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DR-0689-0

UCID-20276

LLNL Radioactive Waste Management Plan
as per
DOE Order 5820.2

December 10, 1984

Lawrence
Livermore
National
Laboratory

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Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7465-Eng-48.

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1. WASTE MANAGEMENT SITE PLAN

1.1. PROGRAM ADMINISTRATION

1.1.1. Site

The Lawrence Livermore National Laboratory (LLNL) is located about 65 km east of San Francisco at the southeast end of the Livermore Valley in Southern Alameda County. The City of Livermore is located about 5 km to the west. LLNL occupies essentially all (2.54 km) of Section, 12, T3S, R3E of the USGS Altamont Quadrangle, California. The LLNL property also has an open storm-drain right-of-way extending northward from the northwest corner of the site to the Western Pacific tracks, a distance of 317 m, covering a land area of 5700 m². Figure 1 shows the location of the Laboratory with respect to the City of Livermore. Lands to the north, west and south are zoned industrial, although present usage is mostly agricultural. Land immediately to the east is zoned agricultural and is currently used as pasture.

Site 300, located about 19 km southeast of Livermore in the sparsely-populated hills of the Diablo Range, is an LLNL high-explosives test facility. This 27-km² site is roughly rectangular in shape; its southern boundary is adjacent to Corral Hollow Road. About one-sixth of the site lies in Alameda County, with the remainder in San Joaquin County. Figure 2 shows the location of Site 300 with reference to Livermore.

1.1.2. Office Responsible

The San Francisco Operations Office (SAN) is the DOE office responsible for the implementation of Waste Management Plans at LLNL.

1.1.3. Contractors

The Lawrence Livermore National Laboratory is operated by the University of California for the United States Department of Energy. The Laboratory was established in 1952 to conduct nuclear weapons and controlled thermonuclear

reaction research. Today, about 60% of its resources are devoted to defense programs, which include weapons and laser fusion research. Other major areas of focus are magnetic fusion energy; laser isotope separation; chemistry, engineering, and physics research; biomedical and environmental sciences; applied energy technology; and work for other governmental agencies.

1.1.4. Lead Responsibility for Site Plan

The lead responsibility for the Site Plan is the Toxic Waste Control Group. The organization chart for the Technical Services and Environmental Services program is shown in Fig. 3.

1.1.5. Source of Funds for Waste Management

Funds for waste-management activities are obtained from the Laboratory-wide overhead funds furnished by all programs.

1.1.6. Status of Compliance with 5820.2 Requirements

Table 1 summarizes the non-compliance items for LLNL. The estimated costs are very preliminary and are subject to change. The schedule for correcting the indicated deficiencies will depend on the availability of DOE funds.

Table 1. Item and Cost Summary of LLNL Noncompliance items as per DOE Order 5820.2.

Item	Expected Compliance Date	Estimated Funds Required to Comply (Figures in thousands)	Comments
I. <u>Toxic Waste Control</u>			
Contamination of Non-radioactive hazardous wastes by radioactive waste during liquid treatment of Bldg. 514	6/89	Included in line-item project	\$30 million
Inadequate solification size reduction	6/89		\$30 million
Decontamination Building provides inadequate containment	6/89	Included in line-item project	\$30 million
Radiation storage un-bermed, exposed to weather and improper segregation	10/86	\$ 286	Location dependent line siting
Waste containers stored over 1 year and some are deteriorated	10/85		Shipping and packing accelerated
Logging system inadequate	N/A	N/A	
II. <u>Remainder of LLNL</u>			
Records of activity, quantity & chemical content inadequate Bldg. 253	N/A	N/A	
Retention tank system and HEPA deficiencies in Bldgs. 231 & 321	10/87	300	

Table 1. (Continued)

Item	Expected Compliance Date	Estimated Funds Required to Comply (Figures in thousands)	Comments
Need to dispose of D-38 from Material Management	10/85	100	
Need for Bldg. 281 reactor decommissioning	1989 or beyond	3000	
III. <u>Site 300</u>			
Inactive firing tables landfills deficiencies	1989 or beyond	4200	Primarily final cover and ground water monitoring
New firing tables waste landfill(s)	1989	7000	Permits may take 2 to 3 years to obtain
ATA extic radioactive gases Uranium and Beryllium	1987	150	Assessment needed
Uranium and Beryllium dispersal study	1987	290	Firing tables may require \$20 million expenditure

Figure 1. DOE Livermore site (looking west toward Livermore, 1981).

Figure 2. Location of LLNL, SNLL, and Site 300 with respect to Livermore, and surrounding communities.

TECHNICAL SERVICES - PROGRAM ORGANIZATION

Figure 3. Technical Services - Program Organization.

Figure 3. (Continued)

1.2. DESCRIPTION OF WASTE GENERATING PROCESSES

Appendix B is a copy of the Draft Report, "Candidate Mixed Hazardous Waste Streams" (Heckman, McNaab, 1984); waste-process flowcharts and radiological and chemical characteristics of wastes are described.

1.3. RADIOACTIVE WASTE MANAGEMENT

Unlike the wastes produced at a production facility, the varied research programs at LLNL produce a continually changing amount and type of radioactive waste. Radioactive wastes are shipped to NTS for disposal, and chemical wastes are collected by a commercial waste disposal firm. The subparagraphs that follow describe LLNL procedures.

1.2.1. Collection

1.3.1.1. Collection of Radioactive Solid Waste. Operations in a glove box produce contaminated articles, such as laboratory glassware, transfer containers, small equipment, absorbent paper, rubber gloves, etc. These items are placed in an uncontaminated secondary container within the glove box. All such containers are removed from the box by bagging the container in plastic (bagging out). The plastic-bagged items are placed in covered, metal garbage cans, lined with a plastic bag and a paper inner bag.

Radioactive solid waste generated in areas other than glove boxes is placed directly in the metal waste container. These containers are handled as follows:

- o When a contaminated-waste collector is full, the plastic bag is sealed and placed in a covered metal drum.
- o The filled drums are transferred to the Solid Waste Disposal Facility (Bldg. 612), where the contaminated waste may be compacted into bales using a compacting/baling machine or otherwise be prepared for shipment.
- o Drums containing quantities of transuranium nuclides in which the specific activity exceeds 100 nCi/g are accumulated for transfer to NTS for long-term retrievable (above-ground) storage. Drums

containing waste in the nonretrievable category (≥ 100 nCi/g) are shipped to a land burial site at NTS.

1.3.1.2. Collection of Radioactive, Liquid Waste in a Building with a Retention-Tank System. These liquid wastes are handled as follows:

- o Laboratory sinks, lavatories, janitors' sinks, and floor sumps drain to retention tanks outside the building. This system helps prevent the inadvertent release of radioactivity to the sanitary sewer.
- o When a tank is full, drainage from the building is switched to another tank, and a sample is withdrawn from the filled tank and analyzed for radioactivity.
- o If the activity is below standards and is considered to be as low as practicable, the liquid waste is released to the sanitary sewer.
- o If the activity exceeds these standards, the liquid waste is transferred to a portable tank and moved to the waste treatment area. The liquid waste is either added to a holding tank to await normal decontamination treatment, or the waste is segregated and decontaminated individually by a method appropriate for the radionuclides present.

1.3.1.3. Collection of Radioactive Liquid Waste in Carboys and 5-Gallon Drums. These liquid wastes are handled as follows:

- o Dilutions, rinses, excess solution, etc., are collected in 5-gal drums, or in glass or plastic carboys protected by a metal secondary container, located in the work area.
- o When a 5-gal drum or carboy is nearly full, it is loosely capped and moved outside the building to a designated collection area. The carboys are periodically collected and moved to the waste-treatment area, where they are evaluated for treatment procedure and scheduled for the treatment indicated.

Radioactive wastes originate in over 20 buildings in which many different operations are performed. However, five of these facilities are responsible for producing the bulk of all radioactive waste. These facilities are described in Sections 1.3.2.1 through 1.3.2.5.

Radioactive wastes are products of, chemical laboratory research and analytical processes, of accelerator operations, and of mechanical operations.

1.3.1.4. Collection of Radioactive Airborne Effluents. At the Livermore site, and typically at all DOE contractor facilities, high-efficiency particulate-air (HEPA) filters are used in exhaust air systems to assure that hazardous particulate matter is not released into the environment. All facilities handling plutonium, uranium, and beryllium are equipped with these filters. In buildings such as Nuclear Chemistry Operations and the Plutonium Facility, exhaust air from the glove boxes is double-filtered. Following this filtration, the air enters a manifold system and is filtered a third time before being exhausted into the outside atmosphere.

Before being installed, every HEPA filter is tested for efficiency using a monodispersed 0.3- μ m aerosol of dioctylphthalate (DOP). To be acceptable, the efficiency of the filter in removing 0.3- μ m particles must be 99.97%. As 0.3 μ m particles are the most difficult to remove, particles larger or smaller than 0.3- μ m will be removed with efficiencies greater than 99.97%. After installation, the HEPA filters are tested in-place to assure that filter damage has not occurred during installation and that the filters are properly gasketed. Spent filters are as solid radioactive waste.

1.3.2. Major Sources of Radioactive Wastes.

Chemical-laboratory research and analytical processes primarily involve analyses or studies of radionuclides, which produce contaminated liquid and solid waste. A few operations involve separation of high-level material for diagnostics and for transplutonic-element studies. Chemical engineering research and development operations contribute low-level liquid and solid waste.

The five major producers of radioactive waste at LLNL are:

- o Heavy Element Chemistry--Building 251.
- o Metallurgy Chemistry--Building 332.
- o Light Isotope Chemistry--Building 331.
- o RTNS-2--Building 292.
- o Materials Fabrication Division--Building 321.

The types of waste materials and the method of generation of each of these facilities are described in Sections 1.3.2.1 through 1.3.2.5.

1.3.2.1. Heavy Element Chemistry--Building 251.

Solid Waste. Transuranic-contaminated solid-waste material is normally generated during hot-cell or glove-box operations. In either case, the material is transferred out of the enclosure into a primary container that is free of contamination. Following an estimate of the identity and quantity of radionuclides present, the material is placed in a secondary container, usually a heavy paper sack and a heavy plastic bag. This bag, when full, is sealed in a metal 210-l drum and sent to the solid-waste handling area (Bldg. 612) for final disposal. Larger items, such as pumps, manipulators, or enclosures, also are packaged and sent to Bldg. 612 for disposal.

Liquid Waste. Highly contaminated liquid waste is processed within the building. Processing consists of drying high-level liquids into a solid dry form. They are then handled as solid waste. Moderately contaminated liquids may be placed in polyethylene waste jugs and sent to Bldg. 514 for treatment and disposal. All water discharged from Bldg. 251 is held in retention tanks until it is analyzed for radioactivity. Retention is achieved by a central collection system that directs all water, except sanitary sewage, to two 4-m³ retention tanks. Water flow to the tanks is continuously monitored for gross contamination by a scintillation detection system. The detector will sound an alarm when the water-contamination level is twice the background-radiation level. All water in the tanks is held until laboratory analyses show that contamination levels are within acceptable discharge limits. Water exceeding discharge limits is transferred via tank truck to Bldg. 514 for treatment prior to disposal.

1.3.2.2. Metallurgy Chemistry--Building 332.

Solid Waste. Plutonium-contaminated solid waste is generated and handled by methods similar to those described for Bldg. 251. All waste barrels are assayed for plutonium content with a segmented gamma-drum scanner before being released to TWC. The segmented gamma counter is operated and maintained by the Materials Management Group.

Liquid Waste. All retrievable highly and moderately contaminated liquid waste is sent to Bldg. 419 for solidification. Water from within the facility is retained in two 4-m tanks until analysis indicates that contamination levels are within sanitary sewage discharge limits. Water is then released to the sanitary sewer. If contamination levels exceed the limits, the water is transferred to Waste Disposal for treatment prior to disposal.

1.3.2.3. Light Isotope Chemistry--Building 231. Tritium waste is generated within Building 331 by the various experimental operations performed there and takes the form of tritiated hydrogen gas (HT), tritiated water (HTO), or solids or liquids contaminated with HT or HTO.

Solid Wastes. Solid waste is generally doubly contained, placed in metal drums, and sent to the Solid Waste Disposal Facility (Building 612) for disposal.

Liquid Waste. Building 331 has no liquid waste retention tank system. The majority of low-level liquid waste (less than 5 Ci/y) is released to the sanitary sewer. The majority of intermediate-level (1 to 10 Ci/liter) liquid waste is vacuum pump oil (approximately 400 liters/y). This oil is solidified before leaving the building and is then packaged inside 210-liter drums, which are handled as solid waste.

1.3.2.4. RTNS-2--Building 292.

Solid Waste. The primary wastes generated from Building 292 include tritium and some Cobalt 60 contaminated equipment, rags, tools, accelerator targets, and molecular sieves.

Liquid Wastes. No liquid waste streams are generated in this area.

1.3.2.5. Materials Fabrication Division--Building 321.

Solid Waste. Uranium- and thorium-contaminated wastes are generated in this building. This waste consists of metal parts, shop debris, rags and other combustibles.

Liquid Wastes. Contaminated machine coolants, solvents (including chlorinated solvents), metal turnings in coolants, and other small quantities of various liquid waste streams are generated in this building. All liquid wastes are transported to the Liquid Waste Treatment Facility. Machine coolants and liquids are replanted; oils and solvents are solidified. The remaining liquid wastes are mixed with other incoming liquid-waste streams and are chemically pretreated and filtered, then discharged to the sanitary sewer.

1.3.3. Waste Management Facilities.

The waste management facilities consist of:

- o Retention-tank systems located in buildings where significant quantities of liquid waste could become contaminated. All effluent from sinks and floor drains is retained in 4- to 40-m³ tanks until the radioactivity status is determined. If the radioactivity is not as low as practicable, the liquid is transferred to a portable tank and sent to the liquid decontamination facility at Building 514. Each retention system has at least two tanks so that operations can proceed while the radioactivity of the filled tank is being determined.
- o Carboy or small-tank accumulation of intermediate-level (1 to 10⁶ μ Ci/liter) liquid waste at any location and of low-level (<1 μ Ci/liter) liquid waste at buildings without retention tank systems. These wastes are sent to the Solid Waste Disposal Facility and stored there prior to treatment.
- o A collection and decontamination plant at Bldg. 514 for treatment of low-level radioactive liquid waste.
- o A facility in the waste treatment area that is presently used for the accumulation of intermediate-level liquid waste.
- o A collection, packaging, and disposal facility at Bldg. 612 where solid contaminated waste is prepared for shipment to a commercial underground storage site.
- o A decontamination facility in which contaminated articles are cleaned of radioactivity.

1.3.4. Liquid Waste Treatment Plant Description.

The Liquid Waste Treatment Plant receives building retention-tank waste shown by analysis to exceed permissible limits for discharge to the sanitary sewer. The liquid waste is transported in 4-m³ portable plastic-lined steel tanks. This liquid waste is transferred to a 5.7-m³ treatment tank to await decontamination treatment. Four 5.7-m³ plastic-lined steel tanks are used for decontamination.

The principal treatment technique involves chemical precipitation pretreatment followed by vacuum filtration through diatomaceous earth on a rotary-drum filter. The filter cake is collected in plastic-lined drums and sent to the Solid Waste Disposal Facility. A drum typically shows a gamma radiation of 1 mR/h at the surface and may contain 100 μ Ci of alpha emitters and 150 μ Ci of beta emitters, with an overall specific activity of about 2 nCi/g. The vacuum filtering produces dry-appearing flakes that contain about 45% water. No separation is expected since diatomaceous earth can absorb three times its weight of water without appearing wet. Centrifuging samples of filter sludge produces a 10% volume separation of liquid. Tests to determine if the vibration from transportation to the underground storage site releases free liquid have not shown any free liquid.

Liquid waste with known, specific contaminants can be treated by a method more suitable for that material than the regular coagulation-flocculation treatment. Specific chemical treatments or pre-treatments may be employed.

1.3.5. Solid Waste Disposal and Storage.

The solid waste packaging, holding, and shipment activities are housed in Bldg. 612 and its fenced and paved yard area. The contaminated waste accumulated in drums at the generating buildings is delivered to Bldg. 612 and temporarily stored. In the past, storage of these materials has exceeded one year. The bagged, compactible, low-level waste is compacted using a hydraulic compacting/baling press and then sealed, marked, and recorded. Transuranium (TRU) contaminated waste is packaged in hot-dipped galvanized DOT-Specification 17-C drums. These drums are designed to comply with the 20-year retrieval policy of the DOE. Other waste is packaged in yellow DOT-Specification 17-H drums. The yellow drums are moved to the yard area,

and the galvanized drums are stored under sheds in the yard to await shipment to a DOE-approved storage site at NTS.

1.3.5.1. TRU Only one oversized TRU waste box is currently in storage at LLNL. An estimated additional six will be generated in FY85, an additional 15 will be generated between FY85 and FY89, and 9 more will be generated after FY89. These boxes will be stored at LLNL until the Size Reduction Facility is constructed and is operational. The construction of this facility, if approved in the FY86 budget, will be operational in late 1989.

1.3.5.2. LLW Currently 236 drums, thirty-nine 4 X 4 X 7-ft boxes, and two 2 X 4 X 7-ft boxes of backlogged wastes are on inventory. These wastes have been stored at LLNL for more than one year; some have been stored for as long as five years.

1.3.6. Effluent Control Systems.

The primary control system for preventing the release of excessive amounts of radioactivity to the environment in waste liquids is the network of retention tank systems describes previously. These tanks are located at the buildings where the waste liquids are generated. The systems are designed so that all fluids entering the building sinks or floor drains are collected in a tank that is isolated from the domestic sewer lines. An alarm system sounds when a tank is full, and fluid flow is switched, manually or automatically, to another tank. A laboratory analysis of a sample from the full tank governs the disposition of the contents.

All domestic sewer effluent leaves the site at the northwest boundary where a sampling station provides continuous monitoring. Samples are also collected at this location for detailed laboratory analysis. A 51-x-51mm sodium-iodide detector monitors continuously for medium- and high-energy gamma emitters and a 3-x-127-mm-diam sodium-iodide crystal monitors continuously for low-energy gamma emitters. The minimum detectable concentration of ^{239}Pu is 30 nCi/l. If contaminants in the effluent exceed preset limits, an alarm sounds at the Fire Station, which is manned continuously. The effluent contamination status is evaluated by a health physicist. A 3-hr period elapses between the alarm and the arrival of the effluent at the Livermore

Water Reclamation Plant (LWRP), so there is time for evaluation of the alternatives. Upon notification, the LWRP personnel will divert the effluent into one of their holding ponds. To date diversion for radioactive release has been required.

If a diversion became necessary the diverted sewage would be disposed of in accordance with the contaminant concentration found in the holding pond. The most likely occurrence is a release that would exceed by a small factor the standards for drinking water.

The LWRP is prepared to dispose of such sewage by a controlled release from the pond into the sewage treatment stream to assure adequate dilution.

In the unlikely event of a large release that results in significant contamination in the holding pond, the corrective action would be dictated by the level of contamination and the radionuclide involved.

1.3.7. Site Administration Limits on Effluents.

The policy of the Laboratory is to maintain concentration of liquid and airborne radioactive effluents levels to as low as reasonably achievable below the standards set by DOE Order 5480.1A. The current policy regarding liquid-effluent-tank releases is to discharge no more than a total of 5 μ Ci of alpha activity, 50 μ Ci of beta activity, and 30 mCi of tritium activity per day to the sanitary sewer. Factors considered in making this decision are as follows:

- o The total quantity of radioactivity involved.
- o Whether or not there has been an attempt to remove the radioactivity from the waste solution.
- o The ability to remove the radioactivity from the waste solution.
- o The currently available storage and treatment capacity at the Liquid Treatment Facility.

Releases of radioactivity to the sanitary sewer system are usually smaller than 1000 times less than permissible levels, and it is expected that this fact will hold true as new facilities are constructed. These guidelines and considerations are applied in an effort to minimize discharges of radioactivity to the Livermore Water Reclamation Plant.

1.3.8. Radioactive Waste Releases.

Airborne and liquid radioactive effluents released at the Livermore site in 1980 are shown in Table 1. Both normal and accidental releases are included. Liquid releases should be reduced as new treatment equipment is installed. At Site 300, radioactive waste is restricted to depleted-uranium-contaminated high-explosive debris, which is buried on-site.

Effluent	Discharge (Ci)
<u>Airborne:</u>	
$^3\text{H}_2$	2305
^{41}Ar	165
$^{13}\text{N} - ^{15}\text{O}$	1656
Unidentified β - α	5.1×10^{-5}
<u>Liquid:</u>	
HTO	5
^{239}Pu	2.8×10^{-4}

Table 1. Airborne and liquid radioactive effluents released in 1980 at the Livermore site.

1.4. SANITARY WASTE MANAGEMENT

1.4.1. General

Sanitary sewage and effluent from the LLNL sewer system is treated at the Livermore Water Reclamation Plant (LWRP). The sewage is continuously monitored, as it leaves the LLNL site, for pH and radioactivity to detect any potentially hazardous release soon enough to permit the sewage to be diverted into holding ponds at the treatment plant. Any diverted sewage is held until analyses show what, if any, special treatment is needed before the sewage can

be treated in the municipal plant. In addition to the continuous sampling, composite sewage samples are collected daily and analyzed for radioactive materials and toxic metals.

Radioactive waste below the acceptable limits for radioactivity and chemical concentration is discharged from facility retention tanks and TWC operations, after radioactivity and concentration levels are confirmed by laboratory analysis.

1.4.1.1. Sewage Monitoring. For rapid identification of potentially harmful releases into the sewer, a continuous stream of 40 liters/min is pumped to a small LLNL building that houses detection instruments. Inside this building, the sewage is piped through a 26-liter lead-shielded tank that contains a recording pH meter, a low-energy NaI (Tl) detector, and a higher energy NaI (Tl) detector. Output from these radiation detectors allows for detection of radionuclides commonly used at the Laboratory. The sewage stream also flows through an x-ray fluorescence monitor capable of detecting transition metals, such as copper and chromium.

1.4.1.2. Discharge Limits. Discharge limits must be below those listed in DOE 5480.1A and the City of Livermore Sewer Ordinance 1134, June 1983, which regulates hazardous waste discharges only.

1.4.1.3. Sewer Release Incidents. There have been several incidents of toxic-or radioactive-material releases into the sanitary sewer. For each incident, corrective measures were recommended to prevent a recurrence. Because most of the releases were from the plating shop, a special process-waste treatment system was installed. This unit significantly reduced the incidence rate of low- or high-pH discharges. However, the rapid warning provided by the continuous monitoring station provides the time needed to evaluate other possible sources of pH excursion and to recommend diversion, if necessary.

1.4.2. Excess Properties, Salvage, and Reclamation Operation

1.4.2.1. General. Material not needed for use by LLNL personnel may be disposed of in a number of ways. If the item is being removed from a

radioactive materials area, it must first be monitored by Hazards Control and tagged with the type of radiation, level, and date. If Hazards Control determines that the item is contaminated, it is sent to the decontamination group to be decontaminated. If the radiation level cannot be brought down to meet applicable standards, the item is as radioactive waste.

Items not from a radiation area, decontaminated items, and items that have been determined by Hazards Control not to be contaminated, can be sent to one of two places. Capital equipment must be sent to the Redeployment Center, and all other items may be sent to the Reclamation and Salvage Section.

The Redeployment Center evaluates the condition and the Laboratory's need for a particular item. If the Center determines the item to be of potential value to LLNL or other government agencies, it is sent to the Excess Property Section. Materials that cannot be repaired, or those that have no potential value to anyone, are sent to Reclamation and Salvage.

1.4.2.2. Excess Property at LLNL. A list of excess materials is circulated at LLNL for 30 days. Materials not needed on-site are reported on a list to DOE, which is circulated another 30 days. Items still not used are reported on a list to the General Services Office in San Francisco. This list is circulated to other federal agencies for 60 days. If the materials are not needed by other federal agencies, they are then reclassified as federal surplus and made available for 15 days for donation to state education agencies or other organizations specified by federal surplus guidelines. Materials remaining after this series is completed are taken to the Concord site of the Alameda Defense Properties Disposal Office where they can be sold or stored. A schematic representation of this disposal process is shown in Fig. 4.

1.4.2.3. Reclamation and Salvage. Non-capital materials are evaluated by Reclamation and Salvage for condition and need. If the item is a stock item (currently stocked by LLNL Supply Department) and is in good condition, it is returned to stock for reissue. An item may be sent for repair before being returned to stock. Materials that are not in stock condition but that still may have future value to LLNL are held in the surplus yard or surplus shelves in the Materials Control warehouse. After 6 months, the surplus items are turned over to the Excess Property Section and processed as described above.

Finally materials that are non-repairable and non-usable are first disassembled for salvageable parts, then sent to scrap.

Scrap materials are sold by bid. Metals are segregated by type (ferrous, copper, etc.) and sold by bulk weight on 3-month contracts. The exception is mercury, which is collected and redistilled (by an outside contract or) for LLNL reuse. Solvents and oils are stored in 210-liters drums and sold on a yearly contract. Tires are collected and sold on contract as accumulated. Paper and unclassified IBM cards are sold on a yearly contract. Scrap lumber is made available to LLNL personnel on Saturday mornings.

1.4.2.4. Space Used for Excess Properties, Salvage, and Reclamation.

Reclamation and Salvage uses approximately 93 m^2 of inside storage space and 1900 m^2 of outside storage area. The Excess Property Section uses approximately 110 m^2 of inside storage area and 460 m^2 of outside storage area.

1.4.2.5. Decontamination. Building 419 is LLNL's decontamination center for the removal of radioactive and toxic contaminants from equipment. Soak tanks, steam guns, mechanical abrasives, ultrasonics, and a vapor degreaser use mechanical, chemical, and heat energy to remove contaminants. All wastes generated in the cleaning operation are transferred to Waste Management. Discharged air is passed through double HEPA filters and monitored.

1.4.2.6. Nonhazardous Waste Landfill LLNL generates approximately 44 m^3 of waste per work day, which is transported to the Alameda County sanitary-landfill site. This debris consists primarily of 8 m^3 of shredded computer printout paper, 24 m^3 of waste paper and garbage, and 12 m^3 of wood and other construction rubble. All such waste is covered immediately with several feet of clean earth. Compaction is performed by large dirt-moving equipment. Burning is not permitted. No radioactive or toxic materials are sent to the landfill.

1.5. SITE 300 OPERATIONS

As part of its national defense mission, LLNL operates the Site 300 field-test facility in the eastern Altamont Hills, about 21 km (13 mi)

Figure 4. Disposal of excess material.

southeast of Livermore, California. The site location is shown in Fig. 1, pg. 8 LLNL's nonnuclear explosive tests are conducted at Site 300. The handling of radioactive and toxic material and the detonation of high-explosive assemblies containing these materials are the principal sources of possible environmental impact.

There are no tests at Site 300 involving high-explosive assemblies that contain fissile material. However, static and dynamic tests are performed at Site 300 that do involve plutonium. Two sealed barriers are required for static tests and three such barriers are required for dynamic tests, and the ventilating exhaust air from these test facilities is passed through HEPA filters. No breach of any barriers is expected in any of these tests involving fissile material. All such tests are verification-design tests and are not tests to failure. The shipment or transfer of explosives and of radioactive material other than depleted or natural uranium and thorium in the same container or to the same facility at Site 300 is prohibited.

An environmental monitoring program ensures that the LLNL controls are indeed restricting effluent releases to levels well below appropriate standards. Because of the remoteness of this site, these experiments can be performed with minimal off-site impact from annoying noises or damaging overpressures (667 Pa or 0.1 psi for tightly-fitted window glass). Based on meteorological measurements made twice daily, a limit is set on the weight of high explosives that can be detonated without impact in populated areas. The Laboratory uses an offsite overpressure limit of 40 Pa (0.006 psi) for areas 4.8 km (3.0 mi) beyond the detonation point. To monitor the correctness of these limits, four microbarograph sensors are maintained in or near Tracy. The probability of overpressure is greatest in this area due to the direction of the prevailing winds. In 1976, an unexpected change in the direction of the upper winds caused noticeable overpressure. There were no complaints of damage.

A Site 300 ecology study was made in 1974 to determine if LLNL operations have had measurable impact on plants and animals native to the area. The ecosystem is dominated by perennial grasslands, and small rodents abound which are preyed upon by snakes, raptors, and a variety of carnivorous mammals. The study involved collection of plants and animals in the vicinity of the high-explosive firing bunkers. Similar samples, for use as control samples,

were also collected about 10 km west of the Site during this period. This direction (normally upwind) and distance gave reasonable assurance that the latter samples would represent background conditions unaffected by LLNL operations.

Analysis of the data showed that while tritium, beryllium, and uranium were present in some plants and animals, in general the levels measured in the biota on Site 300 were not significantly different from those found in the control samples.

In 1975, approximately 100 acres on the east side of Site 300 was transferred to the California Department of Fish and Game for use as a wildlife preserve. A radiological survey of this property was made in 1973 prior to the release and in compliance with AEC requirements for disposal of land. A terrestrial survey was made using a sensitive sodium iodide gamma detector with readings made at a nominal height of 1m above the soil surface. Soil samples were also collected for uranium analyses. The terrestrial radiation exposure rates, which vary from 4.0 to 6.5 $\mu\text{R/h}$, are typical natural background readings for soils in this area. Likewise, the variation of 1-3 ppm in the total uranium is within the normal range observed in Northern California.

Other impacts, such as noise pollution from DOE high-explosive testing, are negligible due to the distance of the firing bunkers from the eastern site perimeter. The closest bunker, Bunker 812, located in a deep ravine, is nearly 3/4 mi from the perimeter. Concentrations of airborne beryllium at sampling points between this bunker and the east site boundary are less than 1% of the permissible standard.

It was concluded from these measurements that Site 300 operations had no measurable impact on the area up to 1973. Since that time, annual surveys near the site perimeters have not indicated off-site impact. No construction is presently planned along the east perimeter.

1.5.1. Waste Management at Site 300

1.5.1.1. Solid Radioactive or Chemical Wastes. Solid wastes resulting from detonation of test assemblies constitute the principal source of radioactive or chemical wastes at Site 300. Most of these assemblies contain depleted

uranium and beryllium, although a few assemblies have contained natural uranium or thorium. A limited number of experiments involving tritium have also been conducted at the Site.

Solid waste consisting of contaminated rubble is collected from the gravel-covered firing table after each shot. It is estimated that most of the uranium in the test assembly is associated either with this debris, or remains in the gravel. That uranium debris is limited to areas adjacent to the firing bunkers was confirmed by the EC&G aerial radiological survey in 1975 and by soil analyses.

Firing-table gravel and associated debris are buried in designated disposal areas within Site 300. These burials are made in accordance with regulations set forth in 10CFR20 Paragraph 20.304, which permits land burials of radioactivity equivalent to 300 kg of depleted uranium per year. Each firing bunker maintains records of the uranium and beryllium in the test assemblies expended on its firing table. Based on these records, the firing-table gravel is taken to the disposal pit when an estimated 300 kg of uranium is contained in this gravel and in the contaminated rubble previously trucked to the pit. Pits are trenches. Gravel and rubble containing the estimated 300 kg of uranium are covered with 1.2 m of soil; a 1.8-m-wide soil barrier is established between trenches.

Land-burial of contaminated rubble from Site 300 is an effective disposal method. Depleted uranium is a by-product in the process by which enriched uranium (enriched in ^{235}U) is produced from natural uranium. In a preliminary step of this process, uranium-decay products, including radium, are chemically separated from the uranium. Because the radiological hazard from uranium is predominantly due to radium and its decay products, essentially no radiation hazard is associated with the land burial of depleted uranium at Site 300. Starting with radium-free uranium, it takes over a million years for the ^{226}Ra activity to grow back into equilibrium with the parent ^{238}U , as shown by the following tabulation:

<u>Time after separation (years)</u>	<u>% Equilibrium</u>
1×10^4	0.07%
1×10^5	7.9
1×10^6	90.6
3×10^6	100.0

High-explosive wastes generated in formulation and processing are collected from the firing tables and periodically burned in a remote burn area on the Site.

At one time, solid waste from LLNL, consisting largely of bulky items from radiation workplaces at LLNL and from large-animal experiments conducted at LLNL and LBL, were buried at Site 300. Approximately 100 000 ft³ of waste was buried at the Site 300 Pistol Range Pit between 1964 and 1973. Animal wastes and carcasses contaminated with short-lived radionuclides accounted for 23 000 ft³ of the total volume. The animal burial practice was stopped in 1973 when large-animal experiments were discontinued. The remaining 77 000 ft³ of buried waste consists of compressed drums, capacitors, glove boxes, beryllium-contaminated filters and equipment, gas bottles, assorted waste chemicals, and scrap metal primarily from the Taxi Strip and Salvage storage areas. Burial of this type of waste was discontinued in 1970 as a result of an LLNL policy change.

1.5.1.2. Liquid Chemical Wastes. Liquid wastes from high-explosives processing are passed through clarifiers (settling tanks). Clarified liquid is then pumped and evaporated in holding ponds. Solids are treated in the same manner as solid high-explosive waste.

1.5.1.3. Sanitary Wastes. In all areas except the General Service Area (GSA), sanitary wastes are handled by individual septic tanks or by chemical toilets. All septic tanks are equipped with leach fields.

A sanitary sewer system is provided in the GSA area, pipes sewage to an asphalt-lined, oxidation pond at the southeast corner of the Site. This pond has a surface area of about 4000 m². It was designed to accommodate a population of approximately 200. At present, about 100 persons are assigned to the GSA area. The depth of the liquid is maintained between 1 and 1.5 m. During the summer months, water must be added to the pond to maintain the minimum level. A smaller overflow pond was constructed to provide additional capacity during the winter, when evaporation is minimal.

Samples from the oxidation pond are analyzed on a quarterly basis as part of the environmental monitoring program for Site 300.

1.5.2. Facilities Description

Site 300 covers an area of 27 km^2 (11 mi^2), located in both Alameda and San Joaquin Counties. The topography of the site is characterized by steep hills with rugged canyons, although rolling hills with flat benches exist in the southern portion of the site. The area around Site 300 is sparsely populated.

Active Landfills 1 and 7 are located in the northern portion of Site 300 with at least 305 m (1000 ft) between the disposal pits and the nearest property line and are situated well outside the 100-year storm-flood line. The pit boundaries, shown in Figs. 5 and 6, are based on field surveys with pit corners marked with steel posts.

The waste disposed at Pits 1 and 7 is generated primarily at Site 300 and consists of the following uranium-contaminated items (predominantly depleted uranium), and beryllium:

1. Firing-table debris, such as dirt, gravel, concrete, and metal.
2. Negligible quantities of equipment and laboratory waste, such as paper and clothes wipes, gloves, shoe covers, and fixture-holding apparatus.
3. Minor quantities of metal parts of uranium and/or beryllium. On rare occasions, thorium is used.

This waste amounts to about 850 kg of ^{238}U (depleted; D-38) and 125 kg of beryllium, for a total yearly debris generation of 1600 m^3 (2090 yd^3), weighing $7.1 \times 10^7 \text{ kg}$. Eighty percent, or 1280 m^3 (1672 yd^3) of the yearly volume is disposed in Pit 7 with the remaining 20% or 320 m^3 (418 yd^3) deposited in Pit 1.

Depleted uranium, beryllium and minor quantities of thorium are the only regulated wastes permitted at Pits 1 and 7. Therefore, there are no incompatible wastes at Site 300 landfills.

Operational controls used at the landfills to limit the quantities of radioactive wastes present were derived using guidelines established by the Nuclear Regulatory Commission (NRC) 10/CFR20, Paragraph 20.304. These restrictions state that: (1) the total quantity of radioactive materials buried at any one location and time may not exceed approximately 0.1 Ci

in any given location (equal to 300 kg of depleted uranium, D-38); (2) burial is at a minimum of depth of 4 ft; and 3) successive burials are separated by distances of at least 6 ft, and (4) not more than 12 cells are opened in any year. This requirement further restricts the quantities of hazardous materials that can be disposed at the landfills.

Diversion ditches have been constructed at Pits 1 and 7 to intercept and divert surface runoffs around the landfills. Surface runoff from areas upslope of Pit 1 is intercepted by drainage ditches located approximately as shown in Fig. 5. The ground surface along the ditch on the northeastern side of Pit 1 has been modified so that the ditch flows freely. The surface of the inactive portion of Pit 1 is graded to drain so that runoff will the ravine located southwest of the pit. This ravine drains into Elk Ravine, the major drainage course in the northeastern portion of Site 300. Surface flows about 2.5 miles from Pit 1 before reaching the Site 300 boundary.

Surface runoff from the area upslope of Pit 7 is intercepted by a drainage ditch located along an abandoned fire road approximately as shown in Fig. 6. Rainfall onto the closed portion of Pit 7 runs off downslope to the east; most of the rainfall probably evaporates or infiltrates before leaving the general pit area, although runoff could conceivably follow surface rainage to the southeast and east and enter Elk Ravine just northeast of the abandoned Pit 2 shown on Fig. 5. The total distance for surface water flow along Elk Ravine and its tributaries from Pit 7 to the Site 300 boundary is 3.7 miles. Figure 7 shows, in addition to the groundwater monitoring wells at active Pits 1 and 7, the entire Site 300 groundwater monitoring network.

Local soils within Site 300 vary from silty, gravelly sands to moderately plastic clays. Observations made during the geotechnical evaluations of Site 300 indicate that the erodibility of these soils decreases and the expansiveness increases with increasing clay content. Soils used to cover filled portions of Pit 1 are not known to have been tested for engineering properties but field observations during geohydraulic studies suggest that the soils are dominantly sandy clays to very clayey, gravelly sands of low permeability. Visual observations indicate that these materials are erosion-resistant and moderately expansive.

Local soils in the vicinity of Pit 7 vary from clayey, gravelly sands to silty clays. When placed as cover, these materials appear to have low permeability and good erosion resistance. Field observations made during

Figure 5. Active Pit No. 1 and the Groundwater Monitoring Wells.

Figure 6. Active Pit No. 7 and the Groundwater Monitoring Wells.

Figure 7. Site 300 showing the Groundwater Sampling Network.

geohydrologic studies of the Pit 7 complex revealed that numerous shrinkage cracks formed in these local soils during the dry season, suggesting a high shrink-swell (expansion) potential for these soils.

1.5.3. Landfill Data

The contaminated firing-table debris and of minor quantities of other low-level radioactive material disposed of in Disposal Pits 1 and 7 introduces approximately 850 kg of depleted uranium and 125 kg of beryllium yearly in debris that occupies approximately 1600 m³ (2090 yd³) and weighs 7.1 X 10⁷ kg (15.66 X 10⁷ lb). This equates to 12 mg of primary depleted uranium and 2 mg of beryllium per kg of waste. Additionally, due to the requirements of the NRC, detailed for separating end cell with inert material, the total pit volume is approximately 7 mg/kg of contaminants, which is considered insignificant.

The following significant data is provided on each of the disposal pits:

	<u>Pit #1</u>	<u>Pit #7</u>
Date opened	Latest cell opened 1969	Jan. 1979
Total area (yd ²)	11 800	6250
Total volume (yd ³)	58 964	31 111
Volume Used (yd ³)	56 000	10 511
Capacity remaining (yd ³) (as of 6/83)	2964	20 600
Average yearly waste disposal rate (yd ³)	418	1672
*Estimated remaining life (years)	3-1/2	6
*Estimated Closure Date	1986	1989

At Pit 1, the construction of a second layer of cells, which would greater extend landfill life, is being considered.

*Estimated life and closure dates are based on the average waste disposal rate plus an allowance for inert fill required by NRC regulations. Disposal rates may vary depending on type and number of experiments.

1.5.4. Schedule of Partial Closures

Whenever an individual cell in the landfill contains 0.1 Ci, or approximately 300 kg of ^{238}U , the cell must be closed to meet the requirements of NRC regulations. This cell closure occurs when approximately 575 m^3 (750 yd^3) of debris accumulates per cell. As the disposal cell is being filled, firing-table gravel and/or other debris is pushed into place with a bulldozer, but no special effort is made to obtain a specific compaction. However, since the debris is not heavily surcharged, and since the amount of organic material is negligible, extra compaction is not considered necessary or future settlement expected to be significant. Local soils—which range from silty, gravel sands to moderate, plastic clays, and appear to have low permeability and good erosion resistance—are used for cover material during these partial closures. Cover material is compacted by bulldozer track-walking, a procedure which results in compaction to approximately 85% relative density. Minor settlement, as a result of slight debris consolidation, may occur in localized areas on the landfill surface. Those interfering with free drainage are corrected as found. Surface and ground-water monitoring, periodic inspections and diversion ditch maintenance, etc., will be performed in accordance with the requirements of the RWQCB Order 80-184 throughout the active life of the landfills.

1.5.5. Maximum Storage Inventory and Equipment Usage

The maximum amount of waste accumulated at the Site 300 firing tables is directly dependent on the number and type of experiments being performed.

LLNL Hazardous Control technicians survey the fire table periodically, normally monthly, to determine when gravel should be removed and replaced with fresh gravel. The landfills employ standard landfill equipment (e.g., bulldozers and scrapers). No other structure or equipment, except for the trucks hauling the debris to the pits, are involved in the landfill operations.

1.6. SCHEDULES AND MAJOR MILESTONES FOR WASTE MANAGEMENT ACTIVITIES

1.6.1. Radioactive Waste Storage Area

A radioactive waste storage area is planned. Construction of this storage area will probably begin FY85 and end FY86.

1.6.2. Toxic Waste Control Decontamination and Waste Treatment Facility

The Decontamination and Waste Treatment Facility line-item project, scheduled for FY86 funding, is currently being rescoped and a new Schedule 44 will be submitted to DOE on or before March 1, 1985. The new project will provide the necessary facilities to assure long-term compliance with foreseeable environmental regulations and requirements and increase the capability for more on-site treatment and recycling. The preparation of the waste management and siting studies and the CDR are currently underway.

The present plans call for the construction in FY85 of new hazardous waste and radioactive-waste storage facilities to provide the storage, segregation, and spill-prevention operations urgently needed. Also in 1985, documentation, recordkeeping, and reporting requirements will be reviewed, upgraded, and brought into compliance.

1.6.3. Waste Generation

Approximately $100 \text{ m}^3/\text{yr}$ of solid TRU waste, $436 \text{ m}^3/\text{yr}$ of solid LSA (non-TRU) and $61 \text{ m}^3/\text{yr}$ of solid LSA (TRU below 100 nCi/g) is generated annually. Projected rates for TRU, LSA (nonTRU) and LSA (TRU) are $100 \text{ m}^3/\text{yr}$, $523 \text{ m}^3/\text{yr}$ and $74 \text{ m}^3/\text{yr}$, respectively. See Tables 2 and 3. The LSA and TRU shipping schedules are outlined in Tables 4 and 5.

1.6.4. Decommissioning of the Livermore Pool Type Reactor

The Livermore Pool-Type Reactor is being decommissioned in two phases.

Under Phase I, the reactor was defueled, with water and liquid wastes removed and processed.

Table 2. LLNL Integrated Waste Stream 4, LLNL Candidate Mixed Waste Streams

Stream Id#	Description of Stream	Chemical Composition	Current Gen Rate L/YR
* Annual generation rate for waste stream number L99			
L99TRA	Aggregated LSA Non trans-uranium Dry radwaste	Drums and 7A boxes of dry usually compactable LSA Non-TRU radwaste	436 ^a
L99TRB	Aggregated LSA trans-uranium dry radwaste	Drums and 7A boxes of dry usually compactable LSA TRU radwaste	61 ^b
<u>SUBTOTAL</u>		<u>497</u>	
* Annual generation rate for waste stream number S96			
S96TRA	Solid waste from shot table operations and cleanup	D-38 and Beryllium, probably present as oxides, mixed with shot table debris and gravel	170
<u>SUBTOTAL</u>			<u>170</u>
<u>TOTAL</u>			<u>667</u>

^a Average LLNL LSA generation rate in cubic meters/per year Current=2053bbbls & Projected=2463 bbls.

^b Average LLNL generation rate in cubic meters/per year Current=294bbbls/per year Projected=353/per year.

^c Rates are in Kg/per year :D-38: No. 3 :Beryllium: 0.405 buried in surface pits at Site 300.

Table 3. LLNL TRU Waste Generation Rates Current and Projected.

Waste Id #	Cr Max Ppm	Cu Max Ppm	Ni Max Ppm	Zn Max Ppm	Be Max Ppm	Other Metals Max	Metals Ppm Max	Comp Fctr	Current Gen Rate (L/YR)	Projected Gen Rate (L/YR)
* Annual generation rates for facility/operation number 199										
L99TRA	0.00	0.00	0.00	0.00	0.00	0.00	2.0	436	523 ^a	
L99TRB	0.00	0.00	0.00	0.00	0.00	0.00	2.0	61	74 ^b	
** SUBTOTAL **									497	597
** TOTAL **									497	597

^a Average LLNL LSA generation rate in cubic meters/per year current = 2053
bbbls & projected = 2463 bbbls.

^b Average LLNL generation rate in cubic meters/per year Current = 294
bbbls/per year Projected = 353/per year

Table 4. LSA shipping schedule.

<u>Month/Date</u>	<u>No. Shipments Scheduled</u>	<u>No. Shipments Completed</u>
OCT 84 1, 8, 15,* 17,* 22		5
NOV 84 5, 12, 26, 27(D)	4	
DEC 84 3, 10, 11,* 17	4	
JAN 85 7, 21, 28	3	
FEB 85 4, 5(D), 11, 12,* 25	5	
MAR 85 4, 18, 25	3	
APR 85 1, 8, 9,* 22, 29	5	
MAY 85 6, 7(D), 11, 12,* 25	5	
JUN 85 3, 10, 11,* 17	4	
JUL 85 8, 15, 29	3	
AUG 85 5, 6,* 12, 13(D), 19	5	
SEP 85 9, 16, 23	<u>3</u>	<u>-</u>
	43	5

NOTES:

- * Denotes dedicated LSA box shipment by commercial carrier.
- (D) Denotes dedicated LSA drum shipment by commercial carrier.

Phase II of the decommissioning plan was scheduled for FY85, after the five-year cool-down period or FY85. However, since funding was not received, a new plan will be developed.

The reactor will be removed in four steps. The first and second steps will consist of removal and demolition operations. Step one will include placing containment building support and safety facilities in operation; installing temporary personnel facilities (change room, decontamination facility, etc.); and removing experimental gear, uncontaminated equipment and accessories. Step two will include removal of radioactive material left in the reactor vessel, the graphite thermal columns, the lead shields, the core grid support and associated hardware. For the third step, a subcontractor will be brought in to demolish the reinforced concrete reactor structure and the cooling tower. All radioactive waste will be processed and packaged under the guidance of Hazards Control, and will be shipped to an approved site for disposal. Under Step Four, all remaining removal and clean-up work will be completed, using both LLNL forces and subcontractors. Phase II will require about 12 months.

1.7. QUALITY ASSURANCE

Organizations involved with the operational and monitoring requirements of DOE Order 5820.2 have quality-assurance plans that address their respective operations. These plans were prepared to assure that quality-control elements are addressed in carrying out responsibilities associated with waste handling and monitoring, and that quality-assurance elements are in place to assure reliability and quality of the methods and equipment.

LLNL's Toxic Waste Control (TWC) Group manages Laboratory-generated hazardous and radioactive waste. The group's responsibilities include the treatment, packaging, and shipment of hazardous waste. The TWC quality assurance plan, which prescribes the formal quality controls necessary to meet federal and state regulations and the mechanism to assure those controls are in place, has been prepared and submitted to LLNL's Quality-Assurance Office (M-078-38, July 1983). This plan is included as Appendix C.

LLNL's groundwater monitoring program is conducted by the Environmental Measurements Group of the Hazards Control Department. Quality control in

Table 5. TRU shipping schedule.

<u>Month/Date</u>	<u>No. Shipments Scheduled</u>	<u>Remarks</u>
OCT 84 1, 8, 22, 29	4	
NOV 84 5, 12, 26	3	
DEC 84 3, 10, 17	3	
JAN 85 7, 21, 28	3	
FEB 85 4, 11, 25	3	
MAR 85 4, 18, 25	3	
APR 85 1, 8, 22, 29	4	
MAY 85 6, 13, 20	3	
JUN 85 3, 10, 17	3	
JUL 85 8, 15, 29	3	
AUG 85 5, 12, 19	3	
SEP 85 9, 16, 23	<u>3</u>	

sample collection, analysis, and calibration, as well as in records and data management are described in the quality-assurance plan for the Environmental Measurements Group (M-078-09, revised February 1984). Quality-assurance elements, such as intercomparison analyses, nonconformance and corrective action, and audits, are included in the Quality Assurance Plan as means to assure that controls are implemented. More detailed information about the LLNL Enrichment Monitoring Program Quality Assurance Plan can be found in Appendix D.

LLNL's groundwater samples are analyzed for RCRA parameters by Brown and Caldwell, an independent off-site laboratory. Brown and Caldwell has established formal quality-assurance and chain-of-custody procedures to assure that proper controls are implemented in sample collection, identification, logging, preservation, and storage, and that the appropriate analytical methods are followed. In addition to the routine calibration of the analytical instruments, duplicate and other EPA state certification and verification methods are used by Brown and Caldwell.

A copy of Brown and Caldwell's quality-assurance and chain-of-custody procedures is provided in Appendix E.

2. ENVIRONMENTAL MONITORING PROGRAMS

A strict effluent-control program that emphasizes controlling effluents at their source has been in effect since the Laboratory began operation. The environmental monitoring program is maintained to evaluate the effectiveness of these effluent-control measures, to document whether effluents from the Laboratory and Site 300 operations are within applicable standards, and to estimate the impact of these operations on the environment. Sensitive monitoring equipment is used to detect radioactive and non-radioactive pollutants at environmental background levels. The program includes the collection and analysis of air, soil, water, sewer effluent, vegetation, foodstuffs, and milk samples. Also, environmental background radiation is measured at numerous locations in the vicinity of the Laboratory using gamma and neutron dosimeters.

Each spring, the Laboratory reports the results of environmental monitoring for the previous year, noting significant changes in either the scope of the program or the levels of effluents. This report is prepared in compliance with the DOE Manual 5484.1, Environmental Protection, Safety, and Health Protection Information Reporting Requirements.

Appendix F is a tabulation of 1983 environmental monitoring data. When appropriate, the tabulated data contain maximum, minimum, and average values. Radioactivity values are tabulated with the associated counting uncertainties at the 2σ (95% confidence) level. Unless otherwise stated, the minimum detection limit of these measurements is assumed to have been reached when the 2σ error is $\pm 100\%$. In the case of radioactivity measurements, an attempt has been made to assess the potential impact on man of the observed environmental levels of artificially-produced radionuclides. This assessment is made by calculating the whole-body or critical-organ doses delivered to man and by comparing these with the much larger radiation dose received locally from natural sources.

Written procedures have been prepared for each environmental monitoring activity at Livermore as part of the quality assurance program developed for environmental monitoring at LLNL. The sample collection and analysis procedures described herein have been reviewed and approved by those

responsible for managing the monitoring program. During a program audit, such written documentation can be used to verify that sampling and analytical procedures meet program specifications.

Section 2.1, "Sampling," describes the sampling procedures used for each sample medium monitored. A general description of each medium is usually provided. This is followed by the collection procedure used, provisions for sample identification, and a schedule for sample replication.

Section 2.2, "Analysis," covers sample analysis. General comments on each sample medium analyzed are followed by specific descriptions of standards and calibrations, analytical procedures, and/or counting procedures as applicable for each medium.

2.1. SAMPLING

2.1.1. Air Sampling

Continuously operating air samplers are used at LLNL to measure the concentration of airborne particulate radioactivity, beryllium, and tritiated water. Samplers placed at 6 perimeter locations at LLNL and at 9 locations at Site 300 measure particulate radioactivity and beryllium. Particulate radioactivity is also measured at 10 off-site locations near the Laboratory. Tritiated-water samplers are operated at the 6 LLNL perimeter locations and at two off-site locations. In all cases, samplers are so placed as to provide reasonable assurance that any significant concentration of effluents from Laboratory operations would be detected regardless of local meteorology.

2.1.1.1. Collection

Particulates. LLNL-perimeter and Site 300 particulate samples are collected on $5.2 \times 10^{-2} \sim m^2$ Whatman filters, using average flow rates of 700 one/minute. Off-site samplers in the Livermore Valley use $4.6 \times 10^{-3} \sim m^2$ Flanders F-700 glassfiber filters operated at a flow rate of 80 one/minute. Particulate sample flow rates are calibrated with a spirometer that has been calibrated against an immersion unit certified by the National Bureau of Standards. Flow rates of Hi-vol air samplers are verified at monthly intervals with a portable field-calibration unit.

Tritiated Water. Samples of tritiated-water vapor are collected by drawing air through silica-gel-packed columns at flow rates of about 0.5 l/min. Columns are exchanged weekly.

2.1.1.2. Identification.

Particulates. Particulate samplers are run continuously, and sample filters are exchanged weekly. Each filter is identified by location, date on, date off, elapsed sampling time, and flow rate. Filter samples are placed in glassine envelopes and are transported to the laboratory, where this information is transferred to log sheets; each sample is then given a serial number that accompanies it during analysis. Half of each LLNL-perimeter and Site 300 filter is used for beryllium analysis; the other half is retained for radioactivity measurements.

Tritiated Water. Tritiated-water vapor samplers are run continuously, and silica-gel holders are exchanged biweekly. Each sample is identified by location, date on, date off, elapsed sampling time, and flow rate. This information is transferred to log sheets in the laboratory, and each sample is given a serial number that accompanies it during analysis.

2.1.1.3. Replication.

Particulates. At bimonthly intervals, a particulate-air sampler is operated in parallel with the permanent sampler at one of the six LLNL perimeter locations. This parallel operation is continued for one month, filters are changed weekly, and both filters are submitted for analysis in the usual manner. Bimonthly rotation of the extra sampler among the six locations ensures that samplers are checked annually. The replicate samples are then compared with respect to gross alpha and beta activities and to ²³⁹Pu content.

Tritiated Water. Parallel samples of tritiated-water vapor are collected at LLNL perimeter locations during alternate months from those locations in which particulate replicates are being collected.

2.1.2. Soil Sampling. Soil samples are collected annually in the Livermore Valley and at Site 300. Radiochemical analysis of these samples serves to document any changes that may have occurred during the year. Increases in radioactivity that may result from Laboratory operations are brought to the public's attention through annual monitoring reports.

2.1.2.1. Collection. Sampling sites are selected in reasonably level areas that show undisturbed soil. A 2-m, square sampling site is marked off in each such area, and an 8.25-cm-diam coring tool designed at LLNL is used to collect 5-cm-deep samples at the corners and center of the square.

2.1.2.2. Identification. The five samples of soil collected from each 2-m square are placed in plastic bags and are identified by number. This number is entered in a log book, together with the sampling data and a description of the sample location. The number is used to identify the sample throughout the laboratory analysis and in the annual monitoring report.

2.1.2.3. Replication. During each annual collection of soil samples, at least 10% of the sites are sampled in duplicate. In such collections, two adjacent 5-cm-deep cores are taken from the corners and center of each 2-m square. Separate composites of the five cores are then made, and the composites are identified by successive numbers.

2.1.3. Water Sampling.

At quarterly intervals, water samples from various sources in the Livermore Valley and at Site 300 are analyzed for gross alpha and beta radioactivity and for tritium content. These analyses determine if detectable changes in radioactivity have occurred. Figure 7, pg. 36 shows the Site 300 Groundwater Sampling Network.

2.1.3.1. Collection. Grab samples of such surface sources as ponds, creeks, and reservoirs are obtained with a tethered plastic pail. The samples are transferred to 4-liter plastic containers to which 6.5 ml of concentrated hydrochloric acid has been added. For tritium analyses, a 1-liter sample is collected in an argon-flushed glass container fitted with a ground-glass stopper.

2.1.3.2. Identification. As samples are collected in the field, they are tagged with sampling location and date. In the laboratory, each sample is assigned the number that accompanies it during analysis.

2.1.3.3. Replication. During each sample collection period, at least 10% of the water samples are duplicates.

2.1.4. Sewage Sampling

Sewage from the Laboratory is discharged into the City of Livermore's sanitary sewer system. Radioactive or otherwise hazardous liquid wastes are first treated to reduce concentration levels to within applicable standards before they are released into the sanitary sewer. Sewage samples are collected from LLNL effluent and from the treated effluent of the Livermore Water Reclamation Plant (LWRP).

2.1.4.1. Collection.

LNL Effluent. A 24-hr composite of LLNL sewage effluent is collected daily by a motorized proportional sampler. Aliquots of this composite are transported to the laboratory in 500-ml, wide-mouthed polyethylene bottles.

LWRP Effluent. Daily composites of treated effluent from the LWRP are also collected by a proportional sampler. Aliquots of these composites are placed in 500-ml polyethylene bottles and are retained for weekly collection by LLNL.

2.1.4.2. Identification. As each sewage sample is collected in the field, it is tagged with the sampling location and date of sampling. In the laboratory, each sample is assigned a number that accompanies it during analysis.

2.1.4.3. Replication.

LNL Effluent. Every Wednesday, one replicate sample of LLNL effluent is taken for gross alpha, beta, and tritium levels. For one month each year, duplicate samples of LLNL effluent are taken each day to permit preparation of duplicate monthly composites.

LWRP Effluent. One replicate sample of LWRP effluent is taken every Wednesday and is analyzed for gross alpha, beta, and tritium. For one month each year, duplicate samples are taken each day to permit preparation of duplicate monthly composites.

2.1.5. Vegetation Sampling

At quarterly intervals, samples of vegetation (usually native grasses) are collected throughout the Livermore Valley, at Site 300, and at the off-site locations near Site 300. After these samples are freeze-dried, the recovered water is analyzed by a liquid-scintillation counting method for tritium content.

2.1.5.1. Collection. Samples of vegetation are routinely collected from the same locations each sampling period. Grass samples are pulled up or cut close to the ground, and any soil is discarded. The bulk volume of these samples is usually between 0.5-1 liter. As each sample is collected, it is placed in a plastic bag and frozen in a dry-ice chest to minimize water loss on the bag surface. The duplicate samples collected at each location are later transferred to a freezer in the laboratory.

2.1.5.2. Identification. Samples of vegetation collected in the field are tagged according to sample type and location. In the laboratory, each sample is assigned a number that accompanies it until the measurement is reported. Measurement data are permanently retained on computer cards.

2.1.5.3. Replication. Two samples of vegetation are collected at each location in case the first sample is lost during analysis or the measurement obtained is questionable. At least one set of each group of samples collected is analyzed in duplicate to furnish replicate measurement data.

2.1.6. Milk Sampling

Milk samples are obtained at monthly intervals from two goat farms located about 5 km south and 5 km southeast of the Laboratory. A 3-liter

portion of each milk sample is vacuum-distilled, and the tritium content of the distilled water determined by liquid scintillation. Each 3-liter sample is then concentrated by evaporation and gamma-counted.

2.2. ANALYSIS

2.2.1. Air Analysis

Environmental air samples are analyzed for gross alpha and beta activity and for various gamma-emitting radionuclides, plutonium isotopes, uranium isotopes, and beryllium.

2.2.1.1. Gross Alpha and Beta Counting. After a four-day delay to allow for decay of the radon-thoron daughters, all environmental-radioactivity air filters are counted for alpha and beta activity. Counting is done in a Sharp gas-proportional counter using 60-min counting periods. Normally, this counter is used only for environmental samples since a duplicate counting system is provided for routine samples.

Standards and Calibration. Separate ^{239}Pu and ^{90}Sr standards on 5-cm-diam stainless steel convoluted planchets are used for determining alpha and beta counting efficiencies, respectively. These standards are traceable to NBS or to equivalent certified sources. Counting-efficiency measurements are made with each set of filters counted, and a background count is taken at the beginning of each run and between each set of 10 samples. Records are kept of background and counting-efficiency variations in the Sharp counter.

2.2.1.2. Beryllium. Every month, half of each weekly LLNL-perimeter and Site 300 paper air filter is composited by sampling location. Two paper filters at a time are wet-ashed with a mixture of 80% nitric and 20% perchloric acid. The solutions are then evaporated to a few ml, taking care not to allow samples to bake dry. After the samples are diluted with water, they are filtered, any residues are discarded, and the filtrates are diluted to 25 ml with deionized water.

Any fine particulate matter passing through the filter is removed by centrifugation. The analysis is performed in an atomic emission spectrometer with a plasma source. Blanks are known spikes and are subjected to the same procedure for quality control.

Standards and Calibration. Beryllium standards are prepared with 0.5 and 1 µg of beryllium per 25 ml of solution. The recorder readout of the Model 306 Perkin Elmer atomic absorption spectrophotometer is set at 30x absorbance expansion, and the spectrophotometer is zeroed while aspirating deionized water into the flame. Instrument responses from the 0.5- and 1-µg beryllium standards are then recorded. Following these calculations, the response of each monthly composite is recorded and its beryllium content is calculated from the calibration data.

2.2.2. Water Analysis

Environmental water samples are analyzed for gross alpha and beta activity and for tritium content.

2.2.2.1. Gross Alpha and Beta Activity. A sample of up to 100-ml sample or less, depending on the solid's content, is digested with a mixture of 80% nitric acid and 20% perchloric acid, and dried. Then residue is taken up with HNO_3 and a few milliliters of 5% hydrogen peroxide. The solution is evaporated to about 5 ml and transferred to a 5-cm-diam serrated stainless steel planchet. After drying and flaming the planchet, the sample is counted for 60 min in a Sharp 3-1/4-in proportional counter.

Standards and Calibration. The ^{239}Pu and ^{90}Sr standards are used with every sample set (see Sec. 2.2.1.1.). Instrument background measurements are made between every 10 sample-counting measurements.

2.2.3. Sewage Analysis

Except for tritium analyses, all sewage samples are wet-digested with a mixture of 20% perchloric acid and 80% nitric acid. Those sewage samples for tritium analysis are distilled to reduce self-absorption before counting.

2.2.3.1. Gross Alpha and Beta Radioactivity. About 25 ml of an 80/20 mixture of nitric acid and perchloric acid is added to a 500-ml aliquot (100 ml of LWRP effluent), and the mixture is dried on a hotplate. The residue is taken up in 10 ml of nitric acid and 5 ml of 5% hydrogen peroxide. The volume is reduced to 3-5 ml on a hotplate and transferred to 5-cm-diam planchets and counted.

2.2.3.2. Tritium. A 5-ml aliquot of sewage sample is added to 15 ml of Packard Insta-Gel in a 25-ml screw-cap polyethylene bottle. Then, 15 ml of Insta-Gel is used to prepare a background for the sample, and both are placed in the refrigerated detection chamber of the Packard scintillation counter for a 6-hr temperature-equilibration period prior to counting. The sample and background levels are each counted for 100 min.

2.2.3.3. Heavy Metals. Monthly composites of LLNL sewage effluent are analyzed for cadmium, chromium, copper, iron, lead, nickel, and silver.

A composite is prepared by combining daily samples of 500 ml, as follows: nitric acid (80%) and perchloric acid (20%) are added to the first 500-ml daily sample of the month, and the mixture is reduced in volume to about 100/ml. Each subsequent day the daily sample is added and the total volume reduced to about 100 ml. After the final 500 ml from the last day is added, the combined volume is reduced to about 50 ml. When cool, about 50 ml of deionized water is added, and the liquid is filtered through No. 40 Whatman paper. The paper is then placed in a platinum crucible and digested with about 5 ml hydrofluoric acid, 16 ml nitric acid and 4 ml perchloric acid to a residue of about 4-5 ml. Water is added, and the liquid is refiltered. The residue is discarded. The filtrates are combined, transferred to a 100-ml volumetric flask, and brought to volume with deionized water. The metals are determined with a Perkin-Elmer Model 306 atomic absorption spectrophotometer. The required standards are prepared by dilution of 1000-ppm NBS-traceable stock solution.

2.2.3.4. Radioactive Waste Documentation Systems. All pertinent radioactive waste data is collected on a Hazard/Control Material ID Tag or a Toxic Waste Control Tag. Nuclides, curie or gram quantities, surface dose rate, and the surface contaminated is specified (see Figs. 8 & 9). Copies are retained by the waste generator.

Data is logged in by TWC and is transferred to the final data package for shipment offsite. When waste is repackaged, compacted, etc., the data are consolidated and reviewed before the data package is prepared.

Data is also transferred from the data package (REECO shipment from) to the Solid Waste Information Management System (SWIMS) integrated data base in Idaho Falls, Idaho, where it is retained. See Refs. 10 and 11 for more information on the SWIMS database.

DISTRIBUTE ONE
SHIPPER - H.S. TECH. - DRIVER-RECEIVER (CARD)

COPY TO:

HAZARD / CONTROL MATERIAL ID TAG

TO: NAME _____ FROM: DATE _____
REC. SIG. _____ NAME _____
LIV. ☐ LIV. ☐ OFF-SITE ☐
300 ☐ 300 ☐
BERK ☐ BLDG. _____ RM. _____ BERK ☐ BLDG. _____ RM. _____

IDENTITY OF ITEM:

SERIAL # _____
AUTH. BY _____
OSP # _____

HAZARDOUS MATERIAL CONTAINED:

YES NO CONTAM ONLY
☐ ☐ ☐
Solid ☐ Dispersable ☐ Liquid ☐
Radionuclide _____ Curies _____
Emission: α _____ β _____ Neut. _____
External Reading (total) _____
Swipe Results _____
Date _____ H.C. Release by _____

YES NO CONTAM ONLY
☐ ☐ ☐
Solid ☐ Dispersable ☐ Liquid ☐
Material _____ Amt. _____
Date _____ H.C. Release by _____

YES NO CONTAM ONLY
☐ ☐ ☐
Material _____ LLL Type _____ Storage _____
Number of units in package _____ Total Net Weight _____
Date _____ Explosive Specialist Release _____

CONTROLLED MATERIAL CONTAINED:

YES NO T F # OR MAT'L. MGMT.
☐ ☐ SPEC. APPROVAL _____
☐ ☐ SS MAT'L.
☐ ☐ CLASSIFIED PART(S)
☐ ☐ SEALED SOURCE
☐ ☐ STABLE ISOTOPE(S) Amt. _____ \$ Value _____
☐ ☐ PRECIOUS METAL
Type _____ Wt. gms _____
☐ ☐ MOCK
☐ ☐ OTHER (Specify) _____

CLASSIFICATION:

(OF ITEM) BY SHAPE _____ BY MAT'L. _____

REMARKS:

(See also Reverse
of Card Copy)

DELIVERED BY
(M.M. DRIVER)

TAG NO.

221001

LL 3076 (REV. 6/80) ★ U. S. GPO: 1984-790-223

Figure 8. Hazard/Control Material ID Tag.

APPENDIX A

COMPLIANCE STATUS OF LLNL WITH DOE ORDER 5820.2.

Table I. Compliance

A. GENERAL	YES	NO	N.A.	N.D.	CURRENT
					POTENTIAL PROBLEM
1. Does this facility generate, transport, store, process or treat, or have on-site in permanent disposal any radioactive waste?		X			
2. Does this waste include high-level waste (HLW)?			X		
(High-Level Waste is defined as the highly radioactive waste material that results from reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid waste derived from the liquid; contains at least as much transuranium radionuclides as TRU waste; and contains fission products in concentrations which requires permanent isolation.)					
3. Does this waste include transuranic waste (TRU)?			X		
(TRU WASTE is defined as radioactive waste that, without regard to source or form, at the end of institutional control periods is contaminated with alpha-emitting transuranium radionuclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g.)					
4. Does this waste include low-level waste (LLW)?			X		
(Low-Level Waste is defined as any gaseous, liquid, or solid radioactive waste not classified as high-level waste, TRU waste, spent nuclear fuel, or mill tailings.)					
5. Does this waste include radioactive material that contains <u>only</u> naturally occurring radionuclides, including uranium or thorium isotopes or their decay products?				X	
6. Are radioactive waste management reports for the site submitted annually according to guidelines in DOE 5820.2, RADIOACTIVE WASTE MANAGEMENT, February 6, 1984?			X		X

SWIMS Report.

Table I. (Continued)

A. <u>GENERAL</u>	<u>YES</u> <u>NO</u> <u>N.A.</u> <u>N.D.</u>	<u>CURRENT</u> <u>POTENTIAL</u> <u>PROBLEM</u>
7. For radioactive wastes at this facility, provide process flowcharts indicating current and projected (3 years) sources, volume, radioactive content, and chemical and physical characteristics:		
None available.		
8. Are radioactive wastes generated at other facilities shipped to this facility for		
Storage?	X	
Treatment or Processing?	X	
Disposal?	X	
9. Have any leaks, spills, effluents from processing, or accidental releases of radioactive wastes been detected during the review period?	X	
10. Are additional radioactive handling, transfer, or storage facilities planned to be constructed within the next 3 years?	X	
10.1. Summarize: Plans are to consolidate the three facilities, and to build a size reduction facility for TRU waste.		
10.2. Will these facilities be doubly contained?	X	
10.3. Will these facilities be used to:		
10.3.1. Transfer existing waste from current system?	X	
10.3.2. Store additional waste?	X	
10.4. Have the plans been submitted to the DOE Line Organization?	X	

Table I. (Continued)

A. <u>GENERAL</u>	<u>YES</u>	<u>NO</u>	<u>N.A.</u>	<u>N.D.</u>	<u>CURRENT POTENTIAL PROBLEM</u>
11. Are radioactive wastes evaluated to determine hazards of chemical wastes?		X			X
Partial Evaluation					
11.1. Do any of the radioactive wastes at this facility contain hazardous chemical wastes? X					
11.1.1. Describe: Organics, coolants, flammable liquids, chlorinated compounds, acid, corrosives					
11.1.2. Do the radioactive wastes require greater confinement because of the chemical wastes?				X	X
12. Does the facility transport radioactive waste? Do the shipping practices conform to: X					
12.1. Dept. of Transportation Hazardous Material Regulations (49 CFR 100-179)? X					
12.2. Regulations for Packaging of Radioactive Materials for Transport (10 CFR 71)? X					
12.3. Other standards or guidelines? (Describe) X					
DOHS, State of California					
13. Does the facility have radioactive wastes on site which were previously disposed of using practices or procedures not meeting current criteria? X					
13.1. Is there a planned retrieval or upgrading of these wastes? X					X
14. Does the facility have a quality assurance plan for radioactive waste management? X X					X
14.1. Describe: Partial quality-assurance plan for TWC facilities.					

Table I. (Continued)

	YES	NO	N.A.	N.D.	CURRENT POTENTIAL PROBLEM
B. <u>HIGH-LEVEL WASTE (HLW)</u>					
14.2. Indicate Status:					
Planned?		X			
Ongoing?				X	
1. Is generated or received HLW treated or processed prior to storage?		X			
Currently ongoing?				X	
Planned?				X	
1.1. Do these processes include separation and recovery of waste by-product for storage or immediate use?				X	
1.2. Do these processes include reduction of volume and mobility to meet applicable disposal requirements?				X	
2. Are programs planned or ongoing for ultimate disposal of the HLW located at the facility?				X	
2.1. Is the anticipated disposal in geologic repositories consistent with the Nuclear Waste Policy Act of 1982.				X	
2.2. Is disposal in-place stabilization with engineered barriers at this facility?				X	
C. <u>TRANSURANIC (TRU) WASTE</u>					
1. Is any material known or suspected to be contaminated with transuranium radionuclides assayed as soon as practicable to avoid comingling with other wastes?		X			
2. Does the facility have a plan to have a certification program to demonstrate that TRU wastes meet disposal acceptance requirements by 9/30/84, (Ref: WIPP-DOE-609, TRU Waste Acceptance Criteria for the Waste Isolation Plant, Sept. 1981)?				X	

Table I. (Continued)

	<u>YES</u>	<u>NO</u>	<u>N.A.</u>	<u>N.D.</u>	<u>CURRENT POTENTIAL PROBLEM</u>
2.1. Has the program been documented and approved by the disposal site management?				X	
Draft plan being reviewed by WIPP.					
3. Does the facility have TRU waste which cannot be certified?		X			X
3.1. Have disposal or treatment plans been developed for these wastes?		X			
Describe: Oversized TRU waste. A plan for a size reduction facility is pending action.					
3.2. Have administrative controls been developed for reducing or completely eliminating generation of TRU wastes that cannot be certified?			X		X
4. Have technical and administrative controls been directed toward reducing the volume and radioactivity of TRU wastes?			X		X
4.3. Will new controls impact the facility fiscal plan?			X		
4.3.1. Have the plans been submitted to the DOE Line Organization (Ref: DOE 5480.1A, XII, Pollutant Abatement Projects)?			X		
5. Have any TRU wastes in the past been buried in shallow land burial sites or emplaced on soil columns?			X		
5.1. Are they periodically monitored in-situ?				X	
5.2. Has the DOE Program Office, in consultation with the DOE Director of Defense Waste and By-Products Management and DOE Asst. Sec. for Environmental Protection, Safety, and Emergency Preparedness, evaluated the need for remedial actions?				X	

Table I. (Continued)

	YES	NO	N.A.	N.D.	CURRENT POTENTIAL PROBLEM
6. Are TRU wastes for off-site disposal placed in approved containers that meet off-site disposal acceptance criteria?		X			
D. <u>LOW-LEVEL WASTE (LLW)</u>					
1. Does this facility conduct on-site disposal of LLW?		X			
1.1. Have site-specific waste-form acceptance criteria been developed and implemented?				X	
1.2. Does the site conform to established DOE Field Organization criteria for:					
1.2.1. Site selection?				X	
1.2.2. Site design?				X	
1.2.3. Site operation?				X	
2. Does this facility have an inactive LLW disposal site?		X			
2.1. Does the site have an established DOE Field Organization site-specific comprehensive closure plan?				X	
3. Does the facility currently have operations involving disposal of liquid LLW directly to the environment?				X	
3.1. Do plans exist to replace these operations with treatment systems such as immobilization before disposal or in-situ immobilization.				X	
E. <u>WASTES CONTAINING NATURALLY OCCURRING RADIONUCLIDES</u>					
1. Indicate the technique(s) used to manage wastes containing naturally occurring radionuclides, other than enriched uranium:					

Table I. (Continued)

	<u>YES</u>	<u>NO</u>	<u>N.A.</u>	<u>N.D.</u>	<u>CURRENT POTENTIAL PROBLEM</u>
1.1. Storage without treatment?		X			
1.2. Stabilization in place?		X			
1.3. Disposal at LLW disposal site?		X			
1.4. Disposal at nuclear fuel or processing sites designated under the Uranium Mill Tailings Radiation Control Act of 1978?		X			
1.5. Other (Explain):					
Incineration.		X			
Tritium evaporation.					
2. Does the facility manage wastes containing enriched uranium?		X			
2.1. Indicate which of the approaches listed under 1. are used:					
Storage without treatment;					
disposal at LLW site disposal					
<u>F. ENVIRONMENTAL RELEASES OF RADIONUCLIDES</u>					
1. Does this facility have any sources of radionuclides released to the environment that:					
1.1. Existed during the review period?		X			
1.2. Are anticipated to begin within the next three years?				X	
2. Did these releases include radionuclide effluents to:					
2.1. The atmosphere?		X			
2.2. Surface streams that cross site boundaries?			X		
2.3. Soil columns or grounded water without engineered barriers?				X	
3. Were any existing sources <u>not</u> monitored or existing or planned effluent data <u>not</u> reported on DOE Form 5821.1?		X			X

Table I. (Continued)

	YES	NO	N.A.	N.D.	CURRENT POTENTIAL PROBLEM
3.1. Identify unmonitored and/or unreported sources and explain reason for omission i.e., exempted under DOE 5484.1, 6.F(14):					
Evaporator release to tritium					
3.2. Do the monitored effluents comply with the concentration guides in DOE 5480.1A, Chapter XI, Attachment 1?					X
4. Have estimates been made of the exposure to radiation of individuals and population groups in uncontrolled areas as a result of existing, planned future, or potential accidental radionuclide releases from site operations?					X
4.1. Indicate the estimated exposure as a percentage of the standards in DOE 5480.1A, Chapter XI, Fig.XI-2 (or alternatively, list report or document where this information is recorded and available for inspection)					
Available for inspection in <u>Environmental Monitoring at LLNL</u> , Lawrence Livermore National Laboratory Livermore, Calif., UCRL-50027-83, (1984).					
4.2. Did the uncontrolled area exposure estimation procedure include data from:					
4.2.1 On-site effluent monitoring?					X
4.2.2. Aerial surveys?					X
4.2.3. Off-site ground-level atmospheric monitoring?					X
4.2.4. Off-site surface-water monitoring?					X
4.2.5. Off-site ground water monitoring?					X
4.2.6. Deposition measurements?					X
4.2.7. Pathway measurements (e.g., concentrations in vegetation or milk)?					X
4.2.8. Dispersion or pathway modeling?					X

Table I. (Continued)

	<u>YES</u>	<u>NO</u>	<u>N.A.</u>	<u>N.D.</u>	<u>CURRENT POTENTIAL PROBLEM</u>
4.2.9. Measurement or estimation of back-ground radiation and offsite sources? X					
4.2.10. Other?				X	
4.2. Have any rapid changes or long-term trends (increasing or decreasing) been observed in uncontrolled area exposure estimates? X					X
4.3.1. If yes, summarize known or suspected causes: Building 514 Tritium evaporator.					
5. Does the facility discharge radioactive effluents to a public sanitary sewage system? X					
5.1. Are these effluents monitored and documented in accordance with DOE 5484.1? [4.B.(2)] X					
5.2. Is there an effluent control system/device to reduce or minimize radioactive discharges to public sanitary sewage systems? If yes, describe: X High-risk areas are on retention systems. Building 514 has facility for liquid waste treatment before release to sewer.					
5.4. Do the average monthly concentrations of radioactivity in effluents discharged to public sanitary sewage systems comply with the concentration guides in attachment XI-1, Table 1, Column 2? [4.B.(5) (A)]. These concentration guides also apply to the City of Livermore Sewer Discharge Ordinance No. 1134. X					
6. Does the facility have quantitative or qualitative interpretations of the DOE goals to maintain radioactivity exposures to the public in uncontrolled areas "as low as reasonably achievable?" (Ref: 5480.1A, XI Requirements for Radiation Protection.) X					

Table I. (Continued)

	<u>YES</u>	<u>NO</u>	<u>N.A.</u>	<u>N.D.</u>	<u>CURRENT POTENTIAL PROBLEM</u>
7. Is there a planned upgrading of facility operations to reduce radionuclide emissions?		X			X
7.2. Is the upgrading required to prevent exposures in uncontrolled areas from exceeding the maximum level given in DOE 5480.1A?	X				X
7.3. Is the upgrading required to reduce the exposures currently below allowable maximums in uncontrolled areas to a level "as low as reasonably achievable" below the standards?	X				
7.4. Will the planned upgrading impact the facility fiscal plan?		X			
7.4.1. Have the plans been submitted to the DOE Line Organization (Ref: DOE 5480.1A, XII.5 Pollution Abatement Projects)?		X			
8. Does the facility have a documented plan for protecting individuals and population groups in uncontrolled areas during unplanned releases of radioactive materials to the atmosphere?		X			
9. Have there been any unplanned releases of radioactive materials to the environment during the review period?		X			
9.1. Were estimates made of the maximum public exposure resulting from this release?		X			
9.1.1. Where exposure limits in DOE 5480.1A exceeded?		X			
9.3. Did the release require notification to DOE Headquarters Emergency Operations Center based on requirements in DOE 5484.1, Chapter 1, "Notification of Occurrences"?		X			
Was the notification made within the prescribed time?		X			
Was a DOE investigation completed and reported?		X			

Table I. (Continued)

	YES	NO	N.A.	N.D.	CURRENT POTENTIAL PROBLEM
10. Does the facility have standard procedures for selecting, testing, and calibrating radioactivity monitoring equipment?		X			
10.1 Does the plan make use of the guidance documents listed under DOE 5480.1A, pp. XI-16, "Monitoring and Protective Equipment"?		X			
11. During the next three years, is there a planned starting up of any new source or an increase in an existing source of environmentally released radionuclides at the facility?				X	
11.1. Has the DOE Field Office or other contracting officer determined if a preoperational background or baseline environmental survey is required (Ref: DOE 5484.1, 6.F(11); III.1; IV.3.G)?					X
11.1.1. Is it required?					X
11.2. Will a preoperational survey be completed?				X	
12. Have internal audits of the radiation protection program been conducted?		X			
12.1. Are the guidelines in DOE 5482.1 used in conducting the audits?		X			
G. <u>ORDER NO. 80-184, WASTE DISCHARGE REQUIREMENTS, CLASS II-1 SOLID WASTE DISPOSAL SITE</u>					
1. Does LLNL perform the monitoring and reporting program No. 80-184?				X	
2. Do results of the monitoring program show compliance with radioactivity standards in surface and ground waters: Article 5, Chapter 15, Title 22, California Administrative Code?				X	

APPENDIX B

WASTE-PROCESS FLOWCHARTS AND RADIOLOGICAL
AND CHEMICAL CHARACTERISTICS OF WASTES.

From R. A. Heckman, J. R. McNabb, Candidate Mixed Hazardous Waste Streams,

Lawrence Livermore National Laboratory, Draft Report.

Integrated Waste Stream Number	Facility/operation
1	Machine Shops, Plating Shops, & Plastic Shops
2	General Plant, ion exchangers, & salvage operations
3	Miscellaneous Laboratory Facilities
4	Major Programmatic Facilities: e.g. MFE, LIS etc.

**L = Livermore location
S = Site 300 location**

Candidate mixed waste streams by category

	No. of streams	% of total	Annual generation*			Average % volume
			Liters liquid waste	Cubic meters solid waste	Kilograms other solid waste	
Mixed waste	10	71.5%	300528	436	203	98.4%
Byproduct RMW	4	28.5%	4639	61	0	1.6%
Total	14	100%	305367	497	203	100%

*Following measurements represent three separate waste streams

LLNL waste sources and disposal methods.

Machine shops,
plating shops,
& plastic shops

General plant,
ion exchangers
salvage operations

Misc laboratory
facilities

Major programmatic
facilities: eg
MFE, LIS, etc

LSA solid waste

Packaging & volume reduction
Liquid mixed
waste

Additives

Solidification

Incineration
Liquid low level radwaste
Sodium hydroxide
Filter

Precipitation

Solids
filtration

Ion
exchangers

NTS disposal site

Stack discharge

To sanitary
sewer

Off-site commercial
disposal site

Integrated shop waste streams

Integrated plant waste streams

Integrated miscellaneous laboratory streams

Facilities

Miscellaneous mixed fission product streams
Miscellaneous LLW radioactive streams
Miscellaneous liquid chemicals
Miscellaneous organic solvents
Be contaminated solvents
Scintillation vials
Animal carcasses

Legend

- RMW candidate
- By Product
- Non-radioactive hazardous
- Non-radioactive non-hazardous
- Radioactive
- Tru-waste to WIPP disposal

Streams

Integrated major programmatic facilities

Facilities

Input

Miscellaneous organic solvents
Optical coating chemicals
Vacuum pump oil
Raw water
Process chemicals
Miscellaneous laboratory liquid waste
Metal feed stock
Personal protective clothing

Laser Facilities

Laser Isotope Facilities

Effluent treatment

MFE Laboratories

Legend

- RMW candidate
- By Product
- Non-radioactive hazardous
- Non-radioactive non-hazardous
- Radioactive
- Tru-waste to WIPP disposal

Streams

LOW LEVEL WASTE ^d

CANDIDATE MIXED WASTE STREAMS ^e

GENERAL PLANT, ION EXCHANGERS, SALVAGE

STREAM ID NUMBER	NAME OR DESCRIPTION OF STREAM	RADIOACTIVE AND CHEMICAL COMPOSITION	CONTAINS BYPRODUCT MATERIAL	LATER MIXED WITH RCRA WASTE	ANNUAL ^a GENERATION RATE	TREATMENT, STORAGE OR DISPOSAL METHODS
01 72	Combination of Aqueous, acidic, and solvent waste streams from Decontamination Facility	o MFP AM ²⁴¹ D38 ^h Freon T.F. Nitric acid and Copper	YES	YES	36227 ^f	o Solidified sent to DOE disposal site.

note: footnote directory and general notes on last pages

LOW LEVEL WASTE ^d

CANDIDATE MIXED WASTE STREAMS ^e

MACHINE SHOPS, PLATING SHOP & PLASTIC SHOP

STREAM ID NUMBER	NAME OR DESCRIPTION OF STREAM	RADIOACTIVE AND CHEMICAL COMPOSITION	CONTAINS BYPRODUCT MATERIAL	LATER MIXED WITH RCRA WASTE	ANNUAL ^a GENERATION RATE	TREATMENT, STORAGE OR DISPOSAL METHODS
02	Cutting, cooling fluids, solvents, and spent plating solutions.	o Waste cutting oil, ^h waste water, Acetone, Isopropanol, MEK, TCE, Stoddard solvent, Chromic Acid Copper, D38, U238	NO	NO	64100 ^f	o Licensed Commercial vendors U238 and D38 To be sent to DOE Disposal Site.
	Spent Plating solutions. Ion Exchange Regenerated waste Organic Solvent	o Copper, Chromium, ^h Iron, Thallium, Nickel, Cobalt, acids, H ₂ SO ₄ and HNO ₃ , Fluoboric Acid, Cyanides, U235	NO	NO	86384 ^f	o Treated water to sanitary sewer. Rest is filtered neutralized and disposed of through licensed commercial vendors. Material with U235 is solidified and disposed of at DOE disposal area.

LOW LEVEL WASTE ^dCANDIDATE MIXED WASTE STREAMS ^eMISCELLANEOUS LAB FACILITIES

STREAM ID NUMBER	NAME OR DESCRIPTION OF STREAM	RADIOACTIVE AND CHEMICAL COMPOSITION	CONTAINS BYPRODUCT MATERIAL	LATER MIXED WITH RCRA WASTE	ANNUAL ^a GENERATION RATE	TREATMENT, STORAGE OR DISPOSAL METHODS
03	General laboratory waste chemicals, waste boiler water waste solvents and acids, Tritiated water and carcinogens	Tritium, Carcinogens boiler water, Scintillation counter solvents, Methylene, Chloride Ethanol, Hydrochloric acid	NO	NO	1632	o Tritiated material and carcinogens are incinerated. Others are disposed of through licensed commercial vendors.
	Tritium contaminated vials, waste rinse water, pump oil solvents.	o Pu239, Tritium ^h Contaminated vials and solvents, pump oil.	YES	YES	2092	o Tritiated material is incinerated. Pu239 contaminated material is disposed of at DOE disposal area.

MISCELLANEOUS LAB FACILITIES - CONTINUED

STREAM ID NUMBER	NAME OR DESCRIPTION OF STREAM	RADIOACTIVE AND CHEMICAL COMPOSITION	CONTAINS BYPRODUCT MATERIAL	LATER MIXED WITH RCRA WASTE	ANNUAL ^a GENERATION RATE	TREATMENT, STORAGE OR DISPOSAL METHODS
	Caustic and acidic waste streams. Misc organic solvents from shops and labs.	o Sodium Hydroxide, ^h Nitric, Hydrochloric Hydrofluoric acids M.F.P., U235, T.C.E P.C.E.	YES	YES	108109	o Solidified and sent to DOE disposal site.
77	Tritiated water spent solvents and plastics, spent acids	Tritium ^h plastic resins cutting fluids T.C.E. hydrochloric Acid, Nitric Acid, Sulfuric Acid	NO	NO	11130	o Tritiated material is incinerated. Other material is disposed of through licensed commercial vendors.
	Various Analytical Lab reagents, spent contaminated oil and organic solvents	Copper, Beryllium ^h Tritium, Scintillation solvents	NO	NO	828	o Tritiated material is incinerated. Rest is sent to DOE disposal site.

MISCELLANEOUS LAB FACILITIES - CONTINUED

STREAM ID NUMBER	NAME OR DESCRIPTION OF STREAM	RADIOACTIVE AND CHEMICAL COMPOSITION	CONTAINS BYPRODUCT MATERIAL	LATER MIXED WITH RCRA WASTE	ANNUAL ^a GENERATION RATE	TREATMENT, STORAGE OR DISPOSAL METHODS
76	Various waste streams from research and analytical labs. solvents and acids, tritiated water and carcinogens	o U238, D38, Copper, ^h Zinc, Nickel, Chromium, TCE. Flammable organic solvents, Carbon Tetrachloride	NO	NO	13064	o Radioactive material sent to DOE disposal site. Some flammable solvents incinerated. Rest is disposed of by licensed commercial vendors.
	Animal carcasses from biomedical experiments.	Tritiated carcinogens	NO	NO	33 ⁹	Incinerated.

LOW LEVEL WASTE ^d

CANDIDATE MIXED WASTE STREAMS ^e

MAJOR PROGRAMMATIC FACILITIES

STREAM ID NUMBER	NAME OR DESCRIPTION OF STREAM	RADIOACTIVE AND CHEMICAL COMPOSITION	CONTAINS BYPRODUCT MATERIAL	LATER MIXED WITH RCRA WASTE	ANNUAL ^a GENERATION RATE	TREATMENT, STORAGE OR DISPOSAL METHODS
04	Contaminated organic, acidic and Aqueous waste streams from Laser Facility	U238, Hydrofluoric, ^h Nitric Acids Copper, Titanium, Zirconium spent oil, TCE Ethanol, Acetone MEK	NO	NO	15370	o Contaminated material to DOE disposal site. Other to be licensed commercial vendors.
	Contaminated spent acid waste stream from LIS Labs	o 038 Freon, TCE ^h Nitric and Hydrofluoric acids.	NO	NO	54316	o Contaminated material sent to DOE disposal site. Other to be licensed commercial vendors.
	Main solid waste stream from LIS operation.	o 038, U238 ^h	NO	NO	57 M ³ ^g	o Sent to DOE disposal site.

MAJOR PROGRAMMATIC FACILITIES - CONTINUED

STREAM ID NUMBER	NAME OR DESCRIPTION OF STREAM	RADIOACTIVE AND CHEMICAL COMPOSITION MATERIAL	CONTAINS BYPRODUCT WITH RCRA	LATER MIXED RATE WASTE	ANNUAL ^c GENERATION	TREATMENT, STORAGE OR DISPOSAL METHODS
	Aggregated LSA dry rad waste for whole lab.	o General low level ^h Plutonium waste from laboratories and test facilities	YES	YES	61 M ³ ^f g	o Sent to DOE disposal site.
	Aggregated dry waste from shot table operations and cleanup	o D-38 and Be, ^f probably present as oxides, mixed with shot table debris and gravel.	NO	NO	170.3 Kg D-38 ^g 0.405 Kg Be	o Disposed of on site.

MIXED HAZARDOUS WASTE STREAMS GENERATED AT LLNL

GENERAL NOTES AND INFORMATION

- o Low-Level Waste (LLW): Radioactive waste not classified as high-level waste, TRU waste, nuclear fuel, or byproduct material as defined by DOE Order 5820.2.
- o TRU Waste: Without regard to source or form, radioactive waste that, at the end of institutional control periods, is contaminated with alphaemitting transuranium radiouclides with half-lives greater than 20 years and concentrations greater than 100 nCi/g. Regarding the Waste Isolation Pilot Plant, high-level waste and spent nuclear fuel as defined by DOE Order 5820.2, are specifically excluded by this definition.
- o DOE Disposal Site.
- o Commercial vendors operated licensed disposal sites at several locations in California.
- o Non-radioactive, non-hazardous solid wastes that are unregulated are disposed of in a local sanitary land fill.

MIXED HAZARDOUS WASTE STREAMS GENERATED AT LLNL

FOOTNOTE DIRECTORY

- a. Generation in liters per year, except as noted.
- b. Generation in kilograms per year.
- c. Generation in cubic meters per year.
- d. The categories of TRU and LLW are defined in DOE Order 5820.2. Low-Level Waste (LLW) streams which comeingle with TRU are included among the candidate mixed waste streams.
- e. The information contained within this report is a preliminary determination of mixed waste stream activity. Final determination will require confirmatory analysis and definition acquired through Department of Energy negotiation with the Environmental Protection Agency. Approximately 71.5% of radioactive liquid and solid waste streams are considered candidate mixed waste streams.
- f. Both liquid and solid-waste streams will be subject to in-depth chemical composition evaluations.
- g. Hazardous components of the solid-waste streams may include hazardous chemical contamination of the waste items and/or hazardous components of the waste items themselves (i.e., chrome-plated tools, organics in plastic materials, etc.).
- h. RCRA substances listed here are those potentially present. Further analysis efforts defined by the Technical Services Program will provide quantitative information regarding the character of this stream.

APPENDIX C

LLNL TOXIC WASTE CONTROL QUALITY ASSURANCE PLAN

1. INTRODUCTION

The Toxic Waste Control Group (TWC) is an LLNL operational group, whose primary responsibility is the management of Laboratory-generated hazardous waste materials. This responsibility includes the treatment, packaging and shipment of hazardous waste materials. Since this responsibility includes packaging waste materials for disposal by other, non-LLNL organizations, the requirements that TWC must meet also come from these other organizations. This Quality Assurance Plan has been prepared to meet both the requirements of the LLNL QA program and the requirements of the external organizations.

The activities of the TWC are described in three documents. The TWC Management Plan describes the management system used in TWC and discusses the risks that the management system is designed to reduce. The TWC Facility Safety Procedures and Operational Safety Procedures combine to define the safety concerns and prescribe the safety procedures to be used in TWC. Third, the Quality Assurance Plan prescribes the formal controls necessary to meet Federal and State regulations.

2. OBJECTIVES

This Quality Assurance Plan has been structured to meet the requirements set forth in 10CFR71, Appendix E, as they apply to the activities of the TWC group. The control described will be applied as necessary to assure the attainment of the following TWC objectives:

- o To assure the safety of the public and employees.
- o To assure the protection of the environment.
- o To assure the provision of a service that supports the LLNL program.
- o To assure that all TWC operations at LLNL are in conformance with applicable State and Federal regulations.

3. SCOPE

This Plan applies to all areas and activities associated with the handling, packaging, and disposal of hazardous wastes under the Toxic Waste Control Group Leader. These areas and activities include activities within the TWC facilities and at field support operations.

4. RESPONSIBILITIES

The following individuals have specific assignments in the planning, implementation and verification of the TWC QA Plan. Figure C-1, shows an organization chart followed by the names of those individuals filling each position. Other LLNL organizations having primary responsibilities within the TWC facility but who do not report to the TWC Group Leader are also identified so that the interfaces between two groups can be monitored.

4.1. TOXIC WASTE CONTROL GROUP LEADER

The Toxic Waste Control Group Leader is responsible for the safe and proper operation of the Toxic Waste Control Group, including personnel, equipment and materials therein. The TWC Group Leader is responsible for appointing the Facility Manager and for approving all other personnel assignments within the TWC. The TWC Group Leader will approve this QA Plan and any revisions for use. The TWC Group Leader will verify through a planned program of audits and appraisals the effectiveness of the quality-management system described in this plan in meeting TWC objectives.

4.2. TWC QUALITY ASSURNACE COORDINATOR

The TWC Quality Assurance Coordinator (QAC) reports to the TWC Group Leader. The QAC prepares the TWC QA plan and maintains a continuing surveillance program to assure that this plan is current is and is being used by TWC personnel.

TOXIC WASTE CONTROL
MANAGEMENT ORGANIZATION

Figure C-1. Organization chart of Toxic Waste Control Management organization.

4.3. TOXIC WASTE CONTROL FACILITY MANAGER

The TWC Facility Manager has the responsibility for the TWC operational activities. The Facility Manager approves procedures, personnel assignments, and provides equipment for TWC operations. The Facility Manager establishes the qualification requirements for TWC personnel.

4.4. TOXIC WASTE CONTROL TRAINING COORDINATOR

The TWC Training Coordinator is responsible for preparing and implementing a training program for TWC personnel such that personnel meet the qualification requirements established by the Facility Manager. The Training Coordinator will certify to the Facility Manager those individuals who have completed the training requirements. The Training Coordinator is responsible for maintaining training records and for notifying and retraining individuals whose certification would otherwise expire.

4.5. TWC LEAD PERSONNEL

The TWC Lead Personnel work under the direction of the Facility Manager and provide on-the-job supervision to ensure that operations comply with approved procedures.

4.6. TWC FACILITY COORDINATOR

The Facility Coordinator is responsible for planning, scheduling, monitoring and verifying work performed in the TWC facility by personnel from other organizations. These personnel may be outside contractors or Plant Engineering, Hazards Control or other LLNL organization employees.

4.7. TWC TECHNICIANS

The TWC Technicians work under the direction of the TWC Lead Personnel and are responsible for performing all work in accordance with procedures documented in the Facility Handbooks, FSP's and OSP's.

4.8. OTHER LLNL ORGANIZATIONS WITH RESPONSIBILITIES TO THE TWC PERSONNEL AND FACILITIES

4.8.1. Hazards Control

The Hazards Control Safety Team will advise the TWC Group Leader on safety practices and training, and has the principal responsibility for the bioassay and lung-scan program for TWC personnel and the environmental monitoring programs for TWC facilities.

4.8.2. Plant Engineering Department

The Plant Engineering Department has the principal responsibility for the maintenance and repair of TWC facilities. The Facility Coordinator will monitor these activities to ensure that the Facility Manager is aware of the condition of TWC facilities.

5. REFERENCES

1. Department of Energy Orders DOE 5480.1A, DOE 5480.2, DOE 5700.6A & DOE 5820.2.
2. Code of Federal Regulations, Title 40.
3. Code of Federal Regulations, Title 49.
4. Code of Federal Regulations, Title 10CFR71 App E.
5. Waste Isolation Pilot Program, Department of Energy 114 (WIPP DOE 114).
6. Waste Isolation Pilot Program, Department of Energy 120 (WIPP DOE 120).

6. ADMINISTRATIVE CONTROLS

This section describes the general administrative controls applied to the TWC. The specific procedure that implements each control in the TWC is identified in Table C-1.

6.1. ORGANIZATION

The organization structure for the TWC is described in the TWC Management Plan and in Section 4. of this Appendix.

Individuals described in Section 4. have principal responsibility for performing and documenting their assigned responsibilities. Individuals performing surveillance, appraisals, and audits of TWC activities or certification of shipments shall be different from those performing the work. These personnel shall have decision-making authority and shall have access to management, where action can be taken.

6.2. DESIGN CONTROLS

Design activities associated with TWC physical plant shall be defined, verified and controlled. Design inputs, interfaces and charges shall be identified, controlled and documented. Design adequacy shall be verified by persons other than those who designed the items.

Responsible Individual: Facility Manager

Design activities for procurement of TWC critical equipment or containers will be controlled by procedure.

Responsible Individual: Facility Coordinator

6.3. PROCUREMENT DOCUMENT CONTROL

Design data and other requirements shall be included or referenced in documents for procurement of items and services. Procurement documents shall require suppliers to have a Quality Assurance program consistent with the requirements of each procurement. These requirements will apply to procured items, such as waste containers, liners and materials used in waste processing or packaging.

Responsible Individual: Facility Coordinator

6.4. INSTRUCTIONS, PROCEDURES AND DRAWINGS

Activities affecting quality shall be prescribed by, and be performed in accordance with, documented instructions, procedures or drawings. These documents shall include or reference appropriate quantitative or qualitative acceptance criteria for determining that prescribed activities have been satisfactorily accomplished.

Responsible Individual: Facility Manager

6.5. DOCUMENT CONTROL

The preparation, issue and charge of documents that specify quality requirements or prescribe activities affecting quality shall be controlled to assure that correct documents are being employed. Such documents, including changes thereto, shall be reviewed for adequacy and shall be approved for release by authorized personnel.

Responsible Individual: Facility Manager

6.6. CONTROL OF PURCHASED MATERIALS, EQUIPMENT AND SERVICES

The procurement of materials, equipment and services shall be controlled to assure conformance with specified requirements. Such control shall provide for the following, as appropriate: source evaluation and selection, evaluation of objective evidence of quality furnished by the supplier, source inspection, audit, and examination of items or services upon delivery or completion.

Responsible Individual: Facility Coordinator

6.7. IDENTIFICATION AND CONTROL OF MATERIALS, PARTS AND COMPONENTS (ITEMS)

Items requiring identification and control shall be specified. Identification shall be maintained either on the item or in documents traceable to the items. Such items include, but are not limited to, waste containers, packages, and batches of wastes.

Responsible Individual: Facility Manager

6.8. CONTROL OF PROCESSES

Processes that may affect waste characteristics or container quality shall be controlled. Processes requiring specially qualified personnel shall be identified. The method and degree of personnel qualification shall also be specified. Methods to assure the adequate performance of controlled processes shall be identified.

Responsible Individual: Facility Manager

6.9. INSPECTION

Inspection required to verify conformance of an item or activity to specified requirements shall be planned and executed. Characteristics to be inspected and inspection methods to be employed shall be specified, and inspection results shall be documented. Inspection for acceptance shall be performed by persons other than those who performed or directly supervised the work being inspected. These inspections may consist of continual monitoring of a process or activity, or of the random sampling of the output of a process or activity, either prior to or after packaging of the waste. The sampling methods and frequency shall be documented.

Responsible Individual: Group Leader

6.10. TEST CONTROLS

Tests for verifying conformance of an item or process, or for the determination of the properties of an item, shall be identified, planned and executed. Characteristics to be tested, test methods, and acceptable property ranges shall be specified. Tests shall be performed by qualified personnel. Results shall be documented and their conformance with acceptable criteria shall be evaluated. When representative samples are tested, the sampling methods shall also be documented.

Responsible Individual: Facility Manager

6.11. CONTROL OF MEASURING AND TEST EQUIPMENT

Tools, gauges, instruments and other measuring and test equipment used for activities affecting quality shall be controlled and at specified limits. Sources for calibration and standardization shall be specified by a procedure. These sources may consist of standards traceable to NBS, of recognized industrial standards, or of other applicable standards.

Responsible Individual: Facility Manager

6.12. HANDLING, STORAGE AND SHIPPLIN

Handling, storage, cleaning, packaging, shipping and preservation of items shall be controlled to prevent damage or loss and to minimize deterioration. These controls shall apply, but not be limited, to procedures used in the handling and storage of waste containers and packages, and procedures controlling the segregation of waste streams.

Responsible Individual: Facility Manager

6.13. INSPECTION, TEST, CERTIFICATION AND OPERATING STATUS

The status of inspection and test activities shall be identified either on the items or in documents traceable to the items. This Program Element will assure that required inspections and tests are performed and assure that items which have not passed the required inspections and tests are not inadvertently used or shipped. Status shall be maintained through indicators placed in a specified location and tagged, marked, stamped, or by other suitable means. The authority for application and removal of tags, markings, labels, and stamps shall be specified.

Responsible Individual: Facility Manager

7. NONCONFORMANCE AND CORRECTIVE ACTION

7.1. NONCONFORMING MATERIALS, PARTS OR COMPONENTS

Items that do not conform to specified requirements shall be controlled to prevent installation or use. These items will be documented, segregated and evaluated. Provisions shall be made for the prompt disposition of nonconforming items and for verification that disposition was implemented.

Responsible Individual: Facility Manager

7.2. CORRECTIVE ACTION

Conditions adverse to quality shall be promptly identified and corrected as soon as practicable. In the case of a significantly quality adverse condition, the cause of the condition shall be determined and corrective action taken to preclude recurrence. The identification, cause and corrective action shall be documented and reported to appropriate levels of management. Follow-up action shall be taken to verify implementation of corrective action.

Responsible Individual: Facility Manager

8. DOCUMENT CONTROL

Records to furnish documentary evidence of quality shall be specified, prepared and maintained. Records shall be legible, identifiable and retrievable. Records shall be protected against damage, deterioration, or loss. Requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be established and documented.

Responsible Individual: Facility Manager

9. VERIFICATION

Planned and scheduled audits shall be performed to verify compliance with all aspects of the quality assurance program and to determine the program's effectiveness. These audits shall be performed in accordance with written procedures or checklists by personnel who do not have direct responsibility for performing the activities being audited. The lead auditor shall be trained and qualified. Audit results shall be documented, reported to, and reviewed by responsible management. Follow-up action shall be taken where indicated.

Surveillance of activities will be done to provide ongoing confidence that operations are being done according to procedures. Surveillance activities need not be formally planned, but the results should be documented. Results of surveillances may be used to determine the scope of audits.

Responsible Individual: Group Leader

Table C-1. Cross-references of the requirements for a Quality Assurance program identified in the Code of Federal Regulations (10 CFR 71, Appendix E) and Waste Isolation Pilot Program, Department of Energy 120 (WIPP DOE 120, UC-70) with the Toxic Waste Control Group Management Plan and other internal procedures.

<u>Requirement</u> <u>10CFR71 Appendix E</u>	WIPP-DOE-120, Management <u>UC-70</u>	TWCG		<u>Procedures</u>
		<u>Plan</u>	<u>QAP</u>	
1. Organization	4.1	3.	6.1	
2. Quality Assurance Program	3.	5.		
3. Design Control (Plant) Design Control (Procurement)	4.2.1.	4.2.	6.2.	Facility Coordinator's Handbook
4. Procurement Document Control	4.4.1.		6.3.	Facility Coordinator's Handbook
5. Instructions, Procedures	4.4.2.	4.1. b,c	6.4.	Facility Handbooks
6. Document Control	4.4.3.		6.5.	Facility Handbooks
7. Control of Purchased Materials, Equipment & Services	4.2.2.		6.6.	Facility Coordinator's Handbooks
8. Identification & Control of Materials, Parts & Components	4.2.3.	4.3. a,b	6.7.	Facility Handbooks
9. Control of Process	4.2.4.	4.1., 4.4.	6.8.	Facility Handbooks

Table C-1. (Continued)

<u>Requirement</u> <u>10CFR71 Appendix E</u>	TWCG			
	WIPP-DOE-120, Management	TWCG		
	<u>UC-70</u>	<u>Plan</u>	<u>QAP</u>	<u>Procedures</u>
10. Inspection	4.3.1.	3.1.d, 4.2.d	6.9.	
11. Test Control	4.3.2.		6.10	Facility Handbooks
12. Control of Measuring & Test Equipment	4.3.3.		6.11.	Facility Handbooks
13. Handling, Storage & Shipping	4.2.5.		6.12.	Facility Handbooks
14. Inspection, Test & Operating Status	4.3.4.		6.13.	Facility Handbooks
15. Nonconforming Materials, Parts or Components	4.5.1.		7.1.	Facility Handbooks
16. Corrective Action	4.5.2.	5.1.	7.2.	
17. Quality Assurance Records	4.4.4.	5.2.	8.	
18. Audits	4.6.	5.3.	9.	

APPENDIX D

QUALITY-ASSURANCE PLAN FOR THE
LLNL ENVIRONMENTAL MONITORING PROGRAM

1. INTRODUCTION

The Lawrence Livermore National Laboratory (LLNL) maintains an environmental-monitoring program to meet the requirements of DOE Order 5484.1, to assess the effectiveness of the Laboratory's effluent containment procedures, and to determine if Laboratory operations have a measurable impact on the local environment. Each spring, an environmental monitoring report is submitted to the Department of Energy covering the operations for the previous calendar year. This report lists the levels of selected radioactive and nonradioactive materials observed in the vicinity of LLNL. The environmental-monitoring reports are distributed to Federal, State, and local government agencies and are available to the public.

2. PURPOSE

The purpose of this quality assurance (QA) plan is to indicate prime responsibilities and to prescribe requirements for assuring that

- o Environmental monitoring data are accurate and reproducible.
- o Sampling locations and collection schedules are identified in permanently retained log books.
- o All analytical data pertaining to environmental samples are readily traceable to permanently retained Laboratory records.

3. SCOPE

This QA plan applies to all environmental-monitoring activities performed for the environmental-monitoring program. Prime responsibilities delineated in this plan pertain to all quality-related controls; however, QA and QA elements address only those areas in which the consequences of error or failure would be unacceptable. Functions judged to be in this category are sample collection, sample analysis, data processing and record keeping.

4. REFERENCE DOCUMENTS

The following documents form the primary reference basis of the QA plan for the Environmental Monitoring Program. However, since procedures are updated periodically between publication, the most current procedures are maintained by the individuals listed in Table D-1, for each of their respective areas of responsibility.

- (1) K. S. Griggs, M. A. Gonzalez, and R. W. Buddemeier, "Sampling and Analytical Procedures for Environmental Monitoring at Lawrence Livermore Laboratory" published as Appendix E of the 1983 LLNL Environmental Monitoring Report, Lawrence Livermore National Laboratory, Livermore, Calif. UCRL-50027-82, (1983).
- (2) C. L. Lindeken, J. H. White, and W. J. Silver, Quality Assurance in Environmental Monitoring at the Lawrence Livermore Laboratory, Lawrence Livermore Laboratory, Livermore, Calif. UCRL 809622, (1978).
- (3) The LLL Quality Assurance Program, Lawrence Livermore Laboratory Report M-078, Vol. 1, March 1978.

5. RESPONSIBILITIES

At LLNL, environmental monitoring is conducted through the combined efforts of the Nuclear Chemistry Division and the Hazards Control Department. The overall program, including QA, is directed by the Environmental Measurements Group in the Radiation and Environmental Safety Division of the Hazards Control Department.

The Group Leader of the Environmental Measurements Group is responsible for implementing this QA Plan.

Responsibility for implementing certain tasks within the QA Plan has been assigned to others within the Environmental Measurements Group, or within Nuclear Chemistry or Hazards Control. For a current listing of these personnel and their responsibilities, see Table D-1. Failure to implement any of the tasks may constitute noncompliance with the QA Plan.

6. QUALITY CONTROL ELEMENTS

Quality Control (QC) elements are those actions taken to ensure that a given activity is functioning properly. In accordance with the scope of the QA Plan, as described in Sec. 3. the elements listed below are applied to sample collection, sample analysis, data processing, and record keeping.

6.1. ENVIRONMENTAL MONITORING OPERATING CONTROL

Figure 1 illustrates the flow of samples and data in the LLNL program. Procedures for sample collection and analysis are outlined in Reference 2, Appendix E.

6.1.1. Sample Collection and Analysis.

Procedures for collection and analysis of samples are outlined in Griggs, Gonzalez, and Buddemeier. The Environmental Measurements Representative assigned the responsibility for sample collection shall maintain bound log books to record evidence of regular collection of all samples. These records shall be reviewed quarterly by the Group Leader of Environmental Measurements to assure that all information is being maintained in accordance with the purpose stated in Section 2. If such review shows that records are not being so maintained, a noncompliance report shall be prepared, as outlined in Sec./7.1.

6.1.2. Data Processing.

Each laboratory supporting the LLNL environmental monitoring program processes its own analytical data. This processing varies from simple hand calculations to computer-controlled programs for automatic data processing. The supervisor of each laboratory shall check an adequate fraction of these data to assure that such data compare reasonably with past measurements. These supervisors shall also verify that all data are being retained in accordance with Section 2. Accuracy of environmental measurements will be based on performance of intercomparison sample analysis, whereas a measure of precision is obtained from replicate sample analysis.

6.2. CALIBRATION CONTROL

Griggs, Gonzalez, and Buddemeier describe the use of standards for checking the performance of equipment employed in environmental monitoring and outline the procedures utilized in the calibration of such equipment. The supervisor of each of the laboratories supporting the environmental monitoring program shall verify that calibrations of all equipment employed in analyzing environmental monitoring samples are made at appropriate intervals. The appropriate supervisor shall maintain records of these calibrations.

7. QUALITY ASSURANCE ELEMENTS

Quality Assurance elements support the previously listed QC elements by providing documentation to verify that quality assurance for the environmental monitoring program is in compliance with the requirements of the LLNL QA program. Such documentation must cover three areas: (1) elements found to be in nonconformance with the requirements of the environmental monitoring program together with the corrective action taken; (2) records of all results of QA intercomparison analyses and replicate sample analyses; and (3) verification that the requirements of the LLNL QA program, QA plan and implementing procedures are being applied and are effective.

7.1. NONCONFORMANCE AND CORRECTIVE ACTION

The purpose of introducing quality assurance measures into the LLNL environmental monitoring program is to provide credibility in the accuracy and traceability of the data being reported. This purpose is served by QA tests, such as intercomparison analyses, which measure the agreement of LLNL measurements with accepted values. The supervisor of each participating laboratory is responsible for determining the acceptable levels of accuracy and precision, unless the levels are explicitly specified in a document or procedure. In case of disagreement, the reason for disagreement is determined and corrective action is promptly taken. The LLNL Quality Assurance Manual requires documentation of any such nonconformance and the corrective action taken. The Nonconformance and Corrective Action Report form prepared by the

LLNL Quality Assurance Office will be used. These records shall be maintained by the supervisor of each participating laboratory. All nonconformance and corrective-action records pertaining to environmental monitoring are to be reviewed and approved by the Group Leader of the Environmental Measurements Group. Nonconformance reports will be restricted to those where the sample type, nuclide or chemical, and the analysis procedure are directly relevant to the Environmental Monitoring Program so as not to inhibit the use of intercomparison samples in development efforts.

7.2. QUALITY ASSURANCE RECORDS AND DOCUMENTS

7.2.1. Record Keeping.

The program, emphasizes maintenance records covering each activity. Sample flow through the system was shown in Fig. D-1. The Environmental Measurements Group, within Hazards Control, is responsible for all sample collection. At the collection time, the sample is described and identified, and these data are entered in a field log book. When delivered to the appropriate laboratory for analysis, this sample information is again recorded and the sample is assigned a laboratory number for identification until the analytical data are reported.

Records pertaining to instrument backgrounds, analytical blanks, calibrations, standardizations, and data reduction are maintained by the participating laboratories at LLNL. Data that are furnished for subsequent reporting are retained by the originating laboratory, either in laboratory notebooks, work sheets, magnetic tapes, or similar computer storage records. Nuclear Chemistry stores all gamma spectra from environmental samples in retrievable computer files. It is our intention to permanently retain laboratory data pertaining to all environmental monitoring measurements.

7.2.2. The Annual Environmental Monitoring Report as a QA Document.

The annual environmental monitoring report is the principal means by which credibility in the environmental monitoring program can be evaluated by the public. To assure that this credibility is not compromised by technical or composition errors, these reports shall be reviewed by all authors, by the

Group Leader of Environmental Measurements and by the Leader of the Radiation and Environmental Safety Division.

The following documents are identified as QA records:

<u>Document</u>	<u>Location</u>	<u>Custodian</u>
QA Plan	2675-105	(See Table D-1)
UCID-17853, "Sampling and Analytical Procedures for Environmental Monitoring and the Lawrence Livermore National Laboratory"	2657-105	
Sample Collection Log Books	2675-104	
Replicate Sample Analytical Data	2675-107	
Quarterly Reports of the DOE Quality Assessment Program	2675-107	
EPA Cross Check Data Reports	2675-107	
EML Quality Assessment Program	2675-107	
Hazards Control Environmental Radioactivity Counting Data	253-1711, 1712, 1728	
Hazards Control Environmental Industrial Hygiene Data	253-1732	
Nuclear Chemistry Data for LLNL Environmental Monitoring Program	151-1309, 2345, 2349	

7.3. QUALITY ASSURANCE AUDITS

Annual audits shall be performed by the LLNL Quality Assurance Office to determine the effectiveness of the QA program and to verify that the quality assurance measures comply with this QA Plan and its elementary procedures.

The Group Leader of the Environmental Measurements Group will request these audits. The Audit Team shall consist of:

- o One QA Office staff member.
- o One member of Hazards Control with knowledge of, but not directly involved with, the Environmental Monitoring Program.

The audit shall follow a preplanned written format, and the Audit Team shall issue a report to the Leader of the Environmental Measurements Group, with copies to the Department Head of Hazards Control, and the Leader of the Radiation and Environmental Safety Division.

Figure D-1. Sample and Data Flow in the LLNL Environmental Monitoring Program.

Table D-1. List of personnel within the Hazards Control Department and the Nuclear Chemistry Division to whom D. S. Myers has assigned responsibility for implementing specific portions of the QA plan. This table is current as of March 1984 and will be updated as required.

<u>Hazards Control Department</u>	<u>Responsibility for</u>
K. S. Griggs	Coordination of quality assurance activities in environmental monitoring within Hazards Control and Nuclear Chemistry; preparation of any revisions to this QA plan; maintaining records of LLNL performance in intercomparison analyses; maintaining replicate sample analysis records; maintaining sample collection log books.
G. L. Seibel	Coordination of quality assurance efforts in environmental monitoring within Hazards Control's Radiation Counting Laboratory; maintaining records of environmental radioactivity data generated in the Radiation Counting Laboratory.
M. W. Nathans	Coordination of quality assurance efforts in environmental monitoring within Hazards Control's Industrial Hygiene Laboratory; maintaining records of environmental monitoring data generated by the Industrial Hygiene Laboratory.

Table D-1. (Continued).

<u>Hazards Control Department</u>	<u>Responsibility for</u>
R. W. Buddemeier	Coordination of quality assurance efforts in environmental monitoring within Nuclear Chemistry; maintaining records of environmental monitoring data generated by Nuclear Chemistry

APPENDIX E

**BROWN AND CALDWELL QUALITY-ASSURANCE
AND CHAIN-OF-CUSTODY PROCEDURES**

1. INTRODUCTION

This Appendix describes procedures employed by Brown and Caldwell, an outside consulting firm employed by LLNL, for sample collection and analysis.

2. QUALITY ASSURANCE

2.1. SAMPLE COLLECTION

Advance planning is essential to the collection of samples. Sampling equipment, appropriate containers and preservatives, and holding times are advance considerations necessary to minimize possibilities for contamination or unnecessary delays. Precision and accuracy are meaningless without the proper collection of a representative sample. Sample bottles are clearly marked, and all pertinent observations recorded, along with sample description, time, date of collection, and initials of the collector.

2.2. SAMPLE CONTROL

A sample control officer is responsible for verification of sample integrity. The sample is to be inspected to assure that its collection preserves sample integrity. Considerations are:

- o Sample identification--the sample must be clearly marked and dated.
- o Sample collection and storage--the sample must be collected in the most appropriate container for the individual analysis, whether it be glass, plastic, or a special vial to avoid headspace.*
- o Sample preservation.
- o Sample quantity--there must be an adequate volume for all analyses involved.

If the above conditions are met, the sample is given a log number, and the sample description and date received, are recorded along with any other relevant information. Aliquots or subsamples to be split are carefully split to ensure that the subsamples are representative of the original. Blending or grinding may be required.

* U.S. Environmental Protection Agency Publication 600/4-79-020.

The sample control officer also establishes a chain of custody to account for the sample from collection to disposal. Samples are normally held for 30 days after completion of the analyses; however, longer holding periods are sometimes employed.

2.3. ANALYSIS

In addition to routine calibration of the instruments with standards and blanks, the analyst runs duplicates and spikes on 10% of the analyses to ensure an added measure of precision and accuracy. Accuracy is also verified through:

- o U.S. Environmental Protection Agency (USEPA) and state certification results.
- o Participation in interlaboratory or round-robin programs.
- o "Blind" samples submitted by Brown and Caldwell quality assurance officer on a weekly basis. These samples are prepared from National Bureau of Standards or USEPA reference standards.
- o Verification of results with an alternative method. For instance, calcium may be determined by atomic absorption, ion chromatography, or EDTA titrimetric methods. Volatile organics may be determined through either purge and trap or liquid-liquid extraction methods.

2.4. MISCELLANEOUS CHECKS FOR ACCURACY

When possible, accuracy is also checked by a cation-anion balance. Where applicable, correlations may be established for total organic carbon, biochemical oxygen demand, chemical oxygen demand, and for other parameters. Dissolved solids and conductance often serve as checks against each other. Mass balance calculations will also assist in identifying error if flow rates of a system are known. The considerations are essential for quality assurance by providing an added means of identifying error.

Where trace analysis is involved, purity of the solvents, reagents, and gases employed is of great concern. Brown and Caldwell maintains service contracts on all major instrumentation; i.e., gas chromatographs, atomic absorption, ion chromatography, and total organic carbon analyzers are all serviced and maintained regularly. Balances and spectrophotometers are also

checked on a regular basis. Programmable calculators are provided to minimize the human error in repetitive calculations.

Brown and Caldwell encourages the professional development of the analyst through reimbursement for books, conferences, and successful completion of courses. Employees are evaluated by the quality assurance officer to ensure their understanding of the individual tests.

3. CHAIN-OF-CUSTODY

Brown and Caldwell's chain-of-custody procedures have been established to document the identity of a sample and its handling from the time of collection until its ultimate disposal.

Proper sample-handling techniques begin with a well-planned sample collection program which includes having sample bottles precleaned and labeled. When sample bottles are requested, they are appropriately prepared and preservatives are added in advance. This assists in eliminating contamination or degradation of samples.

Sample identification initiates a chain-of-custody record (Fig. E-1) which is provided with the bottles and remains with the sample throughout its handling. This includes the transfer of samples from the field crew to the laboratory and, in where necessary, to the subcontractors' laboratories.

Upon receipt at the laboratory, sample integrity is verified by the sample control officer as discussed above. Each sample is then assigned a discrete log number to identify the sample throughout analysis and reporting. This log number will be recorded in the custody record and in the legally required sample log book maintained at Brown and Caldwell. When samples are received through a carrier, an Acknowledgment of Sample Reception (Fig. E-1) form is immediately mailed to the requestor. Arrangements are typically made to immediately contact the requestor by phone if problems are identified.

CLIENT	DATE RECEIVED
ADDRESS	CLIENT JOB #
CITY STATE	PO/CONTRACT #
PHONE	BC JOB NO

No.	Date	Description	Analyses Required	Chain of Custody
				Relinquished By: _____ Date _____
				Received By: _____ Date _____
				Relinquished By: _____ Date _____
				Received By: _____ Date _____
				Relinquished By: _____ Date _____
				Received By: _____ Date _____
				Mailed By: _____ Date _____

BROWN AND CALDWELL
 1255 POWELL STREET
 EMERYVILLE, CA 94608
 (415) 428-2500

BROWN AND CALDWELL
ANALYTICAL SERVICES DIVISION
1255 Powell Street
Emeryville, California 94608
(415)428-2300

SAMPLE RECEPTION ACKNOWLEDGEMENT

CLIENT:

ATTENTION:

Received _____ samples on _____ identified as
(No.) (Date)

Analyses Required: _____

☐ Samples received in good condition.

☐ Sample bottles broken or otherwise unusable. See below.

Explanation: _____

Contact Carol Trent or Ed Wilson at (415) 428-2300 for further information.

NOTE: It is our policy to send this form to our clients upon receiving samples by mail, UPS, etc. If you ship samples to us and do not receive this confirmation within a reasonable time, please contact us.

Figure E-2. Brown and Caldwell sample reception acknowledgement form.

APPENDIX F

TABULATION OF 1983 LLNL ENVIRONMENTAL MONITORING DATA

From K. S. Griggs, D. S. Myers, and R. W. Buddemeier, Environmental Monitoring at the Lawrence Livermore National Laboratory, Lawrence Livermore National Laboratory, Livermore, (1984).

Table F-2. Gross beta activity on air filters—LLNL perimeter and Livermore Valley.

Location ^a	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM	% CG ^b
	(10 ⁻¹⁴ µCi/ml)														
Perimeter															
01	2.2	0.6	0.3	N/A ^c	0.8	0.7	0.7	1.1	1.4	1.4	1.1	0.8	1.0	52	1
02	1.5	0.6	0.5	0.8	0.9	0.8	0.7	1.2	1.6	1.7	1.1	0.8	1.0	39	1
12	2.5	0.7	0.4	0.9	0.9	0.9	0.6	1.7	1.9	1.6	1.2	0.6	1.2	55	1
13	1.4	0.6	0.5	0.8	0.8	0.7	0.6	1.0	1.3	1.3	0.8	0.8	0.9	34	1
14	3.0	0.7	0.5	0.9	0.8	0.8	0.7	0.7	1.4	1.3	0.9	0.8	1.0	64	1
15	2.0	0.6	0.4	0.9	0.8	0.8	0.6	1.0	1.4	1.4	1.1	0.8	1.0	45	1
Valley															
03	2.3	1.2	1.1	1.6	1.5	1.4	1.2	1.6	1.9	1.9	1.6	1.3	1.6	23	2
04	1.6	0.7	0.4	0.6	0.9	0.7	0.8	1.2	1.6	1.5	1.2	0.8	1.0	41	1
05	3.2	1.6	1.9	1.9	2.1	1.6	1.9	2.4	2.6	2.6	2.4	2.1	2.2	21	2
06	3.3	1.9	1.9	2.2	2.1	2.0	2.0	2.2	2.0	2.2	1.6	1.7	2.1	21	2
07	2.4	1.6	1.6	2.0	2.0	2.0	2.0	2.3	2.6	1.8	2.3	1.6	2.0	16	2
08	2.3	0.8	0.5	1.1	1.4	1.0	0.9	1.2	1.8	2.0	1.6	1.0	1.3	41	1
09	4.0	2.4	2.1	2.2	2.6	2.5	2.4	2.9	3.4	3.5	3.0	1.1	2.7	28	3
10	2.1	0.7	0.5	1.0	1.0	0.7	0.7	1.2	1.6	1.8	1.2	0.9	1.1	44	1
11	2.6	1.9	1.7	2.1	2.3	2.2	2.1	2.4	2.7	2.6	2.5	2.3	2.3	13	2
16	2.7	0.6	0.5	1.1	0.9	0.8	0.5	2.4	2.4	1.7	1.2	0.8	1.3	62	1
17	1.9	0.8	0.4	0.8	1.0	0.7	0.6	1.1	1.4	1.6	1.2	0.7	1.0	43	1
Annual average													1.4	40	1

^a See Figs. 3 and 5.^b CG = 1×10^{-12} µCi/ml.^c Not available.

Table F-3. Gross alpha activity on air filters—Site 300.

Location ^a	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM	% CG ^b
	(10 ⁻¹⁵ µCi/ml)														
01	0.4	0.3	0.2	0.3	0.3	0.3	0.4	0.3	0.5	0.5	0.3	0.3	0.3	26	2
02	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.4	0.4	0.5	0.5	0.4	0.4	23	2
03	0.6	0.5	0.5	0.6	0.6	0.8	0.7	0.7	1.9	0.7	0.6	0.5	0.7	52	4
04	0.5	N/A ^c	N/A	0.2	0.4	0.6	0.4	0.4	0.4	0.6	0.5	N/A	0.4	27	2
05	0.4	0.3	0.2	0.3	0.4	0.3	0.4	0.5	0.5	0.7	0.6	0.4	0.4	34	2
06	0.7	0.6	0.6	0.6	0.8	0.6	0.5	0.9	1.1	1.0	0.6	0.6	0.7	27	4
08	0.4	0.3	0.3	0.3	0.4	0.4	0.3	0.4	0.6	0.6	0.4	0.4	0.4	25	2
09	0.8	0.3	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.3	0.4	41	2
10	0.4	0.2	0.1	0.4	0.3	0.5	0.4	0.4	0.4	0.6	0.4	N/A	0.4	35	2
Annual average													0.5	31	2

^a See Fig. 4. Location 6 is in city of Tracy.^b CG = 2×10^{-14} µCi/ml.^c Not available.

Appendix F. Tables

The statistical values (2σ estimates) that accompany individual measurements of radioactivity in the following tables are the result of counting statistics. The minimum detection limit is assumed reached when the 2σ estimate is $\pm 100\%$. Statistical values for groups of data such as annual averages are calculated standard deviations of the mean (average).

Table F-1. Gross alpha activity on air filters—LLNL perimeter and Livermore Valley.

Location ^a	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM ^b	% CG ^c
	(10 ⁻¹⁵ μ Ci/ml)														
Perimeter															
01	0.7	0.6	0.7	N/A ^d	0.7	0.6	0.5	0.7	0.5	0.8	0.4	0.3	0.6	34	3
02	0.6	0.6	0.6	0.8	0.6	0.6	0.5	0.5	0.5	0.7	0.4	0.3	0.6	23	3
12	2.1	0.6	0.6	0.6	0.5	0.6	0.4	0.8	1.0	1.0	0.6	0.6	0.8	57	4
13	0.4	0.3	0.3	0.4	0.5	0.4	0.3	0.5	0.6	0.5	0.3	0.3	0.4	25	2
14	0.8	1.0	0.6	0.5	0.5	0.7	0.6	1.0	1.3	0.9	0.7	0.8	0.8	31	4
15	0.5	0.3	0.3	0.3	0.5	0.4	0.3	0.4	0.6	0.5	0.4	0.3	0.4	25	2
Valley															
03	0.6	0.6	0.6	0.8	0.7	0.7	0.6	0.5	0.6	0.7	0.6	0.6	0.6	13	3
04	0.5	0.5	0.5	0.4	0.5	0.7	0.6	0.6	0.4	0.9	0.6	0.6	0.6	25	3
05	0.8	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.8	0.7	0.7	0.6	0.6	20	3
06	0.9	0.6	0.5	0.6	0.7	0.5	0.7	0.6	0.4	0.8	0.5	0.6	0.6	23	3
07	0.8	0.5	0.5	0.6	0.6	0.6	0.7	0.6	0.8	0.6	0.6	0.6	0.6	16	3
08	0.4	0.3	0.3	0.3	0.4	0.9	0.4	0.6	0.6	0.8	0.6	0.6	0.5	39	3
09	1.0	0.6	0.5	0.6	0.8	0.7	0.6	1.0	1.1	1.2	0.8	0.6	0.8	29	4
10	0.6	0.6	0.6	0.7	0.6	0.7	0.8	0.5	0.6	0.7	0.4	0.3	0.6	24	3
11	0.7	0.6	0.5	0.6	0.6	0.6	0.9	0.7	0.7	0.8	0.6	0.6	0.7	17	4
16	0.9	0.6	0.7	0.6	0.6	0.6	0.5	1.6	3.0	0.8	0.6	0.6	0.9	78	4
17	0.6	0.7	0.8	1.0	0.6	0.7	0.7	0.5	0.6	0.9	0.5	0.5	0.7	24	4
Annual average													0.6	22	3

^a See Figs. 3 and 5.

^b % SDM = % standard deviation of mean at 1σ .

^c Concentration guide (CG) = 2×10^{-16} μ Ci/ml.

^d Not available.

Table F-4. Gross beta activity on air filters – Site 300.

Location ^a	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM	% CG ^b
	(10 ⁻¹⁶ µCi/ml)														
01	1.8	0.8	0.5	1.1	0.9	1.1	0.9	1.4	1.5	1.6	1.0	0.9	1.1	34	1
02	1.8	0.9	0.5	1.2	1.0	1.1	0.9	1.4	1.6	1.8	1.6	1.3	1.3	32	1
03	2.4	1.2	0.7	1.6	1.5	2.0	1.5	3.1	2.6	1.9	1.5	1.1	1.8	39	2
04	3.0	N/A ^c	N/A	0.9	0.9	1.0	0.7	1.3	1.4	1.4	1.0	N/A	1.3	54	1
05	1.7	1.0	0.6	1.2	0.9	1.1	0.9	1.7	1.8	1.7	1.2	0.9	1.2	33	1
06	2.1	0.9	0.4	1.0	1.3	1.0	0.7	0.9	1.1	1.9	1.2	1.3	1.2	41	1
08	1.8	0.8	0.4	1.0	0.9	0.8	0.6	1.1	1.4	1.3	0.4	0.7	0.9	45	1
09	2.1	0.8	0.5	1.0	0.9	1.1	0.7	1.4	1.5	1.5	1.0	0.8	1.1	40	1
10	2.3	1.1	0.6	1.6	1.0	1.2	0.6	1.2	1.2	1.3	1.0	N/A	1.2	39	1
Annual average													1.2	20	1

^a See Fig. 4. Location 6 is in City of Tracy.^b CG = 1 × 10⁻¹² µCi/ml.^c Not available.

Table F-5. Gamma activity on air filters – LLNL perimeter.

Month	⁷ Be [10 ⁻¹³ µCi/ml ± 2σ (%)]	⁴⁰ K	¹³⁶ Rn	¹²⁵ Sb	¹³⁷ Cs	¹⁴⁴ Ce
		[10 ⁻¹⁶ µCi/ml ± 2σ (%)]				
Jan.	65.5 ± 2	0.2 ± 50	1.7 ± 100	0.4 ± 100	0.6 ± 40	1.2 ± 100
Feb.	0.6 ± 2	4.6 ± 66	0.5 ± 100	0.2 ± 100	0.7 ± 20	0.9 ± 60
Mar.	0.6 ± 7	1.1 ± 100	0.5 ± 100	0.2 ± 100	0.9 ± 16	0.9 ± 54
Apr.	0.9 ± 2	5.9 ± 100	1.5 ± 100	0.5 ± 100	2.0 ± 26	1.0 ± 100
May	0.8 ± 2	8.5 ± 32	0.5 ± 100	0.2 ± 100	1.1 ± 15	1.5 ± 64
June	0.9 ± 11	12.2 ± 34	0.6 ± 100	0.5 ± 100	1.0 ± 28	0.5 ± 100
July	0.7 ± 2	1.6 ± 100	0.6 ± 100	0.2 ± 100	1.0 ± 20	0.5 ± 100
Aug.	0.8 ± 7	5.8 ± 50	0.5 ± 100	0.2 ± 100	0.6 ± 26	0.4 ± 100
Sept.	1.1 ± 2	5.4 ± 100	n.d. ^a	0.3 ± 100	0.6 ± 50	0.7 ± 100
Oct.	0.8 ± 2	4.5 ± 60	0.04 ± 100	0.2 ± 100	0.4 ± 30	0.3 ± 100
Nov.	0.6 ± 2	2.4 ± 100	0.4 ± 100	0.2 ± 100	0.3 ± 86	0.5 ± 100
Dec.	0.6 ± 2	1.1 ± 100	0.4 ± 100	0.1 ± 100	0.3 ± 42	0.3 ± 100
Annual average	6.2	4.4	0.6	0.3	0.8	0.7
% SDM	303	79	85	49	59	52
CG (µCi/ml)	4 × 10 ⁻⁸	none	2 × 10 ⁻¹⁰	9 × 10 ⁻¹⁰	2 × 10 ⁻⁹	2 × 10 ⁻¹⁰
% CG	2 × 10 ⁻³		3 × 10 ⁻⁵	3 × 10 ⁻⁶	4 × 10 ⁻⁶	4 × 10 ⁻⁵

^a Not detected.

Table F-6. Gamma activity on air filters—Site 300.

Month	⁷ Be	⁴⁰ K	¹⁰⁶ Ru	¹²⁵ Sb	¹³⁷ Cs	¹³⁸ Ce
	[10 ⁻¹³ μ Ci/ml $\pm 2\sigma$ (%)]			[10 ⁻¹⁶ μ Ci/ml $\pm 2\sigma$ (%)]		
Jan.	102. $\pm$ 2	0.4 $\pm$ 50	2.9 $\pm$ 36	0.2 $\pm$ 100	1.0 $\pm$ 11	2.6 $\pm$ 40
Feb.	9.1 $\pm$ 2	8.4 $\pm$ 100	11.5 $\pm$ 40	4.2 $\pm$ 36	11.7 $\pm$ 10	17.1 $\pm$ 32
Mar.	0.84 $\pm$ 2	0.6 $\pm$ 100	1.3 $\pm$ 42	0.4 $\pm$ 38	1.2 $\pm$ 8	1.7 $\pm$ 32
Apr.	1.5 $\pm$ 2	0.6 $\pm$ 100	1.6 $\pm$ 56	0.8 $\pm$ 58	2.1 $\pm$ 10	2.4 $\pm$ 32
May	1.0 $\pm$ 2	0.3 $\pm$ 100	0.3 $\pm$ 100	0.4 $\pm$ 44	1.4 $\pm$ 7	1.6 $\pm$ 46
June	1.4 $\pm$ 2	4.2 $\pm$ 36	0.3 $\pm$ 100	0.5 $\pm$ 38	1.7 $\pm$ 7	1.4 $\pm$ 39
July	1.0 $\pm$ 2	4.6 $\pm$ 38	0.3 $\pm$ 100	0.1 $\pm$ 100	1.3 $\pm$ 10	1.2 $\pm$ 42
Aug.	1.5 $\pm$ 1	0.5 $\pm$ 100	0.3 $\pm$ 62	0.3 $\pm$ 62	1.1 $\pm$ 10	0.3 $\pm$ 100
Sept.	1.6 $\pm$ 8	5.5 $\pm$ 38	0.4 $\pm$ 100	0.2 $\pm$ 100	1.0 $\pm$ 13	0.4 $\pm$ 100
Oct.	1.1 $\pm$ 2	1.0 $\pm$ 100	0.3 $\pm$ 100	0.1 $\pm$ 100	0.4 $\pm$ 19	0.3 $\pm$ 100
Nov.	0.9 $\pm$ 2	3.3 $\pm$ 44	0.3 $\pm$ 100	0.1 $\pm$ 100	0.4 $\pm$ 20	0.2 $\pm$ 100
Dec.	0.7 $\pm$ 2	1.0 $\pm$ 100	0.4 $\pm$ 100	0.1 $\pm$ 100	0.2 $\pm$ 50	0.3 $\pm$ 100
Annual average	10.2	2.5	1.7	0.6	2.0	2.5
% SDM	284	104	191	186	159	191
CG (μ Ci/ml)	4 $\times$ 10 ⁻⁶	none	2 $\times$ 10 ⁻¹⁰	9 $\times$ 10 ⁻¹⁰	2 $\times$ 10 ⁻⁹	2 $\times$ 10 ⁻¹⁰
% CG	3 $\times$ 10 ⁻³		8 $\times$ 10 ⁻⁵	7 $\times$ 10 ⁻⁶	1 $\times$ 10 ⁻⁵	1 $\times$ 10 ⁻⁴

Table F-7. Plutonium-239 on air filters—selected locations.

Month	Location ^a					
	090-04	090-08	090-10	090-16	090-17	040-06
	[10 ⁻¹⁷ μ Ci/ml $\pm 2\sigma$ (%)]					
Jan.	0.2 $\pm$ 36	0.1 $\pm$ 61	0.1 $\pm$ 100	0.3 $\pm$ 46	0.1 $\pm$ 78	0.1 $\pm$ 70
Feb.	0.1 $\pm$ 56	0.1 $\pm$ 35	0.2 $\pm$ 46	0.2 $\pm$ 41	0.1 $\pm$ 77	0.1 $\pm$ 58
Mar.	0.1 $\pm$ 43	0.1 $\pm$ 37	0.1 $\pm$ 42	0.1 $\pm$ 43	0.2 $\pm$ 46	0.1 $\pm$ 48
Apr.	0.1 $\pm$ 100	0.2 $\pm$ 38	0.3 $\pm$ 37	0.3 $\pm$ 38	0.3 $\pm$ 50	0.2 $\pm$ 50
May	0.3 $\pm$ 25	0.3 $\pm$ 43	0.2 $\pm$ 41	0.2 $\pm$ 32	0.2 $\pm$ 40	0.3 $\pm$ 35
June	0.4 $\pm$ 28	0.1 $\pm$ 50	0.1 $\pm$ 50	0.4 $\pm$ 27	0.2 $\pm$ 49	0.2 $\pm$ 34
July	0.2 $\pm$ 43	0.1 $\pm$ 41	0.1 $\pm$ 85	0.3 $\pm$ 48	0.2 $\pm$ 48	0.1 $\pm$ 65
Aug.	0.1 $\pm$ 39	0.1 $\pm$ 64	0.2 $\pm$ 32	0.4 $\pm$ 52	0.1 $\pm$ 70	0.1 $\pm$ 98
Sept.	0.1 $\pm$ 48	0.1 $\pm$ 43	0.1 $\pm$ 35	0.6 $\pm$ 62	0.1 $\pm$ 63	0.2 $\pm$ 63
Oct.	N/A ^b	0.1 $\pm$ 87	0.1 $\pm$ 57	0.1 $\pm$ 81	0.1 $\pm$ 100	N/A
Nov.	0.1 $\pm$ 100	0.1 $\pm$ 100	0.1 $\pm$ 38	0.1 $\pm$ 76	0.1 $\pm$ 100	0.1 $\pm$ 100
Dec.	0.1 $\pm$ 100	0.01 $\pm$ 100	0.01 $\pm$ 100	0.1 $\pm$ 100	0.1 $\pm$ 100	0.1 $\pm$ 100
Annual average	0.2	0.1	0.2	0.2	0.2	0.1
% SDM	61	50	47	63	45	47
% CG ^c	3 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³	4 $\times$ 10 ⁻³	3 $\times$ 10 ⁻³	2 $\times$ 10 ⁻³

^a See Fig. 5. Location 040-06 is in City of Tracy.^b Not available.^c CG = 6 $\times$ 10⁻¹⁴ μ Ci/ml.

Table F-8. Plutonium and uranium on air filters—LLNL perimeter.

Month	Location ^a	²³⁹ Pu ^b [10 ⁻¹⁷ µCi/mi ± 2σ (%)]	²³⁸ U [10 ⁻⁷ µg/m ³ ± 2σ (%)]	²³⁵ U [10 ⁻⁵ µg/m ³ ± 2σ (%)]	²³⁵ U/ ²³⁸ U (10 ⁻³)
Jan.	01	0.2 ± 34	4.1 ± 3	14.8 ± 3	2.8
	02	0.2 ± 49	2.6 ± 3	4.2 ± 3	6.3
	12	1.0 ± 28	10.7 ± 3	24.5 ± 3	4.4
	13	0.2 ± 29	4.8 ± 3	16.1 ± 3	3.0
	14	0.9 ± 26	5.5 ± 3	21.5 ± 3	2.6
	15	0.2 ± 29	4.8 ± 3	18.7 ± 3	2.6
Feb.	01	0.2 ± 43	2.0 ± 3	2.9 ± 3	6.7
	02	0.2 ± 49	2.6 ± 3	3.9 ± 3	6.8
	12	0.6 ± 25	5.0 ± 3	7.8 ± 3	6.5
	13	0.1 ± 67	3.7 ± 3	5.3 ± 3	6.9
	14	0.2 ± 45	2.6 ± 3	4.2 ± 3	6.2
	15	0.2 ± 44	1.8 ± 3	2.8 ± 3	6.7
Mar.	01	0.3 ± 29	1.5 ± 3	2.3 ± 3	6.4
	02	0.1 ± 39	2.0 ± 3	3.0 ± 3	6.6
	12	2.3 ± 11	4.4 ± 3	7.0 ± 3	6.3
	13	0.1 ± 31	4.7 ± 3	6.8 ± 3	7.0
	14	0.4 ± 21	1.6 ± 3	2.7 ± 3	5.9
	15	0.1 ± 25	1.2 ± 3	1.8 ± 3	6.7
Apr.	01	N/A ^c	N/A	N/A	N/A
	02	0.9 ± 22	3.5 ± 3	5.0 ± 3	7.1
	12	11.1 ± 7	7.4 ± 3	11.3 ± 3	6.6
	13	0.2 ± 30	7.2 ± 3	10.1 ± 3	7.1
	14	1.1 ± 17	3.4 ± 3	4.9 ± 3	6.9
	15	0.2 ± 33	3.8 ± 3	5.3 ± 3	7.1
May	01	N/A	6.0 ± 3	8.4 ± 3	7.1
	02	0.5 ± 19	9.7 ± 3	13.6 ± 3	7.1
	12	4.9 ± 7	7.8 ± 3	11.4 ± 3	6.8
	13	0.2 ± 42	9.3 ± 3	13.1 ± 3	7.1
	14	1.9 ± 17	4.8 ± 3	6.8 ± 3	6.9
	15	0.3 ± 19	5.5 ± 3	7.8 ± 3	7.1
June	01	0.5 ± 29	6.7 ± 3	9.7 ± 3	6.9
	02	0.2 ± 35	5.9 ± 3	8.3 ± 3	7.1
	12	3.6 ± 10	10.9 ± 3	15.8 ± 3	6.9
	13	0.2 ± 26	9.1 ± 3	12.8 ± 3	7.1
	14	3.6 ± 13	13.3 ± 3	19.0 ± 3	7.0
	15	0.4 ± 26	9.2 ± 3	13.0 ± 3	7.1
July	01	0.1 ± 50	7.7 ± 3	11.1 ± 3	6.9
	02	0.1 ± 41	6.2 ± 3	8.7 ± 3	7.1
	12	1.3 ± 23	12.1 ± 3	17.5 ± 3	6.9
	13	0.1 ± 29	6.8 ± 3	9.6 ± 3	7.1
	14	0.6 ± 17	4.9 ± 3	7.0 ± 3	6.9
	15	0.2 ± 29	7.8 ± 3	11.1 ± 3	7.1

Table F-8. (Continued).

Month	Location ^a	²³⁹ Pu ^b	²³⁵ U	²³⁸ U	²³⁵ U/ ²³⁸ U
		[10 ⁻¹⁷ µCi/ml ± 2σ (%)]	[10 ⁻⁷ µg/m ³ ± 2σ (%)]	[10 ⁻⁵ µg/m ³ ± 2σ (%)]	(10 ⁻³)
Aug.	01	0.3 ± 36	5.8 ± 3	8.4 ± 3	6.8
	02	0.1 ± 46	5.0 ± 3	7.0 ± 3	7.1
	12	1.5 ± 22	13.2 ± 3	18.9 ± 3	7.0
	13	0.2 ± 45	6.1 ± 3	8.6 ± 3	7.1
	14	0.7 ± 43	8.2 ± 3	11.7 ± 3	7.1
	15	0.2 ± 37	6.9 ± 3	9.6 ± 3	7.1
Sept.	01	0.2 ± 52	7.2 ± 3	10.5 ± 3	6.8
	02	0.2 ± 41	6.0 ± 3	8.6 ± 3	7.0
	12	1.2 ± 23	16.8 ± 3	24.2 ± 3	6.9
	13	0.1 ± 55	7.7 ± 3	10.8 ± 3	7.1
	14	0.5 ± 41	10.1 ± 3	14.3 ± 3	7.1
	15	0.2 ± 42	6.6 ± 3	9.3 ± 3	7.1
Oct.	01	0.1 ± 100	5.0 ± 3	7.8 ± 3	6.8
	02	0.1 ± 100	4.6 ± 3	6.3 ± 3	7.3
	12	0.5 ± 23	12.4 ± 3	17.9 ± 3	6.9
	13	0.1 ± 45	4.0 ± 3	5.7 ± 3	7.0
	14	0.3 ± 37	6.2 ± 3	8.8 ± 3	7.0
	15	0.1 ± 37	N/A ^c	N/A	N/A
Nov.	01	0.1 ± 52	3.3 ± 3	4.8 ± 3	6.9
	02	0.1 ± 55	3.9 ± 3	5.6 ± 3	7.0
	12	0.7 ± 21	9.9 ± 3	14.1 ± 3	7.0
	13	0.1 ± 62	3.0 ± 3	4.4 ± 3	6.8
	14	0.2 ± 55	5.6 ± 3	8.0 ± 3	7.0
	15	0.1 ± 77	3.3 ± 3	4.7 ± 3	7.0
Dec.	01	0.1 ± 41	1.5 ± 3	2.2 ± 3	6.8
	02	0.1 ± 66	1.8 ± 3	2.7 ± 3	6.7
	12	0.6 ± 38	5.5 ± 3	8.1 ± 3	6.8
	13	0.1 ± 60	1.3 ± 3	2.0 ± 3	6.5
	14	0.1 ± 100	1.9 ± 3	2.8 ± 3	6.8
	15	0.1 ± 100	1.9 ± 3	2.8 ± 3	6.8

Annual averages

Location	²³⁹ Pu			²³⁵ U			²³⁸ U		
	10 ⁻¹⁷ µCi/ml	% SDM	% CG ^d	10 ⁻⁷ µg/m ³	% SDM	% CG ^e	10 ⁻⁵ µg/m ³	% SDM	% CG ^f
01	0.2	62	3 × 10 ⁻³	4.6	51	2 × 10 ⁻⁵	7.5	54	5 × 10 ⁻⁴
02	0.2	103	3 × 10 ⁻³	4.5	50	2 × 10 ⁻⁵	6.4	48	4 × 10 ⁻⁴
12	2.4	125	4 × 10 ⁻²	9.7	39	5 × 10 ⁻⁵	14.9	40	10 × 10 ⁻⁴
13	0.1	43	2 × 10 ⁻³	5.6	44	3 × 10 ⁻⁵	8.8	47	6 × 10 ⁻⁴
14	0.9	113	2 × 10 ⁻²	5.7	61	3 × 10 ⁻⁵	9.3	66	6 × 10 ⁻⁴
15	0.2	47	3 × 10 ⁻³	4.8	55	2 × 10 ⁻⁵	7.9	65	5 × 10 ⁻⁴

^a See Fig. 3.^b In all tables activity listed as ²³⁹Pu includes activity due to ²⁴⁰Pu isotope.^c Not available.^d CG = 6 × 10⁻¹⁴ µCi/ml for ²³⁹Pu (soluble) activity in air.^e CG = 1.9 µg/m³ for ²³⁵U (insoluble) activity in air.^f CG = 15 µg/m³ for ²³⁸U (insoluble) activity in air.

Table F-9. Plutonium, cesium, and uranium on air filters—Site 300.

Month	²³⁹ Pu	¹³⁷ Cs	²³⁹ Pu/ ¹³⁷ Cs (10 ⁻³)	²³⁵ U	²³⁸ U	²³⁵ U/ ²³⁸ U (10 ⁻³)
	[10 ⁻¹⁷ μCi/ml ± 2σ (%)]	[10 ⁻¹⁵ μCi/ml ± 2σ (%)]		[10 ⁻⁷ μg/m ³ ± 2σ (%)]	[10 ⁻⁵ μg/m ³ ± 2σ (%)]	
Jan.	0.1 ± 13	0.1 ± 11	1.0	29.0 ± 3	161. ± 3	1.8
Feb.	0.1 ± 15	1.2 ± 10	0.1	1.31 ± 3	3.23 ± 3	4.0
Mar.	0.1 ± 16	0.1 ± 8	1.0	1.10 ± 3	2.57 ± 3	4.3
Apr.	0.2 ± 12	0.2 ± 10	1.0	3.00 ± 3	5.68 ± 3	5.3
May	0.2 ± 11	0.1 ± 7	2.0	2.76 ± 3	4.60 ± 3	6.0
June	0.3 ± 11	0.2 ± 7	1.5	4.68 ± 3	7.86 ± 3	6.0
July	0.1 ± 12	0.1 ± 10	1.0	4.27 ± 3	7.09 ± 3	6.0
Aug.	0.1 ± 21	0.1 ± 10	1.0	4.43 ± 3	7.49 ± 3	5.9
Sept.	0.04 ± 69	0.1 ± 13	0.4	6.05 ± 3	10.3 ± 3	5.9
Oct.	0.07 ± 17	0.04 ± 19	1.8	3.3 ± 3	5.4 ± 3	6.1
Nov.	0.06 ± 19	0.04 ± 20	2.0	2.3 ± 3	4.2 ± 3	5.4
Dec.	0.02 ± 42	0.02 ± 50	1.0	2.3 ± 3	6.1 ± 3	3.8
Annual average	0.1	0.2		5.4	18.8	
% SDM	68	156		141	239	
CG	6 × 10 ⁻¹⁸ μCi/ml	2 × 10 ⁻⁹ μCi/ml		1.9 μg/m ³	15 μg/m ³	
% CG	2 × 10 ⁻³	1 × 10 ⁻⁵		3 × 10 ⁻⁵	4 × 10 ⁻⁴	

Table F-10. Tritium (HTO) in air—LLNL perimeter and Livermore Valley.

Month	Perimeter location ^a					Valley location ^a		Average	% SDM
	01	02	12	13	14 (10 ⁻¹¹ μ Ci/ml)	15	51	52	
Jan.	1.6	3.0	3.8	2.9	2.4	2.7	2.8	1.8	2.6
Feb.	2.8	3.8	4.3	2.6	3.3	2.8	2.9	2.7	3.2
Mar.	3.1	5.1	5.4	4.7	3.7	4.3	1.5	1.4	3.6
Apr.	N/A ^b	2.0	2.9	1.5	2.2	2.3	1.2	1.0	1.9
May	N/A	0.9	5.6	1.7	1.7	1.7	N/A	0.8	2.1
June	0.6	N/A	1.1	0.6	1.8	1.1	N/A	0.3	0.9
July	0.8	3.4	1.7	0.6	2.1	2.0	0.5	0.4	1.4
Aug.	1.7	1.2	2.5	0.8	4.3	2.6	1.0	0.4	1.8
Sept.	1.8	2.1	3.8	1.9	4.9	2.1	0.5	0.8	2.2
Oct.	3.2	4.7	9.9	3.4	4.5	4.0	2.8	2.6	4.4
Nov.	2.8	4.5	5.2	2.8	5.8	2.7	1.2	1.7	3.3
Dec.	3.0	3.8	6.0	2.9	5.6	3.9	2.7	3.2	3.9
Annual average									
% CG ^c	0.01								2.6
Calculated adult whole-body dose	0.03 mrem								41

^a See Figs. 3 and 5.

^b Not available.

^c CG = 2×10^{-7} μ Ci/ml.

Table F-11. Various radionuclides in soil – Livermore Valley (sampling depth 0-5 cm).

Location ^a	²³⁹ Pu	⁴⁰ K	¹³⁷ Cs	²³⁵ Th	²³⁸ U
	[10 ⁻⁹ μCi/dry g ± 2σ (%)]	[10 ⁻⁵ μCi/dry g ± 2σ (%)]	[10 ⁻⁷ μCi/dry g ± 2σ (%)]	[μg/dry g ± 2σ (%)]	
927	6.2 ± 8	0.5 ± 7	0.3 ± 32	4.6 ± 5	2.4 ± 20
928	10.9 ± 6	1.0 ± 4	2.8 ± 7	5.8 ± 9	2.6 ± 38
929	3.3 ± 13	1.1 ± 4	0.7 ± 21	6.5 ± 9	4.1 ± 11
930	4.1 ± 11	1.2 ± 6	0.3 ± 42	6.2 ± 13	3.0 ± 24
931	3.0 ± 11	0.9 ± 5	0.4 ± 24	5.2 ± 6	3.0 ± 13
932	3.0 ± 9	1.4 ± 9	0.3 ± 60	7.2 ± 10	4.6 ± 11
933	6.7 ± 7	1.5 ± 3	1.9 ± 6	6.8 ± 6	4.1 ± 12
934	5.7 ± 7	0.7 ± 5	0.5 ± 18	4.7 ± 8	1.2 ± 60
935	5.7 ± 7	0.7 ± 10	0.6 ± 25	5.0 ± 14	2.5 ± 34
936	9.5 ± 6	0.6 ± 10	3.9 ± 5	4.0 ± 9	1.7 ± 28
937	9.8 ± 7	0.9 ± 8	2.1 ± 11	4.7 ± 12	2.6 ± 48
938	8.3 ± 7	0.8 ± 8	3.1 ± 7	4.9 ± 9	2.7 ± 28
939	7.9 ± 6	1.0 ± 8	3.1 ± 7	5.9 ± 8	2.8 ± 28
940	8.1 ± 7	1.3 ± 6	3.2 ± 5	6.8 ± 8	3.0 ± 42
941	4.8 ± 9	1.3 ± 12	1.5 ± 8	5.8 ± 9	n.d. ^b
942	4.7 ± 8	1.2 ± 9	1.2 ± 12	6.4 ± 10	2.9 ± 38
943	11.9 ± 7	1.0 ± 8	4.0 ± 8	5.4 ± 7	2.8 ± 42
944	23.4 ± 5	1.1 ± 4	2.6 ± 4	6.8 ± 6	2.8 ± 21
945	5.5 ± 8	1.5 ± 5	2.1 ± 10	4.9 ± 14	2.5 ± 36
946	2.8 ± 10	1.3 ± 4	1.1 ± 16	5.3 ± 12	2.8 ± 44
947	1.9 ± 12	1.0 ± 4	0.8 ± 14	6.0 ± 6	3.1 ± 14

^a See Fig. 6.^b Not detected.

Table F-12. Plutonium, cesium and uranium in soil – Site 300 (sampling depth 0-5 cm).

Location ^a	²³⁹ Pu	¹³⁷ Cs	²³⁸ U
	[10 ⁻⁹ μCi/dry g ± 2σ (%)]	[10 ⁻⁷ μCi/dry g ± 2σ (%)]	[μg/dry g ± 2σ (%)]
948	6.7 ± 7	3.8 ± 5	5.1 ± 20
949	4.6 ± 9	1.6 ± 8	4.0 ± 14
950	2.5 ± 11	2.2 ± 6	62.5 ± 5
951	2.6 ± 10	3.2 ± 5	58.8 ± 5
952	3.1 ± 9	0.2 ± 29	2.3 ± 44
953	7.4 ± 6	2.9 ± 4	1.6 ± 42
954	1.1 ± 14	0.4 ± 21	3.6 ± 30
955	2.4 ± 12	0.4 ± 38	4.8 ± 12
956	0.2 ± 34	2.0 ± 8	5.1 ± 16
957	5.5 ± 8	2.7 ± 6	3.8 ± 23
958	4.5 ± 9	1.7 ± 14	1370. ± 4
959	0.9 ± 17	0.4 ± 23	3.0 ± 14

^a See Fig. 7.

Table F-13. Various radionuclides in effluents - LLNL and Livermore Water Reclamation Plant.

Month	HTO		¹³⁷ Cs		²³⁹ Pu	
	[10 ⁻⁶ μ Ci/ml $\pm$ 2 σ (%)]		[10 ⁻¹¹ μ Ci/ml $\pm$ 2 σ (%)]		[10 ⁻¹² μ Ci/ml $\pm$ 2 σ (%)]	
	LLNL	LWRP	LLNL	LWRP	LLNL	LWRP
Jan.	2.6 $\pm$ 50	0.51 $\pm$ 91	6.4 $\pm$ 15	3.0 $\pm$ 43	44.3 $\pm$ 9	0.8 $\pm$ 72
Feb.	3.4 $\pm$ 41	0.68 $\pm$ 65	22.3 $\pm$ 8	1.2 $\pm$ 100	13.2 $\pm$ 21	0.2 $\pm$ 100
Mar.	2.8 $\pm$ 36	1.1 $\pm$ 62	6.2 $\pm$ 17	0.8 $\pm$ 100	12.5 $\pm$ 15	1.0 $\pm$ 45
Apr.	3.6 $\pm$ 38	0.4 $\pm$ 55	6.8 $\pm$ 23	1.1 $\pm$ 50	10.5 $\pm$ 14	1.4 $\pm$ 37
May	1.9 $\pm$ 42	0.4 $\pm$ 100	5.7 $\pm$ 18	1.6 $\pm$ 50	9.3 $\pm$ 14	1.0 $\pm$ 47
June	1.8 $\pm$ 52	0.5 $\pm$ 50	4.6 $\pm$ 14	0.6 $\pm$ 100	60.0 $\pm$ 8	1.9 $\pm$ 35
July	3.4 $\pm$ 38	0.4 $\pm$ 84	4.5 $\pm$ 14	2.5 $\pm$ 33	4.4 $\pm$ 18	0.5 $\pm$ 60
Aug.	5.8 $\pm$ 30	0.5 $\pm$ 32	2.8 $\pm$ 36	1.0 $\pm$ 100	6.6 $\pm$ 16	0.8 $\pm$ 57
Sept.	1.6 $\pm$ 62	0.6 $\pm$ 76	5.4 $\pm$ 23	1.0 $\pm$ 100	9.9 $\pm$ 16	0.7 $\pm$ 54
Oct.	4.2 $\pm$ 25	0.7 $\pm$ 71	5.2 $\pm$ 26	0.8 $\pm$ 100	3.5 $\pm$ 28	0.2 $\pm$ 100
Nov.	16.8 $\pm$ 17	2.8 $\pm$ 47	7.5 $\pm$ 20	0.9 $\pm$ 100	29.4 $\pm$ 11	0.7 $\pm$ 56
Dec.	3.6 $\pm$ 40	0.5 $\pm$ 85	4.8 $\pm$ 30	3.2 $\pm$ 40	4.6 $\pm$ 20	0.1 $\pm$ 100
Annual average	4.3	0.8	6.8	1.5	17.4	0.8
% SDM	96	88	73	62	103	67
CG (μ Ci/ml)	0.1	3 $\times$ 10 ⁻³	4 $\times$ 10 ⁻⁴	2 $\times$ 10 ⁻⁵	1 $\times$ 10 ⁻⁴	5 $\times$ 10 ⁻⁴
% CG	4 $\times$ 10 ⁻³	2 $\times$ 10 ⁻²	2 $\times$ 10 ⁻³	8 $\times$ 10 ⁻⁵	2 $\times$ 10 ⁻⁵	2 $\times$ 10 ⁻⁵

Table F-14. Gross alpha activity in water - Livermore Valley.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ μ Ci/ml $\pm$ 2 σ (%)]				
11	4	$\leq$ 3.0	$\leq$ 2.6	$\leq$ 2.7	7	$\leq$ 9
15	4	$\leq$ 3.0	$\leq$ 2.6	$\leq$ 2.7	7	$\leq$ 9
16	4	$\leq$ 5.2	$\leq$ 2.6	$\leq$ 3.4	36	$\leq$ 11
19	4	$\leq$ 3.0	$\leq$ 2.6	$\leq$ 2.7	7	$\leq$ 9
20	6	$\leq$ 2.7	$\leq$ 0.3	$\leq$ 2.0	55	$\leq$ 7
24	4	$\leq$ 3.0	$\leq$ 2.6	$\leq$ 2.7	7	$\leq$ 9
26	4	$\leq$ 3.0	$\leq$ 2.6	$\leq$ 2.7	7	$\leq$ 9
29	4	$\leq$ 3.0	$\leq$ 2.6	$\leq$ 2.7	7	$\leq$ 9
31	4	$\leq$ 4.2	$\leq$ 0.4	$\leq$ 2.5	63	$\leq$ 8
33	3	$\leq$ 3.0	$\leq$ 2.6	$\leq$ 2.7	8	$\leq$ 9
34	3	$\leq$ 3.0	$\leq$ 2.6	$\leq$ 2.7	8	$\leq$ 9
37	4	$\leq$ 4.2	$\leq$ 2.7	$\leq$ 3.1	23	$\leq$ 10

^a See Fig. 9.^b CG = 3 $\times$ 10⁻⁸ μ Ci/ml.

Table F-15. Gross alpha activity in water – Site 300.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ µCi/ml ± 2σ (%)]				
01	4	≤4.2	≤2.6	≤3.0	26	≤10
02	4	≤4.2	≤2.6	≤3.0	26	≤10
04	12	22.0 ± 40	≤2.7	≤8.8	68	≤29
05	12	≤4.2	≤2.5	≤2.9	21	≤10
06	4	≤4.2	≤2.6	≤3.0	26	≤10
07	4	≤5.2	≤2.6	≤3.7	34	≤12
14	11	≤4.2	≤2.5	≤2.9	22	≤10
20	7	≤4.2	≤0.3	≤2.6	45	≤9
21	4	30.0 ± 56	≤2.6	≤10.2	131	≤34
22	12	≤4.2	≤2.5	≤2.9	21	≤10
23	4	≤4.2	≤2.6	≤3.0	26	≤10

^a See Fig. 10.^b CG = 3×10^{-8} µCi/ml.

Table F-16. Gross beta activity in water – Livermore Valley.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ µCi/ml ± 2σ (%)]				
11	4	13.0 ± 54	≤8.1	≤9.5	25	≤3
15	4	≤8.8	≤8.0	≤8.2	4	≤3
16	4	≤16.0	≤8.0	≤10.2	38	≤3
19	4	≤8.8	≤8.0	≤8.2	4	≤3
20	6	≤8.0	≤1.8	≤6.2	46	≤2
24	4	12.0 ± 57	≤8.1	≤9.2	20	≤3
26	4	≤8.8	≤8.0	≤8.2	4	≤3
29	4	≤8.8	≤7.9	≤8.2	5	≤3
31	4	≤12.0	≤1.6	≤7.4	58	≤2
33	3	14.0 ± 51	≤8.8	≤11.3	23	≤4
34	3	27.0 ± 34	13.0 ± 55	≤18.7	39	≤6
37	4	≤12.0	≤7.9	≤9.2	21	≤3

^a See Fig. 9.^b CG = 3×10^{-7} µCi/ml.

Table F-17. Gross beta activity in water—Site 300.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b
		[10 ⁻⁹ μCi/ml ± 2σ (%)]				
01	4	≤12.0	≤8.0	≤9.1	22	≤3
02	4	≤12.0	≤8.0	≤9.1	22	≤3
04	12	32.0 ± 27	≤8.0	≤16.0	38	≤5
05	12	12.0 ± 61	≤8.0	≤9.1	20	≤3
06	4	≤12.0	≤8.0	≤9.1	22	≤3
07	4	≤16.0	≤8.0	≤11.0	34	≤4
14	11	17.0 ± 43	≤8.0	≤10.0	28	≤3
20	7	20.0 ± 36	≤1.8	≤9.6	57	≤3
21	4	79.0 ± 18	10.0 ± 65	37	90	12
22	12	23.0 ± 36	≤8.0	≤10.9	43	≤4
23	4	≤12.0	≤8.0	≤9.1	22	≤3

^a See Fig. 10.

^b CG = 3×10^{-7} μ Ci/ml.

Table F-18. Tritium (HTO) in water—Livermore Valley.

Location ^a	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b	Calculated adult whole-body dose
		[10 ⁻⁷ μCi/ml ± 2σ (%)]					(mrem)
11	4	0.55 ± 12	0.45 ± 14	0.48	10	2 × 10 ⁻³	4 × 10 ⁻³
15	4	0.87 ± 9	0.56 ± 11	0.71	18	2 × 10 ⁻³	5 × 10 ⁻³
16	4	2.45 ± 5	1.65 ± 5	1.92	19	6 × 10 ⁻³	15 × 10 ⁻³
19	4	0.62 ± 12	0.57 ± 11	0.60	3	2 × 10 ⁻³	5 × 10 ⁻³
20	10	44.6 ± 2	1.86 ± 8	16.5	76	6 × 10 ⁻²	126 × 10 ⁻³
24	4	1.39 ± 6	0.52 ± 12	1.00	36	3 × 10 ⁻³	8 × 10 ⁻³
26	4	1.75 ± 6	1.61 ± 6	1.68	4	6 × 10 ⁻³	14 × 10 ⁻³
29	4	0.37 ± 17	0.59 ± 13	0.45	20	2 × 10 ⁻³	3 × 10 ⁻³
30	4	0.54 ± 12	0.45 ± 17	0.50	10	2 × 10 ⁻³	4 × 10 ⁻³
31	4	0.92 ± 7	0.37 ± 20	0.61	38	2 × 10 ⁻³	5 × 10 ⁻³
33	3	1.04 ± 8	0.62 ± 10	0.79	28	3 × 10 ⁻³	6 × 10 ⁻³
34	3	0.96 ± 8	0.75 ± 10	0.86	13	3 × 10 ⁻³	7 × 10 ⁻³
37	4	0.78 ± 8	0.46 ± 12	0.59	26	2 × 10 ⁻³	5 × 10 ⁻³

^a See Fig. 9.

^b CG = 3×10^{-3} μ Ci/ml.

Table F-19. Tritium (HTO) in water—Site 300.

Location	Number of samples	Maximum	Minimum	Average	% SDM	% CG ^b	Calculated adult whole-body dose
		{10 ⁻⁷ µCi/ml ± 2σ (%)}					(mrem)
01	4	0.75 ± 19	0.58 ± 11	0.69	11	2 × 10 ⁻³	5 × 10 ⁻³
02	4	0.91 ± 8	0.30 ± 18	0.49	58	2 × 10 ⁻³	4 × 10 ⁻³
03	1	0.65 ± 10				2 × 10 ⁻³	5 × 10 ⁻³
04	12	0.66 ± 11	0.05 ± 90	0.21	85	7 × 10 ⁻⁴	2 × 10 ⁻³
05	12	0.45 ± 14	0.06 ± 83	0.22	62	7 × 10 ⁻⁴	2 × 10 ⁻³
06	4	0.12 ± 51	0.05 ± 100	0.08	39	3 × 10 ⁻⁴	1 × 10 ⁻³
07	4	0.38 ± 18	0.10 ± 53	0.23	51	8 × 10 ⁻⁴	2 × 10 ⁻³
14	12	0.80 ± 9	0.41 ± 14	0.58	20	2 × 10 ⁻³	4 × 10 ⁻³
20	9	2.1 ± 5	0.28 ± 22	0.81	78	3 × 10 ⁻³	6 × 10 ⁻³
21	4	1.22 ± 6	0.26 ± 22	0.55	83	2 × 10 ⁻³	4 × 10 ⁻³
22	12	0.50 ± 16	0.05 ± 100	0.18	72	6 × 10 ⁻⁴	1 × 10 ⁻⁴
23	4	0.52 ± 11	0.06 ± 98	0.19	112	6 × 10 ⁻⁴	1 × 10 ⁻⁴

^a See Fig. 10.^b CG = 3 × 10⁻³.

Table F-20. Tritium (HTO) in groundwater—Livermore Valley.

Location ^a	Well identification	Well depth (m)	Activity	% CG
			[10 ⁻⁷ µCi/ml ± 2σ (%)]	
01	3S1E-1P2	15	10.2 ± 2.5	3 × 10 ⁻²
02	3S1E-1R2	17	0.93 ± 7.4	3 × 10 ⁻³
03	3S1E-2R1	10	8.8 ± 2.6	3 × 10 ⁻²
04	3S1E-8H2	62	1.2 ± 6.4	4 × 10 ⁻³
05	3S1E-9G1	49	3.2 ± 3.6	1 × 10 ⁻²
06	3S1E-9P5	32	2.4 ± 4.2	8 × 10 ⁻³
07	3S1E-10A2	26	6.2 ± 29	2 × 10 ⁻²
08	3S1E-11B1	13	11.7 ± 2.5	4 × 10 ⁻²
09	3S1E-12A2	23	2.2 ± 4.4	7 × 10 ⁻³
10	3S1E-12D2	14	6.2 ± 2.8	2 × 10 ⁻²
11	3S1E-12G1	26	5.9 ± 2.9	2 × 10 ⁻²
12	3S1E-12N1	93	1.1 ± 7.0	4 × 10 ⁻³
13	3S1E-16H2	29	0.84 ± 7.6	3 × 10 ⁻³
14	3S2E-1P2	44	0.25 ± 22	1 × 10 ⁻³
15	3S2E-7N1	40	1.3 ± 5.8	4 × 10 ⁻³
16	3S2E-11A1	20	1.3 ± 6.2	4 × 10 ⁻³
17	3S2E-11C1	21	0.79 ± 8.6	3 × 10 ⁻³
18	3S3E-7D2	23	0.26 ± 22	1 × 10 ⁻³

^a See Fig. 11.^b CG = 3 × 10⁻³ µCi/ml.

Table F-21. Tritium (HTO) in vegetation – Livermore Valley.

Location ^a	Number of samples	Maximum [10 ⁻⁷ μCi/ml ± 2σ (%)] in water recovered	Minimum	Average	% SDM	Calculated adult whole-body dose (mrem)
04	3	3.0 ± 35	1.0 ± 97	2.1	49	6 × 10 ⁻³
15	3	26.9 ± 5	9.9 ± 11	18.4	46	6 × 10 ⁻²
20	4	9.2 ± 12	4.9 ± 21	6.3	31	2 × 10 ⁻²
23	3	38.6 ± 4	10.9 ± 10	22.4	64	7 × 10 ⁻²
29	5	33.8 ± 4	9.2 ± 12	16.8	59	5 × 10 ⁻²
31	4	16.5 ± 7	3.4 ± 29	8.1	72	2 × 10 ⁻²
32	5	14.4 ± 8	2.7 ± 36	8.3	65	2 × 10 ⁻²
33	3	2.8 ± 35	1.7 ± 62	2.1	29	6 × 10 ⁻³

^a See Fig. 12.

Table F-22. Tritium (HTO) in vegetation – Site 300.

Location ^a	Number of samples	Maximum [10 ⁻⁷ μCi/ml ± 2σ (%)] in water recovered	Minimum	Average	% SDM	Calculated adult whole-body dose (mrem)
01	4	1.8 ± 62	1.0 ± 100	1.4	20	4 × 10 ⁻³
02	4	2.5 ± 46	0.9 ± 100	1.4	55	4 × 10 ⁻³
03	4	1.9 ± 50	0.9 ± 100	1.2	37	4 × 10 ⁻³
06	2	10.3 ± 12	1.6 ± 60	6.0	100	2 × 10 ⁻²
12	3	2.1 ± 45	1.1 ± 100	1.8	32	5 × 10 ⁻³
13	4	49.5 ± 4	1.4 ± 67	14.5	161	4 × 10 ⁻²

^a See Fig. 13.

Table F-23. Tritium (HTO) in wine.

Location	Number of samples	Maximum [10 ⁻⁷ μCi/ml ± 2σ (%)] in water recovered	Minimum	Average	% SDM
Livermore Valley	5	8.5 ± 4	1.7 ± 17	4.2	68
Other California areas	2	1.8 ± 11	0.7 ± 26	1.2	60
Europe	2	8.8 ± 4	2.6 ± 8	3.7	77

Table F-24. Tritium (HTO) in honey.

Location	Number of samples	Maximum	Minimum	Average	% SDM
		[10^{-7} $\mu\text{Ci/ml} \pm 2\sigma$ (%) in water recovered]			
Livermore Valley	3	9.1 ± 4	6.26 ± 5	7.3	21
Other California areas	1	6.4 ± 5			

Table F-25. Various radionuclides in milk—Livermore Valley.

	HTO	^{40}K	^{137}Cs
	[10^{-7} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]	[10^{-8} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]	[10^{-9} $\mu\text{Ci/ml} \pm 2\sigma$ (%)]
Number of samples	9	8	8
Maximum	3.1 ± 36	2.01 ± 1	2.46 ± 22
Minimum	1.0 ± 100	1.29 ± 4	0.43 ± 100
Average	1.6	1.63	1.07
% SDM	49	16	71
Calculated adult whole-body dose (mrem)	1×10^{-2}	9.1	2×10^{-2}

Table F-26. Environmental radiation measurement (TLD)—LLNL perimeter.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual
	(mrem)				
1	12	14	15	12	53
2	10	12	15	13	50
3	11	14	16	14	55
4	12	14	15	13	54
5	12	14	15	14	55
6	12	14	15	14	55
7	10	12	14	12	48
8	11	13	14	12	50
9	11	13	14	12	50
10	10	12	12	12	46
11	9	11	16	17	53
12	13	16	29	15	73
13	11	12	14	13	50
42	10	12	13	12	47
47	11	12	12	12	47
48	11	12	13	11	47
49	11	12	13	12	48
50	10	12	13	12	47
52	11	12	13	12	48
53	11	13	13	13	50
54	11	12	13	12	48
56	10	13	13	11	47
Average	11 ± 1	13 ± 1	14 ± 3	13 ± 1	51 ± 6

^a See Fig. 14.

Table F-27. Environmental neutron monitoring – LLNL perimeter.

Location ^a	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec.	Annual
	(mrem)				
1	1.2	1.6	0.8	1.1	4.7
2	1.2	1.4	0.9	1.8	5.3
3	21.	31.	34.	27.	113.
4	1.5	1.5	0.8	1.3	5.1
5	3.3	3.3	0.6	2.8	10.
6	1.4	1.2	0.7	1.4	4.7
7	1.9	1.2	1.3	1.5	5.9
8	1.9	1.7	1.0	1.6	6.2
Average	4.2	5.2	5.0	4.8	19.2

^a See Fig. 3.

Table F-28. Beryllium on air filters – LLNL perimeter.

Month	Location ^a						Average	% SDM	% Standard ^b
	01	02	12	13	14	15			
	(10 ⁻⁵ µg/m ³)								
Jan.	2.1	3.0	7.3	2.6	2.0	1.3	3.1	71	0.3
Feb.	0.9	1.1	2.5	1.7	1.3	0.2	1.3	61	0.1
Mar.	0.6	0.9	2.0	2.5	0.6	0.6	1.2	70	0.1
Apr.	N/A ^c	1.5	3.9	2.5	0.1	0.1	1.6	101	0.2
May	2.7	3.0	2.9	4.8	2.1	3.4	3.2	29	0.3
June	3.5	3.2	3.8	4.5	5.1	4.9	4.2	19	0.4
July	2.5	2.8	3.2	1.4	2.6	1.7	2.4	29	0.2
Aug.	1.4	1.0	1.6	1.3	1.2	1.0	1.2	18	0.1
Sept.	2.4	2.0	4.8	2.8	8.4	7.1	4.6	58	0.5
Oct.	2.5	2.6	3.6	2.1	1.0	1.5	2.2	41	0.2
Nov.	1.6	1.4	2.8	1.0	1.0	1.0	1.5	48	0.2
Dec.	2.2	1.8	4.7	1.1	0.9	1.6	2.1	67	0.2
Average	2.0	2.0	3.6	2.4	2.2	2.0	2.4		0.2
% SDM	41	42	42	53	107	103			

^a See Fig. 3.

^b Ambient concentration limit set by the Bay Area Air Quality Management District is 0.01 µg/m³.

^c Not available.

Table F-29. Beryllium on air filters – Site 300.

Month	Location ^a								Average	% SDM	% Standard ^b
	01	02	03	04	05	08	09	10			
	(10 ⁻⁵ µg/m ³)										
Jan.	0.5	0.6	1.5	1.7	1.1	0.7	0.4	0.9	0.9	51	0.1
Feb.	0.2	0.2	1.3	N/A ^c	0.2	0.3	0.2	0.2	0.4	110	0.1
Mar.	0.3	0.5	0.8	N/A	1.4	0.3	0.2	0.1	0.5	88	0.1
Apr.	1.2	1.5	3.4	1.4	2.9	1.5	1.0	1.5	1.8	48	0.2
May	1.0	1.2	2.0	1.7	6.0	1.3	0.9	1.6	2.0	85	0.2
June	1.4	1.7	5.2	3.3	5.5	2.3	1.6	2.9	3.0	54	0.3
July	1.0	1.4	3.8	1.7	3.6	2.4	2.1	2.2	2.3	44	0.2
Aug.	3.5	3.2	5.2	2.6	5.8	2.5	1.2	2.1	3.3	48	0.3
Sept.	0.8	0.7	5.0	0.9	1.4	3.6	1.0	1.2	1.8	87	0.2
Oct.	2.3	1.5	3.8	1.7	4.5	5.5	1.5	1.4	2.8	58	0.3
Nov.	1.6	1.7	2.4	1.6	2.7	1.0	1.0	1.7	1.7	35	0.2
Dec.	0.7	2.3	1.8	N/A	1.0	2.5	1.1	N/A	1.6	47	0.2
Average	1.2	1.4	3.0	1.9	3.0	2.0	1.0	1.4	1.8		0.2
% SDM	77	60	53	40	68	75	56	58			

^a See Fig. 4.^b Ambient concentration limit set by the Bay Area Air Quality Management District is 0.01 µg/m³.^c Not available.

Table F-30. Various elements in LLNL liquid effluent.

	Cd	Cr	Cu	Fe	Pb	Ni	Ag	Zn	Al	Be
	(m)									
Jan.	0.002	0.14	0.01	2.06	0.01	0.14	0.015	0.11	2.5	0.00
Feb.	0.003	0.15	0.13	1.6	0.01	0.05	0.029	0.31	1.1	0.00
Mar.	0.002	0.15	0.09	2.2	0.02	0.02	0.089	0.20	3.0	0.00
Apr.	0.002	0.16	0.10	1.1	0.02	0.02	0.017	0.51	0.5	0.00
May	0.002	0.22	0.13	0.90	0.02	0.01	0.031	0.17	0.4	0.00
June	0.003	0.22	0.14	0.87	0.03	0.16	0.003	0.19	0.3	0.00
July	0.002	N/A ^a	N/A	0.49	0.00	N/A	0.02	N/A	0.3	0.00
Aug.	0.002	0.16	0.11	0.45	0.04	0.02	0.003	0.14	0.2	0.00
Sept.	0.002	0.40	0.25	0.91	0.04	0.01	0.012	0.33	0.4	0.00
Oct.	0.002	0.18	0.12	0.64	0.01	0.01	0.010	0.15	0.2	0.00
Nov.	0.002	0.19	0.15	0.66	0.02	0.07	0.020	0.22	0.5	0.00
Dec.	0.001	0.06	0.18	0.44	0.01	0.01	0.012	0.41	0.2	0.00
Average	0.002	0.18	0.13	1.03	0.02	0.05	0.022	0.25	0.8	0.00
% SDM	± 48%	± 53	± 46%	± 59%	± 63%	± 114	± 106%	± 51%	± 119%	

^a Not applicable.

Table F-31. Physical and chemical examinations of LLNL liquid effluent.

	Jan.-Mar.	Apr.-June	July-Sept.	Oct.-Dec. ^a	Average	% SDM
	(mg/liter)					
BOD	47.	64.	78.		63.	25
COD	120.	116.	213.		150.	37
Ammonia nitrogen (as N)	21.	26.	20.		22.	14
Total Kjeldahl nitrogen (as N)	29.	29.	31.		30.	4
Nitrate nitrogen (as N)	0.06	<0.01	<0.1		0.03	120
Nitrite nitrogen (as N)	0.03	<0.001	<0.01		0.01	73
Oil and grease (FEM)	19.	<5.	<5.		10.	84
Sulfate	47.	52.	43.6		48.	9
Arsenic	<0.001	<0.001	<0.001		<0.0001	
Boron	0.57	0.39	0.52		0.49	18
Cyanide	0.09	0.058	<0.02		0.06	71
Mercury	0.009	0.0002	0.0015		0.004	140
Selenium	<0.001	<0.001	<0.001		<0.001	-
Total alkalinity (as CaCO ₃)	104.	102.	88.		98.	9
Total phosphorous (as P)	3.9	4.0	4.5		4.1	8
Chloride	26.	36.	16.		26.	38
Phenols	0.021	0.042	0.016		0.026	53
Calcium	11.	9.0	8.0		9.3	16
Magnesium	2.0	2.2	1.0		1.8	37
Sodium	28.	34.	18.		27.	30
Chromium	0.07	0.12	0.13		0.11	28
Copper	0.034	0.14	0.27		0.15	81
Nickel	0.005	0.17	0.010		0.06	146
Potassium	20.	21.	21.		21.	3
Zinc	0.23	0.14	0.42		0.26	53
Sodium as % of cations	50.	57.	43.5		50.	13
Total solids	185.	283.	192.		220.	25
Total dissolved solids	164.	200.	165.		176.	12
Volatile solids as % of total solids	17.6	20.	86.5		41.	94
Settleable solids (ml/liter/h)	1.3	0.3	0.12		0.57	112
Total suspended solids	-	17.3	23.		20.2	20
Total organic carbon	-	49.	64.		56.	19
Identifiable chlorinated hydrocarbons including PCB	Lindane: 0.07 µg/liter	n.d. ^b	n.d.			

^a No sample was taken during the fourth quarter.^b None detected.

The following compounds would have been reported had they appeared at or above their respective detection limits as indicated below:

<u>Organochlorine pesticides</u>	<u>µg/liter</u>	<u>Polychlorinated biphenyls</u>	<u>µg/liter</u>
Aldrin	0.05	Aroclors 1016-1262	0.3
Chlordane	0.3		
Endrin	0.1		
Dieldrin	0.05		
BHC (mixed isomers)	0.05		
DDT (mixed isomers)	0.1		
DDE (mixed isomers)	0.05		
DDD (mixed isomers)	0.05		
Heptachlor	0.05		
Heptachlor Epoxide	0.05		
Methoxychlor	0.2		

Table F-32. Site 300 water samples down gradient from liquid-discharge locations.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average	% SDM
Specific conductance (μ mhos/cm at 25°C)														
Location ^a	4	1350	1300	1300	1200	1570	1180	1210	1340	1280	1260	1240	1294	8
	5	992	1000	1070	949	1050	1220	1080	980	991	1010	960	1027	7
	14	1610	550	698	1040	1300	1260	1400	1580	1580	1510	1600	1268	28
	22	930	930	903	890	1080	1090	1140	1010	978	980	830	978	10
Total hardness as CaCO ₃ (mg/l)														
Location	4	22	24	24	22	21	21	22	21	21	22	25	22	6
	5	43	44	42	43	45	55	55	54	46	51	42	47	11
	14	420	350	250	360	416	376	428	403	420	430	540	404	17
	22	42	43	46	47	45	42	59	55	58	47	55	49	13
Chloride (mg/l)														
Location	4	159	160	162	158	165	158	158	156	150	148	160	158	3
	5	86	84	88	78	80	78	65	65	73	66	79	77	11
	14	116	31	36	80	90	112	113	129	130	140	150	102	37
	22	66	66	65	70	72	71	67	69	70	64	71	68	4
Total organic carbon (mg/l)														
Location	4	9	15	34	21	15	2	13	16	12	9	15	15	55
	5	<5	13	35	10	<5	1	12	12	<5	11	12	11	81
	14	21	34	47	17	12	4	24	20	17	<5	26	20	61
	22	8	16	28	7	<5	3	16	7	9	7	14	11	66

^a See Fig. 10.

Table F-33. Estimated radiation dose to the public from LLNL airborne effluents during 1983.

Nuclide	Facility	Curies	Dose at site boundary (mrem)	Dose to nearest resident (mrem)	Dose within 80-km radius of LLNL ^a (man-rem)
³ H	Tritium facility	3024	0.27	0.1	0.8
	Insulating core accelerator	140	0.25	0.1	0.1
	Rotating target neutron source	81	0.1	0.0	0.0
¹⁵ N, ¹⁸ O	Linear accelerator	855	0.77	0.2	0.0

^aDose rounded to nearest one-tenth mrem.

Table F-34. Radioactive effluent releases from LLNL from 1976 through 1983.

Year	Airborne effluents (Ci)			Liquid effluents (Ci)	
	⁴¹ Ar	³ H	¹⁵ N, ¹⁸ O	HTO	²³⁹ Pu
1976	470	3991	1035	10	1.5×10^{-4}
1977	380	5210	990	13	3.6×10^{-4}
1978	766	5362	1445	9	8.6×10^{-4}
1979	383	4517	829	7	9.8×10^{-4}
1980	165	2305	1656	5	2.8×10^{-4}
1981	0	2620	344	6	0.92×10^{-4}
1982	0	2014	584	1.6	0.43×10^{-5}
1983	0	3245	855	1.7	0.67×10^{-5}

Table F-35. LLNL nonradioactive liquid effluent – storm drain runoff.

Analyses	Influent	Effluent (mg/liter)	Lake
Nitrate nitrogen (as N)	0.34	<0.01	<0.01
Total phosphorous (as P)	0.61	0.90	0.67
Cyanide	<0.02	<0.02	<0.02
Phenols	<0.040	<0.029	0.026
Oil & grease (freon extractable)	3.4	6.7	9.3
Surfactants (MBAs)	0.41	0.10	0.39
Sulfate	11.3	13.8	14.7
Total identifiable chlorinated hydrocarbons	none ^a	none	none

^a The following compounds would have been reported had they appeared at or above their respective detection limits as indicated below:

Organochlorine pesticides	μg/liter
Aldrin	0.05
Chlordane	0.1
Endrin	0.1
Dieldrin	0.05
BHC (mixed isomers)	0.05
DDT (mixed isomers)	0.1
DDE (mixed isomers)	0.05
DDD (mixed isomers)	0.05
Heptachlor	0.05

Polychlorinated biphenyls	μg/liter
Aroclors 1016-1262	0.3

Table F-36. Summary of analyses for the quality assurance program.

Analyses	Media	Value reported (pCi/liter)		
		LLNL	Known	Grand average of all Laboratories
Gross alpha	Water	9 ± 1	14.0 ± 9	N/A*
		5 ± 1	7 ± 5	8 ± 2
		6 ± 0	11 ± 5	11 ± 3
		27 ± 2	29 ± 7	26 ± 6
Gross beta	Water	19 ± 1	16 ± 9	N/A
		25 ± 1	22 ± 5	22 ± 4
		63 ± 4	57 ± 5	54 ± 8
		39 ± 2	31 ± 5	32 ± 5
Plutonium	Water	8.6 ± 0	8.9 ± 1	8.2 ± 1.5
Gross alpha	Air	16 ± 1	22 ± 10	N/A
		53 ± 2	46 ± 20	N/A
Gross beta	Air	68 ± 2	67 ± 9	N/A
		140 ± 0	143 ± 12	N/A
Tritium	Water	2317 ± 70	2389 ± 608	N/A
		1296 ± 113	1210 ± 329	1226 ± 185
		1843 ± 101	1846 ± 342	1864 ± 207
		1543 ± 110	1529 ± 337	1552 ± 202
		3293 ± 32	3330 ± 362	3298 ± 241
		2673 ± 46	2560 ± 353	2534 ± 273
The following values are relative; the exponents are not included, and therefore do not indicate actual concentrations.				
Be ⁷	Air	0.322	0.300	0.306
		0.338		
Co ⁵⁷		0.386	0.264	0.287
		0.389		
Co ⁶⁰		0.264	0.264	0.265
		0.276		
Sb ¹²⁵		0.278	0.795	0.687
		0.227		
Cs ¹³⁷		0.353	0.341	0.332
		0.365		
Pu ²³⁹		0.294	0.299	0.287
		0.301		
U (μg)		0.508	0.409	0.449
		0.516		
K ⁴⁰	Soil	0.110	0.164	0.156
		0.170	0.240	0.250
Ra ²²⁶	Soil	0.672	1.04	0.914
Pu ²³⁸		0.237	0.270	0.258
Pu ²³⁹		0.141	0.156	0.146
Am ²⁴¹		0.284	0.177	0.217
U (μg)		0.178	0.280	0.239
³ H		0.106	0.108	0.126
Mn ⁵⁴	Water	0.502	1.66	1.64
Cs ¹³⁷		0.228	0.239	0.228
Ce ¹⁴⁴		0.430	10.9	10.3
Pu ²³⁹		0.705	0.870	0.688

* Not available.

APPENDIX G

**ENVIRONMENTAL ACTIVITY CONCENTRATION --
GUIDE LEVELS**

The standards for Radiation Protection (DOE Manual 5480.1 Chg 2, issued April 29, 1981) state that the average activity of a mixture of radionuclides (whose identities and concentrations are unknown) in air and water should not exceed the following values:

1. Air (controlled area) 6×10^{-13} $\mu\text{Ci/ml}$
2. Air (uncontrolled area) 2×10^{-14} $\mu\text{Ci/ml}$
3. Water (controlled area) 4×10^{-7} $\mu\text{Ci/ml}$
4. Water (uncontrolled area) 3×10^{-8} $\mu\text{Ci/ml}$

If alpha emitters and ^{227}Ac are definitely not present, the following values may be used to determine permissible average activity:

5. Air (controlled area) 3×10^{-11} $\mu\text{Ci/ml}$
6. Air (uncontrolled area) 1×10^{-12} $\mu\text{Ci/ml}$

If ^{129}I , ^{226}Ra , and ^{228}Ra are definitely not present, the following values may be used:

7. Water (controlled area) 3×10^{-6} $\mu\text{Ci/ml}$
8. Water (uncontrolled area) 1×10^{-7} $\mu\text{Ci/ml}$

Both air and water samples are subjected to gross alpha and gross beta measurements. The average annual alpha activities of samples may not exceed the activity values listed as 1-4 above. Since the alpha emitters have been accounted for in the gross alpha measurements and the assumption is made that ^{129}I , ^{227}Ac , ^{226}Ra , and ^{228}Ra are not present in the samples, the average annual gross beta activities of the samples may not exceed the activities listed as 5-8 above. The assumption that ^{129}I , ^{227}Ac , ^{226}Ra , and ^{228}Ra are not present in air and water samples is reasonable in view of the minute quantities of these radionuclides available at the Laboratory. This reference also states that the average tritium activities in off-site water samples may not exceed 3×10^{-3} $\mu\text{Ci/ml}$.

The external whole-body radiation dose to workers in controlled areas may not exceed 5 rem/y, and the dose to an individual in an uncontrolled area may not exceed 500 mrem/y. Also, a group of individuals in an uncontrolled area may not receive an average dose of more than 170 mrem/y.

APPENDIX H

METHODS OF DOSE CALCULATIONS

The doses shown in this report have been calculated using the models and methods in the Nuclear Regulatory Commission Regulatory Guide 1.109, Calculation of Annual Doses to Man from Routine Releases of Reactor Effluent. Examples of these calculations and assumptions are shown in this appendix.

ANNUAL DOSE FROM POTABLE WATER

Assuming that all water sampled is available as drinking water, the annual whole-body dose for tritium has been calculated using the following equation:

$$R_{\text{total body}} = C_w U_w D_w \quad (1)$$

where

C_w = concentration in pCi/liter,

U_w = intake rate, liters/y,

= 730 liters/y for maximum exposed individual,

D_w = dose factor, mrem/pCi,

= 1.05×10^{-7} mrem/pCi for the whole-body ingestion pathway for an adult.

ANNUAL DOSE FROM FORAGE-COW-MILK PATHWAY FOR TRITIUM IN VEGETATION

Assuming that all feed for the cattle was pasture grass, the annual whole-body dose per $\mu\text{Ci/ml}$ HTO for the maximum exposed individual has been calculated using the following equation:

$$D_{\text{total body}} = D_{\text{veg}} + D_{\text{meat}} + D_{\text{milk}} \quad (2)$$

$$D_{\text{veg}} (\text{leafy vegetables}) = U_{\text{veg}} \times C_{\text{veg}} \times D_{\text{HTO}} \quad (2a)$$

where

U_{veg} = intake rate, kg/y, 64 kg/y for maximum exposed individual,

C_{veg} = concentration in pCi/kg = $10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}} \times C_{\text{veg}} \mu\text{Ci/ml}$ (measured) ,

D_{HTO} = dose factor, mrem/pCi = 1.05×10^{-7} mrem/pCi for ^3H for the adult whole-body ingestion pathway.

$$D_{veg} \text{ (mrem/y)} = 0.67 \times 10^4 C_{veg} \text{ } \mu\text{Ci/ml (measured)} .$$

$$D_{meat} = U_{meat} \times C_{meat} \times D_{HTO} , \quad (2b)$$

where

$$U_{meat} = 110 \text{ kg/y},$$

$$D_{HTO} = 1.05 \times 10^{-7} \text{ mrem/pCi},$$

$$C_{meat} = (F_f)(Q_f)(C_{veg})\exp(-\lambda_i t_s).$$

F_f = fraction of daily intake of nuclide per kg of animal/fish, days/kg,

Q_f = amount of feed consumed, kg/day,

C_{veg} = same as above,

λ_i = radiological decay constant, day⁻¹,

t_s = time between slaughter to consumption, days.

$$C_{meat} = \left(1.2 \times 10^{-2} \frac{\text{day}}{\text{kg}}\right) \left(50 \frac{\text{kg}}{\text{day}}\right) \left(C_{veg} \frac{\mu\text{Ci}}{\text{ml}}\right) \left(10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}}\right) \\ \times \exp[-4.5 \times 10^3(20)] = 0.6 \times 10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}} \times C_{veg} \frac{\mu\text{Ci}}{\text{ml}} \text{ (measured)} ,$$

$$D_{meat} \text{ (mrem/y)} = 0.69 \times 10^4 \times C_{veg} \text{ } \mu\text{Ci/ml (measured)} .$$

$$D_{milk} = U_{milk} \times C_{milk} \times D_{HTO} , \quad (2c)$$

where

$$U_{milk} = 310 \text{ liters/y},$$

$$D_{HTO} = 1.05 \times 10^{-7} \text{ mrem/pCi},$$

$$C_{milk} = F_m Q_f C_{veg} \exp(-\lambda_i t_f),$$

F_m = fraction of daily intake of nuclide per liter of milk,
day/liter,

Q_f = amount of feed consumed, kg/day,

C_{veg} = same as above,

λ_i = radiological decay constant, days⁻¹,

t_f = transport time from the feed to milk receptor,

$$C_{milk} = \left(1.0 \times 10^{-2} \frac{\text{day}}{\text{liter}}\right) \left(50 \frac{\text{kg}}{\text{d}}\right) \left(C_{veg} \frac{\mu\text{Ci}}{\text{ml}}\right) \left(10^9 \frac{\text{pCi/kg}}{\mu\text{Ci/ml}}\right) \\ \times \exp[-4.5 \times 10^3(2)] = 0.5 \times 10^9 \frac{\text{pCi/liter}}{\mu\text{Ci/ml}} \times C_{veg} \frac{\mu\text{Ci}}{\text{ml}} \text{ (measured)} .$$

$$D_{milk} \text{ (mrem/y)} = 1.63 \times 10^4 \times C_{veg} \text{ } \mu\text{Ci/ml (measured)} .$$

$$D_{total} \text{ (mrem/y)} = 0.67 \times 10^4 C_{veg} \text{ } \mu\text{Ci/ml (measured)} + 0.69 \times 10^4 C_{veg} \text{ } \mu\text{Ci/ml (measured)} \\ + 1.63 \times 10^4 C_{veg} \text{ } \mu\text{Ci/ml (measured)} = 2.99 \times 10^4 C_{veg} \text{ } \mu\text{Ci/ml (measured)}$$

ANNUAL POPULATION DOSE

To calculate the "fence-line" site boundary, nearest-resident, and population doses, a continuous-point-source computer code based on the Gaussian plume model was used.

$$C_{\text{downwind}} = 3.17 \times 10^4 (\chi/Q)(Q) \quad (3)$$

where

χ/Q = diffusion parameter, sec/m^3 ,

Q = release rate, Ci/y ,

$$3.17 \times 10^4 = 1 \times 10^{12} \frac{\text{pCi}}{\text{Ci}} / 3.15 \times 10^7 \frac{\text{sec}}{\text{y}} .$$

C_{downwind} = concentration downwind, pCi/m^3 .

$$D_{\text{max individual}} = U \times C_{\text{downwind}} \times D \quad (4)$$

where

U = intake rate, $\text{m}^3/\text{y} \approx 8000 \text{ m}^3/\text{y}$, inhalation rate
for adult maximum exposed individual ,

$C_{\text{downwind}} = 3.17 \times 10^4 (\chi/Q)(Q)$,

D = dose factor, mrem/pCi

for ^3H , $D = 1.05 \times 10^{-7} \text{ mrem}/\text{pCi} \times 1.5$ to include
immersion dose = $1.58 \times 10^{-7} \text{ mrem}/\text{pCi}$.

for ^{41}Ar , $D = 8.84 \times 10^{-3} \frac{\text{mrem} \cdot \text{m}^3}{\text{pCi} \cdot \text{y}}$,

(Inhalation rate is included in the dose factor)

for ^{13}N , $D = D(^{41}\text{Ar})$.

for ^{15}O , $D = D(^{41}\text{Ar}) \times \frac{1.74}{1.2}$,

$D_{\text{max individual}} = \text{mrem}/\text{y}$.

For population dose, the diffusion factors and population figures for an area within 80 km of the Laboratory were summed over all directions.

$$\text{Dose (man-rem)} = 3.17 \times 10^4 \left[\sum_i^n (\chi/Q)_i P_i \right] Q U D \quad (5)$$

where

$$\left[\sum_i^n (\chi/Q)_i P_i \right] = \text{Summation of the } (\chi/Q) \text{ for region } i \text{ times the population in region } i \text{ for all regions } n, \frac{\text{man-sec}}{\text{m}^3} .$$

Q = release rate, Ci/y,
U = inhalation rate, average individual (adult),
D = dose factor, rem/pCi,
Dose = man-rem.

APPENDIX I

DISCHARGE LIMITS TO THE SANITARY
SEWER SYSTEM OF THE CITY OF LIVERMORE

Sections 18.62, 18.62.2, 18.62.3, 18.62.4, and 18.62.5 of the Code of the City of Livermore (1983) state the discharge limits for Livermore's sanitary sewer system. These limits are as follows:

Section 18.62. General Discharge Prohibitions.

No person shall contribute or cause to be contributed, directly or indirectly, any pollutant or wastewater which will interfere with the operation or performance of the publically-owned treatment works (POTW). These general prohibitions apply to all such users of the POTW whether or not the user is subject to national categorical pretreatment standards or any other national, state, or local pretreatment standards or requirements. A user may not contribute the following substances to the POTW:

(a) Any liquids, solids or gases which by reason of their nature or quantity are, or may be, sufficient either alone or by interaction with other substances to cause fire or explosion or be injurious in any other way to the POTW or to the operation of the POTW. At no time, shall two successive readings on an explosion hazard meter, at the point of discharge into the system (or at any point in the system) be more than five percent (5%) nor any single reading over ten percent (10%) of the lower explosive limit (LEL) of the meter. Prohibited materials include, but are not limited to, gasoline, kerosene, naphtha, benzene, toluene, xylene, ethers, alcohols, ketones, aldehydes, peroxides, chlorates, perchlorates, bromates, carbides, hydrides, and sulfides and any other substances which the city, the state or EPA has notified the user is a fire hazard or a hazard to the system.

(b) Solid or viscous substances which may cause obstruction to the flow in a sewer or other interference with the operation of the wastewater treatment facilities such as, but not limited to: grease, garbage with particles greater than one-half inch (1/2") in any dimension, animal guts to tissues, paunch manure, bones, hair, hides or fleshings, entrails, whole blood, feathers, ashes, cinders, sand, spent lime, stone or marble dust, metal, glass, straw, shavings, grass clippings, rags, spent grains, spent hops, waste paper, wood, plastics, gas, tar, asphalt residues, residues from refining, or processing of fuel or lubricating oil, mud, or glass grinding or polishing wastes.

Specifically excluded from the sewers are waste products resulting from the handling, storage, and sale of fruits and vegetables from other than retail produce establishments, or other foods not intended primarily for immediate consumption.

(c) Any wastewater having a pH less than 6.8 or greater than 8.5, unless a city permit is obtained. Wastewater having any other corrosive property capable of causing damage or hazard to structures, equipment, and/or personnel of the POTW is also prohibited.

(d) Any wastewater containing toxic pollutants in sufficient quantity, either singly or by interaction with other pollutants to injure or interfere with any wastewater treatment process, constitute a hazard to humans or animals, create a toxic effect in the receiving waters of the POTW, or to exceed the limitation set forth in the categorical pretreatment standard. A toxic pollutant shall include, but not be limited to any pollutant identified pursuant to Section 307(a) of the Act.

(e) Any noxious or malodorous liquids, gases, or solids which either singly or by interaction with other wastes are sufficient to create a public nuisance or hazard to life or are sufficient to prevent entry into the sewers for maintenance and repair.

(f) Any substance which may cause the POTW's effluent or any other product of the POTW such as residues, sludges, scums, or gases, to be unsuitable for reclamation and reuse or to interfere with the reclamation process. In no case, shall a substance discharged to the POTW cause the POTW to be in noncompliance with sludge use or disposal criteria, guidelines or regulations developed under Section 405 of the Act, any criteria, guidelines, or regulations affecting sludge use or disposal developed pursuant to the Solid Waste Disposal Act, the Clean Air Act, the Toxic Substances Control Act, or state criteria applicable to the sludge management method being used.

(g) Any waters or wastes which contain more than 100 mg/l of freon extractable fat, oil, or grease.

(h) Any substance which will cause the POTW to violate its NPDES Permit or the receiving water quality standards.

(i) Any wastewater with objectionable color not removed in the treatment process, such as, but not limited to, dye wastes and vegetable tanning solutions.

(j) Any wastewater having a temperature which will inhibit biological activity in the POTW treatment plant resulting in interference, but in no case wastewater with a temperature at the introduction into the POTW which exceeds 40°C (104°F).

(k) Any pollutants, including oxygen demanding pollutants (BOD, etc.) released at a flow rate and/or pollutant concentration which a user knows or has reason to know will cause interference to the POTW.

(l) Any wastewater containing any radioactive wastes or isotopes of such half-life or concentration as may exceed the limits established by the state or federal regulatory agency applicable to the POTW user.

(m) Any wastewater which causes a hazard to human life or creates a public nuisance.

(n) Any waters or wastes containing total dissolved solids increment greater than three hundred and twenty-five mg/l, nor chloride increment greater than seventy-five mg/l, increase during a single cycle use of the water supply, unless a city permit is obtained to exceed this limit.

(o) Any water or wastes having a BOD greater than three hundred (the average BOD for residential users), unless a city permit is obtained.

(p) Any waters or wastes containing more than three hundred mg/l of suspended solids (the average suspended solids for residential users), unless a city permit is obtained.

When the Superintendent determines that a user(s) is contributing to the POTW, any of the above-enumerated substances in such amounts as to interfere with the operation of the POTW, the Superintendent shall (1) advise the user(s) of the impact of the contribution on the POTW, and (2) develop effluent limitation(s) for such user to correct the interference with the POTW.

Section 18.62.2. Federal Categorical Pretreatment Standards.

Upon the promulgation of the Federal Categorical Pretreatment Standards for a particular industrial subcategory, the Federal Standard, if more stringent than limitations imposed under this article for sources in that subcategory, shall immediately supersede the limitations imposed under this article. The Superintendent shall notify all affected users of the applicable reporting requirements under 40 CFR, Section 403.12

Section 18.62.3. Modification of Federal Categorical Pretreatment Standards.

Where the city's wastewater treatment system achieves removal of pollutants limited by Federal Pretreatment Standards, the city may apply to the state/EPA for modification of specific limits in the Federal Pretreatment Standards. "Consistent Removal" shall mean reduction in the amount of pollutant or alteration of the nature of the pollutant, by the wastewater treatment system, to the less toxic or harmless state, in the effluent which is achieved by the system in 95 percent of the samples taken when measured according to the procedures set forth in Section 403.7 (c)(2) of (Title 40 of the Code of Federal Regulations, Part 403)--"General Pretreatment Regulations for Existing and New Sources of Pollution" promulgated pursuant to the Act. The city may then modify pollutant discharge limits in the Federal Pretreatment Standards if the requirements contained in 40 CFR, Part 403.7, are fulfilled and prior approval from state/EPA is obtained.

Section 18.62.4. Specific Pollutant Limitations.

No person shall discharge wastewater containing in excess of:

0.1	mg/l arsenic
0.2	mg/l cadmium
2.0	mg/l copper
1.0	mg/l cyanide
1.0	mg/l lead
0.01	mg/l mercury
1.0	mg/l nickel
0.2	mg/l silver
1.0	mg/l total chromium
3.0	mg/l zinc
0.02	mg/l total identifiable chlorinated hydrocarbons
1.0	mg/l phenolic compounds
0.01	mg/l polychlorinated biphenyls

Section 18.62.5. State Requirements.

State requirements and limitations on discharges shall apply in any case where they are more stringent than Federal requirements and limitations or those in this article.

APPENDIX J

**SAMPLING AND ANALYTICAL PROCEDURES
FOR ENVIRONMENTAL MONITORING AT
LAWRENCE LIVERMORE NATIONAL LABORATORY**

Sample collection and analysis procedures are an integral part of the quality assurance program developed for environmental monitoring at Livermore. These procedures provide a basis for verifying that sampling and analytical activities are being performed as specified.

This appendix describes the sampling procedures, analytical determinations, and preparation for radio-counting by the LLNL Hazards Control Department personnel. The radiochemical methods used by the LLNL Nuclear Chemistry Division were detailed in the 1983 Annual Environmental Monitoring Report, Appendix E, and remain essentially unchanged.

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