2.3
Thallium	130
Zinc	58
Organics	
Volatile organic compounds (total)	5
Benzene	0.7
Tetrachloroethene	4
Vinyl chloride	2
1,2 Dibromoethane	0.02
Total petroleum hydrocarbons	50
Polynuclear aromatic hydrocarbons	15
Base/neutral and acid extractable compounds and pesticides	5
Physical	
pH (units)	6.5–8.5
Toxicity	
Aquatic survival bioassay (96 hours)	90% survival median, 90 percentile value of not less than 70% survival

^a Monitoring occurs at first discharge of the rainy season from the CDB and at two additional discharges associated with storm water runoff monitoring. Toxicity testing using the aquatic survival bioassay is required once per year.

9.2 EXTENT AND FREQUENCY OF MONITORING AND MEASUREMENTS

In 1992 the SFBRWQCB approved a sampling program developed by LLNL for the CDB. Discharges are sampled at two locations, one immediately beyond the basin outfall (location CDBX, **Figure 9-1**), and one as the discharge leaves the Livermore site (location WPDC, **Figure 9-1**). The routine CDB management sampling program includes eight locations. Four of these are surface locations, and four are at various depths within the basin. This sampling is used to determine compliance with WDR No. 91-091.

Sampling to determine whether water quality maintenance objectives (**Table 9-2**) are met is conducted at several points within the CDB. Sampling for dissolved oxygen and temperature occurs at all eight locations mentioned above (**Figure 9-2**). During the 1992-93 wet season, sampling for all other constituents and parameters was also conducted at all eight monitoring locations. However, because there was evidence of limited variability between sampling locations, beginning March 31, 1993, only dissolved oxygen and temperature were collected at all eight sampling locations. The remaining parameters listed in **Tables 9-1** and **9-2** were collected at CDBE, located at the middle depth of the CDB.

Past practices have included field duplicates of one parameter per monitoring event as part of the routine quality control of monitoring of the CDB. The Management Plan and basin sampling procedure (EMP-W-DB) are currently under review. This review will include the incorporation of additional QA/QC sampling procedures.

The annual compliance sampling program consists of sampling discharges from the CDB (location CDBX, **Figure 9-1**) and the site storm water outfall (location WPDC; **Figure 9-1**) during the first release from the CDB in the wet season (October through the following April) and two additional storms (chosen in conjunction with storm water runoff monitoring). This sampling frequency was determined by agreement with the SFBRWQCB ("Discharge from LLNL CDB," PRA92-572, January 5, 1993). Surveillance sampling frequencies for each parameter are specified in the Management Plan, based on its water quality management objectives, and are listed in **Table 9-2**. The adequacy of the number of locations and frequency of compliance sampling will be evaluated during the review of the Management Plan.

Discharge monitoring parameters are specified in WDR No. 91-091 (Table 9-1). Water quality management objectives (Table 9-2) set by the Management Plan are used as a tool to optimally operate the CDB. While operation outside these parameters does not constitute noncompliance with limits established in the NPDES permit and CERCLA ROD, it indicates that an action should be taken to properly maintain water quality within the CDB. For example, aeration pumps in the CDB are operated to maintain the dissolved oxygen levels within management parameters.

9.3 PROCEDURES FOR LABORATORY ANALYSIS

Tritium analyses are performed on site by the LLNL Radiation Analytical Sciences Section, Environmental Monitoring and Analysis Division. All other radioactivity and radioisotope measurements are performed off site by IT

Table 9-2. Routine water quality management levels for the Central Drainage Basin.

Parameter	Location	Frequency	Management action levels
Physical			
Dissolved oxygen (mg/L)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	Not less than 5, 80% saturation
Temperature (°F)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	<60 and >80
Total alkalinity (mg/L)	CDBE	Monthly	<50
Chlorophyll A (mg/L)	CDBE	Monthly	>10
pH (units)	CDBA, CDBC, CDBD, CDBE, CDBF, CDFJ, CDBK, CDBL	Weekly	<6.0 and >9.0
Total suspended solids (mg/L)	CDBE	Monthly	
Total dissolved solids (mg/L)	CDBE	Monthly	>350
Turbidity (meters)	CDBE	Monthly	<0.914
Chemical oxygen demand (mg/L)	CDBE	Quarterly	>20
Oil and grease (mg/L)	CDBE	Quarterly	>15
Conductivity (µmhos/cm)	CDBE	Monthly	>900
Nutrients			
Nitrate (mg/L)	CDBE	Monthly	>0.2
Nitrite (mg/L)	CDBE	Monthly	>0.2
Ammonia nitrogen (mg/L)	CDBE	Monthly	>0.1
Phosphate as phosphorous (mg/L)	CDBE	Monthly	>0.02
Microbiological			
Total coliform (MPN/0.1L)	CDBE	Quarterly	>5000
Fecal coliform (MPN/0.1L)	CDBE	Quarterly	>400
Metals (µg/L)			
Antimony	CDBE	Semiannually	>1460
Arsenic	CDBE	Semiannually	>20
Beryllium	CDBE	Semiannually	>0.7
Boron	CDBE	Semiannually	>7000
Cadmium	CDBE	Semiannually	>5
Chromium, total	CDBE	Semiannually	>50
Chromium, hexavalent	CDBE	Semiannually	>11

...continued

Table 9-2. Routine water quality management levels for the Central Drainage Basin. (*concluded*)

Parameter	Location	Frequency	Management action levels
Metals (µg/l) (con't)			
Copper	CDBE	Semiannually	>20
Iron	CDBE	Semiannually	>3000
Lead	CDBE	Semiannually	>5.6
Manganese	CDBE	Semiannually	>500
Mercury	CDBE	Semiannually	>1
Nickel	CDBE	Semiannually	>7.1
Selenium	CDBE	Semiannually	>100
Silver	CDBE	Semiannually	>2.3
Thallium	CDBE	Semiannually	>130
Zinc	CDBE	Semiannually	>58
Organics (µg/L)			
Total volatile organic compounds	CDBE	Semiannually	>5
Benzene	CDBE	Semiannually	>0.7
Tetrachloroethene	CDBE	Semiannually	>4
Vinyl chloride	CDBE	Semiannually	>2
Ethylene dibromide	CDBE	Semiannually	>0.02
Total petroleum hydrocarbons	CDBE	Semiannually	>50
Polynuclear aromatic hydrocarbons	CDBE	Semiannually	>15
Base neutral/acid extractable compounds and pesticide	CDBE	Semiannually	>5
Radiological (pCi/L)			
Gross alpha	CDBE	Semiannually	>15
Gross beta	CDBE	Semiannually	>50
Tritium	CDBE	Semiannually	>20,000
Toxicity (%/96-hour survival)			
Fish bioassay	CDBE	Annually	90% survival median, 90 percentile value of not less than 70% survival

Corporation, St. Louis, MO, and by Lockheed Analytical Laboratories, Las Vegas, NV.

Nonradioactive water analyses are performed off site by California Laboratory Services, Rancho Cordova, CA, and by GTEL Environmental Laboratories,

Concord, CA. For details on analytical laboratory procedures, see Chapter 16, Procedures for Laboratory Analysis.

9.4 QUALITY ASSURANCE REQUIREMENTS

Previous sampling of the CDB has not included the use of field blanks. The use of QA spikes and blanks is currently being evaluated. Quality control samples are part of all monitoring activities (see procedure EMP-QA-S). An assessment of data quality objectives (DQOs) will be completed. The assessment will include acceptable reporting limits; number, frequency and acceptance criteria for field duplicates; laboratory QC samples; laboratory control standards; and matrix spikes and matrix spike duplicates.

The Temp/DO meter is calibrated before field sampling use, following instructions on the back of the meter, which is stored in T5426, Room 1022. Calibration results are recorded on the field tracking form.

9.5 PROGRAM IMPLEMENTATION

All routine water sampling is conducted by LLNL technical staff. Chain-of-custody procedures (EMP-QA-SD) are followed when delivering samples to the laboratories for analysis. The following EMS procedures outline the duties and responsibilities involved in sampling the CDB:

- EMP-RO-S, Storm Water Runoff Sampling
- EMP-W-DB Water Sampling - Central Drainage Basin

Surface samples and discharge samples are collected according to EMP-RO-S. A description of sample collection is provided in Section 8.2.4.1 of this EMP.

Sample collection at depth requires a piece of equipment called a Dipper, a specially designed sampling bottle attached to an extendible rod that allows for sample collection at various depths. The Dipper collects a sample and raises it to the surface without mixing water from any other level. The Dipper is decontaminated before each sampling event by washing it entirely with detergent and rinsing thoroughly with deionized water. The top of the Dipper bottle is plugged with a rubber stopper attached by a cable extending the length of the rod. At the opposite end of the rubber stopper, a stainless steel sampling port allows sample water discharge to be turned on and off. The Dipper rod is twisted counter-clockwise to extend the rod, and the bottle is lowered to the desired depth. The rod is then twisted clockwise to secure it from further extension. With the bottle

in position, the cable is pulled to allow the sample bottle to fill with water. The port is closed, and the Dipper is raised. Attached to the bottom of the Dipper bottle, a stainless steel ball valve provides for easy transfer of the collected water to the sample bottles. The Dipper is rinsed with water to be sampled between each sample collection.

Other samples are collected in a variety of containers. These and any associated field handling procedures are described below.

- Samples for volatile organics are collected in a 60-mL clear glass vial. Samples are preserved with HCl (three drops) to a pH of less than 2. Total organic carbon (TOC) samples are pre-acidified with H_2SO_4 to achieve a pH of less than 2. Acid is added before going to the field to collect samples (preacidification eliminates the need to reopen the bottle after sampling, a step that would enable volatiles to escape the sample). Bottles are placed in an ice chest and refrigerated (4°C) upon return from the field.
- Samples for semivolatile organics are collected in a 1,000-mL amber glass bottle, with air space in the bottle minimized. Bottles are placed in an ice chest and refrigerated (4°C) upon return from the field.
- Samples for oil and grease are collected in a 1,000-mL, wide-mouth, amber glass bottle pre-acidified to a pH of less than 2 with H_2SO_4 . Bottles are placed in an ice chest and refrigerated (4°C) upon return from the field.
- Samples for metals are collected in a 1,000-mL nalgene bottle. Samples are filtered in the field. The sample bottle is triple rinsed with sample water before filling. The sample is preserved with HNO_3 to achieve a pH of less than 2.
- Samples for general minerals are collected in a 1000-mL nalgene bottle. The bottle is triple-rinsed with sample water and then filled. No preservation is required.
- Samples for nutrients are collected in a 500-mL nalgene bottle. The sample bottle is triple-rinsed with sample water and then filled. Upon return from the field, 10 drops of H_2SO_4 are added to achieve a pH of less than 2. Bottles are placed in an ice chest and refrigerated (4°C) upon return from the field.

- Samples for chemical oxygen demand (COD) are collected in a 250-mL nalgene bottle pre-acidified to achieve a pH of less than 2 with H_2SO_4 . Bottles are placed in an ice chest and refrigerated (4°C) upon return from the field.
- Samples for coliform bacteria are collected in a 1000-mL sterilized nalgene bottle. Bottles are placed in an ice chest and refrigerated (4°C) upon return from the field.
- Samples for chlorophyll a are collected in a 1000-mL nalgene bottle. Bottles are placed in an ice chest and refrigerated (4°C) upon return from the field.
- Samples for fish toxicity are collected in a 1-gallon nalgene carboy. Bottles are placed in an ice chest and refrigerated (4°C) upon return from the field.
- Samples for tritium are collected in a 250-mL clear glass bottle. The bottle is triple-rinsed with sample water and then filled. No preservation is required.

9.6 PREPARATION AND DISPOSITION OF REPORTS

Since September 1993, results of routine water quality monitoring for management parameters and discharge monitoring have been reported to regulatory agencies in the monthly, quarterly, and annual Ground Water Project reports submitted under the CERCLA ROD for the Livermore site. Monitoring results are also reported in the annual Environmental Report.

9.7 PLANS FOR THE FUTURE

A technical assessment is under way to determine what changes, if any, to existing monitoring may be needed. This technical assessment will continue the evaluation of the number and frequency of sampling collection, the analytes evaluated, sampling locations, Data Quality Objectives and quality control, reporting limits, and management action levels.

10

Ground Water Monitoring

10.1 RATIONALE AND DESIGN CRITERIA

10.1.1 Regulatory Drivers

Ground water surveillance and compliance monitoring at the Livermore site, in the Livermore Valley, and at Site 300 in the Altamont Hills is carried out as required by DOE Orders, by written agreement with the California Environmental Protection Agency (Cal-EPA), and by permits and other requirements from the California Regional Water Quality Control Boards (RWQCBs). This monitoring can be divided into two general types: that carried out under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), and other surveillance monitoring driven mainly by DOE Order 5400.1. Much of the ground water monitoring at the Livermore site and Site 300 is carried out under CERCLA restoration efforts. This monitoring is fully described in documents issued by the Site 300 Restoration Project and Livermore site Ground Water Project (see Appendix A of the site-wide Environmental Report [Gallegos et al. 1994]). This chapter of the Environmental Monitoring Plan focuses on ground water monitoring under DOE Order 5400.1 and various compliance agreements in addition to that carried out under CERCLA. The following brief discussion of the restoration projects is intended to place the CERCLA-related monitoring into context with the surveillance-driven monitoring described in this chapter.

10.1.1.1 *Restoration Program*

Since being placed on the National Priorities List, the ground water cleanup efforts at both the Livermore site and at Site 300 have been structured to conform with specific EPA guidance under CERCLA as amended by the 1986 Superfund Amendments and Reauthorization Act (SARA) and negotiated Federal Facility Agreements. The scope of the environmental restoration effort encompasses numerous activities designed to be performed over several years to investigate, evaluate, and eventually remediate potentially hazardous compounds that may have affected soil and ground water. The substantive requirements of the Resource Conservation and Recovery Act (RCRA) are the Applicable, Relevant and Appropriate Requirements (ARARs) under CERCLA.

10.1.1.2 Surveillance Program

A great deal of monitoring is carried out in association with remediation activities by the restoration program at both the Livermore site and at Site 300. The surveillance monitoring approach is to provide a complement to the restoration program's suite of analytes. The surveillance emphasis discussed in this chapter is to monitor for possible contamination due to present activities and operations (whereas the restoration program monitors those due to past operations), as well as to monitor for constituents including radionuclides that may be at very low levels, below the restoration program's level of concern, but may have been introduced into the ground water by LLNL operations.

A key driver for this surveillance monitoring comes from DOE Order 5400.1, which states that groundwater that is or could be affected by DOE activities shall be monitored to determine and document the effects of operations on groundwater quality and quantity and to demonstrate compliance with DOE requirements and applicable federal, state, and local laws and regulations. DOE Order 5400.1 also calls for a groundwater monitoring plan that identifies all DOE requirements and regulations applicable to groundwater protection and include monitoring strategy. Groundwater monitoring programs under 5400.1 shall be conducted to:

- (1) Obtain data for the purpose of determining baseline conditions of groundwater 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 groundwater pollution or contamination;
- (4) Provide a reporting mechanism for detected groundwater pollution or contamination;
- (5) Identify existing and potential groundwater contamination sources and to maintain surveillance of these sources;
- (6) Provide data upon which decisions can be made concerning land disposal practices and the management and protection of groundwater resources.

Site-specific characteristics determine monitoring needs. Where appropriate, ground water monitoring programs is designed and implemented in accordance

with 40 CFR Part 264, Subpart F, or 40 CFR Part 265, Subpart F. Monitoring for radionuclides is in accordance with DOE orders in the 5400 series dealing with radiation protection of the public and the environment.

In addition to the surveillance monitoring requirements in 5400.1, this chapter includes specific compliance monitoring carried out at Site 300 in response to:

- (1) Rogers/Pacific Corporation (1990), Lawrence Livermore National Laboratory Site 300 Resource Conservation and Recovery Act Closure and Post-Closure Plans—Landfill Pits 1 and 7 (California EPA Id. No. 2890090002, Volumes I and II). This document contains specific requirements for ground water monitoring, including the wells to be monitored at the closed waste management units, the analytes and parameters to be measured, the frequency of sampling, statistical analyses to be used as part of the data analysis, and the contents and frequency of reports. Regulatory requirements that must be met are contained in Title 22 of the California Code of Regulations (CCR) and by 40 CFR Part 265, Subpart G of RCRA; and,
- (2) CVRWQCB (1985, 1993), Order No. 85-188, Waste Discharge Requirements for University of California Lawrence Livermore National Laboratory Site 300 and U.S. Department of Energy, San Joaquin and Alameda Counties, July 9, 1985; and 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, June 25, 1993. These two Waste Discharge Requirements permits (WDRs) contain additional ground water monitoring requirements to those in (1) above to ensure compliance with the specifications and provisions of the orders.

The post-closure monitoring and reporting requirements in (1) above are administered by the California Department of Toxic Substances Control (DTSC), a department of Cal-EPA. Administrative control was given to Cal-EPA by the U.S. Environmental Protection Agency. RCRA is the regulatory driver behind (1) above.

The monitoring and reporting requirements set forth in (2) above are administered by the Central Valley RWQCB, operating under provisions of the California Porter-Cologne Water Quality Control Act. The Porter-Cologne Act is the general

regulatory driver behind (2) above. It requires an RWQCB to evaluate waste discharges and issue a WDR if the waste could adversely affect water quality in California. Title 23 of CCR, Chapter 9, contains the regulations pertaining to the issuance of a WDR by an RWQCB.

10.1.2 Monitoring Objectives

Monitoring objectives are subdivided into surveillance and compliance monitoring objectives. The objectives of surveillance monitoring are the more general of the two, requiring continual assessment of all LLNL activities for their potential to release contaminants to the ground water. Surveillance monitoring encompasses activities at both the Livermore site and at Site 300. Ground water compliance monitoring objectives, on the other hand, are to detect specific constituents of concern at Site 300 that are contained in closed waste management units and in wastewater evaporation ponds.

10.1.2.1 Surveillance Monitoring Objectives

DOE/EH-0173T states in part that DOE 5400.1 and DOE 5400.5 require environmental programs conducted at all DOE sites to determine

- (1) Compliance with all applicable environmental quality standards and public exposure limits; the requirements of DOE 5400.1 and 5400.5.
- (2) The background levels and site contributions of radioactive materials in the environment.
- (5) The long-term buildup and prediction of environmental trends from site-released radioactive material.
- (6) The detection and quantification of unplanned releases.

DOE Order 5400.5 specifically establishes standards and requirements for operations of DOE and their contractors in order to protect members of the public and the environment against undue risk from radiation. Under DOE Order 5400.5, it is also a DOE objective that potential exposures to members of the public be as far below the limits as is reasonably achievable (ALARA), that DOE facilities monitor routine and non-routine releases, and assess doses to members of the public. In addition to providing protection to members of the public, it is DOE's objective to protect the environment from radioactive contamination to the extent practical. This order further states that it is the policy of DOE to protect persons consuming water from a DOE-operated public

drinking water supply at a level equivalent to that provided by the public community drinking water standards.

10.1.2.2 *Compliance Monitoring Objective (Site 300)*

The primary objective of compliance ground water monitoring at Site 300 is to detect and report any potential release of contaminants to the ground water from two RCRA-closed waste management units, or landfills known as Pit 1 and Pit 7, and from two Class II process water impoundments.

10.1.3 **Potential Sources and Contaminants**

10.1.3.1 *Livermore Site*

DOE 5400.1 requirements for a ground water monitoring program include the identification of existing and potential ground water contamination sources and maintaining surveillance of these sources. Operating RCRA Interim Status facilities include two mixed waste storage areas, Buildings 514 and 612; and a paint shop in an industrial area that includes Building 418 and various other industrial facilities (see **Figure 10-1**). Buildings 418, 514, and 612 are all in the southeastern area, which has been identified as being the most likely area to have ground water contamination from both radioactive and other contaminant sources. This is due both to historical as well as ongoing operations. Ground water from this area appears to be flowing off site toward the southwest (*LLNL Ground Water Project 1993 Annual Report* and *LLNL Ground Water Project Quarterly Progress Report, March 1994*). The southwestern corner of the site where Arroyo Seco exits the site (see **Figure 10-1**) is considered the next most critical area for ongoing monitoring, because any contaminants contained in LLNL ground water in this area may be migrating roughly parallel to the arroyo off site. These southeast and southwest areas are, therefore, critical areas for ground water surveillance. The restoration program already monitors them regularly for volatile organic compounds (VOCs) and other selected compounds.

10.1.3.2 *Site 300*

Compliance monitoring for specific potential contaminants at Site 300 is mandated in Waste Discharge Requirements permits and post-RCRA-closure monitoring plans. For the RCRA-closed landfills known as Pits 1 and 7, potential contaminants have been selected for monitoring based on knowledge of materials deposited in the landfills. Two sets of potential contaminants have been

Figure 10-1. Livermore—site locations of surveillance monitoring wells.

adopted for monitoring. One set, approved by the Cal-EPA for post-RCRA-closure monitoring (Rogers/Pacific Corporation 1990), became effective upon official closure of landfill Pits 1 and 7 in February 1993. A second set of analytes comprise a list of "constituents of concern" for which monitoring is specified in permit WDR No. 93-100, adopted June 25, 1993 and administered by the CVRWQCB (CVRWQCB 1993).

For the two lined Class II surface water impoundments, potential ground water contaminants to be monitored are based on possible constituents of process waters discharged to these evaporation ponds. The set of constituents are specified in permit WDR No.85-188, administered by the CVRWQCB (CVRWQCB, 1985).

Surveillance monitoring at Site 300 is concerned with detecting potential contamination of ground water from materials deposited in inactive landfills not covered by WDRs, i.e., Pits 2, 3, 4, 5, 6, 8 and 9, and for monitoring several known contaminant plumes. The plumes resulted from past operating practices. One plume is a composite of tritium-bearing waters that emanated from inactive landfill Pits 3 and 5 and from the Building 850 firing table in the West Firing Area. Several plumes of water containing the solvent trichloroethene (TCE) are monitored. Surveillance monitoring of potential and known contaminants at Site 300 includes an extensive set of elements, isotopes, minerals, priority organic compounds, and general contaminant indicator parameters.

A number of private water supply wells near Site 300 are sampled in order to determine the background levels of naturally occurring constituents in the Altamont Hills area and to demonstrate that past operations at Site 300 have not adversely impacted water supplies beyond the site boundary.

10.1.4 Sample Collection Methods

Detailed written procedures covering ground water sampling methods are contained in the EMS procedure, *Ground Water Sampling*, EMP-GW-S, and in *LLNL Site 300 Environmental Restoration Project Standard Operating Procedures*, UCRL-MA-109115 Rev. 1(LLNL 1993). These procedures describe the methods used by LLNL field technicians to collect ground water samples for analysis from existing wells and piezometers. EMP-GW-S further describes requirements for sample bottles, sample preservation, special sampling techniques, and other analyte-specific information for all analytes routinely sampled by LLNL in ground water. Special sampling techniques apply to different wells depending

on whether they are fitted with submersible pumps, or must be bailed, or if they contain Barcad devices that use pressurized nitrogen gas to extract water samples. Special procedures are also employed to test lysimeters located beneath the process water impoundments for the presence of water. Wells are typically purged of standing water before sampling takes place. Special care is taken to prevent accidental contamination of ground water samples. Technicians wear disposable gloves during the sampling process. Equipment used at different wells, such as pH meter probes and depth-to-water gauges, is cleaned with deionized water after each well is sampled to prevent cross contamination. Field blank and trip blank samples are analyzed to test the cleanliness of the sampling collection methods.

10.2. EXTENT AND FREQUENCY OF MONITORING AND MEASUREMENTS

10.2.1. Criteria for Sampling Location Selection at Livermore Site

10.2.1.1. Criteria

To identify the need to monitor ground water at the Livermore site, LLNL completed a preliminary evaluation of ongoing ground water monitoring associated with remediation. As part of the overall effort, LLNL has drilled and monitored more than 400 wells on and in the vicinity of the Livermore site. Although the primary function of these monitoring wells pertains to environmental restoration monitoring, data from a subset of these wells fulfill the surveillance monitoring mandates of DOE Orders 5400.1 and 5400.5.

The rationale for selection of existing monitoring wells at the Livermore site has evolved as a result of remediation activity findings, and as a result of the potential sources discussed in Section 10.1.3.1. As stated previously, the focus of the surveillance monitoring effort is to monitor the effects of present operations and/or areas of contamination. DOE Order 5400.1 requires LLNL, in part, to obtain data for the purpose of establishing baseline conditions of ground water quality and quantity. Likewise, 40 CFR Part 265, Subpart F ground water monitoring requirements for RCRA Interim Status facilities include locating at least one monitoring well hydraulically upgradient of the facility to be representative of background ground water quality in the uppermost aquifer; this upgradient well is to be monitored quarterly until background water quality is established. The surveillance monitoring program includes two monitoring wells, MW-221 and MW-291 (see **Figure 10-1**), at the hydraulically upgradient

limits of the facility that are being monitored quarterly to establish background for all likely analytes. The monitoring frequencies will be reanalyzed after the first year to determine the optimal sampling frequency.

DOE Order 5400.1 also requires LLNL to provide data to permit the early detection of ground water pollution or contamination. 40 CFR Part 265, Subpart F, requirements for RCRA Interim Status facilities include locating at least three monitoring wells hydraulically downgradient of each waste management area. Three downgradient wells are to be monitored for each of the two areas (see **Figure 10-1**), southeast and southwest, previously identified as having the greatest probability of possibly undetected analytes (radionuclides, pesticides, semivolatiles, etc.) migrating off site. These monitoring wells are to be MW-112, MW-256, and GSW-444 for the area downgradient of Buildings 514 and 612. These wells will continue to be analyzed for metals, pesticides, semivolatiles, and gamma-emitting isotopes such as Cesium 137, Potassium 40, as well as Uranium and all of its radioactive daughters.

Four wells near the southwestern boundary—MW-143, -262, 457, and MW-513—are to be monitored for the radionuclides mentioned above and for selected trace metals that were initially monitored using methods with relatively high detection limits such as antimony and thallium. Monitoring will continue for all previously detected metals.

In addition, tritium measurements are performed on samples from 22 ground water wells in the Livermore Valley (**Figure 10-2**), at distances of 4 to 16 kilometers hydraulically downgradient from LLNL. This is part of a study that was begun in 1977 to determine the extent of tritium migration into Valley ground water. The number of wells appropriate for investigating tritium migration will be determined during the technical assessment.

Rain and storm water runoff in the Livermore Valley recharge local aquifers. The rain and runoff contain small amounts of tritium from natural sources from past atmospheric tests of nuclear weapons and atmospheric emissions from LLNL and Sandia National Laboratories, California (SNL/CA). Also, a small portion of treated effluent from the City of Livermore Water Reclamation Plant (LWRP) is used to irrigate nearby municipal land. This effluent may contain low levels of tritium from natural sources and from permitted operational releases to the sanitary sewer system by LLNL and SNL/CA (total radionuclides in liquid effluents are limited to 1 curie per year).

The Livermore Valley floor slopes westward, directing surface stream flow and ground water flow generally to the west. Annual measurements have been made from the above-mentioned monitoring wells and drinking water wells to determine the extent of tritium migration into the ground water from the LWRP irrigation water, from tritium washed out of the atmosphere by rain, and from tritium in storm water runoff through the arroyos that recharge the local aquifers. (See also *Lawrence Livermore National Laboratory for Environmental Report 1993*, Gallegos et al. 1994)

10.2.1.2. Geology and Hydrogeology. The Livermore Valley is bordered in the east by the Altamont Hills, where Miocene Neroly and Cierbo Formations and rocks of the Late Cretaceous Great Valley sequence are exposed. Within the valley, lacustrine and fluvial valley fill deposits occur to depths in excess of 1 kilometer.

The oldest of these is the Lower Livermore Formation of late Tertiary age—a hard, locally lithified, predominantly fine-grained sedimentary sequence that is exposed in the hills south of the Livermore Valley. This formation is encountered beneath the Livermore site at depths ranging from 7 meters in the east to 119 meters in the west. Above the Lower Livermore Formation are the heterogeneous, unconsolidated alluvial sediments of the Pleistocene Upper Livermore Formation, which consist of complexly interbedded layers of poorly sorted clay, silt, sand, and gravel. The late Pleistocene and Holocene alluvial deposits that form the uppermost sequence of valley sediments are virtually identical to the Upper Livermore Formation.

The Livermore Formation (and overlying alluvial deposits) contain the aquifers of the Livermore Valley ground water basin. This 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. Zone 7 conducts artificial recharge as needed to maintain ground water levels. This recharge is done by releasing water from Lake Del Valle or from the South Bay Aqueduct into arroyo channels in the eastern portion of the valley. Ground water flow in the valley generally moves toward the central east-west axis of the valley and then westward through the central basin. Ground water flow in the basin is generally assumed to be primarily horizontal, although a significant vertical component probably exists in fringe areas and under localized sources of recharge.

Beneath the Livermore site, the depth to the water table varies from about 43 meters to 8 meters. At the eastern edge of the Livermore site, ground water gradients (change in elevation per unit of horizontal distance) 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 meters/day. This, in combination with the observed water-table gradients, yields ground water velocity estimates of 5 to 90 meters/year. The range in these values reflects the heterogeneity typical of the more permeable of the alluvial sediments that underlie the area.

10.2.2 Criteria for Sampling Location Selection, Site 300

10.2.2.1 Criteria

Many ground water monitoring wells within Site 300, including both compliance and surveillance wells, are optimally located to detect any release of constituents of concern from a number of inactive, closed landfills (Pits 1, 2, 3, 4, 5, 6, 7, 8, 9). Ground water flow directions beneath these landfills are known from area-wide measurements of water table elevations. For comparison purposes, monitoring wells are located both upstream and downstream from the landfills. They are typically screened in the shallowest water-bearing zone beneath the landfills in order to provide the earliest warning of a potentially contaminated release to the ground water. Other wells within the site are situated along surface water courses, such as in the Elk Ravine drainage area, where contaminant plumes caused by past operations have been detected and their extents determined through exhaustive remedial investigation studies. These wells are optimally located to monitor the spread and eventual cleanup of the contaminant plumes. LLNL believes that all areas of ground water contamination due to past operations at Site 300 have been located and are described in the *Final Site-Wide Remedial Investigation Report* (SWRI; Webster-Scholten 1994). Site 300 monitoring wells, lysimeters, and springs can be located on the Site 300 large-scale map drawing 93009-00, dated 10/28/93, produced by LLNL's Environmental Restoration Division.

10.2.2.2 Geology and Hydrogeology

Water-bearing zones beneath Site 300 are located mostly in the Tertiary Neroly Formation and most of the monitoring wells are screened in that formation. Site 300 is underlain primarily by Tertiary sedimentary rocks of Miocene and Pliocene ages. Two stratigraphic units contain water-bearing zones of hydrogeologic significance: the late Tertiary nonmarine sequence, which consists of poorly sorted sandstones, siltstones, and claystones with irregularly distributed channel fills of silty and gravelly sandstones; and the Miocene Neroly Formation, which consists of interbedded sandstones, siltstones, and claystones containing considerable amounts of volcanic ash and some tuff. Two zones in the Neroly Formation are characterized by relatively thick and persistent sandstones that are potential aquifers; these are informally named the Neroly upper blue sandstone and the Neroly lower blue sandstone. The bedrock is overlain *locally* by older alluvial and terrace deposits beneath Quaternary colluvium, alluvium, valley fill, and stream deposits. Along the northern and southern borders of the

site, older beds crop out. These include the marine Cierbo Formation, locally the Eocene Tesla Formation, and the Cretaceous Panoche Formation, part of the Great Valley Sequence.

Local perched aquifers containing small amounts of water occur in some of the channel fill deposits in the nonmarine Tertiary sequence. Perched aquifers are defined as unconfined water separated from an underlying main body of water by an unsaturated perching aquitard; normally they are highly localized and of small extent. Because water quality is poor and yields are low, these perched water-bearing zones do not meet the State of California criteria for aquifers that are potential water supplies.

Small perched aquifers were identified beneath Building 834 in the southeastern part of Site 300; in the vicinity of Building 815 in the south-central part of the site; and between Pit 7 and Elk Ravine in the northern part of Site 300. The perched spring in the south part of the HE Process Area (Spring 5) is an outcrop of the perched aquifer of Building 815. Other small perched springs and isolated perched aquifers occur.

Regional aquifers are found in the sandstones of the Neroly formation. A water-table aquifer occurs in the Neroly upper blue sandstone beneath parts of the site; the aquifer is confined in the southern part of Site 300. Lower in the stratigraphic sequence, in the Neroly lower blue sandstone, the aquifers usually are confined, with some artesian head, except in the northwest, where the water is unconfined. Wells completed in the unconfined water table aquifer tend to produce less water than wells completed in the confined aquifers. These shallower aquifers are not used to produce drinking and process water. A thick Neroly sandstone, stratigraphically near the base of the formation, contains confined water. Wells 18 and 20 are completed in this aquifer. Well 20 supplies drinking and process water. Well 18 is a backup supply well. The wells are located in the western part of the General Services Area.

Interstitial permeability is generally low in the Neroly sandstones. However, these beds usually are strongly fractured, and much of the water flowing to wells probably moves through these fractures. Hydraulic tests indicate that hydraulic conductivity varies widely, from the range of 1×10^{-3} cm/s in the better wells, approximately 1×10^{-4} cm/s in average wells, to a low in the range of 1×10^{-6} cm/s in the worst producers.

The aquifer in the Neroly lower blue sandstone is under water table conditions similar to those in the northwestern part of the site; the aquifer becomes confined to the southeast. The hydraulic head increases progressively in that direction. In the General Services Area, some wells completed in this aquifer flow spontaneously.

Generally, the water table, also known as a piezometric surface, is controlled by the structural configuration of the water-bearing formations. The direction of flow is to the northeast in the northern part of the site, becoming generally southerly to southeasterly in the southern part of the site. A complete description of the stratigraphy and hydrogeologic conditions at Site 300 can be found in the SWRI report (Webster-Scholten 1994).

10.2.2.3 *Compliance Monitoring.*

Compliance monitoring at Site 300 involves analyses of water samples drawn from 23 wells associated with two RCRA-closed landfills and two active Class II process water impoundments. Figure 10-3 shows the test site and locates the closed landfills (pits), the two process water surface impoundments, and all of the on-site and off-site surveillance wells. A brief description of these areas and associated wells follows.

Figure 10-4 shows the locations of Pit 1, the monitoring wells, an adjacent inactive landfill identified as Pit 2, and the Advanced Test Accelerator (ATA). Pit 1 lies in the upper part of the Elk Ravine drainage area at an elevation of 330 meters above sea level. Although the climate at Site 300 is semi-arid, intense rainfall does occur there. In order to combat erosion caused by intense rainfall, runoff from the pit cap and surrounding area is collected in a concrete diversion channel that encircles the pit. The outfall is at the southwest corner of Pit 1 where discharged runoff flows to Elk Ravine. Subsurface water flow beneath Pit 1 is east-northeasterly and generally follows the dip of the underlying sedimentary rocks. Compliance monitoring wells K1-01C and K1-07 are hydrologically upgradient from Pit 1; K1-02B, K1-03, K1-04, and K1-05 are downgradient; and K1-08 and K1-09 are cross-gradient. Pit 2 is hydrologically upgradient from Pit 1 with respect to subsurface water flow, but is downgradient from Pit 1 with respect to rain runoff. The ATA is upgradient from Pit 1 monitoring wells K1-05, K1-08, and K1-09.

Figure 10-3. Site 300 and vicinity surveillance wells and pits (Pit 6 and Pit 9 wells shown elsewhere).

The Pit 1 monitoring wells are completed near or at the contact between the Tertiary Neroly Formation lower blue sandstone member and the underlying Mid-Miocene Cierbo Formation consisting of claystones and siltstones. The Tertiary Neroly and Cierbo sedimentary rock formations are the main water-bearing strata beneath the test site.

Figure 10-4. Pit 1 compliance wells and Pit 2 surveillance wells.

Nine wells monitor the three inactive landfills and the one closed RCRA landfill called the Pit 7 Complex (which consists of Pits 3, 4, 5, and 7; Figure 10-5). The complex of closed landfills lies in the uppermost reaches of the Elk Ravine drainage area at an elevation of 425 meters above sea level. To combat erosion, rain runoff from the pit complex area is collected in several concrete channels. Pit 7 is nearly encircled by one concrete channel that collects rain runoff from the pit cap and directs it southeasterly into the Elk Ravine drainage system. An additional concrete channel lies to the west of Pit 7. Runoff entering this northerly directed diversion channel is sheet flow that develops on a hill slope west of Pit 7. Subsurface water can flow in two directions through this area. With sufficient seasonal rainfall, a shallow, unconfined, southeastward flow can develop that follows the topographic slope in the unconsolidated surficial

Quaternary alluvial deposits. The predominant ground water flow, however, is east-northeasterly within the underlying Tertiary sedimentary rocks of the Neroly and Cierbo formations that dip east-northeast in this area. With respect to the predominant flow direction, well K7-06 is upgradient, wells K7-09 and K7-10 are cross-gradient, and wells K7-01, K7-03, NC7-25, NC7-26, NC7-47, and NC7-48 are downgradient. Wells K7-01, K7-10, and NC7-26 are completed in the lower blue sandstone of the Tertiary Neroly Formation that lies directly beneath the complex. The remaining wells are completed at the base of, or below, the Neroly and within the claystone and sandstone Mid-Miocene Cierbo Formation.

Figure 10-6 shows the portion of the High Explosives (HE) Process Area that includes Building 817 (B-817), the two process water impoundments, and the five compliance monitoring wells. Compliance monitoring of the two impoundments to detect any release of process water to ground is specified in permit WDR 88-185 issued by the Central Valley Regional Water Quality Control Board (CVRWQCB 1988). Not shown in Figure 10-6 are the locations of six lysimeters that are installed between two impermeable liners beneath the process water impoundments. Three operational lysimeters are positioned beneath each of the two impoundments. Their primary purpose is leak detection. In addition to lysimeters, compliance monitoring wells W-817-01, -02, -03, and -04 are completed in the underlying Neroly upper blue sandstone, a water-bearing formation that locally contains trichloroethene (TCE). The fifth compliance monitoring well, W-817-03A, is completed at shallow depth in a non-marine formation, consisting of unconsolidated sediments and sedimentary rocks, that locally overlies the Neroly Formation. The overlying formation contains a perched water-bearing zone that is very restricted laterally and vertically and contains TCE. A natural spring (Spring 5) coincides with monitoring well W-817-03A. The direction of water flow in both

Figure 10-6. HE Process Area compliance wells.

formations is approximately south-southeasterly. Well W-817-01 is an upgradient well with respect to the impoundments. Wells W-817-02, -03, -03A and -04 are downgradient wells.

10.2.2.4 Surveillance Monitoring

Thirty-five wells comprise the ground water surveillance network at Site 300. Further technical assessment of the surveillance network is necessary in light of recent findings. The assessment will determine whether the number of wells is appropriate and if the correct wells are being monitored. Additionally, the frequency of sampling and the list of constituents analyzed for each are being assessed. Primary inputs to the technical assessment are the findings of the SWRI report (Webster-Scholten 1994) and the historical data from all Site 300 monitoring wells as contained in the "Monitor" database.

Twenty-three surveillance wells are located on Site 300 and twelve wells are located off-site. Eleven off-site wells are near to the site boundaries. Methods of sampling are the same for both surveillance and compliance monitoring wells, but the frequency of sampling and the analytes measured may differ. Three of the twelve off-site surveillance wells are located next to Site 300 on the north where the Altamont Hills slope down to the San Joaquin Valley. These are wells MUL1, MUL2, and VIE1. Eight off-site surveillance wells are located adjacent to Site 300 on the south in the Corral Hollow Creek drainage area. These are wells STN, CARNRW1, CARNRW2, GALLO1, W35A-04, CON1, CON2, and CDF1.

The most distant well, VIE2, is located in the Altamont Hills about 6 kilometers west of the site (Figure 10-3).

Twelve of the twenty-three on-site surveillance wells are clustered about inactive landfill pits. Six wells monitor Pit 6 (Figure 10-7). Four wells monitor Pit 9 (Figure 10-8). Three multiple completion wells monitor Pit 2 (Figure 10-4). Nine

of the ten remaining surveillance wells and one natural spring (812CRK, also known as Spring 6) are strewn along the system of fault-marked ravines and valleys that comprise the Elk Ravine drainage area (**Figure 10-3**). Well 20 is a production well that provides potable water to Site 300 (**Figure 10-3**). The wells are described below.

The inactive Pit 2 landfill lies in the upper portion of Elk Ravine at 320 meters above sea level (**Figure 10-4**). Surface runoff from the pit area is southerly into Elk Ravine. Subsurface water flow beneath the pit is east-northeasterly following the dip of the underlying Neroly and Cierbo sedimentary rocks. Monitoring well K1-01, shown in **Figure 10-4**, is completed at three separate depth intervals in the claystone and sandstone Mid-Miocene Cierbo Formation. This multiple completion well contains three Barcad sampling devices. Each Barcad samples a discrete water-bearing zone within the Cierbo Formation. The deepest of the three zones is sampled by Barcad K1-01A, the intermediate zone by Barcad K1-01B, and the uppermost zone by Barcad K1-01C. Barcad K1-01C is an upgradient monitoring point for Pit 1. Surveillance monitoring wells K2-01 and K2-02 are hydrologically cross-gradient from Pit 2. These are also multiple completion wells and are fitted with Barcad sampling devices. Barcads K2-01A, K2-02A, and K2-02B are completed in the Cierbo Formation. Barcad K2-01B is completed in the lower blue sandstone of the Tertiary Neroly Formation that overlies the Cierbo Formation.

Inactive landfill Pit 9 is centrally located within Site 300 at an elevation of 340 meters above sea level. Surface runoff from Pit 9 is northeastward into Elk Ravine. Subsurface ground water flow is also east-northeasterly in the lower blue sandstone of the Neroly Formation. Surveillance monitoring well K9-02 is hydrologically upgradient from Pit 9. Wells K9-01, K9-03, and K9-04 are downgradient. Well K9-02 is completed in the Neroly lower blue sandstone at its contact with the underlying Cierbo Formation. Wells K9-01, K9-03, and K9-04 are completed in the Cierbo Formation, just below its contact with the Neroly Formation.

The Elk Ravine drainage area includes most of northern Site 300, the area between the drainage divides shown on **Figure 10-3**. This semi-arid area collects rare surface runoff from inactive landfill Pits 1, 2, 3, 4, 5, 7, 8, and 9 to form an ephemeral, southeasterly flowing stream. Surface runoff from the Pit 7 Complex area flows southeastward to Doall Road where it is deflected northeastward into Doall Ravine by a colluvial landslide deposit. At the northeastern end of Doall Ravine, the runoff combines with channeled runoff from the Advanced Test

Accelerator area. From this confluence point ephemeral streams flow 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 kilometers to its confluence with Corral Hollow Creek. Except for Doall Ravine, the runoff channels follow faults that can provide conduits to the underlying water-bearing Neroly strata. For this reason, ground waters from wells that lie within this drainage network are monitored. The monitored wells are (from highest to lowest elevation within the drainage area) K7-07, NC7-61, NC7-69, K2-04D, K2-04S, K2-01C, Well 01, NC2-11D, 812CRK (Spring 6), and NC2-07. Individual wells are discussed below.

Well K7-07 is a shallow well, completed in the upper Neroly lower blue sandstone and the overlying Quaternary alluvium. The well is often dry. Wells NC7-61 and NC7-69 sample separate water-bearing zones beneath the upper reach of Doall Ravine, downstream from well K7-07. Well NC7-61 is completed in the shallower Neroly Formation lower blue sandstone and Well NC7-69 is completed in the deeper Cierbo Formation. Well K2-04D, well K2-04S, and Barcad K2-01C are located near the join between Elk Ravine and Doall Ravine. They are all completed in the upper Neroly Formation lower blue sandstone. Well 01 and well NC2-11D are located in Elk Ravine below its join with Doall Ravine (**Figure 10-3**). Well 01, formerly a drinking water production well, is completed in the Neroly Formation lower blue sandstone; it is scheduled for closure and will be replaced in the network by nearby monitoring well NC2-12D. Well NC2-11D is completed at the boundary between the Cierbo and the overlying Neroly formations. Well NC2-07 is the farthest downstream on-site well in the Elk Ravine drainage area. It is completed in the Neroly Formation lower blue sandstone.

The inactive Pit 6 landfill is positioned along the southern boundary of Site 300 at an elevation of 210 meters above sea level (**Figure 10-3**). It lies in Quaternary terrace deposits above and north of the Corral Hollow Creek flood plain. The Tertiary Neroly Formation sedimentary rocks underlie the terrace deposits. Surface runoff from the pit area is southward to Corral Hollow Creek. Ground water flow beneath the pit is also southward, following the south-dipping sedimentary rocks of the Neroly Formation. However, the direction of the subsurface flow changes from south to southeast beneath the southern margin of the landfill where the Carnegie Fault has brought vertically dipping strata on the south into contact with gently dipping strata on the north. A deposit of terrace gravel fills a south-easterly trending trough within the vertically dipping strata

immediately south of the landfill and acts as a channel for the ground water after it passes beneath Pit 6.

Six wells comprise the surveillance monitoring network at closed landfill Pit 6 (Figure 10-7). Well K6-03 is hydrologically upgradient from Pit 6 and is completed in the gently southward dipping Tertiary Neroly sedimentary rocks. Wells K6-04, EP6-07, and EP6-08 are hydrologically cross-gradient from Pit 6 and are also completed in the south-dipping Neroly sedimentary rocks. The completion interval of well K6-04 extends upwards into the Quaternary terrace deposits. Wells EP6-09 and K6-01 are hydrologically downgradient from Pit 6 and are completed in the vertically dipping Tertiary sedimentary rocks.

Well 20 supplied most of the potable water to Site 300 in recent years. It is completed in the Tertiary Neroly Formation upper blue sandstone. Well 20 is intended to become a standby production well in the near future when water from reservoirs in the Sierra mountains becomes available at Site 300. Complete geologic and hydrogeologic information about Well 20 is contained in the SWRI report (Webster-Scholten 1994).

Twelve off-site potable water supply wells near Site 300 are monitored as part of the Site 300 surveillance monitoring program. Four wells—MUL1, MUL2, VIE1, and VIE2—lie to the north of Site 300. Wells CARNRW1, CARNRW2, CDF1, CON1, CON2, GALLO1 STN, and W-35A-04 are located to the south of the test site (Figure 10-3).

10.2.2 Quality Assurance/Quality Control Sampling

Quality assurance/quality control (QA/QC) samples including spikes, duplicates, field blanks, and trip blanks are collected according to procedure EMP-QA-S. QA sampling requirements are specified on the field tracking forms (FTFs) for each sampling event.

A duplicate sample is collected from a randomly chosen well for each of the monitoring networks. Identical analyses are performed on the routine and duplicate samples, and the results are compared. If substantial differences exist between the routine and duplicate sample results, for example, if the three-sigma error limits do not overlap, the discrepancies are investigated by the responsible analyst and the analytical laboratory to determine if re-analysis is required.

A field blank is prepared for each of the monitoring networks, which uses hydrogen-purged deionized water for analyses for organic compounds and High Pressure Liquid Chromatography (HPLC)-grade water for all other required analyses. Field blanks, prepared at well locations chosen at random, are analyzed for the identical parameters as those outlined for each network's routine wells. Field blank data are reviewed by the responsible analyst to ensure that contamination has not occurred as a result of field handling procedures or laboratory processing.

Three equipment blanks are prepared and analyzed quarterly to provide a routine assessment of equipment decontamination and maintenance practices. Two equipment blanks are prepared with hydrogen-purged deionized water, transferred through bailers (used for purging and sampling of wells), and analyzed for volatile organic compounds. The remaining equipment blank is prepared from HPLC-grade water, pumped through a portable metals-filtration unit, and analyzed for various metals.

All hardcopy data from laboratory analyses are received together with the laboratory's QC data, including control standards, matrix QC precision (duplicates and duplicate spikes), matrix QC accuracy (spikes), method blanks, and reporting limits. These laboratory QC data are reviewed and evaluated by the responsible analyst.

10.2.3 Sampling Frequency

10.2.3.1 Livermore Site

The ground water surveillance network of nine wells established for the Livermore site is sampled quarterly for the two upgradient wells and semiannually for the seven downgradient surveillance wells.

Wells used to characterize ground water quality adjacent to the Livermore site for the Ground Water Project are sampled annually, biannually, or quarterly, based on criteria in the CERCLA Work Plan.

All ground water sampling at and adjacent to the Livermore site is conducted by LLNL technical staff or contract staff from Weiss Associates.

Samples from the twenty two wells (associated with the tritium study) in the Livermore Valley and adjacent to the LWRP are collected annually in bottles provided by LLNL by personnel at each of the various facilities:

- California Water Service (five wells)
- City of Livermore (ten wells)
- City of Pleasanton (three wells)
- Zone 7 (four wells).

10.2.3.2 Site 300

Sampling frequencies of Site 300 monitoring wells are determined in monitoring plans included in WDRs and CERCLA closure plans. These are generally the higher frequencies and are associated with required statistical analyses.

Frequencies include four per quarter (four independent samples taken one week apart), three per quarter (monthly), four per year (quarterly), two per year (semiannually), and one per year (annually). No sampling is conducted at a frequency of less than once per year.

Compliance monitoring sampling frequencies are fixed in the monitoring requirements sections of the two WDR permits (CVRWQCVB 1985 and 1993) and the Closure and Post-Closure Plan for Landfill Pits 1 and 7 (Rogers/Pacific Corp., 1990). Sampling frequencies for compliance monitoring are planned to meet quarterly and annual reporting requirements and to satisfy the mandated statistical methodology. For example, quarterly analysis of variance (ANOVA) comparisons of general contaminant indicator parameters and certain constituents of concern require a minimum of four independent measurements (samples taken at least one week apart) per quarter.

For surveillance monitoring purposes, the number and locations of sampling wells, the constituents to be monitored, and the frequency of sampling are prerogatives of LLNL. This allows LLNL to devise a comprehensive, cost-effective monitoring program. Since the flow rates of ground water beneath Site 300 rarely exceed 30 meters per year, the quarterly, semiannual, and annual sampling frequencies are deemed appropriate for data trending and are employed to meet annual reporting requirements. See the discussion of Site 300 analytes, Section 10.2.4.2, below for more information regarding frequencies of sampling.

10.2.4 Analytes

10.2.4.1 Livermore Site

The choices of analytes as subjects for the surveillance sampling program is determined mostly by the specific questions that need to be answered.

The rationale for original selection of analytes is outlined in the revised LLNL Ground Water Project Sampling Plan (Godwin 1987; Rice 1984; also see Figure 2.7-1 in Thorpe et al. 1990). This plan has since been modified so that all wells are now analyzed for general minerals and inorganic materials. In addition, wells selected on the basis of their proximity to possible radionuclide releases are analyzed for gross alpha, gross beta, gamma spectrum, tritium, and sometimes for cesium-137, potassium-40, radium-226, thorium-228 and -232, and uranium-234, -235, and -238).

Some additional ground water surveillance monitoring currently is under way in the area around the Livermore site. Tritium samples are taken from monitoring wells clustered near the Livermore Water Reclamation Plant (LWRP) and in other locations in the Livermore Valley (see Figure 10-2).

Table 10-1 delineates the surveillance sampling and analysis schedule for 1995 at the Livermore site. (Note that the four wells at the southwestern corner of the site are to be sampled and analyzed for radionuclides and for selected trace metals only by EMS.)

10.2.4.2 Site 300 Analytes

Pit 1 ground water samples are analyzed for constituents that fulfill the monitoring requirements of both WDR No. 93-100 and the Closure and Post-Closure Plan for Landfills Pits 1 and 7. Measurements are performed for ground water temperature; water table elevation; total dissolved solids (TDS); specific conductance; pH; metals; the high-explosives compounds cyclotetramethylene-tetranitramine (HMX), cyclo-1,3,5-trimethylene-2,4,6-trinitramine (RDX), and trinitrotoluene (TNT); general minerals; total organic carbon (TOC); total organic halogens (TOX); radioactivity (gross alpha and gross beta); the radioisotopes of hydrogen (tritium), uranium (234, 235, and 238), and thorium (228 and 232); chlorinated herbicides and pesticides (EPA Methods 615 and 608); priority organic compounds (EPA Method 624); and extractable organic compounds (EPA Method 625).

Pit 7 ground water samples are also analyzed for constituents that fulfill the requirements of WDR No. 93-100 and the Closure and Post-Closure Plan for Landfills Pits 1 and 7. Measurements are performed for ground water temperature; water table elevation; TDS; specific conductance; pH; metals; the radioisotopes of hydrogen (tritium), radium (226), uranium (234, 235, and 238)

Table 10-1. Livermore Site Ground Water Surveillance Sampling Schedule.

Analytes	EPA Methods	Sampling Schedule
Beryllium	210.2	Quarterly*/Semiannually
Chromium (VI)	218.4	Quarterly*/Semiannually
Mercury	245.2	Quarterly*/Semiannually
Metals by GFAA	204.2, 206.2, 213.2, 220.2, 239.2, 246.2, 249.2, 270.2, 272.2, 279.2	Quarterly*/Semiannually
Metals by ICP	200.7	Quarterly*/Semiannually
General Minerals	150.1, 160.1, 200.7, 300.0, 310.2	Yearly
Total Cyanide	9010	Quarterly*/Semiannually
Ethylene Dibromide	504	Quarterly*/Semiannually
Purgeable Organics	524.2	Quarterly*/Semiannually
Semivolatiles, including PNAs	625	Semiannually
Chlorinated Pesticides & Herbicides	608/615	Semiannually
Phenolics	420.1	Semiannually
COD	410.4	Quarterly*/Yearly
TOC	415.1, 9060	Quarterly*/Yearly
TOX	9020	Quarterly*/Yearly
Oil & Grease	413.1	Semiannually
TPH Gas	mod-8015	Semiannually
Radiological Parameters	Various RAS Methods	Quarterly*/Semiannually

* Quarterly analyses of Background Monitoring Wells for First Year Only.

and thorium (228 and 232); the high explosives compounds HMX, RDX, and TNT; and volatile organic compounds (EPA Method 601).

As required by the WDR No. 85-188 permit, three previously installed lysimeters beneath each of the two Class II process-water surface impoundments in the B-817 HE Process Area are tested quarterly for the presence of water. If water is detected, a sample is taken and analyzed for pH, specific conductance, and the high-explosives compounds HMX and RDX. (To date, September 1994, no water has been detected in the lysimeters, confirming that the impoundment liners have not leaked). In addition to testing the lysimeters, ground water samples are collected quarterly from the five compliance monitoring wells in the B-817 HE Process Area. Samples from the four deeper wells completed in the Neroly upper blue sandstone formation are analyzed for metals, minerals, TOC, TOX, pH,

specific conductance, high explosives compounds (RDX, HMX, and TNT), volatile organic compounds, and tritium. Samples from the shallow well W-817-03A are analyzed for volatile organic compounds, high-explosives compounds, and tritium.

Samples from the Barcad-fitted wells near Pit 2 are taken quarterly and are analyzed for various metals; radioactivity (gross alpha and gross beta); and the radioisotopes tritium, radium-226, and uranium-234, -235, and -238.

Pit 9 surveillance monitoring wells are sampled and analyzed annually for general contaminant indicator parameters, general minerals, metals, radioactivity, radioisotopes, and a wide range of organic compounds including pesticides and herbicides.

Within the Elk Ravine drainage area, ground water samples from all wells are analyzed for various metals, including beryllium (except NC2-07), radioactivity (gross alpha, gross beta), tritium, and volatile organic compounds (EPA Method 601). Additionally, samples from wells K7-07, NC7-61, and NC7-69 are analyzed for uranium isotopes 234, 235, and 238; samples from wells K2-04D, K2-04S K2-01C are analyzed for nitrogen compounds; and samples from well K7-07 are additionally analyzed for barium, vanadium, and priority organic compounds (EPA Method 624).

Ground water samples from the Pit 6 surveillance wells are taken semiannually and analyzed for metals; general minerals; organic compounds, including priority organic compounds (EPA Method 601), herbicides (EPA Method 615), and pesticides (EPA Method 608); the general contamination indicator parameters pH, specific conductivity, TOC, and TOX; radioactivity (gross alpha, gross beta); and radioisotopes of hydrogen (tritium), radium (226), and uranium (234, 235, and 238).

Quarterly samples taken from Well 20 are analyzed for the metals beryllium, chromium, copper, and lead; for gross alpha and gross beta radioactivity; and for tritium activity. Monthly well samples are also taken and are analyzed for priority organic compounds using either EPA Method 502.2, or 524.2.

Six off-site water supply wells are sampled quarterly. Of these, CARNRW1 and CON2 are tested for priority organic compounds only (EPA Method 601), while CARNRW2, CDF1, CON1, and GALLO1 are tested for a large suite of inorganic chemicals as well as organic compounds. The remaining six wells—MUL1,

MUL2, STN, VIE1, VIE2, and W-35A-04—are tested annually for the same inorganic and organic compounds as the wells listed above. All wells, except CARNRW1 and CON2, are tested at least annually for explosive compounds (HMX, RDX, and TNT), radioactivity (gross alpha, gross beta), and tritium activity.

10.3 PROCEDURES FOR LABORATORY ANALYSIS

Tritium analyses are performed on site by the LLNL Radiation Analytical Sciences (RAS) Section, Environmental Monitoring and Analysis Division. All other radioactivity and radioisotope measurements are performed off site by IT Corporation, St. Louis, MO, and by Lockheed Analytical Laboratories, Las Vegas, NV. (LLNL's RAS analytical laboratory will be utilized for some measurements of individual radiosotopes in addition to tritium at the Livermore site.)

Nonradioactive water analyses are performed off site by California Laboratory Services (CLS), Rancho Cordova, CA, and by GTEL Environmental Laboratories, Concord, CA.

For details on analytical laboratory procedures, see Chapter 16, Procedures for Laboratory Analysis.

10.3.1 Analytical Methods

Table 10-2 lists the potential constituents of concern in ground water, the EPA analytical method or standard analytical method used by LLNL laboratories and contract laboratories to measure each constituent, and a typical reporting detection limit expected for each method. Reporting detection limits for any constituent can vary depending upon the presence of interfering substances dissolved in the ground water. For a method to meet data quality objectives (DQOs), the reporting detection limit must be at or below any associated maximum contaminant limits (MCLs) for the constituent. Analytical laboratories must be certified by the State of California in order to meet LLNL's QA and compliance monitoring requirements.

Table 10-3 lists the detectable organic compounds and reporting detection limits for each of the EPA Standard Methods that are utilized by EMS to analyze ground water for organic constituents of concern. Reporting detection limits depend on the method used as well as the presence or absence of interfering compounds. Methods are selected to give reporting detection limits at or below federal EPA or California MCLs for a particular compound.

Table 10-2. Methods and detection limits for constituents of concern in ground water.

Constituent of Concern	Analytical Method	Detection Limit
Metals and Minerals (mg/L)		
All Alkalinities	EPA 310.1	1.
Aluminum	EPA 200.7	0.05
Ammonia Nitrogen (as N)	EPA 350.3	0.03
Antimony	EPA 6010	0.005
Arsenic	EPA 206.2	0.002
Barium	EPA 200.7	0.05
Beryllium	EPA 210.2	0.0002
Cadmium	EPA 213.2	0.0005
Calcium	EPA 200.7	0.1
Chloride	EPA 325.3	1.
Chromium (total)	EPA 218.2	0.005
Chromium VI	EPA 218.4	0.01
Cobalt	EPA 6010	0.05
Copper	EPA 200.7	0.05
Fluoride	EPA 340.2	0.1
Hardness, Total (as CaCO ₃)	EPA 2320B	1.
Iron	EPA 236.1	0.1
Lead	EPA 239.2	0.002
Magnesium	EPA 200.7	0.1
Manganese	EPA 200.7	0.005
Mercury	EPA 245.1	0.0002
Molybdenum	EPA 6010	0.05
Nickel	EPA 249.2	0.005
Nitrate plus Nitrite (as N)	EPA 353.2	0.1
Potassium	EPA 200.7	1.
Selenium	EPA 270.2	0.002
Silver	EPA 272.2	0.0005
Sodium	EPA 200.7	1.
Sulfate	EPA 375.4	2.
Surfactants	EPA 425.1	0.05
Thallium	EPA 279.2	0.001
Total dissolved solids (TDS)	EPA 160.1	10.
Total Kjeldahl Nitrogen	EPA 351.3	0.5

...continued

Table 10-2. Methods and detection limits for constituents of concern in ground water (concluded).

Constituent of Concern	Analytical Method	Detection Limit
Total suspended solids (TSS) (mg/L)	EPA 160.2	1.
Vanadium (mg/L)	EPA 286.1	0.2
Zinc (mg/L)	EPA 200.7	0.02
Phenolics (mg/L)		
Phenolics (incl. low-level)	EPA 420.1	0.005
General Indicator Parameters		
pH, Units	EPA 150.1	
Specific Conductance, μ mhos/cm	EPA 120.1	1.
Total Organic Carbon (mg/L)	EPA 415.1	0.5
Total Organic Halides (mg/L)	EPA 9020	0.01
Explosive compounds (μg/L)		
HMX	HPLC	20.
RDX	HPLC	30.
TNT	HPLC	30.
Radioactivity (Bq/L)		
Gross alpha	EPA 900	0.06
Gross beta	EPA 900	0.05
Radioisotopes (Bq/L)		
Radium 226	EPA 903	0.00303
Thorium 228	U-NAS-NS-3050	0.009
Thorium 232	U-NAS-NS-3050	0.006
Tritium	LLNL-RAS-011	0.05
Uranium 234	U-NAS-NS-3050	0.004
Uranium 235	U-NAS-NS-3050	0.003
Uranium 238	U-NAS-NS-3050	0.004

Table 10-3. List of ground water analyses showing EPA Method, organic constituent, and typical lower limit of detection reported by analytical laboratory.

Method	Reporting limit (µg/L)	Method	Reporting limit (µg/L)
EPA Method 502.2		Chloroethane	0.2
1,1,1,2-Tetrachloroethane	0.2	Chloroform	0.2
1,1,1-Trichloroethane	0.2	Chloromethane	0.2
1,1,2,2-Tetrachloroethane	0.2	cis-1,2-Dichloroethene	0.2
1,1,2-Trichloroethane	0.2	cis-1,3-Dichloropropene	0.5
1,1-Dichloroethane	0.2	Dibromochloromethane	0.2
1,1-Dichloroethene	0.2	Dibromomethane	0.2
1,1-Dichloropropene	0.2	Dichlorodifluoromethane	0.2
1,2,3-Trichlorobenzene	0.2	Ethylbenzene	0.2
1,2,3-Trichloropropane	0.2	Freon-113	0.2
1,2,4-Trichlorobenzene	0.2	Hexachlorobutadiene	0.2
1,2,4-Trimethylbenzene	0.2	Isopropylbenzene	0.2
1,2-Dichlorobenzene	0.2	m- and p-Xylene isomers	0.2
1,2-Dichloroethane	0.2	Methylene chloride	0.2
1,2-Dichloropropane	0.2	n-Butylbenzene	0.2
1,3,5-Trimethylbenzene	0.2	n-Propylbenzene	0.2
1,3-Dichlorobenzene	0.2	Naphthalene	0.2
1,3-Dichloropropane	0.2	o-Xylene	0.2
1,4-Dichlorobenzene	0.2	Isopropyl toluene	0.2
2,2-Dichloropropane	0.2	sec-Butylbenzene	0.2
2-Chlorotoluene	0.2	Styrene	0.2
4-Chlorotoluene	0.2	tert-Butylbenzene	0.2
Benzene	0.2	Tetrachloroethene	0.2
Bromobenzene	0.2	Toluene	0.2
Bromochloromethane	0.2	trans-1,2-Dichloroethene	0.2
Bromodichloromethane	0.2	trans-1,3-Dichloropropene	0.2
Bromoform	0.2	Trichloroethene	0.2
Bromomethane	0.2	Trichlorofluoromethane	0.2
Carbon tetrachloride	0.2	Vinyl chloride	0.2
Chlorobenzene	0.2		

...continued

Table 10-3. List of ground water analyses showing EPA Method, organic constituent, and typical lower limit of detection reported by analytical laboratory (continued).

Method	Reporting limit (µg/L)	Method	Reporting limit (µg/L)
EPA Method 524.2		cis-1,2-Dichloroethene	1
1,1,1,2-Tetrachloroethane	1	cis-1,3-Dichloropropene	1
1,1,1-Trichloroethane	1	Dibromochloromethane	1
1,1,2,2-Tetrachloroethane	1	Dibromomethane	1
1,1,2-Trichloroethane	1	Dichlorodifluoromethane	2
1,1-Dichloroethane	1	Ethylbenzene	1
1,1-Dichloroethene	1	Ethylene dibromide	1
1,1-Dichloropropene	1	Freon-113	1
1,2,3-Trichlorobenzene	1	Hexachlorobutadiene	1
1,2,3-Trichloropropane	1	Isopropylbenzene	1
1,2,4-Trichlorobenzene	1	m- and p-Xylene isomers	1
1,2,4-Trimethylbenzene	1	Methylene chloride	1
1,2-Dibromo-3-chloropropane	2	n-Butylbenzene	1
1,2-Dichlorobenzene	1	n-Propylbenzene	1
1,2-Dichloroethane	1	Naphthalene	1
1,2-Dichloropropane	1	o-Xylene	1
1,3,5-Trimethylbenzene	1	Isopropyl toluene	1
1,3-Dichlorobenzene	1	sec-Butylbenzene	1
1,3-Dichloropropane	1	Styrene	1
1,4-Dichlorobenzene	1	tert-Butylbenzene	1
2-Chlorotoluene	1	Tetrachloroethene	1
4-Chlorotoluene	1	Toluene	1
Benzene	1	trans-1,2-Dichloroethene	1
Bromobenzene	1	trans-1,3-Dichloropropene	1
Bromodichloromethane	1	Trichloroethene	0.5
Bromoform	1	Trichlorofluoromethane	1
Bromomethane	2	Vinyl chloride	2
Carbon tetrachloride	1	EPA Method 601	
Chlorobenzene	1	1,1,1-Trichloroethane	0.5
Chloroethane	2	1,1,2,2-Tetrachloroethane	0.5
Chloroform	1	1,1,2-Trichloroethane	0.5
Chloromethane	2		

...continued

Table 10-3. List of ground water analyses showing EPA Method, organic constituent, and typical lower limit of detection reported by analytical laboratory (continued).

Method	Reporting limit (µg/L)	Method	Reporting limit (µg/L)
1,1-Dichloroethane	0.5	Benzene	0.4
1,1-Dichloroethene	0.5	Chlorobenzene	0.3
1,2-Dichlorobenzene	0.5	Ethylbenzene	0.3
1,2-Dichloroethane	0.5	m- and p-Xylene isomers	0.4
1,2-Dichloroethene (total)	0.5	o-Xylene	0.4
1,2-Dichloropropane	0.5	Toluene	0.3
1,3-Dichlorobenzene	0.5	Total xylene isomers	0.4
1,4-Dichlorobenzene	0.5		
2-Chloroethylvinylether	0.5	EPA Method 608	
Bromodichloromethane	0.5	Aldrin	0.05
Bromoform	0.5	BHC, alpha isomer	0.05
Bromomethane	0.5	BHC, beta isomer	0.05
Carbon tetrachloride	0.5	BHC, delta isomer	0.05
Chlorobenzene	0.5	BHC, gamma isomer (Lindane)	0.05
Chloroethane	0.5	Chlordane	0.5
Chloroform	0.5	Dieldrin	0.1
Chloromethane	0.5	Endosulfan I	0.05
cis-1,3-Dichloropropene	0.5	Endosulfan II	0.1
Dibromochloromethane	0.5	Endosulfan sulfate	0.1
Dichlorodifluoromethane	0.5	Endrin	0.1
Freon-113	0.5	Endrin aldehyde	0.1
Methylene chloride	0.5	Heptachlor	0.05
Tetrachloroethene	0.5	Heptachlor epoxide	0.05
trans-1,3-Dichloropropene	0.5	Methoxychlor	0.5
Trichloroethene	0.5	4,4'-DDD	0.1
Trichlorofluoromethane	0.5	4,4'-DDE	0.1
Vinyl chloride	0.5	4,4'-DDT	0.1
1,2-Dichlorobenzene	0.5	Toxaphene	1
EPA Method 602		EPA Method 615	
1,3-Dichlorobenzene	0.3	2,4,5-T	0.5
1,4-Dichlorobenzene	0.3	2,4,5-TP (Silvex)	0.2

...continued

Table 10-3. List of ground water analyses showing EPA Method, organic constituent, and typical lower limit of detection reported by analytical laboratory (continued).

Method	Reporting limit (µg/L)	Method	Reporting limit (µg/L)
2,4-D	1	Chlorobenzene	1
2,4-Dichlorophenoxy acetic acid	2	Chloroethane	2
Dalapon	2	Chloroform	1
Dicamba	1	Chloromethane	2
Dichloroprop	2	cis-1,3-Dichloropropene	1
Dinoseb	1	Dibromochloromethane	1
MCPA	250	Dibromomethane	1
MCPP	250	Dichlorodifluoromethane	2
EPA Method 624		Ethylbenzene	1
1,1,1-Trichloroethane	1	Freon-113	1
1,1,2,2-Tetrachloroethane	1	Methylene chloride	1
1,1,2-Trichloroethane	1	Styrene	1
1,1-Dichloroethane	1	Tetrachloroethene	1
1,1-Dichloroethene	1	Toluene	1
1,2-Dichlorobenzene	1	Total xylene isomers	2
1,2-Dichloroethane	1	trans-1,3-Dichloropropene	1
1,2-Dichloroethene (total)	1	Trichloroethene	0.5
1,2-Dichloropropane	1	Trichlorofluoromethane	1
1,3-Dichlorobenzene	1	Vinyl acetate	10
1,4-Dichlorobenzene	1	Vinyl chloride	2
2-Butanone	10	EPA Method 625	
2-Chloroethylvinylether	10	1,2,4-Trichlorobenzene	10
2-Hexanone	10	1,2-Dichlorobenzene	10
4-Methyl-2-pentanone	10	1,3-Dichlorobenzene	10
Acetone	10	1,4-Dichlorobenzene	10
Benzene	1	2,4,5-Trichlorophenol	10
Bromodichloromethane	1	2,4,6-Trichlorophenol	10
Bromoform	1	2,4-Dichlorophenol	10
Bromomethane	2	2,4-Dimethylphenol	10
Carbon disulfide	1	2,4-Dinitrophenol	50
Carbon tetrachloride	1	2,4-Dinitrotoluene	10

...continued

Table 10-3. List of ground water analyses showing EPA Method, organic constituent, and typical lower limit of detection reported by analytical laboratory (*concluded*).

Method	Reporting limit (µg/L)	Method	Reporting limit (µg/L)
2,6-Dinitrotoluene	10	Bis(2-chloroisopropyl)ether	10
2-Chloronaphthalene	10	Bis(2-ethylhexyl)phthalate	10
2-Chlorophenol	10	Butylbenzylphthalate	10
2-Methylphenol	10	Chrysene	10
2-Methyl-4,6-dinitrophenol	50	Di-n-butylphthalate	10
2-Methylnaphthalene	10	Di-n-octylphthalate	10
2-Nitroaniline	50	Dibenzo(a,h)anthracene	10
2-Nitrophenol	10	Dibenzofuran	10
3,3'-Dichlorobenzidine	20	Diethylphthalate	10
3-Nitroaniline	50	Dimethylphthalate	10
4-Bromophenylphenylether	10	Fluoranthene	10
4-Chloro-3-methylphenol	20	Fluorene	10
4-Chloroaniline	20	Hexachlorobenzene	10
4-Chlorophenylphenylether	10	Hexachlorobutadiene	10
4-Nitroaniline	50	Hexachlorocyclopentadiene	10
4-Nitrophenol	50	Hexachloroethane	10
Acenaphthene	10	Indeno(1,2,3-c,d)pyrene	10
Acenaphthylene	10	Isophorone	10
Anthracene	10	m- and p-Cresol	10
Benzo(a)anthracene	10	N-Nitrosodi-n-propylamine	10
Benzo(a)pyrene	10	N-Nitrosodiphenylamine	10
Benzo(b)fluoranthene	10	Naphthalene	10
Benzo(g,h,i)perylene	10	Nitrobenzene	10
Benzo(k)fluoranthene	10	Pentachlorophenol	50
Benzoic acid	50	Phenanthrene	10
Benzyl alcohol	20	Phenol	10
Bis(2-chloroethoxy)methane	10	Pyrene	10

Table 10-4. Inorganics in ground water: regulatory/human health considerations.

Metal	EPA method	Detection limits (mg/L)	CA or federal MCL* (mg/L)	SFRWQCB Basin Plan WQOs (mg/L)	CVRWQCB Basin Plan WQOs (mg/L)	EPA health advisory (mg/L)
Aluminum	200.7	0.2	1	5/20	1	NA
Antimony	204.2 (GFAA)	0.001-0.005	0.006**	NA	NA	0.003
Arsenic	206.2 (GFAA)	0.001	0.05	0.005	0.01	0.00002
Barium	200.7	0.05-0.1	1	1	0.1	2
Beryllium	210.2 (GFAA)	0.0001 - 0.0005	0.004	0.1/0.5	NA	0.000008
Boron	200.7	0.5	NA	0.5/2	0.8-5.8	0.6
Cadmium	213.2 (GFAA)	0.0005	0.005	0.01	0.00022	0.005
Chloride	325.3	5	250***	250/500	150/250	NA
Chromium (total)	218.2 (GFAA)	0.005	0.05	0.05	0.05	0.1
Chromium(VI)	218.4 (GFAA)	0.005	0.05	0.05	0.05	0.1
Copper	200.7, 220.2 (GFAA)	0.01-0.05	1***	0.2-1	0.0056	NA
Cyanide	9010	0.02	0.2	0.01/0.2	0.01	0.2
Fluoride	340.2	0.05	1.4-2.4	0.8/1.7	1.4-2.4	NA
Iron	200.7	0.1	0.3***	0.3	0.3	NA
Lead	239.2 (GFAA)	0.002	0.05	0.05	0.05	NA
Manganese	200.7	0.03	0.05***	0.05/10	0.05	NA
Mercury	245.2 (GFAA)	0.0002	0.002	0.000012	0.002	0.002
Molybdenum	246.2 (GFAA)	0.05	NA	0.01/0.05	0.01-0.05	0.035
Nickel	249.2 (GFAA)	0.005	0.1	0.2/2	0.1	0.1
Nitrate, as N	353.2	0.5	10	NA	10	10
Nitrite, as N	354.1	0.1	1	NA	1	1
pH (unitless)	150.1	0.1	NA	6.0-8.5	6.5-8.5	NA
Selenium	270.2 (GFAA)	0.002	0.01	0.01	0.005-0.026	NA
Silver	272.2(GFAA)	0.01	0.05	0.05	0.01	0.1
Specific Conductance (µmhos/cm)	120.1	NA	NA	0.9/1.6	NA	NA
Total Dissolved Solids (TDS)	160.1	1	NA	0.5/1	NA	NA
Thallium	279.2 (GFAA)	0.001-0.005	0.002**	NA	NA	0.0004
Vanadium	286.2 (GFAA)	0.01	NA	0.1/1	NA	NA
Zinc	200.7, 289.1	0.01	5***	2/10	0.1	2
Sulfate	375.4	1	250**	250/500	NA	NA

* As listed in U.S. Environmental Protection Agency Region IX *Drinking Water Standards and Health Advisories Table*, dated July 1994.

**Federal Maximum Containment Levels (MCLs) for antimony and thallium became effective January 1994.

***EPA Secondary MCL.

Table 10-5. Radionuclides in ground water: regulatory/DOE considerations

Radionuclide	Analytical method	CA or federal MCL (Bq/L)	SFRWQCB/ CVRWQCB Basin Plan WQOs (Bq/L)	DOE's derived concentration guidelines (DCGs; in Bq/L)	EPA health advisory (Bq/L)
Cesium 137	LLNL-RAS-010	NA	NA	2,593 (70,000 pCi/L)	NA
Gross Alpha (excluding Uranium and Radon)	900.0	0.56 (15 pCi/L)	0.56 (15 pCi/L)	NA	0.0056 (0.15 pCi/L)
Gross Beta	900.0	1.85 (50 pCi/L)	1.85 (50 pCi/L)	NA	0.4 μ Sv (0.04 mrem)/yr
Plutonium 239, 240	LLNL-RAS-010	NA	NA	1.11 (30 pCi/L)	NA
Potassium 40	LLNL-RAS-010	NA	NA	259 (7,000 pCi/L)	NA
Radium 226	LLNL-RAS-010	0.185* (5 pCi/L)	0.185* (5 pCi/L)	3.7 (100 pCi/L)	0.008-0.0096 (0.21-0.26 pCi/L)
Radium 228	LLNL-RAS-010	0.185* (5 pCi/L)	0.185* (5 pCi/L)	3.7 (100 pCi/L)	0.008-0.0096 (0.21-0.26 pCi/L)
Thorium 228	LLNL-RAS-010	NA	NA	15 (400 pCi/L)	NA
Thorium 232	LLNL-RAS-010	NA	NA	1.85 (50 pCi/L)	NA
Tritium	LLNL-RAS-011	741 (20,000 pCi/L)	741 (20,000 pCi/L)	74,000 (2,000,000 pCi/L)	NA
Uranium 233, 234	LLNL-RAS-010 or DOE-HASL-300	0.74 (20 pCi/L)	NA	18.5 (500 pCi/L)	0.7 μ g/L (total Uranium)
Uranium 235, 236	LLNL-RAS-010 or DOE-HASL-300	0.74 (20 pCi/L)	NA	22 (600 pCi/L)	0.7 μ g/L (total Uranium)
Uranium 238	LLNL-RAS-010 or DOE-HASL-300	0.74** (20 pCi/L)	NA	22 (600 pCi/L)	0.7 μ g/L (total Uranium)

* For both radium-226 and radium-228.

** The isomers of uranium are undifferentiated by EPA guidance documents.

10.4 QUALITY ASSURANCE REQUIREMENTS

10.4.1 Data Quality Objectives

Tables 10-4 and 10-5 present some regulatory/DOE parameters for DQOs in analytical data results from inorganics and radionuclides. The California or federal MCLs are DQOs that should be met, if possible, for each constituent, i.e., method reporting limits or detection limits should be below MCLS. Other

regulatory/DOE levels represent the most conservative regulatory/DOE limits that may or may not apply to each particular instance but are presented for comparison purposes. For instance, each California Regional Water Quality Control Board (RWQCB) has a Basin Plan that generally identifies specific numerical water quality objectives (WQOs) for beneficial uses of water. The tables present the most stringent of these WQOs from both the CVRWQCB (for Site 300) and the SFRWQCB (for the Livermore site), along with the other regulatory levels.

10.5 PLANS FOR THE FUTURE

10.5.1 Short-Term Plans

10.5.1.1 *Livermore Site*

Immediate short-term plans are to sample and analyze the nine monitoring wells described in this plan for the next year to confirm present baseline conditions and detect any possible additional contamination that may migrate off site. Monitoring activities after that time will depend on the initial monitoring results as well as the availability of resources.

10.5.1.2 *Site 300*

Short-term plans for Site 300 compliance monitoring of Pits 1 and 7 are as follows:

1. After completion of a special one-year sampling plan and receipt and evaluation of all data in October, 1994, concentration limits (CLs) for constituents of concern listed in WDR No. 93-100 as "to be determined" will be calculated. Also, the CLs currently in use will be recalculated, incorporating both historical and new data collected since 1991 (when they were initially calculated). After acceptance by the CVRWQCB, the new CLs will become the standards against which future ground water measurements will be compared, to detect releases of any constituents of concern.
2. The general contaminant indicator parameters pH, specific conductance, TDS, and TOC will continue to be investigated to determine their sensitivity for detecting trace contaminants in the presence of high concentrations of naturally occurring chemicals, as exists at Site 300. This investigation will determine their relative

importance in assessing releases from the two RCRA-closed landfills.

10.5.2 Long-Term Plans

10.5.2.1 *Livermore site:*

Beyond the efforts mentioned above, an analysis is currently under way that will determine the need for long-term additions to the surveillance ground water monitoring program in order to assess the effects, if any, of Livermore site operations and activities on on-site and off-site ground waters. This ground water surveillance plan will be updated on a site-specific basis, taking into consideration facility characteristics, applicable regulations, hazard potential, quantities and concentrations of materials released, the extent and use of local water resources, and specific local public interest and concerns. The specific objectives of the surveillance program are to:

- Verify compliance with applicable environmental laws and regulations.
- Verify compliance with environmental commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official DOE documents.
- Characterize and define trends in the physical, chemical, and biological condition of environmental media.
- Further establish baselines of environmental quality.
- Provide a continuing assessment of pollution abatement programs.
- Identify and quantify new or existing environmental quality problems.

The plan is currently being developed and is expected to be implemented beginning in 1995.

10.5.2.2 *Site 300*

The current technical assessment of the surveillance monitoring program at Site 300 is incorporating results of the SWRI report (Webster-Scholten 1994). If changes to the surveillance monitoring program are indicated by the technical assessment, they will be implemented.

Future expectations for ground water monitoring at Site 300 include the further consolidation of the two separate compliance monitoring plans for Pits 1 and Pit 7 that are currently being followed (Rodgers/Pacific Corporation 1990 and CVRWQCB 1993).

Additionally, a new WDR is expected to be issued by the CVRWQCB regarding compliance ground water monitoring of the HE process water impoundments. LLNL has submitted a monitoring plan for CVRWQCB consideration in the Draft Report of Waste Discharge LLNL Site 300 (Hoppes et al. 1992).

10.6 PREPARATION AND DISPOSITION OF REPORTS

- Annual Environmental Report—Routine ground water monitoring results are summarized and discussed in the surveillance monitoring section of the Environmental Report that is available to the public. All data are summarized and tabulated and significant trends are discussed. Each report also includes an interpretation of the data, as well as possible environmental significance.
- Occurrence Reports—Occurrence reports are usually required when a permit condition is violated and results in a non-routine report to a regulatory agency.
- Site 300 Compliance Monitoring Reports. Monitoring reports to the CVRWQCB are required for Pits 1 and 7 and for the HE Process Area by WDR No. 93-100 and WDR No. 85-188, respectively. The reports, amounting to five per year, are published as the UCAR-10191 series.
- Quarterly reports must contain tables of measurements made over the three-month period, a summary of the measurement data with regard to compliance, and a short discussion of monitoring results, including notations of any water quality violations. The reports are due to the CVRWQCB within 45 days following the end of each quarter.
- Annual reports for Pits 1 and 7 must contain tabular and graphical summaries of the monitoring data obtained during the previous year. If noncompliance has occurred, the report must include a discussion of the progress toward reestablishment of compliance with waste discharge requirements and the water quality protection standard.

11

Other Compliance Monitoring

11.1 RATIONALE AND DESIGN CRITERIA

Most of the environmental monitoring at LLNL is performed in compliance with DOE Order 5400.1, which encompasses the requirements for both air and liquid effluent monitoring and surveillance monitoring. Over the past seven years, state and federal environmental regulations have imposed other compliance monitoring requirements through the permits that are negotiated with regulatory agencies. This chapter discusses three areas of compliance monitoring outside the subject areas discussed in the other chapters. Note that compliance monitoring is part of the Site 300 ground water monitoring program, the storm water monitoring programs, and monitoring at the Livermore site Central Drainage Basin, and has been discussed in their pertinent chapters.

11.1.1 Categorical Pretreatment

Wastewater generated by industrial processes have been found to contain pollutants that can adversely impact the quality of receiving waters. There are 46 identified categories of industrial processes that merit specific discharge standards; two of these are used at LLNL. They are the metal-finishing and the semiconductor subcategories of the Electrical and Electronic Components Category.

Because a number of facilities at LLNL use these processes, LLNL is federally mandated to maintain a pretreatment program (40 CFR 403), consisting of an interlocking series of administrative and engineering controls and procedures, coupled with process monitoring from nondomestic, industrial wastewater sources with specific discharge limits identified in the National Pretreatment Standards (40CFR 403.5). The purpose of such a program is the reduction or elimination of pollutants prior to their discharge to any Publicly Owned Treatment Works (POTW).

A component of the National Pretreatment Standards is the categorical standards. These are codified (40 CFR 405 through 471) standards specifying quantities or concentrations of pollutants that may be discharged to sanitary sewer from specific industrial subcategories 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 POTW to treat wastewater. (At LLNL, disrupting POTW operations could cause contamination of the receiving waters of San Francisco Bay). The LLNL categorical pretreatment self-monitoring program accomplishes this by maintaining complete compliance with all applicable regulations (Tables 11-1 and 11-2).

Table 11-1. LLNL's internal discharge limits for nonradioactive parameters in wastewaters from noncategorical and categorical processes, mg/L.

Parameter	Noncategorical ^b	Discharge limits ^a	
		Metal finishing	Electronic components
Metals			
Beryllium	0.74		
Cadmium	0.9	0.26	
Chromium (total)	4.9	1.0	
Copper	10	2.07	
Cyanide ^c	5	0.65	
Lead	4.9	0.43	
Mercury	0.05		
Nickel	5	2.38	
Silver	1	0.24	
Zinc	15	1.48	
Organics			
Total toxic organics	4.57	2.13	1.37
Physical			
pH (units)	5–10	5–10	5–10
Other			
Oil and grease	500		
Total dissolved solids	375 above background		

^a These standards are specified by the EPA. By regulation, the EPA or City of Livermore limit is used, whichever is lower. Noncategorical limits apply where no standard is specified.

^b These standards have been established to meet the City of Livermore's requirements at the Building 196 outfall.

^c 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.

Table 11-2. LLNL's internal discharge limits for radioisotopes in wastewaters.

Parameter	Individual discharges		Total daily limit for site	
Gross alpha	11.1 Bq/L	(0.3 μ Ci/1000 L)	185 kBq	(5.0 μ Ci)
Gross beta	111 Bq/L	(3.0 μ Ci/1000 L)	1.85 MBq	(50.0 μ Ci)
Tritium	185 kBq/L	(5.0 mCi/1000 L)	3.7 GBq	(100.0 mCi)
Gamma	— ^a		— ^a	

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

As previously stated, the primary regulatory driver of the categorical program is federal regulations; however, as in most municipalities, the program is administered and enforced at the local level. The LLNL categorical pretreatment self-monitoring program is mandated under the terms of the Wastewater Discharge Permit No. 1250(94-95), 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 City of Livermore sanitary sewer system lie with the Livermore Water Reclamation Plant (LWRP) under the authority of San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). LLNL is currently discussing with EPA the extent to which the pretreatment program should be applied at LLNL.

LLNL processes that are regulated under the categorical standards of the National Pretreatment Regulations include metal-finishing (40 CFR 433) such as metal-plating and bright dipping processes (such as those located in the Building 322 Plating Shop), and certain electrical and electronic component (40 CFR 469) processes (such as the micro-fabrication work that occurs in Building 153). Some categorical processes discharge directly to the sanitary sewer and are sampled at the point of discharge; other categorical processes discharge to one of five dedicated retention tank systems, which are sampled and characterized prior to each discharge. Some processes do not discharge to the sanitary sewer; they are contained and sent to LLNL Hazardous Waste Management Division for treatment and/or shipment off site. Those processes that do not discharge to sanitary sewer do not require sampling under this regulatory program.

Grab samples are collected for categorical process monitoring. A grab sample is a sample collected over a period of time not exceeding 15 minutes (40 CFR 403.7 and

40 CFR 136). Composite sampling is not appropriate because volumes are extremely small and flows are not continuous. Also, some constituents, such as cyanide, cannot be held for an extended period of time due to biological, chemical, or physical interactions after sampling that affect the results.

11.1.2 Cooling Towers

Cooling towers located at Site 300 discharge wastewater into surface water drainage courses as part of normal operations. This wastewater discharge is governed by the Federal Water Pollution Control Act (also known as the Clean Water Act) and the California Porter Cologne Water Quality Control Act.

The Clean Water Act was enacted to restore and maintain the chemical, physical and biological integrity of "waters of the Nation." To this end, Section 402 of the Act established the National Pollutant Discharge Elimination System (NPDES) to prescribe conditions under which pollutants can be discharged to waters of the nation. The specific requirements of NPDES permits, developed by EPA, are contained within 40 CFR 122.

The Porter-Cologne Act protects the quality of "waters of the state" by requiring a Regional Water Quality Control Board (RWQCB) to evaluate waste discharges and issue Waste Discharge Requirements (WDRs) if the waste could adversely affect water quality. 23 CCR, Chapter 9, sets forth the specific regulations governing the issuance of WDRs. The Porter-Cologne Act also requires the development of several state-wide water quality plans and individual regional water quality control plans for waters within a defined watershed (region). Any WDR issued by a RWQCB must be consistent with these plans. Based on the location of Site 300, any permit issued by the RWQCB must be consistent with the Inland Surface Waters Plan and Central Valley Regional Water Quality Control Plan.

The discharge of cooling tower wastewater is controlled by the combination WDR (No. 94-131) and NPDES (No. CA0081396) issued by the Central Valley RWQCB. The permit is collectively referred to as WDR No. 94-131. WDR No. 94-131 was issued on May 20, 1994, and replaced the previously issued WDR No. 82-105. It will expire on May 20, 1999, and a renewal application must be submitted to the RWQCB 180 days prior to the expiration date.

WDR No. 94-131 establishes a self-monitoring and reporting program to monitor compliance with established effluent limitations and test for adverse impacts to

the receiving water, Corral Hollow Creek. Effluent limits are established by the Central Valley RWQCB for constituents that could adversely affect waters of the state and nation. Cooling tower wastewater discharges are relatively clean so a minimal monitoring program is required: testing for total dissolved solids (TDS); pH; and measurement of flow. In addition, the monitoring program requires sampling of the receiving water for pH to determine if the cooling tower wastewater discharges affect the receiving water. Visual observations for oil, grease, scum, or other debris in the wastewater flow and receiving waters are also required.

Grab samples are collected for all analyses. Grab sampling is a suitable collection method for water samples of such very low toxicity.

11.1.3 Monitoring Associated with Building Drain Repair Project (BDR)

In 1987, Congress added Section 402(p) to the 1972 Clean Water Act, establishing a framework for regulating industrial storm water discharges under the NPDES program. EPA published the final regulations, 40 CFR 122.26, implementing Section 402(p) in 1990. The regulations established the NPDES permit application requirements for storm water discharges associated with industrial activity. In California, enforcement and interpretation of the storm water regulations were delegated to the California State Water Resources Control Board which, under the authority of both the Clean Water Act and the Porter-Cologne Water Quality Control Act, subsequently issued a combined WDR/NPDES permit titled the *California General Industrial Activity Storm Water Permit* (General Permit), WDR No. 91-13-DWQ and WDR No. 91-12-DWQ, NPDES permit number CA000001.

Section A of the General Permit requires the development and implementation of a Storm Water Pollution Prevention Plan, part of which requires the identification of non-storm water discharges and subsequent permitting or elimination of these discharges. LLNL completed two investigations into potential discharges to the storm drainage system at both the Livermore site and Site 300 to fulfill the requirements of the General Permit. These investigations revealed discharges to the storm drain system that were not permitted. LLNL has submitted for Site 300 and will submit for the Livermore site a WDR/NPDES permit application for several of the discharges identified. The Building Drain Repair Project is responsible for obtaining WDR/NPDES permits for continued site discharges to waters of the state and nation and resolving all corrective activities associated with building drain lines.

To permit waste discharges, the sampling and analysis requirements of the NPDES regulations must be followed. Sampling helps to determine the effect of discharges on receiving waters and thus helps to set appropriate effluent limitations. After the permit is issued, a monitoring and reporting program could be established to ensure compliance with the permit conditions. The monitoring and reporting program will specify the discharges to be sampled, the collection methods, and analytes.

At both the Livermore site and Site 300, most of the sources identified included potable water discharges, equipment condensate, and mechanical equipment wastewater discharged in very low volumes. The Central Valley and San Francisco Bay RWQCBs have indicated that unless LLNL finds high concentrations of pollutants of concern, they will not establish effluent limits but instead require Best Management Practices to ensure that discharges remain of low concern. Best Management Practices will include things such as preventive maintenance, inspection, and administrative controls.

11.2 EXTENT AND FREQUENCY OF MONITORING AND MEASUREMENTS

11.2.1 Categorical Pretreatment

New LLNL wastewater generating processes are evaluated to determine if they meet the definitions of specific industrial subcategories as set forth in the federal regulations. Currently, processes at LLNL fall into two such subcategories, metal-finishing as defined in 40 CFR 433, and semiconductor processes defined under 40 CFR 469. Routine review and evaluation occurs at least semiannually.

Monitoring for all processes occur 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 existing categorical processes that discharge to the sanitary sewer. Currently there are 14 metal finishing and 3 semiconductor processes in use at LLNL. These numbers can change frequently as facilities dismantle existing processes or install new ones. The LWRP permit states that metal finishing processes are sampled semiannually, semiconductor processes are sampled quarterly. 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 and TTO.

11.2.2 Cooling Towers

Wastewater samples are collected at the discharge valve from each cooling tower draining to the surface water course. Sampling here ensures that a representative sample is obtained and the measured parameters are not affected by factors external to the tower.

The pH samples of receiving waters are collected at Corral Hollow Creek upstream and downstream of the potential influence of cooling tower discharges. Corral Hollow is an ephemeral creek which typically flows only during and immediately following heavy winter rain events. Sampling locations are shown on Figure 11-1. Location NSTN provides an upstream background sample and location GEOCRK monitors the cumulative downstream effect of all the tower discharges on the receiving water. These locations were chosen because they are well located, with good access, and they are sampled for other water networks. Visual observations for oil, grease, scum, and other debris are also conducted at these two locations. While NSTN and GEOCRK theoretically demonstrate the effects of the cooling towers on the receiving water, in fact the cooling tower discharges are a very minor contribution to the overall winter flow in the creeks. Natural pH variations, such as mineralogical differences along the streambed and runoff from agricultural and livestock areas, are likely to have a much greater impact on the pH at various locations in the creek than discharge from the cooling towers.

Currently, 17 cooling towers at Site 300 discharge wastewater into surface water drainage courses that eventually flow to Corral Hollow Creek. At the request of the RWCQB, LLNL will eliminate discharges to surface water drainage courses from 14 of the cooling towers by routing the discharges to percolation pits, which are to be constructed by December 1994. (If the RWCQB requires a WDR permit for the discharges to the percolation pits, they might establish a monitoring program.) Routine sampling for those tower discharges will be stopped once they are routed to the percolation pits. Sampling might again be necessary if LLNL must resume discharging to surface water drainage course, which would happen in the event the primary water source, Hetch Hetchy, is interrupted for a long enough period to overflow the percolation pits.

Figure 11-1. Cooling tower locations, upstream and downstream monitoring locations.

In that event, the San Francisco Water Department will notify LLNL of planned service interruptions and LLNL, as required by WDR No. 94-131, will notify the RWQCB.

Cooling towers are numbered for the buildings which they are associated with and are shown on Figure 11-1. The three towers that will continue routine discharges to surface water drainage courses are located at Buildings 801, 836A and 865. The other 14 towers that will be rerouted to percolation pits are located at Buildings 805, 809, 810, 812, 815, 817, 826, 827-1, 827-2, 828, 836D, 851-1, 851-2, and 854.

Sampling frequency and analytes are established by the RWQCB through the WDR No. 94-131 monitoring and reporting program. The program requires quarterly collection of samples and testing for TDS and pH and biweekly flow measurements at all towers discharging to surface water drainage courses. Table 11-3 lists the effluent limits for discharges from the cooling towers. Receiving water observations and sampling are required quarterly when the Corral Hollow Creek is flowing.

Table 11-3. Effluent limits for cooling tower discharges.

Constituent	Monthly Average	Daily Maximum
Effluent limits for towers at 801, 865, and 836A		
TDS (mg/L)	2,000	2,400
pH		10.0
Flow (gal/d)		not to exceed design capacity
Effluent limits for towers 805, 809, 810, 812, 815, 817, 826, 827-1, 827-2, 828, 836D, 851-1, 851-2, 854		
TDS (mg/L)	2,000	5,000
pH		10.0
Flow (gal/d)		not to exceed design capacity

11.2.3 Building Drain Repair Project

To complete the characterization sampling for the NPDES permit application, LLNL (with the agreement of the Central Valley and San Francisco Bay RWQCBs) limited the characterization sampling to discharges from one or two areas that discharged representative types of wastewater. The decision to limit the number of sampling locations was critical since there are several hundred to several thousand discharge locations at the two LLNL sites. If a monitoring and reporting program were to be required by either RWQCB, it is likely that selected sampling, rather than sampling all discharge points, would be required.

At both the Livermore site and Site 300 a detailed sampling plan was developed, which provided sampling and analytical procedures and the rationale for the selected sampling locations. Representative sampling locations for the permit application were determined by comparing the type of equipment discharging wastewater, makeup water source, and chemical treatments, if any.

Should the RWQCBs require a monitoring and reporting program, they will determine the frequency and extent of sampling. Through the permit, LLNL will be required to develop a monitoring program to determine and justify the appropriate discharge locations to be sampled, analytical methods to be used (within the bounds of EPA methods), and establish QA and QC sampling requirements. Analytes to be monitored will be a subset of those sampled for the permit application. Typically RWQCB will select for monitoring those analytes that were detected in the characterization sampling at concentrations high enough to be of concern or analytes of special concern in the water basin, such as copper in the San Francisco Bay.

11.3 PROCEDURES FOR LABORATORY ANALYSIS

All categorical pretreatment sample analyses are performed off site by GTEL Environmental Laboratories, Concord, CA. Analyses of cooling tower and building drain repair samples are performed by California Laboratory Services (CLS), Rancho Cordova, CA. For details on analytical laboratory procedures, see Chapter 16, Procedures for Laboratory Analysis.

11.4 QUALITY ASSURANCE REQUIREMENTS

11.4.1 Categorical Pretreatment

Although the quality assurance requirements for the categorical program (e.g., data quality objectives) have not been through the rigors of a technical assessment, procedures and methods exist and are utilized to ensure sample integrity. For instance, calibration of the hand-held pH meter is performed prior to each day's use, according to EMP-GW-CA. All calibration information is recorded on field tracking forms.

WATS Procedure 205 is the sampling procedure used in the collection of pretreatment samples. It is technically accurate but requires updating to reflect shifting organizational responsibilities for the maintenance of this monitoring network. This procedure states that overall, duplicates should be 10% of the cumulative total of sample locations collected during the monitoring period (quarterly or semiannually, depending on the requirements prescribed in 40 CFR for that category of process). This is not always possible. Duplicates are difficult to obtain for categorical processes because the volume of wastewater (liter quantities) generated by most processes is so small that there is often not enough to meet sample requirements. By regulation, LWRP inspectors are required to sample all discharging processes annually. When they do, LLNL is required to

take split samples with them. These split samples are considered part of the 10% of the cumulative total.

Blank samples are not taken at this time. The need to incorporate blank samples in the future will be addressed when the applicability of the categorical standards to LLNL processes is completely assessed. Pending this determination, a technical assessment of the categorical program may be necessary if LLNL is required in the meantime to comply with the categorical standards.

11.4.2 Cooling Towers

Following EMP-GW-CA, pH meters are calibrated daily. Detection limits for TDS samples analyzed by EPA Method 160.1 are currently 1 mg/L for the current contract laboratory, California Laboratory Services (CLS), and 0.1 (pH units) for pH analyzed by EPA Method 9040.

Quality assurance/quality control (QA/QC) samples that are routinely sampled and analyzed include blind duplicates (i.e., duplicates in which the absolute locations are known by the field personnel and not by the contract laboratory) amounting to at least 10% of the samples per batch, and a method blank with each batch of samples. A field sample blank is not deemed to be necessary since these are non-volatile components. The environmental analyst is responsible for checking all of the QA/QC samples to ensure that they agree with the original samples within a reasonable tolerance interval (a relative percent difference of approximately 10 %). If the agreement is not adequate, then discussions are initiated first with the field samplers and then with the analytical laboratory to ascertain the cause of the discrepancy. These QA/QC requirements will be reevaluated when a technical assessment is performed on this network.

11.4.3 Building Drain Repair Project

Using the EMS sampling protocol method defined in EMP-GW-CA, calibration of the pH meter is performed before it is taken into the field. The pH meter is used to obtain field pH and temperature or measurements. All calibration information is recorded on the field tracking forms (FTFs).

Because limited sampling is done for a permit application, high quality data are essential; thus, extra attention is paid QA and QC sampling. One field blank per day of sampling is analyzed for the same suite of parameters as the routine samples. A minimum of 20% of the samples are replicated (as selected by the environmental analyst). QA samples estimate the precision and accuracy of the

sampling and analysis methods. They are taken, processed, and analyzed in a manner equivalent to a routine sample. Special attention is taken to assure duplication of sampling, location, time, method and analysis.

Quality assurance and quality control requirements for future permits will be developed in the monitoring program.

11.5 PROGRAM IMPLEMENTATION PROCEDURES

11.5.1 Categorical Pretreatment

Continued compliance monitoring of categorical processes may not be necessary, pending the outcome of ongoing negotiations with EPA as described in detail in Section 11.7.1 of this chapter. If components of the existing categorical process requirements remain, even in a changed format from those currently in place, WATS Procedure 205 will have to be updated to reflect both organizational changes within EPD and compliance changes.

Protocols for the categorical monitoring network, used to ensure sample identification and integrity prior to the analytical work, are documented below.

A unique numbering system is used in the field at the time of sample collection. The number begins with the letters "PT" to identify it as a pretreatment sample, followed by a building number, a sample location number, the number of the sample taken at that location, and finally, the calendar quarter in which the sampling occurred, i.e., PT-141-02-01-Q2 indicates a sample taken at Building 141, at the second sampling location, first sample, second quarter of the monitoring period. Following WATS Procedure 205, the sampler wears gloves and changes them between each sampling event. Nonorganic sample bottles have the lids taped shut, and each set of samples is bagged separately. The sampler uses pre-preserved sample bottles when possible and immediately places the collected sample in an ice chest. After all sampling is completed, samples are placed in a locked refrigerator until time for courier pick-up for delivery to the laboratory, at which time the samples are put back in the ice chest with new ice, and placed in a locked pick-up box where the courier retrieves them. A COC form is completed and accompanies the sample(s). Required analyses and methods are requested as specified in the federal regulations (40 CFR 136), and the LLNL Wastewater Discharge Permit. Services of an outside, State-certified analytical laboratory are utilized.

The only monitoring equipment used in this field sampling is a hand-held pH meter which is calibrated daily following the method described in EMP-GW-CA.

11.5.2 Cooling Towers

The LLNL *Experimental Test Site (Site 300) Cooling Tower Monitoring Program*, July 1994, identifies the sampling and analytical methodologies to be employed. The sample handling and collection techniques used for cooling tower compliance monitoring are similar to those for other environmental water sampling, such as EMP-GW-S. Standard COC and FTF procedures (EMP-QA-SD) are employed to ensure legally valid samples and to document field conditions that may affect the sample.

11.5.2.1 TDS. A grab sample is collected in a 500-mL polyethylene container and refrigerated to 4°C. TDS samples are submitted to a contract analytical laboratory for analysis by EPA method 160.1. Approximately 10% of the TDS samples are duplicated and sent to a second analytical laboratory for analysis.

11.5.2.2 pH. A grab sample is collected in a stainless steel bucket for analysis with a pH meter by the sampling technician. Measurements are recorded on the FTF. The pH meter is calibrated by the method described in EMP-GW-CA. Approximately 10% of the pH samples randomly chosen are sent for analysis by a contract analytical laboratory. These samples are collected in a polyethylene grab sample container and refrigerated to 4°C.

11.5.2.3 Flow. Technicians typically employ a stainless steel bucket of approximately 19-L capacity to collect the blowdown flow. The total volume of flow is measured with a 500-mL graduated cylinder. The rate of blowdown flow is calculated by dividing volume by time.

The objective of the monitoring program is to demonstrate that discharges are in compliance with the established effluent limits and that the discharges do not have a deleterious affect on the receiving waters.

Standard field sampling protocols are used to prevent cross contamination of samples. These protocols, called out in EMP-RO-S and EMP-GW-S, include wearing disposable gloves when collecting samples and discarding them after use in each sampling location; 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 inside of the sample bottles.

Sample locations are identified in accordance with the EMS location numbering protocol. For example, 3-B805-01-TW indicates that the location is at Site 300 (3) Building 805 (B805), at the first or only tower at the building (01), and that sample is cooling tower effluent (TW). (This is a variation of the usual numbering protocol—the use of 01 and 02 usually indicates the number of samples taken at the same location. Modifications are being considered that will reconcile the EMS sample numbering system and allow distinction of cooling towers located at the same building.

Action levels for this permit would be a TDS concentration above 2000 mg/L or a pH level above 10. The present practice is to have the technicians sample the cooling tower blowdown in the first month of the quarter so that corrective actions can be employed if TDS values exceed the 2000 mg/L permitted concentration. Such corrective actions would include having the maintenance personnel check the blowdown valves daily to ensure an open flow path; additional measures would be discussed as needed with the Site 300 Maintenance & Operations Division Leader whose staff is responsible for cooling tower operations.

Samples of cooling tower effluent are collected by trained sampling technicians using established sampling procedures. EMP-GW-S details the methods to be used in collecting pH and TDS samples and taking field pH measurements.

Once the laboratory results return, they are first checked in by the assistant environmental analyst who ensures the chain-of-custody is intact, all signatures are present, the data results are complete, and keys all QA/QC sample(s) with the original sample(s) from the same location(s).

WDR No. 94-131 requires that all analyses be performed in accordance with the latest edition of the *Guidelines Establishing Test Procedures for Analysis of Pollutants*, promulgated by EPA (40 CFR 136), or other procedures approved by the RWQCB. In addition, chemical, bacteriological and bioassay analyses must be performed by laboratories certified for such analyses by the California Department of Health Services.

Further quality assurance methods required by WDR No. 94-131 include:

- identification of all certified laboratories used for analyses in all reports submitted to the RWQCB or EPA,
- proper maintenance and calibration of equipment used to fulfill the monitoring program to ensure their continued accuracy,

- strict penalties for the falsifying, tampering, or knowingly rendering monitoring equipment inaccurate,
- maintenance of all calibration and maintenance records for five years from the date of the sample,
- monitoring records to include:
 - a) date, exact place and time of sampling or measurement,
 - b) the individual(s) who performed the sampling or measurements,
 - c) the date(s) analyses were performed,
 - d) the individual(s) who performed the analyses,
 - e) the laboratory which performed the analyses,
 - f) the analytical techniques or methods used,
 - g) the results of the analyses,
- certification of all reports by the duly authorized representative.

All required permit documentation, such as calibration and monitoring records are recorded on field tracking forms and archived by EMS per EMP-QA-SD and EMP-QA-DC.

11.5.3 Monitoring Associated with Building Drain Repair (BDR)

Monitoring of BDR sources will occur if a monitoring and reporting program is required by the RWQCBs. Sampling of these discharges will be similar to other environmental compliance sampling described in this section.

A sample identification system will be developed following the EMS numbering protocol. This protocol uniquely identifies the LLNL site the sample was taken at, the precise location of the sampling, and other information about the sample.

Methods used to prevent cross contamination are similar throughout all sampling events. Those used for the BDR sampling will be drawn from EMP-GW-S. The methods 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 inside of the sample bottles.

BDR sample preservation and handling practices will be performed according to EMS procedures EMP-GW-S, EMP-RO-S, and EMP-W-S. Conditions identified during each sampling event are recorded on the FTF. This information, in conjunction with sampling results, provides a complete summary for each representative sampling discharge location. The FTF may provide information beneficial in identifying constituents of concern.

Samples will be collected using standard sample collection methods described in the EMS procedures manual. Specific types of containers are used for each sampling procedure; storage/preservation and decontamination procedures are followed if necessary. Each sample will be submitted for analysis using sample control and documentation procedures (EMP-QA-S and EMP-QA-SD). Samples are analyzed by outside contract laboratories in accordance with our procurement contract.

Required equipment calibration will be performed before use according to EMS procedure EMP-GW-CA.

Action levels have not been determined at this time since the sampling network and effluent limitations have not been established. The objective of all compliance monitoring is to demonstrate compliance with permitted limits. The effluent limitation will be critical in establishing action levels.

11.6 PREPARATION AND DISPOSITION OF REPORTS

11.6.1 Categorical Pretreatment

All monitoring results, as well as the current status of all the identified processes, are reported in the semiannual wastewater reports that are submitted to the Livermore Water Reclamation Plant every January and July (e.g., Grayson and Brigdon 1993) as required in Part 2A of the LLNL Wastewater Discharge Permit #1250(93-94). LLNL has complied with the reporting requirements in this permit since before December 1993. However, with verbal agreement from the LWRP and pending written concurrence from EPA, LLNL has not submitted the semiannual point-source wastewater reports for the monitoring periods subsequent to November 1993 (the December 1993-May 1994 report).

11.6.2 Cooling Towers

Monitoring results must be submitted to the RWQCB by the 20th day of the month following the end of each calendar quarter, and an annual report that

includes the sampling results and observations must be submitted by July 30 of each year.

In addition, when noncompliance with any permit condition is known, it must be verbally reported within 24 hours, followed by a written report within 5 days unless waived by the RWQCB. The written confirmation must include the nature, time, duration, cause of the noncompliance, and description of any measures taken to remedy it and to prevent its recurrence.

DOE Occurrence Reports are required when a permit condition is violated and results in a non-routine report to the RWQCB.

The cooling tower monitoring results are summarized and discussed in the compliance monitoring section of the annual Environmental Report.

11.6.3 Monitoring Associated with Building Drain Repair

Information on the characterization sampling gathered for Site 300 was included in the *Non-Storm Water Technical Report*. This report was required by the Central Valley RWQCB. Similar information gathered at the Livermore site will be included in the NPDES permit application. The BDR project provides input to several other reports, including the Environmental Report and the Storm Water Annual Reports for both the Livermore site and Site 300.

If a monitoring and reporting program is required, sampling and analysis information will be reported as required by the RWQCB.

11.7 COMPARISON TO EXISTING MONITORING

11.7.1 Categorical Pretreatment

11.7.1.1 Short-Term Changes

Immediate short-term changes consist of better focusing LLNL resources on wastewater generating processes that have the capability to impact water quality. With the verbal agreement of both the LWRP and EPA in October 1993, LLNL has shifted the focus of its pretreatment program from the categorical standards (40 CFR 403.6) to a less process-specific, more general pretreatment effluent control posture. The basis for this shift in emphasis is concurrence between LLNL, LWRP and EPA that the categorical standards were not intended for, nor applicable to, R&D facilities. This agreement on the non-applicability of the categorical standards to R&D facilities should not, however, be viewed as a basis

to neglect those standards. The agreement will likely contain caveats regarding the applicability of the categorical standards to "user facilities." This term is currently in popular use throughout LLNL as plans continue to be formulated for new programmatic endeavors that include cooperative agreements with non-DOE organizations. As of yet, a strict definition of "user facility," as it would apply to compliance with categorical standards, has not been determined. Until that definition is complete and agreed to, LLNL would expect some minimal level of continued compliance with the categorical standards to those types of facilities.

Beginning with the December 1993–May 1994 monitoring period, LLNL and the LWRP have ceased categorical process inspection, compliance sampling and reporting. Negotiations with EPA Region IX are still proceeding regarding future requirements.

11.7.1.2 Long-Term Changes

In the long term, the most important goal will be to maintain a high level of effluent discharge control with full compliance under the appropriate regulatory standards. Future resources will be better focused on those wastewater-generating activities that have the greatest potential to affect water quality.

11.7.2 Cooling Towers

The primary change under consideration at this time is the installation of flow meters to minimize the personnel time required to collect biweekly flow measurements. The flow meters would also give accurate flow readings, as opposed to the estimated flow measurements now being utilized. The expense of their installation appears to be justified. On the other hand, installation of flow meters at the 14 towers that will likely not require sampling after December 1994 is not justified. If the RWQCB requires flow measurement for discharges into percolation pits, the need for flow meters at the 14 towers will be reevaluated.

11.7.3 Monitoring Associated with Building Drain Repair Project

Since the monitoring program has not been established, we do not have any recommended changes. The monitoring program, if required by the RWQCB, will draw upon the methods and findings of the characterization sampling and other compliance networks. As with all EMS monitoring programs, this network will be assigned to an environmental analyst who will be responsible for periodically assessing the network and recommending changes.

12

Soil Monitoring

12.1 RATIONALE AND DESIGN CRITERIA

12.1.1 Regulatory Drivers

Soil and sediment are specifically mentioned in DOE monitoring guidance (U.S. Department of Energy 1991) as environmental media that should be analyzed to determine the impacts of facility operations. Soil is an integrating medium that can contain pollutants originally released directly to the ground, to the air, or through liquid effluents. U.S. DOE (1991) 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."

Sedimentary materials also can accumulate contaminants. According to U.S. DOE (1991), "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...." Sampling and analysis of sediments can be a more sensitive indicator of waterborne radionuclides than direct water sampling because of the potential accumulation of contaminants. (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 settled out of a liquid stream in an arroyo or other drainage for storm water. In a geologic sense, all Livermore-site soils are sediment.)

Contaminated sedimentary materials are regulated by a number of number of federal laws, e.g., the Comprehensive Emergency Response, Compensation, and Liability Act (CERCLA), the Resource Conservation and Recovery Act (RCRA), the Clean Water Act, the Toxic Substances Control Act, the Oil Pollution Act. These laws generally address cleanup of contaminated sediments and do not yet specifically address routine sediment monitoring. However, EPA is developing a *Contaminated Sediment Management Strategy* (U.S. Environmental Protection

Agency 1994). Part of the scope of this strategy is to develop sediment quality criteria, which may be adopted as State water quality standards and used to set National Pollution Discharge Elimination System (NPDES) permit limits.

No specific regulations or guidance 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 organic compounds and that soils samples should be evaluated for beryllium content and compared to background.

12.1.2 Monitoring Objectives

As stated above, the primary purpose of soil and sediment surveillance monitoring is to evaluate the long-term accumulation trends and to estimate environmental radionuclide inventories. DOE monitoring guidance specifies that nuclides in use at the facility, as well as naturally occurring nuclides, should be monitored. In particular, the guidance states that "it is desirable to assess, document, and periodically reassess the distribution and fate of radionuclides in the environment, especially plutonium in soil samples."

The most significant pathway of soil contamination, barring direct contamination by dumping—which is prevented by administrative and management controls—is deposition of materials from the air, whereas the pathway for sediment contamination is a combination of deposition from the air and from water. Consequently, a surveillance soils monitoring program will address the surface of the soil, from which materials can be resuspended and inhaled. However, it should be considered that when air monitoring is carried out routinely, soil sampling plays a supplementary role in a monitoring program (Hardy and Krey 1971).

12.1.3 Potential Sources and Contaminants

At the Livermore site, the major potential sources of radionuclides are Building 332, the Plutonium Facility; Building 331, the Tritium Facility; the southeast quadrant, with low levels of plutonium that can be resuspended; and waste management storage areas, from which materials can be resuspended. At Site 300, the primary radionuclide of concern for surveillance of ongoing activities is

depleted uranium, which is currently used in explosive tests and which is a surface soil contaminant from tests in the past (Webster-Scholten et al. 1994).

Soil contaminants can be both solids and liquids. Plutonium, uranium and nonradioactive metals are particulate contaminants; tritium and organic contaminants of concern are liquid. Both solid and liquid materials can fall out of the atmosphere or can be scoured from the atmosphere and transported by rainfall.

Annual emissions of nonradioactive toxic air contaminants have been estimated in the EIR/EIS (U.S. Department of Energy and University of California 1992). Two tables from that document (Tables 5.1.8-1 and 5.1.8-2) are reproduced here as Tables 12-1 and 12-2. If these materials are released and then deposited in sufficient quantities, they can be a source of soil contamination.

Table 12-1. Annual emissions estimates of toxic air contaminants for baseline conditions and increase by tenth year, Livermore site.

Contaminant	Baseline condition annual amount (lb/year)	Assumed increase by tenth year (lb increase)
Chlorine	675	61
Ethylene glycol ethyl ether acetate	212	19
Fluorocarbons	28,770	2,589
Glycol ethers (other)	24	2
Hydrogen fluoride	<0.1	0.01
Methanol	1,230	111
Toluene	274	25
1,1,1-Trichloroethane	16,270	1,464
Xylenes	117	11
Benzene	196	18
Carbon tetrachloride	493	44
Chloroform	633	57
Dioxane (1,4-)	161	14
Ethylene dichloride	<1	0.1
Formaldehyde	35	3
Methylene chloride	738	66
Trichloroethene	728	66

Table 12-2. Annual emissions estimates of toxic air contaminants for baseline conditions and increase by tenth year, Site 300.

Contaminant	Baseline condition annual amount (lb/year)	Assumed increase by tenth year (lb increase)
5 Boilers/Diesel Fuel		
Arsenic	0.43	0.039
Beryllium	0.026	0.002
Cadmium	0.11	0.010
Chromium	0.014	0.001
Copper	2.9	0.261
Formaldehyde	4.2	0.378
Lead	0.092	0.008
Magnesium	0.27	0.024
Mercury	0.031	0.003
Nickel	1.8	0.162
Polyaromatic hydrocarbons	0.23	0.021
Fuel Dispensers, Gasoline		
Dispensers	110.7	9.963
Tank Loading	968.5	87.165
Spray Booths		
Glycol ethers	117	10.530
Toluene	40	3.600
Xylene	11	0.990
High Explosive Detonation, 801, 850, 851		
Ammonia	20.9	1.881
Benzene	0.18	0.016
HCl	7.3	0.657
HCN	3.9	0.351
HF	26.5	2.385
Polyaromatic hydrocarbons	0.000003	0
Toluene	0.3	0.027
High Explosive Metals		
Beryllium	0.31	0.028
Nickel	0.42	0.038
Cooling Tower		
Chloroform	0.12	0.011
Sodium hydroxide	13.3	1.197

...continued

Table 12-2. Annual emissions estimates of toxic air contaminants for baseline conditions and increase by tenth year, Site 300 (concluded).

Contaminant	Baseline condition annual amount (lb/year)	Assumed increase by tenth year (lb increase)
Limited Chemistry Lab		
Ethylene dichloride	1	0.090
Fluorocarbons	3.9	0.351
Methylene chloride	55	4.950
Toluene	0.36	0.032
Drinking Water Chlorination		
Chlorine hydroxide	15	1.350
Cold cleaning		0
Freon 113	721	64.890
Vapor Extraction System		
Trichloroethene	8	0.720
Refrigerants		
R12	145	13.050
R13	80	7.200
R22	375	33.750
R113	66	5.940
R502	100	9.000
R503	70	6.300
Automotive Parts Cleaning		
Cresol	1.8	0.162
Methylene chloride	4.8	0.432
Linear Accelerator X-Ray Equipment		
R12	580	52.200

12.1.4 Suitable Collection Methods

There are three general methods for collecting soils samples: core, template, and trench. The core method uses a coring tool to take samples of a standard volume and depth; it usually involves taking a number of samples to represent one sampling location. The template method is used where the presence of rocks makes it impossible to collect samples using the coring method; a square cold-rolled steel template, 20 or 30 centimeters on the inner edge, is used to mark an area that is excavated to the appropriate depth with chisels and scoops. The trench method is used to establish a depth profile; a trench about 60 centimeters wide by 90 centimeters long by 60 centimeters deep is dug and samples are taken

by pressing a three-sided square pan with cutting edges on the open side into the face of the trench.

The coring method is the preferred method for collecting surface samples from soil; the sample is taken sufficiently deep to obtain 90% to 95% of airborne material, as determined by previous soil profiles to 30 centimeters deep, and the results are reproducible (Environmental Measurements Laboratory 1990). EMS 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 technician chooses two 1-meter-square areas from which to collect the sample. Surface vegetation is cleared away from the sampling area, and a stainless steel core sampler (8.25-centimeter diameter), designed at LLNL, is driven into the ground to a depth of 5 centimeters for each subsample. The sample is a composite consisting of ten subsamples collected individually, at the four corners and the center of each square (EMS procedure EMP-S-S).

The coring method is also used to collect sediment samples. For particulate radionuclide analysis, the sediment samples are collected the same way as soil samples, except the ten subsamples are taken from 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 from one core of the transect.

12.2 EXTENT AND FREQUENCY OF MONITORING AND MEASUREMENTS

12.2.1 Criteria for Selecting Sample Locations

12.2.1.1 Soils

Choices of soil sampling locations are based on the following criteria: (1) proximity to LLNL and the potential for being affected by LLNL operations from wind deposition of contaminants, (2) background locations with geologically similar substrates as those near LLNL, but unlikely to be affected by LLNL operations, (3) areas of known or suspected LLNL-induced contamination, and (4) proximity to an air sampling location to enable analysis of resuspension. Specific sampling locations are chosen to represent certain geographical areas. Frequently tilled or disturbed areas, locations near buildings or other obstructions, or areas with unusual wind or precipitation influences are avoided because samples are taken to be representative of the geographical area. Practical

considerations also influence selection of sampling locations. The use of private property is discouraged because when private owners change, attitudes toward sampling may also change. Also, private property may be developed, rendering the location no longer useful.

Government installations (federal, state, city, regional) can be good sources of sampling locations as long as appropriate arrangements are made and development does not occur on the property; this will enable evaluation of long-term trends. Other considerations for sampling locations include access during inclement weather, and personnel safety in vehicle operation or sample collection.

For the Livermore site, seven sampling locations are positioned around the site perimeter, four sampling locations are 1 to 5 kilometers from the site (with two locations in a generally downwind direction), and four sampling locations are 5 to 10 kilometers from the site, representing background locations. Six more samples are taken in the Livermore Valley at the

Livermore Water Reclamation Plant; an estimated 32-mCi plutonium release to the sewer in 1967 resulted in local contamination of the area around the plant. Fourteen sampling locations at Site 300 are taken near active or historic experimental test sites and at locations on site representing background. The soil sampling locations are shown in Figures 12-1 and 12-2; specific location descriptions are found in the EMS procedure, *Soil and Arroyo Sediment Sampling Locations*, EMP-S-L.

Figure 12-1. Soil sampling locations, Livermore Valley.

Figure 12-2. Site 300 soil sampling locations.

No set number of sampling locations are required. Sufficient sampling locations have been established so that long term trends and differences between background and closer locations can be found. The two generally upwind perimeter locations L-MET and L-MESQ, may not both be necessary, but both are air particulate monitoring locations. The soils analyst and air analyst will work together to evaluate the need for continued monitoring at both locations.

12.2.1.2 Sediment

The selection of sediment sampling locations are based on the following criteria: (1) an influent or effluent point of an arroyo or storm drainage channel, or (2) a location where sediment collects in large volume, or (3) a location that drains an

area potentially affected by ongoing operations. Other considerations include access to the location, and the use of the location as a storm water sampling point so data comparisons can be made.

Sediment samples are currently taken at seven locations around the Livermore site: three locations are influent points, two locations are effluent points, and two locations are in settling basins that precede drainage into the Central Drainage Basin. The sediment sampling locations are shown in Figure 12-3; specific location descriptions are found in the EMS procedure, *Soil and Arroyo Sediment Sampling Locations*, EMP-S-L. Sediment samples are not taken at Site 300; the need

Figure 12-3. Arroyo and drainage basin sediment sampling locations.

for such sampling, including appropriate analytes and locations, will be evaluated when sediment quality criteria are developed by EPA.

12.2.2 Sampling Frequency

Soil and sediment sampling is conducted annually, as recommended by U.S. Department of Energy (1991) for sampling that is conducted for determining trends. Statistical analysis shows that biennial sampling would also be sufficient to establish trends in local conditions. Nonetheless, to assure sampling technician knowledge of the sampling network, annual sampling will be maintained. Soil and sediment sampling is generally conducted in the same month from year to year.

12.2.3 Analytes

The radiological analytes of interest for the Livermore site are plutonium and tritium. All soil and sediment samples are analyzed for plutonium, and sediment samples, because they are taken in locations that channel water on the site, are also analyzed for tritium.

The radiological analytes of interest at Site 300 are the isotopes of uranium, especially ^{238}U and ^{235}U , and the ratio of these values in a given sample. Depleted uranium, i.e., natural uranium depleted of much of the ^{235}U , has historically been and is currently used in experimental tests at Site 300. The variation of the sample ratio of $^{235}\text{U}/^{238}\text{U}$ from the natural ratio of 0.7% gives an indication of the impact of operations on the site.

Nonradiological analytes currently include beryllium at the Livermore site and Site 300, and heavy metals and organic compounds in sediments from operations at the Livermore site due to the possibility of accumulation of these materials in storm water channels at the site. These analyses were initiated when conditions indicated the need for them. However, only a few operations currently use beryllium at the Livermore site, and an extensive study of sediments (Gallegos, 1994) and the continuing study of soils through restoration activities have made it more clear that the nonradiological impact on soils is minimal.

Beryllium is only used in three buildings at the Livermore site: Buildings 231, 235 and 320. The LLNL rules for safe handling of beryllium as stated in the *Health and Safety Manual*, Supplement 21.10, "Safe Handling of Beryllium and Its Compounds," require that any operation creating beryllium particles be "done wet" and in a fume hood whenever possible. More important, "Exhaust from any Be-processing operations that could produce airborne particulates will be vented

outdoors through an approved high-efficiency particulate air (HEPA) filter." It is very unlikely that sufficient quantities of beryllium will be emitted to the atmosphere and deposited in amounts measurable in soil. In fact, the beryllium soils measurements for the past four years for both on-site and off-site locations follow a single lognormal distribution, which indicates no contamination. In addition, air sampling results since 1989 for beryllium at the Livermore site also follow a single lognormal distribution. Finally, because the major toxic action of beryllium occurs through inhalation, and because results from beryllium in air monitoring are two orders of magnitude smaller than the Occupational Safety and Health Administration standard of $2\text{-}\mu\text{g}/\text{m}^3$, 8-h time-weighted average, further analysis of Livermore site or Livermore Valley soils for beryllium will be discontinued.

Beryllium is used in explosive tests at Site 300. To date, only one surveillance soil sample result has shown levels above background. 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 they are obtained in that footprint. In addition, not all beryllium in the test shot becomes part of the explosive cloud (Baskett, 1994). Samples at Site 300 will continue to be analyzed for beryllium, pending the evaluation of whether such sampling can measure the impacts of operations.

As to sediment sampling for heavy metals and organic compounds, the rationale for this sampling was to determine whether historic laboratory operations had affected sediments. The placement of sampling locations and lack of significant results in five years shows there was no measurable systematic general contamination of drainages on site. In addition, a large-scale investigation of the storm drainage system also did not reveal any systematic contamination. Other sampling conducted by LLNL has identified, and will continue to be used to identify, smaller areas of contamination. These sampling efforts include the sampling and analysis of every well dug for restoration purposes (there are more than 400 wells on the Livermore site), and the preconstruction sampling conducted whenever soil is removed or replaced as part of a construction effort.

Because soils are heterogeneous and because any impacts of current operations would likely be small (see **Tables 12-1 and 12-2**, and U.S. Department of Energy and University of California 1992), the few sediment sampling locations would most likely not indicate whether there were impacts or not. If airborne nonradio-

logical materials were of concern, then appropriate air monitoring should be conducted; this is more direct and more reliable. Other reasons for continuing this sampling effort, such as determining impacts on surface water or ground water, are not sufficiently supported by this effort to justify continuation. Ground water and surface water are measured directly and extensively, so any knowledge gained from sediment sampling would be secondary. The EPA sediment quality criteria, when they are developed, will serve as a guideline for the need for sediment monitoring; however, LLNL may not have sufficient levels of contaminants in sediment to be regulated. Finally, sediment release is regulated under the storm water pollution prevention plan limits for total suspended solids. For all these reasons, it is recommended that the surveillance of sediments for metals and organic compounds be suspended until EPA develops the sediment quality criteria and sediment monitoring is evaluated in light of those criteria.

12.3 PROCEDURES FOR LABORATORY ANALYSIS

Radiological analyses for soil and sediment samples are completed by Radiation Analytical Sciences. Soil samples are sent to California Laboratory Services (CLS) for beryllium analysis. If nonradiological analyses are continued for sediments, the metals analysis will be conducted by CLS and the organic compound analyses will be conducted by Environmental Analytical Sciences, an internal laboratory. See Chapter 16, Procedures for Laboratory Analysis, for details of laboratory procedures.

12.4 QUALITY ASSURANCE REQUIREMENTS

12.4.1 Data Quality Objectives

12.4.1.1. Precision

The detection limits for radionuclides in soils are as follows:

Radionuclide	Detection Limit (Bq/g)
$^{239+240}\text{Pu}$	1.0×10^{-6}
^{137}Cs	1.0×10^{-4}
^{238}U	1.0×10^{-2}
^{235}U	5.0×10^{-3}
^{232}Th	1.0×10^{-3}
^{40}K	1.00×10^{-1}
^3H	1.0×10^{-1} (Bq/L of extracted moisture)

The detection limit for beryllium in soils is 0.05 mg/kg.

The ^{238}U detection limit is not met by gamma spectroscopy, which is the current analytical method for uranium in soils. Alternative analytical methods will be examined to see if the detection limit can be met. A lower detection limit would be advantageous because impacts of LLNL operations at Site 300 are determined, in part, by the ratio of ^{235}U to ^{238}U . When the ^{238}U value is less than the detection limit, this ratio cannot be calculated.

Field duplicate samples are submitted with each batch of soil samples in accordance with EMS procedure EMP-QA-S. At locations chosen for duplicate samples, two identical samples are collected. Adjacent cores are collected from the corners and 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-gram 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 the analytical laboratory does not know where the samples originated (EMS procedure EMP-QA-SD). However, this information is recorded on Field Tracking Forms, which are filled out in the field by the sampling technician and contain detailed information about actual sampling locations and other conditions affecting sampling. Approximately 10% 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 objective is to have the average ratio between 0.7 and 1.3. If the average is not within this range, the data are first examined for transcription errors, then the 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 Needs Changing Report (NCR) to document the actions taken.

Laboratory duplicates (also called splits) are created by the laboratory. These are created following technical implementing procedures (Hall and Edwards 1994) and are introduced blind into the sample processing at a rate of about 10% of samples. Samples outside $\pm 20\%$ of the mean of the ratio of the sample to its split constitutes a warning level and samples outside $\pm 30\%$ of the mean of the ratio constitutes an action level. An investigation for probable cause shall be initiated when any a single data point falls outside of the action level, two consecutive

data points fall outside a warning level, or five consecutive points fall on one side (i.e., either all "+" or all "-") of the mean of the ratios.

12.4.1.2. 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 soils sample from NIST are very expensive, on the order of \$10 a gram. Because about 300 grams per sample are needed, this 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; however, it may be possible to create a field spike from blank materials and this possibility will be explored.

The radiological laboratory does run blank and control 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 two laboratory intercomparison studies: the U.S. EPA Environmental Monitoring Systems Laboratory Intercomparison Program, and the DOE Environmental Measurements Laboratory Quality Assurance Program. In these studies, the federal agency sends samples with known amounts of radionuclides to the participating laboratories and compares the analytical results, thereby determining the accuracy of the various participating laboratories, and publishes reports of the results so the analytical laboratory personnel can see their relative performance.

12.4.2 Laboratory Audits

All analytical laboratories (both LLNL laboratories and off-site contract laboratories) that perform analyses for these networks are scheduled for auditing each year (EMP-QA-A). These audits allow EMS to assess the capabilities of the laboratories. Audits and inspections of EMS operations are performed by the Environmental Protection Department QA Office. Annual self-assessments are also performed by the EMS QA Coordinator at the direction of the EMS Section Leader (EMP-QA-SA).

12.5 PROGRAM IMPLEMENTATION PROCEDURES

The soils and sediment samples are collected by EMS technicians following the written procedures, EMP-S-L, *Soil and Arroyo Sediment Sampling Locations*, and EMP-S-S, *Soil and Arroyo Sediment Sampling*. The locations are marked with permanent location markers, which enable EMS Technicians to readily locate the same sampling location from year to year. The written procedures include requirements for sample collection and submittal for chemical analysis, keeping a log, and filling out field tracking and chain-of custody forms. The procedures also require the technicians to alert the environmental analyst about difficulties encountered during any sampling event.

Before handling any samples, sample collectors put on clean, disposable vinyl gloves so the sample will not become contaminated. New gloves are worn at each sampling location. Samples are double-bagged to avoid sample contamination, and sampling equipment is washed with deionized water between sampling events. After decontamination, the sampling equipment is kept in a clean plastic bag to avoid subsequent contamination.

All samples are taken at locations described in the sampling procedure and marked with permanent markers. In general, three sampling procedures are used. The first is to take surface composite samples. To collect samples for radionuclide analysis, a stainless steel coring device 8.25 centimeters in diameter is used to take ten 5-centimeter-deep samples at the center and the four corners of two 1-meter squares laid out by the sampling technician near the permanent marker. The technician notes the direction and distance from the sampling marker in the log book, to enable replication, if necessary. The second is for the collection of arroyo and drainage channel samples for radiological analysis; a transect is laid in the channel, and ten 5-centimeter-deep samples are collected along the transect. The third is to collect single point samples 5-centimeters deep, using the coring tool, for analysis for tritium, metals, and organic compounds.

To deter analyte evaporation, tritium samples and samples for organic compounds are chilled in the field and kept cool until delivered to the analytical laboratory.

The environmental analyst designs and maintains the networks; schedules the sampling; determines analytes, collection methods, and analytical methods; evaluates the accuracy, precision, technical validity and overall quality of data; communicates and coordinates network activities with sampling technicians and

analytical laboratory personnel; reviews and analyzes the data; and reports the results.

Sample results are compared to the running geometric mean for lognormally distributed materials such as ^{239}Pu , ^{137}Cs , ^{235}U , ^{232}Th , and beryllium. (Results for naturally occurring and fallout materials are examined as an indicator of general problems with the gamma analysis.)

The running geometric (or arithmetic for ^{40}K) mean and standard deviation for radionuclides in soils are as follows:

Radionuclide	Mean (Bq/g)	Standard deviation
$^{239+240}\text{Pu}$	1.28×10^{-4}	2.86
^{137}Cs	5.74×10^{-3}	2.34
^{238}U	3.30×10^{-2}	1.5
^{235}U	1.80×10^{-2}	1.3
^{232}Th	2.45×10^{-2}	1.24
^{40}K	4.56×10^{-1}	0.102
^3H	1.98×10^{-1} (Bq/L)	3.68

The running geometric mean and standard deviation for beryllium is 0.63 and 2.0.

Any results 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 ^{40}K , the results are compared to a running arithmetic mean and standard deviations, with the same warning and action levels. When no transcription, analytical, or other error is found to explain an out-of-limit value, the analyst notifies management of this in writing following the NCR (Needs Changing Report) procedure (EMP-QA-NCR) and further action is taken with management concurrence.

12.6 PREPARATION AND DISPOSITION OF REPORTS

The monitoring results are analyzed after all the results for the calendar year are obtained. The results are reported in the annual Environmental Report (EMP-QA-AER). There is no other required reporting for soils and sediment data.

12.7 SHORT- AND LONG-TERM PLANS

Short-term plans for soil and sediment monitoring are to discontinue plutonium analysis for Site 300 soils, to discontinue beryllium monitoring for Livermore Site soils, and to discontinue nonradiological monitoring for sediments. In addition, the need for sediment sampling at Site 300, including appropriate analytes and locations, will be evaluated. Finally, alternative methods to meet the data quality objectives for the analysis of ^{238}U will be examined. Sediment samples are not taken at Site 300.

Long-term plans are to follow the development of the EPA Contaminated Sediment Management Strategy to determine if sediment monitoring is appropriate, according to policies that will be established in the future.

13 Vegetation and Foodstuff Monitoring

13.1 RATIONALE AND DESIGN CRITERIA

13.1.1 Regulatory Drivers

Sampling and analysis of vegetation can provide information about the presence and movement of radionuclides in the environment. Vegetation and foodstuff also can be biological end points for pollutants originally released to the soil, to the air, or through liquid effluents. Affected vegetation and food can be directly ingested by humans or can indirectly affect human consumers who ingest foodstuff from animals that have consumed contaminated vegetation.

Terrestrial foods are specifically mentioned in *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) as appropriate for surveillance sampling and analysis, even if the potential annual effective dose equivalent from ingestion is below 1.0 mrem; in that case, the guidance prescribes sufficient surveillance monitoring to be carried out to determine if the radionuclides are behaving in the environment as expected. The DOE guidance also calls for pathway analyses and mentions the need for analyses of milk and other representative samples of the pathway-significant agricultural products grown in the proximity of the site (within 16 kilometers). Furthermore, it states that "periodic sampling and analysis of indicator materials, such as soil or vegetation, should be performed to determine if there is measurable long-term buildup of radionuclides in the terrestrial environment."

No other regulatory requirement for vegetation or foodstuff surveillance monitoring has been identified. However, explicit regulatory requirements are not the sole basis for monitoring. Monitoring is also carried out where there is a high level of public interest or concern, or where best management practices indicate monitoring is appropriate. In the past, much public interest, as evidenced by newspaper and television coverage, has existed concerning tritium in wine. Because of that interest, and because consumer products have a potential contribution to radiological doses, LLNL has analyzed more wine samples at more sensitive detection levels than might otherwise be required.

13.1.2 Monitoring Objectives

The primary purpose of vegetation and foodstuff surveillance monitoring is to evaluate the dose to people from radionuclides taken up by the vegetation or foodstuff. Secondary purposes are to conduct pathway analyses, to evaluate long-term accumulation trends, and to estimate environmental radionuclide inventories.

Vegetation and foodstuff monitoring could also include monitoring for nonradiological materials. The impact, if any, of the release of nonradiological materials from LLNL operations on vegetation will be investigated, and appropriate monitoring will be determined after the investigation is complete.

13.1.3 Potential Sources and Contaminants

At the Livermore site, the major contributors of airborne tritium emissions are Building 331 and associated operations, Building 612 yard, and Building 282. The major contributors of airborne uranium emissions are Building 321 and operations associated with Building 514. At Site 300, the primary radionuclide of concern for surveillance of ongoing activities is uranium, which is used in tests at the site. In addition, tritium from historic operations is also present at Site 300.

Tritium is the nuclide of major interest in the EMS vegetation and foodstuff monitoring program because LLNL releases tritium to the air in the course of routine operations, and because tritium has the propensity to move into the environment as tritiated water. Once in the environment, tritium (as tritiated water) can be easily assimilated into vegetation and foodstuff. The tritium can then be ingested directly or indirectly and can therefore contribute to human radiation dose burdens.

Plutonium and uranium are not of concern in vegetation surveillance monitoring because they are only slightly soluble, leading to minimal plant uptake. Healy (1974) states: "Plutonium is only slightly absorbed from the GI tract when ingested.... In rats, chronic ingestion at low mass concentrations of [plutonium] nitrate resulted in an average uptake of 0.0003% of that fed with 90% of the small fraction which was absorbed deposited in the skeleton." Inhalation of these radionuclides is a much more significant environmental pathway, and the air is monitored for these radionuclides. (See also Chapter 4 on Air Effluent Monitoring, Chapter 6 on Air Surveillance Monitoring, and Chapter 18 on Dose and Risk Assessment.)

Collection methods vary by the types and parts of vegetation and foodstuff monitored. Vegetation samples of local grasses consist of green leafy material; roots are not included in the sample because they would not be representative of the parts ingested by foraging animals. Vegetation samples of local produce include leafy and edible parts. Milk and honey samples historically have been collected directly from their sources, i.e., owners of the cows, goats, or bees. Wine is purchased at retail stores.

EMS currently monitors native grasses, locally produced vegetables, and wine samples. Increasing development of the Livermore Valley has resulted in fewer dairy animals, so now neither cow nor goat milk is available for sampling (Gallegos et al. 1994). Honey also is no longer sampled due to the difficulty of obtaining samples from bees kept only in the Livermore Valley, and because the calculated dose to people ingesting honey at the tritium values measured here is extremely low (Gallegos et al. 1994).

13.2 EXTENT AND FREQUENCY OF MONITORING AND MEASUREMENTS

Tritium, the most likely and important LLNL effluent in the context of vegetation and foodstuff impacts, is the primary analyte monitored. Seasonal variability for vegetation is addressed through quarterly sampling. (Samples had been collected monthly in the past, but the data were not sufficiently variable to continue monthly sampling.) Seasonal variability is not an issue for wine because it is an agricultural product that is produced once a year.

13.2.1 Vegetation

For all native vegetation samples, the Environmental Analyst avoids selecting frequently tilled or disturbed areas, or locations near buildings or other obstructions, to assure that the sample is representative. The selected areas are unshaded and exhibit native vegetation for much of the year. Areas with unusual wind or precipitation influences also are avoided. Practical considerations also temper sampling location selections. If a location is chosen on private property, a written access agreement is required. Government installations (federal, state, city, regional) can be particularly good sources for sampling locations because they have the benefit of stable ownership, which is useful in making any required arrangements. Other considerations include access during inclement weather, and personnel safety in vehicle operation or sample collection.

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 sampling locations is presented in EMS procedure EMP-VG-L. All native vegetation sampling locations are marked with permanent location markers. All vegetation and foodstuff sampling, regardless of location, is conducted according to procedure EMP-VG-S.

The vegetation locations for the Livermore site comprise three groups (see Figure 13-1). The first group, "Near," includes locations at or within 1 kilometer of the Livermore-site perimeter (AQUE, GRD, RAIL, MESQ, MET, and VIS). Location GRD was only recently added; it is the on-site recreational garden and is sampled for leafy and edible portions of plants. The "Intermediate" group

Figure 13-1. Livermore Valley vegetation sampling locations.

consists of locations in the Livermore Valley, removed from the site (1 to 5 kilometers 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, "Background," represents locations unlikely to be affected by LLNL operations. Three background locations (MOD, DAN, CAL) are more than 25 kilometers away; the other two (FCC, PARK) are in the Livermore Valley, but are greater than 5 kilometers from the Livermore site and are generally upwind so they are unlikely to be affected by LLNL operations. Two of the more distant locations, MOD and DAN, will not be sampled after calendar year 1994. These locations are no longer necessary because the differences between the intermediate and background locations have become insignificant, and the remaining background locations are adequate for surveillance purposes.

For Site 300, most sampling locations represent background; the analytical results for these locations are indistinguishable. The single location having higher than background results is location DSW (see Figure 13-2; Gallegos et al. 1994). Tritium has been observed in the vegetation of the DSW sampling location since 1971; it is in an area presently being investigated under CERCLA for tritium contamination of ground water. This sampling location is adjacent to a landfill that contains debris contaminated with tritium from past experiments (tritium is no longer used). The landfill area is under continued investigation for soil and ground water tritium, as described in reports published as part of LLNL's Environmental Restoration Program (see, for example, Webster-Scholten et al. 1994). Recently, it was discovered that purge water from the sampling of ground water monitoring wells at this location has been released to the ground. This practice will be discontinued and LLNL will continue to monitor vegetation here to determine if this change affects tritium activities in vegetation samples.

The EVAP location historically has had higher than background tritium values for vegetation; however, these values have declined to background since the operations releasing tritium in this area were discontinued. Furthermore, because location EVAP has become inaccessible due to realignment work at Do-All Road, the location will be evaluated after construction is complete to determine if sampling is still appropriate. In addition, the area near Building 850, another potential source of tritium, will be evaluated to determine if samples can be taken in the area.

13.2.2 Wine

Wine is the most important agricultural product in the Livermore Valley, representing an approximately \$30-million annual industry. Data since monitoring began have indicated that although all tritium concentrations in all wines are low, Livermore Valley wines contain statistically more tritium than do their California counterparts. The annual wine sampling is an extremely sensitive issue because of the potential economic, political, and public relations effects the data may cause and because it involves the purchase and possession of alcoholic beverages on site at LLNL. Alcoholic beverage purchases by LLNL require approval by DOE, and alcoholic beverages are among the items generally prohibited on site. Therefore, the purchase of wine samples requires the special approval of both the Procurement and Security Departments (see procedure EMP-VG-S).

Wine samples of three types are collected and analyzed annually for tritium concentrations: wine produced from grapes grown in the Livermore Valley, wines produced from grapes grown in California (outside the Livermore Valley), and wines produced from grapes grown in Europe (France, Germany, and Italy). California and Europe are divided into 8 (excluding Livermore) and 13 wine-producing regions, respectively. European wines were initially chosen for evaluation because Europe is a significant wine growing region with historically high tritium content in wine from locations near nuclear power plants. The wine sampling regions are described in procedure EMP-VG-L. Wines from the non-Livermore regions serve as background samples for comparative purposes; the continued use of wines from Europe for this purpose is being examined. The use of wines from a number of regions provides better representation of background information because geographic variability of the wines is addressed. When the budget allows, one wine from each region is chosen yearly for analysis. In 1993, 12 estate-bottled Livermore Valley wines, one wine each from 6 of the 8 non-Livermore regions, and one wine each from 4 of the 13 European regions were analyzed.

13.3 PROCEDURES FOR LABORATORY ANALYSIS

Vegetation and foodstuff samples are sent to Radiation Analytical Sciences for radiological analyses. See Chapter 16, Procedures for Laboratory Analysis, for details of laboratory procedures.

13.4 QUALITY ASSURANCE REQUIREMENTS

13.4.1 Data Quality Objectives

Data quality objectives comprise the set of constraints on a given study. They include a specification of the level of uncertainty that the data user is willing to accept in the decision (Keith 1994).

13.4.1.1 Precision

The detection limits for radionuclides in vegetation and foodstuff are as follows:

Medium	Radionuclide	Detection Limit (Bq/L)
Vegetation	^3H	1.7×10^0
Wine	^3H	5.0×10^{-2}

Field duplicate samples are submitted with each batch of vegetation and foodstuff samples in accordance with procedure EMP-VG-S. Approximately 10% of samples are field duplicates. At locations chosen for duplicate samples, two identical samples are collected. The sampling locations of field duplicate samples are not identified on the samples, the sample identification tags, or vial labels, so the analytical laboratory does not know where the samples originated (procedure EMP-QA-SD). However, this information is recorded on Field Tracking Forms. 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, then the 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.

Laboratory duplicates (also called splits) are created by the laboratory. These are created following technical implementing procedures (Hall and Edwards 1994) and are introduced blind into the sample processing at a rate of about 10% of samples. Sample results for splits are compared to the running mean of the ratio of the results. Results outside $\pm 20\%$ are at the warning level, results outside $\pm 30\%$ are at the action level. The laboratory will investigate for probable cause when (1) a single data point falls outside of the action line, (2) two consecutive data points fall outside of a warning line, or (3) five consecutive points fall on one side of the mean (procedure TIP-RAS-001).

13.4.1.2 Accuracy

The radiological laboratory runs blank and control NIST-traceable samples. Vegetation is not very amenable to the creation of field blank and spike samples. It is virtually impossible to create a field blank that would not be immediately obvious to the analytical staff. Field spikes are also very difficult to prepare due to the difficulty of evenly dispersing any known amount of material in vegetation. An air silica gel blank is run as a field blank. To create a laboratory vegetation spike, a sample of vegetation from outside the immediate monitoring area is obtained, desiccated, and evenly ground, sieved, and mixed. Then the sample is spiked with a NIST-traceable standard.

A controlled cask of wine from a location removed from the monitoring area is used as the wine blank. Wine spikes are prepared from the wine blank by adding a known amount of a NIST-traceable standard solution.

The radiological laboratory also participates in two laboratory intercomparison studies: the U.S. EPA Environmental Monitoring Systems Laboratory Intercomparison Program, and the DOE Environmental Measurements Laboratory Quality Assurance Program.

13.4.2 Laboratory Audits

All analytical laboratories that perform analyses for these networks are scheduled to be audited each year (procedure EMP-QA-A). These audits allow EMS to assess the capabilities of the laboratories. Audits and inspections of EMS operations are performed by the Environmental Protection Department QA Office. Annual self-assessments are also performed by the EMS QA Coordinator at the direction of the EMS Section Leader (procedure EMP-QA-SA).

13.5 PROGRAM IMPLEMENTATION PROCEDURES

The responsibilities for activities required by the sampling networks are well defined. The primary responsibility is assigned to the Environmental Analyst, who designs and maintains the networks; schedules the sampling; determines analytes, collection methods, and analytical methods; communicates and coordinates network activities with sampling technicians and analytical laboratory personnel; reviews and analyzes the data; performs dose assessments; and reports the results. This placement of responsibilities with one individual provides excellent accountability.

Sample collection methods are standardized in procedures and are followed in the field. Specified containers are used, and storage/preservation and decontamination procedures are followed. Vegetation and foodstuff samples are collected by EMS technicians according to procedure EMP-VG-S and are submitted for analyses using sample control and documentation procedures (EMP-QA-SL and EMP-QA-SD). This includes sample collection and submittal for chemical analysis, keeping a log, and filling out field tracking and chain-of-custody forms. It also includes alerting the Environmental Analyst as to difficulties encountered during any sampling event.

13.5.1 Vegetation

Vegetation samples usually consist of the green leaves and green stems of annual grasses. However, other herbaceous vegetation, or even perennial vegetation, may be sampled if grasses are not available. Approximately 0.5 to 1 kilograms of vegetation is required for analysis. Two bags of vegetation comprise a single

sample. One bag's vegetation is analyzed, and the other is archived by the analytical laboratory. Each vegetation sample is identified with a unique identifier based on location and date of sampling, which is maintained with the sample to final data reporting.

Before handling any samples, technicians put on clean, disposable vinyl gloves so the sample will not be contaminated. Shears (decontaminated with deionized water between samples) are used to trim the vegetation near the base of the plants. Any obviously dead leaves/stems are removed and any root material is trimmed and discarded. The samples are double-bagged to avoid sample contamination. A sample identification tag is attached to the outside bag. The sample bags are placed on dry ice in an ice chest and are kept frozen until analysis.

The sampling technicians record the distance and direction of the sampling location from the permanent sampling location marker. Other pertinent information about the sample, such as the species (if known) or generalized plant group (annual grass, herb, perennial shrub, tree, etc.) is also recorded. Standard chain-of-custody procedures outlined in EMP-QA-SD are followed.

13.5.2 Wine

All wines used in EMS sampling are purchased subject to general consumer availability. That is, they are purchased from local retailers in a variety of vintages. As such, resultant data can be used to provide information on the potential tritium dose received by the public during the year of purchase (and assumed consumption). However, wine sample data can be decay-corrected to its original tritium concentrations to determine trends and to help determine the impact of LLNL operations during that particular vintage year. Because of the importance of the wine sampling network, EMS samples and analyzes as many of the available Livermore Valley wines as possible.

A wine sampling plan is written each year by the Environmental Analyst and approved by the EMS Section Leader and analytical laboratory personnel. The wine sampling plan describes the number and types of wines to be collected for the annual study (including QC samples), and any special study samples. Quality control loads, including the desired number of duplicates, blanks, lab splits, and standards to be run are discussed. Analytical methods are described, including any anticipated method changes. The plan also states proposed dates for acquisition/submittal of samples, and for data delivery.

The wine sampling plan stipulates the purchase, at commercial wine outlets, of estate-grown wine produced in various geographic areas. For example, one wine each from six of the eight non-Livermore, California, wine growing regions and one wine each from four of the thirteen European wine growing regions are required by the 1993 sampling plan. Twelve samples of Livermore Valley estate wines not previously analyzed were purchased. The selection of samples from all the wines available within a geographic area is random. Any estate wine from a designated area is considered representative of that area. The most recent vintages available are collected, with an equal mix of red and white wines, if possible. In addition, other Livermore Valley wines not previously analyzed are purchased and archived for possible future analysis. Wine samples, purchased in 750 mL to 1 L bottles, are not opened by EMS personnel.

The wine samples are submitted to the Environmental Monitoring Radiological Laboratory unopened, to avoid airborne tritium contamination. Chain-of-custody procedures are followed when delivering samples (see procedure EMP-QA-SD). Wines are analyzed for tritium using ^3He mass spectrometry in the Nuclear Chemistry Noble Gas Mass Spectrometry Laboratory.

13.5.3 Data Analysis

Sample results are compared to the running historic geometric mean for lognormally distributed materials such as tritium. 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, the location is resampled, perhaps in duplicate or triplicate depending on the nature of the problem. When no transcription, analytical, or other error is found to explain an out-of-limit value, the analyst notifies management of this in writing following the Needs Changing Report (NCR) procedure (EMP-QA-NCR) and further action is taken with management concurrence.

13.6 PREPARATION AND DISPOSITION OF REPORTS

Dose assessments, based on the monitoring data and using methods detailed in procedure EMP-R-D, are conducted by the analyst for vegetation and wine once all data for a calendar year are obtained. The monitoring and dose assessment

results are reported in the annual Environmental Report (Sims et al. 1991; EMP-QA-AER). No other reporting is required for these media.

13.7 SHORT- AND LONG-TERM PLANS

The short-term plan for vegetation sampling is to assess location EVAP at Site 300 for whether it will still be an appropriate sampling location after the road alignment work is completed. The short-term plan for wine sampling is to assess the continued need for sampling European wines.

Long-term plans for vegetation monitoring are to assess the need for monitoring for nonradiological metals.

14

Radiation Monitoring

14.1 RATIONALE AND DESIGN CRITERIA

Radiological monitoring is used to establish background radiation levels in the vicinity of LLNL and to help determine the radiological dose impact of LLNL operations. DOE Orders 5400.1, *General Environmental Protection Program*, and 5400.5, *Radiation Protection of the Public and the Environment*, and California Code of Regulations Title 17, Article 1, Section 30250, *Health Standards for Protection Against Radiation*, all require radiological monitoring. DOE Order 5400.5 specifically requires that exposure to members of the public from radiation sources as a consequence of all routine DOE activities shall not be greater than 1mSv (100 mrem) each year. Compliance with this limit must be demonstrated through documentation of an appropriate combination of measurements and calculations to evaluate the potential dose. Similarly, the State of California's *Health Standards for Protection Against Radiation*, requires that protection to workers, the general public, and the environment during routine operations be demonstrated by means of measurements and documentation.

DOE's *Environmental Regulatory Guide for Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991) suggests methods for implementing radiological monitoring programs. This guide recommends thermoluminescent dosimeters (TLDs) for monitoring direct radiation at the fence line to document potential doses from DOE operations. LLNL's Environmental Monitoring Section has installed TLDs at the Livermore-site fence line to measure and document radiological exposures and to determine the resultant dose. LLNL's use of TLDs meets with the specifications required by the above-mentioned orders, regulations, and guidance. Specific TLD-related activities include annealing, calibration, readout, storage, and exposure periods that are consistent with American National Standards Institute (ANSI) recommendations.

In addition, because one of the greatest publicly perceived potential impacts of LLNL operations is public exposure to direct radiation from the use of radionuclides and accelerators, measurements of direct radiation exposure at public-access locations at the LLNL boundary, as well as in the surrounding public areas, are a Best Management Practice. LLNL's environmental radiological monitoring, which includes the evaluation of both gamma and neutron

exposures and resultant doses, is used to assess the potential radiation dose that members of the public could receive as a result of site operations, and therefore meets both regulatory requirements and public expectations.

14.1.1 Usage/Storage of LLNL Radiation Sources

Radiological operations that employ the use of gamma radiation sources in weapons and chemical research are housed in the southwest quadrant of the Laboratory in Buildings 131, 132, 151, 222, 231, 135, 243, 321, 332, 334, 335, and 343. In the southeastern quadrant of the Laboratory, Hazardous Waste Management conducts hazardous waste operations involving gamma radiation sources as waste. They are housed in Buildings 412, 514, 612, and 625. Laser research is conducted in the northwest quadrant of the Laboratory; the associated gamma radiation sources are housed in Buildings 164, 168, 171, 174, 177, 179, 190, 191, 194, 197, 298, and in the Building 390 Complex. Laser isotope separation is conducted in the northeastern quadrant of the Laboratory, with gamma radiation sources housed in Buildings 490, 491, 192, 193, and 494. Biomedical Research is conducted near the center of the Laboratory and gamma radiation sources are housed in Buildings 161, 174, 251, 255, 327, and in the Building 360 Complex.

Neutron sources (isotopes and accelerators) are located in the northwest quadrant of the Laboratory in Buildings 190, 194, 261, 292, 381, and 391. Much of the work in this area is associated with laser research.

It is necessary to reevaluate the storage/usage of gamma and neutron radiation sources as buildings, operations, and missions change, so that appropriate monitoring is performed. EMS analysts obtain information from four principal sources with respect to the use and storage of gamma and neutron radiation sources: (1) participation on Environmental Support Teams (see Chapter 4); (2) consultation with the Hazards Control Department regarding classification of Radioactive Materials Management Areas; (3) review of National Environmental Policy Act documentation for all new and modified operations (see Chapter 4); and (4) review of radioactive materials inventory forms collected as part of the National Emissions Standards for Hazardous Air Pollutants dose evaluation process (see Chapter 19).

14.1.2 Collection Methods/Devices

Penetrating radiation, which cannot be measured by collection of material on filters nor chemically trapped, is measured using radiation dosimeters. The

dosimeters measure the total amount of penetrating radiation—both natural background radiation and any radiation that has man-made origins—at a particular location. LLNL monitors two types of penetrating radiation: gamma radiation, using TLDs, and neutron radiation, using the modified Anderson-Braun passive rem-meter. Please note that both types of dosimeters measure radiation exposure (in milliroentgens). LLNL converts the measured exposure data to radiation dose by calibrating the dosimeters to read out in absorbed dose and then applying a quality factor for a beta/gamma radiation field (a more detailed discussion is found below in Section 14.3.2). The resulting dose equivalents (in millirems or milliSieverts) are compared to DOE Order 5400.5 radiation protection 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 ($\text{Li}_2\text{B}_4\text{O}_7$). Only the CaSO_4 components measure the gamma radiation because it is more sensitive to the low exposures historically seen at LLNL; the $\text{Li}_2\text{B}_4\text{O}_7$ component is too insensitive at these levels. The CaSO_4 element provides thirty times more light when read than other TLDs considered for use, making them an obvious choice for measurements in the milliroentgen range (converted to the single-digit millirem range).

The principle of operation for TLDs is the following: when certain crystals are exposed to gamma radiation, impurities in the TLD 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 LLNL Hazards Control Radiation Dosimetry Group heats the TLD in a three-phase process. When the TLD is heated, the electrons are released from the trapping sites, drop to a lower energy state and photons are emitted. The photons are measured with a photomultiplier tube with the light intensity proportional to the original absorbed dose of radiation. After the TLD is read, it is heated and read again. The second reading should be near zero, indicating that all of the stored energy has been released (and therefore measured). This process is referred to as annealing, and verifies that the TLD is ready for reuse in the field. Before field deployment, each TLD is heat-sealed in a 8.9 cm × 5.7 cm, 4.5-mm-thick foil pouch to protect against light and moisture.

The modified Anderson-Braun passive rem-meter is used to measure neutron exposure. The rem-meter is a track-etch detector that consists of a stainless steel foil with vapor-plated ^{235}U fissile material on one side and two 25-mm diameter

disks of 8- μ m-thick polycarbonate. Both polycarbonate disks are prepared by stretching them over a Lucite ring and are held in place with a steel clamp ring. The ^{235}U -plated stainless steel foil is sandwiched between them. The steel ring also encircles the foil, keeping the ^{235}U foil and one of the polycarbonate disks face to face. The complete assembly is inserted into a casing made of polyethylene. The polycarbonate disk designed to measure the ambient neutrons is placed approximately 0.13 centimeters from the ^{235}U foil so readings from spontaneous fission of the ^{235}U (which are not the result of ambient neutrons) will not be misinterpreted.

The rem-meter works on the principle that the radiation interactions with the polycarbonate will leave a trail of damaged molecules, called tracks, that can be counted on a spark detector. The polyethylene housing of the rem-meter serves to thermalize, or slow down, ambient neutrons. The thermal neutrons induce fission on the ^{235}U -plated stainless steel foil, producing fission fragments that carry off most of the kinetic energy given up in this process. At the time of fission, neutrons as well as gamma and beta radiation are emitted. The polycarbonate disk facing the ^{235}U -plated stainless steel foil is bombarded by the fission fragments. The hydrogen in the polycarbonate provides a high density of protons that are readily scattered by the fission fragments, creating deep tracks in the polycarbonate.

Other direct radiation monitoring devices have been evaluated for use at LLNL. However, the devices currently in use for measuring direct gamma radiation and neutrons have proven to be the most effective methods. Other monitoring devices considered included: CaSO_4 dysprosium-activated TLDs, LiF TLDs, $\text{Li}_2\text{B}_4\text{O}_7$ TLDs, Li_6Li_7 gamma neutron detectors, Anderson-Braun rem-meter with the boron-trifluoride detector and the Anderson-Braun rem-meter with a TLD detector by telemetry.

LLNL used the CaF_2 TLD between 1980 and 1984 and experienced a 25% drop in the environmental gamma radiation measurements. After an investigation, it was found that CaF_2 TLD faded and was more sensitive to sunlight. The $\text{Li}_2\text{B}_4\text{O}_7$ TLD also has been found to fade. The LiF TLD does not yield the sensitivity that is required to measure the low dose levels seen at LLNL. The Li_6Li_7 TLD measures both gamma and neutrons simultaneously, but the background must be subtracted from both the neutron and gamma readings, leaving a high degree of uncertainty with regard to the low exposures measured at LLNL. Gamma measurements by telemetry are not a cost-effective method to institute at LLNL.

14.2. EXTENT AND FREQUENCY OF MONITORING MEASUREMENTS

Radiation monitoring locations must be strategically selected to determine background and perimeter radiation values. The Livermore-site perimeter locations have been chosen based on consideration of LLNL operations, potential public exposure to radiation, and accessibility of the monitoring location. The off-site dosimeters are located to provide information about background radiation in general and about radiation levels in nearby residential areas. All radiation monitoring locations are chosen to ensure that the exposures measured would be representative of those that could potentially be the result of LLNL operations.

External exposures from gamma radiation are measured quarterly, using TLDs, at 16 Livermore-site perimeter locations and 48 off-site locations in the Livermore Valley (see Figures 14-1 and 14-2). Quarterly sampling periods were decided upon as this is the time required to produce a readily detectable dose, following guidance in DOE/EH-0173T, *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U.S. Department of Energy 1991). For TLDs in the LLNL vicinity this represents an exposure on the order greater than 5 mR.

Furthermore, quarterly sampling allows evaluation of seasonal variation and ensures 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, only a single quarter's worth of data is lost.

Figure 14-1. Gamma and neutron dosimeter locations, Livermore site.

Figure 14-2. Gamma dosimeter locations, Livermore Valley.

Currently, the California Department of Health Services, Radiological Health Branch, co-monitors at six of the Livermore-site perimeter locations and selected locations at Site 300; this co-monitoring effort began in 1987. These radiation dosimeters are also collected and read on a quarterly basis.

There are 14 on-site and off-site TLD monitoring locations at Site 300. These locations are illustrated in **Figure 14-3**. Off-site dosimeters are located in areas accessible to the public, including locations at the adjacent ranches, Corral Hollow Road, Tracy Airport, and the City of Tracy.

Neutron radiation is measured at eight locations on the Livermore-site perimeter, which are shown in **Figure 14-1**. Although the neutron monitoring network will require fewer monitors in the future, the eight locations to date were placed to measure doses in proximity to neutron sources and accelerators.

14.3 PROCEDURES FOR LABORATORY ANALYSIS

TLDs are read and annealed by the LLNL Hazards Control Department, Personnel Dosimetry Group. Calibration of the TLDs is performed by the Hazards Control Standards and Calibration Laboratory using standards traceable to National Institute of Standards and Technology (NIST). Neutron rem-meters are prepared and read by the Hazards Control Counting Laboratory. Quality control checks are conducted quarterly on the neutron rem-meters by the Hazards Control Standards and Calibration Laboratory. A detailed description of the detector and spark-counting procedure may be found in Fisher (1976) and EMP-R-S, *Radiation Monitoring*. For details on analytical laboratory procedures, see Chapter 16, Procedures for Laboratory Analysis.

14.3.1 Calibration

Environmental TLDs are calibrated in batches corresponding to each quarterly measurement cycle. Each time a group of TLDs is annealed, another calibration is required. TLDs used to calibrate the Panasonic unit are stored for the first half of the quarter in a zip-locked plastic bag in a lead pig on the LLNL site just north of Building 151. The lead pig protects the TLDs from natural terrestrial and cosmic background radiation. At mid quarter the TLDs are exposed to specified doses and then returned to the lead pig. At the end of the quarter the TLDs are picked up from the lead pig and taken to LLNL's Personnel Dosimetry Laboratory for readings along with the routine TLDs. See EMS procedures EMP-R-S and EMP-R-CA for details on the calibration TLDs.

Figure 14-3. Gamma dosimeter locations, Site 300.

At the end of the monitoring quarter, all the neutron rem-meters are brought to the laboratory for analysis. They are disassembled and the polycarbonate disks are removed for analysis. Three neutron rem-meters are reassembled with new polycarbonate disks and are exposed to a ^{252}Cf source for calibration QC checks. After this known exposure, the three rem-meters are again disassembled and the calibration polycarbonate disks are removed for analytical processing along with those collected from the field. All the rem-meters are then fitted with new polycarbonate disks and are returned to the field to begin the monitoring for the next quarter.

Both TLD and neutron calibration dosimeter readings are transmitted through the LLNL Hazards Control quality assurance coordinator. The average value of the readings must fall within $\pm 20\%$ of the "true" TLD exposure value, or within 5 mR of the "known" neutron exposure.

14.3.2 Analysis

As previously mentioned, 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 known to determine the dose equivalent. A quality factor of one is applied when the dose equivalent in rem is given by the dose in rads.

In the case of neutrons, an absorbed dose rate of 0.047 mSv (4.7 mrem) per year due to cosmic rays was estimated for LLNL from a plot in *Natural Background Radiation in the United States* (NCRP 1976b). This is based upon an energy deposition rate of 0.043 $\mu\text{rad/h}$ and a quality factor of 10. The dose rate was also derived from information in NCRP 50 (NCRP 1976a) as 0.087 mSv (8.7 mrem), which is based on an energy deposition rate of 0.1 $\mu\text{rad/h}$.

All measured doses at the Livermore-site boundary are compared to background measurements to determine the contribution, if any, from LLNL operations. All data are reported as total doses, including those from both background and LLNL sources.

The EMS analyst ensures that the level of confidence in the data due to radiological analyses are estimated by analyzing blanks and spikes of known exposures and comparing the measured exposure to the known.

Any outliers are excluded from the data after thorough investigation that an error has been made in the sample collection, preparation, or data analysis process. As well, all data are entered into the database promptly after analysis. When a TLD is missing, the annual dose is calculated as four times the average quarterly dose determined from available data. TLDs found on the ground wet or damaged are not accepted for use in monitoring. The analyst must indicate in the data tables that the TLDs are reported as missing or damaged.

Summary statistics, accuracy and precision of analytical results are reported using means, range, variance, standard deviation and/or confidence intervals as stated in EMP-QA-D *Data Analysis*.

14.4 QUALITY ASSURANCE REQUIREMENTS

In keeping with DOE Order 5700.6C and LLNL and EMS QA Plan requirements, the EMS analyst ensures that the Hazards Control laboratories participates in interlaboratory comparison studies annually. The intercomparison laboratory studies include the DOE Laboratory Accreditation Program (every two years), the Personal Dosimetry Inter-Laboratory Studies through the Oak Ridge National Laboratory, and calibration accreditation program with Battelle Northwest Laboratory for the LLNL Standards and Calibration Laboratory in Building 255. All radiation measuring equipment and environmental dosimeters must undergo calibration with NIST-traceable standards.

Monitoring network evaluations are continually performed by an EMS analyst to ensure that monitoring locations are suitable and comply with applicable regulations. At a minimum, an annual sampling plan is written.

If any sampling devices are missing, or if any other quality-affecting deviations from procedure occur, Needs Change Reports are completed in accordance with EMP-QA-NCR, *Non Conformance and Discrepancy Reports*. Sampling and analysis procedures are reviewed annually to determine whether the procedures are being performed correctly.

14.4.1 Co-Monitoring

As stated previously, the California Department of Health Services (DHS) co-monitors at six of the Livermore-site perimeter locations. 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 secondary calibration range in Sacramento, CA, for quality assurance purposes. The gross exposures received by the dosimeters are determined by the Radiation Detection Company, Sunnyvale, CA, and are reported to DHS Radiological Branch. Additionally, LLNL Standards and Calibration Laboratory exposes TLDs to specified levels of radiation for the DHS for calibration purposes. The level of exposure is determined by the DHS personnel. These TLDs are treated the same as LLNL TLDs, as described in procedure EMP-R-CA. These results are also used to assess the accuracy of LLNL's reported results, and statistically significant discrepancies must be investigated.

14.4.2 Action Levels

The EMS analyst conducts an investigation, institutes corrective actions, and/or completes a Needs Change Report when: unexposed TLDs readings exceed 8 mrem (including trip blanks); exposed TLD readings vary by more than 10%; duplicate TLD readings vary by more than 5 mrem; background dose levels vary by more than 5 mrem; control foils in the neutron rem-meter exceed zero; QC checks on rem-meters vary by more than 10%; and routine neutron measurements vary by more than 10%. Any outliers are excluded from the data after thorough investigation that an error has been made in the sample collection, preparation, or data analysis process.

14.5 PROGRAM IMPLEMENTATION PROCEDURES

TLDs are issued quarterly by LLNL's Hazards Control Department, Personnel Dosimetry Group, to EMS for deployment to 78 field locations. Eight neutron rem-meters are placed at locations on the site perimeter. EMS technicians are responsible for sample deployment and collection activities, carrying them out according to EMS Procedures EMP-R-S, *External Radiation Monitoring*; EMP-R-L *Radiation Monitoring Locations*; and EMP-R-CA, *Radiation Monitoring Calibration*.

The TLDs are mounted in the field on existing structures (such as fences) at approximately one meter above ground level, in accordance with DOE/EH-0173T. In addition to the TLDs that are deployed to monitoring locations, control TLDs, duplicate quality control (QC) TLDs, and transit control TLDs are included in the issuance. Transit control TLDs, used to provide data concerning exposure as a result of transit, are packaged and transported in the same manner as the field TLDs. Duplicate QA TLDs are placed in the field at various locations

alongside routine TLDs, and packaged in the same manner as routine TLDs. QA duplication is moved from location to location each quarter.

Data analysis is conducted by an EMS analyst who reviews all data for discrepancies, investigates discrepancies, institutes corrective actions, completes and files Needs Change Reports, reports the data in the annual Environmental Report, and releases the data to the Data Management Team through proper chain-of-custody procedures. The Data Management Team enters the data into the database, performs QC checks on the database, makes tables of the data for the SAER, and releases the data for archiving to the quality assurance coordinator through proper COC procedures. The QA coordinator provides the analyst and the technicians with QC guidance to determine the appropriate number of QC samples and ensures data archival.

The effectiveness of the environmental radiological monitoring program can be judged on the basis of a comparison of exposure levels. Based on past measurements (Lindeken et al. 1973), environmental terrestrial exposure rates in the Livermore Valley vary from 0.3 to 0.6 mSv/y (30 to 60 mrem/y). Cosmic radiation is about 0.35 mSv/y (35 mrem/y) as calculated from local elevation and geomagnetic latitude according to the data of Lowder and Beck (1966). This combination results in a typical exposure rate of 0.65 to 0.95 mSv/y (65 to 95 mrem/y). Exposures measured at the LLNL perimeter fall within these predicted values and are statistically identical to the off-site doses, which are considered natural background levels. This indicates that LLNL operations do not contribute to the external dose at or beyond the Livermore-site perimeter. Moreover, DHS data are consistent with the data gathered by LLNL.

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. The off-site locations were chosen to provide exposure information about nearby population centers, as well as background radiation levels. 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 may account for the difference between measured external radiation for each of these areas. However, the Site 300 average measured dose of 0.78 mSv (78 mrem) falls well within the 0.65 to 0.95 mSv/y (65 to 95 mrem/y) range seen in the Livermore Valley.

Based on an environmental gamma radiation monitoring network assessment, it is very apparent that all 78 TLD locations at the LLNL site, the Livermore Valley, and Site 300 are no longer required. The network assessments have shown that high spatial correlation occurs at all three sites. In fact, many locations show redundancies in radiation measurements. Locations L-49-TD, L-50-TD, L-52-TD and L-56-TD on the southeast side of the LLNL perimeter have exhibited nearly identical dose levels from 1988 through 1993. Historical data demonstrates how large correlation reduces the information gained from multiple locations. Nearly all the locations have a standard deviation of less than 2 mrem from 1988 through 1993. Therefore annual average changes as small as 4 mrem that affect an entire area can easily be detected by a single location in that area. Additionally, significant quarterly variation is common to all sites including Site 300.

An evaluation of the numbers and locations of TLDs will be completed by the end of 1994. Based on the evaluation, changes to the TLD monitoring networks at the Livermore site/Livermore Valley and Site 300 will be made for the first quarter's monitoring in 1995. It is anticipated that some existing monitoring locations will be eliminated, and others moved. The evaluation process is described below.

14.5.1 Future Implementation Needs

The optimal network can be designed based on historical data variation and correlations. Before redesigning the monitoring network, many factors must be taken under consideration. At the LLNL site perimeter, the usage/storage of all radiation sources with potential direct radiation exposure must be determined. To date, LLNL houses radiation sources and conducts routine radiological operations with the use of fissile and or direct (penetrating) radiation in the southwest quadrant, southeast quadrant, northwest quadrant, and in the center portion of the Laboratory. However, a more complete assessment of the buildings in the above-listed areas must be conducted, particularly, since TLD placement is directly related to radiation sources. Also, much of the work with the use of radionuclides at LLNL has been redirected, and many operations have downsized or have been discontinued. They therefore require reevaluation.

The following network design criteria will be considered: (1) placement of the TLD and the neutron rem-meters; (2) expected sources of external radiation; (3) maximum exposure; (4) the assurance that sampling locations are based on the probability of exposure from Laboratory operations; (5) the assurance that the

TLDs are placed as far as possible from large or dense objects or that proximity of a structure could alter the measurement; (6) the assurance that sampling areas will not be obstructed and to minimize distortion of the radiation field; (7) consistency in TLD height from the ground (approximately one meter); (8) population distribution and prevailing wind directions; and (9) sample frequency and geology.

Some TLD locations will be eliminated, and some dosimeters will move to new locations. Current sampling locations must be reevaluated to ensure that locations remaining on the network are those that minimize the loss of samples and maximize the measurements from LLNL operations. Duplicate sampling will continue; however, as sampling locations move, so will the duplicate locations move. Sampling locations that are unique will be maintained as some locations have not followed the general trend exhibited by most locations. Other locations may be unique in that they may be associated with known or suspected gamma-emitting Laboratory activities.

Similarly, an assessment will be completed for the neutron monitoring network. The need to continue neutron monitoring will be based on decisions regarding the possible construction of the National Ignition Facility at LLNL, the continued operations of the LLNL Laser Program, and the continued use of neutron generators and accelerators along northern boundary of the Laboratory. While it is possible that the eight neutron monitors may not be required to monitor effectively for all LLNL neutron sources, upgrades and/or new rem-meters and a new or upgraded spark counter will be required for neutron monitoring, should we decide to continue. It is possible, and perhaps probable, however, that the neutron monitoring network will be abandoned in 1995.

14.6 DIRECTION FOR THE PREPARATION AND DISPOSITION OF REPORTS

Data processed from the environmental gamma radiation network are reviewed by the analyst and tables, figures and analysis are prepared for the annual Environmental Report. Sampling location maps, descriptions of collection and analytical methods, all raw 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 Environmental Report.

15

Noise Monitoring

15.1 RATIONALE AND DESIGN CRITERIA

As part of LLNL's comprehensive environmental monitoring, microbarograph overpressure measurements are made in conjunction with high-explosive (HE) tests at Site 300. The purpose of these measurements is to document the overpressure levels (sound levels) that are generated as a result of these tests.

There are no laws or regulations that govern these occasional HE overpressures, which occur approximately once per week. The U.S. Occupational Safety and Health Administration (OSHA) has regulations that govern occupational, eight-hour-per-day continuous or impact workplace noise levels, but these regulations do not apply to infrequent, non-workplace, environmental situations. Some cities have nuisance noise criteria, which usually apply only during sleeping hours and typically apply to construction and vehicular activities in residential neighborhoods. The City of Tracy does not have such an ordinance, and Site 300 is well outside (16 kilometers or more) the Tracy city limits.

In establishing acoustic overpressure (noise) criteria, LLNL considered and evaluated information found in nine publications: Beranek (1960, 1971), Bragdon (1970), Breyse (1972), Glorig (1958), Odell et al. (1978), Smith (1970), U. S. Environmental Protection Agency (1974), and U. S. Department of Commerce (1970). The damage threshold for large windows has been established at 1000 microbar (134 dB). A 400-microbar (126-dB) limit was chosen by LLNL management in the late 1950s as the overpressure (sound) level at which some members of the public might be adversely affected. To be responsive to public well-being, LLNL continues to monitor noise from Site 300 HE tests.

Public inquiries about blast noise are commonly directed to Tracy police and, in turn, to Site 300. An unusually large number of inquiries is generated on the rare occasion where there are three or more HE tests in one day. Only one case in recent memory involved possible Site 300 explosive-test-generated damage to property owned by a Tracy resident who felt that noise from a particular shot created a crack in her window. The window was promptly replaced by a Site 300 craftsman. Experience has shown that most public inquiries are a result of curiosity and come from new residents.

15.2 DESCRIPTION OF NETWORK AND MEASUREMENTS

15.2.1 Sound Level Meters

To monitor this acoustical overpressure/noise limit, six B&K Company micro-barograph sensors are maintained in or near the City of Tracy. **Figure 15-1** is a map showing the location of these environmental noise monitoring stations in Tracy and in the surrounding area. Each station consists of a B&K sound level

meter and an ultra-high-frequency radio telemetry link back to Site 300. Acoustic data are analyzed at blast time to detect overpressures in excess of the LLNL-imposed 400-microbar limit for each of the HE tests. The meters measure the highest sound level for every one-second period. The time response of the meters (35 milliseconds) matches that of human hearing. The combination of the B&K model 4155 microphones and model 2231 meter is considered a top-quality, industry-standard unit. These are mainly used for airports, but are also used for monitoring noise from mining operations and highway construction.

15.2.2 Siting of Monitors

LLNL conducts occasional HE tests at its Site 300 facility in the remote Altamont Hills approximately 16 kilometers west of Tracy. This site is remote so these experiments can be performed with minimal off-site impact from annoying noises or overpressures. The tests are conducted in valleys surrounded by hills that reflect the sound upward; however, variation of temperature and wind speed with height may turn sound waves toward the surface. This process is very complicated and difficult to model due to the chaotic nature of the sound

wave transmission, and there is no clear way to determine the optimal density of monitors.

Currently, there are six noise monitoring locations. Monitoring locations should be reviewed periodically. Placement of sound level meters to monitor distant blast overpressures has incorporated and will continue to incorporate past experience. Locations are selected near residents who may be affected by the blast overpressures. A location where the sound level monitor rarely detects noise from blasting at Site 300 should be abandoned in favor of a new location. Locations that are close to other sources of noise (such as traffic, airplanes, industrial plants) should be avoided because distant blast overpressures may be difficult to discern above high levels of ambient noise. Also, it is known that people become accustomed to high levels of ambient noise, so they may be less likely to notice, or be annoyed by, noise such as infrequent and distant blasting.

15.2.3 Avoidance of Noise

It is LLNL policy to always avoid blasting when conditions may lead to blast overpressures focused toward residents. EMS is not responsible for decisions to abort blast tests due to unfavorable conditions. Staff of B Division author, maintain, and follow procedures for sounding the atmosphere and running sound-propagation computer models. A description of this program is detailed in the LLNL Report, *Blast Forecasting Guide for the Site 300 Meteorology Center* (Odell et al. 1978). In this plan, we will briefly describe the major components of the noise avoidance system.

Before any blast test, a limit must be set on the weight of HE that can be detonated at that time without creating an adverse impact on populated areas. A computer model, LAPS, has been developed to predict the overpressure levels in the surrounding areas. The model is based on acoustic wave propagation in the upper atmosphere, which is obtained from soundings of the wind and temperature. Meteorological sounding measurements are made at least twice a day at Site 300 to provide input to the modeling effort. The operator interprets the graphic output of LAPS looking for predicted paths of sound rays that strike the surface outside the boundaries of Site 300. The computer model, BLASTO, estimates the distant blast overpressure, given the meteorological conditions presented in LAPS and the weight of HE. In other words, BLASTO estimates the maximum weight of HE that will avoid overpressures greater than the LLNL imposed limit of 400 microbars. Over the past few years, LLNL has conducted between 100 and 270 HE tests per year at Site 300. Microbarograph measurements in the vicinity of

Site 300 and in the City of Tracy have demonstrated that the noise limit of 400 microbars has never been exceeded. In recent years, there have been no complaints of noise or overpressure from residents in the vicinity of the test site. Furthermore, none of the tests in recent years have produced sound levels above 120 microbar (116 dB) at any of the six microbarograph stations. Through compliance with the limit of 400 microbars and use of pre-blast noise prediction, LLNL has prevented any significant noise impact.

15.2.4 Proposed Changes to the Noise Monitoring System

We propose few changes to the noise monitoring equipment currently in the field. Equipment performance has been superb and its reliability very high. Noise monitors will remain in their current locations with the possible exception of relocating the most distant monitors to a proposed subdivision adjacent to the site.

We have proposed a new, modern, computer-based system that replaces many obsolete computers currently located at the meteorological station at Site 300. The new computer will actually be a collection of systems that will take advantage of existing hardware and software known to function well together. One of the systems incorporated in it will be the Noise Monitoring System. A small, personal computer will replace the radio-frequency modem at each of the sound monitoring stations and will collect data continuously. In event of any sound pressure reading in excess of a preset limit, the personal computer will create an event file and notify the meteorological station computer that the event has occurred.

Negotiations are currently under way between B Division and the Environmental Protection Department to determine specific upgrades to the systems located at the Site 300 meteorological station. The responsibility for the maintenance and operation of the various components is also being discussed.

15.3 QUALITY ASSURANCE REQUIREMENTS

Automatic self-calibration is performed by every sound level meter immediately after sampling. The results of the self calibration are used to accept or reject the sound level data. Field calibrations are performed at regular intervals following procedures that are recommended by the manufacturer. Each instrument in turn is removed from the field and shipped to the manufacturer or another qualified instrument shop for a laboratory calibration. The manufacturer recommends this calibration check be done once a year. Every calibration procedure performed

must be documented. A Needs Changing Report is written when calibrations indicate that the meter is off specifications.

15.4 PROGRAM IMPLEMENTATION PROCEDURES

EMS is responsible for establishing procedures for field calibrations of the sound level meters and interpretation of sound data to demonstrate compliance to the LLNL self-imposed limit of 400 microbars. Specific methods are standardized in procedures and are described in EMP-N-S. They are followed in the field by the EMS calibration technician and by the noise network analyst. Avoidance procedures, including atmospheric measurements and sound propagation codes, are beyond the scope of EMS activities and are maintained by B Division.

15.5 PREPARATION AND DISPOSITION OF REPORTS

LLNL is not required through regulations to report distant sound levels resulting from blasting activities at Site 300. Noise level data are made available to the public and LLNL programs when requested.

16

Procedures for Laboratory Analysis

16.1 INTRODUCTION

Analytical services are critical to the success of the Environmental Monitoring Section's environmental monitoring program and therefore are subject to strict quality assurance controls (Chapter 17, Quality Assurance and Training; EMS *Quality Assurance Plan* [Garcia and Failor 1993]). QA begins with documentation of requested procedures and pre-qualifying the laboratories who will be performing analytical work.

LLNL's internal laboratories should have an interface document, agreed on by both EMS management and the analytical laboratory, that states the terms under which services will be provided. In accordance with the Environmental Monitoring and Analysis Division's *Quality Assurance Management Plan* (QAMP), these interface documents must also be approved by the EMAD Division Leader. The Environmental Protection Department's QAMP and its implementing procedures require that internal laboratories adhere to strict qualifications standards.

Contract analytical laboratory services must be described in a contract or purchase order arranged by the LLNL Procurement Department. An environmental analyst or group leader and the QA coordinator must ensure that applicable EMS technical and QA requirements are included in these contracts and purchase orders. The supplier qualification process for contract analytical laboratories depends on the extent of services to be provided. Laboratories outside of LLNL should be qualified according to the requirements of the EPD QAMP and supporting implementation procedures.

Depending on the scope of work, evaluation of a laboratory's qualifications can be performed by EMS, EMAD, or EPD. These qualifications will be reviewed periodically during a comprehensive quality assurance audit by EPD, EMAD, or EMS, using a procedure similar to procedure EMP-QA-A. The audits are coordinated through the EPD QA office.

To analyze its monitoring samples, EMS uses five LLNL internal labs: Environmental Analytical Sciences (EAS); Radiation Analytical Sciences (RAS); three Hazards Control Department laboratories, which are Hazards Control Analytical Laboratory (HCAL), Radiation Measurements Laboratory (RML), and

Personnel Dosimetry Laboratory; and five contract analytical laboratories, which are California Laboratory Services (CLS), GTEL, IT, Lockheed, and Fruit Growers (FGL). The selection process for contract analytical laboratories includes a thorough analysis of each laboratory's quality assurance capabilities, including a pre-award audit by LLNL QA, technical, and procurement representatives. Once contract laboratories have been awarded the work, the EPD quality assurance program requires that they be audited annually by LLNL. Each contract analytical laboratory is assigned a primary point of contact within EMS. This person is responsible for maintaining frequent contact with the laboratory to ensure that EMS requirements are communicated to the laboratory and that problems with analyses and analytical results are resolved in a timely manner. Procedure EMP-QA-AR requires all analytical laboratories to be state-certified and to have carefully documented and acceptable analytical and QA/QC plans and procedures. All laboratories used by EMS meet this requirement. Procedure EMP-QA-AR also requires the labs to agree to comply with EMS QA plans and procedures which include, but are not limited to, chain-of-custody procedures, specified analytical procedures, specified detection limits, data reporting, turnaround times, electronic data submittal, discrepancy reporting, audits, and corrective action. These laboratories must also participate in a mutually acceptable, nationally recognized cross-check program for media and analytes specified by LLNL.

LLNL's EAS laboratory is used primarily for waste characterization. For EMS, EAS Lab analyzes wastewater samples collected from retention tanks. LLNL's RAS Lab conducts radiochemical analyses for water, wastewater, sludge, soil and sediments, air, and wine samples. The Hazards Control Department Laboratories are used for analysis of sewage samples, such as the daily composites for radioactivity (gross alpha, gross beta and tritium), weekly composites for metals, and grab samples for sewer alarm verification. Hazards Control Department laboratories also perform analyses of air effluent filters and continuous air monitor (CAM) filters for gross alpha and gross beta activity, analysis of water vapor collected with molecular sieves in the Tritium Facility stacks for tritium, thermoluminescent dosimeter analysis, and neutron rem meter analysis. Occasionally HCAL may also be used for wastewater analysis if EAS is unable to handle the workload.

CLS is the primary lab for non-radiological analyses of monthly sewer monitoring, ground water and surface water monitoring, and non-radiological analysis in soil. GTEL is used as the primary laboratory for categorical

pretreatment monitoring, and as a quality control laboratory for water sample analyses. Quality control laboratories are available to perform analyses on duplicates and splits for interlaboratory comparison information.

IT is the primary lab for radiochemical analysis for ground water and surface water samples. Lockheed is the quality control laboratory for IT. IT performs analysis for gross alpha, gross beta, isotopic uranium, $^{226}\text{Radium}$, and thorium, and can also perform tritium analysis. Even though LLNL has the capability for radiological analyses on site, EMS also uses contract laboratories due to the large number of samples to be analyzed.

FGL analyzes air filters for gross alpha activity, gross beta activity, and beryllium.

Sampling methods and preservation vary by media and analytes. Each monitoring network sampled by EMS has its own EMS procedure which describes in detail the sampling and preservation techniques used. The network-specific chapters in this document also address sampling and preservation methods. EMS uses standard chain-of-custody (COC) forms to track and document the samples as they progress from the sampler to the courier to the analytical laboratory, as well as to track sample data from the analytical laboratory to the analyst, data manager, and, finally, the archivist (procedure EMP-QA-SD).

The following paragraphs describe, separately for each laboratory used by EMS, sample identification systems, cross-contamination prevention measures, sample preservation and handling practices, analytical methods, any modifications to standard methods, analytical capabilities, equipment calibration, and other quality assurance practices. EPA or State methods are used whenever possible. Table 16-1 lists the method used for each analyte by each analytical laboratory, for laboratories that use standard methods. For labs that provide analytical services using other than standard methods, a brief description of the methods is provided.

16.2 CALIFORNIA LABORATORY SERVICES (CLS)

All samples are logged-in within 24 hours of their arrival. The CLS QA coordinator receives the samples and checks their integrity by determining if proper temperature and preservation have been maintained during shipment. A unique job number is assigned to each chain-of custody form (CLS Manual, SOP QC016).

According to the CLS quality assurance program, samples are stored in a cold room (at $4^{\circ}\pm 2^{\circ}\text{C}$), refrigerator, or freezer depending on the type of sample. To prevent cross-contamination, CLS stores samples for volatile organics analysis in separate refrigerators (CLS Quality Assurance Programs Document, Rev. 2.0, March '94).

CLS uses EPA-prescribed methods whenever applicable. Other sources of analytical methods may be used if widely recognized by industrial and government laboratories (e.g., DHS certified analyses). If a specific project requires use of an alternate method, the method is documented in the project records.

CLS's QA Manual discusses their calibration program, which uses procedures recognized by Association for Standards and Test Materials (ASTM) or EPA, or provided by the manufacturers. Frequency of calibration is not specified; this is given in the working SOPs for each method, available in every CLS laboratory. Calibration records are maintained for each piece of equipment.

16.3 GTEL ENVIRONMENTAL LABORATORIES INC. (GTEL)

Each sample container received by GTEL is given a GTEL sample number following internal numbering convention (GTEL Environmental Laboratories, Inc. QA/QC Plan Synopsis, Rev 4, February 1993). The number consists of a letter identifying the lab, followed by the year and month, the sequential work order number that identifies the batch received that month, and a sequential number identifying each sample in the batch. Each replicate sample container for each sample client is identified by an alpha code (A, B, C...) or set number (1 of 3, 2 of 3...) For example, C4-03-123-01 would be Concord lab, March '94, batch 123, sample 1 (GTEL QA/QC Plan Synopsis).

Steps to prevent cross-contamination include physical separation and the use of hoods for extractable and volatile organic samples, as well as segregated sample storage areas (GTELQA/QC Plan Synopsis). Samples are received only by the log-in staff, who are laboratory personnel properly trained to handle legally defensible samples. Sample integrity upon receipt is documented by the log-in staff, who check for presence of ice or coolant packs, intact custody seals, and the record of proper preservation. Samples are not be allowed to warm to room temperature during the log-in and distribution process, are kept under lock and key, and refrigerated if necessary.

Wherever possible, GTEL uses EPA or State of California methods for sample analysis (see Table 16-1).

Calibration is performed in accordance with requirements of specific analytical methods used for particular regulatory purposes. The calibration process involves initial calibration, QC check samples, and continuing calibration verification; it is performed as necessary to maintain the instrument within a specified tolerance. Periodic calibration is carried out at a specified frequency for general-purpose equipment, such as balances. A supervisor is notified of all calibration failures or corrective actions. Notebooks are kept for each piece of equipment documenting the calibration checks.

16.4 FRUIT GROWERS LAB (FGL)

FGL identifies each sample with a unique number. The number is issued sequentially and follows the sample throughout the analytical process. All EMS samples are processed in a low-level radiation sample preparation area that is decontaminated before each group of low level samples is prepared. FGL technicians wear gloves and use forceps to prevent cross contamination.

16.4.1 Gross Alpha and Gross Beta Analyses of Air Filters

Gross alpha and gross beta activities on the filters are determined with a gas flow proportional counter. FGL uses ^{241}Am and ^{137}Cs as calibration sources to determine alpha and beta counting efficiencies, respectively. Cross checks utilizing ^{230}Th and ^{90}Sr are also completed periodically. These standards are certified by EPA. Counting-efficiency measurements are made for each set of counted filters. A background count is taken at the beginning of each run and between each set of 20 samples. At least one blank, one duplicate, and one spike are run with every batch of 20 samples. Records are kept of background and counting-efficiency variations that occur in the counting equipment.

16.4.2 Beryllium on Air Filters

The analytical laboratory adds 40 milliliters of 10% nitric acid to each monthly composite sample. The solution is heated for 30 minutes and decanted into a separate beaker where more nitric acid is added. This step is repeated two more times and the solution is evaporated to less than 20 milliliters (care is taken to prevent the samples from boiling or baking dry). The samples are diluted to 20 milliliters with deionized water. Quantification is accomplished by graphite-furnace atomic-absorption spectrometry.

Procedures for Laboratory Analysis

Table 16-1. List of analyses, methods, and laboratories used.

Analyses	Method	Laboratory
Organics		
Volatile aromatics	EPA 5030/8020, 602	GTEL, EAS
Volatile hydrocarbons	EPA 5030/8010, 601	GTEL, EAS
Volatile organics	EPA 8240, 8260, 624	GTEL, EAS, CLS
Semi-volatile organics	EPA 8270, 625	GTEL, CLS, EAS
Volatile solids	EPA 160.4	GTEL, CLS
Pesticides & PCBs	EPA 3550/8080, 608	GTEL, CLS
Chlorinated acid herbicides	EPA 615	GTEL, CLS
PCBs in oil	EPA 600	GTEL
Total recoverable phenols	EPA 420.1	GTEL, CLS
Total organic carbon (TOC) in water	EPA 9060, 415.1	GTEL, CLS,
Total organic halides (TOX)	EPA 9020	CLS
Total petroleum hydrocarbons (TPH) in water	EPA 418.1	GTEL
Total petroleum hydrocarbons (TPH)	EPA 8015	CLS
Total petroleum hydrocarbons (TPH) in Soil	Standard Method 503, EPA 3550/418.1	GTEL
Polynuclear aromatic hydrocarbons (HPLC)	EPA 610	GTEL
Total recoverable oil & grease—gravimetric	EPA 413.1, 9071, 9070	GTEL, CLS
Total recoverable oil & grease—IR	EPA 413.2, Standard Method 503	GTEL, CLS
Metals—ICP		
Metals—AA spec., flame, furnace, cold vapor	EPA 3050/6010, 200.7, EPA 3050/7000 series, 200 series	GTEL, EAS, CLS, HC
Mercury, cold vapor	EPA 245.1	EAS, HC
Chromium, hexavalent	EPA 7196	CLS
TCLP	EPA 1311	GTEL
Inorganics		
Total cyanide	EPA 9010, 335.2	GTEL, CLS
pH, corrosivity	EPA 9040, 9045	GTEL, EAS, CLS
pH, corrosivity	EPA 150.1	CLS
Alkalinity	EPA 310.1	GTEL, CLS
Conductivity	EPA 120.1	CLS
Anion analysis	EPA 300	GTEL, CLS, IT, EAS
Settleable solids	EPA 160.5	CLS

...continued

Table 16-1. List of analyses, methods, and laboratories used (*concluded*).

Analyses	Method	Laboratory
Inorganics (cont'd)		
Total suspended solids	EPA 160.2	CLS
Total dissolved solids (TDS)	EPA 160.1	CLS
Biochemical oxygen demand (BOD)	EPA 405.1	GTEL, CLS
Chemical oxygen demand (COD)	EPA 410.4	GTEL, CLS
General minerals not otherwise listed	EPA 310.2	GTEL, CLS
Surfactants	EPA 425.1	GTEL, CLS
Hardness	EPA 130.1	GTEL, CLS
Nutrients	EPA 350.2, 351.2	GTEL, CLS
Ammonia	EPA 350	CLS
Total phosphorous	Standard Method 4500-PD	GTEL, CLS
Phosphate as phosphorous	Standard Method 4500-P	CLS
Biological		
Chlorophyll A	Standard Method 10200	CLS
Fecal coliform	Standard Method 9221	CLS
Total coliform	Standard Method 9221	CLS
Total coliform	EPA 9132	GTEL
Fish bioassay	EPA 600	CLS
Radiological		
Gross alpha/beta—water	EPA 9310, 900.0	IT, Lockheed
Radium-226	EPA 903	IT, Lockheed
Thorium-228, -232	NAS NS3050	IT, Lockheed
Uranium-234, -235, -238	NAS NS3050	IT, Lockheed

16.5 IT LABORATORY

Each sample logged into IT's Laboratory Information Management System (LIMS) is given a unique identification number, in sequential order. LIMS allows analytical progress to be monitored at any stage and status reports to be generated at any time.

Samples are received by the Sample Control Department for screening and classification. The radiation safety officer reviews activities in screened samples. The Sample Control team leader is responsible for intra-laboratory custody transfer of samples and maintains internal COCs (SOP No.SL2001 8/93). Samples are handled and stored in the laboratory in such a manner as to: (1) ensure the

safety of all personnel, (2) maintain the integrity of the samples in accordance with requested analytical methods, and (3) prevent potential cross contamination of samples (Sec. 5.8.1). Samples are stored in locations remote from standard reference materials, calibration standards, and any other chemicals or reagents. Samples for volatile organic analysis (VOA) are stored in a location designed for these samples only. Storage walk-in coolers are maintained at $4^{\circ}\text{C} \pm 2^{\circ}\text{C}$.

IT (St. Louis) is licensed by the Nuclear Regulatory Commission and uses EPA-prescribed methods whenever applicable. Its QA plan and instrument-specific SOPs show that it keeps a regular maintenance schedule. A log book is kept for each instrument, which fully documents maintenance activities (Quanterra Statement of Qualifications, September 1994).

IT participates in a number of cross-check programs. Several times each year, samples are analyzed from the EMSL Las Vegas Inter-Comparison Studies for Radiological Assessment. It also participates in the DOE QA Assessment Program for Radiological Analysis and the DOE Mixed Analyte Performance Program.

16.6 LOCKHEED ANALYTICAL SERVICES (LAS)

Each sample is received, screened for radioactivity, and checked for integrity before it is affixed with a unique LAS bar-code label. LAS employees use several measures to control cross contamination, including: (1) segregating samples to be analyzed for VOCs from those to be analyzed for semivolatile compounds, (2) segregating environmental samples from standards, and (3) preparing and analyzing holding blanks to monitor cross contamination (QAMP Sec. 4.9.3 June 1994). Samples are stored at $4^{\circ} \pm 2^{\circ}\text{C}$ to preserve their integrity. The sample custodian has primary responsibility for maintaining chain-of-custody and for receiving and logging samples into the laboratory data management system as prescribed in SOP 90-SOP-0002. LAS uses standard methods for radionuclide analyses. Methods are modified to obtain lower minimum detectable activities; modifications are documented and approved by client prior to use (Executive Summary, Statement of Qualifications). Method calibrations and instrument calibrations are verified independently, on a daily basis. All standards used for instrument calibration are prepared from sources that are traceable to EPA or NIST (QAMP Sec. 6.3.1). Calibration records are maintained for each piece of equipment.

16.7 LLNL—ENVIRONMENTAL ANALYTICAL SCIENCES (EAS)

Per procedure EAS-202, during sample log-in a unique and sequential sample number from the Sample Log Book is issued to identify the sample. EAS laboratory personnel reject samples that have been improperly identified, prepared or preserved; have unclear instructions; or are in leaking containers or warm VOA vials. Per procedure EAS-300, EAS Lab personnel use established preservation methods such as those described in SW-846. Samples are stored in specially designated storage areas and refrigerators, which are locked when unattended. Samples are stored separately from non sample materials.

EAS is a state-certified analytical laboratory and uses EPA methods when available and EAS specific methods when no EPA or California State method is available (procedures EAS-104 and EAS-105). EAS sends samples out to other laboratories when it cannot meet the required turnaround time, when it is more cost effective, or when it does not have the capability to do the analysis. Currently, EAS contracts with IT Lab. Sample preparation for off-site shipment is detailed in procedure EAS-204.

Although specific instrument calibration frequencies are not discussed in EAS procedures, EAS follows the calibration criteria required by each of the EPA methods which include initial calibration and continuous calibration. Calibration records are maintained for each piece of equipment in a separate logbook. EAS procedures state that each instrument shall be kept in good working condition following manufacturer's recommendations for maintenance and trouble shooting. Major repairs shall be done by service engineers. A service repair logbook or binder is kept for each instrument (procedure EAS-107).

16.8 LLNL—RADIATION ANALYTICAL SCIENCES (RAS)

Each sample is issued a unique sequential identifier number which follows it throughout the analytical process, in keeping with chain-of-custody procedures. Sample preparation and counting procedures are performed in an ultra low-level clean radiation area. Only authorized personnel may enter the clean area and they must wear protective shoe covers. Luminous dial watches and all other radioactive materials are prohibited. Samples are handled and stored to minimize cross contamination and contamination from environmental and outside sources. Verified analytical methods are followed for radiological analyses, and standard analytical methods are followed for nonradiological analyses. RAS uses methods consistent with standard methods, but modified for

greater sensitivity. Modifications are different for each medium and type of sample. These radiochemical methods and their associated calibration methods are documented in *Technical Implementing Procedures* (Hall and Edwards 1994). They have been reviewed and certified by the State of California Department of Health Services (DHS) and have met DHS requirements for environmental radiochemistry.

16.8.1 Air Samples

16.8.1.1 *Gamma Activity on Air Filters*

Air filter samples are composited monthly by sample location. The monthly composite samples are placed into individual plastic bags, which are then combined and sealed in a 214-cm³ aluminum can and counted for gamma-emitting radionuclides using low-background Ge(Li) detectors.

16.8.1.2 *Plutonium and Uranium on Air Filters*

The filters are ashed and then dissolved in a mixture of nitric acid and hydrochloric and/or hydrofluoric acids. Plutonium and uranium are separated by an ion-exchange process. Each separated element is purified further by ion exchange. Then plutonium is electroplated onto a stainless steel disk and submitted for alpha spectrometry, while uranium solutions are submitted for analysis by mass spectrometry.

16.8.1.3 *Tritium in Air*

Water is separated from the silica gel by freeze-dried vacuum distillation and the tritium concentration in the water is determined by liquid-scintillation counting. All analytical results are reported as a measured concentration per unit volume of air flow through the sampling medium.

16.8.2 Soil and Sediment Samples

No particular preservation method is required for soils and sediment samples that are analyzed for metals and particulate radionuclides. Soil samples are dried at 100°C for at least 2 days, pulverized in a grinding mill, sieved through a 32-mesh sieve, and blended. The samples are packed in a tared steel can and allowed to stand a minimum of 30 days to equilibrate before counting. Sand is run through the grinding mill and sieve between samples to clear the equipment and prevent cross contamination.

Sediment samples that are analyzed for tritium and organic compounds are chilled in the field and frozen until analyzed.

Plutonium is measured by alpha spectroscopy following acid leaching; tritium is measured by liquid scintillation following freeze-dry extraction of the soil moisture; all other radionuclides are currently determined by gamma spectroscopy, using a Ge detector. Sediments are analyzed for organic compounds following EPA Methods 8010 and 8020. Metals analyses are conducted following extraction with water using inductively coupled plasma-emission spectroscopy (EPA Methods 6010, 7060, 7471, 7740, and 7841). Beryllium analyses are conducted by graphite-furnace atomic absorption spectroscopy (EPA Method 7091).

16.8.3 Vegetation Samples

Verified analytical methods are followed. The samples are delivered on the day of collection to the Radiation Analytical Sciences Laboratory for analysis. The samples are kept frozen prior to processing. Water from the vegetation is collected using freeze-drying techniques (lyophilization). The tritium content of the recovered water is determined by liquid-scintillation counting. The radiochemical methods and their associated calibration methods are documented in *Technical Implementing Procedures*, TIP-RAS-005 (Hall and Edwards 1994).

16.8.3.1 Tritium in Wine

Tritium in wine is measured by ^3He mass spectrometry in the LLNL Nuclear Chemistry Noble Gas Mass Spectrometry Laboratory (Surano et al. 1991). In this process, all the helium initially present is removed through degassing. After complete degassing, the samples are stored for as much as 60 days to allow ^3He to grow in from the radioactive decay of tritium. The ingrown ^3He is extracted and measured, and the amount of tritium necessary to evolve the measured amount of ^3He is calculated. This highly sensitive method is used for wine analysis so that the differences in the tritium content of the samples can be determined. If a less sensitive method were used, the tritium content of all samples would be near or below detection limits and no differences between Livermore wines and other wines would be apparent.

16.8.4 Water, Sewage, and Sludge Samples

16.8.4.1 *Plutonium.*

The plutonium is separated by coprecipitation with manganese dioxide (MnO_2). The MnO_2 then is ashed and dissolved in nitric acid (HNO_3) and hydrogen peroxide (H_2O_2). Plutonium is purified by ion exchange, electroplated onto a stainless steel disk, and submitted for alpha spectroscopy.

16.8.4.2 *Gamma.*

Sludge samples are dried, ashed and homogenized and placed into a 2.5-cm prindle vial and submitted for gamma spectroscopy.

16.8.4.3 *Cesium*

The cesium is separated by ion exchange with ammonium molybdophosphate (AMP). The AMP crystals are transferred to a counting vial with concentrated hydrochloric acid (HCl) and submitted for gamma spectroscopy.

Details regarding the procedures for plutonium, gamma, and cesium analysis in water, sewage, and sludge samples are given in Technical Implementing Procedures TIP-RAS-010.

16.9 LLNL—HAZARDS CONTROL ANALYTICAL LAB (HCAL) AND RADIATION MEASUREMENTS LAB (RML)

All samples, prior to submittal to the Hazards Control Department laboratories, are logged into the HCD sample tracking and receiving (STAR) computer by an EMS or HCD technician. Information given during log-in includes field ID number, origin, sample type, and required analyses. After receipt of a sample by HCAL, the sample information in STAR is transferred to the Laboratory Information Management System. This system assigns each sample a unique, sequential, seven-digit sample identification number and assigns a case number to each set of samples. Sample numbers are recorded on the bottle and cap of each sample, the Environmental Sample receiving log, and the chain of custody record. Samples for gross alpha and gross beta analysis that require no preparation are submitted directly to RML. After receipt of samples by RML, verification of the STAR log-in information is made, a radioactivity sampling record is generated and placed with the samples to track the processing in RML, and the samples are filed for subsequent counting.

The laboratories remain locked at all times. Samples received by HCAL are stored in a specially designated area that includes separate storage for incompatible samples and for volatiles or unstable compounds, a refrigerator that is kept at $\leq 4^{\circ}\text{C}$. HCAL uses established preservation methods found in EPA-600/4-79-020 and *Standard Methods for the Examination of Water and Wastewater* for environmental and waste samples.

All instruments are calibrated with standards traceable to the National Institute for Standards and Technology (NIST). Exceptions to this are detailed in the document *LLNL Hazards Control Laboratory Analytical Quality Control Manual*. Laboratory blanks constitute at least 10% of analyses and serve as indicators of cross contamination within the counters. RML participates in the EPA Environmental Radioactivity Laboratory Intercomparison Studies Program on a quarterly basis, as well as comparison studies with the DOE Environmental Measurements Laboratory and Oak Ridge National Laboratory, to substantiate the validity of analytical techniques.

16.9.1 Wastewater Samples

For processing wastewater samples, HCAL uses EPA and State of California-approved procedures except for digestion of composite sewage samples for metals analysis, where they do standard digestion first, followed by filtration, and then another (stronger) digestion. Sewage monitoring is discussed in more detail in Chapter 7. HCAL performs the standard acid digestion followed by plating on a stainless steel planchette to prepare samples for radiological analysis by the RML. Details describing the radiological analysis are provided in the RML procedures manual.

16.9.2 Air Effluent Filter Samples

Methods for the analysis of air effluent filter samples conform to the requirements of 40 CFR 61, Method 114, specifically, 3.1.4-Method A-4 for gross alpha determination, 3.3.2-Method B-4 for gross beta determination, 3.5.1 for alpha counting using gas flow proportional counters, and 3.5.2 for beta counting by scintillation counters. Detection of gross alpha and gross beta activity resulting from particles collected on the air filters is accomplished using gas flow proportional counters. Analysis is delayed for at least four days from sample termination 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. RML procedures are

in place specifying the handling of the samples, operation of the equipment, and equipment calibration. The laboratory's *Gross Alpha-Beta Procedures Manual*, (November 1992), Section 1.1, directs the receipt and handling of swipes and air filters; Section 1.4 specifies the counter selection, for example, to segregate samples having low and high activities; and Section 2 details the specifics of detector operations. Section 4 provides for a number of tests to verify counter operation and performance including bi-weekly calibration with alpha and beta check sources, voltage plateau checks, planchette screening to verify that the counter was not contaminated by samples, and background counting. Although not routinely used for samples, alpha and beta spectrometry measuring systems are also available if further analysis and radionuclide identification is required. Air particulate filters are stored for at least six months from the time of analysis.

16.9.3 CAM Samplers

Eberline Alpha 3, Alpha 5/5A, and Alpha 6 continuous air monitors are alarm devices that are in use at LLNL for the detection of alpha activity in the form of aerosols. The monitors use a membrane filter to collect particles from the air stream. Currently, Gelman Versapor 3000 filter media are being used in the instruments. The alpha activity is detected by a 490-mm² solid state detector. The instruments have pulse height discriminators for the detection of alpha activity with specific energies. Thus, much of the activity from radon progeny can be rejected, resulting in increased alarm sensitivity for radionuclides having energies near those of the radon progeny. The filters from each CAM monitor are also changed weekly for analysis and are handled in the same manner as the filter samples described above. The Hazards Control Calibration and Standards Laboratory performs calibration of the instruments. Document CSL002 (October 1992) of this laboratory's *Quality Assurance Plan* specifies that the instruments be calibrated annually (Section 4.0), that those failing to meet standards be tagged and set aside for further investigation (Section 5.0), and that calibration and maintenance records be kept for five years (Section 7.0). Specific calibration procedures, including the setting of alarm points, adjustment of energy discrimination ranges, flow calibration, and leak checking are available for the Alpha 3, Alpha 5/5A, and Alpha 6 instruments. Calibration procedures are performed with sources traceable to NIST standards. Instruments are tagged with stickers indicating the most recent calibration date and the next due date for calibration.

16.9.4 Molecular Sieve Samplers for Tritium

Molecular sieves are submitted to the HCAL. The sieves are installed into a recovery system for the bake-out of tritiated water vapor and subsequent collection in cold traps. The analytical laboratory's written procedure, *Recovery of Tritiated Water from Molecular Sieve Stack Samplers* (July 1993), provides descriptions of the sampling and analysis procedure, the sieves, and recovery system; it details the water recovery technique. The retrieved tritium is then forwarded to the RML, where the samples are counted by liquid scintillation techniques. The RML's *Liquid Scintillation Counting Procedures Manual*, Section 1.1, provides general guidance on the handling of samples submitted for analysis; Section 1.8 specifies procedures for the receipt and handling of molecular sieve samples; Section 1.9 specifies counter preferences (molecular sieve samples are analyzed in a low-level counter); Section 2.1 details the operation of the scintillation counter; Section 4.3 specifies diagnostic and calibration procedures for evaluating the performance of the instrument; and Section 5.2 specifies that the tritium samples be retained for three months.

16.9.5 Neutron Rem Meter Analysis

Neutron rem meters are removed from the field after the quarterly exposure period is over and taken to the analytical laboratory. There, the exposed polycarbonate disks are removed and etched with 60°F - 6N sodium hydroxide (NaOH) for one-half hour. The NaOH enlarges the tracks from the fission fragments; these tracks are counted with a spark counter to determine the adsorbed neutron dose. An exposure of 1 mrem corresponds to 35 tracks (this represents the detection limit and sensitivity). The damaged polycarbonate disk is always replaced with a new one before the rem meter is returned to the field.

16.10 PERSONNEL DOSIMETRY LABORATORY

After the thermoluminescent dosimeters (TLDs) are retrieved from the field, they are loaded into reading magazines and returned, along with an Environmental Dosimeter Exchange form and the Chain-of-Custody Record form, to the Hazards Control Department, Personnel Dosimetry Laboratory. All TLD samples are logged into a computer by an HCD technician. Each TLD packet has a unique coded number which is read by an automated TLD reader. Each position in the reading magazine is automatically associated with an EMS sample location. EMS technologists put TLDs in the correct reading magazine location during TLD exchange in the field.

Environmental TLDs are calibrated in batches corresponding to each quarterly measurement cycle. At the end of the quarter, calibration TLDs are read along with routine TLDs.

16.10.1 TLD Analysis

The TLDs are heated in a three-phase process that induces photon emissions which are read with a photomultiplier tube. The TLDs are then reheated and read again (annealed), and returned to field stock for reuse in accordance with Hazards Control *Personal Dosimetry QAP*, Chapter 6, December 1993.

17**Quality Assurance and Training****17.1 REGULATORY DRIVERS**

DOE Order 5400.1 requires the establishment of a quality assurance program for environmental monitoring and surveillance programs consistent with DOE Order 5700.6B. DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (DOE/EH-0173T) identifies American National Standards Institute/American Society of Mechanical Engineers (ANSI/ASME) NQA-1 as the preferred standard for quality assurance programs related to nuclear activities and specifies that a quality assurance (QA) plan developed for environmental monitoring and surveillance should cover applicable elements of the 18 criteria delineated in that standard.

DOE Order 5700.6B was canceled by DOE Order 5700.6C, issued on August 21, 1991. The new order references NQA-1 as a standard that may be used for additional interpretive guidance for the development and implementation of quality assurance programs but does not mandate it as the basis for development of a QA program. It divides quality assurance into three broad subject areas—management, performance, and assessment—which are further subdivided into ten quality assurance criteria. These criteria incorporate the 18 elements defined in NQA-1 plus some additional requirements, particularly in the areas of training, quality improvement, and assessments.

Environmental monitoring and surveillance, as required by DOE Order 5400.1, are the responsibility of the LLNL Environmental Monitoring Section (EMS), a part of the Environmental Monitoring and Analysis Division (EMAD), which in turn is one of four Environmental Protection Department (EPD) divisions. Both EPD and EMAD have developed Quality Assurance Management Plans (QAMPs) that follow the 18 criteria format of NQA-1. Because EMS is a part of these organizations, it must carry out a QA program that meets the requirements of these QAMPs.

17.2 EMS QA PROGRAM

The LLNL Environmental Monitoring Section's QA program is defined in the *EMS Quality Assurance Plan* (Garcia and Failor 1993), which consists of ten sections covering the ten quality assurance criteria defined in DOE Order

5700.6C. Also, like the two QAMPs with which it complies, the *EMS Quality Assurance Plan* follows the 18 criteria format of NQA-1. A cross-reference between the EMS QA Plan and NQA-1 is given in Table 17-1.

Table 17-1. Comparison of EMS QA Plan Sections and NQA-1 Criteria

EMS QA Plan Section	NQA-1 Criterion
1. Program	1. Organization
	2. Quality Assurance Program
2. Personnel Training and Qualification	N/A
3. Quality Improvement	15. Control of Nonconforming Items
	16. Corrective Actions
4. Documents and Records	6. Document Control
	17. Quality Assurance Records
5. Work Processes	8. Identification and Control of Items
	9. Control of Processes
	12. Control of Measuring and Test Equipment
	13. Handling, Storage, and Shipping
6. Design	3. Design Control
7. Procurement	4. Procurement Document Control
	7. Control of Purchased Items and Services
8. Inspection and Acceptance Testing	10. Inspection
	11. Test Control
9. Management Assessment	N/A
10. Independent Assessments	18. Audits

Although the overall responsibility for quality within EMS belongs to its section leader, the achievement of quality is the responsibility of every person who performs work for the section. Section management provides tools, training, information, and support; determines quality requirements; and ensures that quality-affecting activities are regularly assessed and continuously improved. Section personnel are required to meet established quality requirements and to make recommendations and participate in solutions that lead to continuous quality improvement within the section.

The Environmental Monitoring Section's quality assurance coordinator reports directly to the section leader and is considered a part of the section's management staff. In addition, the QA coordinator is the section liaison to the division and department QA programs and participates in regular meetings with those

staff. The QA coordinator is responsible for identifying and correcting quality-related problems within the section and is authorized to bring these problems as far up the QA and management chains as necessary to ensure adequate resolution.

17.3 ENVIRONMENTAL MONITORING SECTION QUALITY ASSURANCE PLAN

The following ten sections summarize the ten elements of the EMS QA Plan. More detailed information regarding each criterion can be found in the EMS QA Plan (Garcia and Failor 1993.) and in the EMS standard operating procedures (Appendix A).

17.3.1 Program

The EMS QA program uses a risk-based, graded approach to the application of QA controls. The program is applicable only to EMS quality-affecting activities. Criteria used to determine which EMS activities are quality-affecting are given in the first section of the QA Plan and summarized in **Figure 17-1**. All section personnel are trained and expected to use these criteria to determine which of their day-to-day activities affect quality and are subject to the requirements of the EMS QA Plan.

Once an item or activity has been classified as quality-affecting, the degree to which QA controls are applied to it is determined. The stringency of QA controls is based on an evaluation of the risk to the section's goals and objectives if the item or activity fails to meet EMS requirements or expectations. The process used to make this determination is also described in the first section of the QA Plan and is outlined in **Figure 17-2**. Risk-based QA controls have been defined in detail for some activities in the QA plan. For example, three levels of procurement are defined, along with associated controls. QA controls for other activities are determined on a case-by-case basis. EMS is in the process of improving the methodology for quantifying risk and standardizing the way that QA controls are determined and applied.

Each person performing work for EMS is responsible for the quality of work, for continually seeking ways to improve efficiency and effectiveness, as well as lowering resource requirements. Improvements are implemented through an established, documented protocol for design changes.

Quality Affecting Activities

Figure 17-1. Summary criteria for determining quality-affecting activities.

Risk Prioritization and Determination of QA Controls - Graded Approach

Figure 17-2. Process for determining risk level of EMS activities.

One of the primary responsibilities of the EMS section leader is the allocation of resources to assure that EMS activities produce high quality results, within budget, and on schedule. This requires the appropriate allocation of qualified staff, staff time, equipment, space, and funding, as well as prioritization of projects. The information needed for resource allocation is obtained through frequent meetings with section personnel, including the QA coordinator, group leaders, project leaders, and environmental analysts. The scope of EMS projects, resource requirements, and progress or planned activities are continually evaluated by section management so support can be allocated to eliminate obstacles and to improve quality, efficiency, and effectiveness.

Section resources are allocated with highest priority given to tasks that protect the health and safety of LLNL personnel and the public, followed by compliance with federal, state, and local laws, compliance with DOE Orders, best management practices, and the long-term needs of LLNL. Upper management is consulted when available resources are considered insufficient for assigned projects; management then provides input to the prioritization of work or assists with the allocation of additional resources.

Health and safety, the environment, compliance, cost, schedule, program, and political and public concern are all considered when evaluating risk and determining quality assurance controls. Products are not released from the section until they meet regulatory requirements or DOE directives and are technically accurate and complete. These requirements take precedence over cost and schedule. Section management is responsible for balancing quality-improvement goals with scheduling requirements and the need to avoid exceeding the resources allocated.

17.3.2 Personnel Training and Qualification

Considerable attention has been paid recently to formalization and documentation of training in the Environmental Monitoring Section. In 1992, the responsibilities of the section's QA coordinator were expanded to include training. The QA coordinator completed DOE-sponsored courses in Instructor Training and On-the-Job Training (OJT) Instructor Training to prepare for the development of a Section Training Plan. A draft training plan was developed in early 1993, but staffing changes refocused training efforts later that year and priority was given to developing and implementing a formal OJT program for sampling technologists. Formal, performance-based OJT lessons were developed for environmental surveillance and effluent sampling activities in order to facilitate the replacement

of experienced personnel as well as the cross-training of technologists who were not trained in all aspects of EMS sampling. Experienced sampling technologists have been trained as OJT instructors and training of less experienced technologists is in progress. Completed OJT is documented on the LLNL Laboratory Repository of Completed Courses (LROCC).

Another addition to the EMS training program is an introductory course for all employees joining the section. Different versions of the course are offered to different employees, ranging from a 20-hour course for career analysts to a 2-hour briefing for summer employees. This has eased the transition of new employees into EMS, eliminated some of the mistakes made by newcomers, and ensured that each new employee receives a section-specific safety briefing. All section employees receive classroom training in Emergency Response and all non-clerical staff are required to maintain certification as Hazardous Waste Operations and Emergency Response for the General Environmental Cleanup Site Workers (29 CFR 1910.120[e]).

Work on the EMS Training Plan has resumed with a target completion date of January 1, 1995. This plan will require the development of individual training plans for each section member and will ensure that institutional and job-specific training is identified, completed, periodically reviewed, and maintained for each EMS employee.

17.3.3 Quality Improvement

EMS personnel are responsible for the quality of their own work, and for continually seeking means to improve efficiency, effectiveness, and to lower resource requirements. Quality improvement in the Environmental Monitoring Section has been steady. Problems are identified, tracked, and resolved using Needs Change Reports (NCRs). Quarterly NCR summaries are prepared by the QA coordinator and reviewed by section and division management, as well as by Environmental Protection Department QA staff. High risk or recurring problems are brought up at the division level for assistance in resolution and may be tracked using the LLNL Deficiency Tracking (DefTrack) system. Improvements are implemented through an established, documented protocol for design changes that allows modifications to be made in near real time.

Weekly meetings of the section management staff, including the QA coordinator, ensure that quality problems are discussed and resolved. Biweekly meetings of division QA staff and weekly meetings of Environmental Protection Department

QA staff, both of which are attended by the EMS QA coordinator, also ensure communication and resolution of quality-related issues.

17.3.4 Documents and Records

EMS documents that specify QA requirements, define EMS quality-affecting activities, or report EMS quality-affecting activities to others must be prepared, reviewed, approved, released, and changed according to specified requirements. EMS produces hundreds of these controlled documents each year, including letters to regulators, periodic data reports required by regulatory agencies, reports and plans required by the DOE, and standard operating procedures that define how the section performs day-to-day sampling, analysis, and quality assurance activities.

Two systems for document control exist within EMS. All regulatory and DOE reports and all documents requiring signature by management higher than the division level are assigned unique identification numbers and indexed by the EMS clerical staff. The group of individuals responsible for review and approval for each such document is determined based on its purpose, destination, and required signatory. This will typically include section, division, and department management and may include managers from other parts of LLNL, as well as LLNL legal staff. Proofreading by a member of the clerical staff who did not prepare the document is also required. Documents are routed through this chain and are not released from EMS until all reviewers' comments have been addressed and all reviewers have approved them. Although this system can be cumbersome at times, it ensures that documents issued by EMS are of the highest possible quality, and guarantees the integrity of data and regulatory interpretation reported by the section.

EMS standard operating procedures (SOPs) are prepared for each environmental monitoring network and for QA activities performed within the section. These procedures describe the rationale for each activity and give detailed explanations of how the activity is to be performed, acceptance criteria, documentation, and other QA requirements. A list of current and planned EMS SOPs is given in Table 17-2 and copies of all completed procedures are included as Appendix A of this document.

Table 17-2. EMS Procedures

Procedure	Title
EMP-AP-CA	Air Particulate Sampler Calibration
EMP-AP-L	Air Particulate Locations
EMP-AP-S	Air Particulate Sampling
EMP-AT-CA	Air Tritium Calibrations
EMP-AT-L	Air Tritium Locations
EMP-AT-S	Air Tritium Sampling
EMP-EM-CA	Emergency Monitoring Equipment Calibration (future)
EMP-EM-S	Emergency Environmental Sampling
EMP-GW-CA	Ground Water Equipment Calibrations
EMP-GW-L	Ground Water Sampling Locations
EMP-GW-QR	Quarterly Ground Water Report
EMP-GW-S	Ground Water Sampling
EMP-M-SCA	Meteorological Monitoring & Equipment Calibration
EMP-N-S	Site-300 Noise/Blast Forecasting (future)
EMP-QA-A	Analytical Laboratory Auditing
EMP-QA-AER	Site Annual Environmental Report
EMP-QA-AR	Analytical Requirements
EMP-QA-CD	Changes in Design
EMP-QA-CS	Courier Service Protocol
EMP-QA-D	Data Analysis
EMP-QA-DC	Document Retention (future)
EMP-QA-DM	Data Management
EMP-QA-ID	Interface Document Preparation (future)
EMP-QA-NCR	Nonconformance and Discrepancy Reporting
EMP-QA-P	Procurement Practices
EMP-QA-PW	Procedure Writing
EMP-QA-R	Reporting and Review Requirements (future)
EMP-QA-RI	Receipt Inspection and Qualification Testing (future)
EMP-QA-RP	Risk Prioritization (future)
EMP-QA-S	Quality Assurance Sampling (future)
EMP-QA-SA	Quality Assurance Assessments (future)
EMP-QA-SD	Sample Tracking Documentation
EMP-QA-SL	Sample Location Designators (future)
EMP-R-CA	Radiation Monitoring Calibration
EMP-R-DA	Radiological Dose Assessment

...continued

Table 17-2. EMS Procedures (*concluded*).

Procedure	Title
EMP-R-L	Radiation Monitoring Locations
EMP-RA-L	Rain Sampling Locations
EMP-RA-S	Rain Sampling
EMP-RO-L	Storm Water Runoff Locations
EMP-RO-S	Storm Water Runoff Sampling
EMP-RT-AL	Retention Tank Analysis List Update
EMP-RT-RA	Retention Tank Release Authorization
EMP-S-L	Soil and Arroyo Sediment Sampling Locations
EMP-S-S	Soil and Arroyo Sampling
EMP-SW-B196	Sewage Sampling at B196
EMP-SW-C196	Sewage Sampling at C196
EMP-SW-CA	Sewer Equipment Calibrations
EMP-SW-DS	Diversion Facility Tank Sampling
EMP-SW-EAR	Sewer Alarm Response
EMP-SW-HCAR	Hazards Control Off-Shift Sewer Alarm Response
EMP-SW-LWRP	Sewage Sampling at LWRP
EMP-SW-M	Sewer Equipment Maintenance
EMP-SW-OP	Sewer Monitoring Operations (future)
EMP-SW-SAS	Satellite Alarm Sampling
EMP-SW-SID	Sewer Spill Source Identification (future)
EMP-SW-SNLL	Sewage Sampling at SNLL
EMP-SW-SSM	Satellite Station Maintenance
EMP-VG-L	Vegetation and Foodstuff Sampling Locations
EMP-VG-S	Vegetation and Foodstuff Sampling
EMP-W-DB	Water Sampling - Central Drainage Basin (future)
EMP-W-L	Water Sampling Locations
EMP-W-S	Water Sampling

The preparation and distribution of SOPs is strictly controlled. Each environmental analyst is responsible for preparing and maintaining the SOPs required for his or her monitoring network. The QA coordinator has overall responsibility for SOPs related to quality assurance but authorship of these documents is often delegated to a subject matter expert (for example, the EMS Data Analysis procedure is written by the section's statistician.) New and revised SOPs are subject to peer, QA, and management review before they are issued. Minor changes to

SOPs can be made between revisions; these changes require management and QA review before they can be implemented.

Standard Operating Procedures are distributed to a controlled list of personnel to ensure that the most current information is available for use in performance of job assignments. Numbered copies are distributed along with acknowledgment forms that must be signed and returned, indicating that the recipient has read and understood the new document, replaced superseded materials, and will use the latest version in performing the tasks described in the new document.

Controlled copies are used to ensure that the latest information is available to those who need it to perform their assigned tasks; if a particular document does not provide this type of information, it is not necessary to control copies of that document. Unless specifically requested by section management, by an author, or by a regulator, EMS documents other than SOPs are not copy-controlled.

Environmental monitoring records are compiled into data packages by the EMS Data Management Team. Data packages include chain-of-custody (COC) forms, field tracking forms, hard copy data, copies of relevant NCRs, invoices, and any other information relevant to the data included in that package. Packages are assembled and filed by environmental medium in chronological order. Although the hard copy data serves as the primary record, environmental monitoring data are also stored on a relational database for ease of trending and reporting. Data are entered into the database either electronically or manually and QC checks are performed after the data are entered to ensure that database records match hard copy records.

Documents prepared for distribution outside EMS are given unique identification numbers and filed in a central location by clerical staff. These numbers are entered into a database along with the date, the addressee, the subject (containing keywords), the author, the originator of the document (if different from author), the recipient's company or organization, the revision number, and the name of the secretary who prepared the document. This system allows documents to be easily located. Current and superseded SOPs are maintained by the QA coordinator. Completed acknowledgment forms for controlled copy distribution are filed by clerical staff.

EMS plans to complete the implementation of its Document Retention Center in fiscal year 1995. This will provide a centralized storage location for EMS

documents and records as well as a comprehensive index that will allow for easy retrieval of records.

17.3.5 Work Processes

Identification and control of environmental samples is maintained through the use of field tracking forms, COC forms, and field logbooks. Each sample is assigned a unique identifier based on the sampling date, the sampling location, and the environmental medium sampled.

EMS uses two types of equipment: sampling equipment and measuring and test equipment. Sampling equipment, such as pumps, bailers, or motors, is used in the acquisition of environmental samples, but not for quantitative determination of monitoring parameters. Unless specified otherwise in an EMS SOP, this type of equipment is not controlled, calibrated, or maintained according to documented procedures. Personnel using this equipment are required to assess its condition each time it is used and remove it from service for repair or replacement as soon as signs of deterioration appear.

Measuring and test equipment used for generation of environmental monitoring data are identified by unique control numbers. Where appropriate, this number is recorded on the field tracking form at the time sampling occurs. Controlled equipment is indexed on a Measuring and Test Equipment Inventory List that is used to ensure that equipment is calibrated when required. Much of the measuring and test equipment used by EMS are calibrated at every use; when this is not the case, personnel are required to verify that equipment has not exceeded its calibration recall date before using it.

All EMS environmental sampling is conducted in accordance with approved SOPs. It is the responsibility of EMS environmental analysts to ensure that these procedures accurately reflect sampling requirements and that they are kept current. The EMS QA coordinator determines when changes can be made using the design change process, which is used for minor changes and requires fewer reviewers; when a revised procedure is required, which involves peer, management, and QA review and takes much longer; and when formal training is required before changes can be implemented. If changes require training or briefing of staff, it is the responsibility of the analyst to ensure that this is done.

EMS COC forms are generated by sampling technologists as soon as samples are taken. Samples remain in the custody of the sampling technologists, either in

their presence or in a controlled access or locked storage area, until they are surrendered to analytical laboratory personnel. At the time of surrender, the responsible technologist and the person accepting custody sign the COC and the samples become the responsibility of the analytical laboratory. After analysis, samples are held by the laboratory for a specified period of time, then discarded. The EMS COC accompanies the hard copy data back to LLNL, where it is relinquished to the responsible environmental analyst. The analyst reviews the data, resolves any discrepancies, and, when data are deemed acceptable, relinquishes custody to the data manager, who supervises preparation of the data package. Change of custody of the data is documented at each step by a signature on the COC.

Handling, storage, and shipping requirements for environmental samples are specified in EMS SOPs. Many samples are analyzed off-site by contract analytical laboratories. Two of five off-site laboratories are local and provide courier service for samples. Couriers pick up samples at LLNL and deliver them to the laboratory. Samples delivered to non-local laboratories are processed through the LLNL Shipping Department. EMS samples are, in general, non-hazardous. All samples except air filters are packaged in ice chests and sealed with tape prior to shipment. COC forms are enclosed in each ice chest. Air filters are packaged in boxes along with COC forms and delivered to the LLNL Shipping Department for shipment by a commercial carrier. Between sample collection and shipment or delivery to analytical laboratories, samples remain in the custody of the sampling technologists and are kept in locked containers or in limited access areas.

17.3.6 Design Control

The rationale and design criteria for the networks that comprise the LLNL environmental monitoring program are described in this Environmental Monitoring Plan (EMP) and in EMS standard operating procedures.

Environmental analysts are responsible for performing technical assessments of their monitoring networks. Technical assessments include rationale and design criteria, extent and frequency of monitoring and measurements, procedures for laboratory analysis, quality assurance requirements, program implementation procedures, preparation and disposition of reports, and comparison of an ideal monitoring network to existing monitoring. Environmental analysts research regulations, DOE Orders, and Laboratory policy to fully understand the requirements for their networks; prepare requisite documentation; obtain

management and QA review and approval; write appropriate SOPs and ensure that they are approved, implemented, and revised as necessary; and maintain contact with regulators and familiarity with regulations to ensure that necessary changes are proposed, reviewed, and implemented. The EMP is subject to annual review and triennial update and SOPs are currently reviewed and updated "as needed." A triennial QA assessment of each procedure is planned. New or changed sampling and analysis procedures are subject to a thorough review by peers, the QA coordinator, and section management.

17.3.7 Procurement

EMS has adopted a risk-based, graded approach to procurement controls to supplement the LLNL Procurement Department's procedures for controlling procurements. At a minimum, EMS will comply with the higher level Procurement Department requirements. The supplementary EMS procurement controls are used when warranted by the potential risk of the item or service to section goals and objectives. This is determined through the assignment of procurement categories by the environmental analysts, with management approval. There are three procurements categories: unrestricted, restricted, and highly restricted. The assigned category determines the QA controls that are applied.

Items are in the unrestricted procurement category if their associated risk is not great enough to justify the resources required for QA controls. Examples of this category includes items that are purchased on a regular basis and have a history of use by EMS without incident, new or infrequently purchased items judged to be of negligible risk to the integrity of environmental results (based on previous history with similar items), or off-the-shelf software purchased for use on a personal computer. The only QA controls needed are verification that the correct item was received and establishment of basic functionality.

Items in the restricted procurement category are those of low- to mid-level risk to section goals and objectives. QA controls such as custom purchase specifications, receipt inspection, or qualification testing are applied to these purchases. Vendor qualification is not required to purchase these items.

Restricted procurement items include complex items (sufficiently complicated or different from off-the-shelf as to require custom purchase specifications, or equipment used to obtain unusual or difficult-to-obtain samples) and items that must be purchased as capital equipment. Also included are measuring and test equipment, non-standard software, and items previously categorized as

unrestricted that were upgraded to the restricted category because of performance problems. One example of a restricted procurement is the recent purchase of a new computer system for LLNL's on-line sewage monitoring facility. The responsible analyst developed a set of criteria for the purchase specifications as well as a set of performance tests that had to be completed successfully before the system was accepted by EMS.

The category of highly restricted procurements consist of high risk items. Procurements in this category require custom purchase specifications, supplier qualification, and periodic QA assessments to verify the supplier's ability to comply with EMS requirements. Analytical services for environmental samples are considered highly restricted procurements. Extremely costly and complex items would also fall in this category. One example of such a procurement is the upgraded stack monitoring equipment for the LLNL Plutonium and Heavy Element Facilities. This was a costly procurement with the potential for a significant regulatory and environmental impact if the equipment did not meet EMS requirements or did not function properly. EMS analysts worked with LLNL Procurement personnel to develop detailed procurement criteria, visited the vendor and reviewed the QA plan to ensure that the vendor was capable of meeting LLNL's needs, reviewed and approved engineering drawings, and inspected items upon delivery.

17.3.8 Inspection and Acceptance Testing

EMS environmental monitoring data are critical to the mission of the Environmental Monitoring Section and are therefore subject to inspection prior to acceptance. Data are reviewed by the responsible environmental analyst and by members of the data management team before they are accepted. Data review includes verification of sample identification using COC and field tracking forms, QC checking of electronically sent and hand-entered data results against hard copy data, data trending, verification of comparability to previous data, and inspection of field and laboratory QC sample results. If any discrepancies are identified during these reviews, an NCR is written and the analytical laboratory is contacted. All issues must be resolved before the data are accepted.

Receipt inspection or qualification testing of items other than data may be required by the responsible environmental analyst. When related to a procurement, receipt inspection must be specified in the purchase specification for the item. Receipt inspection will typically include verification of identity, examination of physical characteristics, and verification of no damage. Qualification

testing typically involves installing the item and ensuring that its performance under operating conditions is comparable to that of existing items, expectations, or specifications. Receipt inspection and qualification test requirements and results should be documented by the responsible analyst, and QA and management approval should be obtained.

17.3.9 Management Assessment

The section leader is responsible for performing management assessments of the entire section. This includes periodic, planned review of the section Quality Assurance Plan, Training Plan, and Environmental Monitoring Plan; review of monthly reports by group leaders and the QA coordinator; review of reports summarizing NCRs; review of Training Status reports; and review of quality verification activities. The section leader is also responsible for preparing monthly and annual reports to EMAD management. The section leader is responsible for determining when management issues are adversely affecting the implementation of the section QA program or preventing the section from meeting its safety, quality, or environmental objectives; for proposing and implementing solutions; and for bringing problems to the attention of EMAD management when appropriate. Weekly meetings with the three EMS group leaders, the QA coordinator, and the section secretary ensure that the section leader is informed of activities and issues, and oversees development and implementation of solutions to problems. Information filters up to the section leader from the monthly reports provided by group leaders who summarize activities of all group members as taken from those members' individual monthly reports.

17.3.10 Independent Assessment

As a part of its Environmental, Safety, and Health (ES&H) program, LLNL developed and implemented an ongoing Laboratory-wide self assessment program to routinely evaluate compliance with existing regulations and directives. This program allows LLNL to identify conditions that could lead to personnel safety, industrial, regulatory, legal, or environmental problems if not promptly detected and corrected.

As part of the self-assessment program, the LLNL Assurance Review Office has established a Deficiency Tracking System (DefTrack) to track the status of ES&H deficiencies from the time they are identified until they are closed and verified. This database is the Laboratory's official ES&H database for deficiency correction

and is intended to allow the individual organizations to track deficiencies at all levels in a consistent manner. Deficiencies identified through LLNL Hazards Control ES&H field inspections, outside audits, and other means are tracked with it. DefTrack is programmed to generate detailed deficiency reports, including the results of corrective actions. Aside from encouraging timely and effective resolution of deficiencies, DefTrack is used for Laboratory-wide trend analysis.

As part of the Plant Operations Directorate, EMS is audited yearly by Hazards Control. Additionally, outside inspection teams, such as EH-24, the Defense Nuclear Facilities Safety Board, the DOE Tiger Team, and the Laboratory's Assurance Review Office perform periodic assessments of EMS. The results of these assessments are tracked with DefTrack, and it is the responsibility of the section leader to ensure that requisite corrective actions are implemented and that findings are closed.

Department and division QA personnel also perform audits of EMS. Though not tracked formally on DefTrack, the section leader is still responsible for responding to these audits and for correcting any identified deficiencies. Responses are formulated by weighting risk to section goals and objectives against the resources required to evaluate problems and implement corrective actions. When resources are not available to adequately address an identified deficiency, the section leader will raise this issue to division and department management so that an acceptable solution can be identified and implemented.

The California Agreement in Principle (AIP) program has done some independent data verification for EMS. AIP personnel currently co-monitor environmental radiation using thermoluminescent dosimeters and they review selected LLNL environmental monitoring reports, including the annual Environmental Report. This program is expected to expand to include additional environmental media.

17.4 FIELD QUALITY CONTROL

EMS approaches field quality control through the use of standard operating procedures, formal OJT for sampling technicians, and the use of field tracking forms and quality control samples. Field QC samples include trip blanks, field blanks, and duplicates. Trip blanks are used for volatile samples in aqueous media, air particulate sampling, and external radiation sampling. For water samples, trip blanks are prepared by the analytical laboratory. Unopened bottles containing trip blanks are taken to the field during sampling, then submitted to

the analytical laboratory and analyzed alongside actual samples. Aqueous trip blanks are submitted daily when sampling for volatile organic compounds. Trip blanks for air particulates consist of an unused air filter that is taken around the sampling route during filter exchange and then submitted with sample filters for analysis. This type of blank is submitted each time the air filters are replaced. For external radiation, thermoluminescent dosimeters (TLDs) equivalent to approximately 10% of the routine samples accompany samplers during the TLD exchange. These are then submitted for analysis with the field TLDs.

Field blanks are also used for aqueous media. This type of blank involves filling sample bottles with water of known quality in the field, then submitting these bottles for analysis alongside the actual samples. One field blank is taken for each sampling event and the same suite of analytes as that for actual samples is requested for it. In addition, a field blank is prepared in the sample preservation laboratory and submitted for analysis once each quarter.

For aqueous media, duplicate samples are taken directly after the routine sample they are to duplicate. One duplicate sample is taken per sampling event and the entire suite of analyses is requested for the duplicate. For the monthly sewer sample, a duplicate sample is taken for one analyte each month and the duplicate is sent to a second analytical laboratory. Duplicate samples equivalent to approximately 10% of the routine sample load are taken for air tritium, vegetation, soil, sediment, and external radiation.

Field tracking forms are used for all environmental sampling except sewer. These forms specify sample identifiers, special handling (such as performing a sampling route in a particular order, triple bagging samples taken from areas of known higher concentration), and information about sampling equipment (such as pump type and depth of wells). The field tracking form is used to record the results of field calibrations, the identification numbers of equipment used, the results of all field measurements, and any special observations made by sampling technologists. Field tracking forms are reviewed by environmental analysts as part of the data acceptance process.

17.5 ANALYTICAL LABORATORY QUALITY CONTROL

Analytical laboratories performing analysis for EMS are required to have quality assurance programs that meet the requirements specified in the EMS QA plan. This is verified during pre-award audits and periodic reassessments by EMS or EPD. EMS has assigned analytical laboratory contacts for each analytical

laboratory. These contacts serve as liaisons between the section and the analytical laboratories. They are responsible for informing the analytical laboratories when discrepancies are discovered and work with analytical laboratory personnel to resolve these issues. This system allows a relationship to be built between the two organizations and facilitates problem resolution.

Contract analytical laboratories are required to provide QA/QC data for each sample analyzed. Typical QC sample requirements include laboratory control standards, matrix spikes, matrix spike duplicates, and method blanks. Laboratories must also provide EMS with reporting detection limits, method detection limits, and surrogate recovery data. QC data are reviewed by environmental analysts before data from associated routine samples are accepted. If QC data do not fall within acceptable ranges, the entire dataset should be rejected.

17.6 LABORATORY INTERCOMPARISON STUDIES

EMS works with five contract analytical laboratories and five on-site laboratories. On-site laboratories participate in the Environmental Protection Agency's Environmental Monitoring Systems Laboratory -Intercomparison Studies Program, the DOE Environmental Measurements Laboratory intercomparison program, and the State of California Environmental Laboratory Accreditation Program intercomparison studies. The results of these analyses are reported annually in the LLNL annual Environmental Report. Participation in laboratory intercomparison studies was required for contract analytical laboratories in new contracts which became effective in summer 1993; however, the results of these studies have not yet been made available to EMS. EMS staff are working with the LLNL Procurement Department to obtain these data.

The LLNL Radiation Analytical Sciences Section (RAS) analyzes samples of environmental origin and low radioactivity for the EMS. RAS laboratories have been involved with external quality assessment programs for over 10 years. RAS currently participates in the external quality assessment programs of the EPA Environmental Monitoring Systems Laboratory-Las Vegas (EMSL) and the DOE Office of Environmental Restoration and Waste Management (Environmental Measurements Laboratory (EML). These agencies provide samples of various environmental media spiked with unknown concentrations of the nuclides of interest to participating laboratories according to the following schedule:

Agency	Months	Study	Matrix
EMSL	June, November January, July, October March, August February, June, September	Gamma Gross Alpha, Gross Beta Tritium Uranium Radium	Aqueous
	March April, October	Plutonium Mixed Alpha, Beta, and Gamma	
EML	March, September	Plutonium Gamma Total Uranium	Air Filter
	March, September	Gamma	Soils
	March, September	Gamma	Vegetation
	March, September	Gamma Plutonium Total Uranium Tritium	Aqueous

Participating laboratories analyze samples and return them to the agency conducting the study. The results are due on specified dates and data received after the deadline are not accepted. Acceptable data from all participating laboratories are statistically analyzed and compared to known values by the agency. Results and statistical analyses from all participating laboratories are published for each sampling month, allowing for an external evaluation of the level of competency of the participating laboratories.

18

Data Management and Analysis

18.1 DATA MANAGEMENT

The Environmental Monitoring Section data are a critical product of the monitoring effort because they provide evidence and documentation of EMS' environmental surveillance and effluent monitoring activities. These data are EMS' means of showing that LLNL has met the environmental monitoring objectives such as those outlined in DOE Order 5400.1; data management allows EMS to "demonstrate compliance with legal and regulatory requirements imposed by applicable federal, state, and local agencies; confirm adherence to DOE environmental protection policies; and support environmental management decisions."

Several regulations suggest the importance of data management. General record-keeping requirements for environmental monitoring activities are outlined in DOE Order 5400.1. The Order "requires maintenance and retention of auditable records relating to the environmental surveillance and effluent monitoring programs." DOE/EH-0173T (U.S. Department of Energy 1991), Chapter 9, states "data handling *should** be recorded or referenced." In addition, DOE Order 5700.6C establishes quality assurance requirements and suggests "the maintenance of records should include provisions for retention, protection, preservation, traceability, accountability, and retrievability." More data quality assurance specifics applicable to EMS are discussed in the EMS Quality Assurance Plan (Garcia and Failor 1993). DOE/EH-0173T, Chapter 7, also gives some guidance on the electronic storage of environmental monitoring data. The document requires that "data *should** be examined and entered into the appropriate data bases promptly after analysis."

Because the EMS environmental monitoring program provides data for environmental impact assessments and site management decisions, EMS must be able to prove the data are valid and reliable. Important aspects of assuring the sample data integrity include sample tracking and data management, in addition to approved sampling and analysis techniques. These points help reduce the variability of results and increase the data reliability (U.S. Department of Energy 1991). Therefore, these aspects must be carefully documented to provide "traceability and accountability" information (DOE Order 5700.6C).

EMS manages several types of data. The majority are sample tracking and analytical data related to routine environmental monitoring activities. Another large portion of the data EMS handles include the data used to determine wastewater disposition, whether or not it may be discharged to sanitary sewer. EMS also deals with air effluent data, meteorological data, special project data, and on-line sewer facility monitoring data. This latter group of material is managed under separate procedures documented by the individual responsible analysts.

18.1.1 Monitoring Data

Data management occurs continuously through EMS monitoring activities. It begins with the creation of medium-specific sampling plans, continues through actual sampling activities to data review and analysis, and concludes with final documentation and data storage. EMS monitoring data management activities are presented in Figure 18-1.

As mentioned above, the scientific validity, acceptability, and legal defensibility of the EMS data depend on careful record keeping and tracking of environmental samples and the corresponding data. The following discussion explains the step-by-step process EMS follows to document the sample handling and data management activities.

18.1.1.1 Sampling Plans

Each medium has a sampling strategy specified by the environmental analyst in an annual sampling plan. The plan includes the purpose of the sampling, sampling locations, sample collection methods, actual number of samples to be taken, sampling frequency, analytical methods to be employed, and sampling analytes. The sampling plan must consider the time necessary for analysis; seasonal conditions; field technician availability; the representativeness of the samples; and local, state, and federal agency sampling requirements. The environmental analyst is responsible for monitoring field sample collection and sample tracking documentation to ensure adherence to the sampling plan.

18.1.1.2 Sample Tracking Documentation

Field sampling technicians take samples each quarter based on the environmental analysts' sampling plans. To ensure sample validity and corresponding data acceptability, the sampling technician must initiate proper documentation. This involves two types of documents: field tracking forms (FTFs) and chain-of-custody (COC) record forms. Proper sample identification must be used

Figure 18-1. Data management of EMS monitoring activities.

consistently. The field tracking form is used by field personnel to document sample collection, record pertinent sampling information, and track conditions that might affect the integrity of the sample. The chain-of-custody record form is a legal document containing vital sample information. It documents sample custodianship during the many steps in the handling and analysis of each sample.

18.1.1.2.1 Sample identifiers. All samples must have individual sample identifiers. The proper EMS procedure for developing a sample identifier is documented in EMP-QA-SL, *Sample Location Designators*, and current acceptable sample location designators are defined in the medium-specific EMS sample location procedures. Quality control samples are given temporary, nonspecific identifiers when they are submitted to analytical laboratories. This is to keep the nature of the QC sample—whether it is a duplicate, blank, standard, or spike—“blind” to the laboratories. When data are received from a lab, the blind identifiers are decoded, according to the field tracking forms, to reveal the actual sample locations.

18.1.1.2.2 Field tracking forms. The FTF is a form or logbook used to document sample collection information in the field. A sample is shown in **Figure 18-2**. All field notes should be entered on the FTFs. These forms contain sample identifiers as well as pertinent information about blind quality control samples. Analysts must decode laboratory QA sample results with the information contained on the FTF.

The FTFs are maintained by the Technical Support Group, with revisions made as necessary to meet regulatory requirements and changes in surveillance monitoring plans. All analytes/analyses must be listed on the FTF for each sample. This information is necessary for proper sample container preparation, according to medium-specific EMS sampling procedures, as well as proper COC completion.

EMS field sampling technicians who collect environmental samples from any medium must complete FTFs according to media sampling, media location, quality assurance sampling, sample designator, and documentation procedures. The sample identifiers on a given FTF and corresponding COC record form must be unique and they must match the labels placed on the sample containers. Each individual sample must have an associated sampling date noted on the FTF. The sampling technician collecting each individual sample must initial the FTF in case questions arise concerning the sampling. Since each FTF may have several corresponding COCs, those COC numbers must be marked on the FTF. The

PCMP/WDR 3Q94

FIELD TRACKING FORM EMP-GW-S-01

LOCATION DESIGNATOR: K7-06

SAMPLE IDENTIFIER: 3-K706-01-MW

pH meter# 007

Date: 8-5-94

Time Started 1130

Time Sampled 1205

Casing I.D.: 3.25

Pump type: 115v Standard

T.D.= 61.65

$$99.50 \times \frac{35.2}{231} = 15.16 \times 3 = 45.48$$

D.T.W.= 26.45

Wtr. Ht.= 35.2

COC#: _____ Lab: _____

DO NOT RINSE ANY GLASS BOTTLES EXCEPT TRITIUM AND H.E. VIALS

FIELD TREATMENTS

Filtered Samples

☒ Metals^a

Refrigerated Samples

☒ EPA601 (x2)☒ TDS^c☒ COND & pH^c

Untreated Samples

☒ HE☒ Tritium☒ Uranium^a 234,235,238☒ Thorium^a 228,232☒ 226 Ra (2L)

pH	Temp.	Gal.	Time
7.77	23.6	0	1133
7.42	21.2	25	1150
7.52	22.1	45	1158
7.57	21.5	46	1200
7.56	22.2	47	1202
7.49	23.4	48	1204

*NOTE: Filter All Radiological Samples

LABORATORY TREATMENTS

See LABORATORY TREATMENTS sheet
for definition of footnotes.COMMENTS: NegativeINITIALS AK

Figure 18-2. Sample of Field Tracking Form EMP-GW-S-01.

sampling technicians should also make notes about general sampling information on the FTF, such as the time the sample was taken, flow information, equipment specifications, field analytical measurement data, accurate descriptions of the distance from the permanent marker at the sampling site, and any comments on unusual, questionable, or noteworthy events that may have occurred during sampling.

18.1.1.2.3 Chain-of-custody record forms. The COC is a five-part, color-coded form used to track samples as they progress from the sample collector to the sample courier and from the courier to the analytical laboratory, then from the laboratory to the environmental analyst and on to the data manager for final storage. The COC contains important sample information, including the name of the laboratory that will analyze the samples; sample identifiers; the sampler's identity; the name and telephone number of the EMS environmental analyst responsible for the sample and resultant data, to whom the data are to be sent; the EMS mailing address; the date the sample was collected; a unique COC number; a release number for analyses to be performed by off-site analytical laboratories; the analyses to be performed; and the signatures documenting custodianship of the samples as they change hands. A COC copy is available for each custodian as samples change hands and signatures are acquired. See **Figure 18-3** for a sample COC record form.

After sampling, the sampling technician should use the data on the FTF to fill out COC record forms. Whenever a sample is submitted for analysis, a COC must be generated. Since collected samples may require analyses from several laboratories, more than one COC may be associated with one FTF. The COC must remain with the sample at all times until analyses are complete, and then must remain with the hard copy.

18.1.1.3 Sample Custody Tracking

After samples are collected and documentation is generated, the sampling technician must deliver the samples to a courier for transport to the off-site analytical laboratories. The technician may deliver the samples directly to an on-site laboratory and, when the courier is missed, directly to an off-site analytical laboratory. The technician is responsible for relinquishing the samples once proper documentation on the COC has been confirmed by both the courier and technician. The technician then delivers the FTF and goldenrod COC copy to the EMS Data Management Team to hold until the sample analyses are completed and data received.

[illegible]

The courier must deliver the samples to the appropriate analytical laboratory on the same day of receipt, with appropriate signatures, so that the chain of custody is not compromised. The samples must be in sound condition when the courier relinquishes them to the laboratory (EMP-QA-CS, *Courier Service Protocol*).

The analytical laboratory personnel must sign the COC when receiving samples from the courier and mail the pink COC copy to the responsible EMS analyst noted on the form. The laboratory is responsible for keeping track of the samples in its custody, using a system acceptable to EMS. When analysis is complete, laboratory personnel must sign the COC form to relinquish custody, keep the canary COC copy as a record, and return the rest of the COC copies with the data to the responsible EMS environmental analyst or designee.

The analytical data is usually received for the analysts by the EMS Data Management Team (DMT). The DMT date-stamps the data reports and original COCs as they are received, decodes any QA identifiers according to the corresponding FTFs, and distributes the COCs and copies of the data to the responsible analysts, who should review the data upon receipt. Initial review may be cursory, to determine whether the required analyses have been performed (EMP-QA-SD, *Sample Tracking Documentation*, and EMP-QA-I, *Invoice Processing*), to ascertain any unusual values, or to flag items requiring immediate response and reporting (EMP-QA-D, *Data Analysis*, and EMS QAP, Section 8, *Inspection and Acceptance Testing*). The analysts make sure problems with any analyses are resolved in a timely manner. Unusual data results must be verified or reanalyzed by the analytical laboratory within thirty days as specified in EMP-QA-SD.

When an analyst determines data are acceptable, he or she signs the COC, retains the green copy as a record, and delivers the form, or completed data package if DMT is not compiling it, to the data manager. The analyst and data manager should both sign off on the COC. The data manager then ensures that the DMT compiles the data package and enters the data into the database (DOE/EH-0173T).

18.1.2 Wastewater Data

Wastewater data management is very different from the management of other EMS monitoring data. Specifics of wastewater data management activities as well as flow charts are included in EMP-RT-RA, *Retention Tank Release Authorization*.

Wastewater data are used to determine the sewerability of wastewater from sources such as building retention tank systems. A member of the EMS Water Guidance and Monitoring Group (WGMG) is designated the responsible person, or WGMG RP, for determining wastewater disposition. This person decides if wastewater generated from various locations throughout LLNL may be discharged to sanitary sewer or if it must be handled by the Hazardous Waste Management Division.

18.1.2.1 Data Gathering and Determination of Disposition

Wastewater samples are not collected by EMS personnel. Designated retention tank staff, as described in EMP-RT-RA, coordinate sample collection. Samples are sent to various analytical laboratories for analyses, and results are delivered to the WGMG RP, who collects the data, date-stamps them, checks them against the Retention Tank Analysis List to determine the completeness of the requested analyses, and verifies the tank volume. The WGMG RP then compares the data against discharge limits and other regulatory requirements to determine if the tank contents may be released to sanitary sewer.

18.1.2.2 Documenting Disposition

The WGMG RP generates a Retention System Disposition Record (RSDR) for the sample. This record is a four-part form used to document the final disposition of wastewater (Figure 18-4). It contains vital information about the original tank number as well as the current container (if the waste has been transferred from its original container). The WGMG RP should note sanitary sewer discharge approval or denial on the form and stamp it to indicate categorical or non-categorical waste, as applicable.

The WGMG RP keeps the goldenrod copy of the form with the original data reports and logs analytical information in the Retention Tank Log. A photocopy of the analytical results is attached to the remaining RSDR copies; the copy is distributed to personnel concerned with the wastewater sample. The responsible person for the tank then ensures that the waste is discharged or handled by Hazardous Waste Management as prescribed on the RSDR. This person also makes final disposition notes on the RSDR, signs and dates it, and returns it to the WGMG RP.

RETENTION SYSTEM DISPOSITION RECORD

0142

DEC 30 1992

(I) System Description

- (a) Building Number: 332 (b) Date sampled: 9-1-92
- (c) System Component (Include specific identification as necessary):
☒ Tank: 332-R101 ☐ Cooling Tower ☐ Other _____
☐ HWM Tankers: _____ ☐ Ion Exchange
☐ Sump: _____ ☐ Paint Booth
- (d) HC Analytical Lab Sample #: _____ HWM Lab Control #: _____
 Brown & Caldwell Log #: _____ Other: EAS Sample # 9202492

Authorization Record

(II) EPD-EGD

- (a) ☒ OK to release to sanitary sewer.
☐ OK to release to sanitary sewer with pH adjustment to 5-10.
☐ May not be released to sanitary sewer due to high _____
☐ Not to be used to determine release information only, no response necessary.
☐ Other _____
- (b) ☒ Results placed in pick-up box per Annette Andrade 9-20-92
☐ Results mailed to _____
- (c) Comments _____
- Name (print) Sgt. Anderson Signature [Signature] Date 9/29/92

(III) Authorized Technicians

- (a) ☒ Released to sanitary sewer on 9/22/92 10am with pH of 7
Date/Time
- (b) ☐ Transferred by Technician to HWM container # _____ on _____
- (c) ☐ No action by Technician; HWM assumed responsibility for contents. Requisition # _____
- (d) ☐ Comments _____
- Name (print) Annette Andrade Signature A. Andrade Date 9-29-92

(IV) EPD-HWM

- (a) ☐ Assumed possession of wastewater on _____ as Requisition # _____ Initials _____
Date/Time
- (b) Ultimate disposition
☐ Retained for treatment
☐ Released to sanitary sewer on _____ with pH of _____
Date/Time
☐ To be shipped off-site for treatment, disposal, or recycling.
☐ Comments _____
- Name (print) _____ Signature _____ Date _____

Four copies:

White: Circulating copy, to be returned to the WATS environmental technician, L-633
 Canary: Retained by authorized technician

Pink: Retained by HWM
 Goldenrod: Retained by WATS technician

Figure 18-4. Sample of Retention System Disposition Record.

The original white RSDR form is circulated for signatures. When it has been returned with the required signatures, it is attached to the goldenrod copy and the original data sheets. The WGMG RP records the final release information taken from this white original into the Retention Tank Log. The completed RSDR and analytical data are then given to the EMS Data Management Team for inclusion in the database.

18.1.3 Data Storage

18.1.3.1 *Official Hard Copy*

As routine monitoring data are received by the Data Management Team, team members date-stamp them, decode any QA identifiers according to the FTFs, copy the analytical sheets, and distribute the copies to the responsible analysts. Additional copies of all water, soil, and vegetation data are sent to the Environmental Restoration Division of EPD for reference and duplicate storage. The DMT or responsible analyst then compiles a data package by matching the original data sheets with the corresponding FTFs and COCs, invoices where applicable, and any associated Needs Changing Reports (NCRs—explained in EMP-QA-NCR, *Nonconformance and Discrepancy Reporting*) related to the sampling or the data.

A data package is an official QA record and is EMS' legally defensible data. Active data packages are filed by sampling quarter and medium and stored in the Data Management Team offices. DMT keeps the data package binders until the first quarter following the publication of the annual Environmental Report for the year in which the data were generated. These binders are then transferred to the Document Retention Center as described in EMP-QA-DC, *Document Retention*. The quality assurance coordinator ensures that the binders are properly labeled and logged into the EMS Document Retention database.

For wastewater data, the completed Retention System Disposition Record and the corresponding analytical results are filed together in the Retention Tank Sample Results file. This file is maintained by the WGMG RP or the EMS Document Retention Center.

18.1.3.2 *Electronic Data Storage*

Electronic storage of EMS data is invaluable because it allows immediate comparative evaluations of data as well as easy generation of report tables, graphs, and charts for data review and regulatory compliance. However, only

the original analytical data reports combined with their corresponding chain-of-custody record form may be considered official hard copy. The database must be considered a "secondary" source.

18.1.3.2.1 System and software description. All routine EMS monitoring data and wastewater data are kept in electronic form within the EPDDATA database. The database is maintained on a VAX 6310 mainframe with 64-MB total memory and over 11 GB of disk space. EPDDATA utilizes INGRES v6.4/03, a commercially available relational database software. INGRES recognizes the Standard Query Language (SQL) for data manipulation but also contains its own forms and reporting tools, allowing efficient, yet secure, electronic access to the data. EPD Computations Support provides both system and network support as well as software maintenance and application development related to this database.

18.1.3.2.2 Database model. EPDDATA records are kept in several "global" tables. (The EPDDATA information model diagrams provide information models of the database). These global tables are readable by all database users. All data must first be entered into a personal work space, a set of work tables which duplicate the shared global table structures. This provides a place to groom and verify the data before it is released as part of the global information tables other users may access. The EPDDATA database is structured to hold all vital sample and analysis information, as well as disposition information for wastewater data. Monitoring data and wastewater data are in separate table sets. EPD Computations has developed custom applications for database access into the different areas; Monitordb allows easy access to the database tables related to routine monitoring, and Watsdb allows access to the wastewater and tank system tables.

The sample tables hold important sample-related data including the location identifiers, sample dates, sample types, QA identifiers, and special comments concerning the sample quality (DOE/EH-0173T, Chapter 7). Analysis information such as the requested analyses, individual analytes, nondetect indicators, results, and limit-of-sensitivity values are kept in the analysis tables. As required in DOE/EH-0173T, the actual instrument reading values for the monitoring data are kept in the database so that negative values or other values below the detection limits may be included in statistical analyses and reports. Reporting units required by DOE Order 5400.1 are maintained in the database. For regulations requiring other units, such as bequerels, the units are converted during report generation only.

18.1.3.2.3 Security/access limitations. The EPDDATA database is shared by three EPD Divisions: Environmental Monitoring and Analysis Division, of which EMS is a part; Environmental Restoration Division; and Operations and Regulatory Affairs Division. Protections are built within the INGRES applications to prevent the users from changing data not belonging to their respective divisions, and access is password-controlled. In addition, although any EMS analyst wishing to make use of the electronic data may access the database, access is read-only. Only Data Management Team members are able to update or add records to the database. Verifications are also built into the database applications to prevent haphazard changes from being made by inexperienced users.

INGRES cleanup routines are run on the database every evening and an optimization/checkpoint routine is run weekly. These procedures help ensure the integrity of the database. For security against data loss, all information kept on the VAX mainframe is copied or archived daily, weekly, and monthly. In addition, INGRES logs each data entry transaction in a journal useful for tracing problems and recreating data. As a backup, the Environmental Restoration Division has implemented a read-only copy of the database on a UNIX machine which EMS may access.

18.1.3.2.4 Data entry. All monitoring and wastewater data are entered to the EPDDATA database as soon as they are received by DMT. Data for which there is no corresponding official hard copy, such as fax reports and early electronic shipments, are held and put into the database only when the official data is received.

18.1.3.2.4.1 Entry Procedures. EMS can receive data electronically in ASCII files or other text formats. EPD Computations designed a laboratory transfer specification document (*Specifications for Transmitting Data from an Outside Analytical Lab*, EPD Computations, 1993) to provide guidelines to the laboratories for consistent transfer of electronic data sets. Each analytical laboratory can download its data files onto the VAX where EPDDATA is housed. EMS DMT members then transfer the files to their database work tables and perform the necessary grooming before adding the data to the rest of the database. EMS utilizes several autogroom procedures to make consistent changes to the data and minimize errors.

Although most monitoring data are electronically downloaded each month, some data, including all wastewater data, must still be entered manually. These data are entered into the EPDDATA database directly from the analytical reports,

RSDRs, or FTFs according to the procedures in the *EMS Data Management Team Data Entry Instructions Manual* (1994).

18.1.3.2.4.2 Verifications. All data entered into the work tables of the Monitordb or Watsdb applications of EPDDATA must be processed through verification procedures. These programs will automatically check most of the data fields against acceptable values. They will report invalid or missing data so the DMT member may correct the mistake before appending the new data to the shared global tables.

All new entries into the database must also be thoroughly proofed against hard-copy reports prior to inclusion in the global tables. As specified in DOE Order 5700.6C and the EMS Quality Assurance Plan, DMT performs a cross verification to determine acceptance of the data entry. A different team member checks another member's entry work, increasing the probability of catching errors. One hundred percent of the data entered manually must be proofed; every data point is verified against the hard copy. For electronic data sends, all sample records must be proofed because of the large amount of manual alterations necessary, but only a 20% random sampling of the analysis data need be proofed. This is because the analytical labs have set their information systems to generate both the analytical reports and the electronic data transfer files, so the two data sets should always include the same values.

18.1.3.2.4.3 Documentation. Each time a Data Management Team member adds monitoring or wastewater data to the EPDDATA database, he or she must create an Append Package according to the *EMS Data Management Team Data Entry Instructions Manual*. Since data entry activities may affect the "integrity of the interpretation and reporting of environmental monitoring results", they are considered to be quality-affecting and must be documented (Garcia and Failor 1993). The Append Package provides an audit trail documenting the data entered, the verifications performed, the names of the data entry initiator and the proofer, and the dates each task was completed. The packet can be used to trace data entry inconsistencies identified later and to determine additional training requirements to correct the problem. Monitor (routine monitoring) and WATS (wastewater) Append Packages are stored in the Data Manager's files for three years for easy access and reference. The packets will then be moved to the Document Retention Center and handled according to the requirements EMP-QA-DC, *Document Retention*, will specify.

The new database additions must also be logged in the Append Log Book. All changes to existing database records should be noted in the Update/Error Log Book. Both log books, kept by the Data Management Team, provide audit trails of changes and additions made to the database.

18.1.3.2.5 Data Retrieval. Data reports can be generated quickly and accurately from the EPDDATA database. Several procedures have been written within INGRES to produce standard formatted reports, but DMT also creates customized reports utilizing front end software, such as DataPrism, and EXCEL spreadsheet applications. Other software systems, such as SAS, a statistical analysis tool, are also used to access the database records.

EPDDATA is used to assist analysts with their data reviews. DMT creates informational and comparison tables for analysts as requested, often providing data files in special formats for direct input into statistical and graphical packages. The database is also used to create various regulatory and other required reports such as the annual Environmental Report data tables, the Site 300 Ground Water Quarterly tables, retention tank disposition status reports, and monthly sanitary sewer effluent reports. Instructions for generating reports from the database are included in the *EMS Data Management Team Reporting Instructions Manual*, the *Monitoring Database User's Guide*, and *INGRES/Reports: Report-Writer Reference Manual*.

18.1.4 Future Plans

Since all current EMS sample tracking is handled manually, EMS is exploring ways of automating these tasks. A portion of the EPDDATA database, used currently by other EPD divisions, allows automated generation of sampling plans and field tracking forms. EMS plans to investigate this option and also to consider sample bar-coding and small field computers for FTF creation and automatic COC generation. This system could help eliminate data entry errors since tracking documentation and transfers into the database would be automated.

The Data Management Team will continue to increase its data interpretation assistance by creating more programmed reports, investigating automated control charting, and developing validation software to run against newly entered data. Also, to speed annual Environmental Report table generation, EMS plans to create a SAS procedure to pull the appropriate data from EPDDATA and

automatically format tables, complete with statistical calculations. Section 18.2.7 below discusses the data analysis details of this project.

The Data Management Team also plans to develop a more structured data verification procedure. This will be in accordance with DOE Order 5700.6C and the EMS QAP and will be based on predetermined standards for inspection including acceptance/rejection numbers such as in the ANSI/ASQC Z1.4-1981 tables.

18.2 DATA ANALYSIS

Data analysis is the act of seeking patterns, trends, and relationships within a set of data, for the purpose of gaining an understanding of the real-world processes the data represent.

The bulk of EMS data consists of analyte concentration data from environmental samples of various media collected in the field, as reported by analytical laboratories. During 1993, EMS collected approximately 6200 samples and received approximately 43,500 analyte concentration values from these samples. In order for these data to provide useful information about the impact of LLNL activities upon the environment and surrounding community, substantial data analysis must take place.

Computer modeling of physical processes, such as fate and transport of chemicals in ground water and NESHAPs dose calculations, is discussed in the relevant chapters.

18.2.1 Regulatory Requirements

Regulatory documents governing EMS activities generally state the purposes for which the data are collected. However, most do not specify how the data are to be analyzed in order to achieve the stated purposes. The EMS procedure EMP-QA-D, *Data Analysis*, provides EMS analysts with guidance to assure that they comply with regulatory requirements and employ good practice when regulatory guidance is absent.

Chapter 7 of DOE/EH-0173T covers data analysis and statistical treatment of environmental monitoring data. Topics include sources of variability in effluent and environmental data, measures of central tendency and dispersion, testing for outliers, distributional analysis, handling of less-than-detectable values, use of significant digits, and comparisons with regulatory or administrative standards.

This order is applicable to all EMS data analyses. Additional discussion of these topics is given in Section 18.2.3 below and in EMP-QA-D.

Data analysis of ground water monitoring at Site 300 is governed by two permits: WDR 93-100 (Pits 1 and 7) and WDR 85-188 (B-817 HE Process Area), issued by the California Regional Water Quality Control Board, Central Valley Region. These permits require that methods of statistical analysis be selected from a list of acceptable methods given in CCR Title 23, Division 3, Chapter 15. EMS uses analysis of variance and prediction intervals with retests to comply with these permits.

EPA-450/4-87-013, *On-Site Meteorological Program Guidance for Regulatory Modeling Applications*, provides detailed technical guidance for the reduction of raw meteorological data for use as input to regulatory air pollution models.

General goals of environmental monitoring are given in DOE 5400.1. For example, in Chapter 4 under the subheading *Environmental Surveillance*, requirements are included to "Verify compliance with applicable environmental laws and regulations; ... Characterize and define trends in the physical, chemical, and biological condition of environmental media; Establish baselines of environmental quality; Provide a continuing assessment of pollution abatement programs; Identify and quantify new or existing environmental quality problems." Under the subheading *Air Monitoring - Environmental Surveillance*, the following goals are stated: "Establish background concentration levels of pertinent chemical species; Determine the highest concentrations of pollutant species expected to occur in the vicinity of DOE operations; Determine representative pollutant concentrations at areas where public health and other concerns should be considered; and Evaluate the effects of emissions on ambient levels of pertinent contaminants." Directives such as these establish the need for data analysis, but not the methods of data analysis. The next section, 18.2.2, lists methods of data analysis appropriate for various purposes.

18.2.2 Purpose of Data Analysis

The purpose of data analysis is to support the objectives of the EMS monitoring networks. Therefore, the kinds of data analysis performed must be appropriate to the objectives of the network. The objectives of EMS sampling networks can be broadly grouped into three categories:

- Characterization: measuring the environment

- Detection: discovering contamination
- Decision: choosing actions in response to either of the above

Most EMS networks include aspects of all of these.

18.2.2.1 *Characterization*

Examples of characterization include such activities as measuring the impact of LLNL operations on the environment, the surrounding population, and employees; establishing background concentrations of specific analytes; establishing a well defined history of the physical, biological and chemical condition of the local environment; quantifying contaminant releases and predicting their distribution; predicting trends; and measuring the performance of emission control systems.

Data analysis methods employed by EMS for characterization include identifying a statistical distribution that appears to model the data (e.g., normal, lognormal); graphing data as a function of time and location; modeling trends; calculating summary statistics (measures of central tendency and variation, cumulative totals, annual maxima); and using geostatistical methods to assess spatial variation (contour plots, kriging, declustering methods).

18.2.2.2 *Detection*

It is essential that any unexpected releases of contaminants to the environment be discovered. In addition, it is important to identify previously undiscovered historical contamination and monitor known areas of contamination for any significant changes.

Data analysis methods used by EMS for detection include plotting the data over time and performing statistical tests for trends, comparing individual sample results with historical data or established standards, and comparing mean concentrations between different locations (such as upgradient and downgradient). The analytical laboratories that serve EMS employ control charts to detect problems with their operations.

18.2.2.3 *Decision*

Some EMS data are used to make specific decisions, for example, may a tank of wastewater be released to the sewer; is LLNL in compliance with a permit; was there a contaminant release.

The EMS uses formal statistical tests, such as t-tests and analysis of variance, and comparisons of individual sample results with regulatory, permitted, or internal standards for making such decisions. Ground water monitoring at Site 300 Pits 1 and 7 uses a retest procedure, in which an initial result exceeding a standard is either confirmed or denied based on the results of two confirmation samples. The standard, called a concentration limit, is calculated from the background, or upgradient, mean and standard deviation. The EMS anticipates that this methodology will in the future be employed for ground water monitoring at other locations as well.

When appropriate, the EMS bases decisions on an evaluation of whether sample results exceed expected natural variation. The use of formal statistical methods in decision making assures a quantitative, reproducible basis for the selection.

18.2.3 Implementation

The EMS expects its environmental analysts to use methods that fairly and accurately convey the information present in the data. Timely and appropriate analysis and proper presentation are essential to achieving this goal.

Much of the data analysis performed by EMS uses basic methods such as plotting concentration versus time, or the calculation of means and standard deviations. However, some environmental data present special problems for which standard methods of analysis do not exist. Discussions of these, and other topics in DOE/EH-1073T, are given below.

18.2.3.1 Extent and Frequency of Data Analysis

For some networks, the extent and frequency of data analysis are specified by permit, regulation, or DOE Order. For example, permit WDR 93-100 governing ground water monitoring at Site 300 Pits 1 and 7 specifies quarterly monitoring, analysis, and reporting. DOE Order 5400.1 requires the preparation of an annual environmental report that includes data summaries.

When not specified by regulation or permit, the extent and frequency of data analysis are at the analyst's discretion. This will be based on an assessment of factors such as the potential threat to the environment or the rate of change in contaminant concentration. For example, the greater the potential threat, the more frequent the analysis.

18.2.3.2 Data Presentation

During 1994, EMS staff received refresher training on the use of significant digits. The basic principle taught is that calculated results should not have more significant digits than the data upon which they are based. It is rare for the results of any EMS data analysis to have more than three significant digits.

Nonradiological data that are reported by an analytical laboratory as being below the detection limit are presented in reports with a less-than (" $<$ ") sign. Radiological data that are reported as being below the minimum detectable activity are also presented with a less-than sign. Other radiological data are presented with their associated 2σ counting error.

18.2.3.3 Outliers

Outliers are unusually extreme (large or small) values within a set of data. Because the environment can have substantial natural variation, EMS data analyses do not routinely omit outliers. When a suspected outlier is determined to be due to an error, the result is either corrected or omitted. Additional details are given in procedure EMP-QA-D.

18.2.3.4 Nondetections

Data sets with a small proportion of values reported as being below the limit of detection can generally be analyzed with standard methods without greatly affecting the conclusions. When the number of nondetections is large, standard methods do not produce meaningful results. EMS staff have researched the environmental statistics literature and found a variety of methods for analyzing data with nondetections. For example, if the lognormal distribution appears to be a reasonable model for the data, there are methods that take into account the percentage of nondetections when estimating the mean and standard deviation. Additional details and references are given in procedure EMP-QA-D.

18.2.3.5 Other Topics from DOE/EH-0173T

There are a variety of factors contributing to the variability of environmental data. These include natural variation with time and location, sample collection, sample handling, sample processing, sample measurement, cross-contamination, and recording. Environmental analysts are expected to be cognizant of these, and take them into account when interpreting their data.

Environmental analysts should examine the distribution of their data; probability plots are recommended and formal statistical tests are available. Environmental data are often positively skewed, in which case an asymmetric distribution such as the lognormal is a better model than the normal distribution. However, EMS analysts do not always examine the distribution of data sets having fewer than ten points, because DOE/EH-0173T permits the use of either a normal or lognormal distribution with such data sets.

Analysts should use appropriate measures of central tendency and dispersion, e.g., the geometric mean for lognormal data and the arithmetic mean for normally distributed data, or medians instead of means when nondetections are present. More detailed guidance is given in procedure EMP-QA-D.

DOE/EH-0173T advises against comparing single sample measurements with regulatory limits, due to the large uncertainty associated with single values. Unfortunately, such comparisons are often specified in permits by regulatory agencies. For example, the disposition of wastewater from a retention tank is based on a single sample result.

DOE/EH-0173T suggests that "radionuclide distributions are typically lognormal." However, it also states that "less than detectable data produce numerical measurements with values below the detection limit and sometimes negative values. All of the actual values, including those that are negative, *should* be used." Unfortunately, the lognormal distribution is only valid for positive values, so these two statements are in conflict. Some work is needed to find a good resolution to this conflict.

The EMS requires analytical laboratories reporting radiological analyses to provide actual instrument values, whether negative, zero, or less than limits of sensitivity. The EMS would like to receive actual instrument values from laboratories conducting nonradiological analyses, but currently accepts detection limit data from such analyses.

18.2.4 Reports

Data analyses contribute vital information to reports prepared by EMS by providing appropriate data summaries, validating and quantifying data interpretation, and drawing conclusions from complex data sets. EMS reports that include a large amount of data analysis are the annual Environmental Report and the Site 300 Ground Water Quarterly Reports.

Attachment A of the EMS procedure EMP-QA-AER, *Annual Environmental Report*, contains Attachment II-1 of DOE Order 5400.1. This attachment requires that the annual environmental report contain "...tables, graphs, or text which clearly and accurately present the overall monitoring results" To satisfy this requirement, the Environmental Report includes summary statistics from all networks in all media, distributional analyses, analysis of variance comparing mean concentrations at different locations, trend analyses, and other data analyses.

As discussed in the EMS procedure EMP-GW-QR, *Quarterly Groundwater Report*, Appendix B of each Ground Water Quarterly contains statistical tests comparing downgradient analyte concentrations with upgradient analyte concentrations. Under permit WDR 93-100, concentration limits are to be recalculated annually.

18.2.5. Data Analysis Quality Assurance

Quality assurance for summary statistics in the Environmental Report is provided by having all summary statistics checked by someone other than the environmental analyst responsible for their initial calculation. In the future, when summary statistics are calculated by the same software that prepares the tables (see Section 18.1.4), QA will be achieved by careful review and checking of the software, as well as checks of hard copy and comparison of software calculations with hand calculations.

All EMS reports, including any data analyses they contain, are reviewed prior to release by individuals other than the author. In reports containing substantial data analysis, the staff statistician is available for review.

The procedure EMP-QA-D was extensively reviewed by EMS staff prior to approval.

EMS efforts to improve the quality of data analyses include providing staff with specialized training. In 1992, EMS analysts attended a statistics class tailored to the needs of EMS analysts, and in 1994 they attended a class on "Principles of Environmental Sampling" that covered (among other things) data quality objectives and sample size determination.

The software used by EMS for data analysis is checked in a number of ways. First, software is purchased or licensed from reputable vendors that perform their own internal testing (see, for example, *The Quality Imperative: Software Development, Validation, and Support*, SAS Institute Inc., 1993). Comparisons of

results from different software packages, using the same data, help verify the software quality. Although not a rigorous check, analysts continually review results for reasonableness. This provides an opportunity to catch gross errors in the software. In addition, software results are from time to time compared with hand calculations and against published solutions to example data sets in statistical textbooks.

SAS Institute maintains a mailing list for reporting problems with its software. The EMS statistician subscribes to this mailing list, thus assuring prompt notification of any errors discovered in the software that may affect EMS analyses. The Internet-based Splus user's group (see Section 18.2.6) provides a similar, but less formally organized, source of information about problems with Splus.

18.2.6 Resources for Data Analysis

The EMS has provided its environmental analysts with substantial resources for data analysis.

The EMS staff now includes a statistician. This provides EMS analysts with a source of data analysis advice and the potential to use specialized or advanced data analysis methods.

A variety of software for data analysis and graphics is now available. It is important to have a variety of software, because no one package provides all the different types of analyses and graphical displays required by the EMS.

All analysts have Microsoft Excel on their desktop computer. This provides basic graphics and data analysis capability. However, most analysts do not have the training necessary to write Excel macros for non-standard analyses. Graphics software such as Kaleidagraph, CA CricketGraph, or DeltaGraph Pro are purchased for analysts upon request. The EMS has purchased the Macintosh statistical software packages JMP, Stata, and Statview. These are available over a local area network on a check-out basis. For more demanding analyses, the staff statistician has copies of SAS and Splus running on a Sun workstation. These can be programmed to perform nonstandard analyses. Splus has a large and active network of users who communicate over the Internet, and develop and share software. The staff statistician participates in this network and has obtained program modules for various statistical methods that otherwise would have taken many months to develop, or have cost a great deal to purchase.

The staff statistician has a small library of books on environmental statistics, general statistics, data analysis, and graphics.

Availability of data is important for data analysis. The EMS has two primary resources for retrieving data from the database. On the Macintosh platform, DataPrism and DataPivot software provide a "point-and-click" interface to the database. Output from this software consists of Excel files. On the Sun platform, the statistical software package SAS has an interface to Ingres, allowing it to work directly with Ingres data, or retrieve data for subsequent analysis.

Interfaces between different vendors' software require cooperation between the vendors, over which EMS has no control. In addition, computer hardware is evolving rapidly and software vendors are constantly introducing new versions of their software. It requires constant attention on the part of EMS staff to keep up with the changes, and make sure that the interfaces between different vendors' software continue to function.

18.2.7 Future Plans—Data Analysis

The EMS plans to continue improving its data analysis capabilities, and to adapt to changes in the EMS mission and new and changing regulatory requirements.

Although analysts are aware of the many sources of variability outlined in Section 18.2.3.5, the EMS has little experience quantifying the variability associated with sample collection, handling, and preparation. Measurement error information is available for radiological analyses, but with a few exceptions has not been used. Measurement error information for nonradiological analyses is generally less available. EMS analysts need to begin incorporating measurement error in summary statistics and other analyses of radiological data. Efforts to measure other sources of variation and incorporate them in analyses are desirable, but are likely to have a low priority relative to other tasks. The EMS should make sure appropriate error propagation is being done, and if it is not, provide the necessary training.

The EMS should consider requiring laboratories conducting nonradiological values to provide actual instrument values, even when they are less than the detection limit. However, this would likely be a controversial requirement; cooperation from other LLNL organizations and the analytical laboratories may be difficult to obtain.

The project to speed annual Environmental Report table generation, mentioned above in Section 18.1.4, includes plans to incorporate measurement error in summary statistics for radiological analyses, and is expected to ensure consistent handling of nondetections in summary statistics.

Interest in and need for geostatistical analyses seems to be gradually increasing. The software now on hand is not user friendly. Purchase of user friendly software should be investigated, and some staff training should be considered. The EMS should explore the use of geographical information systems software, to determine whether such software would help analysts get their job done better or faster.

In cases where permits specify that decisions be made on the basis of single samples, an evaluation of whether this is causing too many incorrect decisions needs to be made. The outcome of this evaluation will be shared with permitting agencies to provide them with a better understanding of the data reported to them.

19

Dose and Risk Assessment

19.1 INTRODUCTION

This chapter describes the methods used to determine potential radiological doses to individuals and populations caused by releases of radionuclides to the environment from Lawrence Livermore National Laboratory, and cites the federal regulations and standards that govern these emissions and define LLNL's compliance strategies. The degree of public exposure is determined from a combination of computer modeling and physical measurements, including the environmental monitoring efforts described in Chapters 4–15 of this report.

19.2 RADIATION PROTECTION STANDARDS

The release of radionuclides and the resultant radiological impact to the public from operations at LLNL is regulated by both DOE and EPA.

DOE environmental radiation protection standards, provided under the authority of the Atomic Energy Act of 1954 and the DOE Organization Act of 1977, are defined in DOE Order 5400.5, *Radiation Protection of the Public and the Environment*. The standards for controlling exposures to the public from operations at DOE facilities are based on recommendations by the International Commission on Radiation Protection and Measurements (NCRP 1987). The radiological impact to the public is assessed in accordance with DOE Order 5400.1, *General Environmental Protection*; DOE's *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance* (U. S. Department of Energy 1991); DOE Order 5480.5, *DOE Accreditation Program for Personal Dosimeters*; and DOE Order 5480.1, *Environmental Protection, Safety, and Health Protection Information Reporting Requirements*.

The primary DOE radiation standards for protection of the public are 1 milliSievert per year (mSv/y), or 100 millirem per year (mrem/y), effective dose equivalent (EDE) for prolonged exposure of a maximally exposed individual (MEI) in an uncontrolled area, and 5 mSv/y (500 mrem/y) EDE for occasional exposure of this individual. These dose limits include consideration of all exposure modes from all routine DOE activities. (EDEs take into account nonuniform irradiation of the body via different pathways of exposure, and varying sensitivity of different organs to different kinds of radiation. Doses are

commonly expressed in units of mrem/y, mSv/y, or $\mu\text{Sv/y}$, where 1 mrem = 0.01 mSv = 10 μSv .) These limits pertain to the sum of the EDE from external radiation and the committed 50-y EDE from radioactive materials ingested or inhaled during a particular year that may remain in the body for many years.

The EPA regulates radionuclide emissions to the atmosphere from DOE facilities under the authority of Section 112 of the Clean Air Act. Subpart H of the National Emission Standards for Hazardous Air Pollutants (NESHAPs), under 40 CFR Part 61, sets standards for public exposure to airborne radioactive materials (other than radon) released by DOE facilities; radon is regulated by Subparts Q and T. NESHAPs implements the dosimetry system recommended by the International Commission on Radiological Protection in its Publication 26 (ICRP 1977).

EPA's radiation dose standard, which only applies to air emissions, specifies that the whole-body EDE to members of the public from radioactive materials released to the atmosphere as a consequence of routine DOE activities shall not cause members of the public to receive, in a year, an EDE greater than 100 μSv (10 mrem). In addition, the EPA regulates the potential emissions (calculated without regard for emission-abatement devices, such as stack filters, that may be present) from any single release point associated with a project or experiment. If the potential emissions would produce an annual dose to the public MEI exceeding 1 μSv (0.1 mrem), then continuous monitoring of the release point is required. EPA regulations specify not only the allowed levels, but also define the approved methods by which airborne emissions and their impacts must be evaluated.

19.3 PREPARATION AND DISPOSITION OF REPORTS

All DOE facilities that conduct significant environmental protection programs are required to prepare an annual Environmental Report for the site that covers activities of the previous calendar year involving releases to all media via all pathways. LLNL presents this report to the DOE Operations Office in Oakland, CA (DOE-OAK), from which it is distributed to appropriate program senior officials, the Office of Scientific and Technical Information, EPA, and to other agencies and organizations, as appropriate. LLNL Environmental Reports are available for the years 1971 through 1993, the latest being Gallegos et al. (1994).

Additionally, radioactive effluent and on-site discharge data reports covering the previous calendar year are required to be prepared annually and submitted to the Idaho National Engineering Laboratory, DOE Idaho Field Office, Idaho Falls, Idaho, for inclusion in the Effluent Information System/Onsite Discharge

Information System (EIS/ODIS) annual report (Meikle 1994). Releases of radioactive materials in effluent from both routine operations and unplanned releases (such as spills or leaks), whether on site or off site, are included in these reports. This documentation of unplanned releases is done in addition to meeting the "unusual occurrence" reporting requirements of DOE Order 5000.3A, *Occurrence Reporting and Processing of Operations Information*. Releases of no environmental concern, including those that are subsequently cleaned up, need not be reported.

Since DOE facilities and operations are subject to the regulatory requirements of EPA, in particular 40 CFR Part 61, Subpart H, DOE facilities are required to submit an annual report to the EPA, showing compliance with NESHAPs (addressing only releases to air). LLNL NESHAPs annual reports are available for the years 1991 through 1993, along with seven quarterly NESHAPs reports covering the last quarter of 1991 through the second quarter of 1993. The most recent annual report is Harrach et al. (1994).

Beyond these periodic reporting requirements, DOE Order 5700.6C, *Quality Assurance*, requires that comprehensive and detailed information on LLNL's dose and risk assessment activities be documented as part of a quality assurance program. The procedure EMP-R-DA, *Radiological Dose Assessment*, meets this requirement, and provides a level of detail and emphasis that complements the annual reports.

19.4 RESPONSIBILITY FOR COMPLIANCE DEMONSTRATIONS

Responsibility for all compliance evaluation/demonstration activities concerning the measurement, modeling, and reporting of radiological doses to the public arising from LLNL operations resides in the Environmental Monitoring and Analysis Division (EMAD) of LLNL's Environmental Protection Department. Specifically, the Terrestrial and Atmospheric Monitoring and Modeling Group within the Environmental Monitoring Section (EMS) of EMAD has responsibility for assessing and reporting doses to the public via the air and land (soils, sediments, vegetation) pathways, as described in Chapters 4, 6, 12, 13, and 14 of this report. The Water Guidance and Monitoring Group of EMS is responsible for assessing and reporting radioactive releases via the water pathway, by measurements of on-site surface water, tap water, storm water runoff, sewer line discharges, and underground water both off site and at Site 300; see Chapters 7, 8, 9, and 10 in this report.

In performing these tasks, EMS must communicate effectively with analytical laboratories that analyze the environmental samples, and with personnel from Hazards Control Division, Hazardous Waste Management Division, and other LLNL divisions and programs that impact LLNL's radiological dose to the public. In summary, EMS is responsible for planning and conducting measurements in environmental media (gathering data from sampling and surveillance activities); performing data analysis, reduction, and assessment; obtaining data on radionuclide inventories and stack release parameters; modeling releases of radionuclides to the environment and assessing doses and risks to the public; reporting the results; archiving the data and results; identifying the need for, and planning and implementing, upgrades in the methods of data acquisition and modeling; and quality checking the radionuclide inventories, data, calculations, and reports.

19.5 EVALUATION OF DOSES

Physical measurements—monitoring of airborne gases and particulates, sampling of soils, water, vegetation, and food products, and monitoring of penetrating radiations—and computer modeling calculations are both important in the determination of the radiation exposure of the public caused by atmospheric releases from LLNL operations. (Releases of radionuclides from LLNL via the water pathway are not consumed [ingested or inhaled] and therefore do not represent a pathway for radiation exposure of the public). Because the amounts of LLNL-generated radioactive material dispersed into the atmosphere cause very small levels of exposure compared to those due to natural background radiation levels—principally from cosmic rays, radioactive materials in soil and rock, radon gas, and naturally occurring radionuclides that are ingested—it is difficult to demonstrate compliance with the federal standards through physical measurements. Furthermore, the DOE and EPA want to assure that the data developed to demonstrate compliance with applicable standards and requirements are correct and representative. Accordingly, the DOE and EPA sanction the use of computer codes that implement their approved dosimetry and dispersion models and mandate that these codes be used to calculate potential doses to the public from exposures resulting from both routine and unplanned releases.

Our primary calculation tool for estimating dose and risk from routine operations is the computer code CAP88-PC (Parks 1992), developed by the EPA under an interagency agreement between the DOE and EPA. CAP88-PC provides the

capability to compute dose and risk to both maximally exposed individuals and collective populations from chronic or long-term radionuclide emissions to air. Other codes, such as the EPA's INPUFF code (Petersen and Lavdas 1992) or the HOTSPOT code (Homann 1993), are used as needed to address unplanned releases or short-term releases from experiments/operations. A complementary approach to deriving EDEs using the built-in dosimetry model in CAP88-PC or other EPA-mandated code is to explicitly calculate doses using mathematical formulas from, e.g., the Nuclear Regulatory Commission's Regulatory Guide 1.109 (U. S. Nuclear Regulatory Commission 1977), which incorporates dose conversion factors consistent with those in the International Commission on Radiation Protection's document ICRP 30 (ICRP 1980). This approach has been used historically at LLNL (preceding the availability of CAP88-PC), and continues to be used, to evaluate annual doses to the public inferred from sampling of local environmental media (air, water, vegetation, milk, honey, and wine). Details are given in Chapter 12 and Appendix B of the 1993 Environmental Report (Gallegos et al. 1994) and in the dose assessments procedure (EMP-R-DA).

Radionuclides that enter the environment via transport in air can cause human health effects principally through internal exposures from inhalation of air (directly and after resuspension from wind-disturbed soil) and ingestion of foodstuffs and drinking water, and by external exposures through irradiation from a contaminated ground surface and immersion in contaminated air. For example, radioactivity in the air can enter the human body directly by being inhaled, or by a more circuitous ingestion route, whereby the radioactivity falls onto pasture grass, is eaten by cows, and reaches humans who consume the cow's milk. The CAP88-PC code evaluates the ingestion, inhalation, immersion, and ground irradiation exposure pathways in arriving at the EDEs.

When assessing probable off-site impacts, three potential doses are emphasized: (1) The dose to the "site-wide maximally exposed individual member of the public," defined below, which combines the effects of all emission points, for evaluation under the 100 $\mu\text{Sv}/\text{y}$ (10 mrem/y) EPA standard; (2) the maximum dose to any member of the public, in any direction, due to each unabated emission point on the site for evaluation of the need to conduct continuous monitoring of that emission point under the 1 $\mu\text{Sv}/\text{y}$ (0.1 mrem/y) standard; and (3) the collective dose to the populations residing within 80 kilometers of each of the two LLNL sites, adding the products of individual doses received times the number of people receiving them.

The site-wide maximally exposed individual (SW-MEI) is defined as the hypothetical member of the public at a single publicly accessible location (where members of the public reside or abide) who receives the greatest LLNL-induced EDE from all sources. Such public facilities include schools, churches, businesses, and residences. The location of the SW-MEI is especially sensitive to the frequency distribution of wind speeds and directions in a given year and can change from year to year. At the Livermore site, the SW-MEI currently is located at the U.N.C.L.E. Credit Union, about 10 meters outside the controlled eastern perimeter of the site. This location lies 948 meters from the principal radionuclide source, the Tritium Facility (Building 331), in an east-northeast direction (the typical wind direction and the prevailing one in 1993). At Site 300, the SW-MEI currently is located in an experimental area termed "Bunker 2" operated by Physics International. Bunker 2 lies about 300 meters outside the east-central boundary of Site 300. This bunker is 2.38 kilometers southeast of the principal firing table at Building 801.

Doses in category (2) are a main concern when new projects or changes to existing projects at LLNL are reviewed for joint compliance with NESHAPS and the National Environmental Policy Act (NEPA). The possible environmental and worker safety issues raised by each proposed activity or project are examined from several different points of view in a process coordinated by LLNL's Environmental Protection Department, including a review and evaluation of potential emissions of radionuclides and air toxics. For more information, see the section on "NESHAPS and the NEPA Review Process" in the second quarterly NESHAPS report for 1993 (Surano et al. 1993).

19.5.1 Specification of Source Terms in Model Runs

The source term(s) from each emission point in the computer modeling calculations is determined by one of two methods: for monitored sources, the continuous sampling data on curies released per unit time for each radionuclide is used directly. Emission points in Buildings 175, 231, 251, 331, 332, 419, 490, and 491 have continuous effluent monitoring systems; see Chapter 4, Air Effluent Monitoring. For unmonitored sources, the emission rate is calculated from radiological inventories, by applying EPA-specified fractions for potential release to air of materials in different physical states (solid, liquid, powder, or gas), in accordance with 40 CFR Part 61, Appendix D. The inventory quantity (in curies) is multiplied by a state-dependent release fraction to give the potential annual release to air, i.e.,

the effective emission rate. If the material is an unconfined gas, the fraction 1.0 is used; for liquids and powders, 1.0×10^{-3} is used; and for solids, 1.0×10^{-6} .

19.5.2 Data on Radionuclide Inventories

All facilities having a potential to discharge radionuclides to the atmosphere report their radionuclide inventories to the Terrestrial and Atmospheric Monitoring and Modeling Group in EMS, giving the quantity (in curies) and the physical state (solid, liquid, powder, contained gas) for each radioisotope, as well as stack data and information on the type of operation; the facilities update this information periodically. A new inventory procedure was implemented in February 1994, pertaining to activities occurring in 1993. In the new procedure, new inventories were obtained for all "key" facilities, defined as those that accounted for 90% of the previous year's (1992) dose to members of the public. Inventory forms, accompanied by detailed guidance for completing them, were sent to all such facilities at the Livermore site. The forms were completed by experimenters, certified by facility managers, and returned. Inventories for all Site 300 explosive experiments were also updated, which were the major source of off-site dose at Site 300 during 1992, and we newly assessed the source terms for all known diffuse (non-stack) sources at both sites. New dose assessment modeling runs were then conducted using 1993 meteorological data (wind roses, precipitation, and average temperature). For a description and justification of our treatment of these and other facilities in this first year of the new inventory procedure, consult Section II of the NESHAPs Annual Report for 1993 (Harrach et al. 1994).

19.5.3 Modeling Emissions with the CAP88-PC Code

CAP88-PC uses a modified gaussian plume equation to estimate the average dispersion of radionuclides released from up to six co-located sources (elevated stacks or uniform area sources). Plume rise can be driven either by momentum or buoyancy, or set to a predetermined level. Flat terrain is assumed; variation in radionuclide concentrations due to complex terrain cannot be modeled by CAP88-PC. Assessments are done for a circular grid with a radius of 80 kilometers or less around a facility, allowing up to 20 user-selected radial distances. Concentrations and doses are sector-averaged for each element of area in sixteen 22.5-degree compass sectors; each area element is bounded above and below by arcs with radii from the set of user-selected distances, and on its sides by radial line segments separating the sectors. Up to 36 radionuclides can be included in a single run, chosen from a total library of 265 radionuclides. CAP88-PC computes

results for each of seven different (Pasquill-Gifford) atmospheric stability categories. The code thus computes, in a single run, dose rates in sixteen 22.5-degree compass sectors for up to 20 radial distances extending as far as 80 kilometers from the radionuclide release point, for each of seven atmospheric stability categories.

The mathematical models and explicit equations used in CAP88-PC are described in Chapter 8 of Parks (1992), under the major headings "Environmental Transport," and "Dose and Risk Estimates." The differences between CAP88-PC and earlier similar codes are also discussed there, in Appendix E.

In order to model atmospheric dispersion and estimate public radiation dose with CAP88-PC, site-specific data for a variety of parameters are required. These data define the emission sources, the meteorological conditions, the local agricultural characteristics and land use, and the distribution of population surrounding the site, with separate data required for the Livermore site and Site 300.

19.5.3.1 *Inputs to CAP88-PC*

(1) **Source:** The most essential feature characterizing a radioactive source is its release rate (number of curies per year, or Ci/y) for each radionuclide. Generally, this information is provided by inventory data (see the preceding subsections, 19.5.1 and 19.5.2). Other aspects of source characterization depend on the type of release—from a stack or an extended area, of a routine or fugitive nature. For a stack emission, additional necessary information includes the height and diameter of the stack and the amount of plume rise (determined, for example, by the volumetric flow rate or temperature of gas in the stack). These data can be obtained from stack monitoring records or estimated from facility operating parameters on file in the EMS Document Retention Center. Unusual releases may require special measurements and calculations to characterize the source. An example is the fugitive emissions from Building 292 at the Livermore site, in which leakage from an underground tank resulted in the release of tritium to the atmosphere via soil evaporation and uptake and transpiration by plants; see the section on "Livermore Site Diffuse Sources" in the 1993 NESHAPs Annual Report (Harrach et al. 1994).

(2) **Meteorology:** As described in Chapter 5, meteorological data are collected from on-site meteorological towers at the Livermore site and Site 300. Wind speed and direction are sampled every few seconds, temperature every minute, and all are averaged into quarter-hour increments, time-tagged and computer-

recorded. The LLNL meteorological data are provided to the air effluent analyst by the Terrestrial and Atmospheric Monitoring and Modeling Group meteorologist. The data reside on a DOS computer diskette and are converted into a CAP88-PC input wind file by the meteorologist in accordance with EPA guidelines, as described in the meteorological monitoring procedure (EMP-M-SCA). Section 4.3.3, Chapter 7, and Appendix B in the CAP88-PC User's Manual (Parks 1992) describe the meteorological data and its conversion for use with that code.

(3) Agriculture: Local agricultural characteristics and land use are model-default parameters established by the EPA, and the particular designation influences the ingestion dose received by the local population. The Livermore site and Site 300 are most accurately characterized as "urban" areas, with regard to CAP88-PC modeling of consumption of food grown in the assessment area. The most conservative choice is to characterize the two LLNL sites as "local" with regard to food consumption, meaning that the population exposed to radionuclide releases from LLNL consumes only locally grown food, maximally contaminated by those releases. Agricultural data inputs for CAP88-PC are described in Section 4.3.5 and Appendix C of Harrach et al. (1994).

(4) Population: Population distributions centered on the two LLNL sites are compiled from 1990 census data and used as input to the model calculations of person-rem (person-sievert) doses for all persons living within an 80-kilometer radius of each of the LLNL sites. The preparation and installation of population files for use with CAP88-PC is described in Appendix F of Parks (1992).

19.5.3.2 CAP88-PC Output

The CAP88-PC code calculates radionuclide dose rates, radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food, and intake rates to people from ingestion of food produced in the assessment area (using the Nuclear Regulatory Commission Regulatory Guide 1.109 terrestrial food chain models [U. S. Nuclear Regulatory Commission 1977]). Summaries of calculated exposures and risks are broken down by organ, pathway, radionuclide.

Further details about CAP88-PC are given in Parks (1992), and information on step-by-step instructions for running the code, illustrative problems, caveats, etc., is provided in the procedure on radiological dose assessments (EMP-R-DA).

19.6 RADIOLOGICAL DOSES FROM LLNL OPERATIONS

The calculated EDE to the site-wide maximally exposed individual member of the public is reported annually to the DOE in the annual Environmental Report (Gallegos et al. 1994) and to EPA in the NESHAPs annual report (Harrach et al. 1994), treating the Livermore site and Site 300 separately. Contributions from point sources (stack emissions) and diffuse (area or volume) sources are distinguished. For both sites, these doses, calculated using EPA-mandated computer dispersion models, are found to be less than one per cent of the EPA's 100 $\mu\text{Sv}/\text{y}$ (10 mrem/y) standard.

Population doses, or collective EDEs, are also presented in these reports. Potentially exposed populations out to a distance of 80 kilometers in all directions from the site-centers are included in CAP88-PC code runs incorporating 1990 census population data. We find levels in the range of 10–100 person-mSv (1–10 person-rem) attributable to the two sites, approximately a hundred thousand times lower than the dose these same populations receive from natural background sources.

19.7 QUALITY ASSURANCE AND QUALITY CONTROL PROGRAMS

Quality assurance (QA) and quality control (QC) efforts associated with our radiological dose assessments and compliance reporting under NESHAPs are in place at the eight LLNL facilities with continuous air monitoring systems (see Chapter 4), as well as in the Radiological Measurements Laboratory (RML) of the Hazards Control Department and within the Environmental Monitoring Section (EMS) of the Environmental Protection Department. Facility Safety Procedures, Safety Analysis Reports, and QA Manuals for each monitored facility describe its organizational structure, responsibilities for sampling locations, and procedures for monitoring air emissions, as well as those to be followed in the event of unplanned releases of radioactive material. For RML, the QA program describes laboratory analysis procedures, precision, accuracy, and completeness objectives, sample tracking procedures, sample handling, QC sampling, and data reporting. EMS, which is responsible for NESHAPs compliance, maintains detailed records of all radionuclide inventories, environmental measurements, model runs and other calculations, and validates selected model runs and inventory data.

LLNL's QC process for operations conducted in 1993 validated inventory data and computer modeling runs. Approximately 15% of the Livermore-site facilities inventoried in 1993 were randomly selected for reevaluation. An EMS

environmental analyst contacted the individuals responsible for the inventories, and visited and inspected the facilities in person to verify the inventory data. Similarly, about 15% of the computer modeling runs for 1993 operations were verified by independent calculations (performed by a different analyst, using a different computer and different copies of software). These modeling re-runs included the randomly selected inventories plus all others that produced a significant contribution to the total EDE. In all cases, these quality control measures demonstrated that quality objectives are being met.

19.8 STATUS OF NESHAPS COMPLIANCE

In August 1993, EPA and DOE signed a Federal Facility Compliance Agreement (FFCA) which established a schedule of work for LLNL to perform to demonstrate compliance with NESHAPs, 40 CFR Part 61, Subpart H. The schedule included an evaluation of individual and collective doses to the public from all radionuclide emission points for the Livermore site and Site 300, progress with regard to continuous monitoring requirements and confirmatory measurements, improvements in the sampling and monitoring systems, and progress on a NESHAPs quality assurance program. These developments are described in LLNL's NESHAPs Annual Report for 1993 (Harrach et al. 1994). The EPA notified DOE and LLNL in April 1994 that all requirements of the FFCA had been met and that LLNL was in compliance with the NESHAPs regulations.

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